Refrigerators Given Cold Shoulder:
Strategies to Improve Sustainable Refrigerator Management in Manitoba

By

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A Thesis
Submitted to the Faculty of Graduate Studies
In Partial Fulfillment of the Requirements
For the Degree of

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Abstract

Refrigerators contain significant amounts of ozone-depleting substances (ODS), which must be recovered prior to disposal to prevent ozone depletion and climate change. Currently, municipal governments are burdened with appliance management – utilizing practices that encourage recovery of highly valuable resources but neglect recycling less valuable and safely disposing of hazardous components. More progressive strategies have emerged, however, incorporating product lifecycle analysis through end-of-life (EOL) manufacturer involvement and technologies that minimize pollution and increase component recovery.

This thesis examined EOL refrigerator management in Manitoba to recommend best practices and sustainable frameworks for management. Objectives included: 1) identifying critical issues in EOL refrigerator management and current waste management policy; 2) identifying gaps in Manitoba's refrigerator management policies, practice and procedure; 3) determining best management frameworks for sustainable management; and 4) recommending feasible management structures for implementation in Manitoba. To achieve these objectives, a number of activities were conducted including a literature review, site tours (Manitoba, UK), consultations with Manitoba Stakeholders, roundtable discussions and distribution of a refrigerator management survey and electronic questionnaires.

Manitoba's management system is unsustainable. The largest concern is that most of the ODS in refrigerators is allowed to be released, as regulations requiring its capture are limited to the cooling circuit only and not CFCs in the insulating foam. The insulating foam typically contains two-thirds of the CFCs in refrigerators. Municipalities

in Manitoba do not consider safe disposal of these foams, which results in the release of CFCs during the recycling process. Another unsustainable factor is that plastics and other components are not recycled but sent to landfill. Lack of waste management legislation for refrigerators has created over 200 individual municipal management strategies – each with their own criteria for disposal. Residents and municipalities lack proper education and pay as you throw disposal fees has resulted in improper disposals. Appliance resale of old inefficient refrigerators, which are twice the energy consumers of Energy Star models, result in large energy bills to the consumer of several hundred dollars per year. Operating one 20 year-old refrigerator has the carbon dioxide equivalent of running two automobiles for one year.

A study tour of refrigerator recycling facilities in the UK and a survey of North American appliance recycling programs provided examples of best management practices (BMPs) from regulatory and voluntary perspectives. Regulations on refrigerator disposal were found to be most effective, as the scope encompasses all units for recycling; targets and standards can be set; most advanced treatment technologies can be utilized; and producers can help with waste management and redesign of sustainable products.

To be proactive, refrigerators with high ozone depleting or global warming potential should be discouraged from use and sale and replaced by hydrocarbon technology, possibly through eco-rebate incentives. The most effective strategy for Manitoba would be to regulate EOL management through extended producer responsibility (EPR), replacing municipal management approaches with a single strategy, managed and financed by industry producers. Eventually, Manitoba's product stewardship framework must begin to include the principles of EPR for greater sustainability and to help drive design changes for increased refrigerator recyclability and lessen their environmental impact. In the absence of political will in Manitoba to implement regulations, a voluntary initiative can provide some level of environmental benefit focusing on reducing greenhouse gas (GHG) emissions and electrical demand by having a second fridge buy-back.

Acknowledgements

As I begin to reflect on this amazing journey I have taken over the past two years, filled with long days, sleepless nights, and lots of hard work, I feel a sense of accomplishment knowing now that a refrigerator is much more complex than keeping things cold. As one of the more unique undertakings at the NRI, perhaps the first of its kind, there are a number of individuals I would like to thank for imparting their knowledge, guidance, and support on developing this project.

Thank you to Shirley Thompson, my advisor and mentor at the NRI, for your support and interest in the subject area. Without your guidance this project would not have been possible. To Mark Miller, who has been an integral part of this project since day one, my thanks to you for introducing me to white goods management and for your assistance with site tours, interviews, and roundtable activities. John Sinclair and Brett Eckstein, your knowledge of stewardship proved most valuable and your participation was much appreciated.

Special thanks to Rauiri Holyoake and Jason Reeves for hosting the UK study tours and agreeing to share information about their jurisdictions management structure. Thank you also to Dr. Thompson, your financial support made the study tours a reality. I also recognize the financial contribution made by the *Waste Reduction and Pollution Prevention* (WRAPP) Fund from Manitoba Conservation – my thanks to you for the support.

Finally, I would like to thank my family and friends for their encouragement over the last two years, the survey participants and Manitoba stakeholders for their input, and to all others not mentioned above.

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Acronyms

ABS	Acrylonitrile Butadiene Styrene
AHAM	Association of Home Appliance Manufacturers
ARCA	Appliance Recycling Centres of America
ARCI	Appliance Recyclers of Canada Inc.
ARF	Advanced Recycling Fee
BAT	Best Available Technology
BMP	Best Management Practice
CAMA	Canadian Appliance Manufacturers Association
CEPA	*Canadian Environmental Protection Act*
CFC	Chlorofluorocarbon
CREEDAC	Canadian Residential Energy End-use Data and Analysis Centre
CUFCA	Canadian Urethane Foam Contractors Association
DfE	Design for Environment
EU	European Union
EPR	Extended Producer Responsibility
GHG	Green House Gas
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HDPE	High Density Polyethylene
HFC	Hydrofluorocarbon
HIPS	High Impact Polystyrene
HRAI	Heating, Refrigeration, and Air Conditioning Institute
IFO	Industry Funding Organization
IIR	International Institute of Refrigeration
ISO	International Standards Organization
ISWA	International Solid Waste Association
kWh	Kilowatt Hour
MOPIA	*Manitoba Ozone Protection Industry Association*
MR 103/94	[Manitoba] *Ozone Depleting Substances and Other Halocarbons Regulation 103/94*
ODS	Ozone Depleting Substance
ODP	Ozone Depleting Potential
OLPP	Ozone Layer Protection Program
PE	Polyethylene
PPP	Polluter Pays Principle
PUR	Polyurethane
PVC	Polyvinyl Chloride
RMC	Refrigerant Management Canada
TEAP	Technical and Economic Assessment Panel
TFDT	Task Force on Destruction Technologies
WEEE	Waste Electrical and Electronic Equipment
WML	Waste Management License

WRAP	*Waste Reduction and Prevention Act*
WRAPP	Waste Reduction and Pollution Prevention [Fund]
WTS	Waste Transfer Station
UN	United Nations
UEC	Unit Energy Consumption
US EPA	United States Environmental Protection Agency

1.1 Background

Refrigerators, along with other white goods (large domestic appliances) are not typical household wastes and cannot be easily disposed of along with the rest of the weekly refuse – because of their bulky nature and hazardous components, particularly their ozone depleting substances (ODS), within. The term "white good" originated within early department stores describing the porcelain finish applied to the appliance by the manufacturer—giving the unit its outer white appearance (Potts and Baker 1998). Over the years, the definition has expanded to encompass all major domestic appliances including those containing an ODS. This project, which focuses on refrigerator and chest freezer management, can also be broadly applicable to other ODS containing white goods such as dehumidifiers, air conditioners, water coolers, and heat pumps. ODS not only deplete the ozone but are potent greenhouse gases.

Refrigerator recycling programs can encompass a number of activities including ODS recovery, hazardous material removal, collection and transportation, and recycling and resource recovery. Other key aspects include energy conservation, climate change, regulations, and secondary use/product refurbishment.

1.1.1 Importance of Studying Refrigerator Management

There are a number of reasons why it is important to study the management of domestic appliances at the EOL stage. These reasons stem from both resource recovery and environmental perspectives.

1.1.1.1 Resource Recovery Perspective

Nearly 100% of all domestic appliances are recyclable. Recycling is very cost-effective for these products as refrigerators are made from a number of highly recyclable/reusable materials such as steel, copper, aluminium, glass, and plastics. Refrigerators, which are 75% steel by weight, contain at least 25% recycled content and upwards of 100% for internal mechanisms. High scrap steel value, $295 per tone on the American Metal Market (November 2007), has helped propel appliance-recycling rates to over 90% in North America – up from 84.9 in 2004. The benefits of recycling steel alone are enormous as it saves 2,500 pounds of raw ore, 1,400 pounds of coal and 120 pounds of limestone, while reducing air and water pollution by a combined 81%. In Canada, more steel is recycled than any other metal at an overall rate of 65%, which saves enough energy to power nearly 3 million homes (Crawford 2005, SRI 2006, SWRC 2007, Lindenbaum 2007, SRI n.d).

1.1.1.2 Environmental Perspective

From an environmental perspective, it is important to recognize that refrigerant from domestic appliances poses a significant risk to both human and environmental health – in the form of skin cancer, cataracts, decreased crop yields, and climate change.

Originally, domestic refrigeration utilized ammonia and sulfur dioxide as refrigerants, which were highly toxic and unstable compounds causing many fatal accidents. A conscience effort was made by industry to find safer replacements. Chlorofluorocarbons (CFCs) were created as a highly stable and safe (non-flammable and non-toxic) refrigerant. At the time, little was known about the destructive properties of

CFCs until a series of scientific discoveries proved otherwise. Dr. James Lovelock was the first to discover CFCs in the atmosphere, which sparked further research on the effects of chlorine in the air. The negative effect of anthropogenic sources of chlorine was never fully understood until Rowland and Molina's ozone depletion theory in their 1974 *Nature* article *Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom-Catalyzed Destruction of Ozone*. They explained when CFCs are released they migrate up into the stratosphere where ultra violet radiation effectively splits them apart, creating a free radical of chlorine. This chlorine then attracts a single oxygen atom (split from an ozone atom during the natural ozone creation/destruction process), thus destroying the natural ozone cycle. The atmospheric lifetime of chlorine from CFCs ranges between 50-250 years and one CFC molecule can destroy upwards of 100,000 or more ozone molecules in its lifetime. Although many were highly skeptical of the uncertainty surrounding the science at the time, their ozone depletion theory was proven when a team of British scientists led by Joe Farman, discovered a severely depleted layer of ozone over Antarctica, which is commonly known as the 'ozone hole.'

The ozone layer is one of the most important aspects protecting life on planet earth. Ozone is dispersed some 40-km thick throughout the stratosphere, however, when compressed its thickness is comparable to that of a penny, such that if it was compressed to zero degrees Celsius at one atmospheric pressure it would be approximately three millimeters thick (ICS 1997). It is the only barrier protecting the planet from the harmful effects of UV A + B radiation from the sun. Without the ozone layer, millions of new cases of cataracts and melanoma skin cancer would be reported on a worldwide basis each year.

The international community, facilitated by the United Nations (UN) adopted the *Vienna Convention for the Protection of the Ozone Layer* (1986). This Convention made it compulsory that participants take the most appropriate actions towards safeguarding the stratospheric ozone layer (Benedict 1991). The result of the *Vienna Convention* was the *Montreal Protocol on Substances that deplete the Ozone Layer* (1987), which "establish[d] a schedule to reduce the global consumption of five CFCs and three halons" (Standing Committee on Environment 1990:19). The original Protocol instructed developed nations to stabilize or freeze CFC consumption (which is defined as production + imports – exports) at 1986 levels one full year following the implementation of the protocol starting January 1, 1989 (CFCs) and January 1, 1992 (halons). The original version of the protocol calls for consumption of CFCs to be reduced by 20% as of 1993-94 and by 50% in 1998-99. A number of amendments have been made to the protocol, which addresses accelerated phase out of new ODS (Standing Committee on Environment 1990).

Canada developed an Ozone Layer Protection Program (OLPP), which involves co-operation between federal and provincial levels of government (Environment Canada 1997). Federal responsibilities focus on issues considered to be of national interest and include ensuring the terms of the Montreal Protocol are implemented within Canada. Two regulations have been developed under the *Canadian Environmental Protection Act* (CEPA), which include the *Ozone-depleting Substances Regulations* and *Federal Halocarbons Regulations.* The ODS regulations are Canada's official commitment to the Montreal Protocol and provide control measures on importing, exporting, manufacturing, consuming, and selling ODS. Changes to the ODS Regulations can "be made as required to reflect changes in reduction and phase-out schedules adopted by the Parties to the Montreal Protocol" (Environment Canada 1997:13). CEPA also contains the *Environmental Code of Practice for Elimination of Fluorocarbon Emissions from Refrigeration and Air Conditioning Systems*, which serves as a guidebook for best practices on emissions reductions and in the absence of regulation, can be upheld in a court of law (Environment Canada 1997, K. Warren, July 19, 2007). Provinces regulate emissions, mandate recovery and recycling of ODS, and administers environmental awareness training and certification for the refrigeration and air conditioning sectors (Environment Canada 1997).

1.2. Problem Statement

Manitoba's current EOL refrigerator management system is, at best, a patchwork of nearly 200 different municipal management systems lacking a unified approach for post consumer management, which often leads to improper management such as incorrect disposal or vented refrigerant.

1.3 Purpose

The purpose of this project was to study the system of EOL refrigerator management in Manitoba, identifying gaps in policy, practice, and procedure to be able to correct shortcomings through recommending frameworks for sustainable management practices. The overall purpose is to ensure sustainable refrigerator management within Manitoba.

1.4 Objectives

The overall objective of this project was to recommend suitable management frameworks and related components for sustainable EOL management of refrigerators in Manitoba. This was accomplished by identifying gaps in policy, practice and procedure within Manitoba's current management system and researching where these areas can be improved through the transfer and incorporation of BMPs learned from other jurisdictions.

The outcome of this study was satisfied by the following four objectives:

1. Identified the critical issues for refrigerator management (resource and environmental management perspectives) and current waste management policy.
2. Reviewed Manitoba's current refrigerator management system to identify where gaps occur in policy, practice and procedures.
3. Determined best management frameworks (including best practices, policies and procedures) for sustainable refrigerator management.
4. Recommended most feasible management structures for sustainable refrigerator management implementation in Manitoba.

1.5 Methods

The following methods, which are discussed in greater detail in Chapter 3: Methods, were employed to fulfill this projects objectives:

1. Municipal landfill site tours
2. Scrap metal recyclers site tours
3. Used appliance dealer site tours

4. Roundtable discussions
5. Manitoba stakeholder interviews
6. UK refrigerator recycling plants site tours
7. Electronic questionnaires
8. Literature review
9. Refrigerator Management Survey

1.6 Project Scope

The scope of this project encompasses North America and Europe, however, it focuses on Manitoba for its recommendations and UK and Manitoba for its tours of facilities. Studies within Manitoba included visiting landfills in selected municipalities to ascertain current management practices. The UK study area included site visits of two refrigerator-recycling plants where all aspects of the EOL phase (collection, transportation, ODS recovery [refrigerant and foam], and material separation and recovery for reuse and recycling) were examined. In North America, participants from various jurisdictions throughout the US and Canada were contacted for participation in a survey examining voluntary management systems.

1.7 My Interest in the Subject Area

I was presented with a unique opportunity to work with the *Manitoba Ozone Protection Industry Association* (MOPIA) in developing a municipal guidebook of suggested practices for white goods management. However, to fully understand the immense scope and nature of this subject area, it was necessary to go beyond MOPIA's limited resources and conduct research on a broader scale. Also, this research builds upon previous experience taking into account my BA in Environmental Studies from the University of Winnipeg and my work with the Waste Reduction and Pollution Prevention (WRAPP) Fund at Manitoba Conservation (responsible for coordinating the Fund).

1.8 Definitions

- Best Management Practices: policies, practices, procedures, and structures that through experience and research have proven to reliably lead to a desired result (Whatis.com 2005).
- White Goods: the term "white good" originated within early department stores describing the porcelain finish applied to the appliance by the manufacturer – giving the unit its outer white appearance (Potts and Baker 1998).
- Ozone Depleting Substance: are stable chemicals comprised of chlorine, fluorine, and bromine, which degrade under ultra-violet light in the stratosphere and are responsible for destroying ozone. ODS include, but are not limited to CFCs, hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, methyl chloroform, and methyl bromide (US EPA 2007).
- Greenhouse Gases (GHG): these are gases that are transparent to incoming short wave solar radiation, but are opaque to outgoing long wave radiation – effectively trapping heat in the earth's atmosphere and creating a greenhouse effect. These gases mimic the glass found in a greenhouse. The two major greenhouse gases are water vapour and carbon dioxide, with other gases including methane, ozone,

nitrous oxide, CFCs, HCFCs, and hydrofluorocarbons (HFCs) (Visionlearning 2006).

- Halocarbon: chemical compounds linking one or more carbon atoms to one or more halogen atoms including chlorine, fluorine, bromine, or iodine and encompass all anthropogenic ozone depleting and global warming substances (Wikipedia 2007c).
- Refrigerant: a chemical compound used to transfer heat – absorbs heat by evaporation and expels heat through condensation (HELMS 2007).
- Refurbishment: upgrades a product to current standards, both aesthetically and mechanically, which may include maintenance and repair work (Wikipedia 2006b).
- Product Stewardship: is a multi-stakeholder approach to end-of-life waste management that includes participation from all actors along the product chain including the producer, manufacturer, importer, distributor, retailer, consumer, reseller, and recycler (NWPSC 2001 *in* Toffel 2002)
- Extended Producer Responsibility: is an environmental policy approach in which the producer is responsible for, both physically and/or financially, a product beyond the post consumer stage of the product lifecycle (OEDC 2001).
- Design for Environment (DfE): which "supports product developers in reducing, already at the development phase of a products life cycle, the environmental impacts through enhancing the product design...[which] includes resource consumption, both in material and energy terms and pollution prevention" (Dantes 2006)

1.9 Thesis Organization

This thesis will be organized into six chapters – after the Introduction (Chapter One) is the Literature Review (Chapter Two) where I focus on examining key elements of refrigerator management and waste management policy. I follow this by Methods (Chapter Three). The findings are divided into two chapters beginning with Refrigerator Management: Manitoba (Chapter Four) and Regulatory and Voluntary Approaches for EOL Refrigerator Management (Chapter Five). Finally, a discussion and recommendations conclude this thesis in Conclusions and Recommendations for Improving Manitoba's Refrigerator Management Policies, Practices and Procedures (Chapter Six).

2.1 Introduction

This literature review is divided into five sections namely: 1) environmental impacts; 2) recycling techniques and resource recovery; 3) refurbishment; 4) waste management policy and 5) case study. Its main focus is to identify relevant waste management policy and establish the critical (base) components for a white goods management strategy.

2.2 Environmental Impacts of Refrigerators

Refrigerators have many impacts on the environment as they can contain ODS and toxic materials (mercury, PCBs and mineral oils), as well as, consuming large amounts of energy. These impacts are discussed in the following sub-sections.

2.2.1 Domestic Refrigeration: Ozone Depletion and Global Warming

The refrigerant in refrigerators used today contributes to ozone depletion and climate change. In this section different refrigerants will be discussed and their impacts on the environment, as well as, options to recover both refrigerant and halocarbons from their insulating foam.

2.2.2 Refrigerant Leaks

One of the biggest concerns regarding domestic appliances is refrigerants and their ability to negatively effect the environment in terms of ozone depletion and climate change. These appliances contain approximately 150g as refrigerant of the following halocarbons: CFCs, HCFCs, or HFCs (Environment Canada 2003). During their useful life, these compounds can escape from the equipment if there is a leak.

Leaks are generally the result of holes that have developed in the hermetic system, which seals in the refrigerant and lubricating oils. These holes can arise from mechanical damage or from a defect that can show up in the later years of appliance use. In some circumstances, holes can be present before the unit leaves the factory and can take up to six years to appear. In most cases, the unit can continue to function even while leaking refrigerant. Aside from using special leak detection equipment the only way to detect a leak is if there is pungent oily smell, where refrigerant is being replaced with normal air while the compressor is still running. The smell will be from the mineral oil, which is not developed to operate in a high heat, oxygen rich environment (Fridge Doctor.com 2003).

2.2.3 Ozone Depleting and Global Warming Potentials (ODP/GWP)

ODP is the ratio of impact a particular ODS has on ozone relative to the impact of the reference gas CFC-11 [ODP = 1] (US EPA 2007). This allows different ODS to be compared using a single universal unit, which is displayed as CFC-11 equivalents – such that not all ODS are uniform in terms of their ODP (i.e. CFC-12 = 1 and HCFC 141b = 0.1) (Scottish Executive: Environment 2003).

Halocarbons have some of the highest GWPs out of all sources of GHGs. GWPs look to assess the possible impacts that a certain gas may have. It is therefore defined as "the cumulative radiative forcing—both direct and indirect effect—integrated over a period of time from the emission of a unit mass of gas relative to some reference gas" (USEPA 2002:8). The chosen gas of reference is carbon dioxide (CO_2), with a GWP of one. Out of all the ozone depleting substances, CFC-12 is the most potent greenhouse gas with a GWP of 10,600 and CFC-11 at 4,600 over a 100-year period.

HFCs, which do not deplete ozone, are powerful greenhouse gases and have been identified within the six main basket gases of the *Kyoto Protocol.* They are primarily used as replacements for ODS refrigerants and are also emitted as a byproduct of the HCFC-22 manufacturing process. The primary refrigerant HFC-134a has a 100-year GWP of 1,300 (US EPA 2002).

2.2.4 Global Warming and Domestic Refrigeration

Carbon dioxide is emitted as a result of generating electricity necessary to power appliances – especially if the power is generated through burning coal. In total, twenty percent of global warming can be attributed to refrigeration, with 20% of that from the release of halocarbons and 80% from electricity consumption (IIR n.d). It is predicted that by the year 2050, without responsible use, HFCs could possibly account for approximately 2% of all GHG releases (AHAM/EPA 2005). The combination of all major domestic appliances in a home can be directly linked to the release of nearly 2,500-kg of GHGs each year (Calgary Think Climate Change 2003). To put the climate impact of a single EOL CFC or HFC/HCFC refrigerator in perspective, assuming the loss of 150 g of refrigerant and more than 125 g of blowing agent (average 25% immediate loss of 500 g), one refrigerator of either type has a carbon dioxide equivalent as calculated in Table 2.1. This is the equivalent of releasing 2.165 metric tons of carbon dioxide.

Table 2.1: Climate Impact of One CFC or HFC/HCFC Refrigerator

Halocarbon	Charge (Metric Tons)	GWP 100 Years	CO_2 Equivalent (Metric Tons)
CFC-11	0.000125	4,600	0.575
CFC-12	0.00015	10,600	1.59
Total			**2.165**
HCFC-141b	0.000125	580	0.0725
HFC-134a	0.00015	1,300	0.195
Total			**0.2675**

(Modified from: Thomas, Tennant, and Rolls 2000).

2.3 Refrigerant Recovery

The first step in any refrigerator management program is the recovery of refrigerant, which is performed by a trained certified refrigeration technician. The literature has identified two best-practice methods for the recovery of halocarbons via the active or adsorption ("Blue Bottle") recovery methods.

2.3.1 Active Recovery Method

The active recovery method involves the use of a compressor equipped with a filter-drier and condenser, which extracts the refrigerant. The recovery unit is first attached to the appliance though the use of hoses. When the refrigerant is in its gaseous state, it is transferred over to the recovery unit by the compressor, which feeds the gas into the condenser—transforming it into a liquid. From there, the refrigerant is sent from the recovery unit to a pressurized cylinder for storage. This system is certified for the recovery of CFC-12, HCFC-22, and HFC-134a, with a recovery efficiency that varies anywhere from 80 to 96% (Environment Canada 2004).

2.3.2 Adsorption Method

The Blue Bottle method uses a cylinder containing a Halozite matrix to adsorb the refrigerant from the appliance. The system is connected to the appliance via hoses and the gaseous refrigerant is transferred through diffusion to the recovery unit as the refrigerant air-stream passes through the cylinder. A vacuum pump is used to create suction to further remove all refrigerants from the unit. When the unit's Halozite matrix is completely saturated, the cylinder is returned to the manufacturer (Halozone), which is a centralized reclamation plant where the refrigerants are desorbed for reuse or destruction. Following desorption, the Halozite matrix is recharged and the cylinder is ready for reuse.

Halozone ensures "virtually 100% recovery of ODS from non-condensable streams emitted when purging chillers, evacuating equipment or leak testing, and from low volume refrigerant applications such as the servicing and decommissioning of...residential refrigerators" (OCETA 2006:1-2). Blue Bottle allows recovery of ODS from the appliance without any changes in chemical composition of the refrigerant. The major drawback to this system is the cost related to transporting the recovered refrigerant to the reclamation facility, which can be far away from the location of desorption (Environment Canada 2004, OCETA 2006).

2.4 CFCs as Auxiliary Blowing Agents in Insulating Foams

Manufacturing a refrigerator requires the use of approximately 400g to 600g of halocarbon blowing agent (often five times the amount found in the cooling circuit), which is used to propel and insulate plastic foams. Most refrigerators utilize rigid