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Managing Change Driven By Environmental Regulations: Can Industries in the United States Eliminate the Use of Chloroflurocarbons (CFCs) in Insulating Foam Plastic Products and Maintain Global Competiveness?

M. Boake-Danquah

MANAGING CHANGE DRIVEN BY ENVIRONMENTAL REGULATIONS: CAN INDUSTRIES IN THE UNITED STATES ELIMINATE THE USE OF CHLOROFLUROCARBONS (CFCs) IN INSULATING FOAM PLASTIC PRODUCTS AND MAINTAIN GLOBAL COMPETITIVENESS?

M. Boakye-Danquah, B.S., M.S.

A Culminating Project Presented to the Faculty of the
Graduate School of Lindenwood College in Partial
Fulfillment of the Requirements for the
Degree of Master of Business Administration

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ABSTRACT

Chemicals emitted into the atmosphere which contain chlorine have been identified as ozone-depleting compounds for several years. These chemicals generally described as chlorofluorocarbons (CFCs) and chlorinated solvents, are used in a wide variety of applications. International agreements and government regulations in the United States are mandating a ban, and requiring industries to seek CFC and chlorinated solvent replacements. The substitutes which are approved by the Environmental Protection Agency (EPA), contain less or no chlorine, and hence, are less damaging to the earth´s ozone layer.

The provisional chemicals are not drop-in replacements for existing products and processes which employ CFCs. There are significant technological and economic barriers to overcome, and U.S. industries are proceeding quickly but cautiously to replace the CFCs. In most cases, firms have to reformulate products to maintain quality and safety, processes have to be modified, and it is often necessary to retrofit equipment in order to use CFC replacements.

The major criteria for choosing alternates are: Environmental acceptability; Toxicity; Safety; Technical feasibility; Availability; Cost effectiveness.

Nearly one-third of worldwide CFC use is in foam plastics. An option to phaseout CFCs in foam plastics for insulation applications is presented. Insulation foam plastics are especially important because of the energy conservation function of the products in refrigeration and construction applications. This thesis outlines the steps necessary to evaluate and choose immediate replacements for CFCs, and eventually, the process necessary to phase in long-term substitutes which have no ozone depleting potential (ODP).

The option presented gives industries in insulating foam plastics a means of meeting the environmental regulations and challenges pertaining to the CFC substitutes, while maintaining a competitive position in the marketplace.

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DEDICATION

I would like to dedicate this work to my dear mother, Madam Rebecca Akua Sagoe, in appreciation for her love, support, and the early lessons about business transactions.

Chapter 1

INTRODUCTION

Regulations for the CFC ban

U.S. industries have to comply with various environmental regulations, which affect the ability to compete globally. In order for industries in the U.S. to meet the changing environmental regulations, it is often necessary for managers to devote resources to attain compliance, which invariably increases the cost of doing business in the short term. The environmental regulations required by the U.S. government do not often apply to other nations which are considered developing countries.

As a response to the discovery of the "ozone hole" over Antarctica, and to growing evidence that chlorine and bromine could destroy stratospheric ozone globally, several members of the international community concluded that an agreement to reduce worldwide production of ozone-depleting substances was needed.

In September 1987, the U.S. and twenty-two other countries signed the Montreal Protocol on substances that deplete the ozone layer. The original terms of the agreement called for a cutback in CFC production to fifty percent of 1986 levels by 1988 (Zurer, 7). The first amendment in London to the Montreal Protocol in 1990 required phaseout of CFCs, halons (fluorocarbons that contain bromine), and carbon tetrachloride (chlorinated solvent) by the year 2000. The London amendments called for a voluntary phaseout of "transitional substances" no later than 2040 (Zurer, 8).

Transitional substances are EPA approved substitutes, which have lower ozone-depleting potential than CFCs. These chemicals are broadly referred to as hydrochlorofluorocarbons (HCFCs). According to the EPA, the HCFCs are supposed to temporarily bridge the gap between CFCs and permanent replacements with zero ozone-depleting potential (ODP). Hydrofluorocarbons (HFCs) do not contain chlorine and have zero ODP. The HFCs have been sanctioned by the EPA as lasting replacement for CFCs.

At a 1993 meeting of the Montreal Protocol's members in Bangkok, the Nordic European nations attempted to speed up the phaseout of HCFCs from 2040 to 2015. This change threatens to de-stabilize the process of reasonably phasing out CFCs, and erode the confidence of three key groups (Fay, 68).

The first group is investors in new technology who support the manufacturers of alternate propellants and equipment for CFC replacements. The second group is equipment users who must decide on retrofit or replacement of existing CFC and HCFC equipment. Currently, only about ten percent of owners of CFC chillers have made that decision, with less than two years to CFC production phaseout. The third group is emerging nations, which is allowed a ten year delay in CFC phaseout. These nations do not know who will manufacture CFCs for their equipment (Fay, 68).

The apparent lack of stability could threaten the "sensitive balance" that was struck among the original Montreal Protocol signatory nations in 1987. So far, the agreements have worked very well to keep the phaseout schedules of CFCs on course. There are concerns though, that some participants of the Montreal Protocol may override others to push the CFC ban dates forward.

The U.S. EPA regulates CFCs under the Clean Air Act. The EPA laws differ notably from the Montreal Protocol in how it treats transitional chemicals, (HCFCs). The Clean Air Act forbids production of HCFCs after 2015 except for servicing equipment, and imposes a total ban after 2030 (Zurer, 8). Though the

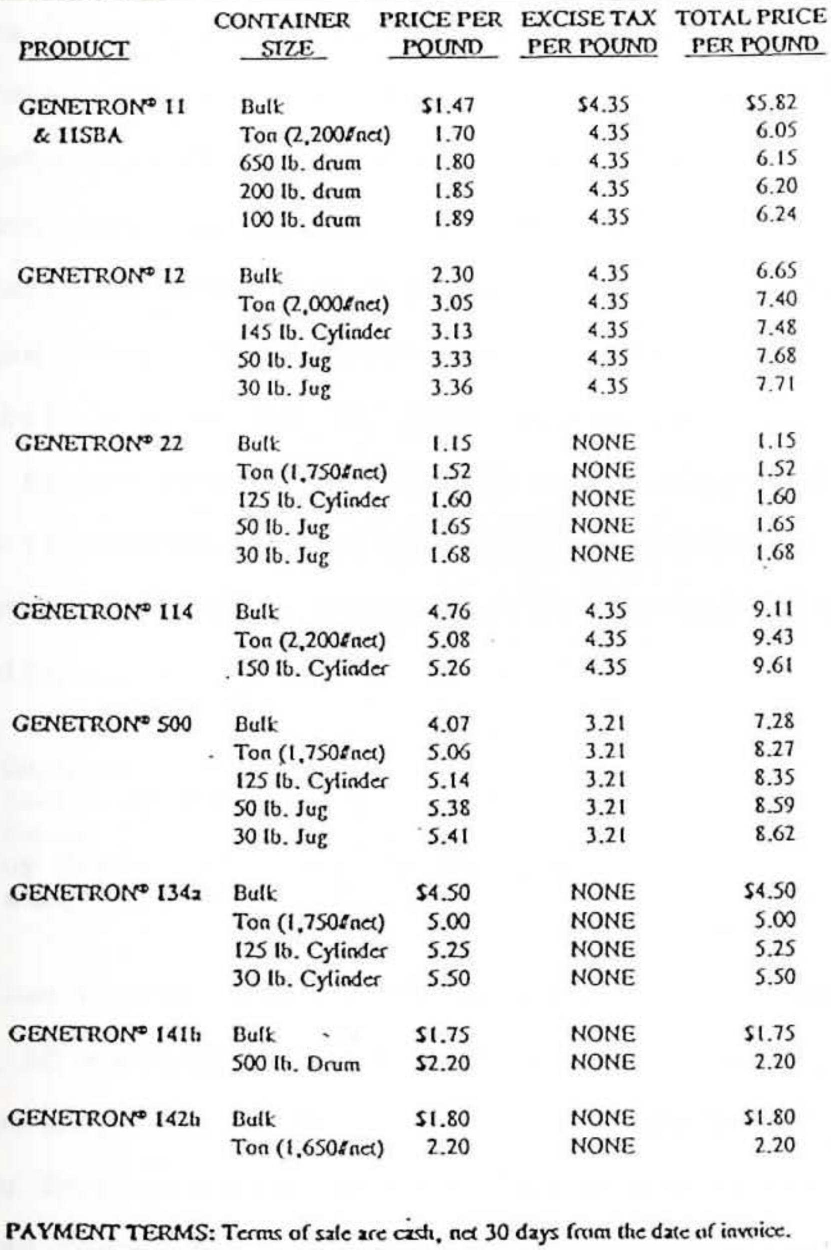
Montreal Protocol serves as the general guideline for banning CFCs, individual countries are at liberty to move dates forward, which troubles U.S. industries. The uncertain timeliness for phasing out interim CFC replacements makes it difficult to plan for the conversion to HFCs. Appendix A presents the most recent CFC phaseout schedule from DuPont.

Incentives for Industries to eliminate CFCs

In 1989, the U.S. Congress levied an excise tax on the sale of CFCs and other chemicals which deplete the ozone layer, with specific exemptions for exports and recycling. The tax went into effect on January 1, 1990 (EPA, 50465). The excise tax was revised for an increase effective January 1, 1993. The increase in the cost of the CFCs with the additional excise tax was meant to deter industries from depending on CFCs in the long term. The U.S. government seeks to push for increased recycling activities, and the development of markets for alternate chemicals and processes (EPA, 50465). Table 1 shows the latest excise tax on CFCs, and the cost of HCFCs and HFCs. The excise tax shown in Table 1 for CFCs is higher than the actual cost of the propellants. Presently, there is no excise tax levied against HCFCs and HFCs.

TABLE 1

GENTRON PRICE SCHEDULE
For OEM Appliance and Blowing Agent Markets
Effective with Shipments of January 1, 1994



PRODUCT	CONTAINER SIZE	PRICE PER POUND	EXCISE TAX PER POUND	TOTAL PRICE PER POUND
GENETRON® 11 & 11SBA	Bulk	$1.47	$4.35	$5.82
	Ton (2,200#net)	1.70	4.35	6.05
	650 lb. drum	1.80	4.35	6.15
	200 lb. drum	1.85	4.35	6.20
	100 lb. drum	1.89	4.35	6.24
GENETRON® 12	Bulk	2.30	4.35	6.65
	Ton (2,000#net)	3.05	4.35	7.40
	145 lb. Cylinder	3.13	4.35	7.48
	50 lb. Jug	3.33	4.35	7.68
	30 lb. Jug	3.36	4.35	7.71
GENETRON® 22	Bulk	1.15	NONE	1.15
	Ton (1,750#net)	1.52	NONE	1.52
	125 lb. Cylinder	1.60	NONE	1.60
	50 lb. Jug	1.65	NONE	1.65
	30 lb. Jug	1.68	NONE	1.68
GENETRON® 114	Bulk	4.76	4.35	9.11
	Ton (2,200#net)	5.08	4.35	9.43
	150 lb. Cylinder	5.26	4.35	9.61
GENETRON® 500	Bulk	4.07	3.21	7.28
	Ton (1,750#net)	5.06	3.21	8.27
	125 lb. Cylinder	5.14	3.21	8.35
	50 lb. Jug	5.38	3.21	8.59
	30 lb. Jug	5.41	3.21	8.62
GENETRON® 134a	Bulk	$4.50	NONE	$4.50
	Ton (1,750#net)	5.00	NONE	5.00
	125 lb. Cylinder	5.25	NONE	5.25
	30 lb. Cylinder	5.50	NONE	5.50
GENETRON® 141b	Bulk	$1.75	NONE	$1.75
	500 lb. Drum	$2.20	NONE	2.20
GENETRON® 142b	Bulk	$1.80	NONE	$1.80
	Ton (1,650#net)	2.20	NONE	2.20

PAYMENT TERMS: Terms of sale are cash, net 30 days from the date of invoice.

SOURCE: McDonough, P. "GENETRON PRICE SCHEDULE for OEM Appliance and Blowing Agent Markets." *Allied Signal Inc.* 10 January, 1994: 1.

As an additional incentive to switch to permanent CFC substitutes, the U.S. government is ordering manufacturers to notify customers about products that contain CFCs. The labelling requirements provided for in the Clean Air Act prohibit the introduction into interstate commerce, as of May 15, 1993, any CFC (Class I substances) or HCFC (Class II substances), any product containing Class I substances, and any product manufactured with class I substances unless it bears a warning label. The requirements also extend the prohibition after May 15, 1993, and before January 1, 2015, to any products containing or manufactured with Class II substances if a safe alternative is available. The status specifies the content of the warning label as follows.

> WARNING: Contains (or Manufactured) [name of substance], a substance which harms public health and the environment by destroying ozone in the upper atmosphere (Anspach, 21).

Due to the negative public image, the required label is a strong impetus for U.S. companies to discontinue using CFCs and HCFCs in products. The outcry from consumers against CFCs is one of the driving forces for CFC users to attain long-term viable alternatives as soon as possible. There are also civil penalties that run up to $10,000 per day for any violation of the labeling requirements. Criminal penalties may be imposed for "knowing" (intentional) violations (Healy, 1).

Central cause for the CFC ban

In the early 1970s, concerns about the ability of chlorofluorocarbons (CFCs) to react with stratospheric ozone, and cause ozone depletion began to arise. Suggestions were made by some members of the scientific community about the actual chemical reactions which could use ozone as a starting chemical (Zurer, 25). From the earlier reports of ozone depletion until now, the public outcry against the use of CFCs in all products has intensified. The elimination of ozone-depleting chemicals from products, processes, and refrigeration applications have become a serious political and social issue. Companies having anything to do with CFC-containing products are in various stages of converting to alternatives (Mahoney, 1).

Consumer products companies such as fast food chains, have discontinued the use of CFC-blown containers for packaging food. The McDonald´s chain changed the package for sandwiches from styrofoam to paper in order to maintain a responsible image with customers. The rest of the fast food chains have followed suit. According to the U.S. Food and Packaging Institute, producers of foam plastics for food packaging products completed the switch to HCFCs and hydrocarbon propellants in early 1990 (Zurer, 8).

Manufacturers have made public announcements about getting out of producing CFCs in the near future. DuPont Chemical Company, which is the world´s largest producer, announced in October 1991 it would cease manufacture and sales of CFCs by the end of 1994 (Dougherty, 1). In February 1992, President George Bush informed the American public about an accelerated ban on all CFCs, with the phase out schedule pushed forward from 1996 to 1994. The short supply of CFCs in the future will speed up the rate at which U.S. industries convert to alternatives (Mahoney, 1).

The tremendous pressure from the public to ban CFCs has a strong basis that the chemicals deplete the ozone layer (Zurer, 25). The ozone layer is very important for absorbing ultraviolet (UV) radiation from the sun. The reduction in the thickness of the ozone layer in the stratosphere, allows UV radiation to travel all the way into the atmosphere. It is known that the exposure of human skin to UV radiation in the atmosphere can cause cancer. Because of the known hazard, the CFC phaseout schedule has been accelerated The Montreal Protocol and U.S. Environmental Protection Agency (EPA) have provided the regulations and guidelines for banning CFCs (Strobach, 35; Profile, 36). The EPA is the body responsible in the United States to enact the Clean Air Act. Part of the Clean Air Act publishes the serious replacement candidates for CFCs. In 1992, the EPA published the Proposed Rules for CFC phaseout (EPA, 1992; Patrick, 48).

Opportunities created by the CFC ban

Though the ban on CFCs poses serious challenges to chemical processing, refrigeration, and foam plastic industries, some opportunities have resulted from the ban on ozone-depleting chemicals. Effective July 1, 1992, it is illegal to vent CFCs or HCFCs to the atmosphere during repair, maintenance, or disposal. Due to government regulation against venting, recycling and reclamation of CFCs have become a lucrative business. After the ban in 1996, CFCs will be available solely from recycled sources.

Appliance Recycling Centers of America (ARCA) is a Minneapolis-based company that reclaims CFCs from unwanted household appliance. ARCA drains the CFC-12 from refrigerator compressors and cleans it up for resale. ARCA recovers CFC-11 from the insulation foam in refrigerators. The company uses a system for removing CFCs from insulating foams which was developed by Adelmann of Karlstadt, Germany. The process has a certified CFC recovery rate of ninety-nine percent (Zurer, 11).

Manufacturers and retailers of CFC replacements are positioning the companies as being friendly to the environment. The plant capacities for the replacement chemicals have been geared up significantly to handle the exploding demand for CFC alternatives. ATO Chem Company is a large manufacturer of gases identified as replacements for CFCs. ATO Chem informed the public about the corporate philosophy of being friendly to the environment in February 1992 (News Release, 2). DuPont, who was the largest CFC manufacturer, is investing heavily in new plants, and converting the plant capacity for CFCs to producing replacements (Newslines, 3; Chynoweth, 8).

Dupont is also de-marketing its own products, and encourages CFC customers to convert to replacement products. Allied Signal, who manufactures CFCs, recently converted a CFC plant to produce replacements in order to meet the demand for the new propellants (Norris, 1).

General Uses of CFCs

The main applications requiring CFCs are aerosols, foam plastics, refrigeration, and solvents. In refrigeration applications, CFCs are used in compressors for cooling. The solvents are used generally for cleaning and de-greasing purposes in maintenance and manufacturing. The global use of CFCs segmented by application is shown in Table 2.

TABLE 2

1986 Global CFC use by Application

APPLICATION	% of TOTAL GLOBAL USE
AEROSOL	28 %
FOAM PLASTIC	25 %
REFRIGERATION	25 %
SOLVENTS	16 %
OTHER	7 %

SOURCE: Lichtenberg, W. "Technical Progress in Eliminating the Use of CFCs in Polyurethane Industry." Improved Thermal Insulation: Problems and Perspectives. Ed. Dale A. Brandreth. Lancaster: Pennsylvania Technomic Publishing Company, 1991: 30.

There are two categories of aerosol applications: essential and non-essential, which are defined in Appendix A. Aerosols containing CFCs used in the pharmaceutical industry are in the essential use category. Rigid foam plastics which employ CFCs are classified as essential use because of the insulation value. The ability of the foam to reduce energy cost is the primary reason for the special status of insulating foam plastics. When the CFC use is classified essential, the CFCs will be banned last for these applications. On the contrary, applications in the non-essential use category are the first to face the CFC ban.

In 1978, the U.S. first banned the use of CFC propellants in non-essential aerosol products. Since then, products packaged in aerosol form have been subjected to intense regulatory control throughout the world. Currently, more than 95 percent of all aerosol products in the U.S. use alternate propellants, most notably hydrocarbons. Aerosol personal care and household consumer products were the first products to face the CFC ban. Hydrocarbons have been used mostly to replace CFCs since 1978 (Dupont, 1).

Aerosols are used widely in the pharmaceutical industry for the efficient delivery of medications. A good example is asthma medications, which are packaged as aerosols using CFCs. Though CFCs in medications are categorized by EPA as essential use, the pharmaceutical industry is supposed to discontinue using CFCs by the end of 1996.

At the annual meeting of the American Lung Association (ALA) in May 1992, the association announced it´s seeking an exemption from President Bush´s accelerated phaseout schedule for CFCs in pocket-size devices used by patients suffering from asthma, chronic bronchitis, and emphysema (Zurer, 9). ALA estimates about 25 million people in the U.S. depend on metered-dose inhalers. CFCs are used in the inhalers to deliver precisely metered doses of medication in aerosol form directly to the lungs. The ALA reckons that the shortest possible time needed for conversion to CFC-free inhalers is four to six years away, which falls between 1998 and the year 2000 (Zurer, 9).

Uses of CFCs in Foam Plastics

In foam plastics, CFCs are used in applications for thermal insulation, cushioning, and packaging. The foam plastics are generally produced by using a gas or volatile liquid as a "blowing agent" to generate bubbles or "cells" in the plastic structure. CFCs in cushioning is a non-essential use, and CFCs have been eliminated and replaced with an alternate, water-blown process. Packaging foams are also in the non-essential category, and CFCs have been replaced with alternatives (EPA, 2000).

The two main types of foam plastics are thermoset and thermoplastic. Thermoset foam plastics (polyurethanes and phenolics) harden or cross-link permanently, and cannot be heated or melted for reuse. The thermoset foams are made by introducing a volatile "blowing agent" into liquid precursors. During the exothermic reaction between precursors to form the plastic, the liquid blowing agent volatilizes to a gas, forming bubbles which create a cellular structure when the plastic hardens. In contrast to thermoset foam plastics, thermoplastics (polystyrene and polyolefins) can be melted and reused. These are made by injecting a gas blowing agent into a molten plastic resin (Billmeyer, 467).

The resulting plastic foam is described as either close cell or open cell. In the case of foam plastics with close cells, the resulting bubbles generated are closed, trapping the blowing agent inside. For insulation applications, closed cells are sought to prevent heat transfer across the foam. The blowing agent remaining in the cells determines the insulating efficiency (R-value) of the foam. In general, a higher

R-value indicates a superior insulating material. About 90 percent to 95 percent of CFCs used in rigid foam plastics for insulation are retained within the closed cells of the foam, which leads to low thermal conductivity. Insulating foam requires a blowing agent with low thermal conductivity, which is a low rate of heat transfer, to provide a high thermal insulation efficiency (Gross, 20).

Foam plastics with closed cells are also desirable for packaging applications. Foam plastics with open cells allow the blowing agent to escape, which renders a "rebound" quality to the finished product. Cushioning foam plastics are designed to have open cells.

Classes of replacements for CFCs

The choice of materials that can be used in the future as blowing agents in insulating foam plastic applications are: carbon dioxide, hydrocarbons, and CFC alternates.

Carbon dioxide is generally unsuitable for insulation applications because the gas retained in the foam leads to higher thermal conductivity, which becomes more pronounced with age (Gross, 20). The high thermal conductivity produces low R-values in insulating foams blown with carbon dioxide.

Hydrocarbons (HCs) are very inexpensive, and are used extensively in Europe for insulating foams. The HCs have a serious weakness, which is flammability. A non-flammable blowing agent is preferred because it helps improve the safety of the foam manufacturing environment and enhances the fire performance characteristics of the end-product. Also, HCs are classified as volatile organic compounds (VOCs), which are regulated by the U. S.´s Federal, state, and local governments.

Historically, CFCs were excellent for use in insulating foam plastics because of non-flammability, low cost, low thermal conductivity, and other properties which rendered the gases ideal for insulating foam applications. The high ozone-depleting potential of CFCs is the most severe drawback Compared with CFCs, replacements with lower or no ozone-depleting potential is the best choice for insulating foam plastic applications in the future.

The substitution of CFCs with alternates is not just a drop-in replacement. Resources have to be dedicated to modify processes, reformulate products, and market the new products which contain the CFC replacements.

Options to delete CFCs from insulating foams

The technical options to phase out CFCs in insulating foam plastics are as follows:

OPTION #1 -Replace CFCs with alternate blowing agents.

OPTION #2 -Modify present production process to slowly phase out CFCs, or use other technologies which completely eliminate CFCs.

OPTION #3 -Substitute foam plastic products with alternate products (English et. al., 2).

The focus of this paper is to explore the first option. In pursuing this option of using conventional alternate blowing agents, there are three stages to attaining the ultimate goal of using zero ozone-depleting chemicals in foam plastics. The first stage is the search for immediate available substitutes for CFCs. The second stage is to implement the use of intermediate CFC substitutes, HCFCs, which are scheduled to be phased out by the year 2030. The third and final stage is to use identified long term replacements, HFCs.

The criteria for evaluating CFC alternates include: Environmental acceptability; Toxicity and safety; Technical feasibility; Availability; Cost effectiveness. Within product types, the criteria for acceptable alternates can vary depending on various factors which include regional product mix, climate, political factors, social factors, and environmental regulations set by state governments.

For conversion to CFC alternatives, it is imperative for U.S. industries to take a long-term view because of the significant costs involved with equipment, product, and process changes.

There are limited options and few incentives for industries to continue the use of CFCs. First of all, CFC use in insulating foams will be illegal after 1996. There is a strong negative public image in the U.S., which adversely impacts products containing or processed with CFCs. Also, the cost of CFCs is prohibitive because of the excise taxes. Another reason for industries to discontinue the use of CFCs as soon as possible is that the supply and availability is already a problem. Manufacturers are changing plants to produce alternates, and are gradually preparing to cease CFC production by the end of 1996. The supply of CFCs after 1996 will only be available from recycled material. There is really no reason for any industry operating in the U.S. to wait to phase out CFCs.

Purpose of Study

American companies can eliminate the use of CFCs in insulating foam plastics and maintain global competitiveness by reacting immediately to the government´s regulations. Regardless of the potential short-term increase in cost, U.S. industries need to respond positively to the challenges of employing chemicals which are less harmful to the environment.

A proposed approach to coping with the CFC phase out follows: The first step is to investigate and monitor what competitors are doing globally. The suppliers of CFC alternates can be instrumental in this stage. The second step is to identify and rate replacement candidates and undertake extensive evaluation for cost/benefit relations, product quality, and processing the intermediate, HCFC, alternatives. The third and final stage is to replace the HCFCs with lasting CFC replacements, HFCs.

At every stage of phasing out CFCs, the insulating foam plastics industry needs to de-market existing CFC-containing products. Exports are exempt from the U.S. excise tax but the labels have to show that the products contain CFCs. Products made with CFCs cannot be imported into the U. S. after the ban in January 1996. It would be beneficial for the foam plastics industry to de-market CFC use globally for two key reasons: Products containing CFCs are harder to sell because of worldwide publicity against ozone depletion. Secondly, supply of CFCs is shrinking due to suppliers converting plant capacities to produce CFC alternates.

To improve the image of the public toward the use of CFC replacements, it would be essential for U.S. industries to maintain a position of engaging in practices which are "environmentally friendly", by helping to save the ozone layer.

Chapter II

LITERATURE REVIEW

Review of Options for Eliminating CFCs

The first option discussed in the introduction is to replace CFCs in insulating foam plastics with EPA-approved, alternate blowing agents. Eliminating the use of CFCs via approved replacements is presented in Chapter II as the most viable option. In following this option of using alternate blowing agents, there are three stages to attaining the ultimate goal of using zero, ozone-depleting chemicals in foam plastics. The first stage is the search for immediate available substitutes for CFCs. The second stage is to implement the use of intermediate substitutes, HCFCs, which are scheduled to be phased out by the year 2030. The third and final stage is to use identified long term replacements, HFCs.

The second Option, to phase out CFCs, has two approaches. The first is to modify present production processes to slowly phase out CFCs. The second strategy is to use other technologies which completely eliminate the need for CFCs, and coventional replacments such HCFCs and HFCs.

The first approach in Option two to slowly eliminate CFCs is not realistic because of the CFC ban effective January 1, 1996. From now until the ban takes full effect, supply is expected to shrink dramatically (Mahoney, 1).

As shown in Table 1, the cost of CFCs have been raised by including a significant excise tax, which is meant to deter industries from continuing the use of CFCs (EPA, 50465). Compared with replacements, the cost of CFCs is higher than the alternates, and is not cost effective for use in insulating foam plastic applications. In addition, modifying the manufacturing process to reduce CFC often require capital investment, which may need to be repeated in about a year when the CFC ban takes effect in 1996.

Under Option two, technologies which completely eliminate the need for CFCs are currently in use. In these applications without CFCs, HCFC´s, or HFCs, the insulating foams generally employ hydrocarbons. Pentanes, which are hydrocarbons, have been widely accepted in Europe for permanently replacing CFCs in refrigeration applications. There are several reported commercial successes of products with foam containing pentane (Tambosso, 5). The pentane-blown foams are reported to have good physical properties and the

Chapter II

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Hydrocarbons, (HCs) are very inexpensive, and produce foams which have superior energy efficiency, compared with insulating foams plastics containing HCFCs (Jarfelt, 2). But, the central problem with HCs is flammability (Hausgerate, 5). Non-flammable characteristic is preferred due to the fire risk during processing, shipping, storage, and end-use.

The hydrocarbons (HCs), are volatile organic compounds (VOCs). VOCs are organic compounds which when exposed to sunlight in the presence of nitrogen oxides, decomposes at ground level to create smog or ambient level ozone. The ambient level ozone is a health hazard when it reaches certain limits. Thus, the U.S. Clean Air Act directs the EPA to mandate states to reduce emissions of VOCs to the extent required to maintain safe ozone levels (Dunn, 30). The U.S. regulatory pressures on VOCs limits the potential for HCs to broadly replace CFCs in insulating foam plastic applications.

Another technology that eliminates the need for conventional CFC replacements is the use of carbon dioxide (CO_2) in insulating foam plastics. The problem with the technology is that the foams generally have poor properties, and the thermal conductivity is high. The carbon dioxide in the closed cells egress the foam, which results in poor foams (Gross, 20).

Overall, Option two has not been embraced in the U.S. Modifying processes to use less CFCs is not practical because of the high excise tax, short supply, and the pending CFC ban in 1996. The use of HCs contribute to smog formation, which makes the cheap and abundant hydrocarbons, unattractive as long-term CFC replacements. Potential liabilities resulting from flammability renders the HCs unattractive for replacing CFCs in insulating foam plastics. Carbon dioxide, when used in foam applications, causes high thermal conductivity, resulting in low energy efficiency.

Option three is to substitute insulating foam plastics with alternate, non-foam, products. The main non-foam product for insulation is fiberglass. The problem with fiberglass is that thick sections are required for the desired insulating efficiency. In applications where space is restricted, the use of fiberglass is limiting.

The fiberglass does not adhere to any surface, and with time, the material could settle or fall out of place, which defeats the purpose of insulation.

The ease of installing closed cell, propellant-blown foam, is a strength for using insulating foam plastics. Adhesion of the foam to substrates ensures that the insulating foam stays in place.

Based on reasons examined, Option two and Option three are not considered preferred routes for permanently replacing CFCs. Option one is discussed in detail for the remainder of this work, as the route to take for eliminating CFC utilization in insulating foam plastics.

In pursuing Option one, intermediate CFC replacements, HCFCs, will be discussed. HFCs, which are approved for permanently replacing CFCs will be presented. The phase out of CFCs is proposed to take two stages, with the first stage being the use of temporary substitutes. The second stage will be implementation of using HFCs in insulating foam plastics. The phase out of CFCs begins with the critical process of evaluating viable CFC replacements.

Replacements for CFCs must meet certain criteria if they are to be considered practical alternatives. The most important criterion for alternatives is environmental acceptability. This means the replacement must have low ozone depletion and global warming potentials, and negligible photochemical activity (Daly, 34).

In addition to environmental acceptability, the CFC replacements must exhibit low toxicity, and be non-flammable, or at least, exhibit low flammability in end-use. Even if the replacement satisfies the above criteria, a supplier must be able to manufacture it in a practical, realistic commercial process. Other properties such as efficacy also must be satisfactory for the final application for insulating foam plastics. The product must be reasonably priced and have acceptable costs to users (Daly, 34).

The major criteria for evaluating CFCs´ alternates that will be discussed are: Environmental acceptability; Toxicity; Flammability; Technical feasibility; Cost related issues.

Environmental Acceptability

Table 3 presents the environmental impact of CFCs and alternates.

TABLE 3

Environmental Impact of CFC Alternatives

	Atmospheric Lifetime (Years)	ODP	GWP	VOC Status
CFC-11	55	1.0	3400	No
CFC-12	116	1.0	7100	No
HCFC-123	1.75	0.02	93	No
HCFC-22	15.8	0.055	1600	No
HCFC-141b	11.4	0.11	640	No
HCFC-142b	22.6	0.065	1800	No
HFC-134a	15.6	0	1200	No
HFC-152a	1.8	0	150	No
Hydrocarbons				
Propane	Very short	0	3	Yes
Butane	Very short	0	3	Yes
Isobutane	Very short	0	3	Yes
Carbon dioxide				
CO_2	120	0	1	No

SOURCE: UK Department of Environment. Exhibit from "Science Assessment of Ozone Depletion" by WMO, UNEP, NASA, UK Department of Environment (1991). As cited in Spray Technology & Marketing by J. J. Daly and M. L. SanGiovanni (February 1993): 34.

Environmental acceptability of a CFC alternative is based on four key criteria which are ozone depleting potential (ODP), global warming potential (GWP), atmospheric lifetime, and VOC status (Daly, 35).

The ODP is about the most important requirement for CFC replacements. ODP is a rating of a chemical's ability to react with, and in the process deplete stratospheric ozone. As presented in Table 3, CFC-11 and CFC-12 have the highest ODP of 1. The standard for comparing all CFC replacements is CFC-11. The high chlorine content in CFCs is known to react with ozone molecules in the atmosphere, causing depletion. The ODP for alternates are less than CFC-11, and, the lower the ODP the greater the potential for the alternative to become a viable CFC replacement (Daly, 35).

HCFCs which have been approved as interim CFC replacements are; HCFC-123, HCFC-22, HCFC-141b, HCFC-142b. Among the intermediate replacements, HCFC-123 has the lowest ODP of 0.02, compared with CFC-11. The 0.02 ODP designation for HCFC-123 is interpreted as being 98 percent better for the ozone layer than CFC-11. In increasing order, HCFC-22 follows with an ODP of 0.055, which is 94.5 percent better than CFC-11.

Next is HCFC-142b with an ODP of 0.065. HCFC-141b has the highest ODP of 0.11 (Johnson, 29).

HFCs shown in Table 3 both have zero ODP. The HFCs do not contribute to stratospheric ozone depletion, because the chemicals do not contain chlorine. HFC-152a and HFC-134a are presented as the leading candidates for permanently replacing CFCs in insulating foam plastics. The HFC 152a being flammable makes HFC 134a a stronger candidate to be a lasting replacement for CFCs in insulating foam plastics (Johnson 31).

The hydrocarbons shown in Table 3, do not contain chlorine, and have zero ODP. A significant weakness of the hydrocarbons is flammability, and requires special equipment for processing the foam safely (Lerch, 15). Hydrocarbons have a positive VOC status, which is negative for environmental acceptability.

The environmental impact of carbon dioxide (CO_2) is shown in Table 3. Carbon dioxide occurs naturally in small amounts, and is mostly generated from burning fossil fuel. Besides having the longest atmospheric lifetime, carbon dioxide has zero ODP, the lowest GWP of 1, and is not a VOC. The problem with carbon dioxide is that the insulating foam plastics produced have low energy efficiency (Gross, 20).

Global Warming Potential (GWP) follows ODP in order of importance for identifying CFC replacements. GWP is a rating of a chemical´s ability to contribute to global warming. The cause for global warming is normally attributed to "greenhouse gases", that are reported to elevate the temperature of the atmosphere. With a designation of 1, carbon dioxide has the lowest GWP, and is the standard for evaluating the GWP of chemicals. The GWP of HCFCs and HFCs is relatively low compared with CFCs (Johnson, 30).

CFC-11 and CFC-12 have GWP of 3,400 and 7100 times more than carbon dioxide respectively. The high GWP makes the CFC´s very undesirable. HCFC-123 has a GWP of 93, which is very low compared with the CFCs. HCFC-22 has a much higher GWP of 1600, which is still significantly lower than the CFCs. HCFC-141b has a low GWP of 640, which makes it attractive as an interim CFC replacement (Daly, 34). HCFC-142b has a GWP of 1800 which is close to the GWP of HCFC-22.

HFC 134a and HFC 152a have respective GWP of 1200 and 150, which are markedly lower than the GWP for

CFCs. The low GWP of 152a makes it a desirable permanent CFC replacement (Daly, 34).

The third environmental-related requirement for evaluating the CFC alternates is residence time of the chemical, the atmospheric lifetime. When a chemical is exposed to the atmosphere, the number of years it takes for the chemical to decompose is presented in Table 3. The shorter the atmospheric lifetime, the more attractive the chemical is as a CFC replacement The residence time of CFCs is much longer than replacements. CFC-11 has an atmospheric lifetime of 55 years. CFC-12 has an atmospheric lifetime of 116 years, which is very negative to the environment. The lifetime for HCFCs ranges from 1.75 years to 22.6 years which is very short compared with CFCs. The relatively short lifetime of HCFCs makes the chemicals attractive as interim CFC replacements (Daly, 35).

Though it is not a problem for CFCs neither, HCFCs nor HFCs are not classified as VOCs. Hydrocarbons (HCs) are classified as VOCs. The non-VOC status of CFC alternates is very positive for environmental acceptability. There are regulations restricting the use of VOCs in the U.S. (Dunn, 30).

Toxicity

Table 4 presents toxicity data for the CFCs and alternatives.

TABLE 4

Safety Characteristics of CFCs and Alternates

CFCs	TLV or LEL	Toxicity	Flammability
CFC-11	1000	low	non-flammable
CFC-12	1000	low	non-flammable
HCFCs			
HCFC-123	50	Weak mutagen	non-flammable
HCFC-22	1000	low	non-flammable
HCFC-141b	500	Weak mutagen	flammable
HCFC-142b	1000	Very weak mutagen	flammable
HFCs			
HFC-134a	1000	low	non-flammable
HFC-152a	1000	low	flammable

SOURCE: DuPont Fluorochemicals Laboratory. Exhibit from "Alternates to Chlorofluorocarbons" by Joseph Creazzo (1992).

The toxicity is usually rated as low, moderate, or high, but the quantitative measure is by the Threshold Limit Value (TLV^R) or Allowable Exposure Limit (AEL). The TLV is a registered trademark of the American Conference of Governmental Hygienists. TLV reports the legal maximum safe quantity that humans can be exposed to in a normal 8-hour work day. The AEL is a preliminary toxicity assessment by DuPont, which may require additional studies by the government for final TLV rating. In general, the TLV and AEL are used synonymously. The higher the TLV or AEL designation, the less toxic the chemical (Creazzo, 7).

The key strength of the CFCs is that the chemicals are non-toxic and pose minimal health risks during processing or in end-use. The alternatives for CFCs are not drop-in replacements , and, toxicity and product safety issues have to be thoroughly evaluated. (Dishart et. al. 59)

As presented in Table 4, HCFC-123 has a low AEL of 50, which qualifies the alternate as having moderate toxicity. Preliminary toxicity data results for HCFC-123 showed that the propellant caused mutations in laboratory rats. The effect of HCFC-123 on rats concerns industries. The chemical´s ability to cause mutations in rats, correlates to the potential for HCFC-123 to cause cancer in humans (Rotman, 10; Naj, B1).

In order to minimize the potential for excessive exposure of humans, HCFC-123 will be preferred in applications where the propellant remains in the foam, such as for foam plastics for insulating refrigerators (English e. al., 3).

The AEL for HCFC-141b is 500, which is half of HCFC-22 and HCFC-141b with toxicity rating of 1000. Apart from HCFC-123 which is questionable, toxicity does not seem to be a prevalent problem with the CFC alternates (Creazzo, 7).

Flammability

Flammability of CFC alternates is the most important parameter for safety. A non-flammable blowing agent is preferred because it helps improve the safety of the foam manufacturing environment, and enhances the fire performance characteristics of the end product. In Table 4, the fire properties of CFCs and the alternates are presented.

In Table 3, the environmental impact of three hydrocarbons which are propane, butane, and isobutane, were presented. Apart from the positive VOC status, the hydrocarbons have acceptable environmental impact. The atmospheric lifetime is very short, the ODP is zero, and GWP is 3, which is by far better than any of the alternates. The down-side to using HCs in insulating foam plastics is flammability (Hausgerate, 5). The HCs have gained market acceptance in Europe (Tambosso, 5). Studies indicate that the properties of foam made with hydrocarbons are suitable for insulating foam plastic applications (Thijs, 2).

The technology is available to safely handle flammable propellants for commercial production of insulating foam plastics (Lerch, 13). Hence, the technology is not the limitation to using HCs in insulating foam plastics. In the U.S., HCs have received a cold reception as long-term CFC replacements. The potential liability associated with flammability of HCs and the tough U.S. VOC laws render the inexpensive, non-chlorinated chemicals, unsuitable as long-term CFC replacements (Jeffs, 11).

For the intermediate CFC replacements, HCFC-123 and HCFC-22 are non-flammable, which is very advantageous. HCFC-141b and HCFC-142b are flammable, which is a weakness. A blend of 60 percent HCFC-142b and 40 percent HCFC-22 (60/40 HCFC 142b/22 blend) is non-flammable, and available commercially. The HCFC 142b/22 blend is suited for use in insulating foam plastic applications which utilized CFC-12 (Del Perugia, 10). CFC replacements with a non-flammable characteristic is desirable for use in foam plastic applications.

The long term CFC replacement, HFC 134a, is non-flammable. 152a on the other hand, is flammable, which is a significant weakness. For a permanent replacement for CFCs in insulating foam plastics, HFC-134a is a major advantage over HFC-152a because the former propellant is non-flammable (Johnson 31).

Technical Feasibility

The approved alternatives have physical properties which differ from the CFCs. This prevents the replacement of CFCs with alternatives in insulating foam plastics from being a drop-in process.

Table 5 presents some physical properties of CFCs and alternates.

TABLE 5

Physical Properties of Propellants

	Boiling Point (°F)	Molecular Weight	Vapor Pressure 70°F	Vapor Pressure 130°F
CFCs				
CFC-11	75.0	137.4	13.4	24.3
CFC-12	-22.0	120.9	70.2	181.0
HCFCs				
HCFC-123	82.0	152.9	11.4	21.0
HCFC-22	-41.0	86.5	121.4	296.8
HCFC-141b	89.6	117.0	10.0	14.3
HCFC-142b	14.4	100.5	29.1	97.3
HFCs				
HFC-134a	-15.0	102.0	70.9	199.2
HFC-152a	-11.5	66.1	62.5	176.3

SOURCE: Handbook of Aerosol Technology 2nd Ed. Exhibit from "Fluorocarbon Propellants - Current and Alternatives" by John Daly (1987): 30.

The boiling point of the gas is an important property because, the temperature is an indication of how fast the propellant expands in the insulating foam plastic during cure. In general the lower the boiling point, the faster the vaporization rate. The molecular weight refers to the size of the individual units which make up the propellant. The vapor pressures at 70°F and 130°F are important for setting processing parameters. The vapor pressures also impact the size of closed cells attainable in insulating foam plastics.

As shown in Table 5, the physical properties of CFCs are not identical to the substitutes. The closest intermediate replacements for CFC-11 are HCFC-123 and HCFC-141b.

The 60/40 HCFC 142b/22 blend has physical properties close to CFC-12. The key difference between the blend and CFC-12 is the high solvency of the HCFC propellants (Daly, 33).

The problems with HCFC-22 are the high vapor pressure and the high solvency. The solvency is a rough measure of how aggressively the propellants attack rubbers used in seals for equipment. Equipment to process HCFC-22 needs to be adapted with seals resistant to the high solvency. The operating pressure of the equipment needs to be upgraded to handle the high HCFC-22 vapor pressures (Daly, 31).

For the long-term CFC substitutes, HFC-134a presents the best properties for replacing CFCs. HFC-152a is flammable, which weakens the potential for the propellant to be fully adopted for use in insulating foam plastics. The physical properties of HFC-134a are fairly close to CFC-12. Products presently employing CFCs can be converted relatively easily to use HFC-134a (Kuhn et. al., 22).

The intermediate CFC replacements in general produce insulating foam plastics with larger voids, which result in excessive energy transfer. The large voids lower the R-value of HCFC-blown foams compared with foams containing CFCs (Lund et. al., 44).

The solubility of the HCFCs in foams is higher than CFCs. The increased solubility of the propellant in foams has a plasticizing effect, which makes the HCFC-blown foams softer than CFC-blown foams. The aggressive solvent properties of HCFCs can shorten the service life of seals in equipment (Creazzo et. al., 204). Insulating foam plastics containing propellants with high solvency can cause damage to plastics such as panel liners used in refrigerators (Zurer, 9).

The HFCs have low solvency similar to CFCs. The foams produced with HFC´s have excellent quality, and are comparable to CFC-blown foams. As a temporary step, blends of HFCs and HCFCs can be used to enhance the quality of foams blown with CFC alternates. Attaining good foam quality with the permanent CFC replacements will not be a problem (Daly, 34).

Cost Related Issues

Serious financial hurdles for insulating foam industries to switch from CFCs are: Availability of CFC replacements; Cost of CFC replacements; Research and development (R & D) effort necessary to maintain product quality and performance.

Due to the pressures from government regulations, producers of CFCs have converted plant capacities to manufacture alternatives (Mahoney, 1). The only CFC alternate discussed which is not commercially available is HCFC-123. This is because toxicity tests for HCFC-123 showed slightly negative results (Rotman, 10). The supply of other HCFCs overall is not a problem.

Former CFC producers have geared up to manufacture substitutes. HFC 134a is now commercially available in the U.S. HFC-152a for instance, has been on the market for about 10 years, but the propellant has not been attractive for use in insulating foam plastics because of flammability and cost (Dunn, 1).

Conversely, there is a severe squeeze on the supply of CFCs, because, manufacturers are converting plant capacity to make replacements. There is a perceived problem with supply of CFC substitutes, but, the supply of CFCs is what remains uncertain until the ban in 1996. The suppliers have placed current CFC users on allocation, and will be constantly be cutting back the supply in preparation to cease production in 1996 (Mahoney, 1).

A central factor accelerating the CFC phase out is the escalating cost of CFCs. For several years, insulating foam plastics have utilized low cost CFC′s. The price list for CFCs and alternates in the year 1989 is presented in Table 6. As shown in Table 6, the bulk cost for CFC-11 and CFC-12 in 1989 were respectively \$0.80 and \$0.94 per pound with no excise tax. Including the excise tax the corresponding 1994 costs per pound listed in Table 1 are \$5.82 for CFC-11, and \$6.65 for CFC-12. With the excise tax tacked onto the cost of CFCs, the current prices have become very expensive for continued use. Overall, the cost of CFCs have towered above all substitutes.

TABLE 6

ISOTRON PACKAGE PRICE LIST
February 14, 1989

	Cylinder Size	Price Per Pound
CFC-11	Bulk	\$0.80
	Ton (2200 lbs.)	\$0.90
CFC-12	Bulk	\$0.94
	Ton (2000 lbs.)	\$1.00
HCFC-22	Bulk	\$0.95
	Ton (1750 lbs.)	\$1.34
HCFC-142b	Bulk	\$2.30
	Ton (1650 lbs.)	\$2.50

SOURCE: Pennwalt Corporation. Exhibit from "ISOTRON Package Price List" by Thomas E. Vasell (1989).

Table 1 shows the cost for CFCs and alternates. The cost for HCFC 123 is about \$2.00 per pound, but the availability is uncertain. The cost of HFC-152a is at \$2.00 per pound in bulk with no excise tax (Dunn, 1). The cost of the CFCs is higher than the substitutes. The cost of HFC 134a is highest among the alternate propellants, and the cost for HCFC-22 is the lowest.

In 1989, the industry was used to paying below $1.00 per pound for CFCs. In the very near future, the industry will be required to pay much higher prices than $1.00 per pound for permanent CFC replacements.

The cost of CFCs is higher than for their alternates. Hence, there is no cost incentive for industries to delay the elimination of CFC use.

Another problem with switching from CFCs is the R & D effort and costs associated with converting products and processes to replacement propellants. The assumption that getting out of CFCs takes a drop-in replacement with one of the alternatives can be an expensive mistake, because the characteristics of the materials vary vastly. Time needs to be spent by the respective industries to assure that the replacement propellant meets quality standards, and can be successfully processed. Suppliers of propellants in general are an excellent resource for aiding industries in the conversion of equipment and products to use non-CFC products. Though the value of R & D is difficult to assess accurately, it is essential to aiding in the smooth conversion to alternates. Hurried technical conclusions can lead to disastrous consequences.

Statement of Hypothesis

In Chapter I, the technical options to phaseout CFCs in insulating foam plastics were presented as follows:

OPTION #1 -Replace CFCs with alternate blowing agents.

OPTION #2 -Modify present production process to slowly phase out CFCs, or use other technologies which completely eliminate CFCs.

OPTION #3 -Substitute foam plastic products with alternate products (English et. al., 2).

The literature offered in Chapter II supported the technical Option one, as the most viable in the U.S. to phaseout CFCs using conventional CFC replacements. Technical Option two and Option three were not supported by the literature as viable options for eliminating CFC use in insulating foam plastic applications in the U.S..

Option two, presented earlier to phase out CFCs, has two approaches. The first is to modify present production processes to slowly phase out CFCs. The second strategy is to use other technologies which completely eliminate CFCs.

The first strategy in Option two to gradually eliminate CFCs is not pragmatic because of the CFC ban effective January 1, 1996. From now until the ban takes full effect, supply is expected to shrink dramatically. The producers are converting CFC plant capacities to produce alternates (Mahoney, 1).

In addition to limited CFC supply, the cost of CFCs is higher than the interim and long term CFC replacements. CFC prices have been raised by including a mandatory EPA excise tax. With the introduction of the new CFC tax, it has become more cost effective to use replacements in insulating foam plastic applications (McDonough, 1).

Under Option two, the second strategy to use technologies which completely eliminate the need for CFCs are currently available. Hydrocarbons and carbon dioxide are propellants which are different from the conventional CFC replacements. The hydrocarbons and carbon dioxide are readily available, and are used in insulating foam plastics.

The hydrocarbons (HCs), are volatile organic compounds (VOCs) with is a negative for environmental acceptability. VOCs are chemicals which contribute to smog or ambient level ozone. In the U.S., the EPA requires states to maintain safe ozone levels, by controlling VOC emissions (Dunn, 30). The U.S. regulatory pressures on VOCs limits the potential for HCs to broadly replace CFCs in insulating foam plastic applications.

Another technology that eliminates the need for conventional CFC replacements is the use of carbon dioxide (CO_2) in insulating foam plastics. The problem with the technology is that the foams generally have poor properties, and the thermal conductivity is high. The carbon dioxide in the closed cells egress the foam, which results in poor foams (Gross, 20).

Overall, Option two has not been embraced in the U. S.. Modifying processes to use less CFCs is not practical because of the high excise tax, short supply, and the pending CFC ban in 1996. The VOCs contribute to smog formation, which makes the hydrocarbons unattractive as long-term CFC replacements. Carbon dioxide, when used in foam applications, causes high thermal conductivity, resulting in low energy efficiency. The literature presented in Chapter II does not support phasing out CFCs slowly, or replacing

CFCs with hydrocarbons or carbon dioxide in insulating foam plastics in the U. S. (Dunn, 30; Gross, 20).

Technical Option three is to substitute insulating foam plastics with alternate, non-foam products. The central problem with a non-foam product such as fiberglass is that, thick sections are needed to attain the required insulating efficiency. In typical refrigeration applications where space is restricted, the use of fiberglass is limiting. The propellant-blown, insulating foam plastics are suitable for use in small spaces where insulating efficiency is critical.

The adhesion between insulation material and the substrate is essential for providing the necessary insulation efficiency. The presence of air between the insulation and the substrate dramatically reduces the ability of the insulating material to retard energy transfer. Fiberglass does not adhere to any surface, and is installed with mechanical fasteners such as nails. With time, the insulation could settle and allow air to pass through easily, or even worse, fall out completely. The exceptional adhesion properties of insulating foam plastics enable excellent bonding to most surfaces, which ensures that the insulating foam stays in place, which is important for proper insulation.

The ease of installing closed cell, propellant-blown foam is a strength for using insulating foam plastics. Spaces which are not easily accessible can be insulated by spraying into the cavities. When using non-foam insulating materials, areas that are hard to reach become very difficult to insulate.

The literature does not support the use of non-foam insulating materials such as fiberglass. A majority of insulating foam plastic applications are for constructing refrigerators and coolers, where space is restricted, and high insulation efficiency is desired. The non-foam insulating materials are not suitable for replacing insulating foam plastics applications.

Based on the reasons discussed, technical Option two and Option three to phase out CFCs, are not considered preferred avenues for permanently replacing CFCs. Option one is discussed in detail in the remainder of this work, as the technical route to pursue for eliminating CFC utilization in insulating foam plastic applications.

Option one, which is the technical option presented for replacing CFCs permanently, is supported by the literature. The EPA has sanctioned the use of conventional CFC alternates. The CFC substitutes are being used successfully in a variety of commercial, insulating foam applications (Kuhn et. al., 22).

In pursing Option one, the intermediate CFC replacements, HCFCs, have to be identified and evaluated. As mentioned earlier in Appendix A, EPA has published a list of interim CFC substitutes which are; HCFC-123, HCFC-141b, HCFC-142b, HCFC-22. The EPA approval of these materials for use in insulating foam plastics implies the propellants have been evaluated for environmental acceptability, toxicity, and flammability. According to the EPA, the interim CFC replacements are safe alternatives to CFCs.

The technical feasibility of the interim CFC replacements have been widely evaluated and accepted by insulating foam industries. The HCFCs are not drop-in replacements because the physical and chemical properties vary from CFCs. Products have to be reformulated, and processes have to be modified in order to switch from CFCs to HCFCs. The literature provides examples of the successful use of HCFCs in insulating foam plastic applications (Daly, 34).

The cost related issues are being addressed by CFC suppliers. The major producers have converted CFC plant capacities to meet the escalating demand for alternatives. The prices of HCFCs are markedly lower than the CFC cost which includes the hefty excise tax. The interim CFC replacements are generally available, and cost less than CFCs.

The problem with HCFCs is that they are temporary CFC replacements. The EPA is proposing a complete ban on all HCFCs by the year 2030. In preparation for the HCFC ban, insulating foam industries have began evaluating HCFC replacements (Nudel, 3).

The technical Option one proposes that, the use of HFCs be the next step following the implementation of using HCFCs in insulating foam plastics. The HFCs which have been approved by the EPA are HFC-134a and HFC-152a. The HFCs do not contain chlorine, and thus, do not contribute to ozone depletion. The HFCs have been evaluated extensively for insulating foam plastic applications. The EPA has accepted the HFCs as safe, and permanent CFC replacements because of the minimal impact to the environment and low toxicity (Creazzo, 2).

The technical feasibility of using HFCs in insulating foam plastics has been evaluated by industries. Insulating foam plastics can be made with HFCs, which have good insulating efficiency. The literature has examples of insulating foam plastics using HFCs with good properties (Kuhn et. al., 25).

The cost of HFCs remain a barrier for industries to convert from HCFCs. The cost of HFCs is higher than HCFCs. The most expensive CFC alternate is HFC-134a, which costs at least double the other CFC replacements. The supply of HFCs is available, and producers increasing supply by converting CFC capacities to make alternates (McDonough, 1).

The EPA has approved hydrocarbons for permanently replacing CFCs. In the U.S., the hydrocarbons are not attractive because of the VOC status. The VOCs are not preferred in the U.S. because local governments restrict emissions. The VOCs are regulated because they contribute to smog formation Dunn, 30).

The technical option to eliminate CFCs from insulating foam plastics has been identified. Option one, which proposes replacing CFCs with alternates, is supported by the literature.

In pursuing Option one, there are three stages toward attaining the ultimate goal of using zero ozone-depleting chemicals in insulating foam plastics. Table 7 shows the stages for implementing technical Option one for CFC phaseout.

TABLE 7

Technical Option One to Phaseout CFCs

STAGE 1 - Search and identify immediate interim CFC substitutes. EPA has an approved list of short-term CFC replacements which are;

HCFC-123
HCFC-142b
HCFC-141b
HCFC-22

STAGE 2 - Implement the use of HCFCs to replace CFCs in insulating foam plastics. The use of HCFCs is temporary, and EPA has scheduled a total ban by the year 2030.

STAGE 3 - Implement the use of HFCs to replace HCFCs in insulating foam plastics. EPA has approved HFC-134a and HFC-152a as permanent CFC replacements.

Technical Option one has been identified as the most viable option for eliminating CFC use permanently. The literature supports Option one, as the practical approach for U.S. industries to phaseout CFCs in insulating foam plastic applications.

With the uncertainty about future regulations from the EPA, capital expenditure for equipment to process replacements, and R & D costs to advance the change to new propellants, how does a company remain competitive and maintain compliance with the EPA regulations? A viable strategy is presented for U.S. industries to eliminate the use of CFCs in insulating foam plastics effectively. The approach to a complete CFC phaseout from insulating foam plastics is outlined in Table 8.

TABLE 8

Outline of Proposed Strategy to Phaseout CFCs from Insulating Foam Plastics

STEP 1 - Investigate and monitor competitors globally. Industries need to depend on suppliers, product labels, MSDS´s, and product literature to learn about the competition.

STEP 2 - Adopt Stage 1 and Stage 2 of technical Option one. Use EPA list to identify and rate replacement candidates. Undertake extensive evaluation of cost/benefit relations, product quality and processing the intermediates.

STEP 3 - Adopt Stage 3 of technical Option one. Replace the HCFCs with permanent CFC substitutes, HFCs.

The literature supports the proposed strategy outlined in Table 8 to eliminate CFC use in insulating foam plastic applications. The first step is to evaluate what the competition is doing. This is a critical step because the market conditions eventually cannot be ignored. The pricing of products containing the replacements will be dependent on choices available to customers. Suppliers of CFC alternates are instrumental in this stage. The propellant producers provide approximate usage of alternate propellants in the various applications.

An important source for finding what the competition is using is by reading the labels. Due to the recent changes in government regulations, labels provide general information on the types of propellants used in products (Anspach, 21). Another way of finding what is being used in products is by attaining a material safety data sheet (MSDS) on the product of interest. To minimize the potential of being priced out of the market, information on the competition is critical for selecting CFC replacements.

The second step is to identify and rate replacement candidates and undertake extensive evaluation for cost/benefit relations, product quality, and processing the intermediate, HCFC, alternatives. There are approved interim replacements which are listed by the EPA. The major criteria for evaluation are: Environmental acceptability; Toxicity; Flammability; Technical feasibility; Availability and cost. After temporary replacements are in use, permanent substitutes for CFCs need to be sought.

The third stage is to replace the HCFCs with lasting CFC replacements, HFCs. The HFCs have been approved by the EPA as long term CFC replacements. The criteria for evaluating HFCs is similar to HCFCs. HFCs are now commercially available, and can be used successfully in insulating foam plastics.

An essential part of the whole process of phasing-out of CFCs is to educate customers about the changes. The products may not look, perform, or cost the same without CFCs, and all the real and perceived differences need to be communicated early to customers. As part of the effort to strengthen the market position of products containing alternates, customers should be made aware of competitors´ products containing CFCs, or not in compliance with the environmental regulations.

At every stage of phasing out CFCs, the insulating foam plastics industry needs to de-market existing CFC-containing products, and heavily promote products with replacements. To enhance the image of the public toward the use of CFC replacements, it would be essential for industries to maintain a position of engaging in environmentally responsible practices (Franklin, 7).

The change from CFCs creates goodwill for companies. The public outcry against CFCs makes it beneficial for all industries urgently to get out of CFCs. Companies with CFC alternatives can gain market share because of public demand for non-CFC products. There are some proponents for a slow CFC ban, but the public actually set the pace for the CFC phase-out. There are claims that the damage to the ozone layer should not cause a panic (Wingate, 6A). But, there is reason for companies to accelerate the pace of eliminating CFCs because of the ban in 1996. The only option to not phasing out CFCs will be to go out of business.

CHAPTER III

SELECTIVE REVIEW AND EVALUATION OF RESEARCH

Issues Affecting the Phaseout of CFCs

The elimination of CFCs from insulating foam plastics is certain. The EPA under the direction of the Montreal Protocol, oversees the phaseout of CFCs in the U.S.. The EPA has an approved list of chemicals for interim CFC replacements. The temporary CFC substitutes presented in Appendix A are; HCFC-123, HCFC-22, HCFC-141b, and HCFC-142b. The identified long term CFC replacements for insulating foam plastics are HFC-134a, HFC-152a, and hydrocarbons. With the CFC ban approaching fast in 1996, the need for industries to select and implement the use of CFC alternates has become urgent.

Technical Option one has been presented as a significant part of a workable approach for replacing CFCs used in insulating foam plastic applications. The complete strategy proposed to phaseout CFCs permanently is comprised of three major steps.

The first step is to investigate and watch what competitors are doing globally. This is an essential step because the market conditions eventually cannot be ignored. The pricing of products containing the replacements will be dependent on choices available to customers. Suppliers of CFC alternates are instrumental in this stage. The propellant producers provide approximate usage of alternate propellants in the various applications.

An important means for finding what the competition is using is reading product labels. Due to the recent changes in government regulations, labels provide general information on the types of propellants used in products (Anspach, 21). Another way of finding what is being used in products is by attaining a material safety data sheet (MSDS) on the product of interest. To minimize the potential of being priced out of the market, information on the competition is critical for selecting CFC replacements.

The second step is to identify and rate replacement candidates and undertake extensive evaluation for cost/benefit relations, product quality, and processing the intermediate, HCFC, alternatives.

There are approved interim replacements which are listed by the EPA. The major criteria for evaluation previously discussed are: Environmental acceptability; Toxicity; Flammability; Technical feasibility; Availability and cost. After temporary replacements are in use, seeking permanent substitutes for CFCs should follow automatically.

The third stage is to replace the HCFCs with lasting CFC replacements, HFCs or hydrocarbons. The HFCs have been approved by the EPA as long term CFC replacements. The criteria for evaluating HFCs and hydrocarbons are similar to HCFCs. HFCs are now commercially available, and can be used successfully in insulating foam plastics (Kuhn et. al., 22).

The actual implementation of CFC phaseout is not straightforward. The process does not end with evaluating approved EPA substitutes. The scheduled elimination of CFCs by the Montreal Protocol assumes worldwide availability of substitutes, and no further regulations that could resist the ability of substitutes from being adopted on either a global or regional basis (Zurer, 7). In Europe for instance, the interim replacements are being phased out faster than what is required by the Montreal Protocol (Fay, 68). Pentanes, which are hydrocarbons, have already taken the place of HCFCs in several insulating foam plastic applications (Tambosso, 5). Though the Montreal Protocol provides timeliness for eliminating CFCs, the national, regional, and local CFC regulators ultimately determine when industries are supposed to implement the use of long term replacements.

The issues that affect the substitution of CFCs previously presented will be discussed further. The points that concern industries in various stages of phasing in CFC substitutes include: Rate of conversion; Toxicity concerns; Flammability; Environmental concerns; Insulation efficiency.

Rate of Conversion

In 1980, the Alliance for Responsible CFC Policy was formed to help U. S. industries in the process of CFC elimination. The Alliance monitors international efforts in regard to an accelerated CFC phaseout, HCFC controls, technology transfer, and environmental issues. The Alliance assists the U.S. in developing its international position which may vary from the provisions of the Montreal Protocol. Domestically, the Alliance promotes industry's position to the Congress and EPA in the implementation of the stratospheric ozone provisions of the Clean Air Act Amendments of 1990. The Alliance is also responsible for working with other Federal agencies, and the Internal Revenue Service (IRS) on matters relating to CFC tax. In the U. S., the Alliance has a significant role in establishing the EPA's Proposed Rules for CFC phaseout. The Alliance for Responsible CFC Policy is the lobbying group, which heavily impacts the rate at which CFCs and interim replacements are phased out in the U. S. (Stirpe, 1).

Within two years after the initial Montreal Protocol's schedule to phase out CFCs was announced in 1987, the insulating foam plastics industry had began to make significant inroads toward switching from using CFCs to HCFCs worldwide (Dishart et. al., 60). The Alliance for Responsible CFC Policy worked with the EPA to start a program in 1991 called the Significant New Alternatives Policy (SNAP) (Stirpe, 3). The focus of SNAP is to make interim and permanent CFC alternatives available commercially to U. S. industries. Overall, the SNAP program has been successful, and it is now estimated that most of the foam plastics currently on the U. S. market do not contain CFCs (EPA, 50485).

Conversion of plants to handle alternate blowing agents are being undertaken by all the key suppliers in the U. S.. The supply of the interim and long term CFC substitutes is available (Newslines, 3).

Some important considerations which impact the length of time required to entirely convert to technically acceptable CFC alternatives are discussed. The barriers to expediting CFC phaseout include; economic climate, technical support, sufficient supply of propellants and appropriate processing equipment, local regulatory approvals for operation, national CFC legislation, patent situations, and customer preference.

The economic climate significantly influences the rate of CFC conversion. Condition of regional and global economics determine the willingness for industries to allocate money and resources for conversion, unless it becomes absolutely necessary.

Technical support has to be available to sustain the transfer of technology from CFC to non-CFC products and processes. The quality of the products have to be evaluated and certified for use in insulating foam plastic applications. For industries to phaseout CFCs, technology has to be successfully transferred to incorporate alternate blowing agents.

In order to operate, the substitutes for CFCs have to be readily available in quantities sufficient to meet new demand. Also, the equipment for properly processing the CFC substitutes has to be in place.

Regulatory approvals (operating permits) have to be obtained from local and state regulators before operations can begin. For example, the usage of alternative blowing agents is dependent on building regulations (certification rules) of different countries. In some countries, especially in developing countries, insulating foam made with alternative blowing agents can be used without special permission. It is common for countries to require special permission when using the alternate blowing agents in insulating materials. The process of certifying products and processes can impact the choice of the alternatives, and the rate at which they can be implemented (Zurer, 8).

The sense of stability of national legislation that impacts CFCs and alternatives is essential for facilitating the CFC phaseout. Industries become restless when there appears to be no clear policy on a particular environmental issue. This is because swift changes in policies can be expensive for industries to remain in compliance. The governments effectiveness in leading the process for the CFC phaseout can help industries to gain confidence about making the change to alternatives (Fay, 68).

Patent situations have to be thoroughly investigated. There may be potential for conflict over technology ownership. There is a flood of new products and processes for insulating foam plastics requiring CFC substitutes. Hence, care needs to be taken not to infringe on patents for competitors in the process of CFC elimination. In cases where the potential for patent infringement exist, licensing agreements can be negotiated as a means of having access to new technologies.

Possibly, the most important factor which impacts the length of time required to phaseout CFCs is customer preference. Pertaining to insulating foam plastic products, the customers have been used to excellent quality foams which employed CFCs. When compared with CFCs, the interim CFC replacements, HCFCs, generally produce insulating foam plastics with poorer quality (Jarfelt, 2). The resistance of customers to accept conceivably inferior insulating foam plastic products containing CFC substitutes, can delay the process to phaseout CFCs.

In taking into account these factors, the implementation of worldwide conversion to CFC substitutes in insulating foam plastics may require different approaches depending on the country. In the U.S., the insulating foam plastics industry is taking direction from the EPA, with the help of the Alliance for Responsible CFC Policy, to expedite the CFC phaseout process.

Toxicity Concerns

Toxicity plays a major role in determining when a CFC substitute will be used in insulating foam plastic applications. As an example, HCFC-123 has the highest toxicity level among the interim CFC replacements and thus, was the last to be approved by EPA for use in insulating foam plastic products (Rotman, 10). The concerns over health impacts of CFC substitutes include worker and consumer exposure to alternate blowing agents, and, exposure to possible decomposition products formed in foams.

The issues of worker and consumer exposure need to be closely addressed when determining the viability of using identified alternatives, as well as timing their implementation. Clarification of toxicity issues is essential for ascertaining the ability to use a CFC substitute in commercial foam applications. Industries usually shy away from potential CFC substitutes until toxicological tests are complete (Naj, B1).

The key strength of the CFCs is that the chemicals have low toxicity and pose minimal health risks during processing or in end-use. Besides having low toxicity, the CFCs have the added benefit of not being mutagens. A mutagen is a material that causes cells to change, which potentially, can cause cancer in humans. The interim alternatives for CFCs are not drop-in replacements, and generally exhibit higher levels of toxicity (Dishart et. al. 59).

As presented in Table 4, the interim CFC substitutes, HCFCs, have been reported as weak mutagens. During use, additional procedures need to be in place to minimize exposure of workers to the propellants. The exception is HCFC-22 which has a low toxicity comparable to the CFCs. The permanent CFC alternates have low toxicity, which is very desirable. The toxicity level of a propellant literally determines whether an identified CFC replacement is eventually commercialized. The HCFCs have gained EPA approval as interim alternates, but the short term substitutes are mostly more toxic than the CFCs they are replacing (Creazzo, 6).

Flammability

Some of the identified CFC replacements present varying degrees of flammability. These flammable alternatives shown in Table 4 consist of HCFC-141b, HCFC-142b, and HFC-152a. Hydrocarbons, which include pentanes presented in Appendix A, are very flammable, and have been approved for replacing CFCs in insulating foam plastics permanently.

In order to safely use flammable alternatives, it is necessary to complete the evaluation of manufacturing risks from ignition. Plant modifications are needed for increased ventilation and "explosion proofing" to eliminate electrical ignition sources. These plant alterations are essential and require capital investment (Lerch, 13).

Special precautions need to be taken in storage and transportation of foam products containing flammable propellants. If the concentration of flammable blowing agents are emitted during cure or transportation, systems must be in place to identify and minimize the risk of ignition. When a flammable propellant is used, the fire performance of the finished product becomes an issue. Products using flammable blowing agents may need to be reformulated with fire retardants to pass strict fire tests. But, in some cases, this reformulation may not lead to the required results (Lerch, 14).

These flammability and safety issues must be addressed when considering flammable alternatives. However, many of the problems associated with using flammable propellants may be able to be resolved with technical solutions. In several insulating foam applications, the flammable CFC-substitutes have been used safely by recognizing and lessening flammability risks. In some instances, flammability may limit the widespread use of a CFC substitute (Hausgerate, 5).

Environmental Concerns

It is necessary to weigh environmental effects, such as stratospheric ozone depletion, global warming, ground level air pollution, and tropospheric degradation of products, when choosing CFC substitutes.

The HCFCs identified or used as CFC substitutes in insulating foam plastics have a much lower ozone depletion potential (ODP) than CFCs. However, their unrestricted, long-term use, would contribute significant amounts of chlorine to the stratosphere (EPA, 50486).

HCFCs are viewed as transitional alternatives to be used while non-ODP, chlorine-free blowing agents, have been approved by the EPA as permanent CFC replacements. In insulating foam plastic applications in the U. S., efforts are made to decrease the ozone depleting impact of the blowing agent by judicious foam formulation (EPA, 50470). In Europe, the goal is to eliminate HCFCs as quickly as possible because of the small, but existing ozone depleting potential (Fay, 68).

The ODP is a key criteria for a rating CFC replacements. As presented in Table 3, the CFCs have the highest ODPs. The HCFCs which have been approved as interim CFC replacements have significantly lower ODPs.

The ODP designation is of special interest to U.S. industries because the excise tax levied on CFCs correlates directly to the ODP of the substance. Though the HCFCs do not currently have an excise tax, future regulations by the EPA is expected to include an excise tax as an incentive to hasten the HCFC phaseout (EPA, 2003).

HFCs shown in Table 3 have zero ODP. The HFCs do not contribute to stratospheric ozone depletion, because the chemicals do not contain chlorine. The zero ODP of HFCs render the permanent CFC substitutes environmentally acceptable. Unlike the HCFCs which contain chlorine, the hydrocarbons (HCs) shown in Table 3, do not contain chlorine and have zero ODP, which qualifies the HCs for replacing CFCs permanently.

Global Warming Potential (GWP) of a compound is a formulation of its atmospheric lifetime and its ability to absorb infrared radiation. The CFCs have high GWPs, and the leading CFC substitutes have much lower GWPs. The relative ability of a CFC substitute to act as a "greenhouse" gas together with its total emission volume into the atmosphere will affect the choice of alternatives.

CFCs have GWPs that are very high compared with the substitutes, which make the CFCs very undesirable. The GWPs of interim and permanent CFC replacements shown in Table 3, are significantly lower than the CFCs. There has been a global effort by scientists to determine the GWP of propellants emitted into the atmosphere. The consensus among scientists is that the CFC substitutes contribute significantly less to global warming (Daly et. al., 34).

The atmospheric lifetime of CFC alternates is an important criteria for environmental acceptability. The CFC substitutes are chemically less stable than CFCs. The relatively unstable propellants breakdown easily in the atmosphere, and thus, have shorter atmospheric lifetimes. Overall, the shorter the atmospheric lifetime, the more attractive the chemical as a long term CFC replacement.

CFCs are organic chemicals which react negligibly in the lower atmosphere. Nonetheless, some approved permanent CFC substitutes such as pentanes, and other hydrocarbons, are classified as volatile organic compounds (VOCs) in the U. S.. The VOC compounds undergo photochemical reactions in the lower atmosphere and contribute to smog formation. HCFCs and HFCs are not considered VOCs, which is a major advantage over hydrocarbons. Though flammability with hydrocarbons is a negative, the central problem with the hydrocarbons in the U.S. is the VOCs status. Some of the CFC substitutes are flammable like the hydrocarbons, but the non-VOC status of alternates is very positive for environmental acceptability. As a result of the VOC status, although the hydrocarbons can be used successfully in insulating foam plastics, they face strict regulation on a regional basis. For example, the U. S. strictly regulates emissions of hydrocarbons. Ultimately, regional regulations may restrict the use of these permanent CFC substitutes even though they are technically feasible options (EPA, 1998).

Insulation Efficiency

The use of alternate blowing agents or non-CFC insulation materials in insulating foam plastics can impact the energy efficiency of the finished product. In general, the drop-in replacement of CFCs and HCFCs of other alternative blowing agents resulted in products which were poorer insulators. However, once the CFC substitutes had been selected, research and development efforts were focused on reformulation around chosen substitute and modifications to the foam technology. This effort has resulted in products with equivalent insulation efficiency (Lund et. al., 44).

The technical ability for producing insulating foam plastics containing CFC alternates with comparable quality to CFCs exists. There are various examples of insulating foam plastics made with CFC substitutes which are very efficient insulating foams. The problem with using CFC substitutes is to reformulate to ensure that the quality of the product is maintained. The substitutes are not drop-in replacements for CFCs because the physical properties and chemical characteristics are different (Daly, 29).

Ultimately, the acceptability of alternate blowing agents is dependent upon the performance, cost-effectiveness and competitiveness of the finished product in a particular application. The market price of any alternate system is often the determining factor as to whether a substitute can be used and sold competitively on the market. The economic impact of utilizing CFC replacements has already been found to be a significant barrier to substitution, particularly in recessionary environments (EPA, 1998).

The cost for the CFCs and alternates vary widely. As shown in Table 1, the cost of HCFC-22 is the lowest among the propellants. The excise tax elevated the cost of CFCs well above the alternates. The HCFCs are generally lower in cost than the HFCs. The HCFCs do not currently have an excise tax. But, the ODP of the HCFCs makes them a good candidate for the EPA to levy a tax to accelerate the phaseout of the interim CFC replacements. The most expensive CFC alternative is HFC-134a, which has been identified as the most promising permanent replacement for CFCs (Kuhn et. al., 23). The cost of the propellant is critical for determining whether the CFC replacement can be used competitively in an actual product.

Shortfalls in Literature for CFC Phaseout

The CFC ban in 1996 has been widely publicized by suppliers of CFCs and replacements, and confirmed by the EPA. The deadline for eliminating CFCs was accelerated by amendments to the original time lines agreed to by member nations of the Montreal Protocol. If history has any lessons to offer, the timeliness for phasing out interim replacements, HCFCs, will most probably be hastened. The EPA has already advocated for a faster HCFC ban than the schedule outlined by the Montreal Protocol. The literature falls short in predicting the future actions of the EPA to speed up the proposed HCFC ban (Zurer, 8).

The uncertainty about how long the EPA will actually allow the use of HCFCs in insulating foam plastics has caused some procrastination on the part of manufacturers to convert from CFCs. Technically, the literature provides information on how CFCs can be successfully replaced with HCFCs. But, what happens following the initial investment to convert to interim CFC substitutes is very important to industries. The literature does not indicate when insulating foam plastic industries will need to phaseout HCFC use, and commence using permanent CFC replacements. The EPA has the final word on the actual phaseout schedule. The EPA has been known to change its mind because proposed phaseout rules for CFCs and substitutes have been amended in the past (Fay, 68).

Another shortfall of the literature is providing the imminent excise tax schedules for HCFCs. The excise tax for CFCs are assessed based on the ozone depleting potential of chemicals. Though the HCFCs are much better than CFCs, the potential to deplete stratospheric ozone exists for the interim alternates. In the past, the EPA used the excise tax as an incentive for industries to quicken the phaseout of CFCs (EPA, 2003). In case the EPA applies similar reasoning, the HCFC elimination will probably be encouraged by introducing an excise tax. For now, there is no excise tax on HCFCs, but this may change after the CFC ban in 1996.

The mechanics of eliminating CFC use in insulating foam plastics are widely presented in the literature. There are no qualms that the feasibility to convert to CFC substitutes exists. The central problem facing industries is how long will interim replacements be allowed in insulating foam plastics? To minimize the risk of suddenly having to discontinue HCFC use, insulating foam plastic industries need to convert as soon as possible to permanent CFC replacements, HFCs (EPA, 50468).

CHAPTER IV

RESULTS

Timetable and Urgency for CFC and HCFC Phaseout

CFCs have been under tremendous pressure for over a decade because of the danger to public health. The central problem with CFCs is the ability of the substances to deplete atmospheric ozone. The protection of the ozone layer is critical because ozone prevents ultraviolet rays from reaching the atmosphere. Exposure to ultraviolet rays is known to cause skin cancer in humans (Zurer, 25).

In response to the potential danger of CFCs, the international community has embarked on agreements to eliminate the use of substances which deplete atmospheric ozone. In 1987, the Montreal Protocol was enacted as an agreement between nations, to establish guidelines for banning ozone depleting substances (Zurer, 7). With the Montreal Protocol setting the general path for CFC elimination globally, the EPA oversees the ban in the U.S. (Zurer, 8). The

EPA has provided an approved list of CFC replacements which are legal under the Clean Air Act (Nudel, 8). There are civil penalties for accidentally violating the CFC regulations, and criminal penalties for intentional violations. EPA is serious about enforcing the CFC laws (Healy, 1). The EPA´s timetable for CFC and HCFC phaseout is presented in Table 9.

TABLE 9

EPA Timetable for CFC and HCFC Ban

CFCs	PHASEOUT SCHEDULE
CFC-11	100% Phaseout by January 1, 1996
CFC-12	100% Phaseout by January 1, 1996
HCFCs	
HCFC-123	New equipment ban 2015; total ban 2030
HCFC-22	New equipment ban 2010; total ban 2020
HCFC-141b	Total ban 2003
HCFC-142b	New equipment ban 2010; total ban 2020
HFCs	
HFC-134a	None
HFC-152a	None

SOURCE: Nudel, E. "Key Issues Pertaining to CFC Ban." DuPont News Bulletin January 1993; 8.

As presented in Table 9, the elimination of substances which contribute to ozone depletion is eminent. From now until the CFC ban in 1996, the EPA has undertaken some key actions to make the continued use of CFCs unattractive to U.S. industries. The main deterrent to CFC use is an excise tax, which has raised the cost of CFCs above all the replacements. Currently, there is no excise tax levied against HCFCs and HFCs (EPA, 50465). The EPA also requires products containing CFCs to inform customers. The labels are to state that the products contain CFCs, which harm public health by depleting the ozone layer (Anspach, 21).

In preparation for the CFC ban in 1996, manufacturers are converting capacities to make alternates and so the CFC supply is dwindling (Mahoney, 1). Large CFC producers like Dupont and Allied are encouraging customers to switch to alternates (Newslines, 1; Dougherty, 1).

The public has a negative image of CFCs in products. Customers are requiring that manufacturers supply products without CFCs. The McDonald´s chain heeded to public outcry and changed from using CFC-blown styrofoam to paper for packaging food. The U.S. public strongly supports the CFC ban.

With the deadline for the ban approaching quickly, the phaseout of CFCs in the U.S. has become an urgent matter. The government and CFC suppliers are working together to make the CFC ban a reality in 1996 (Mahoney, 1).

Search and Evaluation of CFC Replacements

In the search for CFC replacements, the EPA´s approved alternates presented in Table 10 is the most logical list of substances to evaluate. The criteria for evaluating the alternates include: Environmental acceptability; Toxicity and safety; Technical feasibility; Availability; Cost related issues.

The EPA oversees the determination of environmental acceptability and level of toxicity of potential CFC replacements. The insulating foam industry relies on the EPA to publish the approved substances to use in place of CFCs. The CFC substitutes approved by the EPA in Table 10 indicates that the substances are safe for use in specified applications (Nudel, 8).

TABLE 10

EPA Approved List of CFC Substitutes

Interim CFC Replacements	
Flammable	Non-Flammable
HCFC-123	HCFC-141b
HCFC-22	HCFC-142b
Permanent CFC Replacements	
Flammable	Non-Flammable
HFC-152a	HFC-134a
*Hydrocarbons	

*The hydrocarbons are classified as VOCs. HCFCs and HFCs are not VOCs.

SOURCE: DuPont Fluorochemicals Laboratory. Exhibit from "Alternates to Chlorofluorocarbons" by Joseph Creazzo January, 1992: 6.

The flammability of propellants is an issue due to safety concerns in processing and end-use (Hausgerate, 5). Among the CFC alternates, there are flammable and non-flammable, approved replacements. In Table 10, the replacements are grouped according to fire properties.

Though a non-flammable propellant is desired, there are technical solutions to safely processing flammable propellants. Hydrocarbons are extremely flammable, but have been used safely in aerosol products since 1978. Flammability is not a barrier for propellant use in insulating foam plastics, but additional steps are needed to minimize the risk for fires (Lerch, 13).

The technical feasibility of using CFC replacements in insulating foam plastics has been established in the literature and, reduced to practice. The alternates can be used to make insulating foam plastics with high insulating efficiency. The CFC substitutes are not drop-in replacements. Processes have to be modified and products need to be reformulated to achieve the desired performance (Lund et. al., 44).

The cost of CFCs has risen well above the alternates. Table 11 compares the prices of CFC-11 with the other propellants. There is a significant difference between the CFCs and alternates. As shown in Table 11, there is no cost advantage to the continued use of CFCs (McDonough,1).

TABLE 11

Propellant Prices Compared with CFC-11

	Total Bulk Price Per Pound	Price Per Pound Difference	Percent Difference in Bulk Price
CFCs			
CFC-11	$5.82	--	--
CFC-12	$6.65	0.83	14.3%
HCFCs			
HCFC-123	$2.00	-3.82	-65.6%
HCFC-22	$1.15	-4.67	-80.24%
HCFC-141b	$1.75	-4.07	-69.9%
HCFC-142b	$1.80	-4.02	-69.1%
HFCs			
HFC-134a	$4.50	-1.32	-22.7%
HFC-152a	$2.00	-3.82	-65.6%

SOURCE: McDonough, P. "GENETRON PRICE SCHEDULE for OEM Appliance and Blowing Agent Markets." Allied Signal Inc. 10 January, 1994: 1.

Suppliers of CFC substitutes have geared up production to meet the exploding demand. CFC capacity is being converted to manufacture replacements. The supply of CFC substitutes does not seem to be obstructing the process of eliminating CFC use in insulating foam plastic applications.

Technical Options for CFC Phaseout

The actions necessary to execute the technical options to eliminate CFC use in insulating foam plastic applications are outlined in Table 12. The options presented provide a variety of choices to eliminate the use of CFCs.

The main vehicles needed to discontinue the use of CFCs in insulating foam plastics have been presented in Table 12. The selection of the technical option depends on several factors. The determining factors on which option to adopt to eliminate CFC are Federal, and local environmental regulations, performance, and cost of the finished product.

An option not presented in Table 12 is the continued use of CFCs in insulating foam plastics until the ban in 1996. Future use of CFCs was not explored because of high CFC cost, and shrinking supply, and negative public reaction. It would be very difficult to carry on using CFCs until 1996 and remain competitive. The pursuit of this option could lead to going out of business.

TABLE 12

Summary of Technical Options to Eliminate CFCs

OPTION #1 -Replace CFCs with alternate blowing agents.

List of Activities

-Evaluation of EPA approved interim CFC replacements, HCFCs.

-Implementation of use of HCFC in process or product.

-Replacement of HCFC with EPA approved, permanent CFC substitutes, HFCs.

-Research to find other permanent CFC replacements

OPTION #2 -Modify present production process to slowly phase out CFCs, or use other technologies which completely eliminate CFCs.

Activity to Slowly Eliminate CFCs

-Reduce amount of CFC needed in products and processes.

List of Activities to Use Other Technologies

-Replace CFC´s with EPA approved, permanent CFC replacements, hydrocarbons.

-Replace CFCs with Carbon dioxide.

OPTION #3 -Substitute foam plastic products with alternate products

Activity to use non-foam products

-Replace CFC-containing insulating foam plastic with non-foam insulating materials such as fiberglass and cellulose.

SOURCE: Proceedings of Polyurethanes World Congress Exhibit adopted from "An Effective Strategy to Eliminate CFCs in Refrigerator Insulation" by G. English, W. Bazzo, G. Walker, D. Tomlinson October 1993: 2-4.

A critical part of evaluating the technical options is competitive information. The tools for identifying propellants used in competitive products include: information from suppliers on total propellant use, publications on new products using CFC alternates, material safety data sheets (MSDSs) which accompany products, and product literature. The most reliable source for identifying propellants is the MSDS, which is required by law to be with chemical products. Competitive data is critical for charting a strategy to eliminate CFC use.

CHAPTER V

DISCUSSION

The central problem with CFCs is the ozone depleting characteristic of the chemicals. The CFCs have faced severe pressures for a ban since the mid 1970s. The first large scale elimination of CFCs was in consumer aerosol products in 1978. Since the ban, personal hygiene products, detergents, and cosmetics packaged as aerosols generally have used hydrocarbons instead of CFCs.

The movement to ban CFCs was initiated to save the ozone layer. The protection of the ozone layer is primarily necessary to prevent ultraviolet rays from reaching the earth´s atmosphere. The public is very aware that human exposure to ultraviolet rays can potentially cause cancer. The CFC ban is directed toward shielding the atmosphere from ultraviolet rays.

The first international effort to protect the ozone layer was undertaken in 1987 via the Montreal Protocol. The initial agreement between twenty-two industrialized nations established ecumenical guidelines to eliminate the use of CFCs, HCFCs, and other ozone-depleting substances worldwide.

The individual countries can implement CFC phaseout schedules which are more stringent than the provisions of the Montreal Protocol. In the U.S., the EPA under the Clean Air Act is responsible for executing the CFC ban. As an example, the EPA has a scheduled ban on interim CFC replacements or transitional substances, HCFCs, by 2030. The timetable to ban HCFCs in the U.S. is ten years ahead of the Montreal Protocol´s schedule of 2040. The Montreal Protocol also called for a voluntary phaseout of the transitional substances. On the contrary, the EPA CFC regulations to ban HCFCs are mandated by U.S. environmental laws (Zurer, 8).

The EPA is serious about enforcing the CFC regulations. There are civil and criminal penalties in the form of fines and prison sentences for violating CFC laws in the U.S.. In July 1994, the EPA fined a company $17,500 for not fixing a CFC-12 leak promptly (Howekamp, 1).

The excise tax is exempt for CFCs exported outside the U.S.. A CFC wholesaler was sentenced to eighteen months for CFC tax evasion. The wholesaler sold CFC-12 domestically and falsified export papers to avoid paying the hefty CFC tax in the U.S. (Arkow, 1). With the conditions set by the EPA to police CFC laws strictly, it would be unwise for industries to violate any laws. The practical and legal avenue is to adhere to EPA´s regulations and prepare to discontinue CFC use when the ban takes effect.

The timetable for the ban against CFCs in the U.S. was presented in Table 9. The ban will be in effect January 1, 1996. This means applications still depending on CFCs have less than two years for conversion to use alternates.

Industries which continue to use CFCs from now until the ban face escalating costs and supply problems. The excise tax imposed on CFCs has raised the cost over all the replacements. The supply of CFCs is dwindling rapidly because manufacturers continue to produce less CFCs in preparation for the ban in 1996. The suppliers are actively converting CFC plant capacities to produce alternates.

Though HCFCs have significantly less ozone depleting potential than CFCs, the HCFCs have been targeted as the next group of substances to be eliminated after the CFC ban in 1996. Based on the EPA´s prior actions to expedite the CFC ban, it is anticipated that the HCFC regulations will get tightened as the ban approaches. The HCFCs, which currently do not have an excise tax, will probably be taxed after the CFC ban. The first HCFC is scheduled to be eliminated by 2003. But, the phaseout timetable for eliminating HCFCs will probably be accelerated. There will be a relatively short time allowed for the use of HCFC´s following the CFC ban.

The public has a very negative image of CFCs in products. As a deterrent to CFC users, the EPA has instituted a labelling requirement for products containing CFCs. The labels are to indicate that the products are made with substances which harm public health by depleting the ozone layer. Consumers are constantly reminded by environmental groups about the hole in the ozone layer, which is ascribed to CFCs. The reaction against CFCs is so strong that aerosol packages which have not had CFCs since 1978, now have claims on the labels which declare the products CFC-free. The use of CFCs in products adversely impact the image of the manufacturer. A potent response is being elicited by some customers in the U.S., by avoiding to purchase products containing CFCs.

The assaults on CFCs and other ozone depleting chemicals will continue until eliminated. Any attempts to resist the CFC ban will not be beneficial. The public does not want CFCs in the U.S. It is up to industries to respond to the needs of customers, who are also part of the public. The EPA is definitely reacting to public demand, by ensuring that the CFC regulations will eventually lead to a ban on all ozone depleting substances in the U.S.. There are few benefits for insulating foam plastic industries to continue using CFCs until the ban in 1996.

The CFC ban seems certain, and the search for replacements is inevitable in order for companies in the U.S. to remain in business. It is up to the various industries to identify potential suitable CFC alternates, but, the EPA has the final authority to approve substitutes for CFCs. The CFC replacements presented in Table 10 are the approved substances by the EPA. The approved substances are considered safe alternates to CFCs.

The major criteria used by the EPA to rate CFC replacements encompass environmental acceptability, toxicity, safety and flammability. The factors considered for environmental acceptability of substances are: ozone depleting potential, global warming potential, atmospheric lifetime, and VOC classification. The EPA´s approved list of replacements are all environmentally acceptable, but the individual substances are rated. Among the environmentally acceptable CFC replacements, the substitutes have ratings which depict different levels of acceptability.

The toxicity of substitutes is also assessed by the EPA. The substances are assigned a quantitative safe exposure limit (TLV or LEL). In addition to the assigned safe exposure limit, a qualitative description of toxicity for the substance is provided. In Table 4, the toxicity of propellants was presented. The approved list of CFC replacements are regarded as having acceptable levels of toxicity.

The safety of propellants relates to flammability of the propellants. As shown in Table 10, both flammable and non-flammable propellants have received

EPA´s approval for replacing CFCs in insulating foam plastics. For safety during processing and in end-use, a non-flammable propellant is desired. But, if flammable propellants are used, steps can be taken technically to minimize the risk for fires (Lerch, 13).

The main difference between the hydrocarbons and the other flammable CFC substitutes is the VOC status. The hydrocarbons are the only substances in Table 10 which are classified as VOCs. The HCFC´s and HFCs are not VOCs. The positive VOC status is very negative, and has restricted widespread use of hydrocarbons in insulating foam plastic applications. There are tough regulations restricting the use of VOC´s in the U.S., which makes the hydrocarbons unattractive as long-term CFC replacements (Dunn, 30).

Following EPA´s approval of CFC substitutes, industries have to further evaluate the substances as viable replacements for CFCs in real processes and products. The criteria to evaluate the substitutes consist of technical feasibility and cost related issues.

Evaluating the technical feasibility of using CFC substitutes is essential for successfully phasing in replacements, because, the substitutes are not drop-in replacements for CFCs. This is primarily due to the differences in physical and chemical properties between the CFCs and alternates (Daly, 29). It has been widely reported in the literature that CFC replacements have been used to produce insulating foam plastics with high insulating efficiency. When alternates were used to replace CFCs, the processes needed to be modified and products had to be reformulated to achieve the desired performance (Lund et. al., 44).

At various stages of eliminating CFCs, the cost related issues that have to be addressed by industries insulating foam plastic industries include: Availability of CFC replacements; Cost of CFC replacements; Research and development (R & D) effort necessary to maintain product quality and performance.

The cost of CFCs have escalated with the imposition of the excise tax. Table 11 presented the current, high cost of CFCs compared with the replacements. Among the approved CFC substitutes, the cost per pound of the propellants vary widely. Hence, a thorough evaluation of the cost/benefit relation of the replacements is vital for developing cost effective processes and products, which employ CFC replacements. For U.S. industries using CFCs, the cost is higher than the alternate. There is no cost advantage to continue using CFCs in insulating foam plastic applications in the U.S..

Earlier in Chapter I, three technical options to eliminate CFC use in insulating foam plastic applications were presented. In order to continue operations in U.S., industries will not have a choice but to adopt one or combine the technical options to terminate using CFCs. The ban in 1996 has made the search for replacing CFCs urgent.

A fourth option that was not emphasized is for insulating foam industries in the U.S. to carry on using CFCs. Pursing this option will be short-lived because of the CFC ban in 1996. Continuing to use CFCs is not considered a feasible option because of the eventual outcome, which will be to go out of business. From now until the ban takes effect, rising prices coupled and dwindling supply, coupled with a negative public image, will make the use of CFCs expensive, difficult, and unattractive for industries in the U.S..

An approach using the technical Option one as the vehicle to eliminate CFC use was presented earlier. The general structure of the proposal was outlined in Table 8. The components of the strategy is comprised three key steps which are: studying the market and competition, using interim CFC substitutes, HCFCs, and finally, replacing the temporary HCFCs with permanent HFCs. The proposed strategy is meant to direct insulating foam plastic industries in the U.S. to permanently convert products and processes cost effectively to permanent CFC replacements.

Summary

From the discussions, CFC use will cease to be permitted after the ban in 1996. The interim CFC replacements, HCFCs, are expected to be banned between the years 2003 and 2015. Industries have to seek avenues to prepare for operations without both CFCs or HCFCs. There are replacements approved by the EPA to replace ozone depleting. But, phasing out CFCs and HCFCs from processes and products requires careful planning to successfully convert to the permanent replacements.

To furnish means to eliminate CFC use in insulating foam plastic applications in the U.S., technical options were presented as follows:

OPTION #1 -Replace CFCs with alternate blowing agents.

OPTION #2 -Modify present production process to slowly phase out CFCs, or use other technologies which completely eliminate CFCs.

OPTION #3 -Substitute foam plastic products with alternate products (English et. al., 2).

The literature offered in Chapter II supported the technical Option one as the best for U.S. industries to phaseout CFCs using conventional CFC replacements. Technical Option two and Option three were not supported by the literature as viable options for eliminating CFC use in insulating foam plastic applications in the U.S..

Option two, presented earlier to phase out CFCs, has two approaches: The first is to modify present production processes to slowly phase out CFCs. The second strategy is to use other technologies which completely eliminate CFCs.

The first part of Option two to gradually eliminate CFCs is not pragmatic because of the CFC ban in 1996. Until the ban takes full effect, supply is expected to shrink dramatically. The producers are converting CFC plant capacities to produce alternates (Mahoney, 1). In addition to limited supply, the excise tax has raised the cost of CFCs presented in Table 11, above all the replacements. The excise tax has made it more cost effective to use replacements instead of CFCs in insulating foam plastic applications (McDonough, 1).

Under Option two, the second strategy to use technologies which completely eliminate the need for CFCs are currently available. Hydrocarbons and carbon dioxide are propellants which are different from the conventional CFC replacements. The hydrocarbons and carbon dioxide are readily available, and are used in insulating foam plastics.

The hydrocarbons (HCs), are volatile organic compounds (VOCs) which is a negative for environmental acceptability. In the U.S., the EPA requires states to maintain safe ozone levels by controlling the amount of VOCs emitted (Dunn, 30). The U.S. regulatory pressures on VOCs limits the potential for HCs to broadly replace CFCs in insulating foam plastic applications.

Another technology that eliminates the need for conventional CFC replacements is the use of carbon dioxide (CO_2) in insulating foam plastics. The problem with the technology is that the foams generally have poor properties, and the thermal conductivity is high. The carbon dioxide in the closed cells egress the foam, which results in poor foams. The quality of carbon dioxide blown foams does not appear to meet the product performance requirements for insulating foam plastics. (Gross, 20).

Overall, Option two has not been embraced in the U.S.. Modifying processes to use less CFCs is not practical because of the high excise tax, limited supply, and the pending CFC ban in 1996. The VOCs contribute to smog formation, which makes the hydrocarbons unattractive as long-term CFC replacements. Carbon dioxide, when used in foam applications, causes high thermal conductivity, resulting in low energy efficiency. The literature presented in Chapter II does not support phasing out CFCs slowly, or replacing CFCs with hydrocarbons or carbon dioxide in insulating foam plastics in the U. S. (Dunn, 30; Gross, 20).

Technical Option three is to substitute insulating foam plastics with alternate, non-foam products. The central problem with a non-foam product such as fiberglass is that, thick sections are needed to attain the required insulating efficiency.

The adhesion between insulation material and the substrate is essential for providing the necessary insulation efficiency. Fiberglass does not adhere to surfaces, and is installed with mechanical fasteners such as nails. With time, the insulation could settle and allow air to pass through easily, or even worse, fall out completely. The exceptional adhesion properties of insulating foam plastics enable excellent bonding to most surfaces, which ensures that the insulating foam stays in place, which is important for proper insulation.

The ease of installing closed cell, propellant-blown foam is a strength for using insulating foam plastics. Spaces which are not easily accessible can be insulated by spraying into the cavities. When using non-foam insulating materials, areas that are hard to reach become very difficult to insulate.

The literature does not support the use of non-foam insulating materials such as fiberglass. A majority of insulating foam plastic applications are for constructing refrigerators and coolers, where space is restricted, and high insulation efficiency is desired. The non-foam insulating materials are not suitable for replacing insulating foam plastics applications. The non-foam materials do not meet performance requirements for insulating foam plastics.

Technical Option two and Option three to phase out CFCs, are not preferred avenues for replacing CFCs long-term. For U.S. industries, Option one is proposed as the best technical route to pursue for eliminating CFC use in insulating foam plastic applications.

Option one, which is the technical option presented for replacing CFCs permanently, is supported by the literature. The EPA has sanctioned the use of conventional CFC alternates. The CFC substitutes are being used successfully in a variety of commercial, insulating foam plastic applications (Kuhn et. al., 22).

In pursuing Option one, there are three stages which were presented in Table 7, toward attaining the ultimate goal of using zero ozone-depleting chemicals in insulating foam plastics: The first stage is to search and identify interim CFC substitutes which have been approved by the EPA. The approved list of short-term CFC replacements are: HCFC-123, HCFC-141b, HCFC-142b, and HCFC-22. There is no advantage to seriously evaluating CFC alternates which lack EPA approval.

The second stage in following technical Option one is to completely evaluate and implement the use of HCFCs in insulating foam plastics. HCFCs are not drop-in replacements for processes and products which required CFCs. Judicious product reformulation and modification of processes will probably be needed to switch from CFCs.

The use of HCFCs is temporary because of the anticipated ban. So, the third and final stage of technical option one is to replace the HCFCs with HFCs in insulating foam plastics. The EPA has approved HFC-134a and HFC-152a as permanent CFC replacements.

The EPA has approved hydrocarbons for permanently replacing CFCs. In the U.S., the hydrocarbons are not attractive because of the VOC status. The VOCs are not preferred in the U.S. because local governments restrict emissions. The VOCs are regulated because they contribute to smog formation Dunn, 30).

The technical option to eliminate CFCs from insulating foam plastics has been identified. Option one, which proposes replacing CFCs with conventional alternates, is supported by the literature, as the practical approach for U.S. industries to phaseout CFCs in insulating foam plastic applications. Technical Option one was presented as an essential part of a comprehensive strategy to eliminate the use on ozone-depleting substances in insulating foam plastic applications.

Regulations to ban CFCs, HCFCs, and other ozone-depleting chemicals worldwide are expected to proceed in general accord with the provisions of the Montreal Protocol. The EPA will continue to play the essential role of guiding U.S. industries to cease the production and use on CFCs and HCFCs. The process of meeting the CFC regulations is not simple. Beyond EPA´s approval of CFC substitutes, there are other concerns to industries which include: Cost and availability of new propellants; capital expenditure for equipment to process replacements; R & D costs to advance the change to new propellants; customer acceptance of products containing CFC substitutes.

Considering the numerous factors involved with converting from CFCs to replacements, how does a U.S. firm remain competitive and maintain compliance with the EPA regulations? A viable strategy is presented for U.S. industries to eliminate the use of CFCs in insulating foam plastics effectively. The approach to a complete CFC phaseout from insulating foam plastics outlined in Table 8 had three main steps proposed for eliminating CFCs in insulating foam plastics.

The first step for the proposed strategy to phaseout CFCs from insulating foam plastics is to investigate and monitor competitors globally. This is a critical step because the market conditions eventually cannot be ignored. The pricing of products containing the replacements will be dependent on choices available to customers. Industries need to depend on suppliers, product labels, MSDSs, product literature, and publications to learn about the competition.

As an example, the literature presented in Chapter II indicated that pentanes, which are hydrocarbons, are preferred for replacing CFCs long term in Europe (Tambosso, 5). The hydrocarbons are not preferred in the U.S. due to the VOC classification. VOCs are regulated seriously in the U.S.. In order to develop a strategy to compete with insulating foam products from Europe, it would be helpful for the U.S. competitors to know what types of propellants are being used.

Researching the market for what competitors are doing globally is key to formulating a strategy to eliminate CFC use, and, remain competitive. The U.S. industries need to know what the competition is doing.

The second step is to adopt stage one and stage two of technical Option one, which are to identify and implement the use of interim CFC replacements respectively. After the temporary replacements are in place, permanent CFC replacements need to be sought.

The third step is to adopt Stage 3 of technical Option one, which is to replace the HCFCs with permanent CFC substitutes, HFCs. The HFCs have been approved by the EPA as safe and permanent replacements for CFCs. HFCs are now commercially available, and can be used successfully in insulating foam plastics.

An essential part of the whole process of phasing-out of CFCs, which was not presented in the strategy, is to educate customers about the changes. The products may not look, perform, or cost the same without CFCs, and all the real and perceived differences need to be communicated early to customers. As part of the effort to strengthen the market position of products containing alternates, customers should be made aware of substitute products containing CFCs, or not in compliance with the environmental regulations. The products with pentanes from Europe, for example, need to be stressed to U.S. customers as having VOCs.

At every stage of phasing out CFCs, the insulating foam plastics industry needs to de-market existing CFC-containing products, and heavily promote products with replacements. To enhance the image of the public toward the use of CFC replacements, it would be essential for industries to maintain a positive position of engaging in environmentally responsible practices (Franklin, 7).

The change from CFCs creates goodwill for companies. The public outcry against CFCs make it beneficial for all industries urgently to get out of CFCs. Companies with CFC alternatives can gain market share because of public demand for non-CFC products. There are some proponents for a slow CFC ban, but the public actually set the pace for the CFC phase-out. There are claims that the damage to the ozone layer should not cause a panic (Wingate, 6A). But, there is reason for companies to accelerate the pace of eliminating CFCs because of the ban in 1996. A likely outcome to not phasing out CFCs will be to go out of business.

The proposed strategy to eliminate CFCs is supported by the literature presented in Chapter II. By adopting the strategy presented in Table 8 and educating customers, insulating foam plastic industries in the U.S. can meet the challenging EPA regulations, and maintain global competitiveness.

Limitations

The insulating foam industry has little control over the direction of future HCFC regulations. There is no information on how long the EPA will actually allow the use of HCFCs in insulating foam plastics.

The proposed strategy suggests using HCFCs. In case the time lines for eliminating HCFCs are accelerated like the CFCs, the industries may be forced to implement the use of HFCs without following the proper steps.

Technically, the proposed strategy provides a means of how to replace CFCs successfully with HCFCs. The concern to U.S. industries is what happens following the initial investment to convert to interim CFC substitutes. To minimize the risk of suddenly having to discontinue HCFC use, insulating foam plastic industries need to convert as soon as possible to the permanent CFC replacements, HFCs.

Another limitation to the proposed strategy is the assumption that of HCFC prices will remain stable. Due to the ozone-depleting potential of HCFCs, the EPA will probably introduce an excise tax. This is a valid concern because the excise tax for CFCs are assessed based on the ozone depleting potential of the chemicals. Though the HCFCs are much better than CFCs, the potential to deplete stratospheric ozone exists for the interim alternates. In the past, the EPA used the excise tax as an incentive for industries to quicken the phaseout of CFCs (EPA, 2003). In case the EPA applies similar reasoning, the HCFC elimination will probably be encouraged by introducing an excise tax. For now, there is no excise tax on HCFCs. In case an excise tax is imposed on HCFCs, and the cost rises above HFCs, then the proposed strategy would not make sense. If prices for HCFCs increase dramatically above HFCs, the part to eliminate ozone depleting substances should be from CFCs straight to HFCs.

The proposed strategy assumes that HFCs will not face a ban. Currently, the EPA has listed the HFCs as permanent CFC replacements. As more data becomes available on the HFCs, regulations could swing toward a ban. The main criteria for environmental acceptability, ozone-depleting potential, could change to other factors such as global warming potential. There is no indication in the literature about the future of HFCs regulations.

The use of hydrocarbons are not supported in the strategy based on the tough VOC regulations in the U.S.. Supposing that VOC regulations change to favor hydrocarbons in insulating foam plastics, then the proposed strategy will not be valid. The most cost-effective approach for industries in the U.S. would then be, to go directly from CFCs to hydrocarbons.

Suggestions for Further Research

The long-term replacements for CFCs in insulating foam plastics are HFC-134a, HFC-152a, and hydrocarbons. This a very short list of options on which industries can rely. There is an urgent need for research to identify other permanent CFC replacements which meet the criteria for EPA´s approval.

Apart from the two HFCs, HFC-134a, and HFC-152a, which are approved by the EPA, there are other HFCs which have shown high insulating efficiency in insulating foam plastics. Work needs to continue for the EPA to approve more HFCs for permanently replacing CFCs (Fishback et. al., 23).

Hydrofluorocarbon ethers (HFCEs) are substances which have been identified for potentially replacing CFCs. The HFCEs do not contain chlorine, and thus, have zero ozone-depleting potential. The HFCEs have been used to successfully make foams with good insulating properties (Fishback et. al., 24). The

HFCEs lack the EPA´s approval as a safe alternate to CFCs.

Research needs to proceed to expand the list of EPA-approved substances, especially for non-VOCs, such as new HFCs and HFCEs. The process to attain EPA approval is lengthy, and it would be propitious for the insulating foam industry to have several potential candidates in the pipeline. This would ensure a constant supply of new, EPA-approved, permanent, CFC replacements.

Hydrocarbons are VOCs which are undesirable for insulating foam plastic applications in the U.S.. Regulations in the U.S. emphasize reduction of emissions when using substances classified as VOCs. Research for equipment which is capable of capturing all VOC emissions during manufacturing processes may enhance the acceptance of hydrocarbons in the U.S.. The use of equipment which captures VOC emissions, may make it possible for hydrocarbons to be used without restrictions in the U.S.. The VOC status has handicapped hydrocarbons as serious, permanent CFC replacements. The absence of emissions could make hydrocarbons an option in the U.S. for taking the place of CFCs long-term.

Carbon dioxide is a substance that occurs naturally, and can be used in insulating foam plastics. The problem with foam blown with carbon dioxide is low insulating efficiency. Research to improve the insulating efficiency of foams containing carbon dioxide will be advantageous. The ability to obtain foam made carbon dioxide with good insulating properties may provide another viable alternate to replace CFCs permanently, and broaden the choices available to U.S. industries for new propellants.

In conducting further research on the proposed strategy to eliminate CFCs in insulating foam plastic applications, it would be helpful to gather information on the actual length of time it takes for manufacturers of insulating foam plastics to complete the various steps for phasing out CFCs. A survey conducted of insulating foam plastic industries in the U.S. and Europe, on the future concerns of CFC regulations, may shed some light on what may be the next generation of propellants after HFCs and hydrocarbons.

APPENDIX A

Key Issues Pertaining to CFC Ban

ACCELERATED PHASEOUT OF CFCs

- MONTREAL PROTOCOL PHASEOUT DATES REVISED AT UNITED NATIONS ENVIRONMENTAL PROGRAM (UNEP) MEETING IN COPENHAGEN:

  100% PHASEOUT BY JANUARY 1, 1996
  75% REDUCTION FROM 1986 LEVELS BY JANUARY 1, 1994

- U. S. CFC PRODUCTION AT 50% OF 1986 LEVELS IN 1992 AND 1993

  100% PHASEOUT BY JANUARY 1, 1996

- EPA LIKELY TO ADOPT INTERIM REDUCTION TO 25% OF 1986 LEVELS FOR 1994

- EPA CONSIDERING REDUCTION TO 15% OF 1986 LEVELS FOR 1995

HCFC PHASEOUT

- MONTREAL PROTOCOL AMENDED TO REGULATE HCFCs

  CONSUMPTION CAP BEGINNING IN 1996

  1989 HCFC CONSUMPTION PLUS 3.1% OF 1989 CFC CONSUMPTION (ON WEIGHTED ODP BASIS)

  35% REDUCTION OF CAP BY 2004
  65% REDUCTION OF CAP BY 2010
  90% REDUCTION OF CAP BY 2015
  99.5 REDUCTION OF CAP BY 2020
  100% REDUCTION OF CAP BY 2030

- EPA PLANNING FASTER PHASEOUT OF SOME HCFCs

HCFC-141b	2003
HCFC-22; HCFC-142b	2010 (new equipment) 2020 (total)
HCFC-123	2015 (new equipment) 2030 (total)

- EPA WILL ENSURE COMPLIANCE WITH HCFC CAP.

CFC TAX

- TAX ON CFCs IMPOSED AS PART OF OMNIBUS BUDGET RECONCILIATION ACT OF 1989

- INCREASE IN BASE TAX RATES PASSED OCTOBER, 1992 - EFFECTIVE JANUARY 1, 1993

- BASE TAX RATES FOR CFCs:

1993	$3.35/lb
1994	$4.35/lb
1995	$5.35/lb
1996	$5.80/lb
1997	$6.25/lb

- TAX ON CFCs IN RIGID INSULATION FOAMS REMAINS AT ~$0.25/lb THROUGH 1993 - FULL SCHEDULE BEGINNING 1994

- CURRENTLY NO TAX ON HCFCs

LABELING
SEC. 611 CAA

- FINAL RULE ISSUED FEBRUARY 11, 1993 (58 FR 8136)

  EFFECTIVE DATE MAY 15, 1993 WITH PROVISION FOR NO ENFORCEMENT DURING FIRST 9 MONTHS

- REQUIRES LABELING OF:

  ALL CONTAINERS OF CFCs AND PRODUCTS CONTAINING OR MANUFACTURED WITH CFCs

  CONTAINERS OF HCFCs

  PRODUCTS CONTAINING OR MANUFACTURED WITH HCFCs AFTER JANUARY 1, 2015 UNLESS EPA DETERMINES SUITABLE ALTERNATIVES ARE AVAILABLE

- LABEL MUST SAY:

  "WARNING: CONTAINS (OR MANUFACTURED WITH) [NAME OF SUBSTANCE], A SUBSTANCE WHICH HARMS PUBLIC HEALTH AND ENVIRONMENT BY DESTROYING OZONE IN THE UPPER ATMOSPHERE"

- RULE CONTAINS DETAILED INSTRUCTIONS FOR SIZE, PLACEMENT, PASS-THROUGH OF LABELS, ETC.

NONESSENTIAL USES OF CFCs
(SEC. 610 CAA)

- EPA FINAL RULE ISSUED JANUARY 15, 1993 (58 FR 4768)

  PROHIBITS SALE OR DISTRIBUTION IN INTERSTATE COMMERCE OF "NONESSENTIAL" PRODUCTS CONTAINING OR PRODUCED WITH CFCs

- EFFECTIVE DATES:

  FEBRUARY 16, 1993 FOR MANY SOLVENT AND AEROSOL APPLICATIONS

  JANUARY 17, 1994 FOR NON-INSULATING FOAMS

- EXCLUDES INSULATING FOAMS

- EPA CAN ADD TO LIST OF "NONESSENTIAL" APPLICATIONS

NONESSENTIAL USES OF HCFCs
(SEC. 610(d) CAA)

- CLEAN AIR ACT REQUIRES EPA TO PROHIBIT USE OF HCFCs IN:

  PLASTIC FOAMS, EXCEPT FOAM INSULATION PRODUCTS AND SOME AUTOMOTIVE SAFETY FOAMS

  AEROSOL PRODUCTS, UNLESS USE IS DETERMINED TO BE "ESSENTIAL" BASED ON FLAMMABILITY OR WORKER SAFETY

- EFFECTIVE DATE JANUARY 1, 1994

  PROPOSED RULE MAY, 1993
  FINAL RULE OCTOBER, 1993

  BAN IN EFFECT AFTER JANUARY 1, 1994 EVEN IF FINAL RULE HAS NOT BEEN ISSUED

- (THERMAL) INSULATION FOAMS EXCLUDED

  EPA REVIEWING EXEMPTIONS FOR AEROSOL, SOLVENT AND OTHER FOAM APPLICATIONS

SIGNIFICANT NEW ALTERNATIVES POLICY (SNAP)
(SEC. 612 CAA)

- PROPOSED RULE ISSUED MAY 12, 1993
  (58 FR 28094)

  45 DAY COMMENT PERIOD ENDED JUNE 21, 1993

  FINAL RULE FALL 1993

- LIST APPLICATIONS OF CLASS 1 SUBSTANCES AND PROPOSED SUBSTITUTES

  EACH SUBSTITUTE DESIGNATED "ACCEPTABLE," AND "UNACCEPTABLE" OR "PENDING"

  PETITION PROCESS FOR ADDING OR DELETING SUBSTANCES

- ACCEPTABLE SUBSTITUTES FOR CFCs IN RIGID INSULATING FOAMS INCLUDE:

  HCFC-141b, HCFC-22, HCFC-142b
  HCFC-123, HFC-134a, HFC-152a
  AND HYDROCARBONS

- NONESSENTIAL USES REGULATIONS OVERRIDE SNAP REGULATIONS

SOURCE: Nudel, E. "Key Issues Pertaining to CFC Ban." DuPont News Bulletin January 1993: 1-8.

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