

# Early experiences in estimating HFC emissions at country-level

Paul Ashford for UNDP

Monday 2<sup>nd</sup> November 2015

# Scope of country-level work conducted so far

## Initial Pilot

– Chile

- Draft report completed

## Follow-up Countries

– Bangladesh

– Colombia

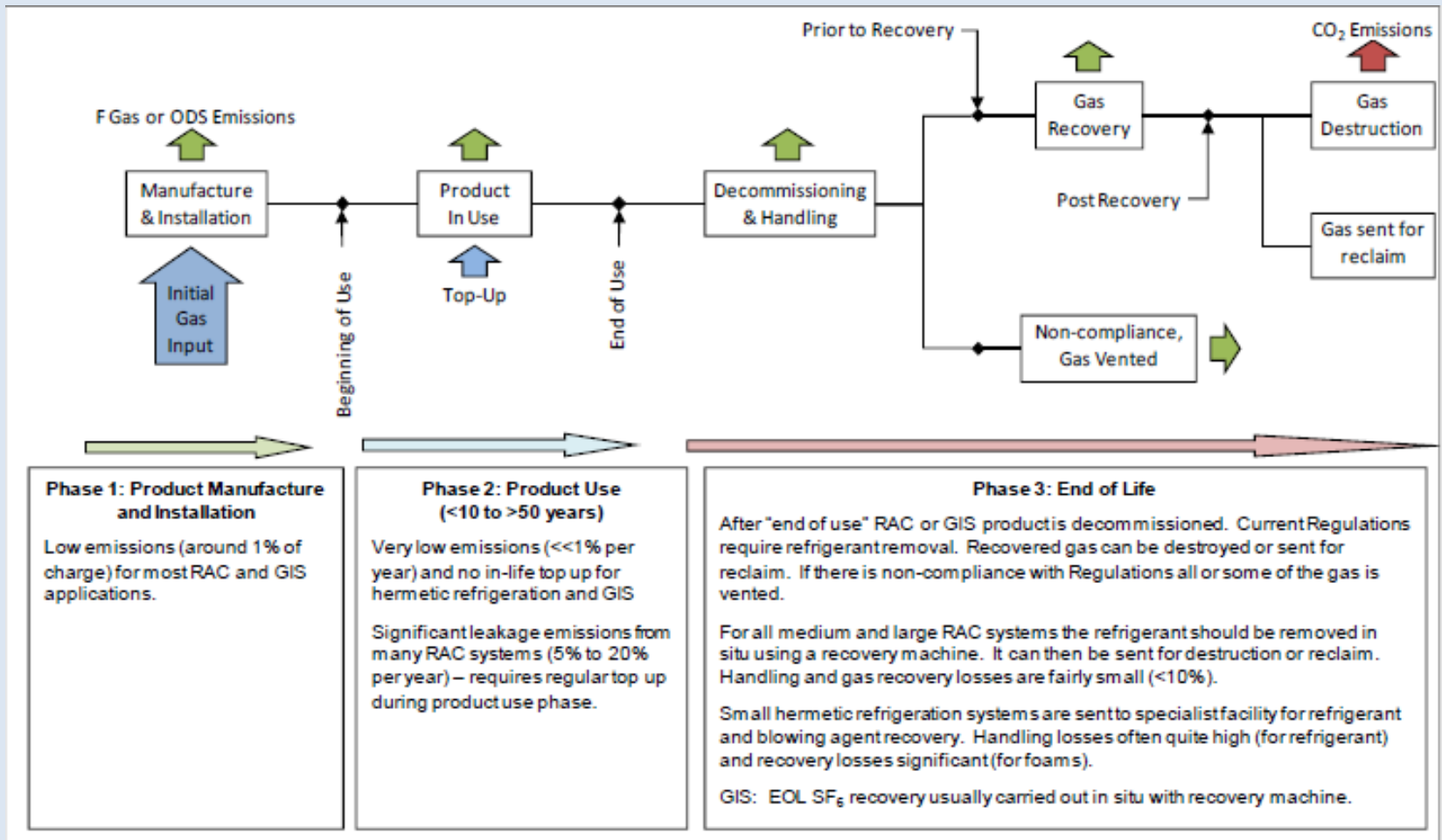
– Ghana

– Indonesia

– Nigeria

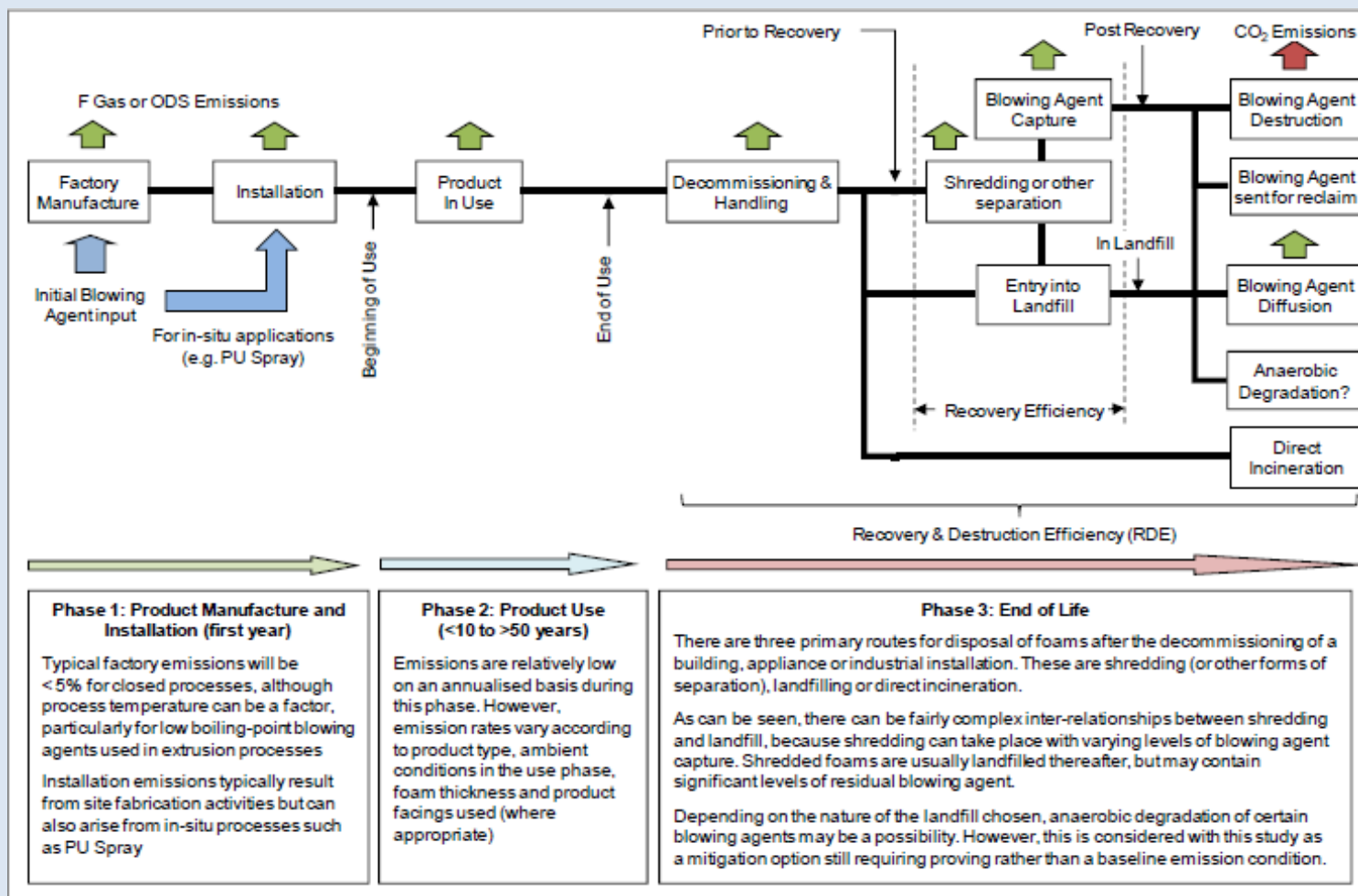
- Initial analysis of data underway

# Sources of Emission can be complex: RAC



Source: SKM Enviros/Caleb

# Sources of Emission can be even more complex: Foams



Source: SKM Enviros/Caleb

# Can simplify these to three major phases

## Initial phase

- Manufacture
- Installation
- Commissioning

First year losses

## Use phase

- Emissions by diffusion and leakage
- Emissions during maintenance

In many cases losses may be replenished through servicing

## End of Life phase

- Emissions during decommissioning
- Emissions following decommissioning (e.g. venting, destruction, recycling)

# Three phases consistent with IPCC Guidelines

## Tier 2 methodology

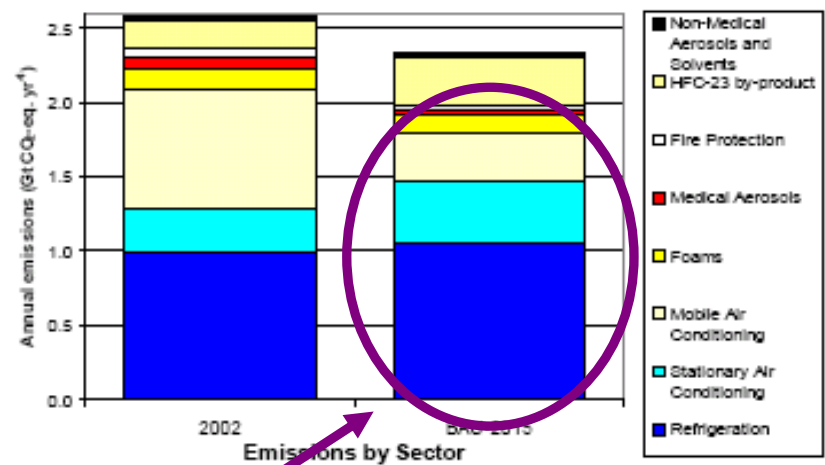
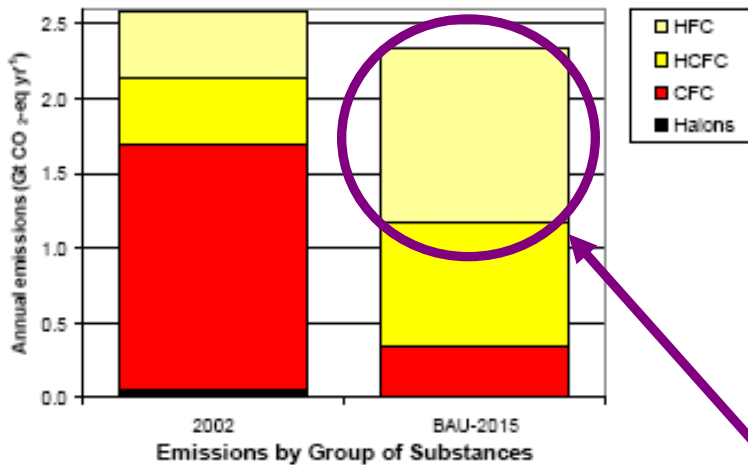
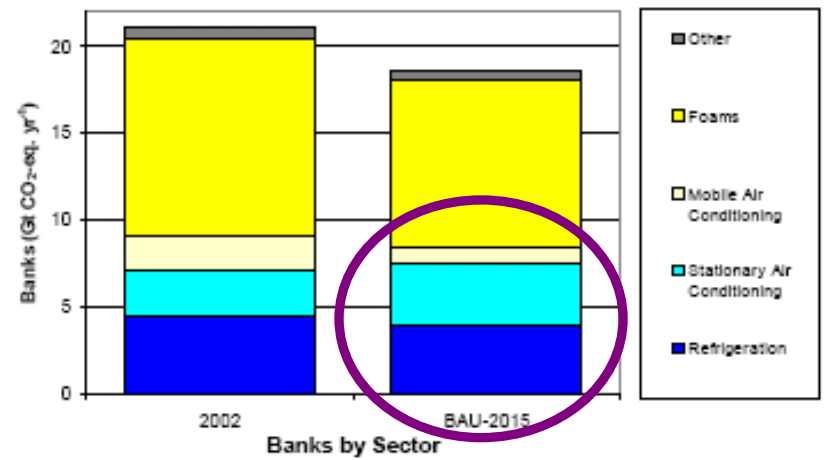
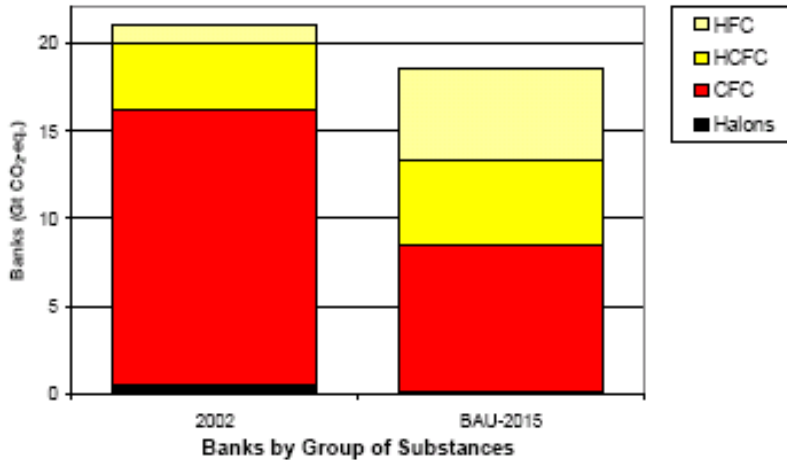
TABLE 7.7  
DEFAULT EMISSION FACTORS FOR HFC-245fa/HFC-365mfc/HFC-227ea USES (FOAM SUB-APPLICATION)

HFC-245a/HFC-365mfc Applications	Product Life in years	First Year Loss %	Annual Loss %	Maximum Potential End-of-Life Loss %
Polyurethane – Continuous Panel	50	5	0.5	70
Polyurethane – Discontinuous Panel	50	12	0.5	63
Polyurethane – Appliance	15	4	0.25	92.25
Polyurethane – Injected	15	10	0.5	82.5
Polyurethane – Cont. Block	15	20	1	65
Polyurethane – Disc. Block for pipe sections	15	45	0.75	43.75
Polyurethane – Disc. Block for panels	50	15	0.5	60
Polyurethane – Cont. Laminate / Boardstock	25	6	1	69
Polyurethane – Spray	50	15	1.5	10
Polyurethane – Pipe-in-Pipe	50	6	0.25	81.5
Phenolic – Discontinuous Block	15	45	0.75	43.75
Phenolic – Discontinuous Laminate	50	10	1	40
Polyurethane – Integral Skin	12	95	2.5	0

Source: Ashford and Jeffs (2004) assembled from UNEP FTOC Reports (UNEP-FTOC, 1999; UNEP-FTOC, 2003)

- Last formally updated in 2006
- Only now being widely adopted
- Some discussion still on-going on sub-sector definition (see later slides)
- Not yet taken into account in this work

# IPCC/TEAP Special Report on Ozone & Climate



# Emission Factor Ranges in 2006 Guidelines excessive?

- Ranges in 2006 were certainly too large (see table 7.9) and can be addressed by one or more of the following approaches:
  - Greater sub-division of the RAC sector. Best practice currently uses 13 sub-sectors compared with 8 previously
  - Consideration of creating separate tables by region to reflect the differing regulatory approaches being adopted (e.g. Europe, North America, Developing Countries?)
  - Taking advantage of greater experience with HFCs, including comparison of top-down and bottom-up assessments of consumption, emission and atmospheric concentrations based on known refrigerant blends

**TABLE 7.9**  
ESTIMATES<sup>1</sup> FOR CHARGE, LIFETIME AND EMISSION FACTORS FOR REFRIGERATION AND AIR-CONDITIONING SYSTEMS

Sub-application	Charge (kg)	Lifetimes (years) <sup>2</sup>	Emission Factors (% of initial charge/year) <sup>3</sup>		End-of-Life Emission (%)	
			(k)	(x)	( $\eta_{rec,d}$ )	(p)
Factor in Equation	(M)	(d)	Initial Emission	Operation Emission	Recovery Efficiency <sup>4</sup>	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	$0.5 \leq M \leq 1.5$	$9 \leq d \leq 16$	$0.2 \leq k \leq 0.5$	$10 \leq x \leq 20^5$	$0 < \eta_{rec,d} < 50$	$0 < p < 50$

<sup>1</sup> Based on information contained in UNEP RTOC Reports (UNEP-RTOC, 1999; UNEP-RTOC, 2003)  
<sup>2,3</sup> Lower value for developed countries and higher value for developing countries  
<sup>4</sup> The lower threshold (0%) highlights that there is no recovery in some countries.  
<sup>5</sup> 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.



# Comparison of the 13 sub-sectors with 8 sub-sectors

<i>2006 Guidelines</i>	<i>Current Best Practice</i>
• Domestic Refrigeration	• Domestic Refrigeration
• Stand-Alone Commercial Applications	• Small Hermetic Stand-Alone Units
• Medium & Large Commercial Refrigeration	• Commercial Condensing Units
	• Centralised Supermarket Refrigeration
• Industrial Refrigeration (incl. Food/CS)	• Industrial Refrigeration
	• Small Stationary A/C
• Stationary A/C (including Heat Pumps)	• Medium Stationary A/C
	• Heat Pumps
• Chillers	• Large Stationary A/C (Chillers)
	• Land Transport Refrigeration
• Transport Refrigeration	• Marine Transport Refrigeration
	• Light Duty Mobile A/C
• Mobile A/C	• Other Mobile A/C

# Information available from HFC Report – Chile (1)

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	256.334	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	
Chesterton SP 296®	40	1.167	26	732	1.212
<b>Total general</b>	<b>498.543</b>	<b>474.046</b>	<b>762.787</b>	<b>929.783</b>	<b>915.386</b>

Total Consumption  
by substance



RAC Split between  
HFC and HCFC-22



	2008 (kg)	2009 (kg)	2010 (kg)	2011 (kg)	2012 (kg)
<b>Total HFC (*)</b>	475.659	442.789	732.503	866.439	866.642
<b>HCFC-22</b>	829.485	920.652	797.723	1.045.280	864.886
<b>% HCFC-22 v/s HFC(*)</b>	63,56%	67,52%	52,13%	54,68%	49,95%

# Information available from HFC Report – Chile (2)

## Qualitative use patterns by substance



SECTOR	Chesteron SP 296®	HFC-125	HFC-134a	HFC-152a	HFC-227ea	HFC-23	R-404A	R-407C	R-410A	R-507A
<b>Refrigeración</b>										
Refrigeración doméstica			X							
Refrigeración comercial			X				X			
Refrigeración industrial y supermercados						X	X			X
Transporte refrigerado			X				X			
<b>Climatización</b>										
Aire acondicionado fijo, equipos compactos			X					X	X	
Aire acondicionado fijo, sistemas de climatización			X					X	X	
Aire acondicionado móvil			X				X			
Otros climatización			X							
Solventes y Aerosoles	X		X	X						

SECTOR	Chesteron SP 296®	HFC-125	HFC-134a	HFC-152a	HFC-227ea	HFC-23	R-404A	R-407C	R-410A	R-507A
<b>Refrigeración</b>										
Refrigeración doméstica			15%							
Refrigeración comercial			5%				20%			
Refrigeración industrial y supermercados						100%	70%			100%
Transporte refrigerado			22%				10%			
<b>Climatización</b>										
Aire acondicionado fijo, sistemas de climatización			15%					100%	100%	
Aire acondicionado móvil			40%				(*)			
Otros climatización			2%							
Solventes y aerosoles	100%		1%							
Extinción de fuego		100%				100%	(**)			
Otros Usos (fabricación de vidrios)				100%						



Proportional use patterns by substance

# Dealing with the determination of banks of HFCs

- With time series only from 2008, some information on equipment stocks becomes essential

No information in specific HFC Report

Alternate source cited in Report (Rio Flores, Cerda)

Categorisation of equipment sectors is not identical to HFC Report

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)	N° Equip. Equiv.	Tipo de Gas más Usado (2)	Cantidad de Gas por Equipo	Total Stock de Gas (2)	Requeri- miento Anual en Mantenión (3)	Requeri- miento Anual en Mantenión	Requeri- miento Anual en Eliminación (4)
	GWh	Unidades		Kg	Ton	%	Ton/año	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
<b>Total R&amp;AA (E)</b>	<b>11.397</b>				<b>5.967</b>	<b>16%</b>	<b>941,6</b>	<b>172,3</b>

# Information available from HFC Report – Chile (3)

Sometimes information provided includes projections



**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

# What is then done with the information provided?

- Working at the substance level, the consumption by sub-sector can be derived

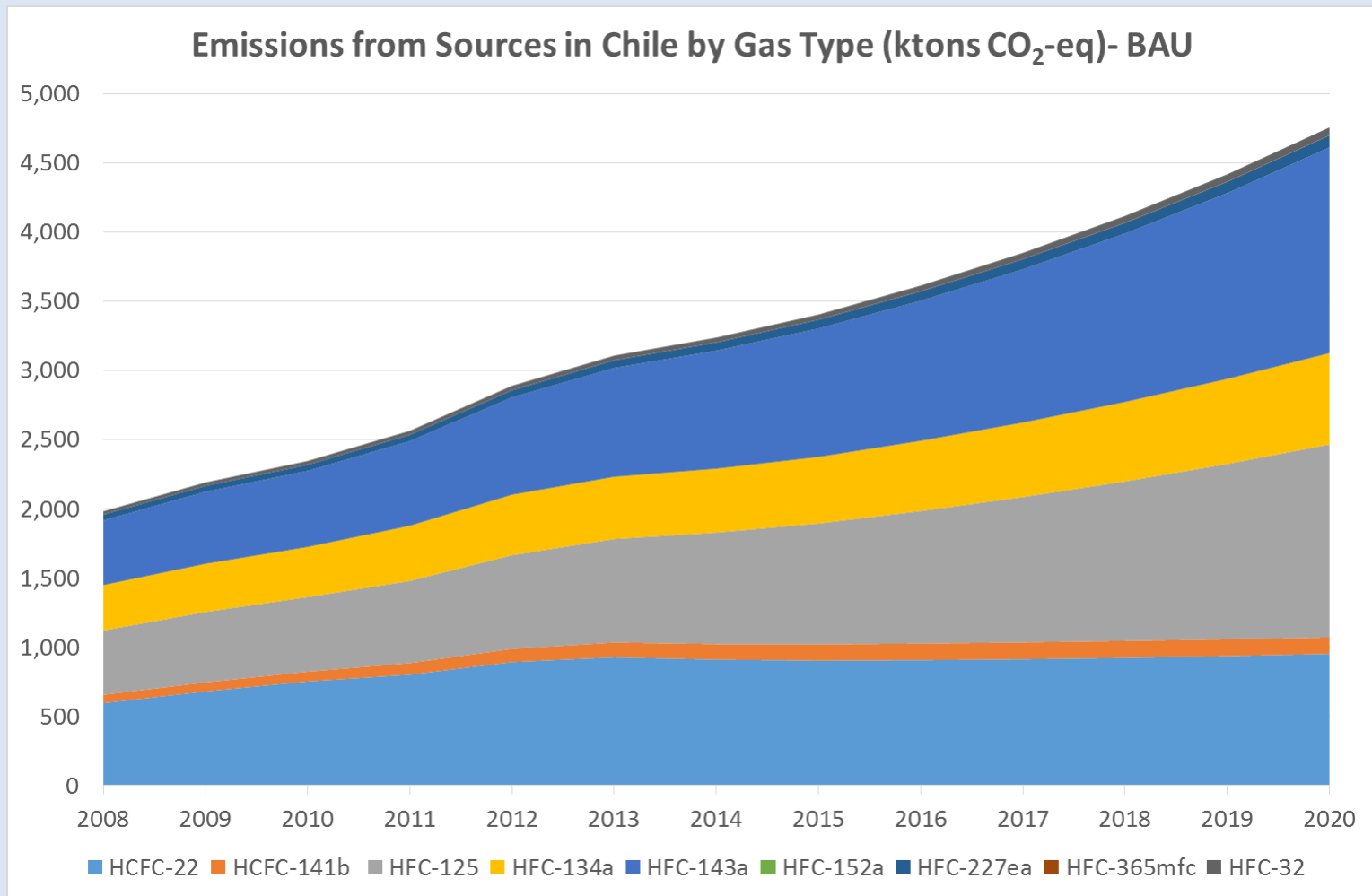
		Consumption of Gas by Sector - HFC134a													
		%	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
<b>Total Consumption</b>			233,720	256,334	379,067	413,802	350,133	387,376	428,543	474,084	524,465	580,200	641,859	710,069	785,529
Refrigeration	Domestic	15%	35,058	38,450	56,860	62,070	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

- Hopefully, you will recognise the data outlined from the HFC Report inputs

# From substance analysis to sub-sector analysis

Kg		Consumption of Gas by Sector - Refrigeration Commercial													
	%	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
<b>Total Consumption</b>		513,160	549,351	506,828	645,514	549,050	410,017	411,984	404,353	397,270	390,786	384,952	379,827	375,474	
HCFC-22	83%	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	
HCFC-141b	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	
HFC-134a	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	
R404A	12%	56,902	20,970	41,150	55,407	47,208	50,751	54,557	58,049	65,047	67,776	72,859	78,525	84,196	
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		1,111,000	1,124,210	1,178,909	1,178,807	1,329,222	1,333,291	1,209,992	1,150,079	1,117,402	1,101,234	1,095,575	1,097,076	1,103,897	
Cons as % Bank		46.18%	48.87%	42.99%	54.76%	41.31%	39.75%	34.05%	35.16%	35.55%	35.49%	35.14%	34.63%	34.91%	
Emissions Est.	45%	45%	44%	43%	42%	41%	40%	39%	38%	37%	36%	35%	34%	33%	
Addn to Bank		13,210	54,699	-102	150,416	4,069	-123,300	-59,913	-32,677	-16,168	-5,658	1,501	6,821	11,188	
<b>GWP</b>															
HCFC-22	1810	413,436	409,055	419,209	409,425	450,675	441,029	390,238	361,404	341,895	327,842	317,097	308,459	301,248	
HCFC-141b	730	0	0	0	0	0	0	0	0	0	0	0	0	0	
HFC-125	3500	26,609	26,327	26,980	26,351	29,005	28,385	25,116	23,260	22,004	21,100	20,408	19,852	19,388	
HFC-134a	1430	28,458	28,157	28,855	28,182	31,021	30,357	26,861	24,877	23,534	22,566	21,827	21,232	20,736	
HFC-143a	4470	31,447	31,114	31,886	31,142	34,279	33,545	29,682	27,489	26,005	24,936	24,119	23,462	22,913	
HFC-152a	124	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 <sub>2</sub> -eq		1,022.71	1,011.88	1,036.99	1,012.79	1,114.83	1,090.97	965.33	894.00	845.74	810.98	784.40	763.03	745.19	

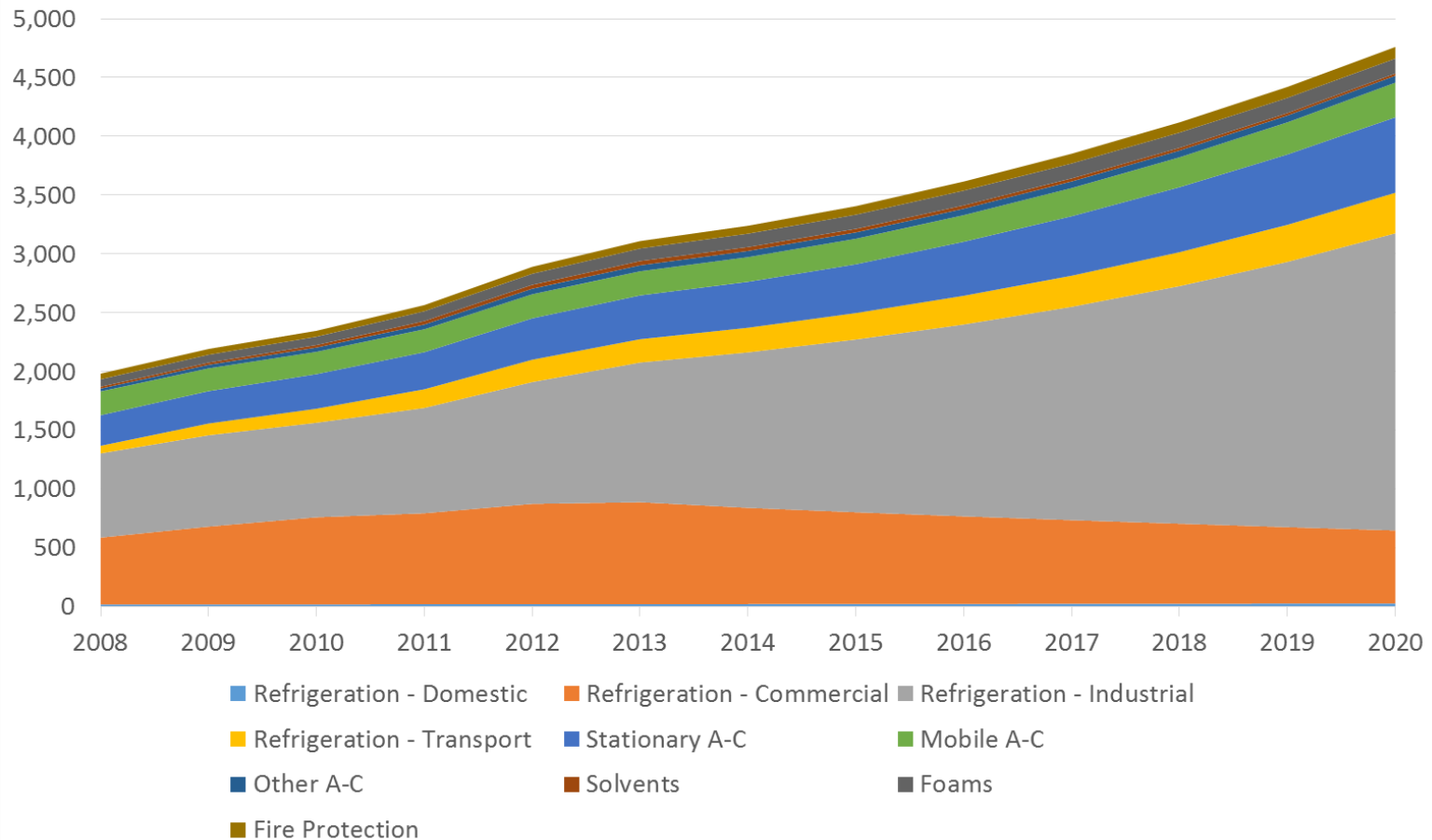
# Outputs for by substance type for Chile





# Outputs for by sub-sector for Chile

Emissions from Sources in Chile (ktons CO<sub>2</sub>-eq) - BAU



# Core information required from HFC Surveys

## Essential

- Time series of HCFC/HFC consumption by substance
- Qualitative assessment of sub-sector use pattern by substance
- If time series does not pre-date 2000 then information on equipment stocks and average charges

## Valuable, but not essential

- Proportional assessment of use pattern by substance
- Projections of consumption beyond 2014
- Localised emission factors (as alternative to IPCC 2006 defaults)
- Age profile of products/equipment by sector/sub-sector

# Analysis of HFC Reports from other countries

<i>Essential</i>	Chile	Bangladesh	Colombia	Ghana	Indonesia	Nigeria
Time Series by substance	Yes					
Qualitative Use Patterns	Yes					
Time Series pre-dates 2000 or Equipment stock data	Yes					
<i>Valuable</i>						
Proportional Use Patterns	Yes					
Projection beyond 2014	Yes					
Localised emissions factors	Yes					
Age profile of products	No					

# Lessons learned so far from current assessments

- It is possible to derive meaningful emissions estimates using consumption data-sets collected from HFC Surveys
- Minimum criteria have been established for the derivation of estimates from HFC Surveys in other countries
- For the Chilean case, emissions from refrigeration and air conditioning sources dominate the emissions estimates, as expected
- In BAU scenarios, blends such as R-404A and R-507A will influence outcomes considerably because of their high GWP
- Using the same models, it would be possible to assess emission mitigation scenarios using assumptions for substitution
- It is still too early to say how representative the Chilean case study will be in terms of sectoral distribution of emissions
- It may still be that some countries do not meet the minimum criteria