PROJECT

”SURVEY OF THE HYDROFLUOROCARBON (HFC) MARKET IN CHILE”

FINAL REPORT

MINISTRY OF ENVIRONMENT

UNPD

SANTIAGO

April, 2014

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1. SCOPE OF THE STUDY AND WORK METHODOLOGY

To best ascertain country hydrochluorocarbon (HFC) consumption, at the request of the Climate and Clean Air Coalition (CCAC) the Ministry of Environment of Chile (acronym MMA) and the United Nations Development Program (UNDP) contracted the "Survey of the Hydrofluorocarbon (HFC) Market in Chile". The object was to obtain a detailed profile of the HFC market, and more specifically, to define current consumption by substance and sector; define growth patterns (also by substance and sector); and identify low GWP alternatives in the different applications.

The survey was conducted using a top-down methodology to assess information from national and sectoral sources (mainly HFC importers) and validate an analysis and forecast of the country market for these substances.

Work was structured in four main stages: collection of baseline information, definition of current HFC consumption by substance and sector, definition of growth trends, and identification of HFC alternatives.

The primary information analyzed was consequently the database on HFC entry (import statistics on HFC and blends containing them) provided by the National Customs Service as the control agency for Chile's foreign trade operations.

Based on this, statistical work was done to filter important data and important background in light of the study objectives, to ascertain main substances entering the country, HFC importer companies and countries of origin between 2008 and 2012.

Together with the technical counterpart (MMA Ozone Unit), importers and companies marketing products with HFCs were selected for a semi-structured survey to obtain specifics on HFC trade and export in Chile and their context, as well as other commercial information on market prices, company share of the national market and aspects related to the handling of these substances.

With the technical counterpart, this report and its contents were then structured based on consideration of statistics generated from the National Customs Service database and information obtained from surveying importers and other companies and trade entities directly connected with the sector.

The survey instrument ("Survey of the HFC Market in Chile") is found in main body of this document.

FINAL REPORT

"STUDY OF THE HYDROFLUOROCARBON (HFC) MARKET IN CHILE"

MMA – UNPD

APRIL 2014

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LIST OF ACRONYMS AND ABBREVIATIONS

CIF	Cost, Insurance and Freight
UNFCCC	United Nations Framework Convention on Climate Change
FOB	Free on Board
HCFC	Hydrochluoroflurocarbons
HFC	Hydrofluorocarbons
HFO	Hydrofluorooelfins
HPMP	HCFC Phase Out Management Plan
MMA	Ministerio del Medio Ambiente de Chile (Ministry of Environment of Chile)
ODP	Ozone-depleting Potential
GWP	Global Warming Potential
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
ODS	Ozone-depleting Substances
VRV	Variable Refrigerant Volume

IDENTIFICATION OF MAIN HFC, HCFC and HC[1]

HFC, HCFC or Blend	Chemical Name-Blends	ODP	GWP (100 years)[2]
HCFC-22	Chlorodifluoromethane	0,055	1810
HFC-23	Trifluoromethane	0	14800
HFC-32	Difluoromethane	0	675
HFC 43-10mee	1,1,1,2,3,4,4,5,5,5-decafluoropentane	0	1640
HFC-125	Pentafluoroethane	0	3500
HFC-134a	1,1,1,2-tetrafluoroethanol	0	1430
HFC-143a	1,1,1-trifluoroethanol	0	4470
HFC-152a	1,1-difluoroethanol	0	124
HFC-161	Ethyl fluoride	0	12
HFC-227ea	Heptafluoropropane	0	3220
HFC-245fa	1,1,1,3,3-pentafluoropropane	0	1030
HFC-365mfc	1,1,1,3,3-pentafluorobutane	0	794
R-404A	HFC-125 / HFC-143a / HFC-134a (44.0 / 52.0 / 4.0)	0	3900
R-407C	HFC-32 / HFC-125 / HFC-134a (23.0 / 25.0 / 52.0)	0	1800
R-410A	HFC-32 / HFC-125 (50.0 / 50.0)	0	2100
R-417A	HFC-125 / HFC-134a / R-600 (46.6 / 50.0 / 3.4)	0	2300
R-507A	HFC-125 / HFC-143a (50.0 / 50.0)	0	4000
R-508B	HFC-23/ FC-116 (46.0/54.0)	0	13000
R-290	Propane	0	~ 20
R-600	n-Butane	0	~ 20
R-717	Ammonia	0	<1
Chesterton SP 296 ®	HFC-134a / HFC-245fa / HFC-365mfc / isopropanol (40-50% / 20-30% / 20-30% / 1-5%)	0[3]	[4]

[1] Chilean Standard NCh 3241-2011, "Good Practices in Refrigeration and Air Conditioning" (*Buenas Prácticas en Sistemas de Refrigeración y Climatización*); INN-Chile and commissioned by UNDP for the Ministry of Environment of Chile, 2012.

[2] IPCC Fourth Assessment Report: Climate Change 2007". Available at www.ipcc.ch/publications_and_data/ar4/wg1/en/tssts-2-5.html, consulted August 2, 2013.

[3] http://www.chesterton.com/ENU/Products/Pages/Product.aspx?ProductLine=TPD&Category=Cleaners%20and%20Degreasers&ModelID=296&DocumentType=Catalog. Consulted September 6, 2013.

[4] No information.

Survey of the HFC Consumption in Chile

Executive Summary

Introduction

Chile is partner of the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC). In February 2012, the governments of Bangladesh, Canada, Ghana, Mexico, Sweden and the United States and the United Nations Environment Programme (UNEP) have formed the Climate and Clean Air Coalition to Reduce Short Lived Climate Pollutants (CCAC), a unique initiative to support fast action to reduce short-lived climate pollutants (SLCPs) such as black carbon (soot), methane and some hydrofluorocarbons (HFC). Additionally the country has ratified the Vienna Convention and the Montreal Protocol with all its amendments to control the consumption of the substances that deplete the Ozone layer and currently is in the implementation of the first phase of the HCFC Phase-out Management Plan (HPMP).

It is in this context that the current HFC survey was conducted. A top-down methodology was followed that involved the analysis of the government information, particularly the National Customs Service, and the interaction with upstream chemical and equipment suppliers and importers, industry associations and key end users.

Brief overview of the country's HFC consumption from 2008 to 2012

There is no HFC production in Chile. The table 1 presents the country consumption of HFC during the years 2008-2012 by substance calculated as imports minus exports:

Table 1. HFC consumption (kg)

Substance[5]	2008	2009	2010	2011	2012
HFC-23		5		4	135
HFC 43-10mee					1
HFC-125	6,889	6,483	4,354	10,564	3,685
HFC-134a	233,720	256,334	379,067	413,802	350,133
HFC-152a	846	2,459	3,181	1,599	976
HFC-227ea	14,120	20,183	21,275	46,662	42,735
HFC-365mfc	975	960	960	1,920	
R-404A	184,811	104,848	205,751	197,337	236,038
R-407C	31,528	29,836	35,601	46,616	24,071
R-410A	2,825	18,363	31,605	69,955	60,320
R-417A			454	1,808	
R-422D			25		
R-507A	22,775	33,408	80,479	138,729	196,080
R-508B	14		9	55	

[5] For convenience to analyze the different market sectors the refrigerant blends (R-404A, R-507A, etc.) are not decomposed in their components.

Table 1. HFC consumption (kg)					
Substance[5]	**2008**	**2009**	**2010**	**2011**	**2012**
Chesterton SP 296®	40	1,167	26	732	1,212
Total general	498,543	474,046	762.787	929,783	915,386

China and the United States are the main source of HFCs imported by Chile. In 2012 these two countries accounted for 99.61 % of the total imports. As reflected in the table 2 in the last five years there has been a relevant increase of the imports from China at the expense of Europe and the United States:

Table 2. Source of HFC Imports				
	2008		**2012**	
Source	**kg**	**%**	**kg**	**%**
China	321,703	64.46	815,778	88.07
USA	133,705	26.79	106,853	11.54
Europe	30,223	6.06	0	0
Singapore	12,500	2.50	3,525	0.38
Others	960	0.19	120	0.01
Total	499,091	100.00	926,276	100.00

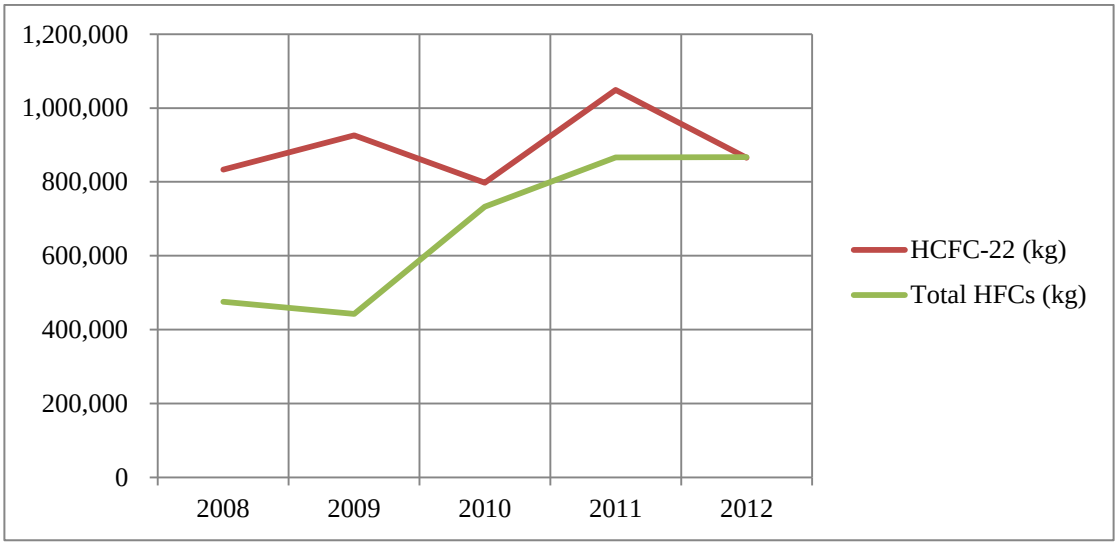
The HFC used in the refrigeration/air conditioning (RAC) market (HFC-134a and HFC blends) are not summited to any repackaging process in the country. They are imported in containers in the same presentation that will reach the end users (cylinders from 10.9 to 13.6 kg). The table 3 shows the price evolution of relevant HFC coming from China. A significant peak in the FOB price of all substances is observed in 2011.

Table 3. FOB price evolution of HFC (US $/kg)					
Substance	**2008**	**2009**	**2010**	**2011**	**2012**
HFC-134a	3.9	4.0	5.9	8.5	4.8
HFC-227ea		12.0	11.9	25.1	16.1
R-404A	5.0	4.7	5.4	10.1	7.1
R-407C	4.8	4.6	6.4	10.6	5.5
R-410A	5.2	4.4	6.3	10.7	4.7
R-507A	5.0	4.6	5.1	10.6	5.3

In the 2008-2012 Chile exported limited amounts of HFC. In 2012 they represented 1.18 % of the total imports. Since 2010, although small in total quantities, there are increased exports to Peru and Bolivia of refrigerant blends R-407C and R-507A.

The HFC are basically consumed in two market segments: RAC and fire protection. In 2012 they accounted for 94.69 and 5.07 % of the total market respectively. The remaining 0.24 % is represented by the use of HFC-152a in the glass industry and Chesterton® SP 296 as cleaning agent for electronics. There is no HFC consumption in the foam industry, where pentanes and HCFC-141b are the preferred blowing agents.

The main products used in the RAC sector are HFC-134a (40.4 %), R-404A (27.24 %) and R-507A (22.63 %). Adding to them the R-410A, that showed a compounded growth rate of 115 % in the years 2008-2012, they reached 97.2 % of the total HFC for RAC in 2012. Along with the HFC, the other important player in the refrigeration industry is HCFC-22, introduced in the market as CFC-12 replacement[6]. The graph 1 shows the evolution of its consumption compared to that of the main HFC used in RAC.



Graph 1. Evolution of HCFC-22 consumption compared to the main HFCs in the RAC sector (HFC-134a, R-404A, R-507A and R-410A)

[6] Small amounts of R-417A were imported in 2010 and 2011.

The table 4 describes the RAC sub-sectors where the different products are used:

Table 4. Products used in RAC subsectors					
Sub-sector	**HFC-134a**	**R-404A**	**R-407C**	**R-410A**	**R-507A**
Refrigeration					
Domestic	X				
Commercial (stand-alone equipment, cold rooms, super-markets, etc.)	X	X			
Industrial		X			X
Transportation (reefers, trucks)	X	X			
Air Conditioning					
Stationary					
Compact equipment (residential and commercial)	X		X	X	
Systems	X		X	X	
Mobile air conditioning	X	X			

It is estimated that 42 % of HFC-134a is used in refrigeration and the rest in air conditioning (most for mobile air conditioning). The percent distribution for R-404A is 20 % in commercial refrigeration, 70 % in industrial refrigeration and 10 % in refrigerated transportation approximately.

In 2012 the total consumption of HFC-227ea and HFC-125 was used in the fire protection sector. They are used in the mining industry (30 %), particularly in the electrical excavators, and in data centers (70 %). The Novec™ 1230, a fluoroketone, is aggressively penetrating in the market as a replacement of HFC in the data center subsector.

Projection of HFC consumption for the years 2013-2020

The table 5 shows the estimated HFC consumption for the years 2013-2020 in a business-as-usual (BAU) scenario. This projection was calculated assuming the following items:

- The refrigeration sector as a whole will continue to grow at its historical rate (7.5 %).
- The HCFC-22 consumption will follow the chronogram defined by the Montreal Protocol in Decision XIX/6 for the HCFC phase-out in the Article 5 parties.
- In accordance with the historical data the refrigeration products will grow at differentiated rates following in magnitude the same historical order (R-410A>R-507A>HFC-134a>R-404A>R-407C).
- The two products dedicated to the fire protection industry will grow at the same rate of the GDP (2013 projection): 4.8 %.

Table 5: Estimated HFC consumption for 2013 - 2020, Business-as-usual scenario (kg)								
Substance	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
HFC-134a	387,376	428,543	474,084	524,465	580,200	641,859	710,069	785,529
R-404A	253,753	272,784	293,243	315,236	338,879	364,295	391,617	420,988
R-407C	25,453	25,708	25,965	26,224	26,487	26,751	27,019	27,289
R-410A	104,488	140,806	259,907	288,754	311,815	327,340	333,219	541,720
R-507A	242,842	286,553	338,133	398,997	470,816	555,563	655,564	773,566
HFC-125	3,862	4,047	4,242	4,445	4,658	4,882	5,116	5,362
HFC-227ea	44,786	46,936	49,189	51,550	54,024	56,618	59,335	62,183
Total	1,062,560	1,205,377	1,444,763	1,609,671	1,786,879	1,977,308	2,181,939	2,616,637

Based on table 5, in the business-as-usual scenario the HFC consumption will almost triple in 2020 (2,616 tones) the 2012 value (926 tones). The most popular products will be HFC-134a, R-507A, R-410A and R-404A. They will in 2020 represent respectively 30.02, 29.56, 20.70 and 16.09 % of the total HFC consumption.

Future Actions & Projects

The projected significant growth in HFC consumption in a BAU scenario, driven partially by the HCFC-22 phase-out, represents a significant challenge for the country because of its climate change impact.

Based on the recent reports published by the Refrigeration Technical Options Committee of the Montreal Protocol (RTOC) low GWP options have been identified for several market subsectors (table 6).

Table 6. Low GWP options for relevant RAC sectors			
Sector	**Subsector**	**Current substance**	**Low GWP options**
Refrigeration	Domestic	HFC-134a	HC-600a, HFC-1234yf.
	Commercial	Stand-alone equipment: HFC-134a y R-404A.	HC-600a and HC-290 for small units with charges lower than 1.5 kg. HFC-1234yf and CO_2.
	Supermarkets	R-404A, R-507A y HFC-134a.	Transcritical CO_2, cascade systems using CO_2 at the low temperature level combined with a variety of refrigerants at the high temperature level such as ammonia, HC-290 and HC-1270
	Transportation, trucks	R-404A, HFC-134a.	HFC-1234yf as replacement of HFC-134a
	Transportation, reefers	R-404A, HFC-134a.	CO_2
Air Conditioning	Split and window type	R-407A, R-410A y HFC-134a.	HC-290
	Mobile	HFC-134a	HFC-1234yf, CO_2

The preparation of a national strategy for the HFC phase down that includes the actions to undertake, the time line and the associated costs represents a path forward.

In the RAC sector the following demonstration/investment projects are pertinent:

- Conversion of the production of domestic and stand-alone commercial units to hydrocarbon refrigerant technology (replacement of HFC-134a by the HC-600a).
- Demonstration/installation projects in the supermarket subsector aiming at the HFC refrigerant replacement by CO_2 refrigerant based technology:
  - ✓ Refrigeration cascade system using R-717 (ammonia)/R-744 (CO_2)
  - ✓ Refrigeration cascade system using R-290 (propane)/R-744 (CO_2)
  - ✓ Refrigeration trans-critical CO_2 system (demonstration project)
- Demonstration/installation project: use CO_2 refrigerant technology for reefers refrigeration systems.
- Demonstration/installation project: use a low GWP refrigerant in the air conditioning system to be installed in a public building.

The Chilean foam sector, specifically the discontinuous panels and spray subsectors, currently using HCFC-141b, offer an opportunity for introducing a safe low-GWP alternative while enhancing energy efficiency. The pertinence of the following projects is visualized:

- Demonstration project to develop cost effective PU formulations based on unsaturated HFCs (HFO) for the discontinuous panels in a developing country.
- Demonstration project to develop cost effective PU formulations based on unsaturated HFCs (HFO) for spray in a developing country.

1. Frame of Reference

In February, 2012, the governments of Bangladesh, Canada, Ghana, Mexico, Sweden and the United States, and the United Nations Environment Programme (UNEP) formed the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC), a unique initiative supporting immediate actions to reduce short-lived pollutants such as black carbon (soot), methane and certain hydrofluorocarbons (HFCs)[7].

Short-lived pollutants are responsible for a substantial portion of current global warming, with particularly large impacts on urban areas and sensitive regions of the world, such as the Arctic, and can have serious effects on human health and the environment. Their mitigation can thus have immediate multiple benefits, protecting human health and the current environment and slowing the pace of climate change in the first half of the century.

The Coalition's objectives are to raise awareness about short-lived climate pollutant impacts and mitigation strategies; to enhance and develop new national and regional actions, including by identifying and overcoming barriers, enhancing capacity and mobilizing support; to promote best practices and showcase successful efforts; and to improve scientific understanding of short-lived climate pollutant impacts and mitigation strategies.[8]

Chile, through its environmental ministry (MMA for its name in Spanish), joined the Coalition considering that its objectives are consistent with country efforts to plan and implement public policy on reducing these pollutants in the region.

MMA is the Chilean secretariat[9] responsible for collaborating with the President of the Republic in design and application of environmental policies, plans and programs, as well as protection and conservation of biological diversity and renewable natural and water resources, promoting sustainable development, the integrity of environmental policy and its legislative regulation. Under this framework, MMA has worked on several lines of action aligned with the Coalition's objectives[10]:

a. control of black carbon emission in public transportation;

b. control of emissions from use of wood and biomass for domestic heating;

c. control of emissions from manual fabrication of bricks;

d. control of methane emissions from sanitary landfills, water treatment plants and farm-raised animals;

e. elimination of agricultural burns and control of forest fires;

[7] http://www.unep.org/spanish/ccac/. Consulted August 2, 2013.
[8] http://www.unep.org/spanish/ccac/Información/tabid/102635/language/en-US/Default.aspx. Consulted August 2, 2013.
[9] Art. 69, Law 19.300/1994 on General Foundations of the Environment, modified by Law20.417/2010.
[10] Chile's letter of application to the Climate and Clean Air Coalition.

f. design and implementation of MAPS Chile- Mitigation Options to Address Climate Change- allowing Chile to meet its voluntary CO_2–reduction commitment before the United Nations[11]. The consultancies must analyze indicators on local pollutants, among others.[12].

In the specific case of HFCs, Chile has regularly presented emission inventories in compliance with its commitments before the United Nations Framework Convention on Climate Change (UNFCCC).

Additionally, under the Montreal Protocol on Substances that Deplete the Ozone Layer, since 2008 proposals on amendments to this legally binding international instrument have been presented to include HFC control measures, given their increasing use as alternatives to hydroclorofluorocarbons (HCFCs).

According to the most recent proposed amendment[13] presented by the United States of America, Canada and Mexico at the 33rd Meeting of the Open-Ended Working Group of Parties to the Montreal Protocol (33-OEWG, Bangkok, June 2013), U.S. government estimates indicate accumulated environmental benefits from HFC reduction amount to almost 1.9 billion metric tonnes CO2 equivalent (Gt CO_2eq) up to 2020, and approximately 84.1 Gt CO_2eq as of 2050. Altogether, the cumulative benefits of control on emissions of HFC-23 as byproduct reach another 11.3 Gt CO_2eq as of 2050. Along a similar line, the European Union proposal to the UNFCCC is that Convention parties signal the Montreal Protocol to promote a reduction of HFCs given their high global warming potential[14].

Chile is now implementing the first stage of the HCFC Phase-out Management Plan (HPMP), under which it executes activities and projects aimed at reducing and phasing out use of these substances, thereby complying with Montreal Protocol goals, and introducing non-ozone-depleting alternatives.

The work in this first stage of the HPMP is primarily focused on training and retrofitting in refrigeration and air conditioning, where some of alternatives used are HFC-134a and HFC blends. The introduction and use of these short-lived pollutants has been increasing in the country, with R-404A and R-410A the blends used most as HCFC-22 replacements in certain refrigerant and air conditioning applications, respectively.

It should be noted that Chile ratified the Vienna Convention and Montreal Protocol and all amendments, making these international instruments legally binding for the country. It also has a

[11] http://unfccc.int/resource/docs/2011/awglca14/eng/inf01.pdf. Consulted August 2, 2013.
[12] http://mapschile.cl/la-investigacion/el-proceso-de-investigacion. Consulted August 2, 2013.
[13] UNEP/OzL.Pro.WG.1/33/3. Consulted August 2, 2013.
[14] http://unfccc.int/files/documentation/submissions_from_parties/adp/application/pdf/adp_eu_workstream_2_20130527.pdf; "A decision at the 19th Conference of the Parties in Warsaw to urge the Montreal Protocol to undertake a global phasedown of the production and consumption of HFC would be a very useful step, greatly encouraging effective action to stop the current rapid increase in HFC emissions and thereby making a significant contribution to the effort to close the emissions gap pre -2020. This should therefore be discussed as part of Workstream 2 of the Durban Platform for Enhanced Action." Consulted August 2, 2013.

framework law on ozone layer protection and accompanying regulations associated with control of ODS including HCFCs.

In this context, the Chilean Ministry of Environment through the Ozone Unit has generated this study of HFC consumption between 2008 and 2012, which will establish baseline information to identify trends in each user sector and subsector, with the aim of facilitating implementation of low-GWP alternatives in these different sectors.

The organization of this document consists of an initial characterization of HFC consumption through quantification of imports and exports, followed by an analysis of market consumption in user sectors and a projection of HFC consumption trends based on potential increase as a consequence of HCFC phase-out, especially HCFC-22. Lastly, it presents current alternatives and those being introduced as definitive replacement for these substances.

2. Import of HFC

Statistics on HFC and blends containing it imported between 2008 and 2012 were provided by the National Customs Service, which is responsible for control of foreign trade operations. Table N° 1 below shows total imports of each HFC, both pure and blended.

During the study period a significant rise is seen in total HFC imports, which practically doubled between 2008 and 2012. Among these, imports of HFC-134a, R-404A and R-507A were most notable, altogether representing more than 85% of 2012 imports. Important growth of HFC-227ea and R-410 is also noticeable during the period; along with R-507A, these show the highest rates of growth.

Table N° 1: Imported HFC, as pure Substances and in blends (2008-2012, in kg)

HFC	2008	2009	2010	2011	2012
HFC-23		5		4	135
HFC 43-10mee					1
HFC-125	6,889	6,483	4,354	10,564	3,685
HFC-134a	233,720	256,984	379,067	414,680	350,164
HFC-152a	846	2,459	3,181	1,599	976
HFC-227ea	14,232	20,287	21,275	46,662	42,735
HFC-365mfc	975	960	960	1,920	
R-404A	185,247	104,848	205,855	197,640	236,049
R-407C	31,528	29,836	35,885	47,056	25,201
R-410A	2,825	18,363	31,605	69,955	60,320
R-417A			454	1,808	
R-422D			25		
R-507A	22,775	36,572	82,287	142,664	205,798
R-508B	14		9	55	
Chesterton SP 296®	40	1,167	26	732	1,212
Total general	499,091	477,964	764,983	935,339	926,276

Source: by author based on information from the National Customs Service

2.1 Main HFC importers

In Chile a total of 29 importer companies registered international trade operations in 2012. Of these the five most important captured 76.9 % of this highly concentrated market, led by Unión Química E.I.R.L with 36.6% of total consumption. This share remained relatively constant over the study period, as a comparison of 2008 and 2012 imports shows in Table Nº 2, where importers are listed according to volume.

Table N° 2: Main HFC Importers (2012, kg)

Importer	Chesterton SP 296®	HFC-125	HFC-134a	HFC-227ea	R-404A	R-407C	R-410A	R-507A	Other HFCs (See Appendix 2)	Grand Total
UNIÓN QUIMICA E.I.R.L.			108,528		104,432	12,882	31,414	103,282	135	360,673
PROQUIEL LTDA.			47,192		63,399		3,390	57,517	0	171,498
ORICA CHEMICALS CHILE S.A.			44,166		25,615		1,356	5,650	0	76,787
INDUSTRIAS QUIMICAS RENO S.A.			13,600		13,298	4,859	9,040	11,978	0	52,775
INDURA S.A.			36,207		2,612			2,602	0	41,421
DISTRIBUIDORA PORTLAND S.A.			14,361		4,273	3,277	7,831	8,181	0	37,923
WESTFIRE SUDAMERICA LTDA.		3,231		30,548					0	33,779
HELSON MUÑOZ Y CIA. LTDA.			30,240						0	30,240
MIMET S.A.			11,400		8,250				0	19,650
SUDAMÉRICANA AG. AER. Y MAR. S.A.			15,572						0	15,572
Other Importers (see Appendix 1)	1,212	454	28,898	12,187	14,170	4,183	7,289	16,588	977	85,958
Grand Total	1,212	3,685	350,164	42,735	236,049	25,201	60,320	205,798	1,112	926,276

Source: by author based on information from the National Customs Service

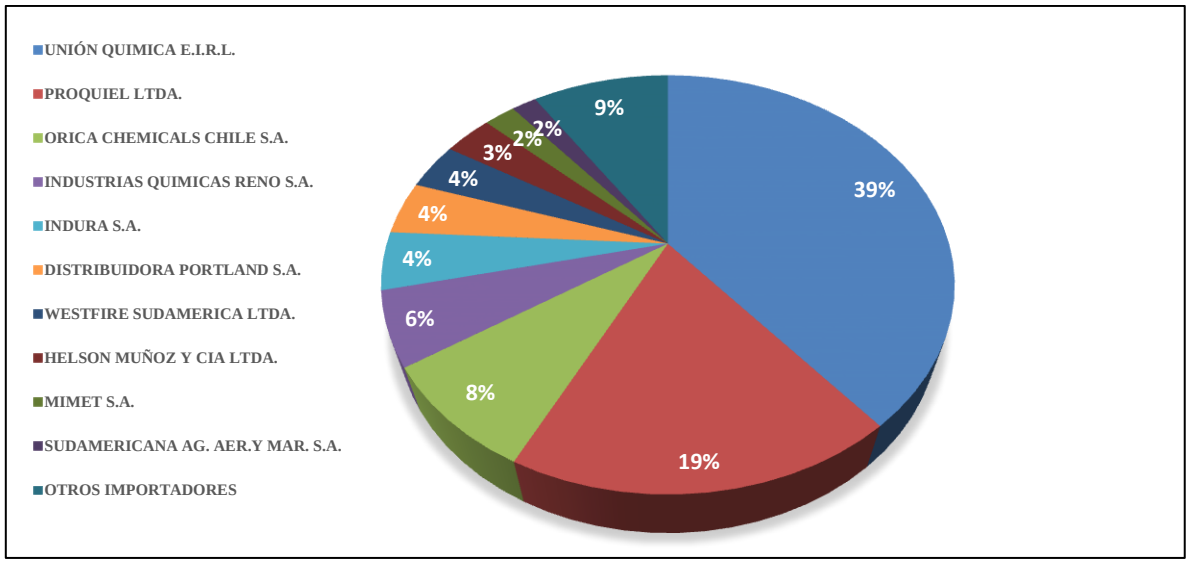


Figure N° 1: Percent distribution of HFC imports by main importers (2012)

Table N° 3: Comparison of HFC imports by importer 2008 and 2012, kg)

Importer	Total 2008	Total 2012
UNIÓN QUIMICA E.I.R.L.	145,608	360,673
PROQUIEL LTDA.	90,631	171,498
ORICA CHEMICALS CHILE S.A.	77,369	76,787
INDUSTRIAS QUIMICAS RENO S.A.	35,033	52,775
INDURA S.A.	47,546	41,421
DISTRIBUIDORA PORTLAND S.A.	12,240	37,923
WESTFIRE SUDAMERICA LTDA.	13,657	33,779
HELSON MUÑOZ Y CIA LTDA.	(*)	30,240
MIMET S.A.	(*)	19,650
SUDAMERICANA AG. AER.Y MAR. S.A.	(*)	15,572

Source: by author based on information from the National Customs Service

(*) No imports by these companies recorded in 2008

2.2 Origin and presentation

For the purposes of this study, "country of origin" is understood as the country registered in the entry declarations of the National Customs Service, so it could in actuality represent transit countries.

Under this precept, data on country of origin reveal China's importance as provider of these substances. Tables N° 4 and N° 5 indicate the sustained growth in imports from China during the period, showing that its relative share also rose significantly from 64.5% to 88.1%, broadly surpassing the second-place exporter, the United States. Together the two countries represent 99.6% of imports in 2012.

Table N° 4: Import of HFC, pure and blended, by country of origin (2008 – 2012, kg)

Country of Origin	2008	2009	2010	2011	2012
China	321,703	394,163	654,950	747,293	815,778
United States (U.S.)	133,705	48,976	83,175	101,383	106,853
United Kingdom	18,868	15,994	24,997	35,563	
Singapore (*)	12,500	17,353		35,262	3,525
Germany	11,355			12,670	
Other Countries (see Appendix 3)	960	1,478	1,861	3,168	120
Grand Total	499,091	477,964	764,983	935,339	926,276

Source: by author based on information from the National Customs Service
(*) Since Singapore does not produce HFC, it acts only as transit country for substances of this type from China.

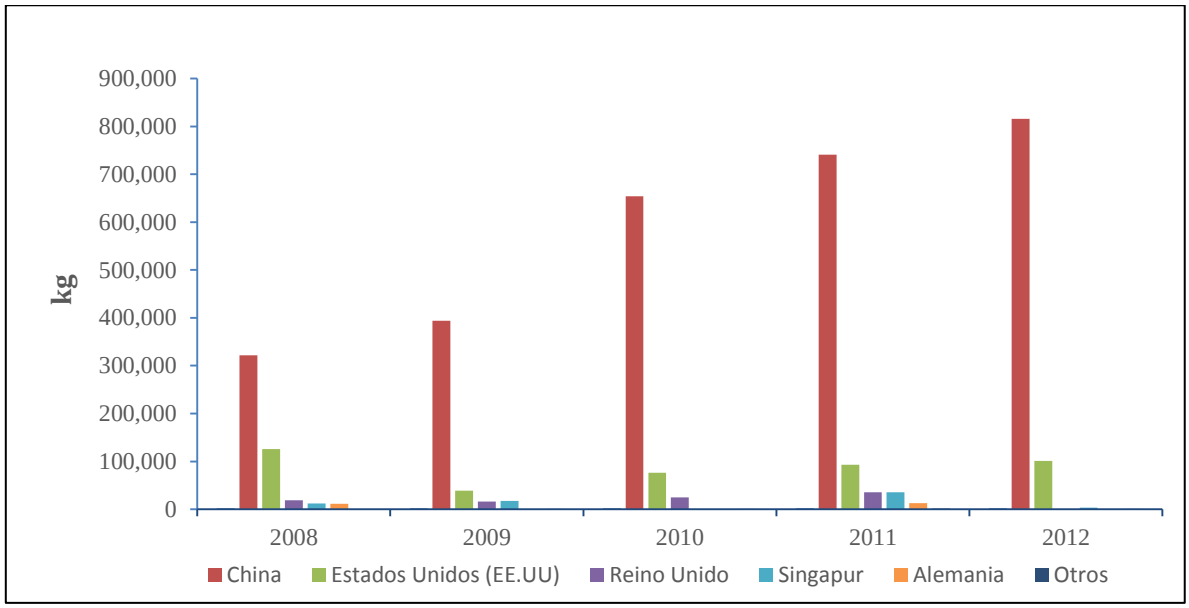
Table N° 5: Percent comparison of amount of HFC imported according to country of origin in 2008 and 2012

Country of Origin	2008		2012	
	kg	%	kg	%
China	321,703	64.46	815,778	88.07
United States (U.S)	133,705	26.79	106,853	11.54
United Kingdom	18,868	3.78		
Singapore (*)	12,500	2.50	3,525	0.38
Germany	11,355	2.28		
Other Countries	960	0.19	120	0.01
Grand Total	499,091	100	926,276	100

Source: by author based on information from the National Customs Service
(*) Since Singapore does not produce HFC, it acts only as transit country for substances of this type from China.

As can be seen, there were no imports from the United Kingdom and Germany during 2012, which reflects their sporadic nature, while in the case of Singapore, for example, there were imports in 2012 but not in 2010. All these countries have only a minimal share of total imports in comparison to China and the U.S.

The graphic below (Figure N° 2) depicts the evolution of imports from major countries of origin and respective volumes.



China *United States* *United Kingdom* *Singapore* *Germany* *Others*

Figure N° 2: Evolution of imports of HFC-134a, HFC-227ea, R-404A, R-407C, R410A and R-507A per countries of origin (2008 – 2012, thousands of kg)

Table N° 6: Percent share of exporter countries for HFC substances consumed most (2012)

HFC	China	United States (U.S.)	Singapore	Netherlands
HFC-134a	82.47%	17.50%		0.03%
HFC-227ea	16.38%	83.62%		
R-404A	98.89%	1.11%		
R-407C	84.75%	1.80%	13.45%	
R-410A	100%			
R-507A	99.56%	0.44%		

Source: by author based on information from The National Customs Service

Table N° 6 shows percent of imports from main importer countries (China and U.S.) and main substances imported in 2012 (Figure N° 2). As can be observed, the U.S.'s share centered on HFC-134a (17.5%) and Singapore's was limited to R-407C (13.5%). The remaining HFC imports are amply dominated by China. Note that this analysis includes R-407C since 13.5 % of this refrigerant arrived by way of Singapore in 2012 (according to Table N° 6); while consumption of this substance is not great, it is salient for having a country of origin different from China.

Concerning presentation, according to National Customs Service information and interviews with the main importers, nationally these substances are commercialized in the same storage containers

in which they arrived. There are no operations related to local re-packaging or transfer to different containers for use in refrigeration, air conditioning and fire protection sectors. The table below shows cylinder capacities for the main HFCs.

Table N° 7: Cylinder capacities of main HFC imports

HFC	Cylinder Capacity (kg)
HFC-134a	13.6 kg
HFC-227ea	9 – 453.5 kg (20 lb - 1000 lb)
R-404A	10.9 kg
R-407C	11.3 kg
R-410A	11.3 kg
R-507A	11.3 kg

Source: by author based on information from the National Customs Service and interviews with importers

2.3 Evolution of import prices

China has the greatest participation in importation of pure and blended HFCs (88.1% in 2012). The evolution of average FOB prices for HFCs imported from that country in the study period are shown in Table N° 8, while Figure N° 3 illustrates price evolution for the main refrigerants imported (HFC-134a, R-404A and R-507A).

For pure HFCs, prices fluctuate between US$ 3.90/kg and US$ 25.10/kg, with the highest corresponding to HFC-227ea in 2011 and the lowest to HFC-134a in 2008. For blends, prices range from US$ 4.40/kg for R-410A and US$ 14.5/kg for R-417A.

Table N° 8: Average FOB import prices (US$/kg) for HFC and blends from China

HFC	FOB Prices (US$/kg)				
	2008	2009	2010	2011	2012
HFC-125			6.7	10.3	
HFC-134a	3.9	4.0	5.9	8.5	4.8
HFC-227ea		12.0	11.9	25.1	16.1
R-404A	5.0	4.7	5.4	10.1	7.1
R-407C	4.8	4.6	6.4	10.6	5.5
R-410A	5.2	4.4	6.3	10.7	4.7
R-417A				14.5	
R-507A	5.0	4.6	5.1	10.6	5.3

Source: by author based on information from the National Customs Service

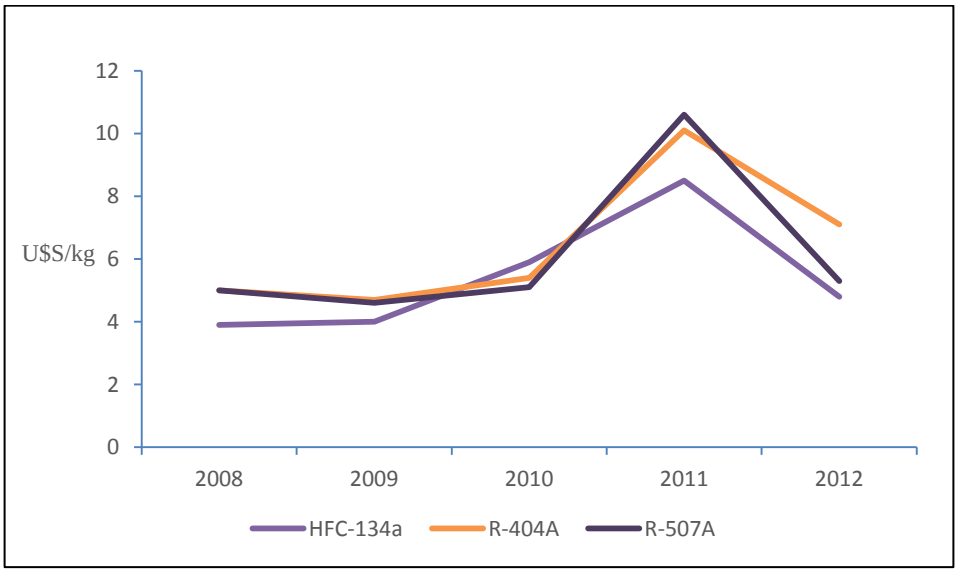


Figure N° 3: Evolution of FOB Prices (US$/kg) in Chile for HFC-134a, R-404A and R-507A (2008 – 2012)

Table N° 8 and Figure N° 3 show that prices of all HFCs rose in 2011, and then in 2012 dropped below those of 2010. In the particular case of HFC-227ea, in 2011 there was a considerable price increase of more than 100% over 2010. Importers indicate this was because production plants were moved from Europe to China, generating uncertainty in the market and consequent over-stocking of the substances. This pushed prices upward, but as the situation stabilized they declined to previous levels of HFC production and availability.

3. Exports of HFC

Exports of pure HFCs and blends are far below imports during the study period, equivalent to slightly more than 1%. Of these, most exports were R-507A (89.2%), followed by R-407C (10.4%), both showing a sustained rising trend and each one representing 5% of all imports. No particular trends are noted for other exported substances, HFC-134a, HFC-227ea and R-404A, whose share of imports in 2012 was minor at 0.4%.

Table N° 9: Amount of HFC and blends exported (2008 – 2012, kg)

HFC	2008	2009	2010	2011	2012
HFC-134a		650		878	31
HFC-227ea	112	104			
R-404A	436		104	303	11
R-407C			284	440	1130
R-507A		3.164	1.808	3.935	9.718
Grand Total	548	3.918	2.196	5.556	10.890

Source: by author based on information from the National Customs Service

As Tables N° 9 and N° 10 show, there was a constant flow of mostly R-507A from Chile to Peru, exported by one company to meet requirements for charging operations and servicing of refrigeration equipment in Peruvian supermarkets and commercial centers.

Table N° 10: HFC Exports (pure and blends) by Chile according to country destination and exporter (2008 – 2012, kg)

Destination	2008	2009	2010	2011	2012
Peru					
PROQUIEL LTDA.		3,164	1,808	3,949	10,848
INDURA S.A.		650		1,110	
ORICA CHEMICALS CHILE S.A.	436				
SOCIEDAD IMPORTADORA Y EXPORTADORA BASH LTDA.		104			
REFRICENTRO S.A.				28	
Subtotal Peru	**436**	**3,918**	**1,808**	**5,087**	**10,848**
Bolivia					
IMPOVAR S.A.			226	440	
WESTFIRE SUDAMERICANA S.A.	112				
SISTEMAS Y SUMINISTROS DE INGENIERÍA S.A.			58		
Subtotal Bolivia	**112**		**284**	**440**	
United Kingdom					
SISTEMAS Y SUMINISTROS DE INGENIERÍA S.A.			104		
Subtotal United Kingdom			**104**		
United States (USA)					
INDURA S.A.				29	17
Subtotal USA				**29**	**17**
Falkland Islands					
INDURA S.A.					25
Subtotal Falkland Islands					**25**
Grand Total	548	3,918	2,196	5,556	10,890

Source: by author based on information from the National Customs Service

Table N° 11: Amount of HFC and blends exported according to country destination and exporter (2012, kg)

Destination	HFC-134a	R-404A	R-407C	R-507A	Total
Peru					
PROQUIEL LTDA.			1,130	9,718	10,848
Falkland Islands					
INDURA S.A.	14	11			25
United States (USA)					
INDURA S.A.	17				17
Grand Total	31	11	1,130	9,718	10,890

Source: by author based on information from the National Customs Service

4. Analysis of HFC Consumption

For the purposes of this study, Chilean HFC consumption is understood in the same way as in the Montreal Protocol: the sum of production plus imports minus exports. Currently Chile does not have HFC production plants. As seen in the previous chapter, its exports are negligible so national consumption is marked by imports.

Table N° 12: HFC consumption (pure and blends) in Chile (2008 – 2012, kg)

HFC	2008	2009	2010	2011	2012
HFC-23		5		4	135
HFC 43-10mee					1
HFC-125	6,889	6,483	4,354	10,564	3,685
HFC-134[a]	233,720	256,334	379,067	413,802	350,133
HFC-152[a]	846	2,459	3,181	1,599	976
HFC-227ea	14,120	20,183	21,275	46,662	42,735
HFC-365mfc	975	960	960	1,920	
R-404A	184,811	104,848	205,751	197,337	236,038
R-407C	31,528	29,836	35,601	46,616	24,071
R-410A	2,825	18,363	31,605	69,955	60,320
R-417A			454	1,808	
R-422D			25		
R-507A	22,775	33,408	80,479	138,729	196,080
R-508B	14		9	55	
Chesterton SP 296®	40	1,167	26	732	1,212
Total general	498,543	474,046	762,787	929,783	915,386

Source: by author based on information from the National Customs Service

Consumption, dominated by imports, reflects a concentration of three main substances in 2012: HFC-134a, R-404A and R-507A. All together these represent 85% of consumption in that year (see Table N° 13). In addition, R-507A along with HFC-227ea and R-410A experienced the highest growth in the period. As can be seen in the next chapter, their primary application is refrigerant for air conditioning and refrigeration; only HFC-227ea is used in fire protection systems, but in smaller quantities.

Table N° 13: Percent HFCs (pure and blends) consumed most in Chile (2012, kg)

HFC	2012	%
HFC-134a	350,133	38.31%
HFC-227ea	42,735	4.68%
R-404A	236,038	25.82%
R-407C	24,071	2.63%
R-410A	60,320	6.60%
R-507A	196,080	21.45%
Total de los 6 HFC	909,377	99.49%

Source: by author based on information from the National Customs Service

Consumption of R-407C along with HFC-404A and other lesser-used HFCs was unstable during the study period (see Figure N° 4). Consumption in 2012 was below 2008, but import peaked in 2011. As will be discussed in the following chapter, the R-407C blend is used in refrigeration, but with certain technical complications that curtailed its growth, and the industry is opting for other refrigeration alternatives.

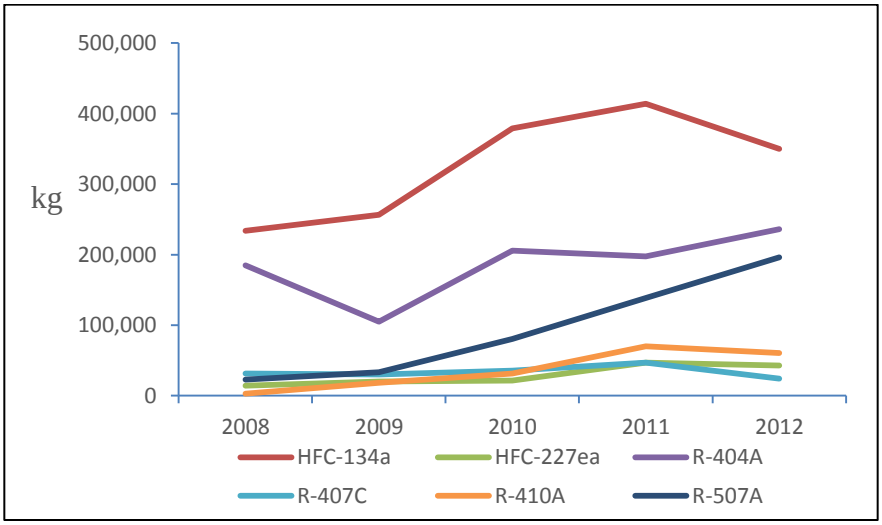


Figure N° 4: Evolution in consumption of the 6 refrigerants used most in Chile (2008 – 2012, kg)

Of the other substances imported, consumption of HFC-152a and Chesterton SP 296® is low but steady as it responds to specific uses. Consumption of the remaining substances (HFC-23, HFC-43-10mee, HFC-125, HFC-365mfc, R-417A, R-422D and R-508) has been sporadic and exploratory, so no trends are recorded.

5. Characterization of the HFC User Market

To characterize the HFC user market, baseline consumption information was used and information compiled through surveys and technical documents. The former was constructed based on HFC import/export records provided by the National Customs Service, as described in the previous chapter.

Surveys were conducted through semi-structured questionnaires taking into account themes of interest and characteristics of the surveyed use sector. These were given to representatives of companies dedicated to HFC importation, representatives of companies that maintain and install equipment, and representatives of companies that use equipment with HFCs, such as supermarkets, appliance manufacturers, hospitals, independent professionals with experience related to these substances, and others. The following characteristics took priority in compiling the survey list: experience of the professional in the category, importance of the company with respect to amounts of HFC imported, and company presence in the market in its category.

The respective technical documents were obtained from reliable sources, such as the Climate Change area of the United States Environmental Protection Agency (US EPA), the Ozone Secretariat of the United Nations Environment Programme (UNEP) and the United Nations Framework Convention on Climate Change (UNFCCC), among others.

The HFC market is characterized by a high concentration at the beginning of the consumption chain, at the level of importers. Consumption is considerably scattered farther upstream, where the chain includes distributors and installers of refrigeration and air conditioning equipment.

The main user sectors identified[15] in national consumption are summarized in the following list with their respective applications, and outlined in the preceding Table N° 14:

Refrigeration

- Domestic refrigeration
- Commercial refrigeration (stand alone equipment, *e.g.* refrigerated display cases for beverages, medium and low-temperature horizontal coolers, and others).
- Industrial refrigeration (e.g., supermarkets, food industry, forest industry, etc.).
- Refrigerated transportation (e.g., trucks and reefers)

[15] Since HFC is not used in the foam industry it is not included in the analysis of national consumption.

Air Conditioning

- Stationary air conditioning (*e.g.* splits, compact equipment, chillers)
    - Residential equipment (*e.g.* company equipment, wall-mounted split) and commercial (*e.g.* console split system, duct separated systems, cooler units)
    - Air conditioning systems (*e.g.* chillers)
- Mobile automotive air conditioning
- Others (Metro, military sector, industrial)

Solvent and Aerosols

Fire Protection

Other Uses: Treatment of the surfaces of glass bottles[16]

These user sectors are characterized and described below to illustrate their relative importance in national HFC consumption. Based on this, a general estimate of the distribution of each HFC (pure and blends) in the user sectors is also shown.

Table N° 14: Identification of HFC use sectors

SECTOR	Chesterton SP 296®	HFC-125	HFC-134a	HFC-152a	HFC-227ea	HFC-23	R-404A	R-407C	R-410A	R-507A
Refrigeration										
Domestic refrigeration			X							
Commercial refrigeration			X				X			
Industrial refrigeration and supermarkets						X	X			X
Refrigerated transport			X				X			
Air Conditioning										
Stationary air conditioning, compact equipment			X					X	X	
Stationary air conditioning, air conditioning systems			X					X	X	
Mobile air conditioning			X				X			
Other air conditioning			X							
Solvents and Aerosols	X		X	X						

[16] Source: Information provided by HFC-152a importer

SECTOR	Chesterton SP 296®	HFC-125	HFC-134a	HFC-152a	HFC-227ea	HFC-23	R-404A	R-407C	R-410A	R-507A
Fire Protection		X			X					
Other Uses (glass treatment)				X						

Source: by author based on surveys of importers and users

Table N° 14 breaks down the different applications in HFC consumption, with HFC-134a used most in the various air conditioning and refrigeration subsectors. This is in line with import and consumption data on these substances. HFC-134a along with R-404A, R-407C, R-507A and R-410A represent more than 90% of national consumption, as reflected in Table N° 15. As for distribution in different sectors, HFC-134a is the only substance with applications in almost all of them; R-404A and R-507A are used specifically in refrigeration, R-407C and R-410A in air conditioning and HFC-125 and HFC-227ea in fire protection and in Chesterton SP 296® as solvent. Consumption volumes of any other substances in 2012 is practically negligible, thus demarcating and clarifying consumption in each user sector. To lesser degree, HFC-152a is used in the wine industry to eliminate impurities and porosity on the surface of glass materials[17].

Table N° 15: Amount of pure HFC and blends most consumed in refrigeration and air conditioning (2008 – 2012, kg)

HFC	2008	2009	2010	2011	2012
HFC-134a	233,720	256,334	379,067	413,802	350,133
R-404A	184,811	104,848	205,751	197,337	236,038
R-407C	31,528	29,836	35,601	46,616	24,071
R-410A	2,825	18,363	31,605	69,955	60,320
R-507A	22,775	33,408	80,479	138,729	196,080
Grand Total	475,659	442,789	732,503	866,439	866,642
% of total consumption	95.1%	93.41%	96.03%	93.19%	94.68%

Source: by author based on information from the National Customs Service

In sum, the refrigeration and air conditioning sector represents approximately 95% of HFC consumption in the 2008-2012 period, primarily HFC-134a, R-404A and R-507A (see Table N° 15). HFC uses and applications in the different sectors and subsectors are described in the following sections.

5.1. Refrigeration

[17] Document "Propuesta de mejora del nivel metodológico de Estimación de las emisiones generadas por la subcategoría de Consumo de halocarbonos del Inventario de Emisiones de Gases de Efecto Invernadero". Instituto Nacional de Ecología y Cambio Climático (INECC), United Nations Development Program (UNDP), Mexico, Chile.

5.1.1. Domestic refrigeration

This sector comprises refrigeration equipment for domestic use, such as refrigerators and freezers, in the different formats and sizes available in the market. Of the two companies that produce refrigerators in Chile, the one with the largest sales volume, CTI S.A., uses HFC-134a. Síndelen has switched to isobutane (R-600a) in phasing out use of CFC-12 in its refrigerators, so is not included in this analysis.

The sector represents an estimated 15% of all HFC-134a use in the country, with CTI S.A. the primary consuming company in manufacture of domestic refrigerators. Most HFC consumption occurs in maintenance of existing equipment.

5.1.2. Commercial refrigeration

The systems[18] and/or equipment in this category are used to maintain the temperature of fresh produce and beverages and store frozen foods: refrigerated display cases, ice machines and others. These are used in commercial premises supplying the public, signifying that their distribution is scattered among multiple owners of small locales.

The sector is estimated to represent some 5% of HFC-134a consumption and 15% of R-404A in the manufacture of stand-alone equipment. There is one main producer of display refrigerated cases (MIMET) and several small companies. The refrigerant is used in the initial charge during equipment manufacture and servicing operations.

5.1.3. Industrial refrigeration and supermarkets

According to Chilean Standard NCh3241-2011, systems and/or equipment in this category are "aimed at processes in the food, chemical, plastics, wine and other industries, and in storage, through cold chambers, refrigeration plants, food processors, slaughterhouses, and others."

The category also includes supermarket refrigeration systems that use centralized systems supplying refrigerators, back room equipment, along with equipment distributed in the stores as shelving or islands for medium-temperature refrigeration, used for preserving vegetables, meats, cold cuts, dairy products and desserts available for sale to the public.

HFC use in refrigerants for industrial refrigeration is limited and mainly concentrated in R-507C and R404A (or the substances HFC-507C and HFC-404A). The study also identified specific use of HFC-23 in systems requiring critical temperatures (-80°C).

Supermarkets also have stand alone equipment using HFC-134a. Currently there is a large quantity of installed equipment with HCFC-22; once its use life ends it is being replaced with new equipment using HFC.

The dominant supermarket conglomerates are Walmart, Cencosud, SMU and Tottus.

[18] Definition of NCh 3241-2011, Good Practices in Refrigeration and Air Conditiong Systems (*Buenas Prácticas en Sistemas de Refrigeración y Climatización*), INN with authorization for the Chilean Ministry of Environment; 2011.

5.1.4. Refrigerated transport (reefers, trucks)

Chilean Standard NCh3241-2011 defines systems and/or equipment in this category as that "aimed at preserving the cold chain and process temperature and that used in refrigerated vehicles, containers, maritime transport and others."

Refrigerated containers ("reefers") primarily use HFC-134a; R-404A is used for low temperatures ranging from -29°C to -40°C. Each container has a 4-kg charge of refrigerant. Recharge frequency varies depending on the age of the container. A container with very few leaks can go up to five years without recharge.

According to information provided by Sitrans, there are many companies with few trucks and vehicles equipped with refrigeration systems (approximately 15 vehicles per company), leading to an estimated total of some 15,000 refrigerated trucks and vehicles in all Chile, most using HCFC-22. Use of HFC-134a and R-404A for new equipment is currently expanding to comply with restrictions under the Montreal Protocol.

5.2. Air Conditioning

5.2.1 Mobile air conditioning

5.2.1.1 Vehicles (trucks, autos)

According to statistics from the national automotive association (Asociación Nacional Automotriz de Chile-ANAC A.G.), 248,720 air-conditioned vehicles were traded in 2012, amounting to 73% of all sales. These vehicles are imported with air conditioning installed and charged with HFC 134a refrigerant. This sector is responsible for approximately 15% of HFC-134a consumption for maintenance and recharge of the installed equipment. A lesser portion use R-404 in buses and trucks.

5.2.1.2 Others (Santiago Metro, planes, military)

Other air conditioned transportation systems include Metro de Santiago, planes and armed forces vehicles (e.g., planes and tanks). For this study it was confirmed that Metro cars use R-407C, R-410A and HFC-134a.

5.2.2 Stationary air conditioning systems

This application corresponds to compact equipment and air conditioning systems used in public and private buildings.

There is a wide variety of equipment in the market. Compact equipment includes split (ceiling split, wall-mounted and duct); multi-split, window-mounted, compact and backpack equipment (self-contained equipment). Also used are air conditioning systems with centralized equipment that then distributes the cold/heat to the installation or building. This subsector contains installations such as chillers and, finally, VRV (Variable Refrigerant Volume) equipment, which is more important in building installations.

HFC-134a, R-407C and R-410A are mainly used in this subsector. Installed equipment mostly contains HCFC-22, now declining in new equipment thanks to restrictions on import.

5.3. Solvents and Aerosols

A large variety of propellants are used in the aerosol subsector, such as the hydrocarbons n-butane and isobutane. Only a slight percentage of aerosols use HFC-134a in small quantities. During meetings it was reported that HFC-152a has been tested, but not yet proposed for regular use due to market conditions.

Chesterton SP 296® is used a great deal for solvents as HFC blend: 40-50% HFC-134a, 20-30% HFC-245fa, 20-30% HFC-365mfc, the one that comes in a preparation ready-made for sale and use.

5.4. Fire Protection

Fire protection applications cover 5.1% of total HFC consumption (2012), a direct calculation since this sector uses two HFCs exclusively. The main substance used is HFC-227ea, sold under the brand name FM-200® (DuPont), followed by HFC-125. HFC-227ea is mostly imported from the United States (Table N° 17). The tables below show HFC consumption from 2008 to 2012 and imports of HFC-227ea by country of origin.

Table N° 16: HFC Consumption in fire protection (2008 – 2012, kg)

HFC	2008	2009	2010	2011	2012
HFC-227ea	14,120	20,183	21,275	46,662	42,735
HFC-125	6,889	6,483	4,354	10,564	3,685
Total	21,009	26,666	25,629	57,226	46,420
% of total HFC consumed	4.21%	5.63%	3.36%	6.15%	5.07%

Source: by author based on information from the National Customs Service

Table N° 17: Amounts of HFC-227ea imported, by country of origin 2008 – 2012, kg)

Country	2008	2009	2010	2011	2012
United States (USA)	14,232	15,924	16,464	33,580	35,738
China		4,000	4,000	12,000	7,000
Italy		360	805	771	
Spain				307	
Grand Total	14,232	20,284	21,269	46,658	42,738

Source: by author based on information from the National Customs Service

5.4.1 Stationary fire protection systems

Stationary systems can be installed in mobile equipment such as electric shovels or drills in the mining sector, or placed in stationary installations such as data centers or offices. HFC is used in low concentrations to fight fires compromising the electrical part (Class C).

An estimated 70% of HFC consumption in this sector is used in data centers and 30% in electric shovels. In turn, 70% of this consumption goes to installing new systems and the remaining 30% to recharge existing equipment. Of total recharge, 80% is used in electric shovels, which have an escape rate much higher than in stationary systems.

The HFC used most is HFC-227ea, followed by HFC-125. As low and zero GWP alternative, NOVEC 1230® would be coming into the market as definitive replacement for the HFCs.

5.4.2 Portable extinguishers

HFC-23 is used in some portable extinguishers, which are imported with the respective charge.

5.5. Other Uses

The only application not classified in the sectors previously described corresponds to use of HFC-152a in manufacturing glass. This substance is also used as sample in industrial refrigeration applications, however no regular use is discerned that would indicate trends for any of the uses identified for this substance.

In the particular case of the glass industry, there is a minor development in that previous use of CFC 12 is turning to HFC 152a. The basis for this market involves injecting the product at the moment the glass piece is fabricated (mainly in the wine industry) with the aim of eliminating surface impurities and porosities through a reaction between components of the glass at a high temperature[19].

[19] Document "Propuesta de mejora del nivel metodológico de Estimación de las emisiones generadas por la subcategoría de Consumo de halocarbonos del Inventario de Emisiones de Gases de Efecto Invernadero". Instituto Nacional de Ecología y Cambio Climático (INECC), United Nations Development Program (UNDP), Mexico, Chile.

6 HFC Consumption by User Sector

Based on meetings and surveys of expert users in HFC use and refrigerants in general, estimated consumption by sector and subsector reveals the most important for each substance (Table N° 18 and Figure N° 4). Estimates take into account main current uses, where it is possible to establish sectors that require more analysis and main risks of consumption rising over time, providing the foundation for the trend analysis in the next chapter.

Table N° 18: Estimated percent distribution of HFC by sector (2012)

SECTOR	Chesterton SP 296®	HFC-125	HFC-134a	HFC-152a	HFC-227ea	HFC-23	R-404A	R-407C	R-410A	R-507A
Refrigeration										
Domestic refrigeration			15%							
Commercial refrigeration			5%				20%			
Industrial refrigeration and supermarkets						100%	70%			100%
Refrigerated transport			22%				10%			
Air Conditioning										
Stationary air conditioning, air conditioning systems			15%					100%	100%	
Mobile air conditioning			40%				(*)			
Other air conditioning			2%							
Solvents and Aerosols	100%		1%							
Fire Protection		100%			100%	(**)				
Other Uses (glass manufacture)				100%						

Source: by author based on interviews with importers

(*) R-404A in mobile air conditioning is used in minimal quantities and therefore not included in this estimate.

(**) HFC-23 would be used in portable extinguishers entering as “product” (e.g., “extinguisher”) and not as substance (e.g., HFC), so amount imported is not known. According to statistics from the National Customs Service, import of pure HFC-23 is as industrial refrigerant.

With the estimated percent consumption by sector we can add total kg of pure HFC and blends consumed to obtain total consumption of these substances by each sector, which is reflected in Figure N° 4. Topping the list is consumption in industrial refrigeration and supermarkets, which is marked by R-404A and R-507A, substances destined mainly for this sector at approximately 40%

of total HFC consumption. Ranking second, third and fourth at very similar shares around 15% are mobile air conditioning, stationary air conditioning and air conditioning systems, and refrigerated transport. The third most important group of applications corresponds to commercial and domestic refrigeration and fire protection, with approximately 5% of total consumption in each sector. Finally, both solvents and aerosols and other minor applications take up in total less than 2% of national consumption.

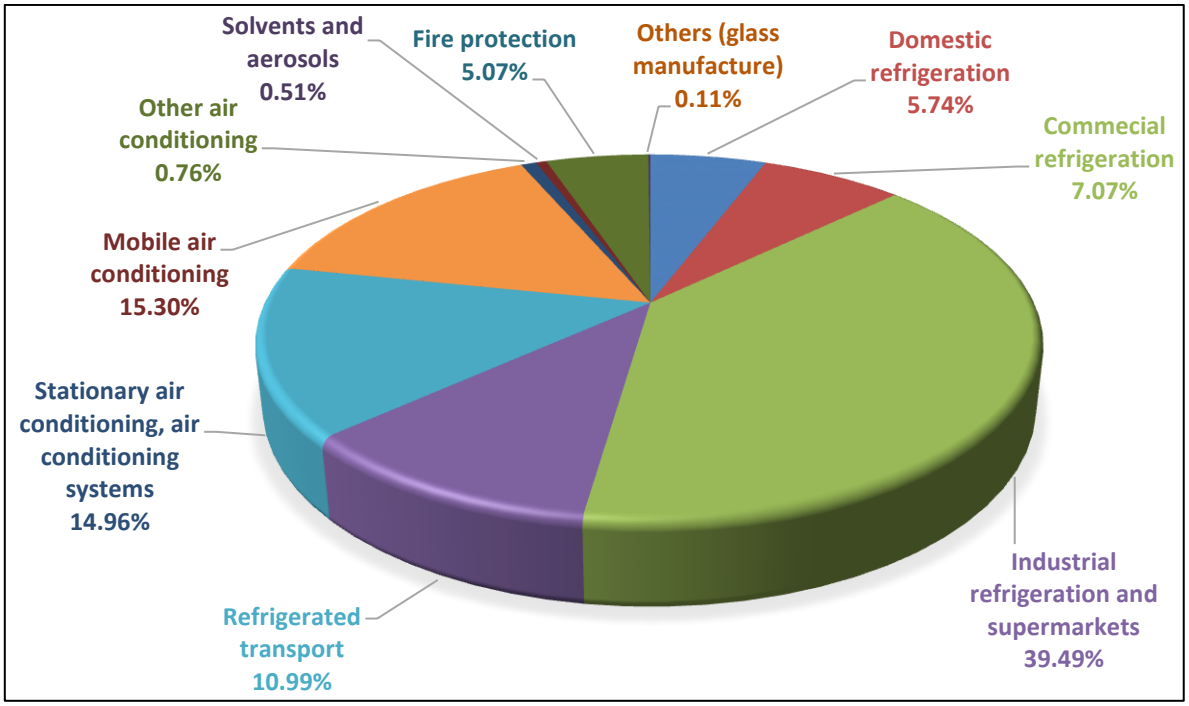
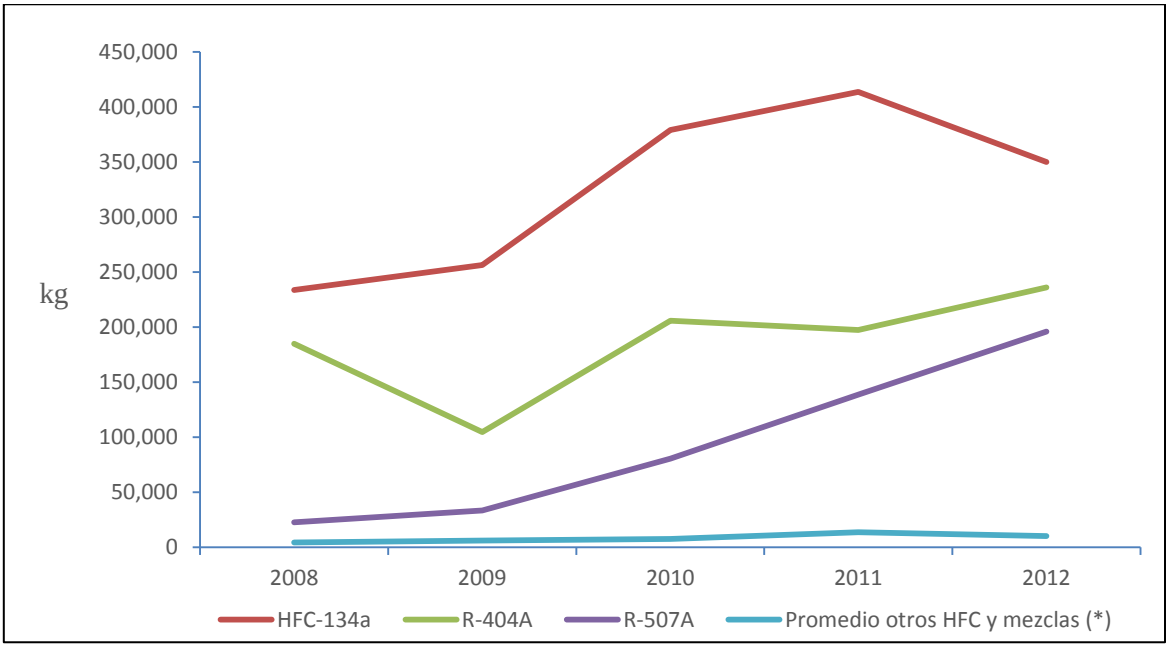


Figure N° 5: Estimated percent distribution by HFC use sector (pure and blends) (2012)

7 Trends in HFC Consumption

To analyze HFC consumption trends, consumption and its historical growth was examined against the market applications where they are used. In other words, their behavior as shown in substances used in refrigeration and air conditioning markets, which represent more than 90% of total consumption, as seen previously. Based on this analysis, the evolution of user markets and their characteristics with respect to the substances that have predominated in each one were considered. Evolution in consumption of HFCs and their blends during the study period (2008 to 2012) is thus presented in Figure N° 5, and the growth rate of each substance calculated. This is compared with the trend of HCFC-22 consumption, since this refrigerant is subject to restrictions under the Montreal Protocol and is being replaced by HFC in other applications. Assumptions for estimating forecasts on growth are established on this basis.

The figure below indicates consumption evolution for each HFC and its blends during the period, according to import and export data of the National Customs Service.



HFC-134a *R-404A* *R-507A* *Average other HFC and blends(*)*

Figure N° 6: Evolution in consumption of each HFC and its blends (2008-2012, kg)
(*) Corresponds to the average of the amounts of refrigerants consumed (and graphed in Figure N° 7): HFC-23, HFC-43-10mee, HFC-125, HFC-152a, HFC-227ea, HFC-365mfc, R-407C, R-410A, R-417A, R-422D, R-508B and Chesterton SP 296®

Likewise, Figure N° 7 shows evolution of consumption of other HFCs and blends that are consumed in amounts less than 100,000 kg/year.

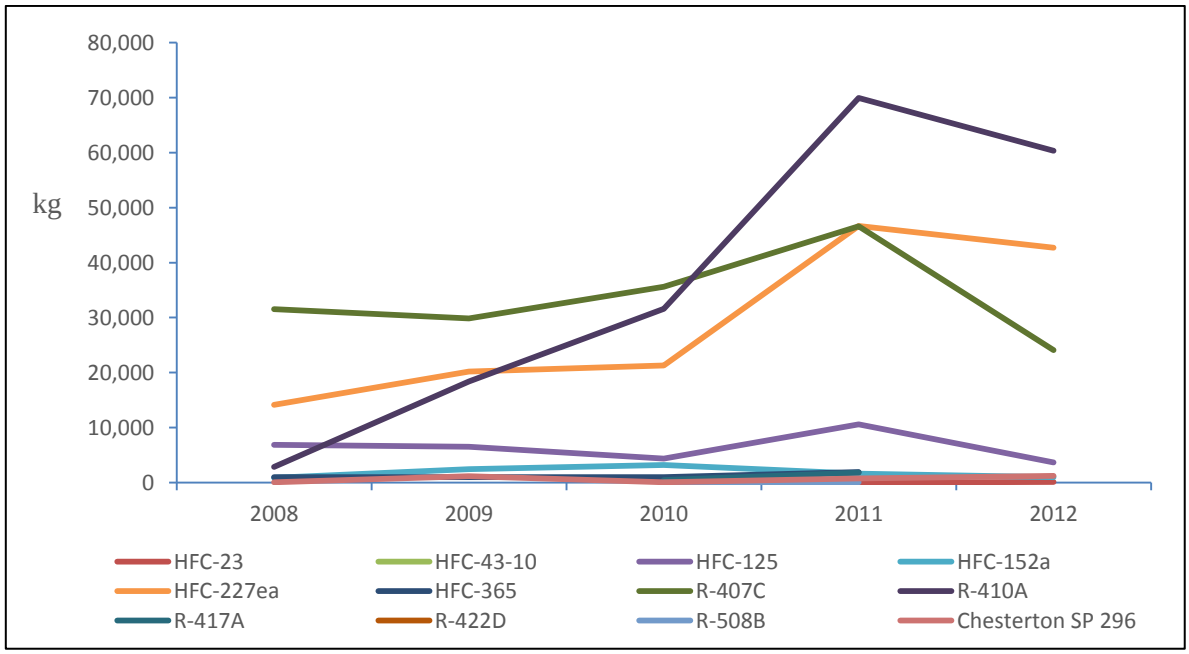


Figure N° 7: Evolution of consumption of HFC and blends of lesser amount (2008 – 2012)

HFC-134a stands out as the main HFC used in Chile, with marked growth up to 2011 and significant decline in 2012, resulting in a more moderate compound growth rate for the period. Other imported substances showed rose steadily except for R-407C, as observed in the following summary table.

Table N° 19: Compound rate of growth of main HFCs and their blends, compared to HCFC-22 (2008-2012)

HFC	Compound Growth Rate
HFC-134a	10.6%
R-404A	6.2%
R-407C	-5.4%
R-410A	115.0%
R-507A	73.4%
HCFC-22	1.1%
Total Growth of Refrigerants	7.5%

Source: by author based on Customs information

Table N° 19 shows that the HFCs with highest compound growth rate were R-410A and R-507A. Nonetheless, it should be noted that these are blends whose consumption volumes are lower compared to HFC 134a, having been introduced in the market in recent years and their uptake occurs from 2010 on, when consumption of R-507A doubled and tripled volumes consumed of R-410A.

In turn, growth in consumption of HFC-134a and R-404A has been moderate, with both showing an important share of HFC consumption since 2008. The only refrigerant that declined during the

period was R-407C; while it peaked in 2011, no definite trend can be observed. According to experts, this refrigerant has not been important in its application primarily for technical reasons associated with its handling, indicated as response to the advantages of using series 500 instead of series 400 refrigerants in those applications.

This advantage is explained by the fact that series 500 refrigerants, azeotropic mixtures[20], are liquid-gas mixtures that do not decompose from phase-change or pressure. In practice, this means that in case of leaks, the refrigerant is lost in the same proportion and can only be recharged in the missing quantities. In exchange, series 400 refrigerants, zetropic mixtures[21], decompose when the phase or pressure changes so when there is a leak the entire contents of the refrigerant circuit must be replaced, which can be anticipated especially in systems most vulnerable to leaks.

7.1 Projection of HFC Consumption Compared to HCFC-22

Estimation of future growth was based on an analysis of the refrigeration and air conditioning market, which makes up approximately 95% of HFC consumption. It is important to consider the behavior of these industries as a whole in estimating that of HFCs as substances largely being introduced as alternatives to those used historically, especially now with the scheduled phase-out of HCFC. This will impact on demand for alternative substances, particularly certain HFCs, as will be discussed further on.

In this context, trend analysis will focus on the main HFC-based refrigerants along with HCFC-22, as shown in both Table N° 20 and Figure N° 6. These indicate that imports of HCFC-22 are at a relative standstill while the main HFCs used in refrigeration and air conditioning rose significantly during the same period.

[20] Blend of two or more refrigerants of differing volatility which when they change phase at constant pressure do not change their composition in volume or saturation temperature. Their behavior is like that of a pure compound (NCh 3241-2011, INN-MMA, 2012, Good Practices in Refrigeration and Air Conditioning).

[21] Blend of several refrigerants with different volatility characteristics, which when they change phase at constant pressure change their composition in volume or saturation temperature. (NCh 3241-2011, INN-MMA, 2012, Good Practices in Refrigeration and Air Conditioning).

Table N° 20: Evolution in consumption of HFCs used in refrigeration and air conditioning, compared to consumption of HCFC-22 (2008 – 2012)

	2008 (kg)	2009 (kg)	2010 (kg)	2011 (kg)	2012 (kg)
Total HFC (*)	475,659	442,789	732,503	866,439	866,642
HCFC-22	829,485	920,652	797,723	1,045,280	864,886
% HCFC-22 v/s HFC(*)	63.56%	67.52%	52.3%	54.68%	49.95%

Source: by author based on information from the National Customs Service
(*) Total HFC corresponds to the sum of consumption of the substances R-404A, R-507A, R-410A, R-407C and HFC-134a, used in refrigeration and air conditioning

Except in 2009, percent consumption of HCFC-22 declined against that of HFC and blends used during the period. However, consumption of HCFC-22 remained constant with no definite trend detectable. The fact that its growth has not matched that of HFCs meant that relative share dropped from 63% to around 50%, a trend that can be expected to deepen in the future especially once restrictions on HCFCs under the Montreal Protocol enter into force.

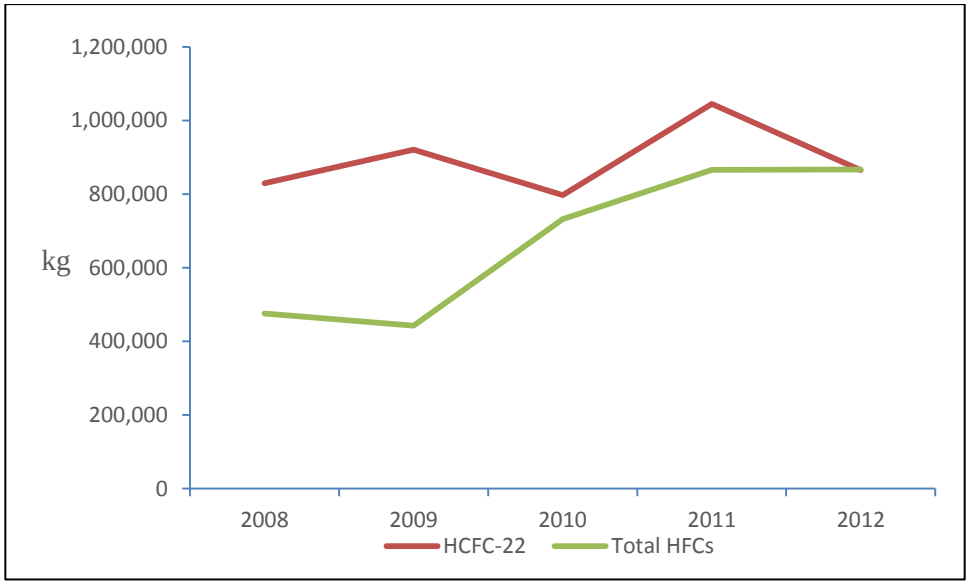


Figure N° 8: Evolution in consumption of HFC[22] used in refrigeration and air conditioning compared to HCFC-22 (2008 – 2012, kg)

In this context, an estimate was made taking into account the aforementioned core elements, first, identification of the historical growth rate of HFCs used in the sector along with HCFC-22. This provided the basis for a series of assumptions enabling a quantitative estimate of growth in HFC consumption.

- It is assumed that growth in consumption of the substances will remain constant at the rate of the last five years, calculated at 7.5%, as indicated in Table 19.

[22] Total HFC corresponds to the sum of HFC-134a, R-404A, R-407C, R-410A and R-507A consumption.

- Different growth rates are assumed for HFC substances, in accordance with the historical rates for each one.

- The order of consumption growth rates was maintained as follows: R-410A > R-507A > HFC-134a > R-404A > R-407C.

- The estimate was forecasted up to the year 2020, in consideration of the time horizon of the Climate and Clean Air Coalition for countries to voluntarily phase out pollutants.

- HCFC-22 consumption goals established in the Montreal Protocol phase-out timeline will be met as if they were an individual goal. Hence, their baseline is calculated as average consumption in 2009 and 2010, and on that basis future consumption is defined taking into account the freeze in 2013 and reductions in 2015 and 2020 (the 2030 and 2040 goals are outside the scope of this forecast).

- It is assumed that R-410A replaces HCFC-22 for recharge operations and absorbs the differential between the total sum of refrigerants and industry forecast with respect to the substance.

Prepared bearing these assumptions in mind, Table N° 21 shows estimated future growth of HFCs, wherein each substance generally maintains its trend or relative tendency, at least, and the market is compared in light of HCFC restrictions.

It can be observed that HFC-134a, now the predominant substance of that group imported and used, could be reached by R-507A in 2020, while R-404A and R-410A consumption would rise significantly.

This situation is also borne out in the refrigeration and air conditioning industry, since to date the HFCs, particularly blends showing strong growth, are considered replacement substances for HCFCs, especially HCFC-22. This is reinforced by the fact that these substances may be subject to future restrictions under the United Nations Framework Convention on Climate Change. New equipment and installations are also primarily using HFC and its blends, including those with strong entry into the market, such s R-507A.

On the other hand, estimation of growth in future consumption takes into consideration that HFC-134a has been a replacement substance for CFC-12 and not for HCFC-22, meaning that its growth currently has to do with growth of consumption in the market. Unlike some of the blends, high growth rates driven by HCFC-22 replacement would occur, especially in air conditioning applications, as in the situation of R-410A.

Table N° 21: Future Growth Scenarios (2013-2020, kg)

Substance	Rate Assumed	2013	2014	2015	2016	2017	2018	2019	2020
HFC-134a	10,63%	387,376	428,543	474,084	524,465	580,200	641,859	710,069	785,529
R-404A	7,5%	253,753	272,784	293,243	315,236	338,879	364,295	391,617	420,988
R-407C	1%	25,453	25,708	25,965	26,224	26,487	26,751	27,019	27,289
R-410A	26,5%	104,488	140,806	259,907	288,754	311,815	327,340	333,219	541,720
R-507A	18%	242,842	286,553	338,133	398,997	470,816	555,563	655,564	773,566
Total HFC	**14,08%**	**1,013,912**	**1,154,394**	**1,391,332**	**1,553,676**	**1,728,197**	**1,915,808**	**2,117,488**	**2,549,092**
HCFC-22	MP target	859,188	859,188	773,269	773,269	773,269	773,269	773,269	558,472
Total		**1,873,100**	**2,013,582**	**2,164,601**	**2,326,945**	**2,501,466**	**2,689,077**	**2,890,757**	**3,107,564**

Source: by author based on information from the National Customs Service

8 Technical Alternatives to HFCs

Study and research on production of alternative technologies for widely used refrigerants has been ongoing since the need to phase down CFC. A great quantity of alternative substances has been developed and uptaken along the way. Among these, the so called “transition” substances and substances affecting global warming (HFCs) have stood out, along with a series of refrigerants and natural substances that have been quite successful in certain applications. Nonetheless, today there are applications for which tested and economically viable alternatives are not yet available, which is problematic in the attempt to phase out and eliminate HFC consumption.

This chapter presents the main alternative substances for ODS and now HFCs for the refrigeration, foam, fire protection and solvents sectors, identified as potential replacements by the Technical and Economic Assessment Panel (TEAP) of the Montreal Protocol in its May 12, 2012 publication, “Additional Information on Alternatives to Ozone-Depleting Substances”. This is later summarized in a table with alternative substances in each sector, understanding that in many cases there are only potential alternatives that are untested and/or high cost.

Below are those low GWP options analyzed in the TEAP report.

a) Refrigeration and Air Conditioning

Refrigerant	GWP	**Application**	Other Comments from the Report	Current Status	Efficiency	Flammability	Toxicity
R-744	1	CR, HP, CH	CR (units): viable in cool and moderate climates, but the equipment is not available for all capacities Central systems: viable in cool and moderate climates with direct expansion systems in a trans-critical/sub-critical cycle depending on the ambient temperature	CA	Similar to HCFC-22		
R-717	0	CR, AC, HP, CH		CA	Similar to HCFC-22	+	++
HC-290	< 20	CR, AC, HP, CH	CR: requires more development to optimize safety in larger-capacity systems	CA	Similar to HCFC-22	+++	
HC-1270	< 20	CR, AC, HP, CH		CA	Similar to HCFC-22	+++	
HFC-161	12	CR, AC, HP, CH		PT	Similar to HCFC-22	+++	
Unsaturated HFC (HFO-1234yf)	<4,4	HP, CH, CR	CR: no components available	PT	Probably similar to HCFC-22	+	
Unsaturated HFC (HFO) blends		CR, AC, HP, CH		PT			

Source: TEAP (Technology and Economic Assessment Panel), May 2012, Table 3-9 "Additional Information on Alternatives to Ozone-Depleting Substances"

Abbreviations:
CR: Commercial refrigeration
AC: Air conditioning
HP: Heat pump
CH: Chiller
CA: Commercially available
PT: Prototype testing

It should be mentioned that in some sub-sectors implementation of low GWP alternatives requires the design of new refrigeration systems, as in the case of centralized systems in supermarkets. Some of the options proposed in the report are:

- Indirect systems
- Evaporating secondary systems
- Cascade systems
- Indirect distributed systems
- Hybrid systems involving a combination of any of the above

This report also indicates that certain risks must be born in mind regarding these substances, such as flammability in the case of HFC-161[23], HC-290, HC-1270[24], R-717 and HFO-1234yf[25]. For some of them, international safety standards limit the quantity of refrigerant that can be used in certain situations and also demand special construction features, including elimination of potential sources of ignition. With respect to R-717 toxicity, there are international safety standards limiting its use.

b) Fire Protection

A viable alternative for fire extinction systems at local level is NOVEC 200® by 3M, a commercial product being introduced into the market.

c) Solvents and Aerosols

Consumption of HFC and its blends is negligible in this industry. Based on interviews, there seem to be no issues in substituting HFC with alternative substances now being used without restriction in the market.

d) Foams

Even though Chile does not use HFC in foam manufacturing, HCFC elimination could induce a rise in consumption of HFC-245fa and the blend of HFC-365mfc and HFC-227ea (added to lower the blend's flammability), both with high GWP. In these cases the low GWP options visualized are use of hydrocarbons, CO_2 and especially unsaturated HFC or HFO.

[23] Fluoroethane. HFA-161; HFC-161; Monofluoroethane; R-161; R 161; CAS Number . http://www.epa.gov/enviro/html/emci/chemref/353366.html http://nj.gov/health/eoh/rtkweb/documents/fs/0884.pdf (New Jersey Department of Health and Senior Services, "Hazardous Substance Fact Sheet – Ethyl Fluoride"). Consulted September 12, 2013.

[24] Propene. 1-Propylene; HC 1270; Methylethylene; Propylene; R 1270; CAS Number 115-07-1. http://www.epa.gov/enviro/html/emci/chemref/115071.html y http://nj.gov/health/eoh/rtkweb/documents/fs/1609.pdf (New Jersey Department of Health and Senior Services; "Hazardous Substance Fact Sheet – Propylene"); Consulted September 12, 2013.

[25] HFO-1234yf, hidrofluoroolefina de fórmula 2,3,3,3-tetrafluoropropileno, CAS 754-12-1; ODP = 0 and GWP = 4. Manufactured by Honeywell and Dupont. http://www.epa.gov/cpd/mac/Final%20EPA%20HFO-1234yf%20Coml%20Mtg_2_6_09,%20Modified%20Version.pdf. Consulted September 12, 2013.

9 Conclusions

Chile's HFC market is dominated by imports, with exports minimal at approximately 1%. Of those imports, 85% corresponds to three: HFC-134a, R-404A and R-507A. In turn, 95% of consumption is associated with substances used in refrigeration and air conditioning, with the remainder primarily used in fire protection systems, and a lesser portion (around 2%) in aerosols and other minor uses.

Around 90% of HFCs brought into Chile come from China, whose share of imports rose by some 50% during the period analyzed (2008-2012), a trend that is expected to strengthen in the next few years thanks to low prices compared to other exporter countries, especially the United States.

With regard to exports, these are sporadic with the exception of R-507A to Peru. This has been increasing over the past three years due to a specific trade relation of Chilean companies in Peru.

As for specific consumption by sector, the main substance, HFC-134a, is used in several while two others, R-404A and R-507A, are coming into the industry with high rates of growth. R-410A, another substance of interest due to its high growth, is being used as substitute in applications that use HCFC-22. During the study period consumption of this substance rose more than 100% a year, doubling from year to year, a clear trend indicating that its participation in the market will become more important in upcoming years.

In this context, estimation of growth in total refrigerant consumption (including HCFC-22) assumes that the historical rate of 7.5% (2008-2012 period) will remain constant. In this scenario, and assuming that HCFC-22 maintains the proportion of consumption goals committed to in the Montreal Protocol, growth of HFC consumption is quite pronounced at 14% annually. At this yearly rate, total growth from 2013 to 2020 would reach approximately 250% in total HFC consumption for refrigeration and air conditioning.

In this growth scenario and in light of industry perception toward use in new installations and equipment with HFC, actions are deemed necessary if the objective is to control that growth and avoid high costs of conversion should there be a need for measures to reduce consumption in the industry. In this sense, it is also necessary to work on developing projects aimed at modifying the likely growth scenario toward one in which refrigerants are more in line with low GWP alternatives.

10 Future Perspectives

The context presented in this study points to the advisability of developing demonstration investment projects that encourage the industry to consider low GWP alternatives, particularly the following.

Refrigeration and Air Conditioning

- Conversion toward natural refrigerants in the production of compact commercial and domestic refrigeration units (replace HFC-134a with HC-600a)
- Demonstration projects in supermarkets aimed at replacing HFCs with R-744 (CO_2), based on technologies such as:
    - Cascade systems using R-717 (ammonia)/R-744 (CO_2)
    - Cascade systems using R-290 (propane)/R-744 (CO_2)
    - Trans-critical systems using R-744 (CO_2) (demonstration project)
- Demonstration projects for refrigerated containers (reefers) using R-744 (CO_2)
- Demonstration projects for air conditioning in public buildings using low GWP refrigerants

Foams

This sector, specifically with respect to discontinuous panels and spray applications using HCFC-141b, offers opportunity to introduce safe low-GWP options also improving energy efficiency. Projects recommended for this purpose include:

- Demonstration projects to develop formulations based on unsaturated CO_2/HFC (HFO) offering a good cost/performance balance for discontinuous panels in a developing country
- Demonstration projects to develop formulations based on unsaturated CO_2/HFC (HFO) offering a good cost/performance balance for spray applications in a developing country.