Protocol
6D: CH_4 and N_2O emissions from composting and fermentation plants for GFT waste

IPCC Category:	6D
NFR Code:	n.a.
NOSE Code:	n.a.
NACE Code 2008	3821

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 describes the monitoring of CH_4 and N_2O emissions that are released during the processing of separately collected household GFT (fruit, vegetable and garden) waste into compost and/or biogas in the Netherlands (IPCC category: 6D). Emissions released during processing (composting and/or fermentation) of other organic waste, mostly generated by companies, are not included in this protocol. These activities concern SBI (industrial) code 3821 (Treatment and disposal of non-hazardous waste).

This protocol also includes the method use to determine the precursors: ammonia (NH_3), nitrogen oxide (NO_x) and sulphur dioxide (SO_2).

This protocol concerns the monitoring of methane (CH_4), ammonia (NH_3), laughing gas (N_2O), nitrogen oxide (NO_x) and sulphur dioxide (SO_2) emissions that occur during the processing of separately collected household GFT waste in composting and fermentation

plants. During this process the GFT waste is converted into compost and/or biogas. These processes occur in enclosed facilities (halls, tunnels and/or fermentation tanks), whereby air emissions can be filtered off in a controlled way. These gases can then be filtered through a biobed before being emitted to the air. The material in the biobed is renewed periodically.

Emission measurements are hardly ever conducted at the biobed.

1.2 Significance and influences

1.2.1 Contribution to total national emissions

CH_4 emissions from this source contribute less than 0.1% to the annual greenhouse gas emissions from the Netherlands.
N_2O emissions from this source contribute less than 0.1% to the annual greenhouse gas emissions from the Netherlands.

1.2.2 Developments that infuence emissions

At the present time there are no known specific measures being implemented to reduce emissions. As indicated in Section 1.1, processing occurs in enclosed facilities that allow the operator to filter off, and break down, the emissions via a biobed.

At the beginning of the 1990s this process was rather different. At that time it was possible to compost material in an open environment, which resulted in gases being emitted directly to the ambient air. Since the composting/fermenting of separated household GFT waste only began after 1990, this process is not included into the emissions data for the base year (1990). The expansion of the composting/fermentation of GFT waste is the result of compulsory separate GFT waste collection that began in 1994. Emissions that are now occurring due to composting/fermentation were occurring as landfill gas (from landfill waste sites) at the beginning of the 1990s.

It is not possible to guarantee that the composition of the separated GFT waste will not change in the near future. Various local authorities are placing more emphasis on the separate collection of garden waste, and less on the fruit and vegetable fraction. This means that the GFT waste will not only be larger (in structure), but also drier. These developments can have consequences for the individual emission factors (see also Section 2.1), and thus also for the emissions. The extent of these consequences cannot be quantified at this time.

2. Method, emission factors and activity data

2.1 Calculation method

The emissions that are released during composting and fermentation of GFT waste are calculated (in the Netherlands) by multiplying the processed amount per component by an emission factor for composting or an emission factor for fermentation. As previously mentioned in Section 1.1, only sporadic research has been conducted into these emission factors.

The calculation formulas for the individual components are as follows:

Methane (CH_4)

$$CH_{4,comp} = EF_{CH\,4,comp} * T_{composting}$$

$$CH_{4,ferm} = EF_{CH\,4,ferm} * T_{fermentation}$$

Where:

- $CH_{4,comp}$: Total methane emissions from composting GFT waste (in gram per year)
- $EF_{CH4,comp}$: Emission factor for methane from composting = 2400 (in gram per ton composted GFT waste)
- $T_{composting}$: Total amount of composted GFT waste (in ton per year)
- $CH_{4,ferm}$: Total methane emissions from fermenting GFT waste (in gram per year)
- $EF_{CH4,ferm}$: Emission factor for methane from fermentation = 1100 (in gram per ton fermentation GFT waste)
- $T_{fermentation}$: Total amount of fermented GFT waste (in ton per year).

Ammonia (NH_3)

$$NH_{3,comp} = EF_{NH\,3,comp} * T_{composting}$$

$$NH_{3,ferm} = EF_{NH\,3,ferm} * T_{fermentation}$$

Where:

- $NH_{3,comp}$: Total ammonia emissions from composting GFT waste (in gram per year)
- $EF_{NH3,comp}$: Emission factor for ammonia from composting = 200 (in gram per ton composted GFT waste)
- $T_{composting}$: Total amount of composted GFT waste (in ton per year)
- $NH_{3,ferm}$: Total ammonia emissions from fermenting GFT waste (in gram per year)
- $EF_{NH3,ferm}$: Emission factor for ammonia from fermentation = 2.3 (in gram per ton fermented GFT waste)
- $T_{fermentation}$: Total amount of fermented GFT waste (in ton per year).

Laughing gas (N_2O)

$$N_2O_{comp} = EF_{N2O,comp} * T_{composting}$$

$$N2O_{ferm} = EF_{N2O,ferm} * T_{fermentation}$$

Where: N_2O_{comp}: Total laughing gas emissions from composting GFT waste (in gram per year)

$EF_{N2O,comp}$: Emission factor for laughing gas from composting = 96 (in gram per ton composted GFT waste)

$T_{composting}$: Total amount of composted GFT waste (in ton per year)

N_2O_{ferm}: Total laughing gas emissions from fermentation of GFT waste (in gram per year)

$EF_{N2O,ferm}$: Emission factor for laughing gas from fermentation = 46 (in gram per ton fermented GFT waste)

$T_{fermentation}$: Total amount of fermented GFT waste (in ton per year).

Nitrogen oxide (NO_x)

$$NO_{x,ferm} = EF_{NOx,ferm} * T_{fermentation}$$

Where: $NO_{x,ferm}$: Total nitrogen oxide emissions from fermenting GFT waste (in gram per year)

$EF_{NOx,ferm}$: Emission factor for nitrogen oxide from fermentation = 180 (in gram per ton fermented GFT waste)

$T_{fermentation}$: Total amount of fermented GFT waste (in ton per year).

Sulphur dioxide (SO_2)

$$SO_{2,ferm} = EF_{SO2,ferm} * T_{fermentation}$$

Where: $SO_{2,ferm}$: Total sulphur dioxide emissions from fermenting GFT waste (in gram per year)

$EF_{SO2,ferm}$: Emission factor for sulphur dioxide from fermentation = 10.7 (in gram per ton fermented GFT waste)

$T_{fermentation}$: Total amount of fermented GFT waste (in ton per year).

The aforementioned methods are country-specific. The Revised 1996 IPCC Guidelines (IPCC, 1997) and the Good Practice Guidance (IPCC, 2001) do not define any method for determining emissions resulting from composting and fermenting GFT waste.

2.2 Emission factors

The emission factors included in the formulas under Section 2.1 are determined on the basis of the sparse literature concerning emissions from composting and/or fermenting separated GFT waste. It appears that there is hardly any monitoring conducted at the biobed reactors, or the literature cannot be considered relevant due to the clearly differing operational methods used in the Netherlands.

During the 1990s the Ministry of VROM (Housing, Spatial Planning and the Environment) organised a large-scale monitoring programme concerning the composting and fermenting of GFT waste. The results of this programme (emissions per processed amount of GFT waste) were incorporated into a report (DHV, 1999). This information was then reflected in the environmental effect report for the national waste management plan 2002-2012 (VROM, 2002) as the average emission factor (of all available sources) for the various components, for both composting and fermentation. These factors are determined based on the processing of one ton of GFT waste.

2.3 Activity data

When determining emissions it is important to have proper insight into the processed amounts of GFT waste in composting and fermentation plants (per year). The only source of this information is the annual reports by the Werkgroep Afvalregistratie[1] (working group for waste registration). This group conducts an annual survey among all waste processing companies, including those composting and fermenting separated GFT waste.

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.

[1] The following organisations participate in the Werkgroep Afvalregistratie: Ministry of VROM, Vereniging Afvalbedrijven (association of waste companies), IPO (association of provincial authorities) and SenterNovem (formerly AOO and SCG).

INPUT	PROCESS	OUTPUT	BY WHOM
- Annual report, Werkgroep Afvalregistratie (working group for waste registration)[2]	Determine amounts of composted and fermented GFT waste at all processing plants in the Netherlands	Overview of amounts of GFT waste that have been composted and/or fermented	Work package leader, ENINA task force
- Amounts of composted and fermented GFT waste - EF (Emission Factor) (MER of the LAP)	Calculate	Emissions and activity data in ER (Emissions Registration) format	Work package leader ENINA task force
CH_4 and N_2O emissions from GFT waste	Check figures	Figures validated by task force	ENINA task force
Validated figures	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 $_{total}$ 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.

[2] At the time of writing this protocol, the last report available from the Werkgroep Afvalregistratie was [AOO, 2004].

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

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 $_{tot}$
6D	OTHER waste handling CH_4	CH_4	20	25	32
6D	OTHER waste handling N_2O	N_2O	20	50	54

The emissions in this source category (large-scale compost production) were calculated using an average emission factor that was obtained from the literature. The uncertainty in activity data was estimated at 20%. The uncertainty in the CH_4 and N_2O emission factor was estimated at 25 and 50%, respectively [Olivier et al, 2009]. The uncertainty in annual emissions from CH_4 and N_2O was estimated at 32 and 54%, respectively.

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
Up to and including the 2004 NIR (Klein Goldewijk, 2004), emissions resulting from composting, as reported in this protocol, were not calculated or reported in the CRF. This situation changed with effect from the 2005 NIR (Klein Goldewijk, 2005).

4.4.2 Future
Not applicable

5. Remaining aspects

5.1 Point source criteria
Not applicable

5.2 Substance profiles
Not applicable

5.3 Regionalisation
The figures can be determined per plant, and can thus be 'located' accurately throughout the Netherlands.

5.4 Time-based variations in source strength
Not applicable

6. References and additional information

6.1 References

- AOO, Afvalverwerking in Nederland, gegevens 2005, Werkgroep Afvalregistratie, september 2006, AOO 2006-07, ISBN: 90-5748-049-2 (in Dutch)
- DHV, 1999: *Eindevaluatierapport meetprogramma GFT-verwerkingsinstallaties SMB, SOW/CAW en Arcadi (Final evaluation report of the monitoring programme for GFT processing plants)*. DHV Final report, commissioned by the Ministery of VROM, registration number ML-TE981217, January 1999, the Netherlands.
- 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
- Klein Goldewijk K., Olivier J.G.J., Peters J.A.H.W., Coenen P.W.H.G. and Vreuls H.H.J.: *Greenhouse Gas Emissions in the Netherlands 1990-2002, National Inventory Report 2004,* RIVM, report 773201008/2004, NIR, 2004, Bilthoven, the Netherlands.

- Klein Goldewijk K., Olivier J.G.J., Peters J.A.H.W., Coenen P.W.H.G. and Vreuls H.H.J: *Greenhouse Gas Emissions in the Netherlands 1990-2003, National Inventory Report 2005,* Milieu- en Natuurplanbureau, report 773201009/2005. RIVM, Bilthoven, the Netherlands.
- 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
- VROM, 2002: *MilieuEffectRapport Landelijk afvalbeheerplan 2002-2012 (Environmental Effect Report, national waste management plan 2002-2012),* Ministry of VROM, report 02.0115/04-03 21770/206. The Hague, the Netherlands.

6.2 Additional information

Not applicable