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HFC Emissions Report for Chile

Prepared under contract to UNDP for CCAC

PROJECT OBJECTIVE

TO DEVELOP AN EMISSIONS MODEL FOR HFCs IN CHILE BASED ON INFORMATION AND MATERIALS GENERATED IN AN EARLIER COUNTRY REVIEW OF HFC CONSUMPTION.

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OUTLINE OF THE BASIC METHODOLOGY

The CCAC sponsored HFC Survey (GISMA Report) on the historic consumption of HFCs in Chile and the predictions in growth in demand to 2020 has been used as the basis for the assessment of likely emission profiles. Annual demand within Chile can be viewed as being consumed in either one of two ways:

1. Servicing demand to replace refrigerants and fire protection agents emitted during the year

or

2. Demand created by the installation of new products or equipment within the year

All demand for sectors such as foam will fall into the 'new product' category, since no servicing of foam products takes place once installed. However, the split between (1) and (2) for refrigerants and fire protection agents will depend on the balance between annual leakage rates by sector and the growth in the overall installed base of relevant equipment.

For the purposes of this work, it has been assumed that the historic and projected consumption values for each HCFC and HFC (and blends thereof), as presented in the GISMA Report, are reliable. This sets a clear value on the sum of (1) + (2). Hence, the identification of leakage rates in each sub-sector will have an immediate bearing on the projected growth of the installed base, since diversion of consumption into servicing will result in lower allocations to new equipment and vice versa.

ANALYSIS OF CONSUMPTION AND DERIVATION OF EMISSIONS

The model to assess emissions of HFCs from various sources was developed by firstly generating an analysis of consumption patterns for each agent (whether an individual substance or a blend) by sub-sector of use. In the case of Chile, this was assisted by Table 18 of the HFC Survey which provided the necessary sub-sectoral analysis to support this. Projections through to 2020 were extracted from Table 21. It was assumed that the percentages assigned in Table 18 remained constant over the period to 2020. An example of the outputs from this development is shown for HFC-134a in Table 1 overleaf.

	Kg						Consumption of Gas by Sector - HFC134a									
			%	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
	Total Consumption			233,720	256,334	379,067	413,802	350,133	387,376	428,543	474,084	524,465	580,200	641,859	710,069	785,529
Sector	Refrigeration	Domestic	15%	35,058	38,450	56,860	62,070	52,520	58,106	64,281	71,113	78,670	87,030	96,279	106,510	117,829
		Commercial	5%	11,686	12,817	18,953	20,690	17,507	19,369	21,427	23,704	26,223	29,010	32,093	35,503	39,276
		Industrial/Supermarkets	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
		Transport	22%	51,418	56,393	83,395	91,036	77,029	85,223	94,279	104,298	115,382	127,644	141,209	156,215	172,816
	Air Conditioning	Stationary A/C	15%	35,058	38,450	56,860	62,070	52,520	58,106	64,281	71,113	78,670	87,030	96,279	106,510	117,829
		Mobile Air Conditioning	40%	93,488	102,534	151,627	165,521	140,053	154,950	171,417	189,634	209,786	232,080	256,744	284,028	314,212
		Other A/C	2%	4,674	5,127	7,581	8,276	7,003	7,748	8,571	9,482	10,489	11,604	12,837	14,201	15,711
	Solvents		1%	2,337	2,563	3,791	4,138	3,501	3,874	4,285	4,741	5,245	5,802	6,419	7,101	7,855
	Foams		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aerosols		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fire Protection		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other Uses		0%	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1 – Consumption trends by sub-sector for HFC-134a (2008-2020)

Although there was less information available on the consumption patterns for HCFCs (notably HCFC-22 and HCFC-141b) in the HFC Survey, Anthesis-Caleb was able to assign appropriate proportions to each sub-sector based on information available from various TEAP Reports and other sources on Article 5 Country consumption patterns. This is shown in Table 2 below:

	Kg						Consumption of Gas by Sector - HCFC-22									
			%	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
	Total Consumption			829,485	920,652	797,723	1,045,280	864,886	606,960	600,000	575,000	550,000	525,000	500,000	475,000	450,000
Sector	Refrigeration	Domestic	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
		Commercial	56%	464,512	515,565	446,725	585,357	484,336	339,898	336,000	322,000	308,000	294,000	280,000	266,000	252,000
		Industrial/Supermarkets	16%	132,718	147,304	127,636	167,245	138,382	97,114	96,000	92,000	88,000	84,000	80,000	76,000	72,000
		Transport	1%	8,295	9,207	7,977	10,453	8,649	6,070	6,000	5,750	5,500	5,250	5,000	4,750	4,500
	Air Conditioning	Stationary A/C	18%	149,307	165,717	143,590	188,150	155,679	109,253	108,000	103,500	99,000	94,500	90,000	85,500	81,000
		Mobile Air Conditioning	1%	8,295	9,207	7,977	10,453	8,649	6,070	6,000	5,750	5,500	5,250	5,000	4,750	4,500
		Other A/C	5%	41,474	46,033	39,886	52,264	43,244	30,348	30,000	28,750	27,500	26,250	25,000	23,750	22,500
	Solvents		1%	8,295	9,207	7,977	10,453	8,649	6,070	6,000	5,750	5,500	5,250	5,000	4,750	4,500
	Foams		2%	16,590	18,413	15,954	20,906	17,298	12,139	12,000	11,500	11,000	10,500	10,000	9,500	9,000
	Aerosols		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fire Protection		0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other Uses		0%	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 – Consumption trends by sub-sector for HCFC-22 (2008-2020)

Anthesis-Caleb has adopted a linear decline in HCFC-22 consumption between 2014 and 2020, recognizing that there are Montreal Protocol obligations in 2020 as outlined in Table 21 of the HFC Survey.

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In a second step, the consumption by agent (substance or blend) as set out by example in Tables 1 and 2 was then transposed to an analysis by sub-sector, which then assembled the different agents used and the emission factors related to each of those sub-sectors. In some instances, where there was evidence of a potential reduction in emission rates over time, this was factored into the modelling of emissions (see Tables 4 & 5 of this Report).

The example of Domestic Refrigeration shown in Table 3 overleaf shows that only HFC-134a is being used as a refrigerant and that emissions are relatively low (1%). However, this emission rate is not simply applied to the annual consumption in the sector, but to the aggregated installed bank of HFC-134a in domestic refrigerators installed across Chile. This, therefore, requires information on the installed equipment base in Chile, which is the subject of the next section of this Report

	Kg					Consumption of Gas by Sector - Refrigeration Domestic									
		%	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
	Total Consumption		35,058	38,450	56,860	62,070	52,520	58,106	64,281	71,113	78,670	87,030	96,279	106,510	117,829
By Gas	HCFC-22	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HCFC-141b	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-134a	100%	35,058	38,450	56,860	62,070	52,520	58,106	64,281	71,113	78,670	87,030	96,279	106,510	117,829
	R404A	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	R407C	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	R410A	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	R507A	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-125	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-227ea	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-152a	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-365mfc	0%	0	0	0	0	0	0	0	0	0	0	0	0	0
	Estimated Bank		1,535,000	1,554,708	1,577,611	1,618,695	1,664,578	1,700,452	1,741,554	1,788,420	1,841,649	1,901,902	1,969,913	2,046,493	2,132,538
	Cons as % Bank		2.28%	2.47%	3.60%	3.83%	3.16%	3.42%	3.69%	3.98%	4.27%	4.58%	4.89%	5.20%	5.53%
	Emissions Est.		1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
	Addn to Bank		19,708	22,903	41,084	45,883	35,874	41,102	46,866	53,228	60,253	68,011	76,580	86,045	96,504
		GWP													
Emissions	HCFC-22	1810	0	0	0	0	0	0	0	0	0	0	0	0	0
(kg)	HCFC-141b	730	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-125	3500	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-134a	1430	15,350	15,547	15,776	16,187	16,646	17,005	17,416	17,884	18,416	19,019	19,699	20,465	21,325
	HFC-143a	4470	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-152a	124	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-227ea	3140	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-365mfc	782	0	0	0	0	0	0	0	0	0	0	0	0	0
	HFC-32	675	0	0	0	0	0	0	0	0	0	0	0	0	0
	$ktCO_2$-eq		21.95	22.23	22.56	23.15	23.80	24.32	24.90	25.57	26.34	27.20	28.17	29.26	30.50

Table 3 – Consumption trends by Refrigerant for Domestic Refrigeration (2008-2020)

INSTALLED BASES BY SUB SECTOR AND EMISSION RATES

As noted previously, in order to determine actual emissions in a year from an installed base, it is necessary to understand the size of that installed base and the likely annual emission rates. The fulfilment of this project was helped by the fact that some prior investigation of these issues had been carried out as part of a project conducted by Río Flores, Cerda, for MMA during the preparation of the Chilean HPMP. The extracted summary overleaf shows the estimates of total stocks of installed refrigerant for various refrigeration and air conditioning sub-sectors, together with an estimate of the annual emission rates associated with each according to Rio Flores.

The installed bases for each sub-sector were taken as reliable and the indicated annual emission rates were then applied. In some instances, the annual emissions calculated from these data exceeded the annual reported consumption, meaning that a reduction in installed base would be necessary to explain this phenomenon. Since this was unlikely in practice, the annual emission rates were corrected to ensure that installed bases in each sub-sector remained at least constant over the period from 2008 to 2020. Table 5 indicates the annual emission rates assumed and the growth in installed base resulting over the 12 year period:

Tabla N° 9: Estimación de Stocks y Flujos de HCFC y HFC usados en R&AA en Chile, por sectores de Uso, incluyendo estimación de cantidades anuales que puedan requerir ser eliminadas

Uso	Consumo (1) GWh	N° Equip. Equiv. Unidades	Tipo de Gas más Usado (2)	Cantidad de Gas por Equipo Kg	Total Stock de Gas (2) Ton	Requeri-miento Anual en Mantención (3) %	Requeri-miento Anual en Mantención Ton/año	Requeri-miento Anual en Eliminación (4) Ton/año
Residencial (R)	2.985	4.386.179	R134A	0,4	1.535	1%	15,4	51,2
Autos (AA)		1.934.780	R134A	0,5	871	5%	43,5	43,5
Camiones (R)		6.408	R134A	10,0	64	5%	3,2	4,3
Com & Serv (AA) (Otros)	124	5.558	R22	250,0	1.390	5%	69,5	46,3
Comercial (R)	3.630	111.140	R22	10,0	1.111	60%	666,8	22,2
Minero (R)	1.029	31.490	R22	10,0	315	5%	15,7	0,5
Agrícola (R)	242	2.964	R22	20,0	59	5%	3,0	0,1
Industrial (R)	3.388	20.746	R22	30,0	622	20%	124,5	4,1
Total R&AA (E)	**11.397**				**5.967**	**16%**	**941,6**	**172,3**

Estimación propia, basada en estadísticas del INE de refrigeradores y autos en Chile; en estadísticas del Servicio Nacional de Aduanas, en cuanto a importación valorada de aparatos de climatización, y Estadísticas sectoriales de consumos de Energía, de la CNE.
(1): Funcionamiento de compresores estacionarios, asumiendo 12 hrs. diarias, todo el año (valor consultado a técnicos en equipos de refrigeración; corresponde a un valor estimado referencial, solamente, para efectos de la estimación).
(2): Supuesto propio en base a datos de refrigeración de espacios, en etapa de chequeo.
(3): Estimación propia; algunos datos se basan en información referencial dada por distribuidor.
(4): Estimación propia, en función de proyección de vida útil de equipos y tamaño del parque de equipos, en cada caso. Se asumen 30 años de vida útil para equipos de R&AA, en general; 20 años para autos y 15 para camiones. Corresponde a una referencia propia, que será chequeada.

Sub-Sector	*Annual Emission Rate*	*Change in Installed Base (2008-2020)*
Refrigeration – Domestic	1%	138.9%
Refrigeration – Commercial	45% reducing to 33%	99.36%
Refrigeration – Industrial	20%	353.2%
Refrigeration – Transport	40%	532.1%
Stationary A/C	5%	320.6%
Mobile A/C	5%	246.2%
Other A/C	5%	335.8%
Solvent	50% reducing to 26%	221.0%
Foams	4%	202.9%
Fire Protection	5%	206.4%

Table 5 – Adjusted Annual Emission Rates and resulting Growth in Installed Bases

As shown in Table 3, the emissions of each agent from the sub-sector were aggregated following their conversion into CO_2-equivalents leading to the following projection of emissions by sub-sector:

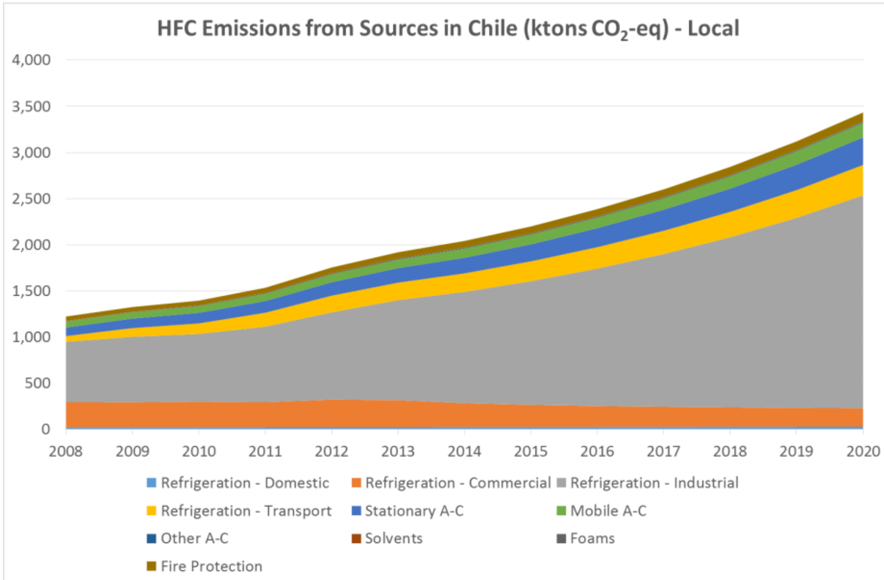

Figure 1 – HFC Emissions from Sources in Chile based on adjusted Río Flores Emission Rates

The graph illustrates the projected growth of HFCs despite the minor decline in emissions from commercial refrigeration on the assumption that overall annual emission rates will reduce over the period to 2020. The growth is primarily arising from transitions out of HCFC-22. For industrial refrigeration, the growth in installed base is expected to drive growth in overall emissions from the sector, coupled with the wider use of blends involving HFC-143a and HFC-125 (notably R-404A and R-507A). This is shown in the following graph:

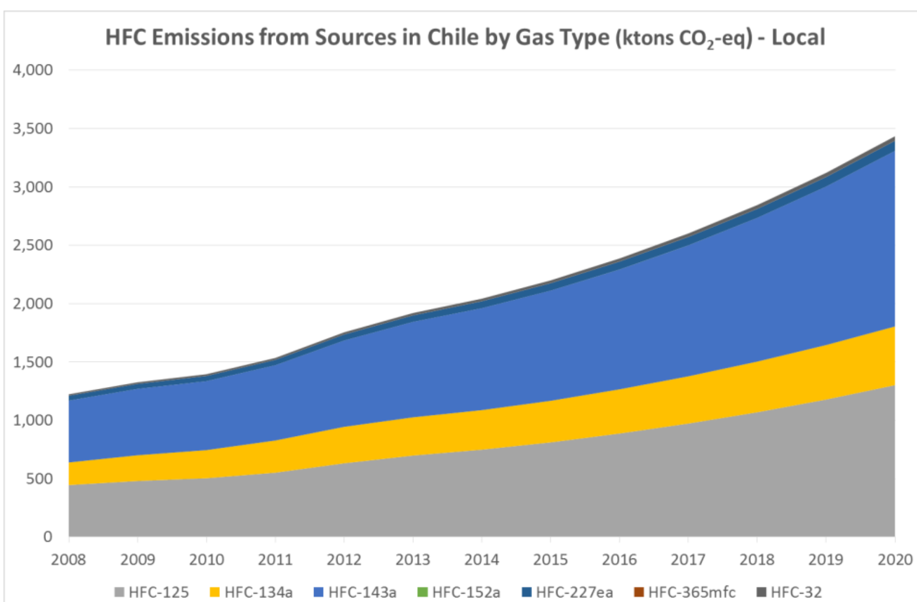

Figure 2 – HFC Emissions by Gas Type in Chile based on adjusted Río Flores Emission Rates

An alternative approach to annual emission rates can be taken using data from Chapter 7 of the 2006 IPCC Reporting Guidelines (Table 7.9) below.

TABLE 7.9
ESTIMATES[1] FOR CHARGE, LIFETIME AND EMISSION FACTORS FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS

Sub-application	Charge (kg)	Lifetimes (years)[2]	Emission Factors (% of initial charge/year)[3]		End-of-Life Emission (%)	
Factor in Equation	**(M)**	**(d)**	**(k)**	**(x)**	**($\eta_{rec,d}$)**	**(p)**
			Initial Emission	**Operation Emission**	**Recovery Efficiency[4]**	**Initial Charge Remaining**
Domestic Refrigeration	$0.05 \leq M \leq 0.5$	$12 \leq d \leq 20$	$0.2 \leq k \leq 1$	$0.1 \leq x \leq 0.5$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Stand-alone Commercial Applications	$0.2 \leq M \leq 6$	$10 \leq d \leq 15$	$0.5 \leq k \leq 3$	$1 \leq x \leq 15$	$0 < \eta_{rec,d} < 70$	$0 < p < 80$
Medium & Large Commercial Refrigeration	$50 \leq M \leq 2000$	$7 \leq d \leq 15$	$0.5 \leq k \leq 3$	$10 \leq x \leq 35$	$0 < \eta_{rec,d} < 70$	$50 < p < 100$
Transport Refrigeration	$3 \leq M \leq 8$	$6 \leq d \leq 9$	$0.2 \leq k \leq 1$	$15 \leq x \leq 50$	$0 < \eta_{rec,d} < 70$	$0 < p < 50$
Industrial Refrigeration including Food Processing and Cold Storage	$10 \leq M \leq 10{,}000$	$15 \leq d \leq 30$	$0.5 \leq k \leq 3$	$7 \leq x \leq 25$	$0 < \eta_{rec,d} < 90$	$50 < p < 100$
Chillers	$10 \leq M \leq 2000$	$15 \leq d \leq 30$	$0.2 \leq k \leq 1$	$2 \leq x \leq 15$	$0 < \eta_{rec,d} < 95$	$80 < p < 100$
Residential and Commercial A/C, including Heat Pumps	$0.5 \leq M \leq 100$	$10 \leq d \leq 20$	$0.2 \leq k \leq 1$	$1 \leq x \leq 10$	$0 < \eta_{rec,d} < 80$	$0 < p < 80$
Mobile A/C	$0.5 \leq M \leq 1.5$	$9 \leq d \leq 16$	$0.2 \leq k \leq 0.5$	$10 \leq x \leq 20$[5]	$0 < \eta_{rec,d} < 50$	$0 < p < 50$

[1] Based on information contained in UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003)
[2, 3] Lower value for developed countries and higher value for developing countries
[4] The lower threshold (0%) highlights that there is no recovery in some countries.
[5] Schwarz and Harnisch (2003) estimates leakage rates of 5.3% to 10.6%; these rates apply only to second generation mobile air conditioners installed in European models in 1996 and beyond.

Since the IPCC data is intended to cover a range of jurisdictions, the highlighted annual emission rates are quoted as ranges. Accordingly, for the Chilean assessment, Anthesis-Caleb has selected values within those ranges which it believes are consistent with the consumption data and installed product/equipment bases identified in the Río Flores, Cerda Report. These are shown in Table 5 overleaf.

Sub-Sector	*Annual Emission Rate*	*Growth in Installed Base (2008-2020)*
Refrigeration – Domestic	1%	138.9%
Refrigeration – Commercial	25% reducing to 13%	209.8%
Refrigeration – Industrial	20%	353.2%

Refrigeration – Transport	40%	532.1%
Stationary A/C	10%	246.7%
Mobile A/C	15%	145.6%
Other A/C	10%	243.5%
Solvent	50% reducing to 26%	221.0%
Foams	4%	202.9%
Fire Protection	5%	206.4%

Table 5 – Adopted IPCC Annual Emission Rates and resulting Growth in Installed Bases

Again, reductions in emissions rates in the Commercial Refrigeration sector are foreseen. The adoption of these slightly higher emission factors leads to the following projections for HFC emissions between 2008 and 2020.

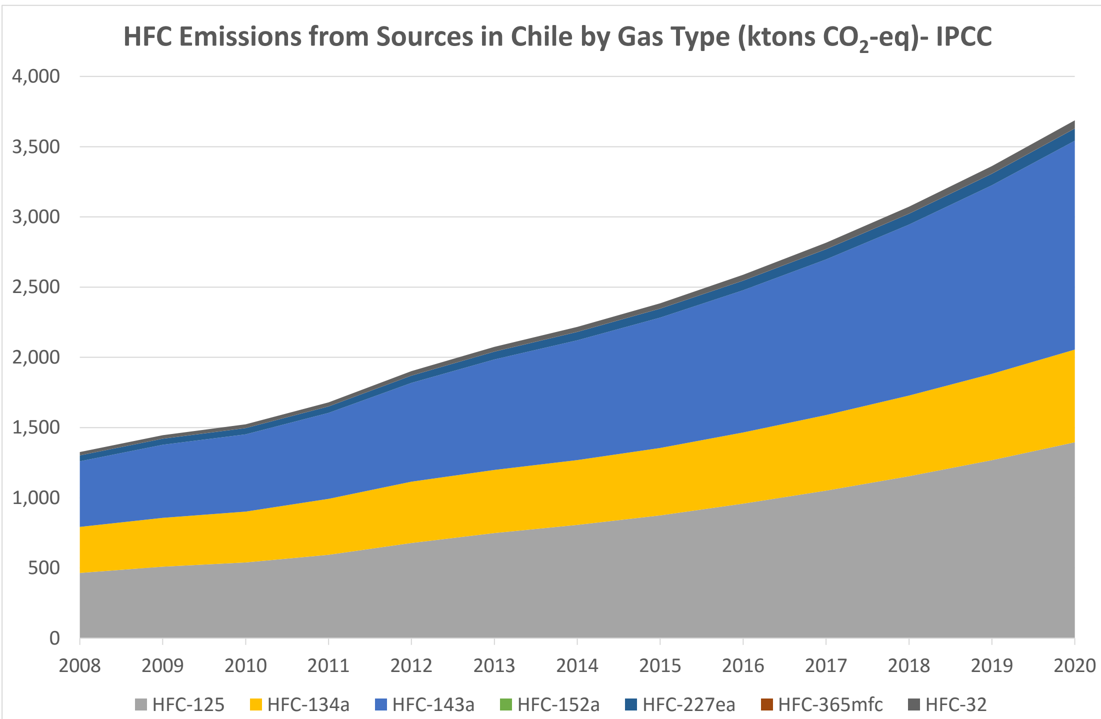

Figure 3 – HFC Emissions by Gas Type in Chile based on adjusted IPCC Annual Emission Rates

In general, the changes between the Río Flores, Cerda assumptions and those adopted from the IPCC Guidelines are a reduction in the commercial refrigeration leakage rates on the one side, but an increase in the air conditioning leakage rates on the other. This is shown by the emissions by sub-sector in Figure 4.

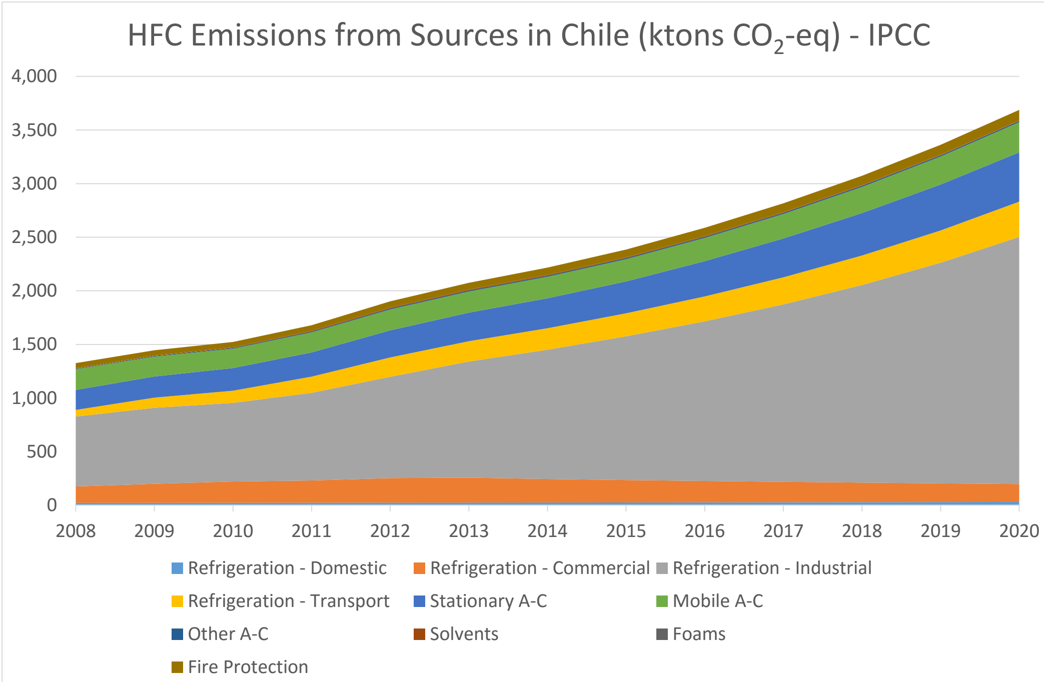

Figure 4 – HFC Emissions from Sources in Chile based on adopted IPCC Emission Rates

LIMITATIONS OF ANALYSIS

It is clear from this Report that the emission assessments are being derived from datasets that have not been collated in a coordinated fashion. In particular, there has been a need to read-across from the Rio Flores categories to the HFC Survey (Gisma) categories when the criteria have not been identical. In addition, the dataset is limited by the extent of consumption projections (to 2020), even though both consumptions and emissions are expected to increase beyond that date.

HCFC emissions have been omitted from this Report in line with the sponsor's scope of assessing HFC emissions only. However, since HCFC's are being replaced, there should be a commensurate reduction in HCFC emissions over time. Accordingly, these are aggregated into the analysis within the graphs included in Annex 1.

CONCLUSIONS

The assessment of annual trends in HFC emissions has for Chile has proved possible based on the availability of the HFC Survey (Gisma Report) and supporting work on installed products/equipment for the HPMP conducted by Río Flores, Cerda. The approach adopted has assumed that the annual consumption figures reported by Gisma and the installed based reported by Río Flores are reliable.

Annual emission rates have been derived from local intelligence (Río Flores) and from 2006 IPCC Guidance. Although the differences from these two sources can be significant for certain sub-sectors, the impact on overall emission estimates in the period from 2008-2020 is relatively modest, with the adapted Río Flores approach yielding an emissions peak of 3.45 Mtons CO_2-eq in 2020 and the adopted IPCC approach yielding an emissions peak of 3.6 Mtons CO_2-eq in 2020.

Further information on installed bases would be helpful in determining more accurately the split between servicing requirements and original product/equipment manufacture, but the overall findings of this analysis are believed to be relatively robust.

Paul Ashford – Anthesis-Caleb, June 2016

Annex 1 – Graphs inclusive of HCFC emissions

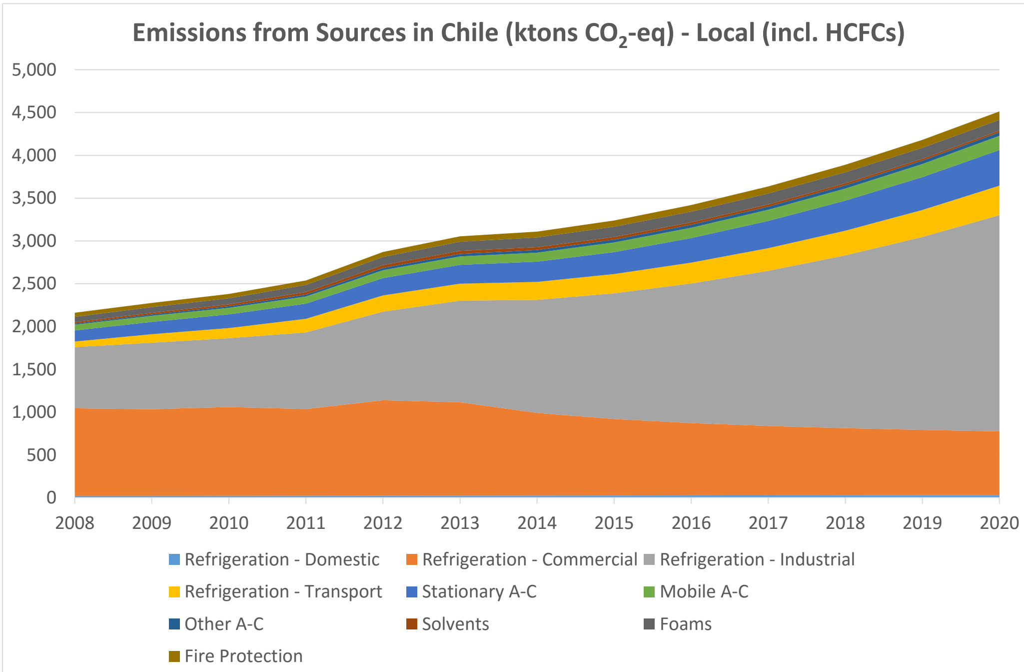

Figure A1 – Emissions from Sources in Chile based on adjusted Río Flores Emission Rates

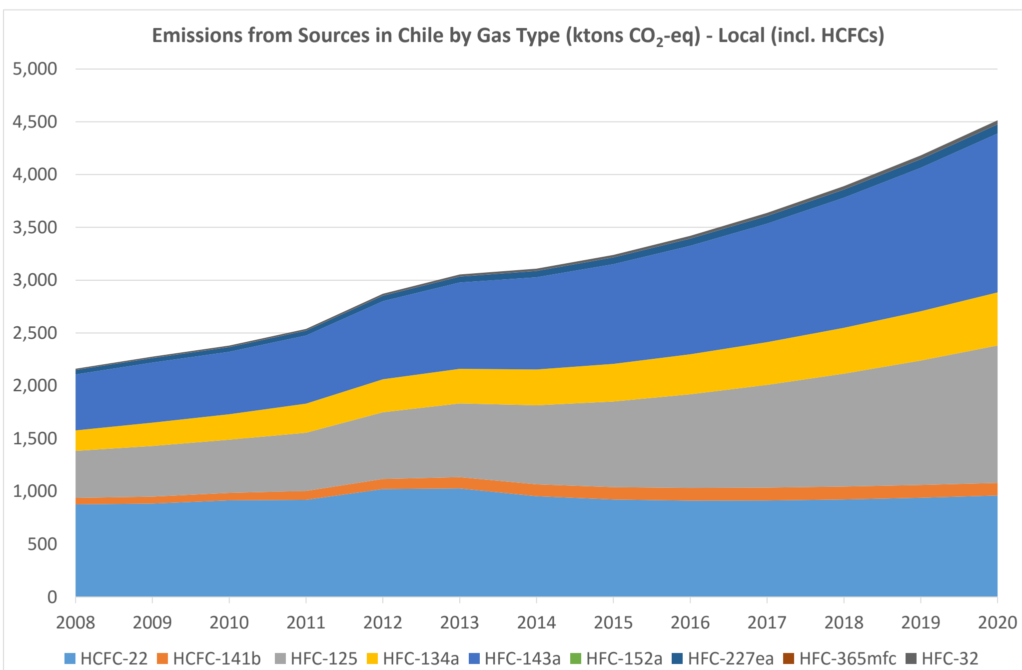

Figure A2 – Emissions by Gas Type in Chile based on adjusted Río Flores Emission Rates

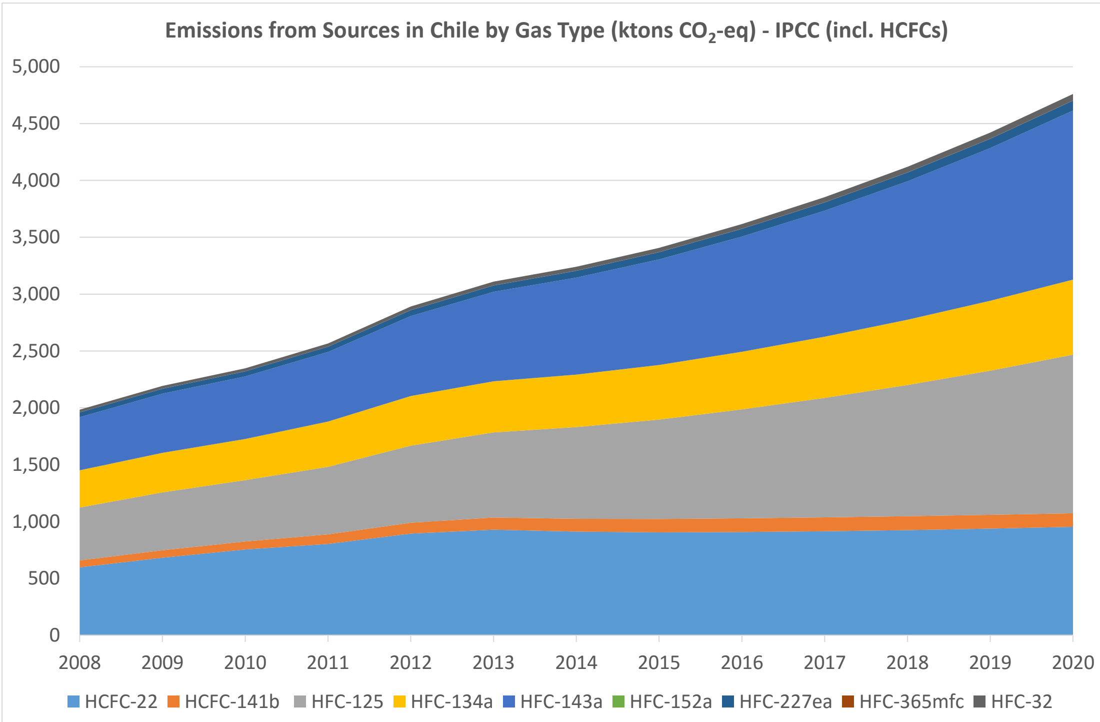

Figure A3 – Emissions by Gas Type in Chile based on adjusted IPCC Annual Emission Rates

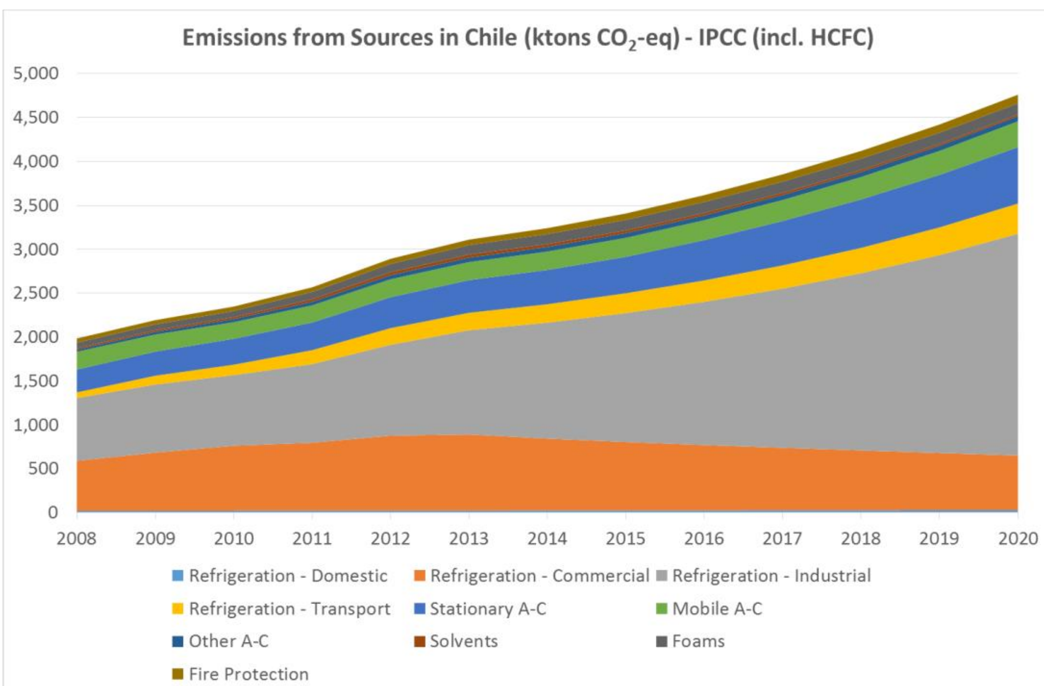

Figure A4 – Emissions from Sources in Chile based on adopted IPCC Emission Rates