Protocol
2F1: HFC EMISSIONS FROM STATIONARY COOLING

IPCC Category:	2F1
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code	10/11/12, 5210.2, 8299.1

FOREWORD

Under the Kyoto Protocol, the Netherlands is required to set up and maintain a national system to monitor its greenhouse gas emissions. One of the elements of this system is a transparent and verifiable description of the methods and processes used in this monitoring system. These methods must meet international guideline criteria, which have been defined by the United Nations (UN) and the European Union (EU).

The Netherlands meets the aforementioned requirement, for example, by defining a series of Monitoring Protocols, which describe the methods and work processes used to determine greenhouse gas emissions and the amounts of carbon sinks available. Protocols have been written for about 40 greenhouse gas sources or sinks. This document describes the protocol for one of these sources or sinks.

The individual protocols have been drawn up in a close collaboration between experts from various sectors of Dutch society, the Emissions Registration (ER, which is coordinated by PBL, the Netherlands Environmental Assessment Agency), SenterNovem, the Ministry of Agriculture, Nature and Food Quality (LNV), and the Ministry of Housing, Spatial Planning and the Environment (VROM).

1 SCOPE AND SIGNIFICANCE OF EMISSION SOURCES/ACTIVITIES

1.1 Scope and definition

This protocol describes the methodology and working processes for determining the HFC (hydrofluorocarbon) emissions that are released during the assembly, usage and disposal phases of stationary cooling equipment in the Netherlands. This concerns SBI (industrial) codes 10/11/12 (the manufacture of foodstuffs and snacks), 52102 (storage in cold stores etc.), 8299.1 (auctions of agricultural, horticultural and fish products).

The stationary cooling situation in the Netherlands includes cargo-bays in refrigerated lorries as well the air conditioning systems in buses, coaches and trains (as per IPCC) due to the size of the equipment and the techniques applied (IPCC category 2F1).

The monitoring of emissions from comfort cooling in smaller vehicles (air conditioning systems up to 3 kg in cars, small vans and lorry cabs, tractors and various equipment) occurs via another method and is described in the protocol for automotive comfort cooling.

Stationary cooling plants in the Netherlands currently use fluor-based gases such as CFC (chlorofluorocarbon), HCFC (hydrochlorofluorocarbon) and (since 1995) HFC (hydrofluoro-carbon), plus the ‘alternatives’ such as propane, butane and ammonia (NH_3). Since July 2001 some success has also been booked with natural cooling agents (CO_2) in industrial freezing plants. The use of non-fluor-based coolants is still limited, for example because there are strict safety criteria attached to the use of ammonia. There are no manufacturers of cooling installations established in the Netherlands, although the (larger) cooling plants are assembled there.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

The HFC emissions during the assembly (among other things, filling of new installations), usage and disposal phases of stationary cooling equipment contribute less than 0.5% to the total annual Netherlands greenhouse gas emissions.

1.2.2 Developments that infuence emissions

Emissions from stationary cooling plants have been considerably reduced over the past few years due to improvements in sealing this equipment. However, this has also been accompanied by the increased use of HFCs as coolant, as alternative for HCFCs. European legislation currently stipulates that, as per 1 January 2001, HCFCs may no longer be used in new cooling, freezing or climate-control plants. Up to 2010 existing installations may be refilled with HCFCs. However, this legislation also states that the amount added to the existing coolant may not be more than half the existing capacity.

2 METHOD, EMISSION FACTORS AND ACTIVITY DATA

2.1 Calculation method

This section describes the annual determination of the HFC emissions from stationary cooling installations in the Netherlands. This starts with the determination per source, followed by the determination of the total emissions.

Filling of (new) installations

$$E\ nw(t) = V\ nwv * v/100$$

Where:

E nw(t) = emissions during the filling of the (new) installations in year (t);
V nwv(t) = the volume of refrigerant used in (new) installations in year(t);
v = percentage lost during the filling, expressed as a % of V nwv(t)

Emissions from working systems

$$E\ sys(t) = [\ V\ sys(t-1) + [Vnw(t) * 0.5] - [Vafg(t) * 0.5]\ ] * lk/100$$

Where:

E sys(t) = emissions from working systems in year(t);
V sys(t-1) = original volume at 31 Dec (t-1) of working systems;
V nw(t) = volume of refrigerant refilled in (new) installations in year(t);
V afg(t) = original volume of dismantled installations in year(t);
Lk = leakage percentage during operation;
0.5 = because both the filling of new and dismantling of old installations takes place throughout the year, it is assumed that each new and dismantled installation are operational for an average of six months in year (t).

Losses from dismantling installations

E afg (t) = V afg(t) * v/100

Where:
E afg(t) = (emission) losses that occur during dismantling of installations;
V afg(t) = original volume of dismantled installations in year(t);
v = percentage lost during dismantling of old installations.

Finally, the total emission of HFCs by stationary cooling installations is determined each year using the following formula:

Annual Emission = E nw(t) + E sys(t) + E afg(t)

Further information on the activity agenda and emission factors used is available in Sections 2.2 and 2.3 of this protocol.
The method used conforms to the tier-2-top-down method described in the IPCC Good Practice Guidance (GPG, 2001, pp. 3.100 through 3.106).

2.2 Emission factors

The percentage lost during filling of new-retrofit installations is set at 0.5% (= default value (IPCC GPG, 2001) for mobile air-conditioning systems).

In 2001 a (one-off) NOKS (national study into coolant flows) study was implemented for the year 1999 [De Baedts et al., 2001], which concluded the average leakage percentage for working systems to be 5% per year. This is an average leakage percentage for all stationary cooling application areas for the year 1999. Based on these new insights the leakage percentages for the years previous to 1999 have been adjusted downwards (see Section 4.4.1 for an overview of historic values).

From 2001 onwards the following leakage percentages for working systems have been used:

1994	11%
1995	10%
1996	9%
1997	7,5%
1998	6%
from 1999	5%

These new insights/research allow the leakage percentage to be updated in the future.
The percentage lost during dismantling of old installations is set at 5% of the original filling.

2.3 Activity data

Annual sales
The relevant activity data is taken from the sales figures of individual HFCs to the total cooling sector in the Netherlands, which are available annually via the Handelsstromen-onderzoek (trade flow study). The data are gather using surveys completed by manufacturers,

traders and users of HFCs (and HCFCs). The annual sales are equal to the sum on the annual re-filling of existing installations and the filling of new installations.

Refilling existing installations / Filling new installations
Until now the trade flow study has been used to gather information on the annual sales figures [Verk(t)], but this is not sufficiently reliable to be split into the annual filling of new installations [V nw(t)] and the refilling [Bijv(t)] of existing installations.

The decision has therefore been made to set up a stock model to show the refilling [Bijv] of existing installations. This stock model uses the following starting points:
The starting year is the year in which a certain HFC is used for the first time.
During this starting year there is no refilling [Bijv=0) of existing installations, only filling of new installations. Therefore, the filling of new installations during this first year is equal to the annual sales, minus any losses during the filling process.
During the following years, refilling is defined as:

Bijv(t)	= Emission(t-1) at 31 Dec (t-1) for working systems * - [V afg(t+1) * Lk]

* See Section 2.1 for emission calculations

Where:
Vafg(t+1) = the original volume of the installations to be dismantled in year(t+1); these will no longer be refilled

Lk = leakage percentage during the operation.

The filling of new installations [V nw(t)] can therefore be determined using the annual sales [Verk(t)] and the refilling [Bijv(t)] figures as:

V nw(t)]	= Verk(t) – Bijv(t) – filling losses

Dismantled installations
The coolants that installers remove from dismantled installations[1] are offered to recognised collectors. These may destroy or regenerate the coolants, so that they can be reused.

There is very little information concerning dismantled installations, destroyed coolants and regeneration of HFCs. This is why the emission calculations during this phase are based on an average lifespan for the installations of 12 years, and 5% during the dismantling of the installation. This means that, in year (t), the installations are dismantled that in year (t-12) were noted as new installations. The original volume of these amounts to [V afg] (see also Section 2.1).

3 WORKING PROCESSES

Process for estimating (t-1)
If preliminary figures are required at any point, the following process is used to estimate the figure for t-1. The preliminary data for the work package leader are calculated by extrapolating

[1] Since 1 January 1993 only STEK-authorised companies are allowed to handle CFCs, HCFCs and HFCs in cooling equipment, including the extraction of these substances from dismantled installations. Extracted HFCs are considered commercial waste, and are transported to authorised collectors.

them from the previous years' figures, based on prognoses for the developments in the most important activity data (taken from CBS (Statistics Netherlands) or other statistical sources).

INPUT	PROCESS	OUTPUT	BY WHOM
Preliminary data work package leader (t-1)	Include t-1 data in ER database	ER-db with (t-1) data	Work package leader
ER-db with (t-1) data	Check emission figures: compare with previous years (trend), modify if required and document everything	ER-db (t-1) with any modified figures	Task force

Process for final determination of (t-2)

The final emission figures (as described in this protocol) are calculated using the following process.

INPUT	PROCESS	OUTPUT	BY WHOM
- Annual HFC consumption figures in the Stationary Cooling/Airco sector (source: Trade-flow research) - Amount of coolant destroyed annually (HFCs) (Source: Trade-flow research)	Control of consumption figures and destroyed amounts: - Comparison with previous years - Watching the trend Contacting the operator submitting the annual report if unsubstantiated deviations are found → modifying consumption figures as required and documenting everything	Approved consumption figures and destroyed amounts	Work package leader
- Approved consumption figures and destroyed amounts - Most recent Emission Factors (EFs), leakage percentages etc. from studies/ literature (both national and international)	Entering into (Excel) model 'Calculating F-gas emissions'	Detailed and aggregated emissions (=Final data Work package leader (t-2))	Work package leader
Final data Work package leader (t-2)	Include (t-2) data in ER database	ER-db with (t-2) data	Work package leader
ER-db with (t-2) data	Check, and trend analysis of air emissions: explain deviations or modify figures	Final defined emission figures (t-2)	Task forces and PBL experts

4 UNCERTAINTY AND QUALITY

4.1 Estimating uncertainties

A Tier-1 uncertainty analysis is implemented every year before the NIR is submitted by the ER, based on the greenhouse gas inventory and in compliance with IPCC guidelines. The assumptions used and the results thereof are described in a background report to the NIR. In addition to this, where included in the QA/QC programme for the relevant period, extra analyses are implemented regularly in specific situations, which include any updating of the Tier-2 uncertainty analyses.

The Tier-2 uncertainty assessment was last updated in 2006. This assessment showed that a Tier-1 uncertainty assessment is sufficiently reliable and that Tier-2 uncertainty assessments need only be implemented at periodic intervals of around 5 years, unless a major change in an important source is sufficient to require earlier reassessment.

- Source-specific uncertainty

The uncertainty estimate-totaal concerns the root of the sum of uncertainty in the data sources used (AD_{onz}) in the square and the uncertainty of the emission factor (EF_{onz}) in the square. The extent of the total uncertainty is here primarily determined by the greatest AD or EF uncertainty.

$$\text{Uncertainty estimate}_{\text{total}} = \sqrt{EF_{onz.}{}^{2} + AD_{onz.}{}^{2}}$$

The uncertainty estimates concerning the data sources (AD) and emission factors (EF) used, and the total uncertainty estimate, are listed in the following table.

IPCC	**Category**	**Gas**	**AD $_{onz.}$**	**EF $_{onz.}$**	**Uncertainty estimates $_{tot}$**
2F	Emissions from substitutes for ozone depleting substances (ODS substitutes): HFC	HFC	10	50	51

The uncertainty in HFC emissions from HFC consumption was estimated to be 51%. The uncertainty in the activity data for the HFC sources was estimated at 10%. For the emission factor, the uncertaintie was estimated at 50%. All of these figure s were based on expert judgements [Olivier et al, 2009].

4.2 Quality assurance and quality control (QA/QC)

The ER work package leaders check that:

1. the basic data are well documented and adopted (check for typing errors, use of the correct unit sizes and correct conversion);
2. the calculations have been implemented correctly;
3. assumptions are consistent, also whether specific parameters (e.g. activity data) are used consistently;
4. complete and consistent data sets have been supplied.

Any actions that result from these checks are noted on an ‘action list’. Before defining the data, supervisors check whether the relevant actions on this list, plus the QC checks, have all been completed. Defining the data is carried out by the WEM (working group on emissions monitoring), and confirmed in writing via an e-mail from the institute representatives to the ER project leader at PBL.

The work package leaders fill out a new documentation sheet when adding new data. For reasons of efficiency a minimum level has been set for obligatory documentation, i.e. 5% changes at target group level, and 0.5% at levels concerning the national total. These documentation sheets form part of the trend analysis, as well as the eventual definition of the data set.

The ER work package leaders communicate by e-mail regarding these QC checks, results and actions. They send a printed copy to the ER secretary, who keeps a logbook and compiles these e-mails into an ‘action list’. This shows explicitly that the required checks and corrections have been carried out.

4.3 Verification

In order to check the quality of the emission figures for the sources in this protocol, general QA/QC procedures have been followed that are in line with the IPCC guidelines. These are described further in the QAQC programme used by the National System, and the annual working plans published by the ER.

- Sector-specific QC

No additional specific verification procedures are implemented for the sources defined in this protocol.

4.4 Possibilities for improvement compared to the current calculation method

4.4.1 History

As previously mentioned in Section 2.3, up to 2001 information from the literature was used to determine the annual amount of coolant used to ‘refill existing installations’. For the years 1995 and 2000 these data were taken from [Matthijsen and Kroeze, 1996] and for the intermediate years these percentages were interpolated and resulted in the following leakage percentages for these years:

1995	17%
1996	16%
1997	15%
1998	13%
1999	12%
2000	10%.

Up to and including the year 2009, the inventory of emissions was determined via a complicated mass-balance method in which an emission factor was used as an aid. Because this led to considerable confusion, this method was replaced in 2010 by a so-called Emission Factor approach.

With the exception of dismantled installations, this method conforms to the tier-2-top-down method described in the IPCC Good Practice Guidance (GPG, 2001, pp. 3.100 through 3.106).

4.4.2 Future

Studies are currently being conducted into whether or not actual figures can be obtained on refilling of existing installations, filling of new installations, and dismantled installations.

5 REMAINING ASPECTS

5.1 Point source criteria

Not applicable

5.2 Substance profiles
Not applicable

5.3 Regionalisation
Not applicable

5.4 Time-based variations in source strength
Not applicable

6 REFERENCES AND ADDITIONAL INFORMATION

6.1 References

- De Baedts, E.E.A. et al., 2001: *Koudemiddelgebruik in Nederland (Use of coolants in the Netherlands).* STEK
- IPCC, 1997: Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories, Three volumes: Reference Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Office, Bracknell, UK
- IPCC, 2001: Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, IPCC-TSU NGGIP, Japan
- Matthijsen, A.J.M.C. and C. Kroeze, 1996: *Emissies van HFK's, PFK's FIK's en SF6 in Nederland in 1990, 1994, 2000, 2005, 2010 en 2020 (Emissions of HFCs, PFCs, FICs, and SF6 in the Netherlands).* RIVM report 773001-008. Bilthoven, Nederland.
- KPMG September 2002: *Gebruik van HCFK's, HFK's, Methylbromide en aanverwante stoffen in Nederland in 2001 (Use of HCFCs, HFCs, methyl bromide and related substances in the Netherlands in 2001).* Den Haag. KPMG report
- Olivier J.G.J., L.J. Brandes and R.A.B. te Molder, 2009 (in print) Uncertainty in the Netherlands' greenhouse gas emissions inventory: Estimate of annual and trend uncertainty for Dutch sources of greenhouse gas emissions using the IPCC Tier 1 approach, PBL-Report 500080013, Bilthoven
- Verwoerd, M, 2001: *Toetsingsinstrument met betrekking tot maatregelen om het broeikaseffect te reduceren van koudemiddelen in koelinstallaties en warmtepompen. Fase 2: nadere uitwerking en invulling (Test instrument concerning measures to reduce the greenhouse effect from coolants in cooling installations and heat pumps. Phase 2: further definition and content).* TNO report R 2001/338
- PWC December 2004, *Handelstromenonderzoek 2003, Onderzoek naar het gebruik van fluorverbindingen in Nederland (Trade-flow study 2003, research into the use of fluor compounds in the Netherlands),* Utrecht

6.2 Additional information
Not applicable