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Project Report

COMMERCIAL ANALYSIS OF CHLOROFLUOROCARBON APPLICATIONS IN CANADA

Prepared for

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I

EXECUTIVE SUMMARY

Chlorofluorocarbons (CFC's) are manufactured in Canada by DuPont Canada Inc. and Allied Chemicals Inc. Together these two firms produced in 1987 approximately 17.6 kilotonnes of the five CFC's that are Ont. the restricted list of the Montreal Protocol.

Additionally, a number of companies, including CIL, import CFC's, totalling about 3.2 kilotonnes in 1987.

CFC's find their way into a large number of end-use applications. A brief overview of these applications is provided in Exhibit I-1. This Exhibit is organized into 'Process Groups' and "Product Groups'. Process Groups are broad categories of use which are representative of the major industry usage of CFC's. Product Groups are subsets within each Process Group which focus in Ont. a more specific use of CFC's. This terminology is used throughout this report.

EXHIBIT I-1
Chlorofluorocarbons process group and product group classifications

PROCESS GROUP	PRODUCT GROUP
AEROSOL PRODUCTS	Personal Pharmaceutical Household Commercial and Industrial Insecticides
RIGID FOAMS	Polyurethane foam bunstock and laminated boardstock Polyurethane poured and sprayed foams Phenolics Extruded polystyrene foam boards Extruded polystyrene and low density polyethylene foam
FLEXIBLE FOAMS	Slabstock Molded
REFRIGERATION & AIR CONDITIONING	Aftermarket and wholesale (service and start-up). Commercial institutional and industrial products and systems
SOLVENTS	Electronic applications Other applications
OTHER APPLICATIONS	Sterilants Miscellaneous categories

The manufacturing, importation, distribution and use of CFC's in Canada is extremely complex. The products are sold both directly to users by the manufacturer-importer group, as well as through a large group of wholesalers. In turn these wholesalers are, in some cases, major users of the CFC's themselves, as in the autmobile industry. In other cases they are independent supply houses.

Control of the use of CFC's in Canada through restrictions placed Ont. the user industry, must consequently be carefully planned.

In this report we also examine a number of substitute products or materials that might be used in place of the restricted CFC's. In some cases compounds such as HCFC 22 are immediately available and can readily substitute for the high ozone-depleting potential (ODP) of the restricted CFC's. In other situations, extensive conversion costs are necessary before other substances can be used. For still other uses, alternate substances are not yet proven and may be very expensive.

We also review the direct and indirect employment in each of the major producers and user groups. Parallel studies under contract by Environment Canada will use this information to explore the impact Ont. Canadian industry of legislating against these restricted substances.

The information in this report was developed through extensive discussions - both individual and group - with industry and industry associations. We worked closely with the Society of Plastics Industries who assisted with these discussions. We have also incorporated some of the extensive documentation and published reports about the industry.

II

INTRODUCTION

This report summarizes the results of our findings regarding the structure of chlorofluorocarbon (CFC) supply and consumption in Canada. It also summarizes our findings Ont. substitute materials for chlorofluorocarbons and the impact of using these substances in various applications.

The scope of this report includes the five fully halogenated chlorofluorocarbons which fall under the terms of the 1987 Montreal protocol and are therefore to be restricted by Environment Canada under its implementation of the protocol. These are shown in Exhibit II-1, along with their ozone depletion potential (ODP). ODP is a measure of the relative ozone destruction potential of each CFC.

EXHIBIT II-1
Restricted CFC's and Relative Ozone Depletion Potential (ODP)

Restricted CFC	ODP
• CFC 11	1.0
• CFC 12	1.0
• CFC 113	.8
• CFC 114	1.0
• CFC 115	.6

Other chlorofluorocarbons exist and are in use but are not part of the Montreal protocol because of significantly lower ozone depletion potential. The most common of these is HCFC 22, a partially halogenated chlorofluorocarbon that has an ozone depletion potential of 0.05, more than ten times lower than any of the 5 CFC's above. In the discussions in Chapter V Ont. alternatives, HCFC 22 is cited frequently as an alternative to the potentially more damaging CFC's.

The findings in this document are based Ont. discussions with CFC suppliers, industrial users, organizations representing industrial users, and other knowledgeable industry participants. We also reviewed many of the numerous documents and research findings which have been prepared Ont. CFC issues in Canada and the United States.

A top down approach has been followed in compiling this material. We have asked that senior spokesmen for industries and industry groups advise us about the structure of usage and alternatives within the areas they represent. In certain industries focus groups have been held to gather input from a representative industry cross-section. Our approach did not include a survey of the entire group of CFC users. Detailed information Ont. the use of CFC's by individual firms has already been compiled by Environment Canada.

In Chapter III, we discuss chlorofluorocarbon supply in Canada, in terms of the current manufacturers and importers, estimated employment and estimated volume. We then discuss, in Chapter IV, chlorofluorocarbon consumption in terms of six "Process Groups", i.e. major categories of CFC usage. These Groups are further detailed in the individual sections within Chapter IV.

In Chapters V and VI, we summarize an extensive range of alternatives which exist or have been considered for each of the categories of CFC usage. These findings are presented in the form of data sheets Ont. each alternative which summarize the key implications of using each alternative.

III

CHLOROFLUOROCARBON SUPPLY

Chlorofluorocarbons (CFC's) are manufactured in Canada by DuPont Canada Inc. (DuPont) and Allied Chemicals Canada Inc. (Allied). Both companies also import CFC's, principally from their respective United States operations. A third major importer is Canadian Industries Limited (CIL), which distributing products from ICI in the United Kingdom. The vast majority of CFC consumed in Canada comes from the above production and imports and is supplied directly by these companies. Imports by other companies typically vary between 2% and 5% of total supply in any given year. CFC's have not historically been exported in significant quantities (i.e. more than 5%).

DuPont and Allied nameplate capacities are estimated as follows:

EXHIBIT III-1
Production Capacities

Company	Plant location	CFC's produced	Capacity (kt/yr.)
DuPont	Maitland, Ont.	11,12,113,114	18.0
	Maitland, Ont.	113, 114 or 22	3.5-4.5
Allied	Amherstburg, Ont.	11,12,113, 114, or 22	13.5
TOTAL PRODUCTION CAPACITY (kilotonnes per year)			35.0-36.0

Source: Stevenson Kellogg Ernst & Whinney estimate based Ont. external and internal sources

CFC 115 is not produced in Canada. It is generally supplied through imports of CFC 502 (which is 50% CFC 115).

Total Canadian supply of CFC 11, 12, 113, 114 and 115 is estimated as follows (excluding any exports):

EXHIBIT III-2
Supply

	1986	1987
Canadian production (kilotonnes)	16.7	17.6
Canadian imports (kilotonnes)	2.8	3.2
TOTAL SUPPLY	19.5	20.8

Source: Stevenson Kellogg Ernst & Whinney estimate based Ont. external and internal sources

The value of this supply in revenue to Canadian companies is difficult to calculate because of a lack of information about the split between the various CFC's and actual selling prices (as opposed to list prices). However, a reasonable estimate of the value of 1986 would be $42 to $48 million; for 1987 supply, $46 to $52 million.

DuPont Canada has recently announced that it has "set as its goal an orderly transition to the total phase-out of fully halogenated chlorofluorocarbon production" as part of a worldwide E.I. DuPont de Nemours policy. The nature and timing of the impact of this policy Ont. DuPont's plant in Maitland or the timing of reduction in Canadian CFC supply have not yet been announced. As a result, the overall impact Ont. Canadian CFC capacity and production are not yet known.

Estimated employment for production of CFC's by the 3 producer/importers to Canada is as follows:

Direct employees	98
Indirect employees	48
TOTAL:	146

Employment is estimated in terms of full time equivalents. In certain cases, this means that a representative number of employees has been estimated for functions such as sales, where staff may be responsible for more than just CFC's. Direct employment includes all individuals that are directly occupied within each company with manufacturing, handling and promoting. Indirect employment includes inside environmental, legal, administrative and outside employees. For comparative purposes, total Canadian employment for Allied, CIL and DuPont is approximately 15,000.

IV

CHLOROFLUOROCARBON CONSUMPTION

Exhibit IV-1, which follows, summarizes the structure of CFC consumption in Canada. The estimates of companies, employment and consumption are organized by the Process Groups outlined in Chapter I. The importance of CFC's to Cost of Goods Sold in the companies in which they are used is then discussed below. Following Exhibit IV-1, we discuss the nature of CFC usage in terms of each of the Process and Product Groups.

A. CFC USAGE

Although certain more detailed information Ont. usage exists for certain Product Groups within each Process Group, much of it cannot be presented for confidentiality reasons. This applies for example, to the breakdown of consumption within certain Process Groups where individual companies dominate usage of a specific CFC or in a specific Product Group. In other areas, such as the 'Solvents' and 'Other Applications' Process Groups, accurate information does not exist Ont. the number of companies or employment represented because of the diversity of uses involved. The total number of companies using CFC's in Canada, estimated at 2,000, is a reliable estimate based Ont. information supplied by producers.

Estimates of direct and indirect employment are also shown. The definitions of each employment category are the same as those used in Chapter III. That is, direct employment includes employees directly involved in manufacture and supply of products using CFC's (direct labour, shipping, receiving, material handling, marketing and sales). Indirect labour includes employees such as those involved in general management, administrative support functions, contract services etc. As noted, this total excludes automotive assembly related employment. This is done for two reasons. First, automotive assembly is a 'downstream' application in that it involves use of already-manufactured mobile air-conditioning units. Second, as discussed later in this chapter, Canadian consumption of CFC's for mobile air conditioning is complex to define because of the combination of Ont. and off-line charging and the movement between Canada and the United States of both components and finished automobiles.

EXHIBIT IV-1
Summary of CFC Usage

Process Group	Number of Companies	Direct Employees	Indirect Employees	Total Estimated Usage (Kilotonnes)	CFC's Used 11	12	113	114	115
Aerosol Products	16	700	200	1.9	X	X	X	X	
Rigid Foams	280	4,500	1,600	6.9	X	X	X		
Flexible Foams	18	6,000	400	1.7	X				
Refrigeration and Air Conditioning	190	6,000	1,000 (1)	7.5	X	X	X	X	X
Solvents	20 + (2)	N/A	N/A	2.0			X		
Other Applications	50 + (2)	N/A	N/A	0.8		X			
TOTAL	2,000 (2)	17,200 + (2)	3,200 + (2)	20.8					

Source: Stevenson Kellogg Emst & Whinney estimates based on internal and external sources.

(1) Note: Excludes automobile production -- related employment.

(2) Note: There are an estimated 2,000 users of CFC's in Canada. The majority of these consume only small quantities of CFC's.

B. COST OF GOODS SOLD

The importance of CFC's to cost of goods sold (COGS) varies tremendously, depending Ont. the application in which the CFC is used. (Cost of Goods Sold is defined as the estimated average cost of all CFC's used in manufacture or supply as a percentage of all direct manufacturing costs. Direct manufacturing costs include direct labour and materials, and applicable indirect labour and manufacturing overhead costs). The importance of CFC in each Process Group is summarized as follows.

- For Aerosol Products, CFC's range between 20% and 80% of COGS depending Ont. its use as a propellant, vapour depressant or slurrying agent.
- For Rigid Foams, CFC's range between 2% and 15% of COGS depending Ont. the specific foam being considered.
- For Flexible Foams, CFC's represent less than 1% COGS for both Molded and Slabstock Product Groups.
- For Refrigeration and Air Conditioning, CFC's typically represent significantly less than 1% of COGS for products and systems in which it is used as a refrigerant. It represents very close to 100% of COGS for aftermarket and wholesale distribution activities.
- For both Solvents and Other Applications, CFC's typically represent 40% to 80% of COGS since they are usually being used in blended or near-pure form directly (i.e. not as part of manufacturing process).

C. NATURE OF CFC USAGE IN PROCESS AND PRODUCT GROUPS

1. Aerosols

Use of CFC's in Canada for aerosol products has declined dramatically in the past decade as a result of the 1980 restriction Ont. use of CFC in selected personal aerosol products. In 1987, the single dominant end-use was for cooking sprays. This has now changed significantly, with Boyle-Midway's decision to stop using CFC in Pam, the market leader. At this point, aerosol uses are spread among a wide variety of other applications. These include the following product groups and products:

a) Personal

- Breath sprays
- Perfume sprays
- Shave lubricants
- Depilatory sprays

b) Pharmaceutical

- Bronchial dilators
- Anti-perspirants (regulated as a pharmaceutical product)
- Foot powders
- Topical applications (anesthetic and antiseptic wound spray)

c) Household

- Cooking products
- Air fresheners
- Room deodorants
- Gum remover

d) Commercial and Industrial

- Mold release agent
- Electrical cleaner solvent
- Electrical dust eliminator
- Lubricants
- Silicone sprays
- Specialty mine products
- Film coating (photographic film development)
- Analytical fixatives
- Adhesives
- Lock de-icer

e) Insecticides

- Insect repellant
- Insecticide sprays

CFC's are consumed both by manufacturers of end-use products and by custom manufacturers (or co-packers). The primary custom manufacturer is CCL Industries Inc., Toronto, which produces a large range of aerosols in almost all end-use product categories.

2. Rigid foams

CFC's are used in 5 Product Groups within the Rigid Foams Process Group. The vast majority of products within each of these groups are foams of one type or another. The product groups are:

Insulating foams

- Polyurethane foam bunstock and laminated boardstock
- Polyurethane poured and sprayed foams
- Phenolic foams
- Extruded polystyrene foam boards

Packaging foams

- Extruded polystyrene and foam
- Low-density polyethylene foam

Note that expanded polystyrene foam (EPS) is a water-blown, not CFC-blown foam.

a) Polyurethane foam bunstock and laminated boardstock

Three companies in Canada produce polyurethane foam bunstock and laminated boardstock insulation products, using CFC 114 as a blowing agent. They are Cartier Insulation (Montreal, P.Q.), Guilford Ltd. (Dartmouth, N.S.) and Hanson Inc. (Toronto, Ont.). This is a highly competitive market in Canada, dominated by imports from major U.S. manufacturers.

b) Polyurethane poured and sprayed foams

Foam manufacturers using polyurethanes can be broken down into two categories. These categories are those companies who blend their own compounds and then manufacture products with them, and those who manufacture but do not blend. This latter group buys from systems houses (see the discussion below). Only companies in the first category actually buy and blend CFC's; however, the role and importance of the CFC is the same for both groups.

Polyurethane foam products are used in a wide range of end-uses, including insulation, packaging, marine products, furniture and automotive products. Insulation is used in roof, wall and floor applications; walk-in coolers; curtain walls; doors; modular building structures; domestic and commercial freezers, refrigerators and coolers; display cases, shipping containers; refrigerated road and rail cars and liquid natural gas tankers; water heaters; vehicles carrying perishable foods and consumer products such as picnic coolers and chests.

Some packaging uses exist for polyurethane foams. These include fragile products which must be moved or shipped such as electronic devices, instruments, appliances and pottery and glass products. Marine uses include flotation devices, floating decks and buoys, rafts, life saving products and as both a structural and flotation material in vessels ranging from sailboards to boats.

In addition to the polyurethanes consumed in-plant to manufacture foams the insulation sector also has a field applied product. There are approximately 250 contractors in Canada who mix the polyol and isocyanate components on-site and spray urethane insulation for residential, commercial and industrial purposes. Applications include pipe and storage tanks, walls, floors and foundations, roofs, and agricultural and cold storage buildings.

Many manufacturers of polyurethane products do not carry out their own blending, but rather, purchase from systems suppliers who supply them with components ready for blowing into foam. Examples include BASF Canada, General Latex, Iroquois Chemical, CIL and Witco Chemical. The application areas of these companies' products span the full range outlined above. Because of their position in the supply structure, each of these companies is generally a significant consumer of CFC's. However, because of the diversity of end-use applications in this product group area, it is difficult to relate systems house CFC consumption to specific end-use products or industry sectors.

c) Phenolics

Bunstock and laminates can be manufactured from phenolic foam for use as insulation and packaging shapes. These foams are generally blown with CFC 11 or 113 blended into the resin to produce finished products with densities of 30 to 40 kg/m^3. Use of phenolic foam has been growing in the past few years as an industrial roofing material and as building sheathing. This growth has occurred more quickly in the United States than in Canada (led by Koppers), but both Building Products of Canada and Fiberglass Canada (which recently announced a phenolic foam plant) are active in this market. At present, some market demand is being satisfied, especially in eastern Canada, by imported finished products.

The only other significant phenolic application in Canada at present is for use in floral arrangements. Here, the foam provides both structural support and a means of retaining moisture for the floral arrangement. The only known Canadian manufacturer of floral foam products is Smithers-Oasis Canada Ltd. in Ajax, Ont.

d) Extruded polystyrene foam boards

Dow Chemical (plants in Toronto, Ont. ; Varennes, P.Q.; and Fort Saskatchewan, AB.) and Celfort Ltd. (Grande-Ile, P.Q.) manufacture extruded polystyrene boardstock for insulation applications using CFC 11 and 12. Extruded polystyrene foam competes with phenolics and polyurethanes in the huge foam insulation market in Canada. Although fiberglass still dominates this market, each of the other products (all of which use CFC's) have been gaining increasing market shares.

e) Extruded polystyrene low-density polyethylene foam

Extruded polystyrene and low-density polyethylene foams used in a variety of packaging applications. These include trays used for meat, eggs, fast-foods and institutional purposes single service plates, cups etc. and hinged containers. These products generally have densities of approximately 30 to 40 kg/m^3.

3. Flexible foams

Flexible polyurethane foam is manufactured as continuously-poured slabstock and as individually molded products. Flexible polyurethanes are generally produced through a reaction of a polyol, isocyanate and water. One product of the reaction is carbon dioxide gas, which serves as the primary blowing agent in the process. Another is a urea product which provides firmness and load characteristics. Additives used include surfactants (to stabilize cell structure and control size), catalysts to control the reaction of the three active ingredients, and where necessary, colouring and fire retardants. CFC 11 is generally used in the process as an auxiliary blowing agent for softness and density reduction in the resulting foam. In many foams, the CFC also acts to dissipate the heat generated by the water - isocyanate reaction.

a) Slabstock

In Canada, the major application areas for flexible slabstock are furniture and bedding. There are 12 slabstock manufacturers. Some manufacturers combine foam production with manufacture of finished products using the foam. This is particularly true in the furniture end-use sectors.

b) Molded

The major application for molded flexible polyurethane foam in Canada is automotive This sector consumes the vast majority of molded flexible foams for automotive seat cushions and backs. There are 6 manufacturers of molded flexible foam in Canada.

4. Refrigeration and air conditioning

At about 36% of total CFC consumption in Canada, the refrigeration process group is the largest user; slightly higher than the rigid foam process group. End-use applications here are split between CFC sold as refrigerant for the aftermarket and CFC used in manufacture of refrigeration, chilling and air conditioning products. These latter applications embrace the commercial, industrial, residential and mobile end-use sectors. The dominant CFC used is 12, which is the principal refrigerant in commercial, industrial and domestic refrigeration systems as well as automobile air conditioning. However, all five restricted CFC's are used in refrigeration systems to satisfy various space, performance and pressure application needs.

a) Aftermarket and (Wholesale service and start-up)

Perhaps two-thirds of CFC consumed by the refrigeration process group is in the form of refrigerant supplied in the aftermarket for service and start-up. The major CFC supplied is CFC 12 as indicated above, followed by CFC 11, 113, 114 and 115 (as part of CFC 502). There are an estimated 25 companies with 100 wholesale locations which distribute refrigerants in various end-use sectors. Twelve of these are major suppliers with another 13 secondary suppliers. Wholesalers supply both smaller original equipment manufacturers, refrigeration and air conditioning installation and service companies, and large systems charged after installation. There are an estimated 23 million units in the field in Canada using controlled CFC's as refrigerants.

In the automotive sector, Ford, General Motors and Chrysler all purchase CFC's for use in their own on-line charging for vehicle assembly needs. Each also acts as a distributor to their respective dealer networks. (There are 3,900 automobile dealers in Canada, in addition to many thousands of service stations almost all of which use at least some refrigerant as part of their vehicle service and repair activities).

b) Commercial, institutional and industrial

Commercial products and systems, institutional and industrial refrigeration products and system include units for building air conditioning, food storage (both portable and walk-in), pharmaceutical storage, chemical storage and processing, chillers for water and soft drinks, process chillers for manufacturing applications and a significant percentage of ice rinks. Many large systems are charged in the field in this group. As a result, the CFC consumption is accounted for in the aftermarket totals above.

CFC 11 and CFC 12 are the main products used in this product group. CFC 11 and 113, and to a limited extent, CFC 114, are used in office tower centrifugal systems (almost all office buildings over 10 stories high use low pressure centrifugal air conditioning systems). CFC 113 is also used in commercial system. A smaller quantity of CFC 115 is consumed (in CFC 502) in the food storage refrigeration products.

There are 25 manufacturers of commercial and industrial air conditioning units, some of which source CFC's directly from the producers/importers, others which purchase from wholesalers. This product group consumes an estimated 13% of the total CFC's in the refrigeration process group.

c) Domestic products

There are 6 manufacturers of five main products: window air conditioners, central air conditioners, household refrigerators, dehumidifiers and freezers. CFC 12 is the refrigerant used in this product group.

The end-use sector for domestic refrigeration products encompasses appliance and other retailers and chains who typically purchase directly from manufacturers of the units.

d) Mobile products

There are 6 manufacturers producing mobile refrigeration units, typically for truck applications in transporting perishable products. These generally use CFC 12. Although automotive end-uses are a significant portion of consumption, the majority of this in Canada is for a on-line charging, not manufacture.

Consumption of CFC (12) for mobile air conditioning applications is difficult to identify because of the Auto Pact (which allows essentially free movement of automobiles between Canada and the U.S., subject to certain contraints) and the fact that air conditioning units are charged both on-line during vehicle assembly and at the point of manufacture. Seventy-five percent of the automobiles assembled in Canada (1.5 million per year) are exported to the United States. Another 1.1 million are brought into Canada. Because approximately 90% of the automobiles sold in the United States have air conditioning (compared to 30% to 40% in Canada), the assembly (and therefore a certain percentage of the unit charging) in Canada is disproportionately large relative to the Canadian market demand. No air conditioner units are manufactured in Canada in captive OEM plants.

5. Solvents

CFC solvents have selective solvent action, which means they can be used to remove oil, grease and dirt from objects without affecting metal, plastic or elastomeric parts being contacted. They are available in very high purities (i.e. very low particulate content) and are highly miscible which enables them to be mixed with other solvents or chemicals to suit specific requirements. In addition they are inherently stable and non-conductive. In many applications, they can be effectively recycled using distillation techniques which lowers the effective cost of using them (in addition to reducing the effective release quantities).

As a result, CFC's have become increasingly in demand in electronic, microelectronic and certain other precision metal cleaning applications such as aerospace and medical equipment manufacturing. CFC solvent usage is limited in conventional metal cleaning. The principal method of use is vapour degreasing with the balance mostly in cold cleaning. Vapour degreasing uses the hot vapour of a heated solvent to condense Ont. a part and dissolve the contaminants. Cold cleaning uses the solvent at or near room temperature to dissolve the contaminants which are then removed by wiping or some other method.

CFC 113 is the dominant solvent used because its higher boiling point makes it more widely applicable. CFC 11 is also used, but much less frequently because its boiling point is too low for most uses.

CFC solvents are supplied as pure solvents, blends, azeotropes and special cleaning systems for specific applications. CFC 11 is generally sold unblended. An estimated 10 to 20% of CFC 113 is sold unblended with the balance in blends, azeotropes and systems mixed with ethanol, isopropanol, or nitromethane primarily. More specialized blends include methylene chloride, methanol and cyclopentane with the CFC.

CFC solvents are distributed by producers, distributors and systems suppliers, depending Ont. the specific product involved. Various blended and unblended solvents are produced in Canada. Others are imported.

6. Other applications

a) Sterilants

CFC 12 is mixed with sterilizing agents (generally ethylene oxide) and sold to medical equipment manufacturers and hospitals for use in sterilizing respiratory equipment, anesthetic equipment, catheters and associated tubing, syringes, gloves and other medical supplies. The primary advantage of using the CFC is that it makes the sterilizing agent non-flammable without degrading in any way its sterilizing characteristics.

V

CHLOROFLUOROCARBON ALTERNATIVES

Across the range of 6 process groups and approximately 20 product groups, there are well in excess of 250 potential alternatives for reducing consumption of the five restricted chlorofluorocarbons (CFC11,12,113, 114,115). These alternatives can be categorized in three ways: chemical, process and product alternatives. Each is discussed further below.

In Appendix A, which follows this report, we have summarized the list of potential alternatives for each Process and Product Group. This list was developed for use by the industry representatives and focus groups in discussing the applicability of each potential alternative.

In Chapter VI, which follows, we introduce the 'Functional Alternative Data Sheets' which comprise the balance of this report.

1. Chemical alternatives

These are new or substitute chemicals which would replace some or all of the CFC used in the manufacture of a particular product. The majority of reduction in CFC use will likely come through chemical alternatives. Examples of these alternatives include CFC substitutes being developed such as HCFC-134a, HCFC-142b, HCFC 123 and HCFC-141b. Other chemical substitutes include existing chemicals such as ammonia and methylene chloride as well as HCFC-22, a partially halogenated chlorofluorcarbon with relatively low ozone depletion potential (0.05). The substitutability of these chemicals varies tremendously, depending Ont. the process and product groups, and often the end-use as well. Overall comments, even about some of the 'drop-in' CFC substitutes, are generally possible to only a limited extent. As a result, specific chemical alternatives are often discussed several times in this chapter for different process/product group combinations.

2. Process alternatives

These are modifications or major changes to existing manufacturing processes which would reduce (generally not eliminate) CFC consumption. Examples include carbon adsorption with recovery in foam blowing and CFC capture techniques in refrigeration repair. Many process alternatives have or are being widely implemented, even in the past 6 months by industrial users. Others, such as carbon adsorption with recovery, are either developmental or extremely costly. Because of both of these factors, and the nature of Process Alternatives, these alternatives are not likely to yield major reductions in CFC consumption.

3. Product alternatives

These are changes to a marketplace which would have the effect of reducing CFC consumption by virtue of reducing or eliminating demand or shifting it to other products which do not use CFC. Examples include substituting pulp packaging for foam packaging or fiberglass for foam insulation. Because product alternatives are also affected by other issues (such as corporate strategy), it is very difficult to draw meaningful conclusions about their potential substitution impact without making specific assumptions about control strategies and addressing specific companies individually. This is true in most process/product groups, particularly in rigid foam insulation which is discussed more fully below to illustrate, by example, these issues. A small group of product alternatives are discussed under certain Product Groups in the later sections of this report.

The dominant end-use for rigid foams is in insulation applications. Because of the size and diversity of the markets into which these products are sold, an extensive range exists. These foam products frequently compete against one another based Ont. price, appearance and physical properties such as R-value, dimensional stability, thickness and water absorption characteristics. Depending Ont. the specific applications being considered, each generally has strengths and weaknesses which will determine its marketability.

Other insulating products such as fiberglass, perlite, fiberboard, cellular glass, vermiculite, rock wool and gypsum may also compete with one or more of the foam products based Ont. their properties and the end-use being considered.

Over the past 20 to 30 years, use of rigid foams has grown steadily through both development of new markets where they are well suited and through replacement of previously non-foam applications with foam products. An example of this latter replacement is in freezer and refrigerator applications. Previously fiberglass-based, they have moved essentially completely to rigid foam. Among other advantages, foam allows a freezer or refrigerator to have increased interior volume for a given set of exterior dimensions and insulating performance level.

Many of the rigid foams use either CFC 11, CFC 12 or CFC 113 as a blowing agent and as a component of the foam structure to contribute to the insulating characteristics. Each different foam generally uses different quantities of CFC and uses the CFC in slightly different ways in the manufacturing process.

Because of this complexity in both manufacturing process and marketplace competition, summary comments regarding product substitutions cannot be made. The impact of controls Ont. CFC consumption Ont. each foam insulation manufacturer may vary significantly depending Ont. a number of factors. These will include:

- Which foam or foams are made by the manufacturer.
- What the implementation mechanics of the control are, particularly as they relate to other foam products. For example, will a given control affect polyurethane manufacturers in the same way as it is expected to affect polystyrene manufacturers?
- What chemical or process alternatives exist and what effect they are expected to have Ont. the price, appearance and physical properties of the foam. For example, a chemical alternative which increases the price of a foam by 10% and reduces its R-value by 15% may dramatically alter its market positioning by bringing it into competition with different products than has historically been the case.
- What possible end-use impacts exist in the marketplace. For example, a chemical alternative for a rigid foam which decreases its insulating performance may, barring other marketplace options, have a catastrophic effect Ont. construction practice and

cost by requiring thicker walls for the same insulating performance.

Given assumptions or expectations about each of these points, each manufacturer will have a number of strategic options. These will include use of chemical or process alternatives, if they exist or change to other new or existing foam (or non-foam) products. The choices for each manufacturer will likely vary depending Ont. the assumptions made. Furthermore, the competitive strategy in the marketplace may also need to change.

The overall impact of this Ont. the industry as a whole can thus not be predicted without making more specific assumptions about controls. Clearly this cannot be done Ont. an industry-wide basis publicly, as can the conclusions Ont. chemical and process alternatives which follow. It may be appropriate to carry out this analysis confidentially at a later date for some or all of the industry, if the existing or any new control options need to be evaluated at this level of detail.

VI

FUNCTIONAL ALTERNATIVE DATA SHEETS

Although more than 250 potential alternatives exist, the list of these which can be discussed is considerably smaller because many product-related alternatives can only be addressed in company-specific terms (as discussed above). In addition, many alternatives are not considered practical or effective because of high cost or major technical weaknesses.

For each process group, a series of data sheets have been completed which summarize the key characteristics of the alternative for all or specific end-uses. These characteristics include availability, potential market penetration, end-use marketplace comparability and cost and benefits, to the extent known. Although some alternatives are clearly better than others (i.e. more effective and/or more practical) no attempt has been made to rank alternatives. This is not possible without considerable additional work at the company-specific level combined with assumptions about probable control options and their likely impact Ont. individual companies.

Each alternative has been considered independently, as if it were the only alternative available. The relationship of alternatives to each other and the implications for companies which result can only be considered at a much more detailed level and with assumptions about control options.

Terminology used in each data sheet is defined as follows:

1. Alternative

A functional alternative to the current CFC-based product(s). This includes product substitutes (such as fiberglass for foam insulation), chemical substitutes (such as a an HCFC replacement for a CFC or a different chemical), and process/engineering substitutes (such as equipment modification to reduce CFC consumption during manufacture).

2. Process group

Refers to the process group containing product groups. As discussed in Chapter I, process groups are major groupings of product types.

3. Product group

Refers to the product group which the functional alternative applies to. Product groups are groupings of 'related' products. The relationship may be because of the end-use application, production methods or product format.

4. End-use

The end-use application of the current CFC - based product. End uses are defined within each product group where necessary, if the implications of a given alternative change for different end-uses.

5. **Availability and timing**

This section addresses the timing associated with developing each functional alternatives, and bringing it to market.

a) **Technical**

The total elapsed time, from 1988, before the functional alternative will be sufficiently understood technically so that it could be available for commercial production. Technical availability would generally equate to the availability of a manufacturing process to make a product.

b) **Commercial**

The total elapsed time from 1988 before the functional alternatives can be commercially produced. Note: this period must be at least as long as the technical period, but based Ont. industry confidence levels, and the type of approvals needed, some commercial production preparation work may be done in advance of government approval or final technical completion in order to expedite commercial release.

c) **Market**

The projected total elapsed time from 1988 until the first end-use function alternative will be sold.

6. **End-use market penetration and timing**

This section explores the anticipated market-place acceptance and penetration.

a) **Expected**

The expected highest level of market-place penetration and the elapsed time from 1988 for that penetration level to be achieved. The expected percentage of penetration incorporates assumptions about market-place acceptance of the product as well as considering applications where this functional alternative could not completely replace the current CFC use.

b) **Maximum**

The maximum potential market penetration assuming no buyer preference against the functional alternatives. It should be noted that the only barriers to achieving a maximum penetration of 100% are those caused by technical problems where the alternative cannot satisfy all of the current CFC based products' markets requirements.

c) **Substitution Potential**

The percent reduction in use of the controlled CFC(s) at the expected level of market penetration.

7. End-use market place comparability

This section discusses key characteristics of each functional alternative as it relates to the user in comparison to the current CFC based product.

a) Acceptance

Comments concerning the "hows" and "whys" of customer acceptance and the barriers which need to be (or are not expected to be) overcome.

b) Quality

Comments concerning the importance of, as well as actual and perceived quality of, the functional alternative. For the purposes of this discussion, quality describes perceived value and usefulness.

c) Durability and life

Comments concerning the durability and product life of the functional alternatives compared to the CFC-based product for that end-use application.

d) Environmental and health issues

Comments concerning the environmental and health issues associated with the functional alternative.

8. Cost and benefits

This section reviews the specific types of costs encountered across Canadian industry for a given CFC functional alternative. These costs are stated in 1988 dollars and are estimates for all companies, except where noted. The objective here is to estimate order of magnitude costs with relative consistency or identify where costs are unknown. Specific estimates will clearly not be possible.

a) Research and Development Costs

Capital, one-time costs and on-going expenses related to the research and development of each alternative.

b) One-time Conversion Costs

Both capital and one-time expenses are estimated across the projected "Availability and Timing" period and stated in 1988 dollars. Cost categories consider such items as facilities and equipment conversions and additions, employee training, product design, testing and market research.

The reported costs are incremental to current capital budgets over the anticipated period.

c) **Annual operating cost changes**

On-going operating cost changes, either increases or decreases, as a result of converting to the functional alternative. Included in this figure are changes to both direct and indirect costs incremental to current costs.

d) **Spin-off costs and benefits**

Costs and benefits that will be achieved in other areas/product lines as a result of the shift to the functional alternative. Examples of this are the ability to sell by-products of the production process or enter markets previously not available to the CFC-based product.

e) **End-use modification costs**

Incremental costs/benefits to the end-user caused by a shift to the functional alternative. These costs are only for those users who could use that alternative. Examples are increased energy costs and increased space requirements.

f) **End-use cost changes**

Changes in product/service costs to the end-user's product caused by the shift to the function alternative, if the alternative is not an end product. Examples are cost changes to polyurethane foam which may have a relatively higher or lower impact Ont. the cost of products using that foam.

N/C Biblio

Stevenson Kellogg Ernst & Whinney

COMMERCIAL ANALYSIS OF
CHLOROFLUOROCARBON
APPLICATIONS IN CANADA

Project Report

A. AEROSOL PRODUCTS

Major end-use categories and substitute substances that we review in the Aerosol Products group are described in this section:

1. Personal Products

- ► Breath sprays
  - HCFC 22
  - Hydrocarbon
- ► Shave lubricants
  - HCFC 22
  - Hydrocarbon

2. Household

- ► Cooking products, air fresheners, room deodorants
  - Hydrocarbon
- ► Gum removers
  - HCFC 22

3. Pharmaceutical

- ► Bronchial dilators
  - No known substitute
- ► Anti-perspirants
  - HCFC 22
  - Hydrocarbon
- ► Wound sprays
  - HCFC 22/142
  - Hydrocarbon

4. Commercial and Industrial

- ► Mold release agents
  - Hydrocarbon

- Electrical cleaner solvents
  - No known substitute
- Electrical dust eliminators
  - HCFC 22
- Lubricants/silicone sprays
  - HCFC 22/142 and 152 blend
  - Hydrocarbon
- Film coating (photographic)
  - HCFC 22/142/152 blend
- Fixatives/adhesives
  - HCFC 22/hydrocarbon blend
- Mining lubricants
  - No known substitutes

5. **Pesticides**

- Insect repellants
  - Hydrocarbon
- Insecticide sprays
  - HCFC 22
  - Hydrocarbon/chlorinated solvent blends

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: PERSONAL
Process Group: AEROSOL PRODUCTS

END-USE		BREATH SPRAY	PERFUME
AVAILABILITY AND TIMING	Technical Commercial Market	Currently available in the market	Currently available in the market
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC12 consumed for breath sprays	100% of CFC12 consumed for perfume aerosols
END-USE MARKETPLACE COMPARABILITY	Acceptance	No difference	No difference
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	Increased human toxicity, ozone depleting substance (ODP of 0.05)	Increased human toxicity, ozone depleting substance (ODP of 0.05)
COSTS AND BENEFITS	Research and development costs	A formulation is available	Formulations are available
	One-time conversion costs	$50,000 for testing and registration	$50,000 for testing
	Annual operating cost changes	Unknown (HCFC 22 is higher cost)	Unknown (HCFC is higher cost)
	Spin-off costs and benefits	None	None
	End-use modification costs	None	None
	End-use cost changes	Unknown	Unknown

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HYDROCARBON PROPELLANT Product Group: PERSONAL Process Group: AEROSOL PRODUCTS	
END-USE		BREATH SPRAY	PERFUME
AVAILABILITY AND TIMING	Technical Commercial Market	Currently available in the market	Currently available in the market
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	100% in 1 year
	Maximum	100% in 1 year	100% in 1 year
	Substitution potential	100% of CFC12	100% CFC12
END-USE MARKETPLACE COMPARABILITY	Acceptance	Dependant on flammability issue	Dependent on flammability issue
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	Increased flammability	Increased flammability
COSTS AND BENEFITS	Research and development costs	Formulation is available	Formulation is available
	One-time conversion costs	$50,000 for registration amendments and label changes	$50,000 for registration amendments and label changes
	Annual operating cost changes	None	None
	Spin-off costs and benefits	Cheaper propellant costs	Cheaper propellant costs - no effect on product cost.
	End-use modification costs	None	None
	End-use cost changes	None	None

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: PERSONAL
Process Group: AEROSOL PRODUCTS

END-USE		SHAVE LUBRICANT	DEPILATORY
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market	Currently available in the market	Currently available in the market
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC12 consumed for shave lubricants	100% of CFC12 consumed for shave lubricants
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	Acceptable
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	Increased human toxicity, ozone depleting substance	Increased human toxicity, ozone depleting substance
COSTS AND BENEFITS	Research and development costs	None	None
	One-time conversion costs	$50,000 for testing and label changes	$50,000 for testing and label changes
	Annual operating cost changes	Unknown (HCFC is higher cost)	Unknown (HCFC is higher cost)
	Spin-off costs and benefits	None	None
	End-use modification costs	None	None
	End-use cost changes	Unknown	Unknown

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANTS
Product Group: HOUSEHOLD
Process Group: AEROSOL PRODUCTS

END-USE		COOKING PRODUCTS, AIR FRESHENER, ROOM DEODORANT	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC11 consumed for these end-uses	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Poor due to product efficacy, weight problems	
	Quality	Inferior	
	Durability and life	No change	
	Environmental and health issues	Increased flammability	
COSTS AND BENEFITS	Research and development costs	A formulation is available	
	One-time conversion costs	$50,000 for label changes $50 to $100,000 for obsolete packaging costs	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	Cheaper formulation	
	End-use modification costs	None	
	End-use cost changes	Unknown	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANT
Product Group: PERSONAL
Process Group: AEROSOL PRODUCTS

END-USE		SHAVE LUBRICANT	DEPILATORY
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	Currently available in the market
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC12 consumed for shave lubricants	100% of CFC12 consumed for shave lubricants
END-USE MARKETPLACE COMPARABILITY	Acceptance	Depends on flammability issue	Depends on flammability issue
	Quality	No difference	No difference
	Durability and life		
	Environmental and health issues	Increased flammability	Increased flammability
COSTS AND BENEFITS	Research and development costs	None	None
	One-time conversion costs	$50,000 for testing and label changes	$50,000 for testing and label changes
	Annual operating cost changes	None	None
	Spin-off costs and benefits	Cheaper propellant	Cheaper propellant
	End-use modification costs	None	None
	End-use cost changes	None, based on current knowledge	None, based on current knowledge

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC--22
Product Group: HOUSEHOLD
Process Group: AEROSOL PRODUCTS

END-USE		GUM REMOVER	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC12 used for this application	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Blend is less efficient	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	Ozone depleting substance	
COSTS AND BENEFITS	Research and development costs		
	One-time conversion costs	$50,000 for testing and label changes	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Unknown	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative:
Product Group: PHARMACEUTICAL
Process Group: AEROSOL PRODUCTS

END-USE		BRONCHIAL DILATORS - 15g PACKAGE	
AVAILABILITY AND TIMING	Technical Commercial Market	There are presently no known alternatives to CFC 114 for bronchial dilators. Use of hydrocarbons is known to have both suspension and flammability problems. Costs for developing, testing and conversion are unknown, but expected to exceed $1 million for the industry. Potential end-use cost changes are also unknown, and will depend on the most viable alternative developed.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: PHARMACEUTICAL
Process Group: AEROSOL PRODUCTS

END-USE		ANTI-PERSPIRANTS	FOOT POWDER
AVAILABILITY AND TIMING	Technical Commercial Market	Currently available in the market	Currently available in the market
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	
	Maximum	100% in 1 year	
	Substitution potential	100%% of CFC11 consumed for this end-use	100% of CFC11 and 100% of CFC12 consumed for this end-use
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	Acceptable
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	Ozone depleting substance (ODP is 0.05)	Ozone depleting substance (ODP is 0.05)
COSTS AND BENEFITS	Research and development costs	Formulation is available	Formulation is available
	One-time conversion costs	$50,000 for testing and label changes	$50,000 for testing and label changes
	Annual operating cost changes	None	None
	Spin-off costs and benefits	None	None
	End-use modification costs	None	None
	End-use cost changes	None	None

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANT
Product Group: PHARMACEUTICAL
Process Group: AEROSOL PRODUCTSS

END-USE		ANTI-PERSPIRANT	FOOT POWDER
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	Currently available in the market
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	100% in 1 year
	Maximum	100% in 1 year	100% in 1 year
	Substitution potential	100% of CFC11 consumed for this end-use	100% of CFC11 and 100% of CFC12 consumed for this end-use
END-USE MARKETPLACE COMPARABILITY	Acceptance	Limited	Limited
	Quality	Efficacy is less	Efficacy is less
	Durability and life	Unknown	Unknown
	Environmental and health issues	Increased flammability. Use of chlorinated solvent	Increased flammability. Use of chlorinated solvent.
COSTS AND BENEFITS	Research and development costs	Formulation available	Formulation available
	One-time conversion costs	$50,000 for testing and label changes $100,000 capital equipment costs	$50,000 for label change (weight) $100,000 capital equipment cost
	Annual operating cost changes	None	None
	Spin-off costs and benefits	None	None
	End-use modification costs	None	None
	End-use cost changes	None	None

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22/142
Product Group: PHARMACEUTICAL
Process Group: AEROSOL PRODUCTS

END-USE		TOPICAL APPLICATIONS - ANESTHETIC & ANTISEPTIC WOUND SPRAY	
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1-2 years	
	Maximum		
	Substitution potential	100% of CFC11 and 100% of CFC12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	
	Quality	Unknown	
	Durability and life	Unknown	
	Environmental and health issues	Ozone depleting substance (HCFC 22) increased flammability and toxicity (HCFC 142)	
COSTS AND BENEFITS	Research and development costs	A formulation is available	
	One-time conversion costs	$50,000 for testing, registration changes and label change and $50,000 - $100,000 for capital equipment blend cost	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Unknown	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANT
Product Group: PHARMACEUTICAL
Process Group: AEROSOL PRODUCTS

END-USE		TOPICAL APPLICATIONS - ANESTHETIC AND ANTISPETIC WOUND SPRAY	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC11 and 100% of CFC12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	
	Quality	Reduced anaesthetic action.	
	Durability and life		
	Environmental and health issues	Increased flammability	
COSTS AND BENEFITS	Research and development costs	A formulation is available	
	One-time conversion costs	$50,000 for testing, registration changes and label change	
	Annual operating cost changes	Slight reduction, assuming no cost: increases to deal with flammability	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Propellant cost reductions - minor product price decrease	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HYDROCARBON Product Group: COMMERCIAL & INDUSTRIAL Process Group: AEROSOL PRODUCTS	
END-USE		MOLD RELEASE AGENTS FOR PLASTICS & ELASTOMER MATERIALS	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	100% of CFC11 and 100% CFC12;	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Limited, because of solubility and flammability issues	
	Quality	Dissolves plastic surface	
	Durability and life	No difference	
	Environmental and health issues	Increased flammability - safety concerns on heated surface	
COSTS AND BENEFITS	Research and development costs	Estimated $50,000 to $100,000.	
	One-time conversion costs	$50,000 for label change	
	Annual operating cost changes	No difference, assuming no additional costs are incurred to deal with flammability issues.	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Propellant costs are slightly lower, therefore a cost reduction may result.	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: Product Group: COMMERCIAL & INDUSTRIAL Process Group: AEROSOL PRODUCTS	
END-USE		CLEANER SOLVENTS (ELECTRICAL APPLICATIONS)	
AVAILABILITY AND TIMING	Technical Commercial Market	There are presently no known alternatives for cleaner solvents for electrical applications (currently CFC 113). Other chlorinated solvents are known to have toxicity problems. A replacement solvent must also maintain the product residue performance characteristics of CFC 113. When developed, an alternative may also need to conform to existing electrical standards, or initiate changes, with the associated costs and timing.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		DUST ELIMINATORS (ELECTRICAL APPLICATIONS)	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 5 years	
	Maximum	100% in 5 years	
	Substitution potential	100% of CFC12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	Ozone depleting substance	
COSTS AND BENEFITS	Research and development costs	$50,000 to $100,000 for testing and development.	
	One-time conversion costs	$50,000 for label change.	
	Annual operating cost changes	None	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	None	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22/142 & 152 BLEND
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		LUBRICANTS/SILICONE SPRAYS	
AVAILABILITY AND TIMING	Technical		
	Commercial	Unknown (some 142b is available but only 1 supplier exists; U.S. - based Pennwalt)	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	100% of CFC11; 100% of CFC12; 0% of CFC 113 for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	
	Quality	Unknown	
	Durability and life	Unknown	
	Environmental and health issues	Ozone depleting substance (HCFC 22). Increased toxicity (142/152)	
COSTS AND BENEFITS	Research and development costs	Formulations are available	
	One-time conversion costs	$50,000 for testing and label change	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	Unknown	
	End-use modification costs	Unknown	
	End-use cost changes	Unknown	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HYDROCARBON PROPELLANT Product Group: COMMERCIAL & INDUSTRIAL Process Group: AEROSOL PRODUCTS	
END-USE		LUBRICANTS/SILICONE SPRAYS	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	
	Maximum	100% in 1 year	
	Substitution potential	100% of CFC11 and 100%of CFC12; unknown % of CFC 113	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	Increased flammability	
COSTS AND BENEFITS	Research and development costs	Formulations are available in the United States	
	One-time conversion costs	$50,000 for testing and label change	
	Annual operating cost changes	No difference, assuming no additional costs are incurred to deal with flammability issues	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Propellant costs are slightly lower, therefore a cost reduction may result	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative:
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		MINING APPLICATIONS - VARIOUS PRODUCTS SUCH AS LUBRICANTS, CLEANERS	
AVAILABILITY AND TIMING	Technical Commercial Market	There are presently no known alternatives for lubricants or cleaners in mining applications. Hydrocarbons are not feasible because of their flammability.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANT
Product Group: PESTICIDE
Process Group: AEROSOL PRODUCTS

END-USE		INSECT REPELLANT	INSECTICIDE SPRAYS
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in market	Currently available in market
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	100% in 1 year
	Maximum	100% in 1 year	100% in 1 year
	Substitution potential	100% of CFC12 consumed for repellants	100% of CFC11 and 100% of CFC12 consumed for sprays
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	Acceptable
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	Increased flammability	Increased flammability, increased toxicity because of chlorinated solvent content
COSTS AND BENEFITS	Research and development costs	None	Formulations are currently available
	One-time conversion costs	$50,000 for label changes	$50,000 for label changes
	Annual operating cost changes	No difference, assuming no additional costs are incurred to deal with flammability issues	No difference, assuming no additional costs are incurred to deal with flammability issues
	Spin-off costs and benefits	None	None
	End-use modification costs	None	None
	End-use cost changes	Propellant costs are slightly lower, therefore a cost reduction may result	Propellant costs are slightly lower, therefore a cost reduction may result

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22/HYDROCARBON/CHLORINATED SOLVENTS BLENDS
Product Group: PESTICIDE
Process Group: AEROSOL PRODUCTS

END-USE		INSECTICIDE SPRAY	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	100% of CFC11 and 100% of CFC12 consumed for pesticides	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	Each alternative has a significant weakness: HCFC 22 is an ozone depleting substance; Hydrocarbons have increased flammability, chlorinated solvents have increased toxicity	
COSTS AND BENEFITS	Research and development costs	Formulations are available	
	One-time conversion costs	$50,000 for testing and label changes	
	Annual operating cost changes	None	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	None	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22/142/152 BLEND
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		FILM COATING (PHOTOGRAPHIC FILM DEVELOPMENT)	
AVAILABILITY AND TIMING	Technical		
	Commercial	Unknown	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	100% of CFC11 and 100% of CFC12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Professional use - acceptance unknown at this point	
	Quality	May have performance problems compared to existing CFCs	
	Durability and life	Unknown	
	Environmental and health issues	Ozone depleting substance (HCFC 22). Increased toxicity (142/152)	
COSTS AND BENEFITS	Research and development costs	An estimated $100,000 for R & D into specialized equipment/process	
	One-time conversion costs	Unknown, but may be significant for laser machine changes	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	Unknown	
	End-use modification costs	Unknown	
	End-use cost changes	Unknown	

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FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22/HYDROCARBON BLEND
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		ANALYTICAL FIXATIVE/ADHESIVES	
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC11; uncertain regarding % potential for CFC114	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	
	Quality	Water based formulation therefore there are technical limitations in application	
	Durability and life	Unknown	
	Environmental and health issues	Safety problem in lab use if using hydrocarbon blend; ozone depleting substance (HCFC 22)	
COSTS AND BENEFITS	Research and development costs	Formulation is available	
	One-time conversion costs	$50,000 for testing. Capital equipment changes up to $200,000	
	Annual operating cost changes	None	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	None	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HYDROCARBON PROPELLANT/HCFC-152
Product Group: COMMERCIAL & INDUSTRIAL
Process Group: AEROSOL PRODUCTS

END-USE		HYDROCARBON PROPELLANT FOR LOCK DE-ICER	HCFC 152 PROPELLANT FOR LOCK DE-ICER
AVAILABILITY AND TIMING	Technical Commercial Market	Currently available in the market	Unknown (Not currently commercially available)
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential	100% of CFC12 consumed for this end-use	100% of CFC12 consumed for this end-use
END-USE MARKETPLACE COMPARABILITY	Acceptance	Unknown	Uknown
	Quality	No difference	Unknown
	Durability and life	No difference	Unknown
	Environmental and health issues	Increased flammability	Increased toxicity
COSTS AND BENEFITS	Research and development costs	Estimated $100,000	Estimated $100,000
	One-time conversion costs	Estimated $50,000 for label change (weight). Obsolete packaging components	Unknown
	Annual operating cost changes	None assuming no additional costs are incurred to deal with flammability issue	Unknown
	Spin-off costs and benefits	None	Unknown
	End-use modification costs	None	Unknonn
	End-use cost changes	None	Unknown

B. RIGID FOAMS

Below are the major end-use categories and substitute substances that we review in the Rigid Foam category.

1. **Polyurethane foam bunstock and laminated boardstock**
   - HCFC 123
   - HCFC 141b
   - Carbon adsorption with recovery
2. **Polyurethane poured and sprayed foams**
   - HCFC 123
   - HCFC 141b
   - CFC 11/HCFC 22 blend
   - CFC 11/water
3. **Extruded polystyrene foam boardstock**
   - HCFC 123
   - HCFC 141b
   - HCFC 22
   - HCFC 124
   - HCFC 134a
   - HCFC 142b
4. **Extruded polystyrene foam sheet/low density polyethlyene**
   - HCFC 22
5. **Phenolic foam**
   - HCFC 123
   - HCFC 141b
   - Carbon adsorption with recovery

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-123
Product Group: POLYURETHANE FOAM BUNSTOCK AND LAMINATED BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	Available now	
	Commercial	4 to 5 years — All estimates assume that toxicity test results (now underway) are favourable, and may also vary depending on the length of inhalation studies needed.	
	Market	5 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	
	Maximum	100% in 7 to 8 years	
	Substitution potential	100% of CFC 11 consumed for this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptance will be highly dependent on the price of comparable end products.	
	Quality	Expected to yield a lower R-value per given thickness	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Ozone depletion potential of 0.05; otherwise no issues assuming toxicity testing is favourable.	
COSTS AND BENEFITS	Research and development costs	Estimated $100,000 for the industry (note that polyurethane foam bunstock and laminated boardstock is a very small industry in Canada and is heavily import driven.	
	One-time conversion costs	Minimal, based on current technical information	
	Annual operating cost changes	Minimum 10% increase in Cost of Goods Sold based on expected chemical cost increase of 200 to 500% over CFC 11.	
	Spin-off costs and benefits	None	
	End-use modification costs	Unknown, but possibly major implication for end-use costs and applications because of lower R-value.	
	End-use cost changes	Probable 22 to 25% increase for equivalent R-value.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-141b
Product Group: POLYURETHANE FOAM BUNSTOCK AND LAMINATED BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	1 to 2 years	
	Commercial	3 to 5 years — Toxicity tests have not yet started on 141b (123 and 141b are comparable, however 123 is ahead of 141b developmentally)	
	Market	4 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	
	Maximum	100% in 7 to 8 years	
	Substitution potential	100% of CFC 11 consumed for this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, depending on end use impacts of expected higher price	
	Quality	No difference, based on currently available information	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Ozone depletion potential is less than 0.05; 141b is known to have flammability risks (more data is required as to flammability)	
COSTS AND BENEFITS	Research and development costs	Estimated $100,000 for the industry	
	One-time conversion costs	Potential significant upgrade costs to deal with flammability. In addition, because of the need for a new production line, there is some likelihood that conversion costs would be prohibitive for the existing manufacturers.	
	Annual operating cost changes	Independent of operating cost increases to deal with flammability (such as explosion proofing and insurance), expected increase is probably 7 to 8% Cost of Goods Sold.	
	Spin-off costs and benefits	None known	
	End-use modification costs	None known	
	End-use cost changes	Probable end-use cost increases of 15 to 16%.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: CARBON ADSORPTION WITH RECOVERY
Product Group: POLYURETHANE FOAM BUNSTOCK AND LAMINATED BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Applicability of carbon adsorption to bunstock is extremely limited because of the high percentage of CFC retained in the foam cell structure after manufacture.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-123
Product Group: POLYURETHANE POURED AND SPRAYED FOAMS
Process Group: RIGID FOAMS

END-USE		POURED AND SPRAYED	
AVAILABILITY AND TIMING	Technical	Available now	
	Commercial	4 to 5 years — All estimates assume that toxicity test results (now underway) are favourable, and may also vary depending on the length of inhalation studies needed.	
	Market	5 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	
	Maximum	100% in 7 to 8 years	
	Substitution potential	100% of CFC 11 consumed for this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptance will be highly dependent on the price of comparable end products.	
	Quality	Expected to yield a lower R-value per given thickness	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Ozone depletion potential of 0.05; otherwise no issues assuming toxicity testing is favourable.	
COSTS AND BENEFITS	Research and development costs	Unknown	
	One-time conversion costs	Minimal, based on current technical information	
	Annual operating cost changes	For poured, a minimum 10% increase in Cost of Goods Sold based on expected chemical cost increase of 200 to 500% over CFC 11. Sprayed costs will likely be 15 to 20% higher although there is some possibility that the increase will be less, depending on the success of reformulations.	
	Spin-off costs and benefits	None	
	End-use modification costs	Unknown, but possibly major implication for end-use costs and applications because of lower R-value.	
	End-use cost changes	Probable 22 to 25% increase for equivalent R-value in poured, up to 35% higher for sprayed. The increased cost of sprayed in particular, will likely have major competitive implications for the industry.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-141b
Product Group: POLYURETHANE POURED AND SPRAYED FOAMS
Process Group: RIGID FOAMS

END-USE		POURED AND SPRAYED	
AVAILABILITY AND TIMING	Technical	1 to 2 years	
	Commercial	3 to 5 years Toxicity tests have not yet started on 141b (123 and 141b are comparable, however 123 is ahead of 141b developmentally)	
	Market	4 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	
	Maximum	100% in 7 to 8 years	
	Substitution potential	100% of CFC 11 consumed for this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, depending on end use impacts of expected higher price	
	Quality	No difference, based on currently available information	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Ozone depletion potential is less than 0.05; 141b is known to have flammability risks (more data is required as to flammability)	
COSTS AND BENEFITS	Research and development costs	Unknown	
	One-time conversion costs	Potential significant upgrade costs to deal with flammability.	
	Annual operating cost changes	Independent of operating cost increases to deal with flammability (such as explosion proofing and insurance), expected increase is probably up to 20% of Cost of Goods Sold for poured and approximately 15% for sprayed.	
	Spin-off costs and benefits	None known	
	End-use modification costs	None known	
	End-use cost changes	Probable end-use cost increases of up to 20% in poured and 30% in sprayed.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: CFC-11/HCFC-22 BLEND
Product Group: POLYURETHANE POURED AND SPRAYED FOAMS
Process Group: RIGID FOAMS

END-USE		POURED AND SPRAYED	
AVAILABILITY AND TIMING	Technical Commercial Market	This alternative replaces the CFC 12 currently blended with CFC 11 (94% CFC 11; 6% CFC 12) with HCFC 22. The blend still remains 94% CFC 11, thus the alternative has a very limited effect on reduction in CFC consumption. In addition, its applicability is also limited to poured applications where frothing is needed only (no sprayed applications at all). The total reduction potential is unknown but judged to be very small because of the replacement of only the relevant CFC 12 and the limited market applicability.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET	Alternative: CFC-11/WATER Product Group: POLYURETHANE POURED AND SPRAYED FOAMS Process Group: RIGID FOAMS

END-USE		POURED AND SPRAYED	
AVAILABILITY AND TIMING	Technical Commercial Market	Although technically feasible and available as an alternative, the CFC 11/Water combination is not a preferred alternative by many users for a number of reasons. First, it would cause a reduction in R-value with resulting implications for end uses, such as wall thickness in building applications. Second, moisture sensitivity may increase, again impacting end use markets such as freezers. Third, a loss in rigidity and compressive strength could result, making the product weaker or more compress-	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential	ible. This would affect markets such as building insulation. Fourth, the production process generates carbon dioxide. Fifth, conversion costs would be very high. For spray applications for example, the equipment conversion costs would likely range between $500,000 and $1 million. An alternative view is presented by at least one systems supplier, who feels that, although not perfect, the CFC-11/Water combination is a relatively inexpensive and	
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues	viable solution, particularly given uncertainty about the availability of other alternatives. Their conclusion is that the potential problems such as moisture sensitivity and loss of rigidity can be overcome through formulation, that carbon dioxide emmissions would be minimal and the conversion costs relatively competitive with other alternatives.	
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-123 and HCFC 141b
Product Group: EXTRUDED POLYSTYRENE FOAM BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	HCFC 123 and HCFC 141b are not presently commercial alternatives for extruded polystyrene foam. The potential applicability of each in this product group remains to be determined.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: EXTRUDED POLYSTYRENE FOAM BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	Available now	
	Commercial	Commercially available in Europe for certain types of equipment. A blend of HCFC 22 with CFC 12 in proportions up to 100% HCFC 22 is also feasible. The discussion below addresses the 100% HCFC 22 situation since it demonstrates the maximum CFC 12 reduction potential alternative.	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum	100% in 1 year	
	Substitution potential	100% of CFC 12 currently used in extruded polystyrene foam.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, depending on the price of comparable performing products.	
	Quality	Probable minimum 15 to 20% reduction in R-value.	
	Durability and life	No difference	
	Environmental and health issues	Ozone depletion potential of 0.05; otherwise no known issues.	
COSTS AND BENEFITS	Research and development costs	Estimated $1 million for required full scale testing	
	One-time conversion costs	Estimated $1 million for industry	
	Annual operating cost changes	Estimated 5 to 6 % increase in Costs of Goods Sold	
	Spin-off costs and benefits	None	
	End-use modification costs	Unknown, but possible major implications for end-use costs and applications because of significant R-value reduction.	
	End-use cost changes	Increase for equivalent R-value, but will vary by end-use application.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-124
Product Group: EXTRUDED POLYSTYRENE FOAM BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	HCFC 124 appears to have potential as an alternative for CFC 12 in extruded polystyrene applications but with limitations and some difficulty in manufacture. At present there is no timetable for availability and no scheduled toxicity testing.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HFC-134a Product Group: EXTRUDED POLYSTYRENE FOAM BOARDSTOCK Process Group: RIGID FOAMS	
END-USE			
AVAILABILITY AND TIMING	Technical	1 to 2 years (technical issues remain to be resolved)	
	Commercial	4 to 5 years HFC 134a was designed as a replacement for CFC 12 in refrigeration applications but also appears to be technically applicable in this product group.	
	Market	5 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 7 to 8 years	
	Maximum	100% in 7 to 8 years	
	Substitution potential	100% of CFC 12 consumed for extruded polystyrene boardstock	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, based on current HFC 134a technical information	
	Quality	Potential increase in R-value if HCFC 134a retains the HCFC in the cell when blown	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	Unknown	
	One-time conversion costs	Unknown	
	Annual operating cost changes	Unknown (probable chemical cost increase is on the order of 300 to 400%)	
	Spin-off costs and benefits	None known	
	End-use modification costs	None known	
	End-use cost changes	May be positive in some situations, depending on specific end-use applications (i.e. the combination of increased R-value and higher price is favourable for certain products). The overall impact will depend to a large extent on the changes in price and performance which occur with other competing insulation products.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-142b
Product Group: EXTRUDED POLYSTYRENE FOAM BOARDSTOCK
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial	Available now; the only North American supplier is U.S. based Pennwalt	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown; depends heavily on Pennwalt's market strategy and the resulting HCFC 142b availability to various markets.	
	Maximum		
	Substitution potential	100% of CFC 12 consumed for extruded polystyrene boardstock	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable.	
	Quality	A small R-value decrease is anticipated	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Ozone depletion potential of 0.05 and some flammability issues.	
COSTS AND BENEFITS	Research and development costs	Estimated $1 to $2 million for the industry	
	One-time conversion costs	Estimated $2 million	
	Annual operating cost changes	Assuming a 1 to 1 chemical volume substitution is feasible, Cost of Goods Sold increases of 6 to 12% are expected based on a chemical cost increases of 200 to 400%.	
	Spin-off costs and benefits	None known	
	End-use modification costs	Modification costs will be highly dependent on how significant the R-value change is and what approaches users need to adopt as a result.	
	End-use cost changes	Also R-value and application dependent; could range from negligible to 15%.	

FUNCTIONAL ALTERNATIVES - DATA SHEET

Alternative: HCFC-123
Product Group: PHENOLIC FOAM
Process Group: RIGID FOAMS

END-USE		OPEN CELL	CLOSED CELL
AVAILABILITY AND TIMING	Technical	1 to 2 years	Available now
	Commercial	4 to 5 years — All estimates assume that toxicity test results (now underway) are favourable, and may also vary depending on the length of inhalation studies needed.	4 to 5 years — All estimates assume that toxicity test results (now underway) are favourable, and may also vary depending on the length of inhalation studies needed.
	Market	5 to 6 years	5 to 6 years
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	100% in 6 to 7 years
	Maximum	100% in 7 to 8 years	100% in 7 to 8 years
	Substitution potential	100% of CFC 11 consumed for open cell products	100% of CFC 11 consumed for closed cell products
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptance will be highly dependent on the price of comparable end products	Acceptance will be highly dependent on the price of comparable end products and the market implications of lower R-value performance.
	Quality	No difference, based on currently available information	Expected to yield a 10 to 15% reduction in R-value per given thickness
	Durability and life	No difference, based on currently available information	No difference, based on currently available information
	Environmental and health issues	Ozone depletion potential of less than 0.05; otherwise no issues assuming toxicity testing is favourable.	Ozone depletion potential of 0.05; otherwise no issues assuming toxicity testing is favourable.
COSTS AND BENEFITS	Research and development costs	Estimated $1 million for the entire product group	See comments regarding open cell costs
	One-time conversion costs	Estimated $0.5 million for the entire product group	See comments regarding open cell costs
	Annual operating cost changes	Probable 20 to 25% increase in Cost of Goods Sold based on expected chemical cost increase of 200 to 500% over CFC 11.	Probable 35% increase in Cost of Goods Sold based on expected chemical cost increase of 200 to 500% over CFC 11.
	Spin-off costs and benefits	None	None
	End-use modification costs	None, based on current information.	None, based on current information
	End-use cost changes	Probable 35% increase.	Probable 45 to 50% increase.

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-141b
Product Group: PHENOLIC FOAM
Process Group: RIGID FOAMS

END-USE		OPEN CELL	CLOSED CELL
AVAILABILITY AND TIMING	Technical	1 to 2 years	1 to 2 years
	Commercial	3 to 5 years Toxicity tests have not yet started on 141b (123 and 141b are comparable, however 123 is ahead of 141b developmentally)	3 to 5 years Toxicity tests have not yet started on 141b (123 and 141b are comparable, however 123 is ahead of 141b developmentally)
	Market	4 to 6 years	4 to 6 years
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 7 years	100% in 6 to 7 years
	Maximum	100% in 7 to 8 years	100% in 7 to 8 years
	Substitution potential	100% of CFC 11 consumed for open cell products	100% of CFC 11 consumed for open cell products
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	Acceptable, depending on impact of R-value reduction.
	Quality	No difference, based on currently available information	Expected reduction in R-value (the range of reduction is unknown at this point)
	Durability and life	No difference, based on currently available information.	No difference, based on currently available information
	Environmental and health issues	Ozone depletion potential is less than 0.05; 141b is known to have flammability risks (more data is required as to flammability)	Ozone depletion potential is less than 0.05; 141b is known to have flammability risks (more data is required as to flammability)
COSTS AND BENEFITS	Research and development costs	Estimated $2 million for the entire industry	See comments regarding open cell foam
	One-time conversion costs	Unknown, but potential significant upgrade costs to deal with flammability.	Unknown, but potential significant upgrade costs to deal with flammability.
	Annual operating cost changes	Independent of operating cost increases to deal with flammability (such as explosion proofing and insurance), expected increase is probably 25% Cost of Goods Sold.	Independent of operating cost increases to deal with flammability (such as explosion proofing and insurance), expected increase is probably 30 to 35% Cost of Goods Sold.
	Spin-off costs and benefits	None known	None known
	End-use modification costs	None known	None known
	End-use cost changes	Probable end-use cost increases of 30 to 35%.	Probable end-use cost increases of 40 to 45%.

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: CARBON ADSORPTION WITH RECOVERY
Product Group: PHENOLIC FOAM
Process Group: RIGID FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Carbon adsorption is not feasible for closed cell applications because of banking. For open cell applications, it is technically feasible but judged to be prohibitively expensive. The practicality of pursuing this alternative is also questionable given the movement in the insulation marketplace from open to closed cell foams.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: EXTRUDED POLYSTYRENE FOAM SHEET/LOW DENSITY POLYETHYLENE FOAM
Process Group: RIGID FOAM

END-USE			
AVAILABILITY AND TIMING	Technical	Currently available in the market	
	Commercial		
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	
	Maximum	100% in 1 year	
	Substitution potential	100% of CFC 12 consumed for rigid foam packaging applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable (HCFC-22 is becoming the new standard for these product groups)	
	Quality	Acceptable	
	Durability and life	No difference, based on current information	
	Environmental and health issues	Ozone depletion potential of 0.05	
COSTS AND BENEFITS	Research and development costs	None	
	One-time conversion costs	Estimated $1 million for the industry	
	Annual operating cost changes	Unknown, at this stage, but HCFC-22 is somewhat more expensive than CFC 12	
	Spin-off costs and benefits	None	
	End-use modification costs	None expected	
	End-use cost changes	Increase, based on pass through chemical cost increase	

C. FLEXIBLE FOAMS

Below are substitute products for the flexible foam category reviewed in this section.

1. **All flexible foams**

   - HCFC 123
   - HCFC 141b
   - Engineered plastic cushion

2. **Slabstock**

   - Methylene chloride
   - Formic acid "AB" process
   - Molded polyol systems
   - Carbon adsorption
   - E-max system
   - Verticle foam chamber with carbon adsorption
   - Natural/synthetic fibrefill
   - Alternative foams; e.g. latex
   - Minimum foam density

3. **Molded**

   - Water and modified polyols
   - Carbon adsorption
   - Design changes to reduce consumption
   - Firmer seat requirements

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: NATURAL/SYNTHETIC FIBERFILL
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE		FURNITURE	BEDDING (QUILTING)
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	Currently available in the market
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	30% in 2 years Key area of substitution is in supersoft foams up to 2" thick	50% in 2 years
	Maximum	65% in 5 years	90% in 5 years
	Substitution potential	7.5% of CFC 11 consumed for slabstock applications	10.5% of CFC 11 consumed for slabstock applications
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable (some resistance because of inferior durability and support characteristics)	Same comments apply here as for furniture applications
	Quality	Most customers will perceive little difference in quality	
	Durability and life	Compacts more easily and quickly, hence less durable	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	There is adequate existing supply of natural/synthetic fiberfill alternative products on the market. As a result, there is little likelihood that existing manufacturers will convert. This particular segment of flexible foam production would simply disappear.	Same comments apply here as for furniture applications
	One-time conversion costs		
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: ALTERNATIVE FOAMS (E.G. LATEX)
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE		FURNITURE	BEDDING (CORES)
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market	Currently available in the market
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	2.5% in 2 years Alternate foams have a very limited market applicability	5% in 2 years Market for alternative foams in these end-uses is also limited
	Maximum	5% in 5 years	10% in 5 years
	Substitution potential	0.7% of CFC 11 consumed for slabstock applications	1 to 2.5% of CFC 11 consumed for slabstock applications
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, but more expensive (as much as a 100% cost increase)	Same comments apply here as for furniture applications
	Quality	Acceptable for most applications (better for natural-based products than synthetic-based but natural-based products have limited availability)	
	Durability and life	Acceptable	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	There is adequate existing supply of alternative foams (natural-based foams are limited by raw material availability worldwide). Current producers are not likely to convert to this alternative.	Same comments apply here as for furniture applications
	One-time conversion costs		
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes	Foam cost increase of up to 100%	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: ENGINEERED PLASTIC CUSHION
Product Group: ALL
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Engineered Plastic Cushion is unknown as an alternative either technically or for end-use applications in Canada.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: METHYLENE CHLORIDE
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Currently used in conjunction with CFC 11 as a blowing agent. Depending on the company and product, methylene chloride may be well under 50% of the agent or as much as 85%. The estimated average percentage across the industry is 35% CFC 11/ 65% methylene chloride.	
END-USE MARKET PENETRATION AND TIMING	Expected	50 % in 2 years	
	Maximum	50% in 2 years	
	Substitution potential	50% of CFC 11 consumed for slabstock applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable except for health issues discussed below	
	Quality	No difference to CFC 11 based products	
	Durability and life	No difference to CFC 11 based products	
	Environmental and health issues	Methylene chloride is a suspected carcinogen and is banned in certain U.S. states. Use requires properly designed and installed ventilation systems. There may also be barriers to use once the WHIMIS legislation is in effect. Emissions are slower than CFC 11, typically meaning more gas is emitted after products are shipped.	
COSTS AND BENEFITS	Research and development costs	R&D to convert to maximum levels would cost approximately $100,000 per plant or $1 million for the industry.	
	One-time conversion costs	Costs to convert would also be approximately $100,000 per plant or $1 million for the industry.	
	Annual operating cost changes	Range from a slight reduction (<0.5% Cost of Goods Sold) to an increase of 1% or more depending on individual plant conditions and environmental changes required.	
	Spin-off costs and benefits	Unknown environmental costs	
	End-use modification costs	No significant changes	
	End-use cost changes	No significant changes	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-123
Product Group: ALL
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	2 to 3 years	
	Commercial	3 to 4 years All estimates assume toxicity test results are favourable	
	Market	3 to 4 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 8 to 9 years	
	Maximum	100% in 8 to 9 years	
	Substitution potential	100% of CFC 11 consumed for flexible foam applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, depending on end use impacts of expected higher price	
	Quality	No difference, based on currently available information	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Unknown until toxic test results are available	
COSTS AND BENEFITS	Research and development costs	Estimated $0.5 million for the industry	
	One-time conversion costs	Expected to be minimal if anticipated complete technical compatibility with CFC 11 is maintained. Significant costs would be incurred if some side by side use of CFC 11 was needed after introduction of HCFC 123.	
	Annual operating cost changes	Expected 1 to 2% increase in Cost of Goods Sold, based on expected chemical cost increase of 100 to 150% over CFC 11.	
	Spin-off costs and benefits	None known	
	End-use modification costs	None known	
	End-use cost changes	Probable end-use cost increases of 2 to 4% for slabstock applications with molded applications slightly (i.e. 10%) higher incrementally due to blowing efficiency losses.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-141B
Product Group: ALL
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	3 to 4 years	
	Commercial	5 to 6 years . Toxicity tests have not yet started on 141B (123 and 141B are comparable, however 123 is ahead of 141B developmentally)	
	Market	5 to 6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 10 to 11 years	
	Maximum	100% in 10 to 11 years	
	Substitution potential	100% of CFC 11 consumed for flexible foam applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, depending on end use impacts of expected higher price	
	Quality	No difference, based on currently available information	
	Durability and life	No difference, based on currently available information	
	Environmental and health issues	Unknown until toxicity test results are available, however 141B is known to have flammability risks during storage.	
COSTS AND BENEFITS	Research and development costs	Estimated $0.5 million for the industry	
	One-time conversion costs	Expected to be minimal if anticipated complete technical compatibility with CFC 11 is maintained. Depending on flammability characteristics however, conversion costs for flammable storage capability and explosion proofing may be required.	
	Annual operating cost changes	Probable 2 to 5% increase in cost of goods sold resulting from increased insurance costs in addition to 100 to 150% chemical cost increases.	
	Spin-off costs and benefits	None known	
	End-use modification costs	None known	
	End-use cost changes	Probable end-use cost increases of 4 to 9%	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: MINIMUM FOAM DENSITY
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Specifying minimum foam density (i.e. a directive to eliminate CFC use in foams below a certain density) is currently available as an alternative. By itself, it is not expected to necessarily reduce CFC consumption.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: CARBON ADSORPTION Product Group: SLABSTOCK Process Group: FLEXIBLE FOAMS	
END-USE			
AVAILABILITY AND TIMING	Technical	1 year	
	Commercial	2 years	
	Market	2 years	
END-USE MARKET PENETRATION AND TIMING	Expected	25% in 2 years	
	Maximum	30% in 2 years	
	Substitution potential	25% of CFC 11 consumed end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	No impact	
	Quality	No impact	
	Durability and life	Replace filter every five years	
	Environmental and health issues	Disposal of filter would to be evaluated	
COSTS AND BENEFITS	Research and development costs	$1,000,000	
	One-time conversion costs	$17,000,000 with filters replaced every 5 years	
	Annual operating cost changes	Should compare with existing foam production equipment except that every five years the filters would have to be replaced at a cost of $1,000,000 reduced emissions to the atmosphere. Part recovery and recycle of part II..	
	Spin-off costs and benefits		
	End-use modification costs	Sales price of foam would increase by 6% to cover the cost of filters and operating cost with additional cost every year	
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: FORMIC ACID "AB" PROCESS (SEMI-FLEXIBLE)
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE		FURNITURE AND BEDDING	
AVAILABILITY AND TIMING	Technical	2 years (8 years of developmental work has been carried out to date)	
	Commercial	4 years	
	Market	6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	20 % in 9 years	
	Maximum	100% in 11 years	
	Substitution potential	40% of CFC 11 consumed for slabstock applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	No difference anticipated	
	Durability and life	No difference anticipated	
	Environmental and health issues	The formic acid process is highly corrosive and generates carbon monoxide. Both are controllable through proper equipment and monitoring.	
COSTS AND BENEFITS	Research and development costs	Estimated $1 million to complete R&D needed to apply process throughout Canadian industry	
	One-time conversion costs	Estimated $1.2 million, much of which would be required for the equipment and controls to effectively deal with the environmental issues above.	
	Annual operating cost changes	A minor increase is likely, but in addition, a royalty would be payable to the process inventors.	
	Spin-off costs and benefits	Use of this process would reduce isocyanate usage in addition to CFC consumption	
	End-use modification costs	None known	
	End-use cost changes	None known	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: MODIFIED POLYOL SYSTEMS
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE		FURNITURE AND BEDDING	
AVAILABILITY AND TIMING	Technical	2 years	
	Commercial	3 to 5 years, depending on the need for toxicity or other testing	
	Market	3 to 5 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 5 to 10 years	
	Maximum	100% in 5 to 10 years	
	Substitution potential	100% of CFC 11 consumed for slabstock applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	No difference anticipated	
	Durability and life	Unknown - compression set testing is needed although it appears that this would not be a problem. There may be flex fatigue problems as well although this also needs to be tested.	
	Environmental and health issues	None anticipated	
COSTS AND BENEFITS	Research and development costs	Estimated $0.5 million for field trials for the industry	
	One-time conversion costs	Estimated $0.5 million for additional tankage, pumps and other process equipment.	
	Annual operating cost changes	None anticipated	
	Spin-off costs and benefits	None anticipated	
	End-use modification costs	None anticipated	
	End-use cost changes	None anticipated	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: VERTICAL FOAM CHAMBER WITH CARBON ADSORPTION AND HYPERCURE
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAM

END-USE		FURNITURE AND BEDDING	
AVAILABILITY AND TIMING	Technical	4 years	
	Commercial	5 years	
	Market	6 years	
END-USE MARKET PENETRATION AND TIMING	Expected	20% in 10 years	
	Maximum	80% in 14 years	
	Substitution potential	Recovery of 80% of CFC 11 currently emitted during foam manufacture	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Partial acceptance (60% of market) is likely because only short (10 foot) blocks can be manufactured.	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	Improved operating environment resulting from reduced CFC emissions	
COSTS AND BENEFITS	Research and development costs	None anticipated	
	One-time conversion costs	Estimated $15 million required for new foam lines, the recovery systems themselves and plant modifications needed at each site. Approximately $20 million of existing equipment would be obsoleted.	
	Annual operating cost changes	Unknown - anticipated royalty payments and uncertain life cycles for carbon beds would likely increase operating costs.	
	Spin-off costs and benefits	Unknown at this point	
	End-use modification costs	None anticipated	
	End-use cost changes	End use cost increases could range from 0 to 10%	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: E-MAX SYSTEM
Product Group: SLABSTOCK
Process Group: FLEXIBLE FOAMS

END-USE		E-Max system	
AVAILABILITY AND TIMING	Technical	1 year	
	Commercial	2 years available now for production	
	Market	2 years	
END-USE MARKET PENETRATION AND TIMING	Expected	60% in 2 years	
	Maximum	70% in 3 years	
	Substitution potential	70% of CFC 11 consumed	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Yes (advance in one year for small scale production) quality of product produced is comparable with existing system.	
	Quality		
	Durability and life	As per existing foam plant equipment active carbon in adsorption filters will require replacement every 5 years.	
	Environmental and health issues	Environment - concentrations of T.D.I. and feron vapour in the feron will be reduced to 5% of existing M.A.C. levels in the atmosphere reduced by 80/90%. Feron will be recovered (70%) and reused.	
COSTS AND BENEFITS	Research and development costs	$1,000,000	
	One-time conversion costs	$15,400,000 depends on plant size. Plus $6,600,000 for filter system.	
	Annual operating cost changes	Should compare with existing foam production equipment except that every five years the filters would have to be replaced at a cost of $1,000,000.	
	Spin-off costs and benefits	Controlled environment for foam production drastically reduced emission to the atmosphere. Improved foam quality. Recovery recycle of F II.	
	End-use modification costs	New E-Max foam production equipment required at $2,000,000. (A one shot cost)	
	End-use cost changes	Sales price of foam product on E-Max increase by arpox. 6%. Cost advantage may accrue as prices of F11 rises.	

FUNCTIONAL ALTERNATIVES
DATA SHEET

Alternative: DESIGN CHANGES TO REDUCE FOAM CONSUMPTION
Product Group: MOLDED
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available (in effect a different design strategy) for automotive applications which constitute 95 to 99% of the applications for Canadian molded foam products.	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	20% in 3 years	
		Maximum penetration likely to be acceptable in the market	
	Maximum	30% in 5 years	
	Substitution potential	30% of CFC consumed for molded applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Resistance at the design (U.S. OEM) level is expected but market trends and CFC reduction pressures are expected to overcome both of these constraints.	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	None	
COSTS AND BENEFITS	Research and development costs	If introduced non-catastrophically, i.e. as part of the normal automobile programs over a three to five year period, the costs of this alternative are likely to be essentially zero since design changes, retooling and new supply contracts are necessary and expected at these changeover points. It is unlikely that this alternative could be implemented more quickly than this nor more effectively in any other way.	
	One-time conversion costs		
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: WATER AND MODIFIED POLYOLS
Product Group: MOLDED
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical	Currently available	
	Commercial	2 to 3 years	
	Market	3 to 5 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 4 to 7 years	
	Maximum	100% in 4 to 7 years	
	Substitution potential	100% of CFC 11 consumed for molded applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	No difference anticipated	
	Durability and life	Unknown - compression set testing is needed although it appears that this would not be a problem. There may be flex fatigue problems as well although this also needs to be tested.	
	Environmental and health issues	None anticipated	
COSTS AND BENEFITS	Research and development costs	Estimated $100,000 for field trials for the industry	
	One-time conversion costs	Estimated $0.5 million for additional tankage, pumps and other process equipment.	
	Annual operating cost changes	None anticipated	
	Spin-off costs and benefits	None anticipated	
	End-use modification costs	None anticipated	
	End-use cost changes	None anticipated	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: CARBON ADSORPTION
Product Group: MOLDED
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Technically available as an alternative but not considered worthy of serious consideration in molded applications given its prohibitive cost for most manufacturers and two much more feasible alternatives (design changes to seating and water and modified polyols).	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: VERY FIRM AUTOMOTIVE SEATS
Product Group: MOLDED
Process Group: FLEXIBLE FOAMS

END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available as a design strategy. Automotive seat design in North America and Japan has been moving in this direction consistently over the past 5 years.	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	90% in 5 years	
	Maximum	90% in 5 years	
	Substitution potential	20% of CFC 11 consumed for molded applications	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Resistance at the design (U.S. OEM) level is expected but market trends and CFC reduction pressures are expected to overcome both of these constraints.	
	Quality	No difference	
	Durability and life	No difference	
	Environmental and health issues	None	
COSTS AND BENEFITS	Research and development costs	If introduced non-catastrophically, i.e. as part of the normal automobile programs over a three to five year period, the research and development and one-time conversion costs of this alternative are likely to be essentially zero since design changes, retooling, and new supply contracts are necessary and expected at these changeover points.	
	One-time conversion costs		
	Annual operating cost changes	For those seats affected (not all seats), a 5 to 20% increase in the foam cost is expected.	
	Spin-off costs and benefits	None	
	End-use modification costs	None expected	
	End-use cost changes	Probable end-use cost increases of 2 to 3% (for seating). The effect that this would have on automobile costs is not known.	

D. REFRIGERATION AND AIR CONDITIONING

In this section we review substitutes for the applications noted below.

1. Aftermarket and wholesale

- HCFC 22
- HCFC 502
- HCFC 134a
- HCFC 123
- Ammonia
- Alternative leak test gas
- Recovery at charge-up
- Increased isolation valving
- Storage vessels for refrigerant
- Reclamation

2. Commercial, institutional, industrial and residential

- Market mix
- HCFC 22 (high temp)
- HCFC 22 (low temp)
- HCFC 502
- HCFC 134a
- HCFC 123
- HCFC 142b
- Ammonia
- Hydrocarbon
- Alternative leak test gas
- Adequate valves

3. Mobile products

- HCFC 134a
- HCFC 22
- HCFC 22/142b
- HCFC 22/142/114

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-22 Product Group: AFTERMARKET & WHOLESALE Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	HCFC 22 cannot be dropped in to existing field units. The extent and cost of retrofitting required would likely make this option not feasible compared to new HCFC 22 - based units. As a result, this alternative is expected to evolve through the normal life cycle resulting from new units being introduced to the field. Under normal unconstrained conditions, this would take approximately 20 years. If CFC 12 were to be unavailable or become significantly higher in cost (i.e. more than 200% of its current cost), this timetable could accelerate significantly.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-502
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	HCFC 502 cannot be dropped in to the vast majority of existing field units. A very limited number of existing high temperature CFC 12-based systems can be converted to HCFC 502 operation. This conversion, if it were carried out, would have a very limited impact on the CFC consumption level.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-134a
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	5 to 10 years, depending on when HCFC 134a becomes available for original equipment applications and whether units in the field can be easily retrofitted.	
	Commercial	5 to 10 years	
	Market	5 to 10 years	
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	Has potential to replace most or all CFC 12-based units in the field if chemical properties remain comparable, conversion costs are not significant, an adequate lubricant is developed and it is not found to react with desicants.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Primarily dependent on cost of conversion or cost/ability to remain with CFC 12	
	Quality	No differences expected	
	Durability and life	No differences expected	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	All costs are unknown at this stage	
	One-time conversion costs		
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-123
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	5 to 10 years, depending on when HCFC 123 becomes available for original equipment applications and whether units in the field can be easily retrofitted.	
	Commercial	5 to 10 years	
	Market	5 to 10 years	
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Unknown	
	Substitution potential	Has potential to replace most or all CFC 11-based units in the field if chemical properties remain comparable, conversion costs are not significant and an adequate lubricant is developed.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Primarily dependent on cost of conversion or cost/ability to remain with CFC 11	
	Quality	No differences expected	
	Durability and life	No differences expected	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	All costs are unknown at this stage	
	One-time conversion costs		
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: AMMONIA (NH3)
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	No potential as an aftermarket alternative given the very significant barriers expected for extension of use in original equipment applications.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: ALTERNATIVE LEAK TEST GAS Product Group: AFTERMARKET & WHOLESALE Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial	Currently available in the market (HCFC 22 is most common as an alternate leak test gas; helium is also available but considered to expensive for aftermarket applications because of the spectrometer required).	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year, if appropriately regulated	
	Maximum	100% in 1 year	
	Substitution potential	Fractional reduction (probably significantly less than 1%) in CFC 12 used in aftermarket applications. A typical industrial/commercial system is tested with 2 to 3 pounds of refrigerant and then charged with 1000 to 1500.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Use of HCFC 22 as an alternate has increased significantly in the past year. The major barrier to universal use of HCFC 22 or other alternates is not technical but rather the fact that it is most convenient to leak test with the gas which is going to charge the system.	
	Quality		
	Durability and life	No difference	
	Environmental and health issues	None beyond the ozone depletion potential of HCFC 22 as the most common and accepted alternative.	
COSTS AND BENEFITS	Research and development costs	None	
	One-time conversion costs	None	
	Annual operating cost changes	Fractional cost increase (significantly less than 1% cost of goods sold) because of higher cost of HCFC 22 compared to CFC 12.	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	None	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: RECOVERY AT CHARGE-UP, SERVICE AND/OR DISPOSAL Product Group: AFTERMARKET & WHOLESALE Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial	Systems are available now for recovery at charge-up and service, however they are cumbersome and impractical for many applications.	
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected	Unknown	
	Maximum	Potential for recovery is small given that an estimated 70 to 90% of refrigerant is lost prior to the service beginning (i.e. only 10 to 30% of service is on a non-empty unit).	
	Substitution potential	Probable maximum potential would range from less than 1% to 10% of CFC 11 and 12 consumed for aftermarket applications, depending on the mechanism for implementing this alternative and the true maximum potential (which is unknown). Because of the diversity and size of the aftermarket, implementation would be extremely difficult without legislation and even then, difficult to regulate.	
END-USE MARKETPLACE COMPARABILITY	Acceptance		
	Quality		
	Durability and life	Not applicable	
	Environmental and health issues	None	
COSTS AND BENEFITS	Research and development costs	Unlikely, but unknown at this point in time	
	One-time conversion costs	Unknown	
	Annual operating cost changes	Unknown increase	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Unknown pass through increase, depending on the cost of implementing recovery methods.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: INCREASED ISOLATION VALVING
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market	Available now	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year if appropriately regulated (this alternative may be very difficult to regulate effectively)	
	Maximum		
	Substitution potential	Fractional reduction (significantly less than 1%) of CFC 11 and 12 used. This alternative is only of value if valves are installed when a system is being repaired as a possible means of reducing refrigerant loss during pump down in the event of future, non-leak caused service on the same unit.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Would require regulation to enforce.	
	Quality	Not applicable	
	Durability and life	Not applicable	
	Environmental and health issues	None	
COSTS AND BENEFITS	Research and development costs	None	
	One-time conversion costs	None	
	Annual operating cost changes	Unknown but small increase in the per-unit service cost.	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Unknown pass through increase, depending on the increased valve costs.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: STORAGE VESSELS FOR REFRIGERANT CHARGE
Product Group: AFTERMARKET & WHOLESALE
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Storage vessels exist to a certain degree now in many systems, especially large systems where vessels make economic sense. Most HCFC 502 and CFC 12 systems contain them. The CFC reduction potential of regulating useof a vessel in all applications is unknown but estimated to be very small. It is likely that the majority of the CFC loss which is taking place is due to existing vessels which are too small as opposed to those not installed.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: RECLAMATION Product Group: AFTERMARKET & WHOLESALE Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	The extent to which reclamation is now being carried out is unknown. Some technology exists and is known to be in use but there is also known to be a need for technology to test and identify system contents and clean reclaimed refrigerants for future use.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: MARKET MIX
Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE		Centrifugal Chillers - conversion to high pressure systems (only applicable end-use)	
AVAILABILITY AND TIMING	Technical	Available now	
	Commercial	0 to 7 years depending on end-use application	
	Market	0 to 7 years depending on end-use application	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 5 to 7 years, if regulated	
	Maximum	100% in 5 to 7 years	
	Substitution potential	100% of CFC 11 used in centifugal chiller applications (unknown percentage of total CFC 11 consumed for this product group)	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Currently very little acceptance, primarily due to existing legislation which requires an operating engineer for any high-pressure system installation. Acceptance will likely hinge on whether or not this requirement remains.	
	Quality	No difference expected	
	Durability and life	No difference expected, but track record of installed systems is very limited.	
	Environmental and health issues	Conversion to high pressure changes refrigerant to HCFC 22. Ozone depletion potential thus remains albeit at 5% of CFC 11 levels.	
COSTS AND BENEFITS	Research and development costs	None for Canadian industry. All units currently supplied for this end-use are designed and manufactured in the United States.	
	One-time conversion costs	None for Canadian industry	
	Annual operating cost changes	None for Canadian industry	
	Spin-off costs and benefits	None	
	End-use modification costs.	Estimated increase in the order of 10%, based on change to high pressure design.	
	End-use cost changes	Unknown increase, based on operating engineer requirement and increased energy costs per ton	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-22 (Medium and High Temperature Applications) Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE		Medium and High Temperature (2 HP and higher)	Medium and High Temperature (Less than 2 HP)
AVAILABILITY AND TIMING	Technical		0 to 2 years, depending on end-use application
	Commercial		0 to 2 years, depending on end-use application
	Market	Currently available in the market	0 to 2 years, depending on end-use application
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year	100% in 2 to 3 years
	Maximum	100% in 1 year	100% in 2 to 3 years
	Substitution potential	100% of CFC 12 consumed for this end-use (estimated 0.3 kilotonne for all horsepower ranges of this end-use application)	100% of CFC 12 consumed for this end-use (see comments under 2 HP and up section)
END-USE MARKETPLACE COMPARABILITY	Acceptance	No difference	No difference
	Quality	No difference	No difference
	Durability and life	No difference	No difference
	Environmental and health issues	None beyond the ozone depletion potential of HCFC 22.	None beyond the ozone depletion potential of HCFC 22.
COSTS AND BENEFITS	Research and development costs	None	Estimated $1 million for industry
	One-time conversion costs	None	None
	Annual operating cost changes	None	None
	Spin-off costs and benefits	Reduced energy consumption	Reduced energy consumption
	End-use modification costs	None	None
	End-use cost changes	Estimated 7 to 10% reduction in energy cost in operation.	Estimated 7 to 10% reduction in energy cost in operation.

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22 (Low Temperature Applications)
Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE		Low Temperature	
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market	Currently available in the market	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 5 years	
	Maximum	100% in 5 years	
	Substitution potential	100% of CFC 12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable, but prices would likely increase and HCFC 22-based systems are more complex because of the need for 2 stages.	
	Quality	No difference	
	Durability and life	Significantly inferior, expected much higher expected incidence of breakdown.	
	Environmental and health issues	None beyond the ozone depletion potential of HCFC 22.	
COSTS AND BENEFITS	Research and development costs	None for Canadian industry (research and development would be carried out in the United States.	
	One-time conversion costs	None for Canadian industry	
	Annual operating cost changes	None	
	Spin-off costs and benefits	Slightly increased energy consumption	
	End-use modification costs	None	
	End-use cost changes	Estimated 100% increase in cost of units because of design and manufacturing complexity.	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-502 Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	There has been some limited shift to HCFC 502-based systems in medium temperature applications to reduce consumption of CFC 12. HCFC 502 is not considered a viable large scale replacement alternative for CFC 12-based systems for two reasons. First, because of its unique and therefore critical role in low temperature systems where no alternative presently exists. Second, because it has an ozone depletion potential of 50% of CFC 12, it is of limited overall benefit.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-134a
Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS
Process Group: REFRIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	5 years (toxicity testing is starting; a 134a-based cooler unit is also being tested)	
	Commercial	5 to 8 years, depending on the extent of work required to convert existing designs.	
	Market	5 to 8 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 9 years	
	Maximum	100% in 6 to 9 years	
	Substitution potential	100% of CFC 12 consumed in this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	No difference expected, although increased cost may impact acceptance, depending on end-user options.	
	Quality	No difference expected	
	Durability and life	No difference expected, based on current knowledge of chemical properties although a lubricant has yet to be developed.	
	Environmental and health issues	None known	
COSTS AND BENEFITS	Research and development costs	Unknown. A lubricant remains to be developed. Research and development will be driven by automotive applications.	
	One-time conversion costs	Unknown	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	Expected to be 10% less efficient than CFC 12 -based systems. Energy consumption will be higher as a result.	
	End-use modification costs	Unknown	
	End-use cost changes	Unknown increase	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-123 Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical	5 years	
	Commercial	5 to 8 years, depending on the extent of work required to convert existing designs.	
	Market	5 to 8 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 6 to 9 years	
	Maximum	100% in 6 to 9 years	
	Substitution potential	100% of CFC 11 consumed in this product group	
END-USE MARKETPLACE COMPARABILITY	Acceptance	No difference expected, although increased cost may impact acceptance, depending on end-user options.	
	Quality	No difference expected	
	Durability and life	No difference expected, based on current knowledge of chemical properties although a lubricant has yet to be developed.	
	Environmental and health issues	HCFC 123 has an ozone depletion potential rated at 'less than 0.05' which makes it comparable or somewhat better than HCFC 22, but not as low as other replacement chemicals.	
COSTS AND BENEFITS	Research and development costs	Unknown. A lubricant remains to be developed.	
	One-time conversion costs	Unknown	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	None known	
	End-use modification costs	Unknown but expected to be lower than conversion costs to HCFC 22.	
	End-use cost changes	Unknown increase	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-22/HCFC-142b Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	This mechanical mixture is not known to be in use commercially in Canada although it is reportedly available in the United States. It is not considered a viable alternative for two reasons. First, it is not a true direct substitute, in part because it is a mechanical as opposed to chemical mixture. Second, it has flammability problems.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: AMMONIA (NH3) AND HYDROCARBONS (HC) Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Ammonia is technically available as a process and is used commercially in refrigeration systems ranging from 15 to 25 tons upward, most commonly in 50 and 100+ ton applications. It is technically feasible to develop ammonia-based systems in the smaller tonnages currently using controlled CFC-based systems. From a practical standpoint, however, ammonia is not considered a serious alternative for several reasons. First, engineering costs would be enormous. Second, ammonia cannot legally	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential	be used in an enclosed space for expansion-related applications, thus severely restricting even its potential indoor applicability without legislative change. Third, it is both highly toxic and flammable. For essentially the same reasons, hydrocarbons are also not considered a viable alternative.	
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: ALTERNATIVE LEAK TEST GAS Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS Process Group: REFRIGERATION & AIR CONDITIONING	
END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Currently available in the market. HCFC 22 is most common as an alternate leak test gas. Helium is also available and used, but predominantly in small systems (such as domestic units) and primarily for quality control purposes. Use of helium requires a mass spectrometer.	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year, if appropriately regulated	
	Maximum	100% in 1 year	
	Substitution potential	Fractional reduction (probably significantly less than 1%) in CFC 12 used in original equipment applications. A typical industrial/commercial system is tested with 2 to 3 pounds of refrigerant and then charged with 1000 to 1500.	
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality	Use of HCFC 22 as an alternate has increased significantly in the past year. The major barrier to universal use of HCFC 22 or other alternates is not technical but rather the fact that it is most convenient to leak test with the gas which is going to charge the system.	
	Durability and life	No difference	
	Environmental and health issues	None beyond the ozone depletion potential of HCFC 22 as the most common and accepted alternative.	
COSTS AND BENEFITS	Research and development costs	None	
	One-time conversion costs	None	
	Annual operating cost changes	Fractional cost increase (significantly less than 1% cost of goods sold) because of higher cost of HCFC 22 compared to CFC 12.	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	None	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: ADEQUATE VALVES FOR SERVICE
Product Group: COMMERCIAL INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS
Process Group: RERIGERATION & AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	--	
	Commercial		
	Market	Available now	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 1 year if appropriately regulated concurrently in Canada and the United Satets (this alternative may be very difficult to regulate effectively)	
	Maximum		
	Substitution potential	Fractional reduction or none in CFC 11 used since most CFC 11-based systems are adequately designed for valving. Some potential but unknown reduction in HCFC 502-based systems is likely. This alternative is only of value (if installed at original manufacture) for future service requiring pump down, where leakage has not occurred.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Would require regulation to enforce.	
	Quality	Not applicable	
	Durability and life	Not applicable	
	Environmental and health issues	None	
COSTS AND BENEFITS	Research and development costs	None	
	One-time conversion costs	None	
	Annual operating cost changes	Probable 1 to 2% increase in the per-unit cost of manufacture.	
	Spin-off costs and benefits	None	
	End-use modification costs	None	
	End-use cost changes	Probable 1 to 2% increase in cost.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCF-134a
Product Group: MOBILE PRODUCTS
Process Group: REFRIGERATION AND AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	1 to 2 years	
	Commercial	4 to 5 years	
	Market	7 to 10 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 10+ years	
	Maximum	100% in 10+ years	
	Substitution potential	100% of CFC 12 used for moblie air conditioning	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Probably acceptable, would likely be introduced with little visibility to customer from a performance standpoint.	
	Quality	Performance loss, possible requiring larger heat exchangers and higher compressor operating speeds.	
	Durability and life	Unknown, a lubricant needs to be developed.	
	Environmental and health issues	None - ozone depletion factor is zero	
COSTS AND BENEFITS	Research and development costs	Unknown, depends on cost to develop lubricant and whether or not heat exchanges and/or compressor work is required.	
	One-time conversion costs	Unknown, however major retooling is not anticipated because thermo-physical properties are close to existing refrigerant.	
	Annual operating cost changes	Unknown	
	Spin-off costs and benefits	None	
	End-use modification costs	Depends on extent of change required after research and development is completed.	
	End-use cost changes	Unknown, depends on changes required.	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC-22
Product Group: MOBILE PRODUCTS
Process Group: REFRIGERATION AND AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical	Currently available in the market	
	Commercial	6 to 8 years	
	Market	9 to 12 years	
END-USE MARKET PENETRATION AND TIMING	Expected	100% in 12+ years	
	Maximum	100% in 12+ years	
	Substitution potential	100% of CFC 12 used for mobile air conditioning	
END-USE MARKETPLACE COMPARABILITY	Acceptance	Acceptable	
	Quality	Acceptable	
	Durability and life	Greater permeability of HCFC-22 would likely cause more frequent service intervals.	
	Environmental and health issues	Ozone depletion potential of 0.05	
COSTS AND BENEFITS	Research and development costs	Unknown but major; requires total system redesign to operate at 50% higher pressure and new elastomers (because of use of flexible tubing) and lubricants.	
	One-time conversion costs	Unknown but major; requires retooling	
	Annual operating cost changes	Unknown, but higher	
	Spin-off costs and benefits	None	
	End-use modification costs	None, once tooling conversion is complete	
	End-use cost changes	Unknown, but higher	

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: HCFC22/142b OR HCFC 22/142/114
Product Group: MOBILE PRODUCTS
Process Group: REFRIGERATION AND AIR CONDITIONING

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Neither of these blends are considered practical alternatives for several reasons. First, each has the redesign and retooling needs of the HCFC 22 alternative (discussed earlier). Second, because HCFC-142b is flammable, the system may be at risk in use in combination with the permeability of HCFC-22. Third, a lubricant is still required. Fourth, the ozone depletion issue, although reduced, still remains. Fifth, performance problems may result in use because of differing evaporation rates of the various chemicals.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

E. SOLVENTS

Below are the substitute products for solvents, reviewed in detail in this section.

1. Electronics

- Methylchloroform
- Trichloroethylene
- Low solid fluxes

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: SOLVENTS (METHYL CHLOROFORM, TRICHLOROETHYLENE AND OTHERS)
Product Group: ELECTRONICS APPLICATIONS
Process Group: SOLVENTS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	These solvents are technically feasible to replace CFC 113 in certain electronics applications. Each however, has specific toxic, carcinogenic or other environmental hazards associated with it, including wastewater discharges and hazardous solid waste creation problems. As a result, they are considered unacceptable long term and non-preferred short term alternatives which can be implemented, if absolutely necessary.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: LOW SOLID FLUXES
Product Group: ELECTRONICS APPLICATIONS
Process Group: SOLVENTS

END-USE			
AVAILABILITY AND TIMING	Technical Commercial Market	Low solid or cleanerless fluxes are being evaluated by many manufacturers for applicability in electronics applications. Initial results have indicated that some potential may exist, with further development, in less critical applications such as radios, although increased solder joint failures were reported here as well. In more critical close tolerance applications, such as engine control modules, this alternative has been dropped from further consideration due to unacceptable high risks of electrical shorts across circuits.	
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential		
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes		

F. OTHER APPLICATIONS

Substitutes from other major CFC use categories that are descrbed in this section are noted below.

1. Sterilants

- Pure ethylene oxide
- Acid-water scrubber and condensation reclamation
- HCFC 134a/ethylene oxide
- Gamma radiation

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: ETHYLENE OXIDE (EO)
Product Group: STERILANTS
Process Group: OTHER APPLICATIONS

END-USE		ALL STERILANT APPLICATIONS	
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market	Available now	
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC 12 consumed for this end-use.	
END-USE MARKETPLACE COMPARABILITY	Acceptance		
	Quality		
	Durability and life		
	Environmental and health issues	Will have to install EO scrubbers/reclamation units. Highly flammable.	
COSTS AND BENEFITS	Research and development costs		
	One-time conversion costs	Unknown space requirements	
	Annual operating cost changes	USERS: 60% of subcontractors in 8-10 years 50% of medical equipment suppliers 45% of miscellaneous applications	
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: ACID-WATER SCRUBBER AND CONDENSATION RECLAMATION
Product Group: STERILANTS
Process Group: OTHER APPLICATIONS

END-USE		ALL STERILANT APPLICATIONS	
AVAILABILITY AND TIMING	Technical Commercial Market		
END-USE MARKET PENETRATION AND TIMING	Expected Maximum Substitution potential	80-99% of CFC 12 consumed for this end-use.	
END-USE MARKETPLACE COMPARABILITY	Acceptance Quality Durability and life Environmental and health issues		
COSTS AND BENEFITS	Research and development costs One-time conversion costs Annual operating cost changes Spin-off costs and benefits End-use modification costs End-use cost changes	Too costly for most existing systems - e.g. hospitals maybe the necessary short-term solution for contractors and medical equipment suppliers.	

FUNCTIONAL ALTERNATIVES DATA SHEET		Alternative: HCFC-134a/Ethylene Oxide Product Group: STERILANTS Process Group: OTHER APPLICATIONS	
END-USE		FOOD & DRUG APPLICATIONS	
AVAILABILITY AND TIMING	Technical	4 to 7 years	
	Commercial	6 to 10 years because of the need for food and drug approval	
	Market	9 to 13 years	
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC 12 consumed for this end-use	
END-USE MARKETPLACE COMPARABILITY	Acceptance		
	Quality		
	Durability and life		
	Environmental and health issues	Will have to install EO scrubbers/reclamation units. Highly flammable.	
COSTS AND BENEFITS	Research and development costs		
	One-time conversion costs	Possible use in existing equipment unknown space requirements.	
	Annual operating cost changes		
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

FUNCTIONAL ALTERNATIVES DATA SHEET

Alternative: CONVERT TO GAMMA RADIATION
Product Group: STERILANTS
Process Group: OTHER APPLICATIONS

END-USE			
AVAILABILITY AND TIMING	Technical		
	Commercial		
	Market		
END-USE MARKET PENETRATION AND TIMING	Expected		
	Maximum		
	Substitution potential	100% of CFC 12 consumed for this end-use.	
END-USE MARKETPLACE COMPARABILITY	Acceptance	High cost but most effective sterilant.	
	Quality		
	Durability and life		
	Environmental and health issues	Concern over safe transportation and disposal of radiation source.	
COSTS AND BENEFITS	Research and development costs		
	One-time conversion costs	Most expensive sterilant option.	
	Annual operating cost changes	USERS: 5% of sub-contractors in 8-10 years	
	Spin-off costs and benefits		
	End-use modification costs		
	End-use cost changes		

APPENDIX A

Potential Alternatives by process and product group

I

AEROSOL PRODUCTS

A. <u>PERSONAL</u>

A.1. END-USE APPLICATIONS (INCOMPLETE)
- metered - dose drugs for inhalation
- contraceptive foams
- other personal products

A.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

B. <u>HOUSEHOLD</u>

B.1. END-USE APPLICATIONS (INCOMPLETE)
- cooking products
- air fresheners, room deodrants
- oven cleaners

B.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

C. <u>AUTOMOTIVE</u>

C.1. END-USE APPLICATIONS (INCOMPLETE)
- gas filled shock absorbers
- lubricants, cleaners, waxes, etc.

C.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

D. <u>COMMERCIAL & INDUSTRIAL</u>

D.1. END-USE APPLICATIONS (INCOMPLETE)
- mold release agents for plastics and elastomeric materials
- cleaner solvents
- aircraft applications
- lubricants

D.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

E. <u>INSECTICIDES</u>

E.1. END-USE APPLICATIONS (INCOMPLETE)
- aircraft fumigation
- food handling areas

E.2. SUMMARY OF FUNCTIONAL ALTERNATIVES
- HCFC 22
- HCFC 142b
- HCFC 152a
- Hydrocarbons
- dimethyl ether

II

RIGID FOAMS

A. RIGID POLYURETHANE FOAM BUNSTOCK AND LAMINATED BOARDSTOCK

A.1. END-USE APPLICATIONS

Insulating applications
- residential walls
- industrial walls
- industrial roofs

A.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

Product Substitutes
- thick fiberglass batts/thick walls/conventional stud spacing
- thick fiberglass batts/thick walls/wide stud spacing
- other insulation materials/conventional thickness
- other insulations materials/equivalent insulating capacity
- innovative insulation materials and systems
- thick fiberglass batts - industrial insulation systems

Chemical Substitutes
- HCFC-123
- HCFC-141b

Engineering Controls/Process Substitutes
- carbon adsorption with recovery
- carbon adsorption without recovery
- plant exhaust incineration

B. RIGID POLYURETHANE POURED AND SPRAYED FOAMS

B.1. END-USE PRODUCTS AND APPLICATIONS

Poured
- building construction
- industrial construction
- refrigeration/cooling systems
- transportation (all applications)
- packaging
- recreational

Sprayed
- building construction
- industrial construction
- transportation

B.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

B.2.a. Packaging Applications

Product Substitutes

- other packaging materials
- EPS Bead
- innovative packaging materials and designs

Chemical Substitutes

- H_2O only
- HCFC-123
- HCFC-141b

B.2.b. Insulation Applications

Product Substitutes

Industrial Roof

- fiberglass board
- perlite
- expanded PS
- fiberboard
- cellular glass
- insulating concrete

Commercial Roof

- fiberglass board
- perlite
- expanded PS
- fiberboard
- cellular glass
- insulating concrete

Commercial Walls

- fiberglass board
- rock wool
- perlite
- vermiculite
- expanded PS
- fiberboard
- cellular glass
- insulating brick
- thick fiberglass batts/thick walls
- insulating concrete

Commercial Floors

- fiberglass board
- rock wool
- expanded PS
- insulating brick
- insulating concrete

Residential Walls
- fiberglass board
- expanded PS
- fiberboard
- perlite board
- cellular glass
- gypsum
- plywood
- foil faced laminated board
- insulating brick
- thick fiberglass batts/thick walls
- insulating concrete

Foundation/Below Grade
- expanded PS
- high density fiberglass board

Chemical Substitutes
- HCFC-123
- HCFC-141b
- CFC-11/HCFC-22 Blend
- CFC-11/H_2O

C. <u>RIGID EXTRUDED POLYSTYRENE FOAM BOARDSTOCK</u>

C.1. END-USE APPLICATIONS

New Construction
- industrial roofing
- commercial roofing
- residential construction
- commercial masonry walls

Retrofit Insulation
- commercial buildings
- industrial buildings
- residential buildings

C.2. FUNCTIONAL ALTERNATIVES

Product Substitutes

Industrial Roof
- fiberglass board
- perlite
- expanded PS
- fiberboard
- cellular glass
- insulating concrete

Commercial Roof

- fiberglass board
- perlite
- expanded PS
- fiberboard
- cellular glass
- insulating concrete

Commercial Walls

- fiberglass board
- rock wool
- perlite
- vermiculite
- expanded PS
- fiberboard
- cellular glass
- insulating brick
- thick fiberglass batts/thick walls
- insulating concrete

Commercial Floors

- fiberglass board
- rock wool
- expanded PS
- insulating brick
- insulating concrete

Residential Walls

- fiberglass board
- expanded PS
- fiberboard
- perlite board
- cellular glass
- gypsum
- plywood
- foil faced laminated board
- insulating brick
- thick fiberglass batts/thick walls
- insulting concrete

Foundation/Below Grade

- expanded PS
- high density fiberglass board

Chemical Substitutes

- HCFC-123
- HCFC-141b
- CFC-11/HCFC-22 Blend
- CFC-11/H_2O

Chemical Substitutes (continued)
- HCFC - 22
- HCFC - 124
- HFC -134a
- HCFC - 142b

Engineering Controls/Process Substitutes
- none feasible (emissions are relatively small - controlling them would be a high cost for low recovery. Alternative products and chemicals can completely eliminate CFC use and emissions).

D. RIGID EXTRUDED POLYSTYRENE FOAM SHEET

D.1. END-USE APPLICATIONS

- stock food trays
- single service plates, cups, bowls etc.
- egg cartons
- hinged containers

D.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

D.2.a. Options For All Applications

Product Applications Substitute
- substitutes for egg cartons
- substitutes for single service plates, cups, etc.
- substitutes for hinged containers
- substitutes for stock food trays

Chemical Substitutes
- hydrocarbons without carbon adsorption
- hydrocarbons with carbon adsorption
- CO_2 Auxiliary
- HCFC-124
- FC-134a
- HCFC-22/HCFC-142b Mixture
- HCFC-22/Hydrocarbon
- innovative blends
- HCFC-22

Engineering Controls, Process Substitutes
- carbon adsorption with recovery
- carbon adsorption without recovery
- plant exhaust incineration

D.2.b. Summary Of Current Alternative Products

Application	Alternatives
Thermoformed Sheet Stock Food Trays	Hydrocarbon Blown PS Solid Plastic Trays Plastic Film Wrap Coated Paper Trays Butcher Paper Controlled Atmosphere Packaging Pulp Trays
Egg Cartons	Hydrocarbon Blown PS Pulp Trays
Single Service Goods:	
Plates, Cups, and Bowls	Hydrocarbon Blown PS EPS Paper Solid Plastic
Hinged Containers	Hydrocarbon Blown PS Paperboard Containers Solid Plastic Containers Paper Wraps Foil Wraps Plastic Wraps Combination Laminated Wraps

E. EXTRUDED LOW DENSITY POLYETHYLENE FOAM

E.1. END-USE APPLICATIONS

Foam Sheet

- (less than 2 cm thick) surface protection/packaging
- sports and leisure

Plank & Profiles

- foam - (usually 2-10 cm thick)
- padding, cushion packaging
- construction
- sports and leisure
- returnable dunnage
- commercial floatation applications
- thermal insulation

E.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

Product Substitutes
- alternative packaging materials
- innovative packaging materials
- rubber or plastic gaskets
- rubber or plastic flotation devices

Chemical Substitutes
- HCFC-142b (mixture w/HCFC-22)
- HCFC-124
- HFC-134a
- HCFC-22/CFC114 blend

Engineering Controls, Process Substitutes
- carbon adsorption
- plant exhaust incineration

F. LOW DENSITY POLYETHYLENE FOAM

F.1. END-USE APPLICATIONS

Product Substitutes
- electronic and delicate item packaging
- void filling
- antistatic applications
- insulation blankets
- floatation applications

F.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

Product Substitutes
- alternative packaging materials
- innovative packaging materials
- plastic film bubble wrap

F.2.a. Low-Density Polypropylene Alternatives

Product Substitutes
- expanded polystyrene beads
- water-blown polyurethane foam
- plastic film bubble-wrap
- other paper and plastic packaging

Chemical Substitutes
- HCFC-123
- HCFC-124
- HCFC-142b (or mixture with HCFC-22)

Engineering Controls, Process Substitutes
- carbon adsorption
- plant exhaust incineration

G. PHENOLIC FOAM

G.1. END-USE APPLICATIONS

- base material, floral arrangements
- thermal insulation applications

G.2 SUMMARY OF FUNCTIONAL ALTERNATIVES

Product Substitutes

- thick fiberglass batts/thick walls/conventional stud spacing
- thick fiberglass batts/thick walls/wide stud spacing
- other insulation materials - equivalent insulation capacity
- innovative insulation materials and systems
- other insulation materials - conventional thickness

Chemical Substitutes

- HCFC-123
- HCFC-141b

Engineering Controls, Process Substitutes

- carbon adsorption with recovery
- carbon adsorption without recovery
- plant exhaust incineration

H. POLYVINYL CHLORIDE FOAM

H.1. END-USE APPLICATIONS

- gasket and sealing applications
- athletic padding
- flotation devices
- insulation applications

H.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

Product Substitutes

- rubber or plastic gaskets
- rubber or plastic flotation devices

Chemical Substitutes

- chemical blowing agent
- HCFC-124
- HCFC-142b (or mixture w/HCFC-22)

Engineering Controls, Process Substitutes

- carbon adsorption
- plant exhaust incineration

III

FLEXIBLE FOAMS

A. SLABSTOCK

A.1. END-USE APPLICATIONS

- furniture
- transportation
- rug underlay
- bedding
- textile
- packaging
- miscellaneous

A.2. FUNCTIONAL ALTERNATIVES

Product Substitutes

Option Name	Applications	Description
Natural/Synthetic Fiberfill	Slab	Use of presently available low-density batting or fiberfill materials
Alternative Foams and Built-up Cushioning	Slab	Latex or other foams or higher density cushioning systems (e.g. springs)
Engineered Plastic Cushion	Slab	Developmental substitute (porous plastic)
Chemical Substitutes		
Methylene Chloride	Slab	Currently available substitute auxiliary blowing agent
HCFC-123 HCFC-141b	Slab	Developmental substitute blowing agent
Process Modification/Add-on Controls		
Minimum Foam Density	Slab	Foam specification to include a lowest permissible density

Option Name	Applications	Description
Carbon Adsorption	Slab	Activated carbon treatment of plant exhaust, with CFC-11 recovery. (developmental)
Formic Acid "AB" Process (semi-flexible)	Pour-in-place	Developmental process that uses formic acid in place of water in formulation for semi-flexible applications
Modified Polyol Systems	Slab	Advanced polyol chemicals that could reduce CFC-11 blowing agent
Vertical Foam Chamber	Slab	New slab equipment system that employs vertical conveyor
Minimum Density Specifications with MeC1 use	Slab	Combined minimum foam density expanded MeC1 substitution
Vertical foam chamber with Carbon Adsorption	Slab	Combined vertical foam eqiupment with developmental carbon adsorption system

B. MOLDED

B.1. End-use applications

- furniture
- transportation
- rug underlay
- bedding
- textile
- packaging
- miscellaneous

B.2. FUNCTIONAL ALTERNATIVES

Product Substitutes

Option Name	Applications	Description
Natural/Synthetic Fiberfill	Molded	Use presently available low-density batting or fiberfill materials
Alternative Foams and Built-up Cushioning	Molded	Latex or other foams or higher density cushioning systems (e.g. springs)
Engineered Plastic Cushion	Molded	Developmental substitute (porous plastic)
Chemical Substitutes		
Water HCFC-123 HCFC-141b	Molded	Developmental substitute blowing agent
Process Modification/Add-on Controls		
Minimum Foam Density	Molded	Foam specification to include a lowest permissible density
Carbon Adsorption	Molded	Developmental activated carbon treatment of plant exhaust, with CFC-11 recovery
Formic Acid "AB" Process	Molded	Developmental process that uses formic acid in place of water in formulation
MDI - or TDI based, Water Blown HR Systems	Molded	Expanded use of available water-blown HR systems
Min. Dens. Spec. w/Water-Blown HR Systems	Molded	Combined minimum foam with greater use of water-blown HR formulations
Firmer Automotive Seats	Molded	

REFRIGERATION AND AIR CONDITIONING

OVERVIEW OF FUNCTIONAL ALTERNATIVES FOR REFRIGERATION APPLICATIONS

Option Name	Applications	Description
Product Substitutes		
Modified Stirling Cycle	Home Appliances/Small Refrigeration Units/Refrigerated Transportation	Innovative new technology originally developed for cryogenic cooling.
Market Mix	Centrifugal Chillers	Redistribution of future market share to other currently available systems (e.g., CFC-22 screw chillers).
Chemical Substitutes		
HCFC-22	Home Appliances/Small Refrigeration Reciprocating Chillers Food Processing and Handling Industrial Process Refrigeration	Currently available substitute refrigerant.
HCFC-502	Home Appliance/Small Refrigerations Reciprocating Chillers Food Processing and Handling Industrial Process Refrigeration	Currently available substitute refrigerant
HFC-134a	Home Appliances/Small Refrigeration Commercial/Industrial Building Chillers Food Processing and Handling Industrial Process Refrigeration	Developmental substitute refrigerant for CFC-12.
HCFC-123	CFC-11 Centrifugal Chillers	Developmental substitute refrigerant for CFC-11.
HCFC-22/HCFC-142b	Home Appliances/Small Refrigeration Refrigerated Transportation	Developmental non-azeotropic refrigerant mixture to substitute for CFC-12.
Ammonia (NH_3)	Cold Storage Warehouses Industrial Process Refrigeration	Substitute refrigerant currently available

Option Name	Applications	Description
Hydrocarbons (HC)	Industrial Process Refrigeration	Currently available substitute refrigerant.
Process substitutes/Add-on Engineering Controls		
Alternative Leak Test Gas	Commercial and Industrial Building Chillers Retail Food/Cold Warehouses	Substitute HCFC-22 for CFC-12 in leak testing.
Helium Leak Test	Home Appliances/Small Refrigeration Units	Sensitive leak test method using mass spectrometer and helium gas.
Dye D Refrigerant	Retail Food & Arenas	Dye D Refrigerant added to system to locate leaks.
Recovery at Rework	Home Appliances/Small Refrigeration Units Refrigerated Transportation	Recovery of refrigerant during manufacture when repairing or testing systems.
Recovery at Service and/ or Disposal	Commercial and Industrial Building Chillers Retail Food/Cold Storage Warehouses/Home Appliances/Small Refrigeration Units	Recovery of refrigerant at service or when retiring old systems

A. <u>AFTERMARKET AND WHOLESALE</u>

A.1. **END-USE APPLICATIONS**

- all refrigeration and air conditioner applications where:
    - start-up charging is not performed at point-of manufacturer or where the unit is assembled in place
    - all service related re-charges

A.2. **FUNCTIONAL ALTERNATIVES**

A.2.a. <u>Building Chiller Refrigerant</u>

<u>CFC-11 Centrif Chillers</u>

Add-on Engineering Controls

- recovery at Service and Disposal
- recovery at Service

<u>CFC-12 Centrif Chillers</u>

Add-on Engineering controls
- alternative leak test gas
- recovery at service and disposal
- recovery at service
- increased isolation valving

<u>CFC-114 Centrif Chillers</u>

Add-on engineering controls
- recovery at service and disposal
- recovery at service

<u>CFC-12 Reciprocating Chillers</u>

Add-on engineering controls
- alternative leak test gas
- recovery at service and disposal
- increased valving
- storage chamber for refrigerant charge

A.2.b. <u>Food Processing and Handling</u>

<u>Retail Food</u>

Engineering controls/process substitutions
- alternative leak test gas
- leak test gas recovery
- recovery at service
- recovery at disposal

<u>Cold Storage</u>

Engineering controls
- alternative leak test gas
- recovery at service
- recovery at disposal

A.2.c. <u>Aftermarket and Wholesale Control Options for Domestic Products and Small Refrigeration Units</u>

Chemical Subsitute
- HCFC-22
- HCFC-502
- ammonia
- hydrocarbons
- HFC-134a

A.2.d. **Aftermarket and Wholesale Options For Domestic Products and Small Refrigeration Units**

Refrigerators

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

Freezers

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

Dehumidifiers

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

A.2.e. **Mobile Products**

Air Conditioning

Engineering controls
- quality engineering/recovery at service
- recovery at disposal
- recovery at service
- reclamation

Refrigerated Transportation

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

B. COMMERCIAL, INSTITUTIONAL AND INDUSTRIAL PRODUCTS AND SYSTEMS

B.1. END-USE APPLICATIONS

Building Chillers
- vapor compression
- absorption chillers
- includes reciprocating, centrifical and rotary helical (screw) styles

Food Processing and Handling
- retail food store refrigeration
- cold storage warehouses
- restaurant and food service
- food processing plants

Industrial Process Refrigeration
- petrochemical and refinery applications
- ice skating rinks
- ice manufacturers
- environmental test equipment
- processing and storing of volatile liquids
- paper mills

B.2. FUNCTIONAL ALTERNATIVES

B.2.a. Building Chiller Refrigerant

Application	Control
CFC-11 Centrif Chillers	Product Substitute - Alternative technology Chemical Substitute - HCFC-123 Add-on Engineering Controls - recovery at service and disposal - recovery at service
CFC-12 Centrif Chillers	Product Substitute - Alternative technology Chemical Substitute - HFC-134a Add-on Engineering Controls - alternative leak test gas - recovery at service and disposal - recovery at service - adequate storage for total charge
CFC-114 Centrif Chillers	Product Substitute - Alternative technology Add-on Engineering Controls - recovery at service and disposal - recovery at service
CFC-500 Centrif Chillers	Product Substitute - Alternative Technology Add-on Engineering Controls - recovery at service and disposal - recovery at service

IV

CFC-12 Reciprocating Chillers

Chemical Substitute - HCFC-22
- HFC-134a

c. Add on Engineering Controls
- alternative leak test gas
- recovery at service and
- disposal
- adequate storage for complete charge
- adequate valves for service
- reclamation

B.2.b. **Food Processing and Handling**

Retail Food

Chemical Substitute
- HCFC-502

- HCFC-22

Engineering controls - process substitutions
- alternative leak test gas
- leak test gas recovery
- recovery at service
- recovery at disposal
- dye D refrigerant

Cold Storage

Chemical substitute
- CFC-502
- HFC-134a
- CFC-22
- Ammonia

Engineering controls
- alternative leak test gas
- recovery at service
- recovery at disposal
- dyed refrigerant
- adequate valves for service

B.2.c. **Industrial Process Refrigeration**

Chemical Substitute
- HCFC-22
- CFC-502
- ammonia
- hydrocarbons

C. DOMESTIC PRODUCTS AND SMALL REFRIGERATION UNITS

C.1. END-USE APPLICATIONS

- refrigerators
- freezers
- dehumidifiers
- water coolers
- ice machines

C.2. FUNCTIONAL ALTERNATIVES

Refrigerators

Product substitute
- modified stirling cycle

Chemical substitute
- HFC-134a
- HCFC-22
- CFC-22/HCFC-142b
- CFC-502

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework
- ban sale of small cans

Freezers

Product substitute
- modified stirling cycle

Chemical substitute
- HFC-134a
- HCFC-22
- HCFC-22/HCFC-142b
- CFC-502

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework
- ban sale of small cans

<u>Dehumidifiers</u>

Chemical substitute
- HFC-134a
- HCFC-22
- HCFC-22/HCFC-142b
- CFC-502
- CFC-500

Engineering controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

D. <u>MOBILE PRODUCTS</u>

D.1. END-USE APPLICATIONS

Air Conditioning
- automotive, buses, streetcars, etc.
- railway passenger cars, subways

Transport cargo refrigeration
- trucks, trailers
- railroad freight cars

Transportation of:
- volatile liquids
- food products

D.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

<u>Air Conditioning</u>

Chemical Substitutes
- FC-134a
- HCFC-22
- HCFC-22/HCFC142b
- hydrocarbons
- HCFC-12 Mixture

Engineering Controls
- ban sale of small cans
- quality engineering/recovery at service
- use of refrigerant dye
- recovery at disposal
- recovery at service
- quality engineering
- use of higher quality hoses & connectors

Process Substitutes
- alternative refrigeration cycles (e.g., modified stirling cycle)

Refrigerated Transportation

Product Substitute
- modified stirling cycle

Chemical Substitute
- HFC-134a
- HCFC-22
- HCFC-22/HCFC-142b
- CFC-502

Engineering Controls
- helium leak test
- recovery at service
- recovery at disposal
- recovery at rework

Engineering controls/process substitutes
- baseline standards (e.g. cover)
- conveyorized vapour degreasers
- reclamation of waste solvent
- removal of solvent cleaning from certain applications
- increased freeboard ratios
- increased leak testing frequency

A.2.c. Solvent Vapour Degreasing (Conveyorized)

Chemical substitutes
- water
- chlorinated solvents

Engineering controls/process substitutes
- conveyorized units
- carbon adsorber
- drying tunnel
- engineering controls (thermostats, covers etc.
- hot vapour recycle
- reclamation of waste solvent
- elimination of solvent cleaning for certain applications
- regular leak testing

B. NON-ELECTRONICS APPLICATIONS

B.1. **END-USES**
- organic compound removal surface preparation for metals or other manufactured parts e.g:
  - plastics
  - elastomers
  - temperature sensitive materials
  - dry cleaning

B.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

B.2.a. Solvent cold cleaning

Chemical Substitutes
- water
- aliphatic petroleum solvents
- chlorinated hydrocarbons
- alcohols
- other solvents
- chlorinated solvents (e.g., methyl chloroform, methylene chloride, trichloroethylene, 1,1,1 - trichloroethane, perchloroethylene)

Engineering controls/process substitutes

Control Technology	Emission Type
Cover	Bath Evaporation
Increase freeboard ratio (from 0.3 to 1.0)	Bath Evaporation
Proper draining techniques	Carry-Out
Proper waste solvent storage and reclamation	Waste Solvent Evaporation
Proper operating techniques	Spray Evaporation
Elimination of solvent cleaning for certain applications	

B.2.b. Solvent Vapour Degreasing (open-top)

Chemical substitutes

- water
- chlorinated solvents (e.g., methyle chloroform, trichloroethylene, perchloroethylene, methylene chloride)
- carbon tetrachloride
- 1,1,2 - trichloroethane
- newly developed CFC solvents:
  - HCFC-123
  - HCFC-132b

Engineering controls/process substitute

- baseline standards e.g. cover, free board ratio etc.
- refrigerated chiller
- conveyorized vapour degreasers
- reclamation of waste solvent
- removal of solvent cleaning from certain application

B.2.c. Solvent Vapour Degreasing (conveyorized)

Chemical substitutes

- water
- chlorinated solvents

Engineering controls/process substitutes (conveyorized units)

- carbon adsorber
- drying tunnel
- engineering controls (thermostats, covers etc.
- hot vapour recycle
- reclamation of waste solvent
- elimination of solvent cleaning for certain applications
- leak testing
- improved operator training

B.2.d. Dry Cleaning Applications

Chemical substitutes

- perchloroethylene
- methyl chloroform

Engineering /process substitutes

- refrigerated condensers
- waste reclamation
- increased water laundering
- carbon absorption

OTHER APPLICATIONS

A. STERILANTS

A.1 END-USE APPLICATIONS

Sterilization and fumigation process using the sterilant gas "12-8" (12 weight percent ethylene oxide, 88 weight percent dichlorodifluoromethane).

- animal labs
- beehive fumigant
- libraries
- medical equipment
- non-commercial R & D labs
- commercial R & D labs
- pharmaceutical
- spice fumigant
- hospitals

A.2. SUMMARY OF FUNCTIONAL ALTERNATIVES

Control Option	Definition
Contract out	Sending products to be sterilized to a contract sterilization facility that uses either gamma radiation, pure EO, or 12/88 sterilant gas.
Use disposables	Substitute reusable, resterilizable surgical instruments with disposable, presterilized instruments. This option is applicable to hospitals only.
Convert to gamma radiation	Construction of a gamma radiation sterilization facility.
10/90 (E0/C02)	Substitute the sterilant gas 12/88 ethylene oxide/CFC-12 with "10/90" (i.e., 10 weight percent ethylene oxide, 90 weight percent carbon dioxide).
N_2 purge, then pure EO	A process in which the sterilization chamber is purged with nitrogen before sterilizing with pure ethylene oxide. If desired, the facility could opt to evacuate the chamber by drawing a deep vacuum, instead of purging with nitrogen.
Acid-water scrubber and condensation reclamation	Use of an acid-water scrubber to convert ethylene oxide to ethylene glycol followed by nonexplosion-proof
Explosion-proof condensation reclamation	Use of an explosion-proof condensation/reclamation unit to recover both ethylene oxide and CFC-12. The mixture is then reblended to be 12/88 in composition and is reused.
HCFC-22/EO	
HCFC 134a/EO	

B. MISCELLANEOUS CATEGORIES

B.1. END-USE APPLICATIONS

- single station heat detectors
- drain cleaners and pressurized blowers
- odor-warning devices
- skin chillers and presurgical skin cleaners
- whipped topping stabilizer
- tobacco puffing

B.2. SUMMARY OF CONTROL OPTIONS BY END-USE APPLICATION

Single station heat detectors
- HCFC-142b/HCFC-22

Drain cleaners and pressurized blowers
- HCFC-142b/HCFC-22

Odor-warning devices
- HCFC-142b/HCFC-22

Skin chillers and pressurgical skin cleaners
- none

Whipped topping stabilizer
- none

Tobacco puffing
- none
- HCFC-123