German EPA F-Gas Report – Summary and Extracts

A comprehensive report by the German Environmental Protection Agency, produced in February 2004, is now available in English at www.mipiggs.org and from the German EPA. Some extracts are given below.

The report, which is over 240 pages long, identifies existing alternative technologies or processes for every use of f-gases in over 20 sectors.

It shows that f-gases (HFCs etc) are not necessary for the following uses: refrigerants in domestic refrigerators and freezers, commercial or industrial refrigeration, stationary air conditioning of buildings or transport, stationary or mobile air-conditioning units (domestic, commercial, industrial); in domestic heat pumps; as blowingagents to make rigid foams for thermal insulation, flexible polyurethane foams, integral skin polyurethane foams or one component foam; as propellant in technical sprays, medical aerosols, aerosols in households and cosmetic aerosols, in aerosols intended for decorative purposes, party supplies and claxons, fire extinguishing, etching semi conductors circuit board production, extinguishing and electrical insulating gas (switch-gear) cover gas for magnesium processing, degasser for secondary aluminium casting and, filling gas for car tyres.

The exceptions are HFCs in pepper sprays and non-domestic insecticides.

It also identifies many new alternatives currently in testing, and technical measures to reduce emissions.

The authors state that

- The use of HFCs is not necessary ‘as refrigerant nor as blowing agent’
- ‘In almost all areas of application, it is possible to replace fluorinated greenhouse gases (HFCs, PFCs and SF6) by halogen-free alternatives. In addition, there are many more ways to reduce emissions’
- There is an ‘urgent need for action’ on HFCs, PFCs and SF6
- Future emissions will ‘increase enormously’ due to replacement of CFCs
- Automobile air conditioning systems which use CO2 as refrigerant [not HFCs] ‘are now ready to go into production’
- forecasts predict a continued sharp rise in the use of fluorinated greenhouse gases
- 95% of f-gas emissions are HFCs
- ‘In 2020, fluorinated greenhouse gases are anticipated to have a global annual market volume of up to 500,000 t’, Europe accounting for up to 100,000 t of this.
- Annual f-gas emissions(95% are HFCs) up 2020 may total about 330,000 t worldwide and about 60,000 t in Europe.

- In Germany HFC emissions and related emissions will have increased between 1995 and 2010 by approximately +270 %.
- In Germany the number of cars with air conditioning rose from 9% in 1992 to 84% in 2004
- Many German cars are being scrapped in countries without adequate CFC or HFC recovery systems and from 2005 the first HFC systems will be scrapped
- 'Optimisation' of CO2 alternatives to HFC car aircon will be complete by 2006 and the systems ready 'to be placed on the market'
- 'Taking all aspects into account, it can be concluded that CO_2 is the best refrigerant' for car air conditioning

Extracts from

Fluorinated Greenhouse Gases in Products and Processes: *- Technical Climate Protection Measures* – Report of the Federal Environmental Agency, Germany 20 February 2004

Federal Environmental Agency (Umweltbundesamt)
Bismarckplatz 1
14193 Berlin
Phone: ++49 30-8903-0
Fax: ++49 30-8903-2285
http://www.umweltbundesamt.de

Authors: Katja Schwaab, Folke Dettling, Dörte Bernhardt, Dr. Cornelia Elsner, Dr. Rolf Sartorius, Kathy Reimann, Rainer Remus, Dr. Wolfgang Plehn; Editors:
Katja Schwaab
Dr. Wolfgang Plehn

Extracts - Foreword

The following example illustrates the urgent need for action: Between 1995 and 2001, annual consumption of HFC-134a for first-filling automobile air conditioning systems intended for the German market grew from 1,400 to 3,900 tonnes, due to the increase in the number of automobiles equipped with air conditioning systems. In 2002, the cumulative HFC stock in automobile air conditioning systems in Germany already reached a level of 13,700 t. This amount corresponds to about

18 million t of CO_2 equivalents. For comparison: A small fuel-efficient car emits 1.5 to 1.8 t of CO_2 at an annual mileage of 15,000 km.

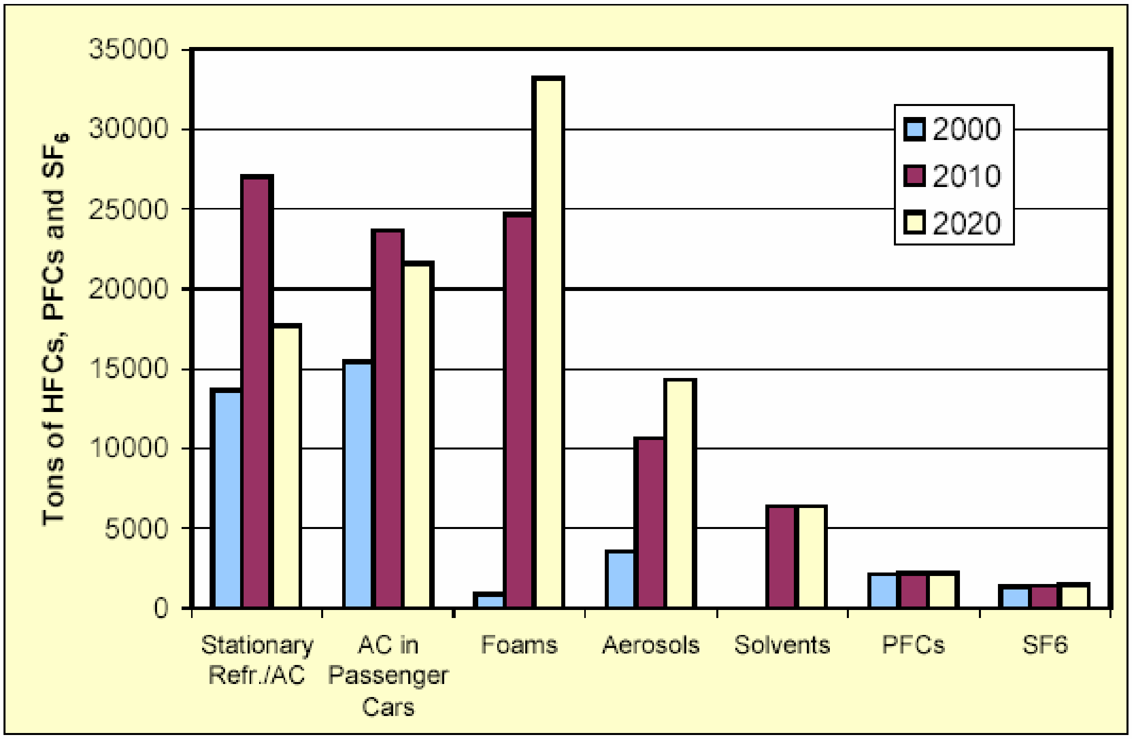
Thanks to the industry's innovative efforts, automobile air conditioning systems which use CO_2 as refrigerant are now ready to go into production. Not only do these systems use the virtually climate-neutral CO_2 as refrigerant, but they are also more economical to operate lower petrol consumption) than systems using fluorinated greenhouse gases.

Another example from the automobile industry shows that the entire product lifecycle needs to be considered in climate protection: Automotive components made of magnesium have a lower weight and thus help reduce fuel consumption. However, sulphur hexafluoride (SF_6), which is used in magnesium production and processing as a shielding gas, has a very high global warming potential which overcompensates magnesium's weight advantage in motor-vehicle manufacture. Here too, industry has developed solutions which should be implemented in industrial practice in the short term.

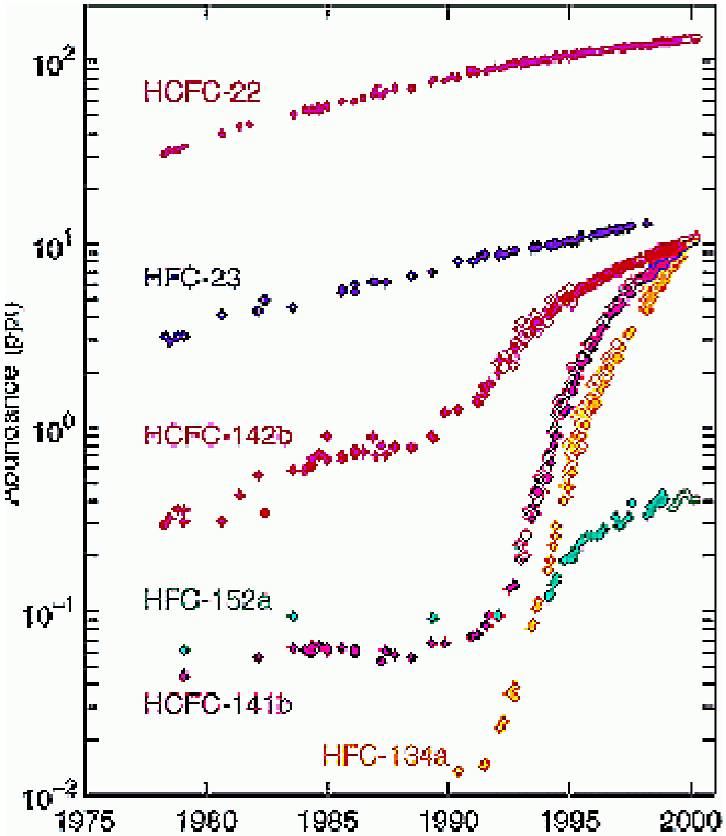
The report describes a multitude of further substitution and emission abatement possibilities. Nevertheless, forecasts predict a continued sharp rise in the use of fluorinated greenhouse gases. In 2020, fluorinated greenhouse gases are anticipated to have a global annual market volume of up to 500,000 t, Europe accounting for up to 100,000 t of this total. Annual emissions of different fluorinated gases to the environment up to the year 2020 may total about 330,000 t worldwide and about 60,000 t in Europe. HFCs account for about 95% of this total.

Extracts – Introduction

Figure 1.1 gives an overview of the HFC and PFC quantities used in the various applications in the year 2000 and the quantities that are predicted to be used in the years
2010 and 2020.



Amounts of Fluorinated Gases Used in Major Applications in Europe (in Tons). - The amounts indicated for PFCs include process emissions. After [Harnisch et al. 2003].



Concentrations of HCFCs and HFCs in the Atmosphere [IPCC 2001].

Compound/ Code	GWP 20 years	GWP 100 years	GWP 500 years
Carbon dioxide	1	1	1
Methane	56	21	6.5
Nitrous oxide	280	310	170
HFC-23	9,100	11,700	9,800
HFC-32	2,100	650	200
HFC-43-10mee	3,000	1,300	400
HFC-125	4,600	2,800	920
HFC-134a	3,400	1,300	420
HFC-152a	460	140	42
HFC-143a	5,000	3,800	1,400
HFC-227ea	4,300	2,900	950
HFC-236fa	5,100	6,300	4,700
HFC-245ca	1,800	560	170
HFC-365mfc	2,600	890	280
HFC-404A	4,760	3,260	1,150
HFC-407C	3,400	1,525	490
HFC-410A	3,350	1,725	560
HFC-417A	4,800	1,950	

HFC-507		3,300	
Chloroform	15	5	1
Methylene chloride	28	9	3
Sulphur	16,300	23,900	34,900
hexafluoride	4,400	6,500	10,000
Perfluoromethane	6,200	9,200	14,000
Perfluoroethane	4,800	7,000	10,100
Perfluoropropane	4,800	7,000	10,100
Perfluorobutane	6,000	8,700	12,700
Perfluorocyclobuta			
ne	5,100	7,500	11,000
Perfluoropentane	5,000	7,400	10,700
Perfluorohexane			

Conclusions [part A general]

From an environmental point of view, of all of the fluorinated compounds' properties, the contribution to global climate change is by far the most significant one.

Although today's additional greenhouse effect caused by fluorinated gases is low, it will enormously increase owing to the replacement of CFCs. This will pose a significant problem in future.

On the other hand, it should be taken into account that emissions of fluorinated gases can often be reduced by 100% if suitable measures are taken - e.g. through substitution. Where traditional greenhouse gases are concerned, this is almost never the case. The emission reduction amounts that can be reached with CO_2, for example, by applying individual measures lie in the same order of magnitude as those that can be achieved with fluorinated gases.

Since fluorinated gases have both direct and indirect effects, emission reduction measures should always take the total contribution to the greenhouse effect into account. This is characterised by the total equivalent warming impact (TEWI) (see Chapter 3.3). It is furthermore important to consider the risks resulting from the persistency of fluorinated gases. When in doubt, halogen-free substances or technology should be given preference, provided they do not lead to any ecological or safety risks.

Extract S2 (emission trends)

HFCs -

According to „Emissions Projections With Approved Measures"/„Mit-Maßnahmen-

Szenario3" prepared on behalf of the Federal Environmental Agency, absolute, use-related HFC emissions will generally increase between 1995 and 2010 by approximately +270 %.

In comparison, without the reduction measures taken since 1998, current estimates presume that the use-related emissions in 2010 would be about 5,000 t higher (i.e. by almost 5 million t of CO_2 equivalent) [Schwarz 2003]. On the other hand, additional reduction measures would help to reduce emissions even further: In comparison to the „Emissions Projections With Approved Measures"/"Mit-Maßnahmen-Szenario" in 2010 by about 2.5 million t of CO_2 equivalent, in 2020 by about 8 million t of CO_2 equivalent (see „Emissions Projections With Additional Measures"/"Mit-weiteren-Maßnahmen-Szenario" [Schwarz 2003]).

Extract conclusions s3 3 1

Approximately 10 years ago, the German manufacturers placed CFC- and HFC-free domestic refrigerators and freezers on the market. Today, such systems are produced in the various countries in Europe, but also outside Europe. They have proved their safety and their economic and ecological benefits. Other European and non-European manufacturers (e.g. manufacturers in the USA) still use HFC-134a in the insulation and as refrigerant. Some of these systems are also available in Germany.

The use of HFCs is neither as refrigerant nor as blowing agent necessary. Consumers should prefer HFC-free products with a high energy efficiency.

Many older appliances still contain CFCs, in some cases also HFCs. During their recovery or disposal, emissions should be kept to a minimum.

Extract Section Mobile Air Conditioning

German cars equipped with air conditioning rose from 9% in 1992 to 84% in 2004 (all HFC 134a).

Between 1995 and 2002, the increasing HFC stock went hand in hand with an increase in
HFC emissions from 120 t to 1,400 t. These amounts are equivalent to a contribution to the greenhouse effect of 0.15 million t or 1.8 million t of CO_2 equivalent respectively (see Table 3.1). If the use of R 134a were to continue as it is, the annual emissions in 2020 would amount to 3,500 t [Schwarz 2003a].

Today, about one quarter of all HFC emissions are caused by air-conditioning units in *passenger cars. There are: regular/normal emissions (gradual loss, i.e. the slow leakage of refrigerant through seals), irregular emissions (sudden loss, due to an accident, a rockfall etc.) and end-of-life emissions (emissions during disposal) [Schwarz 2001]. The annual refrigerant emissions into the atmosphere amount on average to approximately 8.2 % [Schwarz 2001; UBA 2002]. Disposal-related HFC emissions first occurred in 2002 when the first units that had been converted in 1995 from R 12 to HFCs were scrapped.*

These emissions are not included in the average value mentioned above. From 2005 on, the first generation of units initially charged at production with R 134 will be scrapped.

Today, a large portion of passenger cars are not scrapped in Germany but exported to other countries before they are scrapped (e.g. to Eastern Europe and Africa) [Buchert, Hagelüken 2003]. Only few of these vehicles are exported to countries where the necessary legislation is in place to ensure a safe disposal of the refrigerant. No reliable information is available on the whereabouts of these vehicles, their maintenance, the emissions and the disposal of the refrigerant. It is therefore very likely that a large portion of the refrigerant (R 134a) contained in the air-conditioning systems of these vehicles is emitted. As mentioned above, about 13,700 t of HFC-134a are already contained in existing units in passenger cars licensed in Germany. This amount is equivalent to approximately 18 million t of CO_2 equivalent. …

… [on alternative car aircon systems] … *The group of international car manufacturers, which has taken the lead in the development of the CO_2-based technology, presumes that by the year 2006 this optimisation process will have been completed [Mager 2003; COM 2003]. In 2002, Toyota, in cooperation with Denso, placed the first CO_2-based units for passenger cars on the market in Japan and California [COM 2003].*

[conclusion]

Taking all aspects into account, it can be concluded that CO_2 is the best refrigerant. As soon as the planned optimisation is completed, it will be possible to place CO_2-based systems on the market, enabling on a medium and long-term basis all new vehicles with air-conditioners to be equipped with CO_2-based units.

Extracts - section 15

'An Overview of Possible Substitution Measures and Additional Ways To Reduce Emissions in Various Applications'

The report states:

Between 1995 and 2002, HFC emissions in Germany rose by 270 % and the trend is likely to continue. On the other hand, the increase in PFC and SF_6 emissions could be stopped. Since the Mid-1990ies, PFC emissions dropped by 60 %, SF_6 emissions by half. It is therefore particularly important to substitute HFCs and reduce their emissions. On the other hand, for the first time in 2002 more PFCs and SF_6 were emitted again than in the previous year.

In almost all areas of application, it is possible to replace fluorinated greenhouse gases (HFCs, PFCs and SF_6) by halogen-free alternatives. In addition, there are many more ways to reduce emissions.

The report gives (section 15, table 15) a tabulated 'Overview of Possible Susbtitution Measures and Additional Ways To Reduce Emissions in the Various Appliactions …'

This includes*:

Sector: REFRIGERANTS

Subsector:	Domestic refrigerators and freezers
F-gases:	HFC 134a
Alternatives already in use:	600a (isobutane); absorption
Alternatives being tested:	CO2
Subsector:	Commercial refrigeration systems
F-gases:	HFCs 134a, 404A, 407C, 507A
Alternatives already in use:	290 (propane), 600a (isobutance), NH3 (with heat transfer fluid), CO2 cascade (LTR)
Alternatives being tested:	CO2 (LTR and medium temp range), CO2 for small cooling capacities, Stirling cooling
Subsector:	Industrial refrigeration systems
F-gases:	HFCs 134a, 404A, 407C, 507A, 236a, 227ea, PFCs
Alternatives already in use:	290 (propane), 600a (isobutance), NH3 (with and without heat transfer fluid), NH3/CO2 cascade, absorption, adsorption
Alternatives being tested:	CO2
Subsector:	Stationary air conditioning of buildings
F-gases:	HFCs 134a, 407C
Alternatives already in use:	absorption, adsorption, air-conditioning without mechanical refrigeration, NH3, hydrocarbons, NH3/DME
Alternatives being tested:	H2O, air conditioning without mechanical refrigeration
Subsector:	Transport refrigeration systems

F-gases: HFCs 410A, 404A, 134a, 407C
Alternatives already in use: CO_2 used as refrigerant in open systems
Alternatives being tested: CO_2, hydrocrabons, NH_3, NH_3/CO_2

Subsector: Refrigeration and air-conditioning units/ room air conditioners (RACs)
F-gases: HFCs 410A, 417A, 407C
Alternatives already in use: 290 (propane), central unit without HFCs
Alternatives being tested: CO_2

Subsector: Refrigeration and air-conditioning units/ room air conditioners (RACs)
F-gases: HFCs 410A, 417A, 407C
Alternatives already in use: 290 (propane), central unit without HFCs
Alternatives being tested: CO_2

Subsector: Domestic heat pumps
F-gases: HFCs 404A, 407C, 410A
Alternatives already in use: 290 (propane), 1270 (propene)
Alternatives being tested: CO_2, absorption

Subsector: Air-conditioning in vehicles
F-gases: HFCs: 134a, 152a
Alternatives already in use: 290 (propane), sliding roof, window, selection of colour etc
Alternatives being tested: CO_2, reduced heat generation (through foils, colour etc)

Sector: BLOWING AGENT IN FOAM PRODUCTION

Subsector: Rigid foams for thermal insulation (XPS, UPR)
F-gases: HFCs: 134a, 152a, 365mfc, 245fa, 227ea
Alternatives already in use: CO_2, CO_2/ethanol, c-pentane, I-pentane, n-pentane, alternative insulating materials
Alternatives being tested:

Subsector: Flexible polyurethane foams
F-gases: HFCs:
Alternatives already in use: CO_2
Alternatives being tested:

Subsector: Integral skin polyurethane foams
F-gases: HFCs: 134a, 365mfc, 227ea
Alternatives already in use: CO_2, pentane
Alternatives being tested:

Subsector: One component foam
F-gases: HFCs: 134a, 152a
Alternatives already in use: 290 (propane), DME, systems without blowing agent

Alternatives being tested:

Sector: PROPELLANT

Subsector:	Technical sprays: freezer spray, compressed-air (anti dust) spray and other technical sprays
F-gases:	HFCs: 134a
Alternatives already in use:	290 (propane), 600a (isobutane), N2, CO2
Alternatives being tested:	

Subsector:	Medical aerosols
F-gases:	HFCs: 134a, 227ea
Alternatives already in use:	Dry powder inhalers
Alternatives being tested:	600a (isobutane)

Subsector:	Aerosols in households and cosmetic aerosols
F-gases:	HFCs: 134a, 227ea
Alternatives already in use:	Dry powder inhalers
Alternatives being tested:	600a (isobutane)

Subsector:	Aerosols intended for decorative purposes, party supplies
F-gases:	HFCs: 134a
Alternatives already in use:	290 (propane), 600a (isobutane), N2, CO2, Products without propellants (eg paper streamers)
Alternatives being tested:	

Subsector:	Acoustic alarms (signal horns)
F-gases:	HFCs: 134a
Alternatives already in use:	mechanical alarms
Alternatives being tested:	

Subsector:	Pepper sprays
F-gases:	HFCs: 134a
Alternatives already in use:	
Alternatives being tested:	

Subsector:	Insecticides, herbicides etc, for other than domestic uses
F-gases:	HFCs: 134a
Alternatives already in use:	
Alternatives being tested:	CO2

Sector: FIRE EXTINGUISHING AGENT

F-gases:	HFCs: 227ea, 236fa, 23, 125; PFCs

Alternatives already in use: N_2, CO_2, Argon, Inergen, Water mist, fluoroketone, foam, sprinkler, early-earning systems etc

Alternatives being tested:

Sector: SOLVENT

F-gases: HFCs: 43-10mee, outside Germany - various

Alternatives already in use: Halogen-free organic solvents and water-based solvents, HFE, no cleaning, solvent-free cleaning

Alternatives being tested:

Sector: ETCHING

Subsector: Semi-conductor industry

F-gases: SF_6, PFCs, HFCs

Alternatives already in use: Different substitutes depending on the process (eg NF_3)

Alternatives being tested: Different substances depending on the process eg C_4F_8O

Subsector: Production of circuit boards

F-gases: PFCs

Alternatives already in use: (Wet chemical tecniques), laser

Alternatives being tested:

Sector: Extinguishing and insulating gas

Subsector: Switch-gear 110-380kV

F-gases: SF_6

Alternatives already in use: Air

Alternatives being tested: Vacuum

Subsector: Switch-gear >1-36kV

F-gases: SF_6

Alternatives already in use: Air, vacuum

Alternatives being tested:

Sector: COVER GAS

Subsector: Magnesium processing

F-gases: SF_6; HFCs: 134a

Alternatives already in use: SO_2, 134a as a substitute for SF_6, fluoroketone

Alternatives being tested: CO_2

Sector: DEGASSER

Subsector: Secondary aluminium casting

F-gases:	SF6
Alternatives already in use:	Inert gases + elementary halogens
Alternatives being tested:	Inert gases + elementary halogen

Sector: FILLING GAS

Subsector:	Car tyres
F-gases:	SF6
Alternatives already in use:	Air, N2
Alternatives being tested:	Inert gases + elementary halogen

* The report also gives additional emission reduction measures such as low emission disposal, reduced refrigerant charges and hermetic sealing. Technical measures are identified for most uses including fire extinguishing and solvents. LTR – low temperature refrigeration.