

CLIMATE CHANGE
SCIENTIFIC ASSESSMENT AND POLICY ANALYSIS

**Instrumentation of HFC-23 emission
reduction from the production of HCFC-22**

Assessment of options for new installations

Report

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This study has been performed within the framework of the Netherlands Research Programme on Scientific Assessment and Policy Analysis for Climate Change (WAB), project 'Options for the reduction of HFC-23 emissions from the production of HCFC-22 in new installations under CDM'

Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering

Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroep zijn met name de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid.

De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit MNP, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het MNP is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

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The Netherlands Programme on Scientific Assessment and Policy Analysis Climate Change has the following objectives:

- Collection and evaluation of relevant scientific information for policy development and decision-making in the field of climate change;
- Analysis of resolutions and decisions in the framework of international climate negotiations and their implications.

We are concerned here with analyses and assessments intended for a balanced evaluation of the state of the art for underpinning policy choices. These analyses and assessment activities are carried out in periods of several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams organised to handle the various topics consist of the best Dutch experts in their fields. Teams work on incidental and additionally financed activities, as opposed to the regular, structurally financed activities of the climate research consortium. The work should reflect the current state of science on the relevant topic. The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by organisations in society playing an important role in the decision-making process concerned with and the implementation of the climate policy. A consortium consisting of the Netherlands Environmental Assessment Agency, the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of the Wageningen University and Research Centre (WUR), the Netherlands Energy Research Foundation (ECN), the Netherlands Research Programme on Climate Change Centre of the Vrije Universiteit in Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute of the Utrecht University (UU) is responsible for the implementation. The Netherlands Environmental Assessment Agency as main contracting body is chairing the steering committee.

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Preface

This report was commissioned by the Netherlands Programme on Scientific Assessment and Policy Analysis (WAB) Climate Change.

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Executive Summary

This paper addresses the methodological aspects of inclusion of the reduction of HFC-23 by-product emissions from new HCFC-22 production facilities under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Numerous Parties to the Protocol have expressed their fears that inclusion of this type of projects under the CDM will generate such high income that it would create a perverse incentive to invest in new HCFC-22 capacity or to expand the production of HCFC-22 in existing plants with the aim of generating additional CERs. The dispersive use of HCFC-22 is regulated under the Montreal Protocol, with production and consumption not being restricted until 2015 in developing countries.

Current projections indicate that production of HCFC-22 will increasingly shift from the developed to the developing countries, with an overall growth in production of 30% between 2005 and 2015, potentially leading to additional HFC-23 emissions of 90 Mt CO₂-eq. per year. Given these relative high emissions and the availability of a technology (thermal oxidation) that reduces these emissions by over 90% at relative low costs ranging from 0.2 to 0.6 US\$/tCO₂, HFC-23 by-product emission reductions can play an important role in climate change mitigation.

The challenge is to find a framework that both supports the widespread implementation of this reduction option, and at the same time reduces any negative side-effects such as the disturbance of HCFC-22 markets and/or additional emissions of ozone depleting substances (ODSs) and greenhouse gases (GHGs). This framework could be found either within or outside the CDM, as discussed in this paper.

CDM policy options

Thirteen CDM options have been assessed, four of them in detail:

(1) Partial issuing of CERs to HFC-23 emission reduction

Issuing only a fraction of the HFC-23 reduction as CERs would be a solution leading to net global emission reductions, i.e. the CDM host will actually reduce more GHG emissions than the amount of emission reduction sold as CERs for offset. The determination of this fraction can be based on various approaches which all require agreement on a number of variables by the Parties to the Protocol. It may prove to be difficult to agree on a transparent justification for the choice of variables.

(2) Revenues above project costs are transferred to a fund that supports sustainability purposes

In this option CERs are issued fully, and the revenues from the sales of CERs beyond the project costs are transferred to a fund for sustainable purposes. This fund could be organised as either a generic or a dedicated fund. For example, by supporting low-ODP low-GWP HCFC-22 substitutes in developing countries, an earlier and more sustainable HCFC-22 phase-out could be supported. The fund could also finance the recovery and destruction of existing CFC/HCFC banks, which will be responsible for significant ODS and GHG emissions in the coming decades. Such a fund could be allocated within the MLF.

Also under this option, difficulties may arise to agree on a transparent justification for the choice of variables that determine the actual project costs.

(3) Project financing by an independent intermediary institution

Under this scenario an intermediary institution or company is established that guarantees to all future HCFC-22 plant operators that the planning, implementation and operation costs of the HFC-23 incineration will be fully financed by this institution. A fraction of the CERs, covering all project and administration costs would be sold, the rest would be transferred to a cancellation account. This approach would also lead to net global emission reductions. Such an institution could be allocated with the Carbon Finance Unit of the World Bank.

(4) Restrict CDM to HCFC-22 feedstock production

The CDM could be restricted to new production facilities that produce HCFC-22 only for use in feedstocks. Feedstock use will not result in fugitive and end-of-life emissions of HCFC-22.

Furthermore, it is not subject to phase-out under the Montreal Protocol. However, feedstock production can not always be identified with certainty and currently covers only 20-40% of global HCFC-22 production. This means that only with very costly registration systems, identification of production for feedstock use might be possible. At the same time, only a fraction of HFC-23 emissions would be covered. Furthermore, as a result of the incentives from the CDM, HCFC-22 production for feedstock may be shifted from industrialized countries to developing countries beyond what would occur in the absence of the CDM.

Non-CDM policy options

Regarding other policy options outside the CDM framework, two approaches have been assessed:

(5) Funding of HFC-23 destruction through the Global Environmental Facility

In principle, these projects could be financed through the GEF, but a replenishment of the fund of around 30 Million US\$ (in total) would be needed. A number of national governments within the EU have indicated that they are not intending to replenish the GEF for such purposes.

(6) Development of national policies aimed at an earlier or accelerated phase-out of HCFC-22

Developing countries already struggle with the phase-out of CFCs, but many have nevertheless already started to prepare for HCFC phase-out. Acceleration of this process seems difficult, especially as main HCFC-22 alternatives are HFCs which have comparable direct GWPs. Increased application of HFCs would thus lead to increased GHG emissions under the Kyoto Protocol, as HCFC-22 is not in the Kyoto basket but HFCs are. This might be counterproductive for the negotiation of future Kyoto commitments for developing countries. National approaches giving strong signals for the phase-out of HCFC-22 (as in India, where building new HCFC-22 production capacity is prohibited as of the year 2000), combined with promotion of low GHG-alternatives could be of considerable supportive value.

The below table includes an overview of the six options scored against the four most important criteria. The scenario where HFC-23 incineration is allowed under CDM for both existing and new HCFC-22 installations is used as a reference. The criteria are:

- The level of HCFC-22 emissions, which is an ODS as well as a GHG.
- All options apart from option (4) restrict the perverse incentive to the plant owner /project developer to invest in new HCFC-22 capacity. Under option (1) the level to which restriction occurs involves more uncertainties and thus scores +. Option (4) still may result in perverse incentives for HCFC-22 feedstock production but eliminates the incentive for non-feedstock and thus also scores better than the reference scenario.
- Net global emission reductions through HFC-23 destruction
- Here we assume that a CDM project does not lead to net global emission reduction if total HFC-23 emission reductions are issued as CERs. This is the case for option (2). Under option (1) and (3) only part of the emission reductions is issued and thus a better score than the reference is realized. Under option (4) new non-feedstock production does not fall under CDM and thus these plants will continue emitting HFC-23 (score --). Under options (5) and (6) HFC-23 destruction takes place without CDM and thus a considerable net emission reduction is realized. Note that apart from emission through HFC-23 destruction, GHG emissions also occur through consumption from HCFC-22, which is covered under the first criterion.
- Impact on CER prices
- A positive score is given to those options where the CER price increases compared to the reference case as a higher CER price gives more incentives for sustainable projects. The impact on CER prices may be considerable in the reference situation where potentially high amounts of CERs may be issued. The score for option (1), (3) and (4) is positive since the amount of CERs is less than in the reference case. Under option (2) the same amount of

CERs will be issued as in the reference situation, whereas under the last two options no CERs will be issued.

- Feasibility
- All options require more effort than the reference case and thus have a negative score. The first option scores double minus since the barrier to meet CDM rules is considered hard to overcome. The creation of either an investment fund (2) or the project financing intermediary (3) are believed to have less associated implementation barriers. Option (3) for example reduces the need to agree on methodological issue on the funds needed for project implementation. The fourth option is expected to be demanding in terms of monitoring and control. Option (5) would need considerable replenishment of the GEF by Annex I Parties, which may be problematic. The last option will face mainly political barriers as facing out HCFC-22 may lead to more GHG emission which may be counterproductive for the negotiation of future Kyoto commitments.

Table 1 Overview of CDM and non-CDM options scored against four criteria with the scenario where HFC-23 incineration is allowed under CDM for both existing and new HCFC-22 installations as a reference.

Scenario	Level of HCFC-22 emissions	HFC-23 net emission reduction	Impact on CER price	Feasibility
1. Partial issuing of CERs to HFC-23 emission reduction	+	++	++	--
2. Revenues above project costs are transferred to a fund that supports sustainability purposes	++	0	0	-
3. Project financing by an independent intermediary institution	++	++	++	-
4. Restrict CDM to HCFC-22 feedstock production	+	--	++	--
5. Funding of HFC-23 destruction through the Global Environmental Facility	++	+++	+++	--
6. Development of national policies aimed at an earlier or accelerated phase-out of HCFC-22	++	++	+++	--

Both non-CDM policy options seem to have several barriers that may restrict their applicability in the current debate. They can however be of supportive value. Regarding the CDM policy options, the creation of either an investment fund (2) or the project financing intermediary (3) are believed to have less associated implementation barriers. They could be combined as well, resulting in additional funds for general or dedicated measures supporting sustainable development in developing countries.

1 Introduction

The first approved methodology (AM0001) under the Clean Development Mechanism (CDM) involves the incineration of HFC-23 emissions from HCFC-22 production. HFC-23, a potent greenhouse gas (GHG) with a global warming potential (GWP) of 11700¹ is a by-product from HCFC-22 production, a substance used among others for refrigeration. HCFC-22 itself is an ozone-depleting substance (ODS) regulated under the Montreal Protocol as well as a GHG with a GWP of 1780 ± 620², but it is not regulated under the Kyoto Protocol. After various CDM projects were initiated, numerous Parties to the Protocol expressed their fears that the incineration of HFC-23 under the CDM generates such high income that it would create a perverse incentive to invest in new HCFC-22 capacity or to expand the production of HCFC-22 in existing plants and thus to increased HCFC-22 emissions. This could lead to the following developments:

- In case HCFC-22 production is financed for a large share or even beyond production costs with CER revenues, there is an incentive to increase HCFC-22 production. This may even lead to site operators venting the product, in case there is no market demand. As a result, HCFC-22 market prices may drop, leading to an increased demand for HCFC-22, involving increased HCFC-22 emissions from dispersive uses and increased global GHG emissions due to the use of CERs from such activities.
- Lower HCFC-22 prices will have a negative effect on the market development of HCFC-22 alternatives.
- The favourable investment opportunities in developing countries may stimulate accelerated production shifts from developed to developing countries due to CDM. As a consequence, production in sites already equipped with incinerators is transferred to sites where incineration is carried out as CDM-projects. These CERs can in turn be used by developed countries to compensate for their GHG emissions. In this way, emission reduction in developing countries - which are first "transferred" from industrialized countries - allows additional emissions in industrialized countries, resulting in a global increase of GHG emissions.
- The incentives to invest in new HCFC-22 capacity might delay the phase-out of HCFCs under the Montreal Protocol in developing countries. The Montreal Protocol foresees the phase-out of production and consumption of HCFCs for dispersive uses in developing countries between 2016 and 2040. In the year 2016 they have to freeze their HCFC-22 production to the level of 2015 and from the year 2040 onwards are not allowed to produce and consume HCFC-22 anymore. Developing countries however do not have any obligations for the production and consumption of HCFC-22 up to the year 2015 and no specific reduction steps for the phase-out have been negotiated under the Montreal Protocol, but are to be negotiated within the next years. The high financial revenues from HCFC-22 production through CDM may have a negative effect on the willingness of developing countries to agree on ambitious targets regarding the phase-out and may result in a higher base year level in 2015.
- The potentially significant CER flow from HFC-23 projects could overflow the market for CERs, thus considerably lowering the CER market price. This could result in a devaluation of projects with smaller CER outcome, but higher sustainability. Low CER prices also lead to low compliance costs for companies under the EU emission trading scheme and for countries that need to comply with their Kyoto target. As a result the pressure to take actual measures to reduce emissions in developed countries decreases.

Considering these negative consequences, in its fifteenth meeting in September 2004 the Executive Board (EB) of the CDM decided to request the Meth Panel to review the methodology

¹ Recent studies show an even higher value of 14,310 ± 5000 (IPCC/TEAP, 2005). The value of 11,700 is the reporting value to UNFCCC.

² IPCC/TEAP, 2005

AM0001 and put the methodology on hold until the revision process was finalized³. In December 2004, the EB decided that AM0001 should apply only to HCFC-22 production facilities with at least three years of operating history by the end of the year 2004. In addition the following requirements were introduced:

- HCFC-production used as baseline should not exceed the maximum (annual) production during the last three years.
- The HFC-23/HCFC-22 rate should not exceed 3%. If no direct measurement of HFC-23 release or mass balance exists for these three years, the default rate would be set at 1.5 %.

This type of CDM-project covers an area of overlap of the UNFCCC and its Kyoto Protocol and the Montreal Protocol: emission reduction of HFC-23 as regulated under the Kyoto Protocol may indirectly and inadvertently lead to a potential increase of HCFC-22 production and use, which is regulated under the Montreal Protocol. Although HCFC-22 has a GWP of 1780 from direct radiative forcing as well as an indirect negative GWP due to its ozone depleting effect, it is not included in the Kyoto basket⁴.

In order to tackle HFC-23 by-product emissions from new HCFC-22 production facilities, an approach fulfilling two aims is needed: reduction of HFC-23 emissions while avoiding the increase in HCFC-22 production as well as the indirect global increase of GHG emissions. In this paper, four options are discussed that could contribute to tackling this (political) problem within the CDM. They refer to CDM methodologies as well as to alternative means of financing through the Global Environmental Fund (GEF). Additionally two policy options outside the CDM were considered, aiming at funding of HFC-23 reduction measures through other sources or reduction of HCFC-22 production by an earlier phase-out than required through the Montreal Protocol. Beforehand, technological issues of HCFC-22 production, demand projections as well as existing alternative technologies and their market development are discussed, to give an overview on the future necessity of HCFC-22 production.

³ UNFCCC Secretary, 2004

⁴ The Kyoto Protocol covers CO₂, CH₄, N₂O, SF₆, HFCs and PFCs.

2 Background

2.1 Status of HFC-23 CDM projects

The demand for certified emission reductions (CERs) from CDM projects has increased over the last years and continues to increase since both governments and companies under the EU emission trading scheme are looking for low cost options to reach their emission reduction targets. Supply of credits, on the other hand, is still lagging behind, mainly due to long lead times of the approval process of those credits. As a consequence, the price of CERs is rising slowly, with current prices ranging from US\$ 6-12.

The future supply of CERs is difficult to predict due to the many uncertainties surrounding the CDM process. According to (Defra, 2005), supply may be around 30 million tonnes per year in 2007. A CDM pipeline inventory of UNEP shows an annual 133 million tonnes (UNEP/RISOE, March 2006) supply for the coming years based on the current projects in the CDM pipeline. For the longer term, the World Bank estimates that CDM Carbon contracts today will reach towards 200 Mtonne per year for 2012 delivery (Worldbank, 2005).

Currently five HFC 23 projects have been registered as CDM projects, one is currently requesting for registration and another five are under validation, involving a total of 56,1 Mtonne CO₂-eq per year (UNEP/RISOE, 2006). This is already a significant amount compared to the total projected potential of emission reduction through destruction of HFC-23 emissions in developing countries, based on current production data of HCFC-22 which amounts to 83 CO₂-eq.⁵ (McCulloch, 2003). With only taking into account the 56,1 Mtonne CO₂-eq per year of HFC-23 CDM projects currently in the pipeline, the supply of CERs from those project will already amount to 28 % of the projected 200 Mt emission reductions in 2012 CDM.

2.2 HCFC-22 Production and Use

As indicated above, allowing the destruction of HFC-23 in new HCFC-22 production capacity under the CDM leads to lower market prices for HCFC-22 which may have negative consequences for the lower ODP and GHG alternatives of HCFC-22. It may result in a delay in the (further) market introduction of these alternatives, especially in developing countries. This section gives an overview on the various applications of HCFC-22, projected development of production and use as well as existing HCFC-22 alternatives and their position on the market.

HCFC-22 is employed for several purposes: as refrigerant (55-60%), for feedstock purposes in the production of fluoropolymers⁶, i.e. production of polytetrafluoroethylene; (30-40%)⁷ and as solvent (5%) (UNEP-TEAP, 2003). In the CFC-phase-out, which has started in 1986, HCFC-22 is also used as a substitute, including CFC-12 in certain applications, mainly refrigeration, as well as CFC-11 as foam blowing agent.

Regarding its use as refrigerant, HCFC-22 has and is expected to also in the future have a predominant position in small air conditioning equipment (window-mounted and through-the-wall air conditioners, non-ducted and ducted, packaged air conditioners). In 2002 85-90% of new air-

⁵ 13 Mtonnes CO₂-eq. for feedstock use and to 70 Mtonnes CO₂-eq. for non-feedstock uses.

⁶ The production of PTFE consists of several reaction steps, in the first of which HCFC-22 is produced from the reaction of chlorophorm and hydrogen fluoride. In the second step the HCFC-22 is treated to form Tetrafluorethene. HCFC-22 is thus consumed in the process and not used as a product which may lead to emission, as it is the case for the other applications (in the rest of this document referred to as 'non-feedstock uses').

⁷ McCulloch 2004a assumes this fraction to be lower, around 20%.

cooled air conditioning and heat pump equipment was estimated to use HCFC-22. The market is increasing strongly, e.g. the number of units produced increased by 12% between 1998-2001 for window-mounted and through-the-wall air conditioners and by 48.5% for non-ducted or duct-free residential and commercial air-conditioners. (UNEP-TEAP, 2003)

HCFC-22 is widely used as CFC-replacement in commercial refrigeration, because it offers cost advantages in certain applications over other CFC replacements. Commercial refrigeration will be the largest field of application for HCFC-22 in the developing countries. The substance is also used in industrial refrigeration (chillers), in this area it has been used widely as CFC-replacement in developing countries due to its cost advantages for certain applications. A further area of application is transport refrigeration (e.g. ships, refrigerated road vehicles, rail car air conditioning). In reefer ships, merchant marine, naval and fishing vessels HCFC-22 is the main refrigerant in existing systems.

Current HCFC-22 market developments are the following:

- use of small air conditioning equipment in developing countries, esp. in China and in commercial refrigeration is increasing strongly
- due to the phase-out in non-Article 5(1) countries, production is increasingly shifting towards Article 5(1) countries.

HCFC-22 alternatives exist both for new equipment as well as drop-in for existing equipment. HFCs play a major role in the substitution of HCFC-22, both as drop-in as well as in alternative technologies and that such solutions are generally both technically and commercially viable and widely used for new systems – except for the case of small air-conditioning equipment, where HCFC-22 will be dominant also in the future. Low-ODS / low-GHG technologies, using e.g. CO₂, NH₃ or hydrocarbons as refrigerants are often proven to be technically viable, but show a lower level of commercialization or market penetration.⁸

Joint work by IPCC and TEAP shows that in a business-as-usual scenario (BAU) for the period 2002-2015, global demand, banks and emissions of HCFC-22 will increase by 37%, 23% and 94%, respectively. Due to the phase-out of HCFCs, developed countries show an overall decline in demand, banks and emissions, whereas for developing countries these figures are increases of 124%, 130% and 200%. The net effect is a steady increase in HCFC-22 demand on a global level. Compared to this BAU, a mitigation scenario shows significant reduction potentials, as illustrated in tables 1 to 3. Despite the reduction measures in the mitigation scenario, a significant increase in HCFC-22 use is still assumed to take place. Higher market shares of HCFC-22 alternatives, as assumed in the mitigation scenario, will thus not be sufficient to fully avoid an increase in HCFC-22 emissions, but further action will have to be taken.

Table 2, Table 3 and Table 4 respectively show projected HCFC-22 demand, HCFC-22 banks, i.e. in existing equipment, as well as HCFC-22 emissions in 2015 for a BAU and for a mitigation scenario for the various applications.

⁸ For an overview of existing alternatives see Annex II.

Table 2 HCFC-22 demand development (Background data to IPCC/TEAP, 2005; UNEP-TEAP, 2005)

HCFC-banks in ktonne of product	Developed countries			Developing countries		
	2002	2015 BAU	2015 MIT	2002	2015 BAU	2015 MIT
Domestic refrigeration	-	-	-			
Commercial refrigeration	32	10	6	126	341	245
Transport refrigeration	0.4	<0.001	<0.001	0.5	0.9	0.7
Industrial refrigeration	13	8	5	13	17	11
Stationary AC	104	26	5	54	78	49
Mobile AC	0.7	0.1	0.08	2	1	1
Foams	6	0	0	0.2	0.4	0.4
Fire protection	0.3	0.05	0.05	0.04	0.01	0.01
TOTAL	157	44	16	196	438	308

Table 3 HCFC-22 banks development (Background data to IPCC/TEAP, 2005; UNEP-TEAP, 2005)

HCFC-banks in ktonne of product	Developed countries			Developing countries		
	2002	2015 BAU	2015 MIT	2002	2015 BAU	2015 MIT
Domestic refrigeration	-	-	-	-	-	-
Commercial refrigeration	92	30	27	215	729	673
Transport refrigeration	2	0.005	0.005	2	3	3
Industrial refrigeration	80	46	46	62	80	74
Stationary AC	709	392	223	275	470	414
Mobile AC	9	4	3	11	20	20
Foams	71	98	98	0.7	4	4
Fire protection	3	2	2	0.4	0.6	0.6
TOTAL	966	573	400	565	1306	1187

Table 4 HCFC-22 emissions development Background data to IPCC/TEAP, 2005; UNEP-TEAP, 2005)

HCFC-banks in ktonne of product	Developed countries			Developing countries		
	2002	2015 BAU	2015 MIT	2002	2015 BAU	2015 MIT
Domestic refrigeration	-	-	-	-	-	-
Commercial refrigeration	29	10	4	75	288	183
Transport refrigeration	0.9	0.002	0.001	0.7	1	0.9
Industrial refrigeration	13	7	5	11	13	9
Stationary AC	59	58	17	33	60	32
Mobile AC	4	2	0.8	4	9	6
Foams	2	1	0.7	0.007	0.02	0.03
Fire protection	0.05	0.05	0.05	0.01	0.01	0.01
TOTAL	107	78	27	124	371	231

Resulting from the phase-out of HCFC in developed countries, the shift of production capacities from developed to developing countries as addressed in section 1 is foreseen to happen in any case. The speed of this shift and the level of production capacity in developing will depend on the market demand for HCFC-22 and possibly on the incentives created by CER revenues from HFC-23 destruction.

Figure 1 shows that reported emissions from developed countries clearly kept more or less steady after 1990 and decrease since 1998, while atmospheric measurements as well as projections from the IPCC/TEAP Special Report on Ozone and Climate (2005) indicate that global emissions have been continuously rising since 1995. This is attributed to an increase in HCFC-22 production in the developing countries.

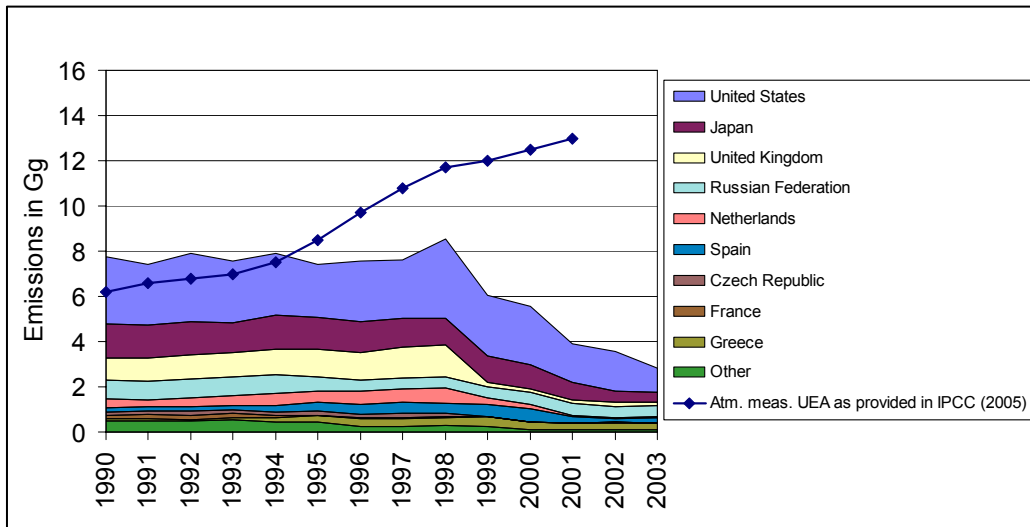


Figure 1 HFC-23 Emission Development (Source: Hoehne and Harnisch 2002a, Hoehne and Harnisch 2002b)

(McCulloch, 2004a) provides scenarios for HCFC-22 production, distinguishing between developed and developing countries as well as between feedstock and non-feedstock uses. Overall growth is projected to be around 30% between 2005 and 2015. Figure 2 shows the projections for non-feedstock use for developing and developed countries.

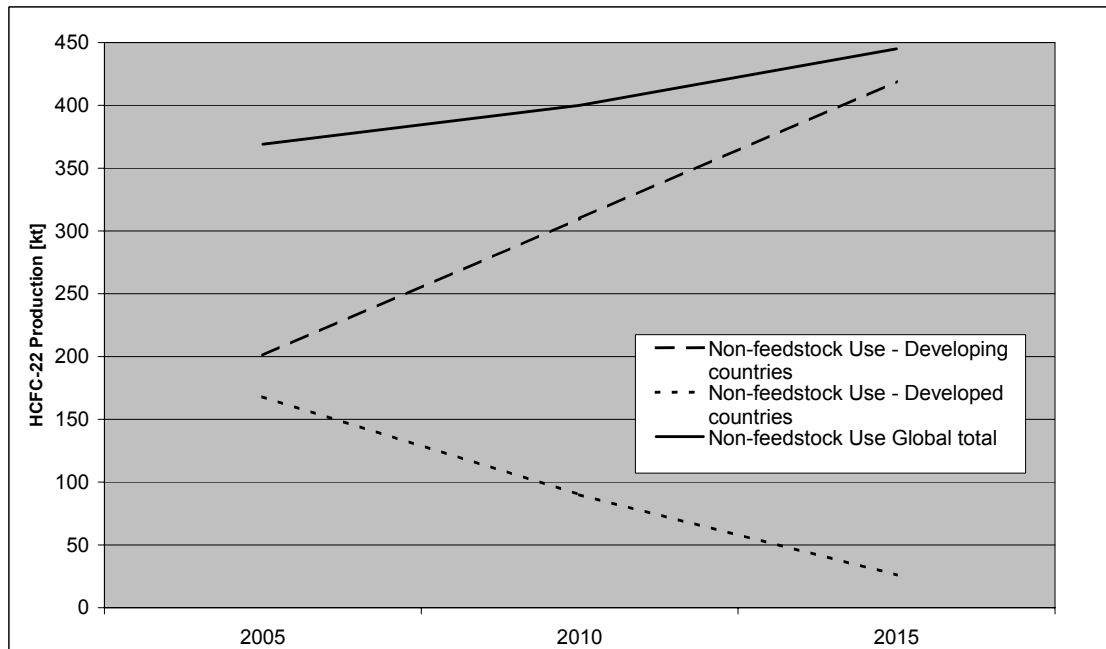


Figure 2 Projections for HCFC-22 Production for non-feedstock uses differentiated by region (McCulloch, 2004)

For the purpose of this study, the potential production in developing countries is of main importance. Projected HCFC-22 production and resulting HFC-23 by-product emissions for feedstock use, non-feedstock use as well as total use is shown in Figure 3. Total HFC-23 emissions are projected to increase by around 90Mt CO₂-equ. between 2005 and 2015.

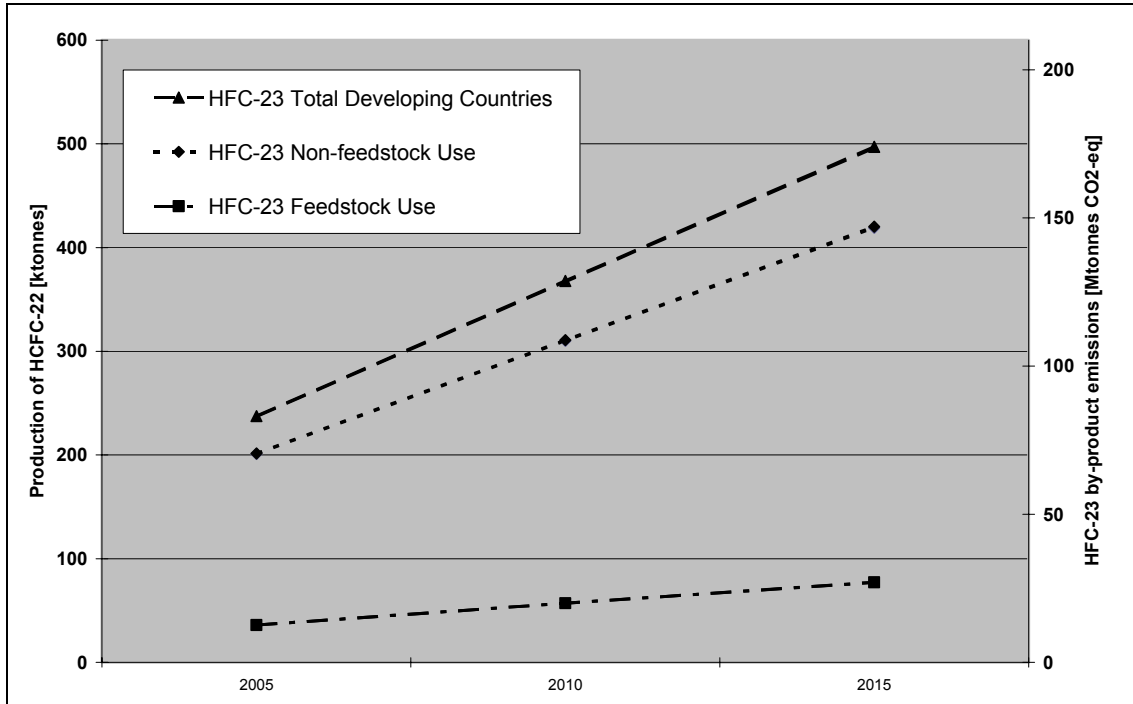


Figure 3 Projections for HCFC-22 Production and resulting HFC-23 by product emissions in developing countries differentiated by use (McCulloch, 2004)

While currently developed countries still dominate the HCFC-22 market, the share of developing countries will increase rapidly. Within the developing countries, the production capacity is currently concentrated in only a few countries: China, India, Brazil, Korea, Mexico and Venezuela as shown in Figure 4.

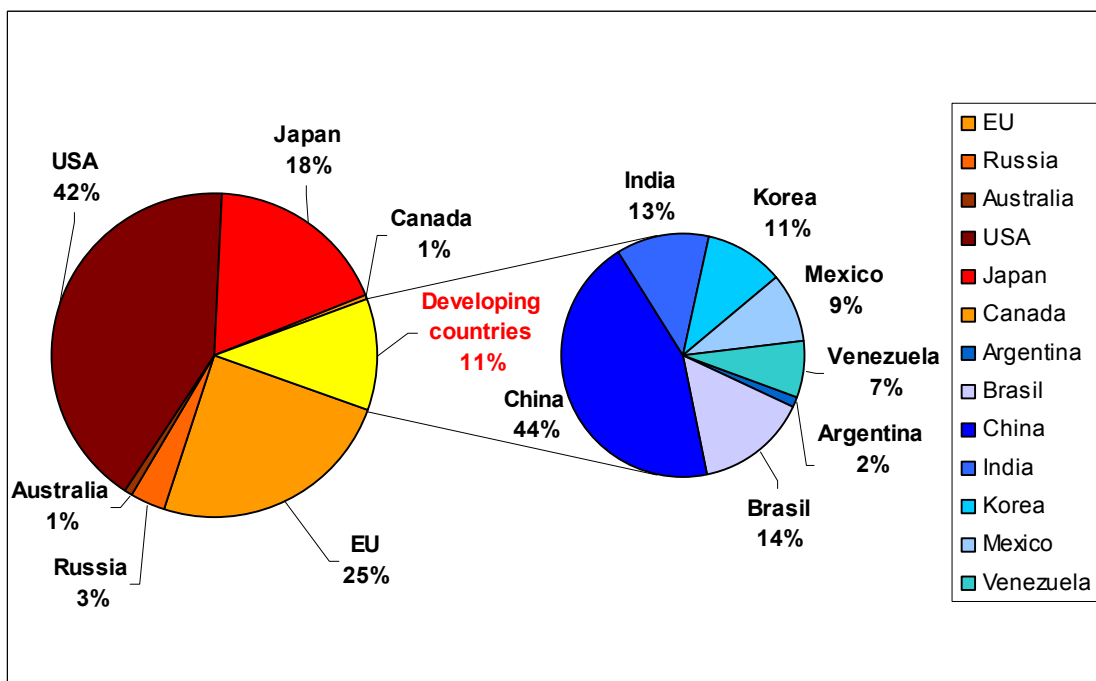


Figure 4 HFC-23 emissions from HCFC-22 production in 2000 (RIVM, 2005)

3 CDM-Options

In this section four options for the design of CDM projects in new HCFC-22 production sites are being discussed in detail and their potential for concrete implementation is being explored. Nine other options, which have not been selected for further assessment, are only addressed briefly.

3.1 CERs are only issued for a fraction of the emission reductions

Issuance of only a fraction of the emission reductions as CERs, aims to reduce the perverse incentive for increased HCFC-22 production arising from the significant additional income generated by the CDM HFC-23 reduction project. Such an approach will lead to a global net emission reduction compared to a situation in which all emission reductions are issued as CERs, as only part of the emission reduction can be used as CERs to offset emissions. In this option therefore the shift from mitigation action from developed to developing countries through the CDM as well as the supply of CERs to the carbon market is limited substantially.

In determining the fraction to be issued there are two general possibilities:

- issuing a fixed fraction of the emission reductions (e.g. 20% of the reductions)
- issuing an amount of CERs corresponding to a certain monetary value, e.g. related to:
 - the value of HCFC-22 produced in the installation
 - the reduction costs (i.e. HFC-23 incinerator investment, operation and maintenance costs)

Having an idea about the number of CERs - but not their value at time of issuance - is the typical situation a CDM project developer has to face. This is the case in the first approach. In the second approach, the CDM developer has greater planning security about the value of CERs he will receive, but not about their number. The amount of CERs will have to be determined ex-post, as prices vary. This could be problematic for CER forwards.

Inconsiderate of whether a fixed fraction is used or whether the amount of CERs is connected to a monetary value, it has to be taken into account that revenues from the issued CERs have to be in a certain range, i.e. they have to be:

- high enough to make a CDM-project financially attractive (in order to ensure the use of CDM resulting in a maximal number of sites equipped with HFC-23 emission reduction technologies).
- low enough to prevent the perverse incentive to increase HCFC-22 production just for the purpose of creating additional CERs.

For the second option of issuing a number of CERs corresponding to a certain monetary value, the lower boundary could be equal to the reduction costs plus a bonus for financial attractiveness, whereas the upper boundary is related to the market value of HCFC-22. In the following paragraphs these lower and upper boundaries will be evaluated for both approaches.

Approach 1: A fixed fraction is used

In order to be still attractive for operators, revenues from a CDM project at least have to cover the reduction costs and the CDM transaction costs. Reduction costs range between 0.2-0.6 US\$/tCO₂ (showing a variation of more than 100%), which translates to 67-201 US\$ / t HCFC-22 produced (UNFCCC, 2005). CDM project development costs should be taken into account as well. Assuming CDM transaction costs to be around 200.000 US\$ (UNDP, 2003), operational

CDM project duration of 7 years⁹ and an average capacity of 15.000 t HCFC-22 p.a. with a level of operation of 90%, this would lead to additional 0.006 US\$ CDM transaction costs per tCO₂ reduced, i.e. US\$ 2.1 per t HCFC-22. Costs per t HCFC-22 produced would then be between 69-203 US\$.

The lower boundary can be determined as follows (for example): Taking the high estimate of the cost range (203US\$ / t HCFC-22), a bonus of e.g. 3% is added to ensure financial attractiveness and cover some of the project risks. This results in a lower boundary condition of 209 US \$ / t HCFC-22 produced.

The upper boundary will be selected in order to prevent the perverse incentive to increased HCFC-22 production, i.e. to remain clearly below the market value of the produced HCFC-22. This can be achieved by restricting the support to a specific fraction of the market price of HCFC-22. For an average market price of 1500 US \$/t¹⁰ (UNFCCC, 2005), the lower boundary of 209 US \$ per tonne of HCFC-22 calculated above, represents 14% of the average market price. Hence, if this fraction is set to e.g. 20%, the upper boundary would equal 300 US \$ / t HCFC-22 produced.

In this example, the range of revenues could lie between 209 and 300 US \$ / t HCFC-22 produced. Assuming a CER price between 5 and 10 US\$ / tCO₂-eq. and taking the above example plant with annual HFC-23 emission reductions of 5,125,500 tCO₂-eq., only 9-16% of reductions would then be issued as CERs. A fixed fraction could be selected in this range, e.g. could then be agreed to be 12%.

This example illustrates that in determining the fraction of CERs to be issued, information and agreement on a substantial number of variables is required:

- the average investment and maintenance costs for a HFC-23 incinerator
- the additional bonus to ensure financial attractiveness
- the fraction of the HCFC-22 market price to which financial support can be given without introducing the perverse incentive
- the HCFC-22 market price
- the future CER price.

Approach 2: The amount of CERs issued is connected to a monetary value

For the two examples mentioned, connecting the amount of CERs to either a fraction of the value of HCFC-22 produced (I) or the reduction costs (II), the calculation of the amount of CERs to be issued would be the following:

(I) Number of CERs (tCO₂-eq.) =

$$\frac{\text{Production}_{\text{HCFC-22}} \text{ [t]} * \text{HCFC-22}_{\text{marketprice}} \text{ [US\$/t]} * \text{share to be issued}}{\text{CER}_{\text{marketprice}} \text{ [US\$/tCO}_2\text{-equ]}}$$

For the plant in the above example with 15,000 t capacity and 90% capacity utilization, an average HCFC-22 market price of 1500 US\$ / t and again using a fraction of 20% of HCFC-22 value to be issued, the total issued value would be 4,050,000 US\$. This would imply 810,000 CERs issued annually for a CER value of 5 US\$ / tCO₂-eq. and 405,000 in case of a CER value of 10 US\$ / tCO₂-eq.

⁹ 7 years is a conservative estimate. Project developers may choose between 10 or 3X7 years. In the latter case the baseline needs to be reconsidered after 7 years with the risk of non-CDM eligibility.

¹⁰ UNFCCC 2005) cites an average price of 1000-2000 US \$ /t HCFC-22. There is no global market place and prices can show considerable variation.

(II) Number of CERs (tCO₂-equ.) =

$$\frac{\text{Production}_{\text{HCFC-22}} [t] * \text{reduction costs}_{\text{HCFC23}} [\text{US\$} / \text{tHCFC} - 22] * \text{bonus}}{\text{CER}_{\text{marketprice}} [\text{US\$} / \text{tCO}_2 - \text{equ}]}$$

This calculation equals the calculation of the lower boundary, again a bonus of 3% has been used in order to render the project attractive. For the plant in the above example and using the high estimate of the reduction cost range of 203 US\$/tCO₂-eq., CERs equaling a value of 2,821,500 US\$ would be issued annually. This would imply 564,300 CERs issued annually at a CER value of 5 US\$ / tCO₂-eq., and 282,150 in case of a CER value of 10 US \$ / tCO₂-eq.

The approaches differ quite substantially regarding the amount of CERs issued. Furthermore again several variables exist:

- HCFC-22 market price
- reduction costs
- CER-market price
- Share to be issued (has to be agreed upon)

If a fixed fraction of the HCFC-22 value is to be issued, an agreed value has again to be developed. In order to do so, the above example for Approach 1 can be followed, with the difference that a number of CERs is calculated, not a fraction to be issued.

So for calculation in both Approaches 1 and 2, several variables exist. The determination of values for those variables is connected to several uncertainties,

For example the determination of the price for HCFC-22 is difficult to assess due to the nonexistence of a stock market for HCFC-22. As a result various regional markets exist and thus no worldwide average price is determined. As addressed under the example for Approach 1, the price for HCFC-22 currently ranges between US\$ 1,000 and 2,000 per tonne, thus showing a variation of 100%. The following options exist to deal with this problem:

1. Establishing the HCFC-22 price ex-post on a project specific basis
2. Ex ante establishment of a fixed HCFC-22 price up to 2012 or beyond

Since price-forming in the HCFC-22 market occurs on a national or regional scale it may be non-transparent with even the risk of attempts to drive up prices. Option (1) may therefore result in market disturbance and high vulnerability for fraud. Option (2) seems more feasible as it is transparent and univocal. The difficulty however is to have Parties agree to a fixed price. Furthermore, this option may involve considerable administrative costs.

Since CERs are traded on a stock market, transparent price information exists for this commodity. Nevertheless also here an agreement on the point of time or timeframe for determination of the price has to be found. Potential approaches are:

- Average price during a specific date: e.g. the day before issuance
- Average price during a timeframe, e.g. the verification period (i.e. the timeframe of CER generation). Using a timeframe would make the result less subject to the volatility of market prices..

Also the other variable, i.e. reduction costs and share to be issued, may face difficulties in coming to an agreement among stakeholders.

In general the determination of the amount of issued CERs in this option does not correspond to the CDM modalities and procedures as prescribed in the Marrakech Accords.¹¹ Discounts on CER amounts to be issued are applied also with other methodologies (e.g. methane capture from landfills), but with the aim to cover uncertainties in emission determination and not to

¹¹ CER (tCO₂-eq p.a.) = Baseline-emissions (tCO₂-eq. p.a.) – monitored Emissions (tCO₂-eq. p.a.) – Leakage (tCO₂-eq. p.a.), see UNFCCC 2001.

reduce project revenues in order to avoid perverse incentives. The EB would need to decide whether such a methodological approach is indeed acceptable. An argument for justification could be the required contribution of CDM projects to sustainable development. It should be noted however that imposing a considerable restriction on the most basic rule of the CDM, could shake confidence in the CDM as a market mechanism. Combined with the difficulties of quantifying some of the variables that vary over time, this approach seems difficult to implement in practice. It only seems feasible if a very transparent way is found in justifying the assumptions taken.

3.2 Revenues above costs of implementation are used to support sustainability purposes

In this option CERs are issued fully, but the revenues from the sales of CERs beyond the costs of project implementation, i.e. investment and maintenance of the HFC-23 incinerator¹², are used to support sustainability purposes. The purpose, similar as in Option 1 is to remove the perverse incentive of HCFC-22 over-production. Unlike Option 1, this option will not lead to a global net emission reduction, as all CERs are issued and sold on the market.

In supporting sustainability purposes, a fund seems most suitable. Below, various ways to structure such a fund are described. The following issues should be taken into account:

- Who will control the fund? Will it be under the control of a national or an international organization? Should a new fund structure be designed or should the fund be linked to an existing fund?
- What sustainability purposes shall be served? Sustainable development in general? Climate change mitigation or adaptation projects as part of the UNFCCC? Phase-out of ODS as under the Montreal Protocol?
- In case of an international fund, how will funds be distributed regionally? Will they only be used in the region they are generated in? Or allocated freely without regional concerns?

Controlling the fund

The advantage of national approaches is that funds can be directed with high precision to where they are needed. The risk however is that resources from the fund are used to replace government funds for sustainability purposes, which are in turn used for other purposes. An independent international institution would therefore need to ensure that the purposes and conditions, under which the funds operates, meet international standards and serve as a fund supervisor. An international solution would be more cost-effective, as structures have to be set up only once.

Furthermore, a national fund could provide incentives for the host country to further encourage the use of HCFC-22, since the revenues of the fund will be directly linked to the production of HCFC-22. However, a phase out schedule for HCFCs in developing countries between 2015 and 2040 has not yet been agreed upon. In this regard, a national fund could be counter effective for the objectives of the Vienna Convention and the Montreal Protocol to phase out ozone depleting substances.

A cost-effective approach would be to use existing fund structures. Potential funds would be the Global Environmental Facility (GEF) (focused on sustainability purposes in general, with sub-areas covering amongst others both climate change and ozone depletion) or the Multilateral Fund (MLF) (focused on implementation of the Montreal Protocol). Resources could be placed at the general disposal of a fund or could be dedicated to a specific purpose. The selection of the fund also depends on the specific purpose that the resources are to be used for.

¹² This requires an agreement on how to determine the costs of project implementation, leading to similar problems as addressed under Option 1.

Purposes of the funds

In general, resources can be dedicated to a number of purposes:

- General sustainability purposes, i.e. non-topical focus
- Focus on climate change
- Focus on ozone depletion
- Projects combining climate change mitigation (and/or adaptation), and ozone depletion

Considering that the resources for the fund stem from projects under the Kyoto Protocol and involve an overlap of targets of the Kyoto Protocol and the Montreal Protocol, stakeholders may prefer to allocate funds to activities under these protocols. This could imply a focus on:

- both climate change and ozone depletion in general, or
- on specific projects addressing both HCFC-22 emissions (being both an ODS and a GHG) and HFC-23 emissions from HCFC-22 production, by supporting the HCFC-22 phase-out.

The first approach could also include an issue that is not covered by either the Montreal Protocol or the UNFCCC and its Kyoto Protocol: the controlled destruction of existing CFC/HCFC banks. These banks are projected to contribute significantly to total GHG and ODS emissions in the coming decade(s). Recovery and destruction of these banks (in foams and refrigeration equipment) is not credited under either Montreal or Kyoto Protocol, and - although destruction itself has limited costs – can have significant associated costs due to organization of infrastructure and logistics.

The second approach could follow approaches taken in the MLF for the phase-out of CFCs. The MLF does currently not support activities for the phase-out of HCFCs employed as substitutes for CFC¹³. Such projects could include technology transfer for alternative technologies, (further) development of alternative technologies, support of implementation of alternatives, etc. With many applications, the main alternative technologies use HFCs (e.g. R-407a, R-410c), again being substances covered by the UNFCCC. It would thus be necessary to support a HCFC-22 phase-out with low-GHG, low-ODS substances. Section 2 gives an overview on the existing substances and technologies.

In case funding of activities focused on CFC and HCFC phase-out is preferred, the fund seems to be better placed with the MLF than with the GEF. Allocation of the resources to such specific purposes at the MLF was generally considered feasible by an MLF fund manager.¹⁴ Taking into account decision-making processes in the UNFCCC context, the decision to set up such a fund could take between 3 months and 1.5 years. The fund could be replenished directly by the UNFCCC/Executive Board. The MLF fund manager indicated that it can be expected that roughly 80% of the resources would have to be allocated (proportionally) to projects in the countries they originated from.

This would mean that the fund would mostly be used by China.

3.3 CDM-projects are carried out by an independent institution

Under this scenario an institution or company is established that guarantees all future HCFC-22 plant operators that the planning, implementation and operation costs of the HFC-23 incineration will be fully financed by the institution. In addition a financial bonus will be supplied to add an incentive to plant operators/owners to participate in such a project. Either the institution (through a third party) or the plant owner can be responsible for technical implementation, while the general project implementation will be carried out by the institution. The institution will also guarantee that technical support is supplied to train plant operators in operating the incinerator.

¹³ Multilateral Fund Secretariat: The Multilateral Fund. Policies, Procedures, Guidelines and Criteria (as of December 2005.); 2005.

¹⁴ Personal communication with Stephan Sicars on 21 May 2006.

The institution generates income by developing each of the HFC-23 incineration projects as a CDM project. They sell such an amount of CERs that the investment costs, operation and administration costs as well as the financial incentives to plant operators are covered. The remainder of CERs are made transferred to a cancellation account and can thus not be used anymore for compliance.

This scenario leads to a net global GHG emission reduction as all HFC-23 will be incinerated but only a fraction of the emission reduction will be issued as CERs. Both consequences of the generation of CERs mentioned above, i.e. the shift from mitigation action from developed to developing countries and the supply of CERs to the carbon market, occur but to a more limited extent compared to full issuances of CERs.

Requirements for such an institution would be:

(a) Acknowledgement by all Parties

The institution is acknowledged by all Parties as being responsible for the implementation of the HFC-23 reduction projects as well as managing the CER revenues. Under this condition it can be ensured that CDM Executive Board only registers projects managed by this institution, as in principle this option is less attractive to operators compared to the option of having a CDM project carried out in a conventional way and receiving most of the CERs.

(b) Funding for set-up and project financing

Sufficient funding is required to pay for the considerable administrative costs to set up such an organisation. By linking the institution to an existing organisation, which has the technical, financial as well as procedural knowledge required for such CDM projects, the effort could be considerably reduced. It might then suffice, to set up the general structure of the institution and some minimal staff for organizational issues and assign financial and technical experts from the parent organisation, which can be contracted by the institution for each specific CDM project. The parent organisation could also offer support in finding pre-financing for setting up the institution, which would have to be paid back from the income of the first project. Furthermore, the institution would need to obtain sufficient fund for upfront financing of the incinerators. Such funds could be acquired as normal bank loans directly or through the parent organisation. The funds will be paid off from CER revenues.

With a view to the project procedure, the contracted experts would carry out all necessary project steps, i.e. project development in cooperation with the operator, selecting of a contractor, setting up, handing in and eventually revising the PDD, choosing operational entities, etc. The experts would need to have in depth knowledge of HCFC-22 plant and HFC-23 incinerator characteristics in order to be able to judge project design and financing which may differ from plant to plant. Clear procedures should be set up to identify the costs for planning, implementation and operating the incinerator.

In order to have some control on its activities and the number of CERs placed on the market, the institution should regularly report to the executive board on the share of CERs sold, the costs covered with these revenues and the CER amounts made invalid.

A potential candidate for allocation of such an institution is the World Bank, namely the Carbon Finance Unit. It can be expected that the World Bank could ensure acknowledgement by all Parties. The Carbon Finance Unit holds the necessary technical and financial experience to assess projects and set up the necessary documentation, e.g. the PDD. Furthermore, extensive country experience is available and the World Bank structure with their numerous country offices could be used. Pre-financing could be arranged through the World Bank.¹⁵ The amount of CERs to be placed on the market might be arranged to be directly sold through the Carbon Funds at the Carbon Finance Unit.

¹⁵ See website <http://carbonfinance.org>.

3.4 CDM-projects are restricted to HCFC-22 feedstock production

Restricting CDM projects for the reduction of HFC-23 emissions from HCFC-22 production to production of HCFC-22 for feedstock purposes has a number of potential effects:

Although the perverse incentive for increased HCFC-22 production applies also in this situation, a possible increase in demand for polytetrafluorethylene (PTFE) due to CER-financed HCFC-22 production, will not lead to additional HCFC-22 emissions, as the substance is consumed in PTFE production. The approach avoids an overlap of Montreal and Kyoto Protocol as only HCFC-22 production for a purpose not subject to a phase-out under the Montreal Protocol is available for CDM projects.

However, the financial incentives from sale of CER might result in accelerated production shifts from industrialized to developed countries for HCFC-22 for feedstock purposes of the whole PTFE chain. This in turn might result in an emission increase at the global level. It is hard to estimate to which extent this scenario would take place.

Under this option non-feedstock HCFC-22 uses would not be tackled, representing a major part of the total production. HCFC-22 production for feedstock use currently accounts for less than 20% of total production and this is projected to remain so in the nearer future. This option requires a verification of the actual use of the HCFC-22 that is produced for feedstock use. In certain cases, HCFC-22 is produced and directly used in integrated plants, in which case verification may be simple. However some PTFE plants purchase part of the feedstock HCFC-22 on the market, or some HCFC-22 producers partly produce for feedstock purposes and for dispersive uses, in which case verification may be complex.

By granting CDM projects only to (new) integrated plants that incorporate all PTFE production steps, the amount of HFC-23 emission reductions that is eligible for CDM is further constrained¹⁶. This approach seems quite simple to implement – as long as potential shortcomings are accepted. For example, in case of temporary lower PTFE production a certain share of HCFC-22 production may be sold for non-feedstock uses. A certain amount of HCFC-22 for PTFE production might also be bought on the market. Trying to integrate these aspects would complicate the approach significantly. Furthermore, it may be difficult to control whether all HCFC-22 produced at a plant has actually been used for PTFE production.

When aiming to cover also PTFE production in non-integrated plants in developing countries, a tracing system for the use of HCFC-22 is needed. The Montreal Protocol requires non-Annex 5 countries to implement a national system controlling imports and exports of substances that are to be phased-out. According to EC Regulation No 2037/2000¹⁷, release for free circulation or inward processing of ODS requires an import licence. Companies who wish to import ODS from a country outside the EU need a quota allocation by the European Commission. These quotas for the following year are decided in October each year and published in a Commission Decision.

When applying for allocated quota, information on the use of the substances has to be provided. This mechanism could help to trace part of the HCFC-22 imported for feedstock use. It has to be kept in mind though, that certain amounts of imported substance might be resold for other purposes or that the purpose has not been stated correctly. The system has not been designed for tracing the use of substances with high security. Furthermore, feedstock use is increasing in Article 5 (1) countries, which do not have such systems. From 2016 on, when the phase-out period for HCFC-22 starts for these countries, such systems will also be implemented.

¹⁶ During the drafting of this paper no data was available on the share of integrated plants in total feedstock production .

¹⁷ EU Parliament and Council: **Regulation** (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer; 2000

Requiring developing countries to introduce such systems ahead of time, would surely pose financial problems.¹⁸

A software approach could solve this problem: A central registry for HCFC-22 feedstock production could be created. Producers with CDM-projects have access to this registry and can state the amount of produced substance and an electronic certificate with a certificate number for identification is created for each unit (e.g. t) of HCFC-22 produced. When an operator of a feedstock plant acquires the substance, he is supplied a set of certificate numbers corresponding to the amount to the HCFC-22 acquired. When the substance is consumed in the process, the operator, who also holds an access to the registry, can enter the certificate numbers, which are then deleted. By comparing certificate numbers for produced and consumed HCFC-22, the amount of feedstock HCFC-22 produced in a plant can be clearly identified and CERs can be issued respectively. The approach implies that an installation might suffer disadvantages in case its HCFC-22 production is consumed later than others – under unfavourable conditions CERs might be issued delayed by a year. This makes planning regarding the annual CER amount to be obtained quite difficult.

The approach is quite demanding on a software and control level and can thus be expected to be rather costly. It furthermore requires verification of produced and consumed HCFC-22 amounts at the installation, in order to make sure, certificate numbers have only been created for the amount produced and certificate numbers are only entered for the amount consumed. The verification requirement will lead to further costs on the side of the operators.

This approach avoids the overlap of the protocols, and could provide an approach valid for the future after the phase-out of HCFC-22 in non-feedstock uses. At the same time it fails to reduce increasing HFC-23 emissions from HCFC-22 production for non-feedstock uses, which are expected to strongly increase until 2016 and thus does not tackle a main aspect of the overall problem.

3.5 Other CDM options

There are other options that were not considered in detail in this paper.

1. Restricted application of the methodology to (currently) existing installations only.

This scenario represents the current status of the CDM methodology for incineration of HFC-23 from HCFC-22 production. The reason for imposing the restriction to existing capacity is to avoid the perverse incentive for the installation of new HCFC capacity beyond market demand. However, under this scenario, HFC-23 emissions from increasing future HCFC-22 capacities in developing countries are not tackled. The amount of CERs issued from the existing HCFC-22 capacity would amount to around 75 Mtonnes CO₂-eq. per year both in 2010 and 2015.

2. Unrestricted application of the methodology for all (current and future) installations

This scenario corresponds to the methodology AM0001 before it was revised, and could have considerable negative effects as described in the introduction. The main problem is that the considerable CER revenues can result in an incentive to solely produce HCFC-22 in order to receive CERs, but not for the market demand. Assuming that production of HCFC-22 is increased by 30% compared to projections, this would lead to the considerable amount of additional HCFC-22 emissions from non-feedstock uses of 166 Mtonnes CO₂-eq. in 2010 and 224 Mtonnes CO₂-eq in 2015. At the same time 151 Mtonnes-CO₂-eq. of CERs

¹⁸ Another problem is that, even if being able to trace the correct overall amount of feedstock use, this does not supply a solution on how to reward specific plants for production of the respective HCFC-22, as with the substance being sold and re-sold, its origin might be difficult to trace.

would be issued in 2010 and 204 Mtonnes-CO₂-eq. issued in 2015 for new capacities – compared to an estimated amount of 200 Mtonnes of CERs to be issued in 2012, according to Worldbank 2005. The large amount of CERs likely to be issued could lead to a considerably lower price for CERs, in return reducing the effect on HCFC-22 production.

A lower CER price will also affect the feasibility of other type of CDM projects. With increasing CER prices, as currently observed, CDM comes within reach of small scale projects that could not overcome CDM transaction costs before. If prices would fall again through increasing supply, this effect would be cancelled out.

In this scenario HCFC-22 emissions will considerably increase on the longer term achieving amounts comparable to CER issuance. As comments to the UNFCCC show, this approach is considered problematic by many Parties¹⁹. The biggest challenge in this approach is thus to overcome the negative side-effects identified by Parties, of which possible approaches are elaborated in the scenarios below.

3. Application of the methodology for each year for existing and new installations up to the production capacity that is projected without the application of the methodology

In this scenario, the methodology aims to limit the production capacity of new HCFC-22 plants eligible as CDM projects to the projected capacity in a baseline situation. In theory overproduction of HCFC-22 in order to generate CERs could then not occur. Even without non-market demand HCFC-22 production significant amounts of CERs would be generated from new installations: around 43 Mtonnes CO₂-eq. in 2010 and 87 Mtonnes CO₂-eq. in 2015. Effects on the market price for CERs can be expected. The assignment of new capacity could be done on a first-come first serve basis or a selection of applications could be based on additional criteria, for example on plant efficiency.

The main difficulty with this scenario is the uncertainty in projections of the future HCFC-22 production capacity. It needs to be decided if and how developments not foreseen at the time the projections were developed will be taken into account. The question would be, by which organizations and on the basis of which data such projections could be developed. Currently, the existing HCFC-22 production capacity in developing countries is not known with certainty²⁰. In case a higher reliability of projections is needed, more market studies are required, involving considerable administrative costs. In gathering data from developing countries it needs to be taken into account that both developing countries and producers of HCFC-22 have an incentive to submit data involving an overestimation of future capacities in order to create a wide scope for CDM-projects from HFC-23 incineration. Considering the uncertainty regarding the existing production capacity, projections may need to be continuously updated under this scenario, again involving administrative costs. Again the question is, which institution should be able to decide that changes are necessary and how data could be ensured to be unbiased.

Secondly, this approach may lead to market regulation as the CER revenues will ensure that the maximum allowed capacity will be filled up completely, whether there is a demand or not. The level of market regulation depends on the difference between maximum allowed capacity under the CDM and the capacity that would have been built in a situation without CDM. In case market demand is higher than the originally projected HCFC-22 production, it is likely that no additional HCFC-22 installations will be built, as that capacity is not eligible for CDM and may therefore not be able to compete with the CER-financed existing installations. This may lead to a short-term shortage of HCFC-22 production and possibly to an increase in HCFC-22 market price. The other way around, a lower demand than originally projected, results in oversupply which may lead to lower HCFC-22 prices.

¹⁹ See UNFCCC 2005.

²⁰ See UNEP-TEAP 2003.

An option to deal with the uncertainties in projected demand is that all Parties agree on a conservative scenario up to for example 2040 which remains unchanged. The deliberate choice to adopt a lower capacity than projected, will stimulate alternatives of HCFC-22 for non-feedstock uses.

4. Application of the methodology after three years when the installation has proven to produce for not subsidized market demand (first proposal by China)

This scenario proposes to ensure that CDM projects are only registered for installations which can prove to produce for actual market demand. It is suggested to allow application as CDM-project only after three years of operation, in order to prove that the plant is operational even without CER-revenues. Again the aim is the restrict issuance of CERs to capacities producing for market demand.

During the first three years, as a prerequisite for the qualification as CDM-project, incineration of HFC-23 at the plant will not be carried out. With productions developing according to projections this approach would lead to around 24 Mtonnes CO₂-eq. of HFC-23 emissions annually. Again the still large amount of 101 Mtonnes CO₂-eq. of CERs to be issued in 2010 and 147 in 2015 is likely to affect the certificate market.

Again implementation is the main problem of this scenario. The approach requires proof of production for "not subsidized market demand". Operating the installation for three years cannot serve as full proof, as with the impressive funds to be obtained through CER revenues in the near future, funds might be available to cover costs for the first three years. So the operator of an HCFC-22 installation will have to prove that the HCFC-22 produced is actually used and not stored (without any purpose of further use) or vented, but sold at average market prices. This could be proven by invoices and delivery notices. Still, with the CER funds at stake, such documents could be forged to a point that even thorough controls by verifiers will not disclose. Potential buyers of HCFC-22 could be willing to cooperate, buying the substance and venting it, while being "refunded" by the HCFC-22 producers. Checks would then have to be extended to buyers of HCFC-22, while no legal basis exists for such action. Thorough check of invoices and delivery notes would lead to high administrative costs, while not ensuring that fraud can be detected.

Compared to scenario 3, this scenario does hardly influence the development of HCFC-22 production capacities and gives no incentive to produce non-market-demand HCFC-22, at least as long as potential operators refrain from illegal activities. After three years it will however supply a substantial amount of CERs to the market. The biggest challenge in this approach therefore is to overcome the high administrative costs and the vulnerability to fraud.

5. Application for new installations while demanding a thorough assesement of leakage, considered from an integral perspective (ODS leakage, Kyoto and non- Kyoto GHG leakage, leakage from additional production assessed form cradle to grave) and compensation for this in the assigned CERs.

While this approach, which has been proposed by Brazil, seems in principle a valid suggestion, it is difficult to implement, as it is not in line with current UNFCCC modalities. In Art. 51 of the Marrakech Accords leakage is defined as: "the net change of anthropogenic emissions by sources of GHGs which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity". Discussion is ongoing about the exact interpretation of GHGs: does it only involve the Kyoto basket GHG or all GHGs? In the latter case the global warming potential of HCFC-22 could be accounted for in the first case not. Also more clarity is needed on the possible accounting of the ozone-depleting potential effect of HCFC-22. This could be addressed by changing the definition of leakage in the Marrakech Accords. Another option would be to use the Kyoto Protocol requirement that CDM should assist Parties to achieve sustainable development.

In both cases it would require an explicit interpretation by the EB. A complete addressing of leakage from cradle to grave seems to be problematic, as it would require this approach to be applied for baseline emissions and project emissions, which would mean that project boundaries are expanded by far. Moreover, it would imply that this procedure would also need to be followed by other CDM projects. In addition, the most complex task seems the identification of "additional" production. Determination of additional production stimulated by the CDM-project is indeed the basic problem of the issue addressed in this paper but is very difficult to quantify. The above approach requires considerable changes in legislation involving lengthy procedures, which will make this approach difficult to implement on a short term.

6. Application for new installations only if the Certified Emission Reductions will be taxed by the hosting country (second proposal by China)

In October 2005 the Chinese government announced to impose a levy of 65% of CER revenue on HFC-23 destruction projects. For renewable energy and energy efficiency projects, only rates of 2 % are imposed. China's motivation is that high rates are applied to projects, such as HFC-23 destruction, with the least sustainable development benefit to the wider community. The fees levied by the Chinese government will go into a fund managed by the Ministry of Finance to be spent on climate change-related activities and projects. The National Development and Reform Commission, which assesses CDM projects for approval in its role as China's designated national authority, and other relevant bodies will be consulted on how best to spend a climate change fund. No other countries are currently known to intend to impose CDM taxes.

China proposed to restrict CDM for new HFC-23 destruction project for new plants to those countries where governments impose a tax, as China does itself. There are two main issues to be discussed for this scenario:

(1) This scenario can shift the perverse incentive from companies to governments.

The incentive for companies/investors to implement new HCFC-22 plants without an actual market demand will be decreased with this measure, depending on the tax level. A 65% levy as is the case in China, may still involve an annual CER income from 2,5 to 6 million US\$ for project owners, based on the two registered HCFC-22 projects²¹. Governments will thus have a high interest in stimulating new HCFC-22 installations, and may do so by imposing favourable tax schemes or other incentives that are difficult to assess by international observers. Special attention needs to be paid to those companies that are state-owned.

(2) It needs to be verified how the government managed funds will be spent. The project that are funded should be additional to those that would already be funded without the CDM-fund. A risk of this scenario is that it leads to diversion of existing climate change funds. Therefore also, current climate change policy and available budget needs to be assessed. This requires a substantial additional burden to for verification by validators and UNFCCC.

7. Coupling of the methodology for new installations to the application of a methodology that results in sizeable application of non-greenhouse gas alternatives for CFCs;

This alternative suggests that CDM projects in new HCFC-22 production sites are only available if the CDM projects trigger projects supporting substitution of CFCs by low GHG low ODS substances. The aim is to compensate potential additional HCFC-22 production and consumption - being a threat to targets both under the Montreal and the Kyoto Protocol - by reducing CFC production and consumption (Montreal Protocol), but to avoid a subsequent increase of GHG emissions, by using only low-GHG substitutes. This approach is only feasible if the substitution takes place in areas in which HCFC-22 is not applied, i.e.

²¹ The two HFC incineration projects registered to date generate 1400 and 3393 kton/yr respectively. The calculation is based on a CER price of US\$5/tonne.

where there is no competition between HCFC-22 and low-GHG CFC-substitutes. Exemplary areas of application and low-GHG substitutes are

- Foams: Pentanes for PU-rigid foam, CO₂ for XPS foams.
- Propellants: Light hydrocarbons without GWP, e.g. butane
- Solvents: electronics, metals and precision cleaning by substances including aqueous and semi-aqueous cleaners, straight organic solvent cleaning

In assessing this approach it has to be kept in mind that the Montreal Protocol foresees CFCs to be phased-out by 2010. The above named approach thus comes at a very late stage. Projects aiming at the substitution of HCFCs, which have in turn been introduced as substitutes for CFCs, by non-GHG substances (or alternative technologies) might thus be more rewarding.

Various ways to implement such projects, can be thought of, e.g.:

- Regarding funds:
 - A certain share of CER revenues are to be spent on the projects (with the remaining share allowing at least to compensate for reduction and CDM transaction costs)
 - A certain amount of ODS emissions is to be avoided through the project (e.g. coupled to HCFC-22 production in the respective installation) given a monetary value by multiplying target emission reductions with fix average reduction costs per metric ton of emissions avoided.
- Regarding the responsible organisation:
 - Projects are carried out by project participants themselves
 - The project participants provide funds to an organization entrusted with the development of such projects.

Sustainability and efficiency of the substitution projects would have to be ensured. Having organizations entrusted with development or at least supervision of such projects would allow ensuring sustainability and a reasonable balance of project types.

The scenario is very open and thus difficult to assess regarding the given characteristics. HFC-23 emissions would be reduced, but again it is not clear to which extent HCFC-22 consumption would increase. This would depend e.g. on the costs for CFC substitution involved, i.e. on the amount of CER revenues the project participants can dispose of. By supporting the substitution of CFCs by low-GHG substances, a high contribution to sustainable development as well as to technology transfer could be made.

8. MLF supports projects that directly or indirectly stimulate destruction of the HFC-23 by-product or the production of substances that replace CFC production that have a lower GWP than HCFC-22.

This option explores the possibilities to apply the MLF to stimulate HFC-23 destruction in a situation where the current CDM methodology will be maintained, i.e. only HFC-23 destruction at existing plants is eligible under CDM.

The Multilateral Fund (MLF) was established in 1991 and is exclusively set up to finance the incremental costs that occur in developing countries to comply with their obligation under the Montreal Protocol. According to the Montreal Protocol developed countries are obliged to phase out the use of HCFCs before 2020²². The EU-15 even decided to phase out before 2015. HFC-23, not being an ODS, is not regulated under the Montreal Protocol.

²² Up to 0.5% of base level consumption can be used until 2030 for servicing existing equipment.

Under current conditions the MLF can therefore not be applied for financing HFC-23 destruction projects directly. Apart from that, the MLF does neither judge project proposals on their contribution to global warming as that is not addressed in the Montreal Protocol²³. Another option with MLF would be to indirectly stimulate HFC-destruction through stimulating the use of alternatives of HCFC-22 for e.g. refrigeration and air-conditioning purposes. However, since the MLF is a compliance-oriented mechanism, only countries that have an obligation under the protocol to phase out specific ODS are eligible for funding. Under the current MLF conditions, developing countries, which do not have any obligations with regard to phasing out HCFC-production and consumption before 2015, are thus not eligible for support on projects that substitute HCFC-22 for other substances with lower ODSs until that year. The conclusion therefore is that an extension of the scope of the MLF would be an addition to the objectives of the Montreal Protocol.

²³ It should be noted that in the Vienna Convention for the Protection of the Ozone Layer (1985) which sets the basis for the Montreal Protocol the definition of "adverse effects" also addresses changes in climate. It is stated that in case of adverse effects of ODS, measures should be taken to 'control, limit, reduce or prevent' ODS emissions.

4 Non-CDM Policy Options

In this paper various options to stimulate HFC-incineration under CDM without a perverse incentive, are elaborated. Opportunities are however also offered by non CDM options. Two policy strategies for supporting HFC-23 emission reduction outside the CDM are explored: (1) applying other funding mechanisms for the HFC-23 incineration projects, or (2) reducing the demand for HCFC-22, thus leading to a reduction of HFC-23 by-product emissions. Please note that it is assumed that in case one of those options is adopted, HFC-23 incinerations projects at new HCFC-22 plants will not be eligible under the CDM.

In this section the general option of financing through the Global Environment Facility (GEF) will be explored. A first assessment of funding through the Multilateral Fund (MLF) of the Montreal Protocol has shown that this can not be considered as feasible, as supporting the phase-out of CFC substitutes is not supported by the MLF.

A reduction of demand can be achieved either by supporting the introduction of alternative technologies, or, as an even stronger alternative, by national legislation, banning production and/or use. As alternative technologies are usually more costly than a well-established technology, additional funding for the introduction would be required. As for developing countries the start of the phase-out of HCFCs is scheduled for 2016, additional national legislation aimed at earlier phase-out (before 2016) or faster phase-out (after 2016) seems suitable. This is explored in the next section.

4.1 Funding of HFC-23 destruction through the GEF

The Global Environment Facility (GEF), established in 1991, is an independent financial organization that provides grants to developing countries for projects that benefit the global environment and promote sustainable livelihoods in local communities. GEF finances both projects that phase out ozone depleting substances (ODS) as well as climate change mitigation projects.

HFC-23 destruction projects could be eligible for financial support under the Short-Term Response Measures (STRM) window, which is established to consider financing of projects that yield short-term benefits at low costs. Highly cost-effective projects with a unit abatement costs below US\$10/tCO₂-eq. could be funded by this window. It is conceivable that a HFC-23 destruction project would be eligible under this window. However, to this date no HFC-23 destruction project has been submitted.

At the moment discussions on the replenishment of GEF are ongoing. One of the issues under discussion is the continuation of the STRM window because it is not the primary responsibility of the GEF. The GEF preferably should focus its attention on sustainable energy projects, which in fact is the primary focus. However still some disagreement exists on whether or not to close the STRM window, especially related to the HFC-23 emissions from new plants.

Another option of stimulating incineration of HFC-23 through indirectly financing HCFC-22 low ODS alternatives. Within GEF, ODS phase-out projects are eligible where these activities would be complementary to those funded under the Multilateral Fund. So as not to duplicate those activities funded under the Multilateral Fund, GEF supports countries with economies in transition (CEIT) not operating under Article 5 of the Montreal Protocol (non-Article 5 countries). These countries do have compliance to the Montreal Protocol but do not meet the criteria that would assign them as 'developing country'. With these guidelines in place, GEF does not finance ODS projects in developing countries.

Summarizing, the GEF can in general finance HFC-23 destruction projects. In order to do so, a replenishment of the fund would be needed, as deviation of existing fund resources for a new issue is not desired. McCulloch estimates the reduction costs for the currently existing 30 plants in developing countries to 31 Million US\$ p.a. This calculation is based on the assumption of 4 Million US\$ per implemented incinerator and annual operating costs of 250,000 US\$.²⁴ (McCulloch, 2004). As production in the developing countries is expected to increase by slightly over 100% between 2005 and 2015 in developing countries, this amount can be expected to roughly double, if also future capacity has to be supplied with systems for thermal HFC-23 destruction.

As the GEF is replenished by the developed countries, the necessary funds would also need to come from this source. Several EU governments (Germany, Austria, The Netherlands) indicated that they would not be willing to replenish the GEF beyond the already planned resources.²⁵ As the EU – and within the EU among others the countries mentioned - has often taken a forefront position regarding climate change, the response indicates that obtaining additional resources for the replenishment of the GEF from developed countries might prove to be difficult.

4.2 The development of national policies aimed at an earlier or accelerated phase-out of HCFC-22

Under the Montreal Protocol the phase-out of HCFC-22 for developed countries is scheduled for the period 2004 and 2030 with several intermediate reduction steps. For developing countries this time period is 2016 to 2040 (with intermediate reduction steps still to be agreed). This implies that capacities in developing countries can still increase without limit before 2016. National policies requiring an earlier phase-out of HCFC-22 – be it with specific reduction requirements or simply an earlier date for freezing the amounts to be produced or consumed – could support the reduction of HFC-23 emissions from HCFC-22 production.

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The EU for example has set up a legal requirement for an earlier phase-out of HCFC-22, which banned the use of HCFC-22 and other HCFCs for the production of new equipment and products since 2004 at the latest, while HCFC-22 production and consumption will be banned from 2010. The use of HCFC-22 in servicing existing equipment will be banned after 2015. This allows for existing equipment to use HCFC-22 until the end of their lifetime in most cases, while no new HCFC-22 equipment will be installed. Other examples of early phase-out are Japan, where use of HCFC-22 for new equipment is only allowed before 2010 and for service purposes in existing equipment before 2020. (UNEP 2003a).

In developed countries, an accelerated phase out of HCFC-22 will result in higher application rates of non-ODS substances, both high-GWP GHGs as HFCs, and low- to near-zero GWPs substances as CO₂, hydrocarbons, and ammonia. For countries that have ratified the Kyoto Protocol, the potentially increased emissions of GHGs (notably HFCs), are being regulated under the Protocol.

For developing countries the situation is different. The growth in demand for cooling and refrigerant equipment is significant. HFCs can expected to be chosen as main alternative to HCFC-22 technologies, as in most cases these technologies have the highest level of

²⁴ With the regional distribution strongly focused on China: 20 plants exist in China with a combined capacity of about 250 kt HCFC-22 per year, 4 plants in India with a combined capacity of about 50 kt HCFC-22 per year, and 1 plant each in Korea, Mexico, Taiwan and Venezuela with a combined capacity of about 40 kt HCFC-22 per year.

²⁵ Personal Communication with Martijn Hildebrand (MinVrom, NL), Lambert Schneider (Öko-Institut, Germany)

commercialization in the developed countries.²⁶ With the considerable growth rates for equipment using HCFC-22, the substitution of HCFC-22 by HFC technologies could lead to significantly increased GHG emissions: HCFC-22 has a direct GWP of 1780²⁷, which is in the same level as the direct GWPs of most HFCs blends (e.g. R-407C: GWP 1610, R-410 A: GWP 1890), but HCFC-22 is not included in the Kyoto-Basket. This means although substitutes with similar GWPs are used, emissions under the Kyoto-Protocol will increase. As developed countries do not have reduction targets under the Kyoto Protocol, substantially increased emissions could further complicate discussions on future commitments. From an environmentally and economically point of view it is important to prevent both an unlimited increase in high-GWP GHG emissions and a double phase-out. This can be achieved either by implementation of high-efficient, low-emission HFC technologies in combination with end-of-life recovery infrastructures; or by implementation of 'near zero-GWP' technologies with high energy efficiencies.

MLF managers have indicated that a significant number of countries are currently applying for financial support of studies on the HCFC phase-out at the national level. Fourteen such studies have already been granted, more than fifty additional applications have been handed in. Developing countries are thus quite aware of their phase-out obligations and act accordingly.

India has made a start in the direction of an earlier phase-out, not by banning the introduction or use of new HCFC-22 equipment on the market, but by prohibiting the building of new HCFC-22 production facilities (Indian Ministry of Environment, 2000) already from January 2000 onwards. This policy allows the industry to further use HCFC-22, but gives a clear signal towards the introduction of alternative technologies. Due to this legal requirement, CDM in new HCFC-22 production capacities is not an issue any more in India. Of course, as long as HCFC-22 use is still allowed, increased demand in the country might also simply lead to new production capacities being implemented in other regions without such regulation.

It is questionable whether all developing countries would be able to enforce an earlier phase-out, as the currently on-going CFC-phase-out already proves to be quite demanding. Here earlier action by developing countries indicating or financing substitution of CFCs by low-ODS, low-GWP alternatives, would have been a necessary step.

As an alternative to an earlier phase-out, an accelerated phase-out schedule as of 2016 could be envisaged. The structure of the Montreal Protocol and its bodies allows for changes in these phase-out schedules if agreement amongst Parties is reached. Accelerating the HCFC phase-out is an objective which is already pursued independently from the HCFC-22/HFC-23 discussion.

Both an earlier and an accelerated phase-out of HCFC-22 production and consumption may require additional financial support for some countries and/or some applications.

²⁶ In general this problem of increased GHG-emission from HCFC-22 phase-out applied also for the developed countries, but on a far lower level, as equipment growth rates were lower than they currently are in the developing countries.

²⁷ See IPCC/TEAP 2005.

References

- Arthur D. Little; Global comparative Analysis of HFCs and alternative technologies for Refrigeration, Air Conditioning, Foam, Solvent, Aerosol Propellant and Fire Protection Applications; March 2002.
- Defra, 2005, EU Emissions Trading Scheme, linking Directive consultation paper, Department for Environment, Food, and Rural Affairs, available at: www.defra.gov.uk, 2005
- Federal Environmental Agency: Ersatz des Kältemittels R22 in bestehenden Kälte- und Klimaanlageanlagen. Aktueller Stand („Substitution HCFC-22 as refrigerant in existing refrigeration and air conditioning appliances. Current Status“), 2005
- Höhne, N. and J. Harnisch; 2002a; Comparison of emissions estimates derived from atmospheric measurements with national estimates of HFCs, PFCs and SF₆; In: Non-CO₂ Greenhouse Gases: Scientific Understanding, Control Options and Policy Aspects (Editors: J. van Ham et al.); pp. 547-552, Milpress, Rotterdam, 2002
- Harnisch, J. and N. Höhne; 2002b; Comparison of emissions estimates derived from atmospheric measurements with national estimates of HFCs, PFCs and SF₆; Env. Sci. Poll. Res., 9 (5), pp.315-320, 2002. (DOI: <http://dx.doi.org/10.1065/espr2002.02.111>)
- Indian Ministry of Environment; Ozone Depleting Substances (Regulation and Control) Rules, 2000.
- IPCC 2000: Good practice guidance and uncertainty management in national greenhouse gas inventories, Geneva
- IPCC 2001; Climate Change 2001. the scientific basis. Contribution of Working Group 1 to the third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA.
- IPCC/TEAP, 2005, Special Report: Safeguarding the Ozone Layer and the Global Climate System, Issues Related to Hydrofluorocarbons and Perfluorocarbons, Special Report of the Intergovernmental Panel on Climate Change, 2005.
- McCulloch, A; 2004a; Incineration of HFC-23 Waste Streams for abatement of emissions from HCFC-22 production: A review of scientific, technical and economic aspects; 2004
- McCulloch, A; 2004b; Global Emissions of HFC-23 estimated to year 2015; 2004.
- Michaelowa, A., J. Buen, A. Eik, E. Lokshall; The market potential of large-scale non-CO₂ CDM projects; Contribution to the NCGG-4 Conference; July 2005.
- SBSTA, 2005, Subsidiary Body for Scientific and Technological Advice (SBSTA); Implications of the establishment of new hydrochlorofluorocarbon-22 (HCFC-22) facilities seeking to obtain certified emissions reduction for the destruction of hydrofluorocarbon-23 (HFC-23) – FCCC/SBSTA/2005/MISC.10; 2005.
- L. Schneider, J. Graichen, N. Matz; Implications of the CDM on other conventions. The case of HFC-23 destruction; April 2005.
- UNDP/BDP Energy and Environment Group, The Clean Development Mechanism: A User's Guide, 2003.
- UNEP, 2003a, United Nations Environmental Panel – Technology and Economic Assessment Panel (UNEP – TEAP); HCFC Task Force Report; May 2003.
- UNEP, 2003b, 2002 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee 2002 Assessment, January 2003.
- UNEP – TEAP, Supplement to the IPCC/ TEAP REPORT, November 2005
- UNEP, 2005, CDM pipeline, available at: <http://www.cd4cdm.org/Publications/CDMpipeline.xls>
- UNFCCC, 2002, United Nations Framework Convention on Climate Change (UNFCCC); FCCC/CP/2001/13/Add.2; 21 January 2002
- UNFCCC, 2004, United Nations Framework Convention on Climate Change Secretariat; Executive Board of the Clean Development Mechanism, Fifteenth Meeting Report; 3. September 2004.
- UNFCCC, 2005, United Nations Framework Convention on Climate Change (UNFCCC), Issues arising from the implementation of potential project activities under the clean development mechanism: the case of incineration of HFC-23 waste streams from HCFC-22 production. FCCC/TP/2005/1; April 2005.
- World Bank/IETA, 2005, State and Trends of the Carbon Market 2005, Carbon Finance, Washington.

Annex 1 HCFC-22 Alternatives

For both refrigerant and solvent applications substitute low-ODP technologies are available, many based on HFCs.

For the future development from HCFC-22 banks and emissions from banks there are two main options. In new refrigeration systems, alternative low-ODS technologies can be used, as far as available. In existing systems using HCFC-22 can be retrofitted, by replacing HCFC-22 by a drop-in substance. Such a substance must allow equivalent functionality of the system, i.e. only certain substances are suitable depending on the specific technology. Systems can be expected to be retrofitted during regular maintenance / refilling, which means that existing banks are retrofitted only gradually

In the following, existing alternatives and drop-in solutions are shown.

In **commercial refrigeration** a number of commercially viable alternative technologies are available. Technologies vary strongly with the specific requirements of the refrigerants. In direct systems, HFCs as R404A (low and medium range temperature) and R-134A (medium temperature) but also CO₂ can be used. In indirect systems substances like HFCs, ammonia, HCs and CO₂ are used as refrigerant. Generally R-134A, mainly for medium temperature low capacity systems, and R404a, esp. in large capacity systems for low and medium temperature level, are strongly gaining ground in developed countries. R-404A or R-407C can be used as drop-in for HCFC-22 in centralized systems, leading to losses in energy-efficiency of 5-10%.

In **industrial refrigeration**, about 75-85% of existing systems use NH₃, the remainder uses HCFC-22, CFCs and HFCs. Where NH₃ cannot be used, mature HFC technologies (HFC 134a, R-404A, R-507a, R-410A) are available and widely used in new equipment, CO₂-technology for low temperatures is also on the market, but with far lower market shares. Other technically viable options are not yet fully commercialized or show low market penetration (NH₃, CO₂ technology for general purposes) or show increased costs due to necessary safety measures because of high flammability (hydrocarbons). Industrial refrigeration plants are often tailor-made, making retrofit difficult. Single cases of retrofitting with CO₂ and NH₃ are known.

Transport refrigeration: For ships, R-407C and R-404A/R-507 are commercial and widely used options for new equipment, R-410A is expected to play the most important role as refrigerant in the marine sector in the future. On merchant ships R-404A/R-507 is dominating new systems. For refrigerated containers fleet HFC-134a and R-404A predominate the market for new units. Furthermore development of carbon dioxide based units has started. For refrigerated road vehicles main alternatives are HFC-134a and R-404A, both also widely used. Research and tests of hydrocarbon, solar and cryogenic systems with liquid air or liquid carbon dioxide are in progress. Alternatives for railcar air conditioning, which are currently gaining ground are R-134a or R-407C, requiring high attention for system containment. For transport refrigeration retrofit is possible, but it is not advised to do so, but to rather keep the systems leak tight and with high energy efficiency for the rest of their lifetime

In **air conditioning equipment** R-134A, HC 290, CO₂ and blends as R-410a and R470C can be used. CO₂ – based alternatives are also on the market, but show low operating efficiencies and require high operating pressure. (TEAP 2003). Costs are estimated to be 20-40% higher than for conventional systems (Arthur D. Little, 2003). Hydrocarbons, like HC 290 requires additional safety measures due to its high flammability, leading to increased costs, compared to conventional systems (Arthur D. Little, 2003).²⁸ For air conditioning equipment, R-407C can be used as drop-in, for heat pumps also HFC-134a and R-404A. HC 290 would technically also be available as drop-in, but there are concerns regarding its flammability, leading to a lower level of commercialization.

²⁸ A study from the early nineties indicated that in the residential air conditioning sector such measures could increase costs by up to 30%.