Deutsche Umwelthilfe

DUH Background Paper

Deficiencies in treatment of CFC-containing waste refrigeration equipment in Germany

(7 November 2007)

I. Current situation

The German Waste Electrical and Electronic Equipment Act (ElektroG) came into force on 24 March 2006 and with it the mandatory separate collection of waste electrical and electronic equipment (WEEE). Since then all waste collection centres operated by local authorities in Germany have been obliged to take back WEEE, which includes refrigeration equipment, free of charge. The recycling or disposal of the waste appliances is paid for by equipment producers.

The ElektroG act requires that treatment of WEEE is carried out using the best available (i.e. "state of the art") technology. According to a study conducted by the German environmental organization *Deutsche Umwelthilfe* (DUH), the post-consumer processing of refrigeration equipment in Germany is currently being carried out a standard far below the statutorily prescribed state of the art. Calculations by DUH have shown that on average almost 280 grams of chlorofluorocarbons (CFCs) are presently being lost from the cooling circuit and insulating foams of each appliance sent for end-of-life recycling. That is approximately 63 % of the total amount of CFCs contained in waste refrigeration appliances (data for 2005).

With about 2.4 million CFC-containing fridges and freezers requiring treatment annually, the CFC losses from fridge recycling activities are equivalent to the emission of about 4.3 million tonnes of CO_2 per year into the atmosphere.

One of the main reasons for this is that fridge recycling companies in Germany are operating at a far lower technological standard than those in other countries, such as Austria, Switzerland, Luxembourg, Sweden or Greece. In Germany, recyclers only managed to recover and destroy on average 36.6 % of the CFC refrigerants contained in the waste appliances in 2005. In contrast, recycling companies operating in a number of other countries are legally obliged to recover 90 %. This demonstrates that it is not only technically but also economically feasible to recover 90 % of the CFCs contained in waste refrigeration equipment in such a way that

these chemicals do not escape into the atmosphere. Complying with such a quality standard represents the current "state of the art" in fridge recycling.

The proper treatment of end-of-life refrigeration equipment is currently described in the following four documents:

- Technical Instructions on Air Quality Control – TA Luft (First General Administrative Regulation of the Federal Immission Control Act – BImSchG; fridge recycling dealt with in sections 5.4.8.10.3 / 5.4.8.11.3)
- Technical Requirements Regarding the Disposal of Waste Electrical and Electronic Equipment and the Installation and Operation of Plants for the Disposal of Waste Electrical and Electronic Equipment (EAG – leaflet of 24 March 2005); fridge recycling dealt with in section 2.2
- UBA [German Federal Environmental Agency] Guidelines on the Disposal of Refrigeration Equipment (January 1998)
- RAL [German Institute for Quality Assurance and Certification] – GZ-728 Quality Assurance and Test Specifications for the Demanufacture of Refrigeration Equipment (September 2007)

II. Survey data

The information requested and analysed by DUH in its study was publicly accessible data available from the statistical offices of the sixteen German federal states (*Länder*). The information concerned the volumes of waste refrigeration equipment collected and treated and the quantities of CFCs actually recovered. The request to the statistical offices was worded as follows (excerpt from letter):

> "[…] As part of the official process of gathering data on activities in the waste management sector, operators of fridge recycling plants are obliged to quantify and document the following important material flows:
>
> 1. Number of CFC-containing waste appliances (in tonnes per year) that were treated in the relevant plant in the reporting year.
> 2. Quantity of CFCs (in tonnes per year) that are forwarded for environmentally safe disposal or recovery.
>
> With reference to the European Council directive on public access to environmental information or its corresponding transposition into national law, please provide us with the data relating to the above named material flows over the last five years. […]"

DUH received data for the years 2004 and 2005 from a total of ten *Länder*. In two federal states there are no plants for recovering CFCs from waste refrigeration equipment. In four of Germany's *Länder* some of the data requested are classified as confidential. Table 1 provides an overview of the data received by DUH.

Table 1. Quantities of waste refrigeration appliances collected and sent for recycling and the amounts of CFCs recovered from these appliances (Source: Statistical offices of the German *Länder*)

Federal state	2004		2005	
	Quantity of refrigeration appliances collected for recycling (tonnes)	Quantity of CFCs recovered from waste appliances (kg)	Quantity of refrigeration appliances collected for recycling (tonnes)	Quantity of CFCs recovered from waste appliances (kg)
Baden-Württemberg	10 909	60 000	12 212	70 400
Bavaria	16 592	68 900	17 740	43 500
Berlin	10 152	[1]	10 312	[1]
Brandenburg	459	[1]	355	[1]
Bremen[2]	-	-	-	-
Hamburg[2]	-	-	-	-
Hesse	7 967	32 000	7 895	36 000
Mecklenburg-West Pomerania	4 367	[1]	4285	[1]
Lower Saxony	8 468	35 000	8 969	26 000
North Rhine-Westphalia	36 547	101 000	33 340	78 000
Rhineland-Palatinate	8 167	21 400	7 451	19 500
Saarland	[1]	[1]	[1]	[1]
Saxony	2 716	5 000	2 411	4 000
Saxony Anhalt	559[3]	906[3]	544[3]	883[3]
Schleswig-Holstein	10 477	[1]	11 648	56 218[4]
Thuringia	5 265	12 000	4 779	9 000

[1] Data classified as confidential
[2] No plant for recovering CFCs from waste refrigeration equipment exists in this federal state
[3] Source: Ministry of Agriculture and the Environment of Saxony Anhalt
[4] Source: Ministry of Agriculture, the Environment and Rural Areas of Schleswig-Holstein

III. Assumptions used in the calculations

- The average weight of a refrigeration appliance was assumed to be 40 kg. This is based on the typical mix of domestic fridges, domestic fridge-freezer units, and domestic chest and upright freezers found in Germany.[1]

[1] Öko-Institut e.V. (2007), Life cycle assessment of the treatment and recycling of refrigeration equipment containing CFCs and hydrocarbons

- Between two and ten per cent of the waste refrigerators collected are commercial or industrial appliances.[2] These are larger than domestic appliances and contain significantly more CFCs. For the purposes of the present calculations, however, they were regarded as domestic units and the extra quantities of CFCs were neglected.
- The calculations also assume that 20% of the waste fridges and freezers reported by the regional statistical offices are CFC-free (e.g. appliances containing hydrocarbons, absorber-type units containing ammonia or appliances with polystyrene or glass wool as the insulation material).[3] This too is a conservative assumption given the fact that less than five per cent of the appliances treated in 2004 and 2005 contained hydrocarbons in the cooling circuits and insulation materials, and hydrocarbons are by far the most common replacement for CFCs. And as the DUH survey expressly asked for information on waste keys 160211 and 200123 (i.e. on CFC-containing waste refrigeration equipment), there should strictly be no need to make any deductions for CFC-free appliances.
- A further factor that would have a negative effect on the results of the calculations is the avoidable emissions from what is obviously the equally inadequate recycling of appliances containing the CFC-replacement refrigerant R134a. The refrigerant R134a has a global warming potential (GWP) about 1430 times that of CO_2 and its recovery and safe destruction is therefore also necessary. As soon as reliable statistical evidence or estimates concerning the fate of R134a in waste refrigeration equipment is available, DUH will be broadening its study to include these data. It is already apparent that in a number of German *Länder* waste refrigeration equipment containing R134a is being "treated" in auto shredders together with appliances containing propane or butane. This is in contrast to the way in which other R134a-waste, such as waste air conditioning systems from ELV, is being processed and is in clear contravention of existing statutory requirements. Here too, the required state-of-the-art processing would necessitate removal of 90% of the refrigerant in suitably designed recycling plants.
- When CFCs are removed from waste refrigeration appliances they typically contain contaminants, principally water. This was confirmed by DUH during a plant inspection. According to reliable information from the fridge recycling sector, contaminants make up between about 5% and 20% of the amounts removed, depending on the particular recycling technology deployed. It can therefore be assumed that the quantities of recovered CFCs that are reported often contain significant fractions of contaminants (principally water) and that strictly these quantities should be corrected downward by about 5–20%. However, DUH maintained its conservative approach and decided against introducing this correction into the calculations.

[2] RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment
[3] The figure of 20% assumed here for the proportion of CFC-free units is twice that assumed by the environmental consulting organization Öko-Institut in its life cycle assessment study published in 2007.

- In addition to their use in refrigerator and freezer appliances, CFCs are also found in the foams that are used to insulate cold rooms, building roofs, boilers, etc. It cannot be ruled out that the volumes of CFCs reportedly recovered from waste refrigeration equipment also contain CFCs from these other sources. This would mean that the quantities of CFCs actually being recovered from refrigeration appliances are even lower than currently reported. As DUH has no reliable figures available, this aspect was also neglected in the calculations used in the present study. Once again, this is a conservative assumption erring on the side of caution.
- The total number of refrigeration appliances requiring end-of-life processing in Germany is estimated to be around three million appliances per year.[4] Deducting the 20 % CFC-free units leaves around 2.4 million CFC appliances requiring treatment.
- Theft, particularly the theft of the compressor, often results in damage to the cooling coils so that the refrigerant escapes from the cooling circuit (but not the insulation materials) into the environment. According to information supplied to DUH from sources in the recycling sector, between five and ten per cent of waste refrigeration appliances suffer this fate. Refrigerant is also lost from appliances whose cooling circuits are damaged during transport. The calculations therefore assume that 20 % of the total number of waste refrigeration appliances have damaged cooling circuits.
- CFCs are removed from the waste appliances in two stages. Stage I involves removal of the CFC from the cooling circuit. In stage II, the CFC in the insulation material is recovered.
- The study assumes that the CFC refrigerant in the cooling circuit is always R12 (removed in stage I) and that the CFC blowing agent within the foam insulation material is always R11 (removed in stage II).[5]
- The calculations assume, in accordance with the UBA guidelines and the RAL GZ-728 specifications (see above), that state-of-the-art processing involves the recovery of on average 90 % of the CFCs contained in a waste refrigeration appliance.[6] This corresponds to the minimum average recovery of about 115 g per appliance of the CFC R12 from the cooling circuit (100 % = approx. 127 g) and about 283 g per appliance of the CFC R11 from the insulation materials (100 % = approx. 312 g).[7]

[4] Öko-Institut e.V., (2007), Life cycle assessment of the treatment and recycling of refrigeration equipment containing CFCs and hydrocarbons
[5] RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment (2007)
[6] This corresponds to the statutory minimum standard required in Austria, Luxembourg and Denmark.
[7] RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment (2007)

- The CFC R12 (stage I) has a global warming potential (GWP) that is 10 720 times that of CO_2; the GWP of CFC R11 (stage II) is a factor of 4 680 times greater than that of CO_2.[8]
- The total number of CFC-containing waste refrigeration appliances still in use in Germany is estimated to be around 36 million.[9]

IV. Calculations

Table 2. Adjusted data on expected and actual quantities of CFCs recovered per appliance

	Total quantity of CFC per appliance(100%)[1] (kg)	Expected quantity of CFC recovered if state-of-the-art processing assumed (90%)[2] (kg)	Actual quantity of CFC recovered per appliance[3 4] (kg)	Actual quantity of CFC recovered as percentage of total quantity of CFC in appliance (%)
Baden-Württemberg				
2004	0.439	0.398	0.275	62.6
2005	0.439	0.398	0.288	65.7
Bavaria				
2004	0.439	0.398	0.208	47.3
2005	0.439	0.398	0.123	27.9
Hesse				
2004	0.439	0.398	0.201	45.7
2005	0.439	0.398	0.228	51.9
Lower Saxony				
2004	0.439	0.398	0.207	47.1
2005	0.439	0.398	0.145	33.0
North Rhine-Westphalia				
2004	0.439	0.398	0.138	31.5
2005	0.439	0.398	0.117	26.6
Rhineland-Palatinate				
2004	0.439	0.398	0.131	29.8
2005	0.439	0.398	0.131	29.8
Saxony				
2004	0.439	0.398	0.092	21.0
2005	0.439	0.398	0.083	18.9
Saxony Anhalt				
2004	0.439	0.398	0.081	18.5
2005	0.439	0.398	0.081	18.5

[8] Intergovernmental Panel of Climate Change (IPCC), (2005).
[9] Estimated by RAL Quality Assurance Association for the Demanufacture of Refrigeration Equipment

	Total quantity of CFC per appliance(100%)[1] (kg)	Expected quantity of CFC recovered if state-of-the-art processing assumed (90%)[2] (kg)	Actual quantity of CFC recovered per appliance[3] [4] (kg)	Actual quantity of CFC recovered as percentage of total quantity of CFC in appliance (%)
Schleswig-Holstein				
2004	0.439	0.398	-	-
2005	0.439	0.398	0.241	55.0
Thuringia				
2004	0.439	0.398	0.114	26.0
2005	0.439	0.398	0.094	21.4

[1] 127 g CFC R12 and 312 g CFC R11
[2] 115 g CFC R12 and 283 g CFC R11
[3] Deduction of the 20 % of appliances received for treatment that do not contain CFCs
[4] Calculation based on the data received from the regional statistical offices

Table 3. Global warming potentials of CFCs contained in waste refrigeration appliances (in kilograms of CO_2 equivalent)

Total quantity of CFC per appliance (100%) (kg)		Global warming potential (GWP)	Potential CO_2 emissions per appliance (in kg CO_2 equivalent)
CFC R12 from stage I	0.127	10 720	1 361.44
CFC R11 from stage II	0.312	4 680	1 460.16
Total	**0.439**		**2 821.60**

Table 4. Mean average CFC-losses per appliance (in %)

Federal state	2004		2005	
	No. of CFC-containing appliances(80 % of total)	Quantity of CFC (kg)	No. of CFC-containing appliances(80 % of total)	Quantity of CFC (kg)
Baden-Württemberg	218 188	60 000	244 240	70 400
Bavaria	331 840	68 900	354 800	43 500
Hesse	159 340	32 000	157 900	36 000
Lower Saxony	169 360	35 000	179 380	26 000
North Rhine-Westphalia	730 940	101 000	666 800	78 000
Rhineland-Palatinate	163 336	21 400	149 028	19 500
Saxony	54 320	5000	48 220	4000
Saxony Anhalt	11 178	906	10 874	883
Schleswig-Holstein	-	-	232 960	56 218
Thuringia	105 300	12 000	95 580	9000
Total	**1 943 802**	**336 206**	**2 139 782**	**343 501**

	2004	2005
Average amount recovered in % (Actual quantity of CFCs recovered / Total quantity of CFCs in CFC-containing appliances[1])	**39.4**	**36.6**
Average CFC losses in %	**60.6**	**63.4**

[1] 439 g CFC per appliance

Table 5. Mean average greenhouse gas emissions due to CFC losses from fridge recycling activities (expressed in kilograms CO_2 equivalent)

	2004 (kg CO_2 equiv.)	2005 (kg CO_2 equiv.)
Average greenhouse gas emissions due to CFC losses from one appliance	1 710	1 789
Average greenhouse gas emissions due to CFC losses from 2.4 million appliances[1]	**4 103 776 915**	**4 295 557 828**

[1] Number of CFC-containing waste refrigeration appliances treated each year in Germany

Compressor theft and transport damage are frequently cited by recycling companies as reasons for poor CFC recovery rates. However, table 6 shows that these negative effects are not a plausible explanation for the poor levels of CFC recovery currently achieved.

If it is assumed that 20 % of the CFC appliances have defective cooling circuits as a result of compressor theft or transport damage, the efficiency of the recycling plants with respect to CFC recovery would still only be about 40 %.

Table 6. Efficiency of CFC recovery in fridge recycling plants expressed in kg CO_2 equivalent (data from 2005)

Theoretical maximum amount of CFC recoverable[1]									
Stage I	0.80[2]	x	2 400 000[3]	x	0.127[4]	x	10 720[5]	=	2 613 964 800 kg CO_2
Stage II	1.00[6]	x	2 400 000[3]	x	0.312[7]	x	4 680[8]	=	3 504 384 000 kg CO_2
					Maximum total amount recoverable				6 118 348 800 kg CO_2
Actual quantities of CFC recovered in fridge recycling plants									
Stage I	0.366[9]	x	2 400 000[3]	x	0.127[4]	x	10 720[5]	=	1 194 908 600 kg CO_2
Stage II	0.366[9]	x	2 400 000[3]	x	0.312[7]	x	4 680[8]	=	1 281 553,200 kg CO_2
					Total amount actually recovered				2 476 461 800 kg CO_2
Efficiency (actual quantity of CFC recovered / maximum theoretical quantity of CFC recoverable)									
2 476 461 800 kg CO_2	/	6 118 348 800 kg CO_2	=	**40.5 %**					

[1] Assuming that 20 % of the appliances received for treatment have cooling circuits that have been damaged by compressor theft or transport.
[2] 80 % undamaged cooling circuits
[3] Number of CFC-containing refrigeration appliances requiring treatment annually in Germany
[4] Amount of CFC R12 recovered from stage I processing (in kg)
[5] Global warming potential of CFC R12
[6] There is no significant loss of CFCs from the insulation materials due to appliance theft or transport damage.
[7] Amount of CFC R11 recovered from stage II processing (in kg)
[8] Global warming potential of CFC R11
[9] Average percentage of CFC actually recovered as percentage of total quantity of CFC in appliance (see table 4)