Protocol
2F2: HFC EMISSIONS FROM HARD FOAMS/FOAM BLOWING

IPCC Category:	2F2 Foam Blowing
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code	222

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 protocols have been compiled in close collaboration with experts from various sectors of society in the Netherlands, particularly experts from the Emissions Registration (ER). The ER is a collaborative group that includes institutions such as CBS, WUR, RIVM and PBL. Until 31 December 2009 this was coordinated by PBL (Planbureau for the Leefomgeving, or the Netherlands Environmental Assessment Agency), but on 1 January 2010 this coordination task was taken over by RIVM (the Netherlands institute for public health and the environment). Other institutions that have contributed to the protocols include NL Agency; Ministry of Agriculture, Nature and Food Quality; and the Ministry of VROM (Housing, Spatial Planning and the Environment).

1 SCOPE AND SIGNIFICANCE OF EMISSION SOURCES/ACTIVITIES

1.1 Scope and definition
This protocol concerns the methodology and working processes for determining HFC (hydrofluorocarbon) emissions that result from the production, usage and demolition phases of PUR (polyurethane) hard foams for the construction sector (2F2). These activities concern SBI (industrial) code 222.

HFC emissions that result from the use of PUR foams in aerosols fall under the sector ‘Aerosols/MDI’ (metered dose inhalers), which are classified as category 2F4 of the CRF (common reporting format) and are therefore not included in this protocol.

There are eight large PUR hard foam manufacturers in the Netherlands, and a larger number (50-80) of smaller manufacturers. The larger companies are members of the NVPU (Netherlands association of polyurethane hard foam manufacturers), which also includes three system design companies that supply raw materials and systems to the smaller foam manufacturers. The NVPU members represent around 70% of the PUR hard foam turnover in the Netherlands. Production by NVPU members amounts to 60% of the total PUR hard foam production in the Netherlands.

PUR hard foams are primarily used in the Dutch construction sector as an insulation material (see also Appendix 1). Smaller amounts are used to insulate refrigerators and freezers. Since pentane is used almost exclusively for this application within the European Union, and there is no production of refrigerator foams in the Netherlands, this application is not included in this protocol.

Prior to 2003, HFCs were not used in PUR hard foams. However, from 2003 onwards, limited amounts have been used. In 2002, for example, 1351 tons of HCFC-141b were used to manufacture PUR hard foams in the Netherlands (KPMG, 2003).

1.2 Significance and influences

1.2.1 Contribution to total national emissions

The HFC emissions from the production, usage and demolition phases of PUR (polyurethane) hard foams for the construction sector are not provided in this protocol, because they originate from only one company. Due to the confidentiality of this information, these HFC emissions are reported under category 2F9 (other HFC emissions). This category (2F9) contributes less than 0.1% to the total annual Netherlands greenhouse gas emissions.

1.2.2 Developments that infuence emissions

The European directive concerning greenhouse gases (no. 2037/2000) was published on 29 June 2000, and included limitations in the use of HCFCs (hydrochlorofluorocarbons) for the production of plastic foams. From 1 January 2004 onwards the use of HCFCs was prohibited in all types of foams. Replacements include: HFC-245fa, HFC-365mfc (possibly blended with HFC-227ea) and HFC-134a. Other alternatives include CO_2 and pentanes, which can be used under certain conditions. It is not expected that the ban on using HCFCs will lead to a one-to-one replacement by HFCs, partly due to the high costs involved.

In June 2006 the European F-Gas Directive came into force, including regulations for the use of F-gases. Since 4 July 2008 it is also prohibited to use HFCs for hard foams.

This means that, since the prohibition, the monitoring of HFC emissions in hard foams only focuses on emissions during the usage phase and the waste phase. Emissions during production are no longer monitored after this date.

2 METHOD, EMISSION FACTORS AND ACTIVITY DATA

2.1 Calculation method

HFCs were first used in hard foam production in 2003. HFC emissions from hard foams are calculated as follows:

HFC emission from PUR foams in year t-2 =
[extent of HFC use in new PUR foams in year t-2 x (emission factor production + emission factor installation)] +
[HFCs in recycled foam that was used in year t-2 x emission factor installation] +
[HFC in existing stock of PUR foams[1] x annual emission factor] +
[HFC in PUR waste foam from construction in year t-2[2] x emission factor demolition phase]

[1] Existing stock = [(new stock 1st year of application - annual emissions) + (new stock 2nd year of application - annual emissions over stock years 1 and 2) + ….etc…..+ (new stock year t-1 - annual emissions over stock years 1 through t-2)] - [amount destroyed by demolition].

[2] Deduced from the usage period of the foams: foams used in year t are assumed to be destroyed in the coming years (t + usage period).

The following assumptions and starting points have been used:

- When determining HFC emissions in the Netherlands it is important to have both production and usage data available for the Dutch situation. Experts currently only know how many (HCFC-based) products have been exported and imported. When calculating emissions it is therefore assumed that the use of hard foam products within the Netherlands is entirely due to domestic production.
- Foams taken from the construction sector are generally incinerated during the demolition phase, whereby the HFCs are destroyed (Vehlow et al., 1995); otherwise they are recycled. This recycled portion is also included in the formula.
- The report *Emissies van CFKs uit PUR-isolatieschuim in de keten van slopen tot verwerken (CFC emissions from PUR insulation foam in the chain from demolition to processing)* (Tauw et al., 2001) assumes a usage phase of 50-60 years for residences, 45 years for non-residential buildings, and 40 years for bituminous roofing. However, this does not include any intermediate demolition. The usage phase for the construction sector is assumed to be 40 years for plates/panels and mouldings. Usage is assumed to be 25 years for materials that are already installed (Kräling et al., 2000).

This calculation method complies with that described by the IPCC's Good Practice Guidance (GPG, 2001, p. 3.93 onwards). This concerns a tier 2 method with country-specific emission factors.

2.2 Emission factors

The extent of foam blowing emissions in the various phases varies according to the foam application. Emission percentages per application and per phase are shown in the following table. The following sources provided data:

1. LCA (life cycle analysis) report by Krähling et al., (2000), contains information concerning HFC emissions in the production and usage phases of the applications 'continuous plates/panels' and 'in situ'.
2. Since the aforementioned report contains no emission percentages for 'discontinuous forms', this information was taken from the Crystal Globe (2000) report and the 'CFC emissions from PUR insulation foam, from demolition to processing' report by Tauw et al. (2001). These emissions data concern CFCs used as propellant, though these are expected to be similar to HFCs. Krähling also assumes that emission percentages depend on the type of propellant used. Percentages for the dismantling/demolition phase are taken from the Tauw et al. (2001) report, because this phase is not included in the Kräling report. Tauw also includes emissions data for plates/panels and for 'in situ' applications, which are similar to those covered by Krähling.

Table 1: Emission percentages of three PUR hard foam applications in the various life phases

	1. Continuous, plates/panels [1)]	2. Discontinuous, forms [2)]	3. In situ [1)]
Production and installation	5%	0.5%	15%
First year usage	-	0.1%	5%
Usage in following years	0.2% per year	0.1% per year	1.2% per year
Dismantling/demolition phase[3)]	1%	-	2-90%

1) *Data taken from Krähling (2000)*
2) *Data taken from Tauw (2001) and Crystal Globe (2002).*
3) *Data taken from Tauw (2001); percentages concern the dismantling and associated processes for the foams; it is assumed that the foams are then incinerated so that the remaining propellants are destroyed. The 'in situ' emissions largely depend on the material to which the foam is attached and the treatment used: 2% for sorted (attached to wood), 10% for dismantled (attached to stone), 90% for crushed rubble (attached to stone).*

2.3 Activity data

The extent of HFC use in new foams is determined via the monitoring study *Gebruik van HCFKs, HFKs en aanverwante stoffen in Nederland (Use of HCFCs, HFCs and related substances in the Netherlands)* (otherwise known as the 'handelsstromenonderzoek', or trade flow study), which is implemented annually (up to 2003 by KPMG, from 2004 onwards by PWC consultants) on behalf of the Ministry of VROM (Housing, Spatial Planning and the Environment). Usage is determined via surveys sent to manufacturers, traders and several large users, as well as via meetings with companies. The stock of HFCs in the construction sector is determined using data from the trade flow study for the past few years.

The following activity data are required for the calculation:

- Extent of HFC usage in new foams, manufactured in year t-2.
- Amount of HFCs in existing stock in the construction sector and in refrigerators/freezers. This can be found from data in year t-3 (historic stock in year t-3 plus usage in year t-2).
- Amount of HFCs in foams, discarded annually, which end up in the demolition phase. This can be found using the lifespan of the foams.

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 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 usage figures in hard foams (currently taken from the annual PWC consultants' report (previously implemented by KPMG)	Check usage figures: - Compare with previous years - Look at the trend If unsubstantiated deviations found, contact the company submitting the annual report → modify the usage figure if necessary and document fully	Approved usage figures	Work package leader

INPUT	PROCESS	OUTPUT	BY WHOM
Aggregated emissions	Enter into 'preliminary' ER work file	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

To comply with international greenhouse gas reporting procedures, emissions must be reported following the Common Reporting Format (CRF; UNFCCC, 2004)[3].

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.

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

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	Categorie	Gas	AD onz.	EF onz.	Uncertainty estimates tot
2F	Emissions from substitutes for ozone depleting substances (ODS substitutes): HFC	HFC	10	50	51

[3] Common Reporting Format, Table 2(II)F Sectoral background data for industrial processes, 2 Foam blowing.

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

With respect to emission factors, the IPCC recommends that closed-cell foams should take account of the phases in which the foams are used, discarded and demolished. The accompanying formula 3.38 from the IPCC Good Practice Guidance states (IPCC, 2001):

> *Emissions from closed-cell foams in year t =*
>
> *[Total use of HFC for new closed-cell foams in year t * EF (t)]*
>
> *+ [total use of HFC in closed-cell foams between year t and year t-n * annual emission factor]*
>
> *+ [(loss from discarded closed-cell foam in year n) – (destroyed HFC)]*
>
> ***Where n = the lifespan of closed-cell foams***

If only aggregated usage figures are available and there is no further information available on specific foam types, then the general default emission factors should be used. The GPG describes the default values for hard foams as follows: 10% of the emission takes place in the first year, and 90% over the following 19 years. This therefore assumes that complete emission of the blowing agents takes place during the production and usage phase, based on a usage period of 20 years. Up to now the Netherlands has always used this calculation method.

Current insight shows that the default values can be replaced by figures that are more realistic. The Netherlands can give a reasonable estimate of the emission factors for the various types of foam. As a result of the halving period (40-80 years) with the exchange of air, the majority of the blowing agent remains in the foam. The blowing agent is thermically destroyed during the demolition phase (J. Vehlow et al., 1995). The current calculation method used by the Netherlands deviates from previous methods in several ways:

- The usage period for the foams is not 20 years, but 25 or 40 years, depending on the type of foam and the application;
- Emission factors are split into four phases, not just production and use, but also installation and demolition/scrap phases;
- Emission factors are adjusted.

4.4.2 Future

When determining HFC emissions for the Netherlands it is important to use both production and usage figures for the national situation. Emission calculations are currently based on the annual trade flow study, which shows the extent to which HFCs are being traded for foam production in the Netherlands. However, it is not currently known how many products (containing HCFCs) are being imported and exported each year. Emission calculations therefore use only hard foam products within the Netherlands that originate entirely from the Netherlands hard foam production. In order to determine the true situation it would be necessary to also determine the HFC quantity that is imported/exported via PUR foam, and imported via XPS foam. It is recommended that research be conducted into the possibilities of gaining a better insight into the extent of import and export trading.

With respect to the Netherlands production of XPS foam, it is necessary to look at developments in the use of blowing gases. If, in the future, HFCs are used in XPS production, then XPS foam will also need to be included in the monitoring protocol.

More information is also required concerning the extent to which PUR foams are recycled. This information, for example, can be obtained by registering the sheets and panels that are recycled.

One point to watch in the future concerns the treatment of in-situ foams during the demolition phase. The emission of blowing agents during demolition greatly depends on the way in which the construction materials containing in-situ foam are treated. When crushing rubble these emissions can increase to 90% of the blowing agent still present in the foam.

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

- Crystal Globe 2002: verbal information.
- EU: *Directive (EG) no. 2037/2000* concerning greenhouse gases.
- 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
- KPMG, september 2002: Gebruik van HCFK's, HFK's en aanverwante stoffen in Nederland in 2001. Den Haag (in Dutch)
- KPMG, September 2003: *Gebruik van HCFK's, HFK's en Methylbromide in Nederland in 2002 (Use of HCFCs, HFCs and Methyl Bromide in the Netherlands in 2002* (in Dutch)*).*
- Krähling H. and Krömer S., March 2000: HFC-365mfc as blowing- and insulation agent in polyurethane rigid foams for thermal insulation. Life Cycle Assessment accompanying application development and market positioning.
- 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
- PWC December 2004, Handelsstromenonderzoek 2003, Onderzoek naar het gebruik van fluorverbindingen in Nederland, Utrecht (in Dutch)
- PWC November 2005, Handelsstromenonderzoek 2004, Onderzoek naar het gebruik van fluorverbindingen in Nederland, Utrecht (in Dutch)
- PWC December 2006, Handelsstromenonderzoek 2005, Onderzoek naar het gebruik van fluorverbindingen in Nederland, Utrecht (in Dutch)
- Tauw, PRC-Bouwcentrum, Crystal Globe, July 2001: *Emissies van CFK's uit PUR-isolatieschuim, in de keten van slopen tot verwerken (CFC emissions from PUR insulation foam, from demolition to processing).*

- UNFCCC, 2004: *Guidelines for the preparation of national communications by Parties included in Annex I to the convention, Part I: UNFCCC reporting guidelines on annual inventories*, UNFCCC/SBSTA/2004/8, 3 September 2004.
- Vehlow J. et al.: *Co-combustion of building insulation foams with municipal solid waste*, Technical paper from APME, Exiba, Isopa October 1995, Forschum Centrum, Karlsruhe, Germany.

6.1 Additional information

Not applicable

APPENDIX 1

HCFCs are used in the following three applications (information obtained via expert judgement from the ROB (Reduction Programme non-CO_2 greenhouse gases) working group for synthetic foams).

1. *Continuous plates/panels*
   These are formed foam plates that are sawn and milled to size; a process causing relatively high emissions. Installation also causes a certain amount of emissions, as the panels are cut to the exact size. Emissions by propellants are negligible during the usage and dismantling phases.
2. *Discontinuous production in forms or moulds*
   This concerns foams that are cast in a particular shape, whereby further processing is unnecessary. Production emissions are low. Installation causes no emissions and the usage phase also causes very few emissions because the gases are well sealed.
3. *In situ applications*
   These are applications where the polyurethane mixture is sprayed or poured on site, usually used to insulate materials such as roofs, storage tanks and depots. Emissions during the pouring/spraying (production and installation phases) are higher than for panels and/or discontinuous production and, since the cells of the material are not covered with a so-called ‘facer’ then emissions during the usage phase are higher. The foam is adhered to another material, e.g. wood or stone. Since the foam is separated from such materials during the demolition phase, this causes fairly high emissions from propellants.

In addition to the aforementioned three applications, the Netherlands report also includes applications of HCFC-based foams in building blocks imported from other countries. Building block production using HCFC-based foams was banned after 2004 (EU Directive 2037/2000). Within the Netherlands such blocks are manufactured using pentane as propellant and it is unlikely that HFCs will be used in the future. Since this protocol covers only relevant production in the Netherlands, production of such blocks falls outside its scope.

At the present time (2002) CO_2 is used in XPS (extruded polystyrene) production in the Netherlands, rather than HCFCs or HFCs. Since it is not possible to say that HFCs will not be used in future XPS production in the Netherlands, it is important to monitor the developments in this area and, if necessary, to set up a monitoring protocol at a later stage. The Netherlands does import XPS foams containing HFCs, but quantities are not known and thus cannot be taken into consideration.

Emissions from hard foams are expected throughout the following four periods:

1. *Production phase*
   Foam production causes emissions. The extent of such emissions depends on the production method used: open applications cause relatively high emissions, and closed applications (such as casting) cause low emissions. Continuous foam production causes extra emissions when processing the foam products in the factory, e.g. milling the sides and sawing the panels.
2. *Installation phase*
   Emissions are caused when hard foams are installed in buildings and products, as they are further cut to the exact size or made to fit.
3. *Usage phase*

Propellant losses can occur when using hard foams in the construction sector, as a result of diffusion through the cell walls.

4. *Dismantling/demolition phase*

   Propellants can be released during the demolition and processing of the waste, e.g. through breakage and damage. The hard foams are therefore included with the rest of the waste products and are either dumped or incinerated. Although incineration is better, most of the foams are currently dumped because the Netherlands has insufficient incineration capacity. Under the framework of the Dumping Decree, landfill gas (with propellants from foams) must be separated and flared or used in a gas engine. Around 50-60% of the gases are captured and the rest are released, thus emitting propellant gases. Emissions also occur during compacting, i.e. flattening a new layer of waste added to the landfill site, whereby materials are reduced in size. It is expected that the first HFC-based foams will be released as waste in around 25 years. It is unlikely that these waste substances will still be dumped at that time, as the government is expected to prohibit the dumping of construction and demolition waste.