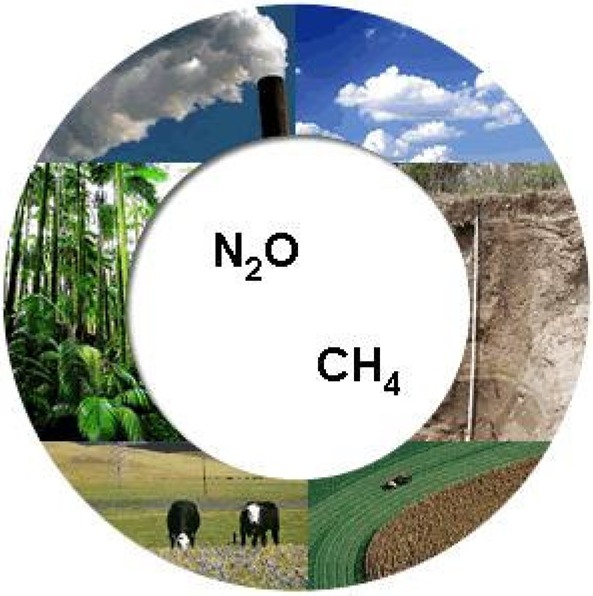
Update of emission factors for N_2O and CH_4 for composting, anaerobic digestion and waste incineration



February 2012
Final report, revision 2012

Gateway to solutions

Update of emission factors for N_2O and CH_4 for composting, anaerobic digestion and waste incineration

file : BA4763
registration number : MD-AF20120044/MK
version : 1

February 2012
Final report, revision 2012

CONTENTS PAGE

SUMMARY

Background

Yearly emissions of greenhouse gases are reported by governments in National Inventory Reports (NIR) as part of obligations resulting from international agreements such as the UNFCCC and the Kyoto Protocol. In the Netherlands there has been a discussion going on for several years with regard to the N_2O and CH_4 emission factors being used in the Dutch NIR for composting and anaerobic digestion of the organic fraction of municipal solid waste. For the incineration of waste also some discussions have risen regarding the emission factors used. The NL Agency has asked DHV consultancy and engineering to perform a review of emission factors for greenhouse gases for these waste treatment options used in several EU member states or described in various research projects. The results of this overview and assessment of the available emission factors have lead to a proposal for emission factors (with a range), which can be used for future National Inventory Reports. The results of this assignment are described in this report.

Method of research

First an inventory has been made of available emission factors. For this inventory several National Inventory Reports of various countries and other relevant documents and information sources have been reviewed. Further more national and international experts have been consulted to verify available data and discuss their expert judgment. Finally the reliability of the reviewed emission factors and the relevance as basis for new emission factors for the Dutch NIR have been analyzed on basis of various aspects: Age of the data, origin of the data, scale of the facility of data origin, number of measurement values and type of technologies used. All available data have been assessed on these aspects and it has been assessed if the data can be considered representative for the Dutch situation and can be used as basis for new emission factors.

Results and recommendations

In the table below an overview is given of the results of this review.

Treatment method (all values in g/ton waste)	**Current emission factors**	**Reviewed ranges of data**	**Proposed future emission factors**	**Change**
Composting				
• CH_4	2.400	80 - 1.000	750	Lower
• N_2O	96	40 - 180	96	None
Anaerobic digestion				
• CH_4	1.100	500 - 3.700	1.100	None
• N_2O	46	< 20 - 120	46	None
Waste incineration				
• CH_4	0	0 - 8,4	0	None
• N_2O (without SNCR)	20	6 - 95	20	None
• N_2O (with SNCR)	100	6 - 95	100	None

The emission factors mentioned are proposed specifically for use in the Dutch NIR. Individual facilities may have emission factors, which differ from the average emission factors proposed. For other purposes then the NIR these individual facilities may use other emission factors if they can support them on basis of research results specifically aimed at their facility.

The CH_4 emission factor, currently being used for composting in the Netherlands, is clearly too high. For composting a new CH_4 emission factor is proposed of **750 g CH_4/ton** of fresh organic waste. This corresponds to a decrease with approximately 65 % of the current value. For N_2O the current emission factor of **96 g N_2O/ton** can be maintained. Both values are backed up by all of the data considered relevant.

For anaerobic digestion the situation is more complicated. The CH_4 and N_2O emission factors, currently being used for anaerobic digestion in the Netherlands, are based on a limited amount of data. However only two relevant data sources are available as basis for new emission factors with totally different research results. Because both these relevant data sources show contradictory values it is not advisable to change the current emission factors on basis of these results. It is therefore proposed to maintain the current emission factors of **1.100 g CH_4/ton** and **46 g N_2O/ton** anaerobic digestion facilities for the time being**.**. Many composting facilities in the Netherlands will (partly) transform to anaerobic digestion facilities in the near future. It is recommended to follow these developments in the future to get more and more accurate information on the emission factors for anaerobic digestion. The UBA 2008 research report formed the first part of a larger research project. In the second part of that project more measurements will take place (for instance in various anaerobic digestion facilities). It will be interesting to see if these additional results give a different point of view on the situation and if this will be a reason for the German government to revise the emission factors in Germany's future NIRs. If new information is available from one of both data sources the necessity of revision of the Dutch emission factors for anaerobic digestion should again be evaluated.

For waste incineration it is proposed that de current emission factors for CH_4 (**0 g CH_4/ton** of fresh waste) and N_2O (**20 (no SNCR) and 100 (SNCR) g N_2O/ton** of fresh waste) are maintained. The CH_4 emission factor of 0 g/ton can only be used if the concentrations of CH_4 in the discharge air of a waste incinerator are lower than the concentrations in the intake air. A first rough calculation confirms that this is the fact for the Netherlands. It is recommended that some more accurate calculations are performed with the actual air flows used in the waste incinerators to confirm it is possible to neglect the CH_4 emission from waste incinerators in the NIR. For the N_2O emission factors relevant data are available resulting from the annual environmental reports of the waste incinerators in the Netherlands. These data seem to be the most fitting data for the Dutch situation. However, until now only a limited number of waste incinerators have supplied the required data. In future years it is important that this number increases to get a better coverage of the incineration sector in the Netherlands so these that can be used to determine future emission factors.

1 INTRODUCTION

The waste management department of NL Agency (part of the Dutch Ministry of Economic Affairs) is responsible for the execution and coordination of various governmental programs and for the implementation of guidelines and legislation for several Dutch ministries. One of these activities is the coordination of the National Inventory of greenhouse gas emissions as a result of waste management in the Netherlands. The NL Agency has assigned DHV consultancy and engineering to perform a review of emission factors for greenhouse gases in the waste sector. This review focuses on emission factors for the greenhouse gases N_2O and CH_4 as result of composting and anaerobic digestion of the organic fraction of municipal solid waste and as result of incineration of municipal solid waste and similar waste. The results of this assignment are described in this report.

Background

The Dutch government has yearly reporting obligations resulting from international agreements such as the UN Convention on Climate Change (UNFCCC) and the Kyoto Protocol. They are required to report regularly on emissions of greenhouse gases and on steps they are taking to implement the agreements. This results yearly in National Inventory Reports (NIR) regarding the emissions of greenhouse gases.

In the Netherlands there has been a discussion going on for several years with regard to the N_2O and CH_4 emission factors being used in the Dutch NIR for composting and anaerobic digestion of the organic fraction of municipal solid waste. For the incineration of waste also some uncertainties have risen regarding the emission factors used. The NL Agency wants to get an overview of available N_2O and CH_4 emission factors for these waste treatment options used in several EU member states or described in various research projects.

Objective

The objective of this assignment was to get an overview of available N_2O and CH_4 emission factors for composting and anaerobic digestion of the organic fraction of municipal solid waste and for incineration of municipal solid waste, used in several EU member states for the national inventory reporting activities or described in various research projects. This included an assessment of the background of these emission factors (based on calculations, measurements at full scale plants, experiments, number of facilities taken into account, year of origin of the data, etc.). The results of this overview and assessment of the available emission factors should lead to a proposal for emission factors (with a range), which can be used for future National Inventory Reports.

Report content

Chapter 2 deals with the method of research used for this project. In chapter 3 the results of the review and assessment are discussed. Finally the conclusions of the project and recommendations for the emission factors are summarized in chapter 4.

2 METHOD OF RESEARCH

During project execution the following project activities have been distinguished:
- Inventory of emission factors for N_2O and CH_4
- Assessment of values and background of these emission factors
- Formulation of a proposal for emission factors for N_2O and CH_4 in future NIRs

2.1 Inventory of emission factors for N_2O and CH_4

For this inventory the following NIR documents have been reviewed:
- Revised 1996 IPCC guidelines for National greenhouse gas inventories
- 2000 Good Practice guidance and uncertainty management in National greenhouse gas inventories
- 2006 IPCC guidelines for National greenhouse gas inventories
- NIR 2009 of the Netherlands (including the NIR 2009 Memo item on CO2 emissions from biomass (translation of the VROM Monitoring Protocol 9088, April 2009) and the NIR 2009 Protocol 6D: CH_4 and N_2O emissions from composting and fermentation plants for GFT waste[1])
- NIR 2009 of Germany
- NIR 2009 of Belgium
- NIR 2009 of the United Kingdom
- NIR 2009 of Austria
- NIR 2009 of Switzerland
- NIR 2009 of Denmark
- NIR 2009 of Japan

For this inventory the following other documents/information sources have been reviewed:
- Emission data of the 12 waste incineration facilities in the Netherlands (information of Mrs. R. Dröge of TNO and Mr. O.R. van Hunnik of the NL Agency in the Netherlands)
- Selected data regarding emissions from incineration facilities from the LCA tool for waste management, WRATE, in the UK (information of Mrs. J. Bates of AEA in the UK)
- "Onderzoek bepalen kentallen methaan en lachgas composteerbedrijven", kenmerk R001-4513106 HJR-srb-V03 NL, dd. 22-11-2007, Tauw unit Environment and Safety in assignment of the corporation of waste management companies (Tauw 2007)
- "Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheid – Abfallwirtschaft – Förderkennzeichen: 206 33 326 – Thema: Ermittlung der Emissionssituation bei der Verwertung von Bioabfällen, dd. Dezember 2008, Gewitra Ingenieurgesellschaft für Wissensstransfer mbH in assignment of the Umwelbundesamtes (UBA 2008)
- "Greenhouse gas emissions from composting and mechanical biological treatment", Waste Management & Research 2008: 26: 47-60 (Amlinger 2008), Florian Amlinger and Stefan Peyr (Compost – Consulting & Development) and Carsten Cuhls (Gewitra Ingenieurgesellschaft für Wissensstransfer mbH)

[1] GFT waste = biodegradable organic fraction of household waste that is separately collected at source

For this inventory the following organizations and experts have been contacted to verify available data and/or discuss their expert judgment:

- Rianne Dröge, TNO, regarding Emission data of incineration facilities in the Netherlands
- Marta Olejnik, Technical & Scientific Officer of CEWEP (Confederation of European Waste-to-Energy Plants), regarding the point of view of CEWEP regarding available data and the IPCC emission factors
- Miet D'heer, Flemish Environmental Agency (Department of Air, Environment and Communication - Emission Inventory Air), contributor to the topic waste incineration in Belgium's NIR.
- Florian Amlinger, Composting Expert of the Austrian firm Compost – Consulting & Development

2.2 Assessment of the values and background of the emission factors

For each of the data sources mentioned above the values of the emission factors for N_2O and CH_4 have been analyzed and the background has been assessed. The background of the emission factors can be very different. The reliability of the values and the applicability as basis for new emission factors for the Dutch NIR depend on the following aspects:

- **Age of the data**: Some of the emission factors are based on relatively old data (1990 to 2000), some on recent information (2007, 2008). For this study more recent information is preferred above old data.
- **Origin of the data**: Some of the emission factors are based on theoretical models and on calculations based on waste composition and degradation processes, others are based on air quality measurements. For this study measurement data are preferred above results from modeling activities.
- **Scale of the facility of data origin**: Some measurement data are collected during laboratory experiments, others are related to full-scale facilities. For this study measurement data from full-scale facilities are preferred above laboratory data.
- **Number of measurement values**: Some of the emission factors are based on information of a single facility or on incidental measurements, others are based on long-term regular measurements taking into account a large number of facilities. For this study data from long term and multiple facility measurements are preferred above incidental and single facility measurements.
- **Representative for Dutch (NL) situation**: Some of the data correspond to waste or technologies not representative for the Dutch situation.

All available data are assessed on these aspects and it has been determined if the data can be considered representative for the Dutch situation. The criteria have been scored as positive (+), negative (-) or neutral (0). If data were not available, this has been indicated with "n.a.". If the information regarding some aspects was not clear, this has been indicated with "?". In chapter 3 of this report the results of the assessment of the values and background of the emission factors are described. This information is taken into account in the proposal for emission factors for N_2O and CH_4 in future NIRs.

2.3 Formulation of a proposal for emission factors for N_2O and CH_4 in future NIRs

The results of the overview and assessment of the available emission factors have lead to a proposal for emission factors (with a range), which can be used for future National Inventory Reports. The conclusions and recommendations with regard to these emission factors have been described in chapter 4 of this report.

3 RESEARCH RESULTS

In this chapter the results of the inventory and assessment regarding the emission factors available for N_2O and CH_4 in various countries and in general IPCC documents are described. A distinction is made between emission factors for composting and anaerobic digestion of organic waste (paragraph 3.1) and those for the incineration of municipal solid waste (paragraph 3.2). For each of these waste treatment options the discussion starts with a summary of the available emission factors and a summary of the reliability of the available data (in paragraph 3.1.1 for composting and anaerobic digestion and in paragraph 3.2.1 for incineration)

3.1 Composting and anaerobic digestion

3.1.1 Summary of available emission factors

Table 1 Overview of N_2O and CH_4 emission factors for composting and anaerobic digestion

Source	Comments	Composting		Anaerobic digestion	
		CH_4 [g/ton]	N_2O [g/ton]	CH_4 [g/ton]	N_2O [g/ton]
IPCC documents					
• 2006 IPCC guidelines	Based on general calculations and old measurement data. Broad range of values	4.000	300	1.000	0
The Netherlands					
• NIR 2009	Based on a small amount of measurements	2.400	96	1.100	46
• Tauw 2007	Technologies representative for the NL	80 - 300	40 - 100	500	< 20
Germany					
• NIR 2009	Based on calculations and assumptions	2.500	83	Not avail.	Not avail.
• UBA 2008	Technologies representative for the NL	710	68	3.700	120
Belgium					
• NIR 2009	Same basis as Dutch NIR	2.400	Not avail.	Not avail.	Not avail.
United Kingdom					
• NIR 2009	Composting and anaerobic digestion not in NIR	Not avail.	Not avail.	Not avail.	Not avail.
Austria					
• NIR 2009	Technologies representative for the NL	750	100	Not avail.	Not avail.
• Amlinger 2008	Technologies partly representative for the NL	500-1.000	20 - 180	Not avail.	Not avail.
Switzerland					
• NIR 2009	Old data and basis of measurements not clear	5.000	70	5.300	70
Denmark					
• NIR 2009	Composting and anaerobic digestion not in NIR	Not avail.	Not avail.	Not avail.	Not avail.
Japan					
• NIR 2009	Based on 2006 IPCC guidelines	4.000	300	Not avail.	Not avail.

The reliability of the values, mentioned in table 1 and the applicability as basis for new emission factors for the Dutch NIR depend on various aspects as discussed in paragraph 2.2. In the table below these aspects have been scored to give an impression of their applicability for the Dutch NIR.

Table 2 Overview of the reliability of the data used

Source	Old/ recent data	Modeling/ measurements	Lab. experiment /Full scale	Number of measurements	Representative for NL situation
IPCC documents					
• 2006 IPCC guidelines	-	-	-	-	-
The Netherlands					
• NIR 2009	-	+	+	-	+
• Tauw 2007	+	+	+	+	+
Germany					
• NIR 2009	0	-	-	?	-
• UBA 2008	+	+	+	+	+
Belgium					
• NIR 2009	-	+	+	-	+
United Kingdom					
• NIR 2009	n.a.	n.a.	n.a.	n.a.	n.a.
Austria					
• NIR 2009	+	+	+	+	+
• Amlinger 2008	+	+	+	+	+
Switzerland					
• NIR 2009	-	+	+	?	-
Denmark					
• NIR 2009	n.a.	n.a.	n.a.	n.a.	n.a.
Japan					
• NIR 2009	-	-	-	-	-

3.1.2 IPCC documents

In the 2006 IPCC Guidelines for National Greenhouse Gas Inventories the subject of biological treatment of solid waste is dealt with in chapter 4.1. In this chapter the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described and emission factors are given for both gases. For these emission factors a distinction is made between composting and anaerobic digestion. These emission factors are shown in the table below. In the 1996 IPCC guidelines and the 2000 Good Practice guidance no information is given on the subject of biological treatment of waste.

Table 3 N_2O and CH_4 emission factors for composting and anaerobic digestion in IPCC documents

Treatment option	Emission factors
Composting	
• CH_4	Average 4.000 g CH_4 / ton wet organic waste (between 30 and 8.000 g/ton)
• N_2O	Average 300 g N_2O / ton wet organic waste (between 60 and 600 g/ton)
Anaerobic digestion	
• CH_4	Average 1.000 g CH_4 / ton wet organic waste (between 0 and 8.000 g/ton)
• N_2O	Assumed negligible

These emission factors are based on various personal communications, on literature describing the subject in general and on the results of pilot experiments with regard to biological waste degradation. Where measurement results of full scale waste treatment facilities are taken into account, they are old data and refer to open windrow composting facilities. This results in a broad range of values and thus in a low accuracy of the emission factors proposed.To the opinion of DHV these data should not be considered as representative for the situation in the Netherlands and should therefore not be used as basis for the emission factors for the Dutch NIR.

3.1.3 The Netherlands

In the Netherlands the methodological issues with regard to the calculations of the N_2O and CH_4 emissions for the purpose of the NIR are described in the NIR 2009 Protocol 6D: CH_4 and N_2O emissions from composting and fermentation plants for GFT waste. For the emission factors a distinction is made between composting and anaerobic digestion. These emission factors are shown in the table below.

Table 4 N_2O and CH_4 emission factors for composting and anaerobic digestion in the NIR protocol in the Netherlands

Treatment option	Emission factors
Composting	
• CH_4	2.400 g CH_4 / ton wet organic waste
• N_2O	96 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	1.100 g CH_4 / ton wet organic waste
• N_2O	46 g N_2O / ton wet organic waste

These emission factors are based on the results of a large-scale monitoring program concerning the composting and anaerobic digestion of the separately collected organic fraction of household waste in the Netherlands. This information was later used as one of the data sources for the Environmental Assessment Report for the National waste management plan 2002-2012 in the Netherlands. During the monitoring program one composting facility and two anaerobic digestion facilities (without post composting unit) where monitored. The technologies of these facilities are (partly) still used for this type of waste in the Netherlands, but are not representative for the total scope of technologies used. Furthermore the process management of the anaerobic digestion plants was not working stable at that time and has improved strongly in the last years. The air quality measurements (and thus the N_2O and CH_4 concentration measurements) where only performed twice in each of the facilities during a two hour period. The emission factors are therefore based on a limited amount of measurements during a short period of time.

To the opinion of DHV these data only give an indication of the order of magnitude of the emission of N_2O and CH_4 as a result of this activity and should not be considered as representative for the situation in the Netherlands. Under assignment of the Dutch corporation of waste management companies a study regarding a representative part of the Dutch organic waste treatment facilities has been performed in 2007 to determine the emission under representative process conditions. The emission factors based on this study are shown in the table below.

Table 5 N_2O and CH_4 emission factors for composting and anaerobic digestion as result of the Tauw 2007 study in the Netherlands

Treatment option	Emission factors
Composting	
• CH_4	Between 80 and 300 g CH_4 / ton wet organic waste
• N_2O	Between 40 and 100 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	500 g CH_4 / ton wet organic waste
• N_2O	< 20 g N_2O / ton wet organic waste

The measurements in this study have been performed at 4 full scale composting facilities (different technologies) and 1 anaerobic digestion facility (including post composting unit) in the Netherlands. These measurements where performed twice in each facility during a twenty-four hour period. The research results show almost no CH_4 emission in the post composting unit of the anaerobic digestion facility. This is remarkable, because a significant emission was expected here. This might be caused by the fact that this specific facility uses a wet scrubber as gas treatment unit and thus limiting the CH_4 emission further than with a biofilter. This is not representative for all anaerobic digestion facilities in the Netherlands. However to the opinion of DHV these data can be considered as more representative for the situation in the Netherlands than the values currently used in the Dutch NIR. They should be taken into account when considering new emission factors for the Dutch NIR.

3.1.4 Germany

Germany's NIR 2009 deals with the subject of biological treatment of solid waste in chapter 8.4. Because Germany could not find satisfying emission factors for N_2O and CH_4 in IPCC guidelines they have developed a national method for calculating emissions from waste composting, including emission factors based the results of a research project performed in 2003. This research project was carried out under commission of the Federal Environment Agency (IFEU) and derived a method for calculating emission factors for the gases CH_4, N_2O and NH_3 from composting. In these calculations average concentrations of carbon and nitrogen in kitchen waste and plant waste were assumed and estimates were made of the average decomposition rates during composting, as well as of the distribution of carbon and nitrogen throughout the relevant emitted decomposition products. The emission factors resulting from this study and used in Germany's NIR are shown in the table below.

Table 6 N_2O and CH_4 emission factors for composting and anaerobic digestion as used in Germany's NIR

Treatment option	Emission factors
Composting	
• CH_4	2.500 g CH_4 / ton wet kitchen waste, 3.360 g CH_4 / ton wet plant waste
• N_2O	83 g N_2O / ton wet kitchen waste, 60 g N_2O / ton wet plant waste
Anaerobic digestion	
• CH_4	Not available
• N_2O	Not available

These emission factors are thus based on calculations on basis of the waste composition. They are not considered very accurate and in Germany's NIR a high uncertainty percentage is taken into account. The emission factors don't give information regarding anaerobic digestion. To the opinion of DHV these data are not based on information that is accurate enough to be used as basis for the emission factors for the Dutch NIR. In Germany this opinion is shared. A research project has been performed in 2008 (UBA 2008) under commission to the Federal Environment Agency, with the aim of improving the database for the emission factors for CH_4 and N_2O. The project includes both research, to obtain pertinent literature data, and measurements at composting and anaerobic digestion facilities. The project's aim is to produce emission factors based on measured emissions from real systems. This project is expected to be the basis for new emission factors to be used in future NIR's in Germany.

The literature discussed in this UBA 2008 study originates from Germany, Austria, Switzerland and the Netherlands. The Dutch literature comprises of the Tauw 2007 research as discussed in paragraph 3.1.3. As a mean result of this literature an emission of 250 to 1.000 grams CH_4 per ton of wet waste can be considered as average under normal operating conditions. On basis of this literature an emission higher than 2.000 grams of CH_4 per ton is considered the result of inefficient process management. A biofilter only has a limited influence (maximum 20 % reduction) on the emission values. For the emission of N_2O values of 70 to 100 grams per ton of wet waste are considered as average under normal operating conditions. A biofilter doesn't have an influence on the emission of N_2O. The values from the Dutch Tauw 2007 form the lowest of the values in the literature analyzed in the UBA 2008 study.

As second part of the UBA 2008 research project measurements have been performed at 12 full scale composting facilities (4 open composting facilities and 8 (partly) closed facilities) and 5 anaerobic digestion faciliies (including post composting unit) in Germany. These measurement have mainly taken place in 2007 and 2008. These measurements where performed continuously during a 7 day period in each facility. The emission factors resulting from the measurements performed in this UBA 2008 study are shown in the table below.

Table 7 N_2O and CH_4 emission factors for composting and anaerobic digestion as resulting from the measurement performed in the research project UBA 2008

Treatment option	Emission factors
Closed composting	
• CH_4	Average 710 g CH_4 / ton wet organic waste (between 300 and 1.500 g/ton)
• N_2O	Average 68 g N_2O / ton wet organic waste (between 49 and 120 g/ton)
Open composting	
• CH_4	Average 1.000 g CH_4 / ton wet organic waste (between 470 and 2.000 g/ton)
• N_2O	Average 110 g N_2O / ton wet organic waste (between 49 and 210 g/ton)
Anaerobic digestion	
• CH_4	Average 3.700 g CH_4 / ton wet organic waste (between 3.200 and 4.600 g/ton)
• N_2O	Average 120 g N_2O / ton wet organic waste (between 38 and 190 g/ton)

To the opinion of DHV both the data from the literature research and the measurement data resulting from the UBA 2008 study can be considered as more representative for the situation in the Netherlands than the values currently used in the Dutch NIR. They should be taken into account when considering new emission factors for the Dutch NIR.

3.1.5 Belgium

Belgium's NIR 2009 deals with the subject of biological treatment of solid waste in chapter 8.2.4. Only the emission of CH_4 is taken into account. No attention is paid to the emission of N_2O. Belgium has used the Dutch emission factor for CH_4 in its NIR. Belgium's NIR therefore doesn't give new insights in this matter. For a discussion regarding this emission factor see paragraph 3.1.3.

3.1.6 United Kingdom

Greenhouse gas emissions as a result of composting and anaerobic digestion of organic waste streams is not taken into account in the NIR 2009 of the United Kingdom.

3.1.7 Austria

Austria's NIR 2009 deals with the subject of biological treatment of solid waste in chapter 8.5. Austria distinguishes two different fractions of waste with regard to composting:

- Residual waste treated in mechanical-biological treatment plants
- Composting of biowaste (collected separately) and loppings

The emission factors for both types of waste are fairly similar. Because biowaste and loppings match the Dutch situation best, the corresponding emission factors are discussed further in this paragraph.

Austria's NIR only gives information regarding emission factors for composting of organic waste. There are no emission factors for anaerobic digestion available. The emission factors as used in Austria's NIR are shown in the table below.

Table 8 N_2O and CH_4 emission factors for composting and anaerobic digestion as used in Austria's NIR

Treatment option	Emission factors
Composting	
• CH_4	750 g CH_4 / ton wet organic waste
• N_2O	100 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	Not available
• N_2O	Not available

These emission factors are based on personal communications of Mr. Amlinger of the Austrian firm Compost Consulting & Development. Mr. Amlinger is an expert in the field of biological treatment of organic waste streams and has based his input for Austria's NIR on long term measurements in 2003 in full-scale composting facilities in Austria. These data have also been used in the UBA 2008 research as discussed in paragraph 3.1.4. To the opinion of DHV these measurement data can be considered as more representative for the situation in the Netherlands than the values currently used in the Dutch NIR. They should be taken into account when considering new emission factors for the Dutch NIR.

For this review Mr. Amlinger has been contacted and he has confirmed his previous findings. In 2008 Mr. Amlinger (together with Mr. Carsten Cuhls of Gewitra Ingenieurgesellschaft für Wissensstransfer mbH, one of the writers of the UBA 2008 report) has reported the results of various pilot windrow composting trials on full-scale in an article in Waste Management & Research: "Greenhouse gas emissions from composting and mechanical biological treatment". These results also confirm the emission factors used in Austria's NIR and are shown in the table below.

Table 9 N_2O and CH_4 emission factors for composting and anaerobic digestion as published by Mr. Amlinger in 2008

Treatment option	Emission factors
Composting	
• CH_4	Between 500 and 1.000 g CH_4 / ton wet organic waste
• N_2O	Between 20 and 180 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	Not available
• N_2O	Not available

3.1.8 Switzerland

In Switzerland's NIR 2009 a distinction is made between emission factors for composting and for anaerobic digestion. These emission factors are shown in the table below.

Table 10 N_2O and CH_4 emission factors for composting and anaerobic digestion in the NIR 2009 in Switzerland

Treatment option	Emission factors
Composting	
• CH_4	5.000 g CH_4 / ton wet organic waste
• N_2O	70 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	5.300 g CH_4 / ton wet organic waste
• N_2O	70 g N_2O / ton wet organic waste

These emission factors are partly based on research in the USA and partly on research in Switzerland. The research in the USA was performed in the period 1995 to 1997 and included emission measurements regarding windrow composting of green waste and co-composting of green waste with sewage sludge. The data from this research can not be considered representative for the current organic waste treatment in the Netherlands. The data are too old, the waste is not comparable and the applied treatment technologies do not correspond to the current Dutch situation.

The research in Switzerland was performed in 1999 and included emission measurements regarding composting and anaerobic digestion technologies comparable to those in the Netherlands. It is however not clear if the results have been based on a long measurement program or on single measurements over a short period of time. This makes the accuracy of these emission factors uncertain.

To the opinion of DHV the Swiss emission factors are not based on information that is accurate enough to be used as basis for the emission factors for the Dutch NIR.

3.1.9 Denmark

Greenhouse gas emissions as a result of composting and Anaerobic digestion of organic waste streams is not taken into account in Denmark's NIR 2009.

3.1.10 Japan

In Japan's NIR 2009 the emission factors of the 2006 IPCC guidelines are used. However, no emission factors for anaerobic digestion are included. These emission factors are shown in the table below.

Table 11 N_2O and CH_4 emission factors for composting and anaerobic digestion as used in Japan's NIR

Treatment option	Emission factors
Composting	
• CH_4	4.000 g CH_4 / ton wet organic waste
• N_2O	300 g N_2O / ton wet organic waste
Anaerobic digestion	
• CH_4	Not available
• N_2O	Not available

As discussed in paragraph 3.1.2 these emission factors are not considered as representative for the situation in the Netherlands and should therefore not be used as basis for the emission factors for the Dutch NIR.

3.2 Incineration of municipal solid waste

3.2.1 Summary of available emission factors

Table 12 Overview of N_2O and CH_4 emission factors for incineration of municipal solid waste

Source	Comments	Incineration	
		CH_4 [g/ton]	N_2O [g/ton]
IPCC documents			
• Revised 1996 IPCC guidelines	Based on generic values of 30 respectively 4 kg/TJ	309	41
	Measurement data (old)		11 - 293
• 2000 Good Practice guidance	CH_4 assumed negligible, N_2O measurement data (old)	0	3 - 80
• 2006 IPCC guidelines	CH_4 detailed observations from Japan, N_2O default value	0,2	50
	CH_4 only when output < input, N_2O recent measurements	0	8 - 47
The Netherlands			
• NIR 2009	CH_4 assumed negligible, N_2O based on data mid 90's	0	20 / 100[2]
• Data waste incinerators	Recent data from part of the waste incinerators in NL	3	20 / 31[2]
Germany			
• NIR 2009	Emission factors not traceable in German NIR	Not avail.	Not avail.
Belgium			
• NIR 2009	CH_4 assumed negligible, N_2O based on data 1990	0	60
United Kingdom			
• NIR 2009	Based on generic values of 30 respectively 4 kg/TJ	285	38
• Data waste incinerators	Data (2005) from three waste incinerators in the UK	Not avail.	6, 43, 53
Austria			
• NIR 2009	Based on generic values of 12 respectively 1,4 kg/TJ	124	14,5
Switzerland			
• NIR 2009	CH_4 assumed negligible, N_2O based on recent data	0	95
Denmark			
• NIR 2009	Based on recent data regarding waste incineration	6	12
Japan			
• NIR 2009	Based on data from 2000 for continuous incineration	8,4	59,8

The reliability of the values, mentioned in table 12 and the applicability as basis for new emission factors for the Dutch NIR depend on various aspects as discussed in paragraph 2.2. In the table below these aspects have been scored to give an impression of their applicability for the Dutch NIR.

[2] First value is for facilities not fitted with SNCR, second for facilities with SNCR as $deNO_x$ technology

Table 13 Overview of the reliability of the data used

Source	Old/ recent data	Modeling/ measurements	Lab. experiment /Full scale	Number of measurements	Representative for NL situation
IPCC documents					
• Revised 1996 IPCC guidelines	-	0	0	+	-
• 2000 Good Practice guidance	-	+	+	+	-
• 2006 IPCC guidelines	+	+	+	+	+
The Netherlands					
• NIR 2009	-	0	0	+	0
• Data waste incinerators	+	+	+	+	+
Germany					
• NIR 2009	n.a.	n.a.	n.a.	n.a.	n.a.
Belgium					
• NIR 2009	-	0	0	-	-
United Kingdom					
• NIR 2009	-	0	0	+	-
• Data waste incinerators	+	+	+	-	+
Austria					
• NIR 2009	-	?	?	?	-
Switzerland					
• NIR 2009	+	+	+	+	+
Denmark					
• NIR 2009	+	+	+	+	+
Japan					
• NIR 2009	0	+	+	+	+

3.2.2 IPCC documents

For the inventory of the N_2O and CH_4 emission factors for waste incineration three IPCC documents have been reviewed:

- Revised 1996 IPCC guidelines for National Greenhouse Gas Inventories
- 2000 Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
- 2006 IPCC guidelines for National Greenhouse Gas Inventories

Revised 1996 IPCC guidelines

In the Revised 1996 IPCC guidelines the subject of waste incineration is dealt with in chapter 6.1 and the subject of energy production in chapter 1. In these guidelines it is stated that for CH_4 and N_2O emissions as a result only preliminary estimates and research results can be reported at that time. In these guidelines the tier 1 method is used for the calculations of the emissions as a result of waste incineration taking into account emission factors for energy production. The following very general emission factors are given:

- 30 kg CH_4/TJ of energy produced
- 4 kg N_2O /TJ of energy produced

These emission factors are based on the incineration of biomass and all kinds of wastes, including dung and agricultural, municipal and industrial wastes. They are not specifically applicable for the incineration of municipal solid waste. If a net calorific value (NCV) of 10,3 MJ/kg[3] is taken into account for the incineration of municipal solid waste, this results in emission factors of:

- 309 g CH_4/ton of wet waste
- 41 g N_2O /ton of wet waste

Chapter 6 of the guidelines gives measurement data between 11 and 293 g N_2O /ton of wet waste depending on incineration temperature, technology used and type of waste handled. No measurement data were given for the emission of CH_4.

All these values are based on measurements during the early 90's taking into account all types of incineration technologies and materials. Therefore the data are old and not specifically applicable to municipal waste incineration.

2000 Good Practice Guidance

In the 2000 Good Practice Guidance the methodological issues of the calculations of emission as a result of waste incineration are dealt with in paragraph 5.3.1. The Good Practice Guidance states that the emissions of CH_4 are not likely to be significant because of the combustion conditions in incinerators (e.g. high temperatures and long residence times). The emissions can therefore be neglected. This differs from the information described in the 1996 IPCC guidelines.

For N_2O it is stated that, where practical, N_2O emission factors should be derived from emission measurements. Continuous emission monitoring is technically feasible, but not necessary for good practice. Periodic measurements should be conducted sufficiently often to account for the variability of N_2O generation (i.e. due to variable waste composition), and different types of incinerator operating conditions (e.g. combustion temperature). The emission factors for N_2O differ with facility type and type of waste. Emission factors for fluidized-bed facilities are higher than for facilities with grate firing systems. Emission factors for the incineration of municipal solid waste are lower than for the incineration of sewage sludge.

---

[3] Based on the Dutch list of energy sources (fuels) and standard CO_2 emission factors, version December 2009 (Nederlandse lijst van energiedragers en standaard CO2-emissiefactoren, versie december 2009)

Ranges of N_2O emission factors reflect the applied abatement techniques[4], temperature, and the residence time of the waste in the incinerator.

If site-specific N_2O emission factors are not available, default factors can be used. In the 2000 Good Practice Guidance data from 1993 and 1999 are mentioned with values between 5,5 and 150 g N_2O /ton dry waste. For wet waste this will be approximately 3 to 80 g N_2O /ton.

2006 IPCC guidelines

The 2006 IPCC guidelines deal with the subject of waste incineration both in volume 2, energy, and in volume 5, waste. In volume 2 the N_2O and CH_4 are based on the revised 1996 IPCC guidelines. This results in the following emission factors:

- 309 g CH_4/ton of wet waste
- 41 g N_2O /ton of wet waste

In the guidelines it is however stated that these emission factors should only be used if no specific facility data are available.

In volume 5, waste, it is indicated, that it is good practice to use the Tier 3 method when plant-specific data are available. All incinerators in a country should be considered and their measured emissions summed. If the exact emissions are not measured continuously country specific emission factors can be applied based on measurements at the incineration facilities of a certain country.

The guidelines state that CH_4 emissions from waste incineration strongly depend on the continuity of the incineration process, the incineration technology and management practices. The most detailed observations have been made in Japan (GIO, 2004), where different CH_4 emission factors based on various technology and operation modes were obtained. For continuous incineration and emission factor of 0,2 g CH_4 /ton wet waste has been mentioned. Furthermore, for the emission of CH_4 the guidelines state that, if detailed monitoring shows that the concentration of a greenhouse gas in the discharge from a combustion process is equal to or less than the concentration of the same gas in the ambient intake air to the combustion process, then emissions may be reported as zero. This is not exactly the same as the statement in the 2000 Good Practice Guidance: *"CH_4 emissions are not likely to be significant and can therefore be neglected"*. Measurements have to show, that the CH_4 concentrations in the air intake are higher than in the air outlet, to make it possible to neglect this emission.

For N_2O the guidelines state that emissions from waste incineration are determined by a function of the type of technology and combustion conditions, the technology applied for NO_x reduction as well as the contents of the waste stream. As a result, emission factors can vary from site to site. Several countries have reported N_2O emissions from waste incineration in their national inventory reports. The differences in the emission factors are mainly caused by varying technologies in the context of NO_x removal. The applied emission factors (based on data from 2003 to 2005) vary between 8 and 47 g N_2O /ton of wet waste. If no country specific information is available it is good practice to use 50 g/ton waste (wet weight) as default.

Overview and conclusions regarding the emission factors in the various IPCC documents

The N_2O and CH_4 emission factors, given for waste incineration in the various IPCC documents, are shown in the table below. The values mentioned in the revised 1996 guidelines and in the 2000 Good practice Guidance are very generic, based on old data and not representative for municipal solid waste. The 2006 guidelines give values based on recent measurement data and currently being used in other

[4] The injection of ammonia or urea as used in some NO_x abatement technologies may increase N_2O emissions

European countries in their NIRs. These guidelines also give a good insight in the order of preference when using emission factors for waste incineration:

- First analyze if plant-specific data are available for all incinerators in a country (concentrations and air flows or another method of calculation) and sum up all their separately measured emissions (Tier 3 method).
- If the exact emissions are not measured continuously country specific emission factors can be applied based on periodic measurements at the incineration facilities of that certain country. Regular checking of these emission factors is then required. Also emission factors from other countries with comparable incineration facilities can be used (Tier 2 method).
- If no information is available at all with regard to concentrations and or amounts of waste incinerated the emission factors in the revised 1996 guidelines (in kg/TJ) can be used as last resort. The total emission will then however be overestimated for CH_4 (Tier 1 method).

Table 14 N_2O and CH_4 emission factors for incineration of municipal solid waste IPCC documents

	Emission factors
Revised 1996 IPCC Guidelines • CH_4 • N_2O	 309 g CH_4 / ton wet waste (based on 30 kg CH_4/TJ of energy produced) 41 g N_2O / ton wet waste (based on 4 kg N_2O/TJ of energy produced), 11 to 293 g N_2O /ton wet waste (measurement data)
2000 Good Practice Guidance • CH_4 • N_2O	 Assumed negligible 3 to 80 g N_2O /ton wet waste (measurement data)
2006 IPCC Guidelines • CH_4 • N_2O	 0,2 g CH_4 / ton wet waste (detailed observations from Japan), 0 g CH_4 / ton wet waste when emission output are lower than emissions input 50 g N_2O / ton wet waste (default value), 8 to 47 g N_2O / ton wet waste (recent measurements various countries)

For this review Mrs. Marta Olejnik of CEWEP (Confederation of European Waste-to-Energy Plants) has been contacted to check on CEWEP's opinion regarding these emission factors. CEWEP only stated that they accept the IPCC default emission factors as reliable.

To the opinion of DHV only the emission factors mentioned in the 2006 IPCC guidelines should be taken into account when deciding on new emission factors for future NIRs in the Netherlands[5]. The very generic emission factors based on the kg/TJ data (revised 1996 IPCC guidelines) can not be considered representative for the Dutch situation.

[5] The default values mentioned in the 2006 IPCC guidelines do not apply to this budget period yet, but apply to the next budget period after 2012.

3.2.3 The Netherlands

In the Netherlands the methodological issues with regard to the calculations of the N_2O and CH_4 emissions for the purpose of the NIR are described in the NIR 2009 Memo item on CO2 emissions from biomass (translation of the VROM Monitoring Protocol 9088, April 2009). For CH_4 the default emission factors of the revised 1996 IPCC guidelines have been used in this protocol (see paragraph 3.1.2). In the NIR itself however the CH_4 emission is considered negligible in conformity with the 2000 Good Practice Guidance. For the N_2O emission a differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology[6]. These emission factors are based on measurement data from 1993 and 1995. Over the past few years the number of plants fitted with SNCR has risen steadily. The Netherlands is the only country, which uses different values for the different $deNO_x$ technologies. The different emission factors are shown in the table below.

Table 15 N_2O and CH_4 emission factors for incineration of municipal solid waste in the NIR (protocol) in the Netherlands

	Emission factors
NIR	
• CH_4	Assumed negligible
• N_2O	20 g N_2O / ton wet waste for plant s not fitted with SNCR, 100 g N_2O / ton for plant s fitted with SNCR
NIR protocol	
• CH_4	309 g CH_4 / ton wet waste (based on revised 1996 IPCC guidelines)
• N_2O	20 g N_2O / ton wet waste for plant s not fitted with SNCR, 100 g N_2O / ton for plants fitted with SNCR

To the opinion of DHV the emission factors used in the NIR only give an indication of the order of magnitude of the emission of N_2O and CH_4 as a result of this activity. The CH_4 emission factor is based on an assumption and the N_2O emission factor on data from the mid 90's. The CH_4 emission factor in the NIR protocol is based on the revised 1996 IPCC guidelines and should not be considered as representative for the situation in the Netherlands. Under assignment of the NL Agency the Dutch organization TNO has analyzed the annual environmental reports of the Dutch waste incinerators with regard to the emission data (2005, 2006, 2007 and 2008) of CH_4 and N_2O (Data checked with Mrs. R. Dröge of TNO). The results of this analysis have been evaluated by the NL Agency and have been used for this review. Not all data in the annual environmental reports is useful. For 2005 one plant has useful data, for 2006 non, for 2007 two plants and for 2008 five plants of which two have SCNR. In total three plants have SNCR in the Netherlands.

On basis of these data emission factors can be calculated for both incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology. These emission factors based on this study are shown in the table below.

[6] SNCR (Selective non-catalytic reduction) is a technology for the removal of NO_x from flue gasses. A reagent (ammonia or urea) is injected in the flue gas, which reacts with NO_x to form nitrogen and water. The optimal injection temperature is between 930 and 980 °C. Removal efficiency lays between 40 and 80 %. A negative by-effect of the reaction can be the formation of N_2O.

The average of the N_2O emission factor has been increasing over the last years partly because of the increasing use of SNCR. The number of incineration plants (in total 12 in the Netherlands) reporting useful data in their annual environmental reports is also increasing.

Table 16 N_2O and CH_4 emission factors based on information in the annual environmental reports of waste incinerators in the Netherlands

	Emission factors
• CH_4 • N_2O	3 g CH_4 / ton wet waste 20 g N_2O / ton wet waste for plant s not fitted with SNCR, 31 g N_2O / ton for plants fitted with SNCR

To the opinion of DHV these data (both for N_2O and for CH_4) can be considered as more representative for the situation in the Netherlands than the values currently used in the Dutch NIR. They form a good basis for the emission factors to be used in future NIRs in the Netherlands. One should aim at getting a complete picture of the emissions of all the Dutch waste incinerators.

With regard to the CH_4 emission there is a possibility that the concentrations CH_4 in the discharge from the incineration process is equal to or less than the concentration in the ambient intake air to the incineration process (see rough calculation in text box below). In that case the CH_4 emission factor could be considered zero as described in the 2006 IPCC guidelines (see paragraph 3.2.2). More detailed calculations are required to decide if the CH_4 emission of waste incineration can be neglected in the NIR.

Rough calculations of the CH_4 concentration in discharge air of an incineration facility in comparison to background concentrations

The background CH_4 concentration is approximately **1,4** mg CH_4 / Nm^3 intake air.

Average emission of waste incinerators is 3 g CH_4 / ton waste incinerated.
Volume of flue gas is approximately 4.000 Nm^3 / ton waste incinerated (average of various data sources).
Thus average concentration of CH_4 in flue gas is 3 / 4.000 = **0,75** mg / Nm^3 discharge air.

Result:
This rough calculation results in a lower CH_4 calculation in the discharge air than in the intake air.

3.2.4 Germany

It has not been possible to trace the emission factors for N_2O and CH_4 used in Germany's NIR. These emission factors may have been described in background documents belonging to the NIR, but have not been available for review in this project. Therefore the German situation has not been taken into account in this review

3.2.5 Belgium

In Belgium the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described in chapter 8.2.3 of the NIR. For CH_4 the emission is considered negligible in conformity with the 2000 Good Practice Guidance (see paragraph 3.2.2). For the N_2O emission an emission factor of 60 g N_2O / ton fresh waste is used. This emission factor is based on emission data, described in a CITEPA (Centre Interprofessionnel Technique d'Etude de la pollution Atmosphérique) document published in 1990. This emission factor was based on an emitted concentration of 10 mg/Nm^3 and the assumption that 6.000 Nm^3 is required for the incineration of 1 ton of municipal solid waste (Information received from Mrs. M. D'heer of the Flemish Environmental Agency). In Belgium's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as deNO$_x$ technology. The different emission factors used in Belgium's NIR are shown in the table below.

Table 17 N_2O and CH_4 emission factors for incineration of municipal solid waste in Belgium's NIR

	Emission factors
• CH_4	Assumed negligible
• N_2O	60 g N_2O / ton fresh waste

The emission factors used in Belgium's NIR are in conformity with those used in the Netherlands. However they are based on old data and give no new insights in the topic. To the opinion of DHV these emission factors should not be used as basis for new emission factors for the Dutch NIR.

3.2.6 United Kingdom

In the UK the emission factors are based on the emission factors, described in the revised 1996 IPCC guidelines (see paragraph 3.1.2), and a net calorific value (NCV) of the waste of 9,5 MJ/kg. In the UK's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as deNO$_x$ technology. The resulting emission factors used in the UK's NIR are shown in the table below.

Table 18 N_2O and CH_4 emission factors for incineration of municipal solid waste in UK's NIR

	Emission factors
• CH_4	285 g N_2O / ton fresh waste
• N_2O	38 g N_2O / ton fresh waste

As discussed in paragraph 3.2.2 these emission factors should be considered as very generic and are based on old data. They can not be considered representative for the Dutch situation. To the opinion of DHV these emission factors should not be used as basis for new emission factors for the Dutch NIR.

Some recent (2005) measurement data from three waste incinerators in the UK (information supplied by Mrs. J. Bates of AEA consultancy) show similar values for the N_2O emission factor as used in UK's NIR. On basis of the load of N_2O emitted by the three incineration plants and the amount of waste incinerated the following emission factors were calculated: 6, 43 and 53 g N_20 / ton fresh waste. These values are in conformity with the values measured in the Netherlands (see paragraph 3.2.3) and based on recent data.

To the opinion of DHV these emission factors should therefore be taken into account when considering new emission factors for the Dutch NIR.

3.2.7 Austria

In Austria the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described in chapter 3.2.2 of the NIR. The following very general emission factors are given:

- 12 kg CH_4/TJ of energy produced
- 1,4 kg N_2O /TJ of energy produced

These emission factors are approximately 1/3 of the emission factors, described in the revised 1996 IPCC guidelines, and are based on the incineration of various types of biomass and all kinds of wastes (data from the mid 90's and 2001). They are not specifically applicable for the incineration of municipal solid waste. If a net calorific value (NCV) of 10,3 MJ/kg is taken into account for the incineration of municipal solid waste the emission factors in gr/ton wet waste can be calculated. In Austria's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology. The different emission factors calculated on basis of Austria's NIR are shown in the table below.

Table 19 N_2O and CH_4 emission factors for incineration of municipal solid waste in Austria's NIR

	Emission factors
• CH_4	124 g CH_4 / ton fresh waste
• N_2O	14,5 g N_2O / ton fresh waste

These emission factors are based on very generic data and are not specifically representative for the incineration of municipal solid waste. The values calculated are based on old data. They can not be considered representative for the Dutch situation. To the opinion of DHV these emission factors should not be used as basis for new emission factors for the Dutch NIR.

3.2.8 Switzerland

In Switzerland the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described in chapter 3.2.2 of the NIR. For CH_4 the emission is considered negligible because of the high combustion temperatures in waste incineration plants. The share of organic matter in the municipal solid waste is estimated to be approximately 60%. The burn-out efficiency in modern municipal waste incineration plants is considered very high. This assumption is in conformity with the 2000 Good Practice Guidance (see paragraph 3.2.2). For the N_2O emission an emission factor is used of 95 g N_2O / ton fresh waste. This emission factor is country specific and based on measurements and expert estimates, documented in the EMIS database EMIS[7] 2009/1A1a). It has not been possible to retrieve the year of origin and background of these data for this review. In Switzerland's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology. The different emission factors used in Switzerland's NIR are shown in the table below.

[7] EMIS = Swiss national air pollution database

Table 20 N_2O and CH_4 emission factors for incineration of municipal solid waste in Switzerland's NIR

	Emission factors
• CH_4 • N_2O	Assumed negligible 95 g N_2O / ton fresh waste

The emission factor for N_2O from municipal waste incineration has increased significantly from 60 g N_2O per ton of waste in 1990 to 95 g/ton in 2007. This is due to the increased use of $DeNO_x$-equipment in the incineration plants. It is expected by Swiss experts that the emission factor will decrease to 14 g/ton by the year 2020 as a result of improvements in the technology.

The emission factors used in Switzerland's NIR are in conformity with those used in the Netherlands. To the opinion of DHV these emission factors give no reason to adjust the emission factors currently being used in the Dutch NIR.

3.2.9 Denmark

In Denmark the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described in chapter 5.6 of the NIR. The N_2O and CH_4 emission factors are based on the research results of a project reported by Nielsen and Illerup in 2003. In this research project existing emission measurements as well as emission measurements, carried out as part of the project, were taken into account. The number of emission data sets analyzed was comprehensive. The emission factors were based on emission measurements in 16 waste incineration plants. The following emission factors resulted from this research:

- 0,59 kg CH_4/TJ of energy produced (the emission factor was actually estimated to be < 0,59 kg/TJ and was used as maximum for the emission factor)
- 1,2 kg N_2O /TJ of energy produced

If a net calorific value (NCV) of 10,3 MJ/kg is taken into account for the incineration of municipal solid waste, the emission factors in gr/ton wet waste can be calculated. In Denmark's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology. The different emission factors calculated on basis of Denmark's NIR are shown in the table below.

Table 21 N_2O and CH_4 emission factors for incineration of municipal solid waste in Denmark's NIR

	Emission factors
• CH_4 • N_2O	6 g CH_4 / ton fresh waste 12 g N_2O / ton fresh waste

The emission factors used in Denmark's NIR are based on recent measurement data and are representative for the incineration of municipal solid waste. To the opinion of DHV these emission factors should be taken into account when considering new emission factors for the Dutch NIR. It is however not clear which percentage of Denmark's waste incinerators is fitted with Selective Non-catalytic Reduction (SNCR) as $deNO_x$ technology. This also has to be taken into account when considering new emission factors.

3.2.10 Japan

In Japan the methodological issues with regard to the calculations of the N_2O and CH_4 emissions are described in chapter 8.4 of the NIR. The N_2O and CH_4 emission factors are based on the results of a measurement survey in 2000. Measurements were performed in different types of incinerators and the emission factors were also differentiated for these different types of incinerators. In Japan's NIR no differentiation is made between waste incineration plants fitted with or without Selective Non-catalytic Reduction (SNCR) as deNO$_x$ technology. The mission factors in Japan's NIR used for continuous incineration are shown in the table below.

Table 22 N_2O and CH_4 emission factors for continuous incineration of municipal solid waste in Japan's NIR

	Emission factors
• CH_4 • N_2O	8,4 g CH_4 / ton fresh waste 59,8 g N_2O / ton fresh waste

The emission factors used in Japan's NIR are based on the results of a measurement survey in 2000 and are representative for the incineration of municipal solid waste. To the opinion of DHV these emission factors should be taken into account when considering new emission factors for the Dutch NIR. It is however not clear which percentage of Japan's waste incinerators is fitted with Selective Non-catalytic Reduction (SNCR) as deNO$_x$ technology. This also has to be taken into account when considering new emission factors.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Composting and anaerobic digestion

Review of the available emission factors

With regard to emission factors for composting of organic waste only a limited amount of useful information is available in the reviewed NIRs, IPCC documents and additionally received information (research reports, articles and personal communications). Most emission factors are based on old data or data based on theoretical analysis and calculations.

To the opinion of DHV only the following data sources should be taken into account when considering new emission factors for N_2O and CH_4 for future NIRs in the Netherlands:

- The Tauw 2007 research report
- The UBA 2008 research report
- Austria's 2009 NIR
- The Amlinger 2008 research article

For anaerobic digestion of organic waste the amount of useful available information is even more limited. Most of the time anaerobic digestion is not taken into account in NIRs of the various countries. The only reviewed NIR with information on anaerobic digestion was Switzerland's NIR. The Swiss emission factors were however not considered more reliable than those of the Netherlands. To the opinion of DHV only the Tauw 2007 and UBA 2008 research reports should be taken into account when considering new emission factors for future NIRs in the Netherlands.

Proposal for emission factors for N_2O and CH_4 in future NIR's

In the table below an overview is given of the values, which should be taken into account when considering new emission factors for N2O and CH_4 for composting and anaerobic digestion in future NIRs in the Netherlands.

Table 23 Overview of values relevant for a proposal for future N_2O and CH_4 emission factors

Source	Comments	Composting		Anaerobic digestion	
		CH_4 [g/ton]	N_2O [g/ton]	CH_4 [g/ton]	N_2O [g/ton]
The Netherlands					
• NIR 2009	Based on a small amount of measurements	2.400	96	1.100	46
• Tauw 2007	Technologies representative for the NL	80 – 300	40 – 100	500	< 20
• UBA 2008	Technologies representative for the NL	710	68	3.700	120
• Austria's NIR2009	Technologies representative for the NL	750	100	Not avail.	Not avail.
• Amlinger 2008	Technologies partly representative for the NL	500-1.000	20 - 180	Not avail.	Not avail.

The CH_4 emission factor for composting, currently being used in the Dutch NIR, is clearly too high. For composting a new CH_4 emission factor is proposed of **750 g CH_4/ton** of fresh organic waste (between 500 and 1.000 g CH_4/ton). This corresponds to a decrease with approximately 65 % of the current value. The current emission factor was based on a small amount of measurements over a short period of time. The newly proposed value is backed up by most of the data considered relevant. Only the Tauw 2007 research shows lower values. These lower values are however already taken into account in the UBA 2008 research. At this moment the results of the UBA 2008 research report are considered leading in this discussion. This report however only describes the results of the first part of a larger research project. When the final report is available the necessity of revision of thish emission factor should again be evaluated.

For the new N_2O emission factor a value is proposed between **70 and 100 g N_2O/ton** of fresh organic waste. This corresponds to the current emission factor, but is based on more reliable data. This means that the current emission factor of **96 g N_2O/ton** can be maintained. This value is backed up by all of the data considered relevant.

For anaerobic digestion the situation is more difficult. Only two relevant data sources are available with totally different research results. The UBA 2008 research report shows emission factors of approximately **3.700 g CH_4/ton** and **120 g N_2O/ton** of fresh organic waste. These values are based on the information of several German anaerobic digestion facilities and are approximately 3 times higher than the current values used in the Dutch NIR. The data of the Tauw 2007 research are based on information from a Dutch treatment facility. Based on this research the emission factors would be **500 g CH_4/ton** and **< 20 g N_2O/ton** of fresh organic waste. This is significantly lower (approximately 50 %) than the current values used in the Dutch NIR. The results of the Tauw 2007 research however show almost no CH_4 emission in the post composting unit of the facility. This is remarkable, because a significant emission would be expected there. This might be caused by the fact that this specific facility uses a wet scrubber as gas treatment unit and thus limiting the CH_4 emission further than with a biofilter. This is not representative for all anaerobic digestion facilities in the Netherlands. Other facilities are equipped with biofilters and will probably therefore have higher emissions. Because both these relevant data sources show contradictory values it is not advisable to change the current emission factors on basis of these results. It is therefore proposed to maintain the current emission factors of **1.100 g CH_4/ton** and **46 g N_2O/ton** anaerobic digestion facilities for the time being**.**

Many composting facilities in the Netherlands will (partly) transform to anaerobic digestion facilities in the near future. It is recommended to follow these developments to get more and more accurate information on the emission factors for anaerobic digestion. It is also recommended to closely follow the developments in Germany. The UBA 2008 research report formed the first part of a larger research project. In the second part of that project more measurements will take place (for instance in various anaerobic digestion facilities). It will be interesting to see if these additional results give a different point of view on the situation and if this will be a reason for the German government to revise the emission factors in Germany's future NIRs. If new information is available from one of both data sources the necessity of revision of the Dutch emission factors for anaerobic digestion should again be evaluated.

The emission factors mentioned in this paragraph are proposed specifically for use in the Dutch NIR. Individual facilities may have emission factors, which differ from the average emission factors proposed. For other purposes then the NIR these individual facilities may use other emission factors if they can support them on basis of research results specifically aimed at their facility.

4.2 Incineration of municipal solid waste

Review of the available emission factors

With regard to emission factors for the incineration of municipal solid waste various reviewed NIRs en some measurement results obtained and analyzed for this review give information relevant for the Dutch situation. To the opinion of DHV the following data sources should be taken into account when considering new emission factors for N_2O and CH_4 for future NIRs in the Netherlands:

- The emission data (2005, 2006, 2007, 2008) described in annual environmental reports of the Dutch waste incinerators
- The recent (2005) measurement data from three waste incinerators in the UK
- Switserland's 2009 NIR
- Denmark's 2009 NIR
- Japan's 2009 NIR

The revised 1999 IPCC guidelines and the 2000 Good Practice guidance of the IPCC don't give information that is of great use when deciding on new emission factors for future Dutch NIRs. The information in these documents is very generic and often not specifically aimed at waste incineration. The emission factors and data mentioned in these documents are often based on old research. However, the 2006 IPCC guidelines propose emission factors based on recent measurement data or currently being used in other European countries in their NIRs. These guidelines also give a good insight in the order of preference when using emission factors for waste incineration:

1. First one should analyze if plant-specific data are available for all incinerators in a country (concentrations and air flows or an other method of calculation) and sum up all the separate emissions.
2. If the exact emissions are not measured continuously country specific emission factors can be applied based on periodic measurements at the incineration facilities of that certain country. Regular checking of these emission factors is then required. Also emission factors from other countries with comparable incineration facilities can be used.
3. If no information is available at all with regard to concentrations and/or amounts of waste incinerated the emission factors in the revised 1996 guidelines (in kg/TJ) can be used as last resort. The total emission will then however be overestimated for CH_4.

The first option has been tried in the Netherlands and in other countries but most of the time only limited information is received from the waste incinerators, resulting in an incomplete data set. The third option results in an extreme overestimate of the CH_4 emission. The second option should therefore preferably be used when determining new emission factors for the Dutch NIR.

Proposal for emission factors for N_2O and CH_4 in future NIR's

In the table below an overview is given of the values, which should be taken into account when considering new emission factors for N_2O and CH_4 for the incineration of municipal solid waste in future NIRs in the Netherlands.

Table 24 Overview of values relevant for a proposal for future N_2O and CH_4 emission factors

Source	Comments	Incineration	
		CH_4 [g/ton]	N_2O [g/ton]
The Netherlands			
• NIR 2009	CH_4 assumed negligible, N_2O based on data mid 90's	0	20 / 100[8]
• 2006 IPCC guidelines	CH_4 detailed observations from Japan, N_2O default value	0,2	50
	CH_4 only when output < input, N_2O recent measurements	0	8 - 47
• NL Data waste incinerators	Recent data from part of the waste incinerators in NL	3	20 / 31[8]
• UK Data waste incinerators	Data (2005) from three waste incinerators in the UK	Not avail.	6, 43, 53
• Switzerland's NIR 2009	CH_4 assumed negligible, N_2O based on recent data	0	95
• Denmark's NIR 2009	Based on recent data and waste incineration	6	12
• Japan's NIR 2009	Based on data from 2000 for continuous incineration	8,4	59,8

The relevant data available are within certain limits comparable to the current emission factors used for both N_2O and CH_4 regarding the emission from municipal waste incineration in the Netherlands.

For the CH_4 emission factor all values are within the rang of 0 to 8,4 g CH_4/ton of fresh waste. The emission factor of **3 g CH_4 / ton** of waste resulting from the annual environmental reports of the waste incinerators in the Netherlands seem to be the most fitting for the Dutch situation and could be used for future NIRs. It is than however required that a complete picture of all waste incinerators is obtained. It is recommended that these annual environmental reports are scanned regularly for changes in the emission factors. Currently 0 g / ton is being used as emission factor in the Netherlands. In conformity with the 2006 IPCC guidelines this is only allowed if the concentrations of CH_4 in the discharge air of a waste incinerator are lower than the concentrations in the intake air[9]. A first rough calculation shows that this might be the case in the Netherlands. It is proposed that some more accurate calculations are performed with the actual air flows used in the waste incinerators to confirm it is possible to neglect the CH_4 emission from waste incinerators in the NIR and use an emission factor of **0 g CH_4 / ton** of waste.

For the N_2O emission factor it is difficult to make a thorough comparison between the various values. The Netherlands is the only country which has separate emission factors for incineration plants fitted or not fitted with SNCR as $deNO_x$ technology. All values considered relevant are in the same order of magnitude and vary between 6 and 100 g N_2O/ton of fresh waste. Again the emission factors of **20 g N_2O / ton** of waste for incineration plants not fitted with SNCR and **31 g N_2O / ton** of waste for incineration plants fitted with SNCR resulting from the annual environmental reports of the waste incinerators in the Netherlands seem to be the most fitting for the Dutch situation and could be used for future NIRs. However, until now only a limited number of waste incinerators have supplied the required data. In future years it is important that this number increases to get a better coverage of the incineration sector in the Netherlands. It is proposed that, until a larger percentage of the waste incinerators is actually supplying the required data, the current emission factors of **20 (no SNCR) and 100 (SNCR) g N_2O/ton** of fresh waste are maintained.

---

[8] First value is for facilities not fitted with SNCR, second for facilities with SNCR as $deNO_x$ technology

[9] The default values mentioned in the 2006 IPCC guidelines do not apply to this budget period yet, but apply to the next budget period after 2012.

The emission factors mentioned in this paragraph are proposed specifically for use in the Dutch NIR. Individual facilities may have emission factors, which differ from the average emission factors proposed. For other purposes then the NIR these individual facilities may use other emission factors if they can support them on basis of research results specifically aimed at their facility.

5 COLOPHON

Client	:	NL Agency
Project	:	Update of emission factors for N_2O and CH_4 for composting, anaerobic digestion and waste incineration
File	:	BA4763
Length of report	:	33 pages
Author	:	Mark de Groot
Contributions	:	
Internal check	:	Wim van Lierop
Project Manager	:	Mark de Groot
Project Director	:	Hanneke van de Ven
Date	:	15 February 2012
Name/Initials	:	MdG

DHV B.V.
Ruimte en Mobiliteit
Laan 1914 no. 35
3818 EX Amersfoort
P.O. Box 1132
3800 BC Amersfoort
The Netherlands
T +31 33 4682000
F +31 33 4682801
E info@dhv.com
www.dhv.com