Finland is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. As a member of the European Union, Finland has reporting obligations also under the mechanism for monitoring European Community greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism, Decision 280/2004/EC of the European Parliament and the Council). According to the EU monitoring mechanism Member States have an obligation to prepare every two years a report including information on national policies and measures for the assessment of projected progress.

In this report the policy scenarios and greenhouse gas emission calculations of waste sector and F-gases are described. In the first part, the calculation procedure, main data sources and assumptions in waste sector are explained in detail. We also discuss briefly the economical assessment of waste sector that has been identified as a target for further development. In the second part, the data collection, calculation parameters and policy projection calculations of F-gases are explained briefly. More detailed description of methods and is available in reports of Finnish Environment Institute.
Calculations of greenhouse gas emissions of waste sector and F-gases for policy scenarios in Finland

Maija Mattinen, Mikael Hildén and Jouko Petäjä
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LIST OF ABBREVIATIONS

CH$_4$ Methane
CO$_2$ Carbon dioxide
CO$_2$e Carbon dioxide equivalent
BL Baseline
BOD Biological oxygen demand
CDW Construction and demolition waste
COD Chemical oxygen demand
DOC Degradable organic carbon
DOC$_f$ Fraction of degradable organic carbon decomposed
DOC$_m$ Degradable organic matter
EF Emission factor
FOD First order decay
FTA Fraction of BOD in sludge that degrades anaerobically
HFC Hydrofluorocarbons
I$_{sludge}$ Industrial sludge
IPCC Intergovernmental Panel of Climate Change
ISW Industrial solid waste
M$_{sludge}$ Municipal sludge
MCF Methane correction factor
MSW Municipal solid waste
MSW$_F$ Fraction of MSWT sent to SWDS
MSW$_T$ Total municipal solid waste
OX Oxidation factor
PAM Policies and measures
PFC Perfluorocarbons
RAC Refrigeration and air-conditioning
SBF Fraction of BOD that readily settles
SWDS Solid waste disposal site
SYKE Finnish Environment Institute
WAM With additional measures
WEM With existing measures
LIST OF NOTATIONS

A  Constant in a sum
a  Constant in methane recovery rate
b  Constant in methane recovery rate
BOD(t)  Biological oxygen demand in year t
BODS\textsubscript{coming}(t)  5-day biological oxygen demand (coming) in year t

c\textsubscript{m\textsubscript{mun}}  Methane emission factor constant for municipal

c\textsubscript{N\textsubscript{mun}}  Nitrous oxide emission factor constant for municipal

c\textsubscript{m\textsubscript{ind}}  Methane emission factor constant for industry
x  Years of which input is required
E\textsubscript{e}  Emitted methane
E\textsubscript{g}  Generated methane
E\textsubscript{r}  Recovered methane

E\textsubscript{m\textsubscript{st}}(t)  Methane emissions of septic tanks in year t
E\textsubscript{N\textsubscript{st}}(t)  Nitrogen emissions of septic tanks in year t

E\textsubscript{m\textsubscript{mun}}(t)  Methane emissions of municipalities in year t
E\textsubscript{N\textsubscript{mun}}(t)  Nitrogen emissions of municipalities in year t

E\textsubscript{m\textsubscript{ind}}(t)  Methane emissions of industry in year t
E\textsubscript{N\textsubscript{ind}}(t)  Nitrogen emissions of industry in year t

E\textsubscript{m\textsubscript{ff}}(t)  Nitrogen emissions of fish farming in year t

F  Fraction by volume of methane in landfill gas
k\textsubscript{i}  Generation rate of i’th type of decay
L\textsubscript{d}(t)  Methane generation potential in year t
MCF\textsubscript{1}(t)  Methane correction factor 1 in t
N\textsubscript{tot,pop}(t)  The total nitrogen burden of population
pop(t)  Population (number of habitants) in year t
pop\textsubscript{Aland}  Constant coefficient that takes into account Aland in population

\( t \)  Year of inventory
\( t_{\frac{1}{2}} \)  Half-life of a waste type
V  Variable type
\( \Delta E_{g} \)  Difference in generated methane
1 Introduction

Finland is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. As a member of the European Union, Finland has reporting obligations also under the mechanism for monitoring European Community greenhouse gas emissions and for implementing the Kyoto Protocol. Emission calculations of waste sector and fluorinated gases (F-gases) are performed at the Finnish Environment Institute.

CH₄-emissions from landfills are the most important greenhouse gas emissions in the waste sector. It is also relatively easy to reduce these emissions significantly, as demonstrated by a 45% reduction in emissions from the waste sector between 1990 and 2010 in the Finnish greenhouse gas emission inventory.¹ In 2007 projections for the waste sector were made both with existing measures (WEM) and with additional measures (WAM) for the national climate strategy. The calculations for the projections follow the IPCC guidance (2000) with a projected time-frame from 2008 to 2050.² (Fig 1).

![Figure 1](image-url)  
**Figure 1.** Projected emissions of waste sector with measures and with additional measures (WEM and WAM projections, respectively). Based on data provided by Jouko Petäjä.

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² The calculations were performed using excel spreadsheets at SYKE by Senior Scientist Jouko Petäjä.
At present, Finland’s national greenhouse gas inventory follows a recent IPCC guidance, see IPCC (2006). The national inventory is documented by Statistics Finland (2009). In future, policy projections of waste sector will be done according to this newer guidance.

The purpose of this report is to present the materials and methods used for evaluating the climate impact of policies and measures (PAMs) in the waste sector in Finland. The purpose is also to provide a basic reference for the reporting of policies and measures in the waste sector and for F-gases. The report therefore describes in detail the WAM and WEM calculations for the waste sector projection. The report is structured as follows. Part I considers the waste sector. Chapter 2 gives an overview of the approach and essential concepts related to calculations. In Chapter 3 we describe calculations in detail. The emissions calculation of waste water is discussed in Chapter 4. Calculations related to methane and nitrous oxide emissions of composting are covered in Chapter 5. Chapter 6 deals with projections of waste management and its impacts. Second part of the report deals with fluorinated greenhouse gases (F-gases). Chapter 7 is devoted to describing the activity data of emission inventories and its processing methods. In Chapter 8 we discuss the F-gas emission projections and the corresponding subsector projections. Finally, the report is summarized and concluded in Chapter 9.
PART I: Waste
2 Materials and Methods

2.1 Overview of Approach

The calculations are mostly based on the guidelines provided by the Intergovernmental Panel on Climate Change (2000, 2006). The calculations have been set up in Excel spreadsheets.

The essential data, calculations and assumptions are collated in separate interconnected Excel files, see Fig. 2. Projections “with measures” and the analysis of policy options are performed in separate files. Emissions originating from solid waste disposal sites (SWDS) are calculated in separate sheets. In addition, wastewater-related calculations are performed in corresponding spreadsheets. Finally, the emissions of wastewater, composting and SWDS are aggregated in separate spreadsheets, i.e. one for baseline analysis and another for the analysis of policy options.

Figure 2. The Excel-files used in 2011 for projections of waste sector. Each file include one or more sheets that are listed in the figure. If there exist several files, it is indicated by the dashed line.
For the EU PAMs reporting in 2011 the data needs and the links to the existing spreadsheets are schematically shown in Fig. 3.

![Figure 3. Linkage between existing calculation sheets and EU PAMs reporting excel.](image)

2.2

**Basic Concepts**

2.2.1

**Waste Fractions and Types**

To carry out the calculations it is necessary to identify all different fractions of waste that can contribute to emissions of GHG.

In recent IPCC guidelines (2006) MSW has been divided into the following 11 waste types:

- food waste
- garden (yard) and park waste
- paper and cardboard
- wood
- textiles
- nappies (disposable diapers)
- plastics
- metal
- glass (and pottery and china)
- other (e.g. ash, dirt, dust, soil, electronic waste)
The decay rate of the waste fractions can be divided into three types: fast, slow, and default decaying types. In Table 1 the types of waste and the split according to the decay rate is presented. Of the municipal solid waste approximately 16% is considered to be slowly decaying (MSW_{slow}), details of waste fractions are given in Sec. 3.2. Later in the inventory the decay rate has been divided into four groups: very slow, slow, default, and fast. In addition the MSW includes inert waste that is assumed not to decompose at all.

![Table 1. Waste types used in 2011 reporting, and the corresponding decomposition rates: slow, fast, default (for abbreviations see list in the beginning of the report). In parenthesis approximate proportion of the particular type of decomposing waste is given.](image)

### 2.2.2

**First Order Decay Model**

The first order decay (FOD) model is the default method for calculating methane emissions from solid waste disposal sites (SWDS). Annex 3A1 in IPCC (2006) provides detailed information and the essential equations of this model.

According to IPCC guidelines, emissions from industrial waste and sludge are estimated in a way similar to that for bulk municipal solid waste (MSW).

The default methane generation rates $k_i$ are given for slowly degrading, moderately degrading, and rapidly degrading waste types (Tab. 3.3 in IPCC (2006)). The used values are listed in Tab. 2 with the corresponding half-life ($t_{1/2}$) values. We can write the relation between generation rate and the half-life mathematically as:

$$k = \frac{ln2}{t_{1/2}}.$$  

![Table 2. The methane generation rate values used in 2011 PAMs reporting.](image)

Table 3 shows the country-specific methane generation rate constants that follow IPPC 2006 Guidelines.

![Table 3. The country-specific methane generation constants.](image)
2.2.3  
Degradable Organic Carbon

Degradable organic carbon (DOC) is the organic carbon that is accessible to biochemical decomposition. It can be calculated from a weighted average of the carbon content of various components of the waste stream.

2.2.4  
Fraction of Degradable Organic Carbon Dissimilated

The fraction of degradable organic Carbon dissimilated (DOC\textsubscript{f}) is an estimate of the fraction of carbon that is ultimately degraded and released. This means that some organic carbon does not actually degrade, or degrades very slowly, when deposited in SWDS. In Finnish calculations the value 0.5 for DOC\textsubscript{f} has been used.

2.2.5  
Methane Correction Factor

Managed landfills are assumed to produce CH\textsubscript{4} at the highest possible rate whereas unmanaged produce only a fraction of the CH\textsubscript{4} theoretically possible. This is because in unmanaged SWDS a larger fraction of waste decomposes aerobically in the top layers of unmanaged sites. The methane correction factor (MCF) accounts for this property. MCF should be interpreted as the ‘waste management correction factor’ that is specific to the area of disposal site (IPCC, 2000).

MCF is written mathematically as:

\[
MCF(t) = MCF_1(t) \cdot MCF_{\text{managed}} + (1 - MCF_1(t)) \cdot MCF_{\text{unmanaged}},
\]  

where MCF values of managed and unmanaged SWDS are presented in Tab. 4. The classification and methane correction factors for SWDS can be found in IPCC (2006) (Tab.3.1 therein).

Historical shares of managed SWDS, i.e. sites in which MCF=1 (notation MCF1), are also estimated. In Fig. 4 the historical development of MCF1 is presented. MCF1 is set as 1 since year 2002.

Table 4. The methane correction factors, used in 2011 PAMs reporting (according to IPCC).

<table>
<thead>
<tr>
<th>MCF</th>
<th>SWDS type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>managed</td>
</tr>
<tr>
<td>0.4</td>
<td>unmanaged</td>
</tr>
</tbody>
</table>
2.2.6

Oxidation factor

The oxidation factor (OX) describes the fraction of methane from SWDS that is oxidized in the soil or other material covering the waste. If no oxidation takes place OX is zero, and if all CH$_4$ is oxidized then OX=1. Most industrialized countries use the value 0.1 for OX (IPCC, 2006). In the calculations one must note that any methane recovered must be subtracted from the amount generated before applying an OX. Finland used OX value of 0.1 in PAMs reporting in 2011.

2.2.7

Methane Recovery

CH$_4$ recovery is the amount of methane generated at SWDS that is recovered and burned for instance in a flare. The default value for methane recovery is zero. However, when information about the amount of methane recovery is available and documented this default value can be changed according to IPCC guidance 2006.
2.3

Emission Calculation

2.3.1

Methane generation

The waste-related methane emissions are schematically shown in Fig. 5. The incoming solid waste can be recycled, reused or then disposed, i.e. landfilled. Only the fraction that is deposited in the SWDS is taken into account. The disposed amount of waste consists of different waste fractions; some of the waste is not degradable. For instance, glass is a fraction that does not contain any degradable organic carbon. Thus, this share of the waste is omitted. However, some share of the DOC (namely 1-DOCf) is degrading very slowly or not at all in the SWDS. This fraction of DOC-type waste does not generate any methane. Additionally, some of the carbon is not methane bound, thus it is excluded from the potential methane generation. In the last phase, the amount of carbon can be converted to methane by using the conversion factor of 16/12.

Figure 5. Schematic of waste flow and generated methane emissions in solid waste disposal sites.

2.3.2

Emission Calculations of Solid Waste

Calculations are made for the total waste amount using the average common methane correction (MCF) value for each year. The year t defines the MCF to be used for the emissions caused by waste amounts landfilled in the previous years (and degraded later in year t) as well. In Finland this is also valid for closed landfills (which have been unmanaged when used) because all the closed landfills have been covered. (Statistics Finland, 2011a)
The so called modified kinetic model is based on the IPCC’s kinetic model. The only modification has been made in Eq.(5.1) of the IPCC’s guidance (2000). The modification takes into account the time-dependence of the methane correction factor MCF(t), which is not covered by the original kinetic model of the IPCC.

The modified equation is as follows:

\[
\text{CH}_4^{\text{gen}}(t) = A \cdot k \sum_x SW(x) L_0(x) e^{-k(t-x)},
\]  

(3)

where \( A \) is the normalization factor, \( x \) is the year for which input data should be added, \( SW(x) \) is the amount of waste disposed at SWDS in year \( x \), and \( L_0 \) is the methane generation potential.

In Eq. (3) the constant coefficient \( A \cdot k \) can be expressed as:

\[
A \cdot k = 1 - e^{-k},
\]  

(4)

which clearly indicates that Eq. (4) gives the amount of generated \( \text{CH}_4 \) in year \( t \).

The calculation procedure is illustrated schematically in Figs. 6 and 7. Emitted methane is calculated from municipal solid waste, industrial solid waste, municipal sludge, industrial sludge, and construction and demolition waste. First the amount of incoming waste to the SWDSs is split according to the decay rate. After this, the emissions for each of type of waste are aggregated to form the total emissions from the waste sector.

Fig. 7 describes the calculations that make use of the modified kinetic model. The corresponding IPCC default parameters are picked according to the waste and decay type, and with the aid of the modified IPCC Eq. (5.1) the amount of generated methane is calculated. The amount of recovered methane is calculated by making use of expert opinions and assumptions on the recovery share of methane. After this, the IPCC Eq. (5.2) is invoked and the emitted amount of methane is finally obtained.
Figure 6. Flow of information in the calculations.

Figure 7. Detailed flow of information in the calculations.
3 Solid Waste Disposal Site Calculations

3.1 General Principles

Calculations are made for all relevant waste fractions and recognizing different decay rates. The methane production and recovery are treated separately.

Biological treatment (composting and fermentation) of waste in the year 2016 is assumed to correspond to the projections in the background document for the National Waste Plan (Huhtinen et al. 2007), i.e. 20% of MSW is deposited, 28% is recycled, 20% is composted or fermented and 31% is used for energy.

3.2 Waste Fractions

Food waste forms the biggest share in the municipal solid waste followed by paper and cardboard (Table 5). The corresponding DOC coefficients are also given.

The MSW composition data according to IPCC is given in Tab. 6 for Northern Europe. The DOC contents and total carbon contents can be found in IPCC guidance (2006) (Vol.5, Tab.2.4).

Table 5. Percentages of waste fractions in Finland used in 2011 reporting. Shares are set as constants for calculation time frame. Also the share of degradable organic carbon in the waste streams is given.

<table>
<thead>
<tr>
<th>Waste fraction</th>
<th>Share of total amount [%]</th>
<th>Share of DOC in respective waste stream (DOC-coefficient)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>16.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Cardboard</td>
<td>9.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Cardboard packaging for liquids</td>
<td>0.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Wood</td>
<td>6.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Clothes and textiles</td>
<td>1.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Food waste</td>
<td>29.3</td>
<td>0.16</td>
</tr>
<tr>
<td>Garden waste</td>
<td>7.5</td>
<td>0.16</td>
</tr>
<tr>
<td>Plastic</td>
<td>5.6</td>
<td>0</td>
</tr>
<tr>
<td>Other combustible</td>
<td>7.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Glass</td>
<td>3.4</td>
<td>0</td>
</tr>
<tr>
<td>Metal</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>Electronics</td>
<td>2.1</td>
<td>0</td>
</tr>
<tr>
<td>Other non-combustible</td>
<td>7.5</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 6. Waste composition of Northern Europe by percent (IPCC 2006).

<table>
<thead>
<tr>
<th>Waste fraction</th>
<th>Share of total waste [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper/cardboard</td>
<td>30.6</td>
</tr>
<tr>
<td>Wood</td>
<td>10.0</td>
</tr>
<tr>
<td>Textiles</td>
<td>2.0</td>
</tr>
<tr>
<td>Food waste</td>
<td>23.8</td>
</tr>
<tr>
<td>Plastic</td>
<td>13.0</td>
</tr>
<tr>
<td>Glass</td>
<td>8.0</td>
</tr>
<tr>
<td>Metal</td>
<td>7.0</td>
</tr>
</tbody>
</table>

3.2.1

Decay-type Split

The initial input is the total amount of municipal solid waste (MSW) in tonnes. This is further divided into four different groups by the decay rate. The split is done according to the different fractions of MSW and is mathematically expressed in the following Eqs. (5)-(8).

\[
MSW_{\text{slow}} = \left[ \frac{\text{paper}\% + \text{carboard}\% + \text{liqcard}\%}{100} \cdot 0.35 + \frac{\text{wood}\%}{100} \right] \cdot MSW. \tag{5}
\]

\[
MSW_{\text{fast}} = \frac{\text{food}\% + \text{garden}\%}{100} \cdot MSW. \tag{6}
\]

\[
MSW_{\text{default}} = \left[ \frac{\text{paper}\% + \text{carboard}\% + \text{liqcard}\%}{100} + \frac{\text{textile}\% + \text{oil}\% + \text{othercomb}\%}{100} \right] \cdot 0.65 \cdot MSW. \tag{7}
\]

\[
MSW_{\text{inert}} = \frac{\text{plastic}\% + \text{glass}\% + \text{metal}\% + \text{electr}\% + \text{othernone}\%}{100} \cdot MSW. \tag{8}
\]

Here paper, cardboard and cardboard for liquids are considered to be slowly decomposing materials. The food waste from kitchen and garden is considered as fast decomposing fractions. MSW default includes paper, cardboard and cardboard for liquids and clothes, oil and other combustible waste fractions. Here paper and cardboard waste is split into slowly and fast decomposing types since some paper waste include lignin and thus decay at different rate.
3.2.2

DOC of Waste Fractions

The amount of DOC (in tonnes) is calculated by using the following equations. The DOC fractions of waste streams are used here (see values given in Tab. 5).

\[
DOC_{\text{slow}} = \left[ \text{paper}_\% + \text{carboard}_\% + \text{liqcard}_\% \right] \cdot 0.4 \cdot \frac{1}{100} \cdot 0.35 + \frac{\text{wood}_\% \cdot 0.3}{100} \cdot MSW
\]  \hspace{1cm} (9)

\[
DOC_{\text{fast}} = \frac{\text{kitchen}_\% + \text{yard}_\%}{100} \cdot 0.16 \cdot MSW.
\]  \hspace{1cm} (10)

\[
DOC_{\text{default}} = \left[ \frac{\text{paper}_\% + \text{carboard}_\% + \text{liqcard}_\%}{100} \cdot 0.4 \cdot 0.65 \right. \\
\hspace{1cm} + \frac{\text{textile}_\% \cdot 0.4 + \text{oil}_\% \cdot 0.1}{100} + \frac{\text{combust}_\% \cdot 0.1}{100} \left. \right] \cdot MSW
\]  \hspace{1cm} (11)

\[
DOC_{\text{inert}} = \left[ \frac{\text{glass}_\% + \text{metal}_\% + \text{elec}_\% + \text{other}_\%}{100} \cdot 0 \right. \\
\hspace{1cm} + \frac{\text{plastic}_\% \cdot 0}{100} \left. \right] \cdot MSW
\]  \hspace{1cm} (12)

The share of DOC in MSW (sDOC\(_i\)) is calculated separately for each decay type by using Eq. (13).

\[
sDOC_i = \frac{DOC_i}{MSW_i},
\]  \hspace{1cm} (13)

where DOC\(_i\) is the amount of DOC in waste type i and MSW\(_i\) is the amount of MSW that decays as type i.
3.3 Generated Methane

The generated methane ($E_g$) in year $t$ is calculated as follows for slowly degrading waste:

$$E_g(t) = MCF(t)k_1A_i \sum_x \frac{E^\text{mbm}(x)}{MCF(x)} e^{-k_1(t-x)},$$  \hfill (14)

where $E^\text{mbm}$ has the expression:

$$E^\text{mbm}(t) = \frac{1}{1000} L_0(t)MSWT_s(t)MSWF_s,$$  \hfill (15)

where MSWT$_s(t)$ is the share of MSW that decays slowly, and MSWF$_s$ is the fraction of MSW (slow) that is disposed at SWDS in year $t$. The methane generation potential $L_0$ can be written as (IPCC 2000):

$$L_0(x) = MCF(x)DOC(x)DOC_F F \frac{16}{12},$$  \hfill (16)

where $F$ is the fraction by volume of CH$_4$ in landfill gas. In order to have total amount of generated methane, one should aggregate generated methane for slow, default and fast waste types.

Eq. (14) can also be written recursively as:

$$E_g(t) = \frac{1}{1000} L_0(t)MSWT_s(t)MSWF_s(t)k_1A_i + \frac{MCF(t)}{MCF(t-1)} e^{-k_s} \cdot E_g(t-1)$$  \hfill (17)

3.4 Methane Recovered

The amount of landfill gas recovered is obtained from the Finnish Biogas Plant Register (University of Eastern Finland 2010). This figure is considered accurate. (Statistics Finland, 2011)

CH$_4$ recovery is calculated differently in baseline (WEM) and WAM assessment. In both cases recovered methane is calculated to the kinetic model, and then by using the mass-balance model.

3.4.1 Baseline Assessment (WEM)

The amount of methane recovered ($E^\text{rec}_{\text{wem}}$) is zero during 1900-1990. After this, the total amount is calculated according to Eq. (18):
\[ E_r^{\text{tot}} = E_{\text{MSW}} + E_r^{\text{Msludge}} + E_r^{\text{ISW}} + E_r^{\text{CDW}} \]  

(18)

For all years applies:

\[ E_r^{\text{Msludge}} = 0 \]  

(19)

\[ E_r^{\text{ISW}} = 0 \]  

(20)

Between 1991-2005 recovered methane is calculated as:

\[ E_r V(t) = \frac{E_{mg}^{\text{km}} \cdot E_r^{\text{tot}}}{E_{mg}^{\text{km}} \cdot E_{\text{MSW}} + E_{mg}^{\text{km}} \cdot E_{R}^{\text{CDW}},} \]  

(21)

where \( V \) can be one of the following: MSW, Msludge, CDW.

After year 2006 recovered amount of methane can be expressed as:

\[ E_V(t) = \begin{cases} 
[a + \frac{b}{10} \cdot (t - t_0)] \cdot E_{mg}^{\text{km}}(t) & \text{if } t \neq t_0 \\
 b \cdot E_{mg}^{\text{km}}(t) & \text{if } t = t_0 
\end{cases} \]  

(22)

where \( a \) and \( b \) are expert judgments on the recovery shares of the landfill gas. In Tab. 7 the expert judgments on the shares of recovered landfill gas are presented. It should be noted that the absolute amount of recovered amount of gas is not estimated but the share of the total gas production. The underlying assumption is that it is easier to provide a reasonable estimate of the share than of the total amount.

The coefficient of Eq. (22) is illustrated in Fig. 8.

![Graph showing recovery shares during 2007-2050 according to expert judgment.](image)

Figure 8. Recovery shares during 2007-2050 according to expert judgment. See text for details.
Table 7. Parameter values for Eq. 22 based on expert judgment.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0.33</td>
<td>0.37</td>
<td>0.40</td>
<td>0.43</td>
</tr>
<tr>
<td>b</td>
<td>0.37</td>
<td>0.40</td>
<td>0.43</td>
<td>0.45</td>
</tr>
<tr>
<td>t₀</td>
<td>2005</td>
<td>2015</td>
<td>2025</td>
<td>2035</td>
</tr>
</tbody>
</table>

One has four options for the parameter set \(\{a,b\}\), depending on the year of calculation. Cases 1-4 apply as documented in Tab. 8.

Table 8. Recovery calculation cases 1-4.

<table>
<thead>
<tr>
<th>Case no</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[2007,2015]</td>
</tr>
<tr>
<td>2</td>
<td>[2016,2025]</td>
</tr>
<tr>
<td>3</td>
<td>[2026,2035]</td>
</tr>
<tr>
<td>4</td>
<td>[2036,2044]</td>
</tr>
</tbody>
</table>

In time frame [2045, 2050] recovery is calculated according to Eq. (22) (case \(t = t₀\)) with the \(b\) parameter of case 4.

The recovered methane can be further divided into three by the decay type. For MSW_{slow}, MSW_{fast}, and MSW_{default} the recovered methane of decay type i \(E_{r,MSW}^i\) is calculated as follows:

\[
E_{r,MSW}^i = E_{r,MSW}^g \frac{E_{km,MSW}^i}{E_{g,MSW}^k},
\]

(23)

where \(E_{r,MSW}^g\) is the total amount of recovered methane of MSW.

### 3.4.2 Policy Assessment (WAM)

Between 2007-2010 the recovered methane is calculated as:

\[
a + \frac{b - a}{10} \cdot (t - t₀) \cdot E_{g,MSW}^k(t),
\]

(24)

where parameters are as in case 1 in the baseline assessment. From year 2011 onwards recovery MSW is calculated as:

\[
E_{r,MSW}(t) = E_{r,MSW}^{pol0} - 0.55 \cdot \Delta E_{g,MSW}^t,
\]

(25)

where \(E_{r,MSW}^{pol0}\) is the CH\(_4\) recovery of the MSW given by the kinetic model of the WEM scenario, the difference in generated CH\(_4\) emission of MSW \(\Delta E_{g,MSW}^t\) has the following expression:
\[
\Delta E_g^{MSW} = E_{g,WEM}^{MSW} - E_{g,mkn}^{MSW},
\]

where \(E_{g,WEM}^{MSW}\) is the generated CH\(_4\) emissions of MSW in year \(t\) in WEM scenario, and \(E_{g,mkn}^{MSW}\) is the generated CH\(_4\) emissions of MSW obtained with modified kinetic model in WAM scenario.

The interpretation of Eq. (25) is that in the WAM scenario the growing amount of incineration reduces waste deposition in SWDS. Therefore, gas recovery has been assumed to be 55%. This growing share of incineration has been subtracted in the WAM scenario’s methane recovery share.

Methane recovery of M\(_{\text{sludge}}\) and CDW are calculated analogically as in baseline (WEM) assessment.

### 3.5 Emitted methane

Emitted methane is calculated for every waste type (MSW, sludges, etc.) The amount of emitted methane of MSW (\(E_{E,MSW}\)) is obtained by using the following equation:

\[
E_{e,MSW} = (E_g - E_r) \cdot (1 - OX)
\]

That fully corresponds to IPCC Eq. (5.2). The emitted CH\(_4\) of other waste types is calculated analogically as in Eq. (27).
4 Wastewater Emissions

4.1 General

Wastewater can be a source of CH\textsubscript{4} when treated or when waste water sludge is disposed anaerobically. In addition, it can be a source of N\textsubscript{2}O emissions. CO\textsubscript{2} emissions are considered to be of biogenic origin and thus not taken into account. The methane and nitrous oxide emissions are summed and multiplied with characterization factors to obtain total amount of wastewater-related GHG emissions. In Finland’s calculations methane emissions arise from the following:

- Septic tanks
- Municipals
- Industry

Nitrous oxide emissions arise from the foregoing and also from fish farming.

The main data sources for calculating the wastewater-related GHG emissions are the VAHTI emission database of Finland’s environmental administration and its registers (e.g. Register for Industrial Water Pollution Control) (Statistics Finland, 2011). The source for the population projection until 2050 is from Statistics Finland. The projection is updated every three years (Statistics Finland, 2009). For uncollected wastewaters the nitrogen load is based on population data and protein consumption. In Tab. 9 the main sources of information are collated.

<table>
<thead>
<tr>
<th>Municipal</th>
<th>Septic tanks</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH\textsubscript{4}</td>
<td>Register for Industrial Water Pollution Control</td>
<td></td>
</tr>
<tr>
<td>N\textsubscript{2}O</td>
<td>Statistics Finland (population scenarios)</td>
<td>Register for Industrial Water Pollution Control</td>
</tr>
<tr>
<td></td>
<td>Protein consumption, e.g. (Information Centre of the Ministry of Agriculture and Forestry 2010, FAOSTAT 2005)</td>
<td>VAHTI-database (N input of industry and fish farming)</td>
</tr>
</tbody>
</table>

4.2 Emission Calculations

4.2.1 Methane Emissions

The methane emissions are calculated according to the following equation:

\[
E_{sl}^{m}(t) = \frac{1}{1000} BOD(t) SBF \cdot EF \cdot FTA,
\]

where the biochemical oxygen demand BOD(t) is proportional to population, SBF is the fraction of BOD that readily settles, EF is the emission factor (kg CH\textsubscript{4}/kg BOD), and FTA is the fraction of BOD in sludge that degrades anaerobically. The values of the constants are presented in Tab. 10.
Table 10. Constants in wastewater calculations.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBF</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>EF</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>FTA</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>$c_{\text{m}}^m$</td>
<td>0.00625</td>
<td></td>
</tr>
<tr>
<td>$c_{\text{ind}}^m$</td>
<td>0.00125</td>
<td></td>
</tr>
<tr>
<td>$\xi_m$</td>
<td>0.0157</td>
<td>kg N$_2$O/tonne Nburden</td>
</tr>
<tr>
<td>$N_N$</td>
<td>0.0157</td>
<td></td>
</tr>
<tr>
<td>$N_{\text{m}}^m$</td>
<td>0.0157</td>
<td></td>
</tr>
<tr>
<td>$c_{\text{eff}}^m$</td>
<td>0.0157</td>
<td></td>
</tr>
<tr>
<td>$c_{\text{n}}$</td>
<td>0.16</td>
<td>kg N/kg protein</td>
</tr>
</tbody>
</table>

$$E_{\text{m}}^m(t) = \frac{1}{1000} c_{\text{m}}^m \cdot BOD_{5,\text{coming}}(t)$$  \hspace{1cm} (29)$$

where $c_{\text{m}}^m$ is the emission factor for municipal (see Tab. 10), $BOD_{5,\text{coming}}(t)$ is the coming 5-day BOD ($BOD_5$ is proportional to 7-day BOD).

$$E_{\text{ind}}^m(t) = \frac{1}{1000} c_{\text{ind}}^m \cdot COD_{\text{tot,coming}}(t)$$  \hspace{1cm} (30)$$

where $c_{\text{ind}}^m$ is the emission factor for industry (see Tab. 10), $COD_{\text{tot,coming}}(t)$ is the total coming chemical oxygen demand (COD) emission in year $t$.

The foregoing emissions are aggregated and the total amount of emissions is characterized by using the factor 21 to obtain emissions in CO$_2$-equivalents.

Methane and nitrous oxide emissions in CO$_2$-equivalents are presented in Fig. 9 and Fig. 10, respectively.
Figure 9. Wastewater methane emissions in WAM scenario during 1990-2050.

Figure 10. Wastewater nitrous oxide emissions in WAM scenario during 1990-2050.
4.3 Nitrous Oxide Emissions

The N$_2$O emissions originating from septic tanks are calculated as:

$$E_{st}^N(t) = c_{st} \cdot N_{\text{burden}}(t),$$

(31)

where $c_{st}$ is the emission factor for septic tanks (see Tab. 10) and $N_{\text{burden}}(t)$ is the total nitrogen burden of population. Obviously $N_{\text{burden}}(t)$ is proportional to population, and it can be written as follows:

$$N_{\text{burden}}(t) = \text{pop}(t) \cdot c_{\text{prot}}(t) \cdot c_n,$$

(32)

where $\text{pop}(t)$ is the population in year $t$, $c_{\text{prot}}(t)$ is the protein amount per person per year, and $c_n$ is amount of nitrogen per kilogram of protein. Parameter $c_n$ has a constant value (see Tab. 10). Information about protein per person has been obtained from the Information Centre of the Ministry of Agriculture and Forestry (2010). The relative amount of protein per person per year is plotted in Fig. 11. In the scenarios $c_{\text{prot}}(t)$ has been set as a constant, 101 g per person per 24 h, in the time frame [2002, 2050].

![Figure 11. Protein amounts per person per year during 1990-2007. The values are presented as proportions compared to protein amount in 1990, i.e. amount in 1990 is set as one.](image)
Municipal emissions are calculated as follows:

\[ E_{\text{mun}}^N(t) = \frac{1}{1000} c_{\text{mun}}^N \cdot \text{pop}_{\text{Aland}} \cdot N_{\text{tot,pop}}(t), \]  

(33)

where \( c_{\text{mun}}^N \) is the emission factor for municipal (see Tab. 10), \( \text{pop}_{\text{Aland}} \) is the correction factor for population to take into account the population of the autonomous Åland Islands, and \( N_{\text{tot,pop}}(t) \) is the nitrogen burden of the population. Values of \( N_{\text{tot,pop}}(t) \) are obtained from registers for years 1990-1997 and from VAHTI data system during 1998-2006. WEM and WAM projections use \( N_{\text{tot,pop}}(2006) \) value 2007 onwards.

The emissions of industry are calculated very similarly:

\[ E_{\text{ind}}^N(t) = \frac{1}{1000} c_{\text{ind}}^N \cdot N_{\text{tot,ind}}(t), \]  

(34)

where \( c_{\text{ind}}^N \) is the constant for emissions from industry (see Tab. 10), \( N_{\text{tot,ind}}(t) \) is the total nitrogen burden of industry in year \( t \). Values of \( N_{\text{tot,ind}}(t) \) are obtained from registers for years 1990-1997 and from VAHTI data system during 1998-2006. WEM and WAM projections use \( N_{\text{tot,ind}}(2006) \) value 2007 onwards.

The \( \text{N}_2\text{O} \) emissions of fish farming in year \( t \), i.e. \( E_{\text{ff}}^N(t) \), are calculated analogically to the two previous ones:

\[ E_{\text{ff}}^N(t) = \frac{1}{1000} c_{\text{ff}}^N \cdot N_{\text{tot,ff}}(t), \]  

(35)

where \( c_{\text{ff}}^N \) is the emission coefficient for fish farming (see Tab. 10), and \( N_{\text{tot,ff}}(t) \) is the total nitrogen burden of fish farming in year \( t \). Values of \( N_{\text{tot,ff}}(t) \) are obtained from registers for years 1990-2006. WEM and WAM projections use \( N_{\text{tot,ff}}(2006) \) value 2007 onwards.

The foregoing emissions are aggregated and the total amount of emissions is characterized by using the factor 310.

### 4.4 Wastewater Scenarios

In Fig. 12 the GHG emissions of WEM and WAM scenarios have been plotted.

In the calculations of emissions scenarios, one main driver is the size of the population that is connected to the sewerage system. In the WAM scenario a bigger share of the population is assumed to be connected to the sewerage system, which causes differences from 2007 onwards.
Figure 12. Greenhouse gas emissions of wastewater scenarios.
5 Emissions from Composting

5.1 General

As explained in the IPCC guidance, composting is an aerobic process in which a large fraction of the DOC in waste is converted into CO₂. Methane is formed in anaerobic sections of the compost, but it is oxidized to a large extent in the aerobic sections of the compost. In addition, composting can produce N₂O emissions. (IPCC 2006)

Activity data are based on the VAHTI system and the Water and Sewage Works Register.

5.2 Relevant Assumptions

Information provided by Huhtinen et al. (2007) serves as a basis for the assumptions for calculating the emissions of composting.

Baseline calculation assume that 90% of the biological treatment of MSW is composting and 10% fermentation. The composting of industrial waste and municipal sludge are assumed to sustain the same levels which they had in 2007.

In policy projections the rate of decomposing increases whereas the increase of composting stops by year 2011. Composting of industrial waste and municipal sludge are assumed to sustain the same levels which they had in 2007.

5.3 Emission calculations

The emission calculation is straightforward. However, due to uncertainties in the activity data, the data correction is laborious and includes multiple stages. The corrections are done manually by using expert knowledge about the data base and its uncertainty. The uncertainty is estimated to be 30% since 1997. Table 11 presents the estimated uncertainties of activity data. The uncertainty information is only used at Statistics Finland to assess the key emission sources.

<table>
<thead>
<tr>
<th>Class of data</th>
<th>Time frame</th>
<th>Uncertainty [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>All except municipal sludge</td>
<td>1990-1996</td>
<td>±40</td>
</tr>
<tr>
<td>Municipal sludge</td>
<td>1990-1996</td>
<td>±30</td>
</tr>
<tr>
<td>All</td>
<td>1997-2005</td>
<td>±30</td>
</tr>
</tbody>
</table>

After the activity data are corrected a certain share is added to the amount of composted waste. This auxiliary share is based either on information provided in the Vahti database (if available) or expert opinion. In Tab. 11 we have collated coefficients to correct the amounts of composted waste and the coefficients to obtain methane and nitrous oxide content of the waste types. Emission factors are based on IPCC’s guidance, (see IPCC 2006). For instance, 20% extra is added to the municipal biowaste relative to the original amount of composted waste to obtain final value that is used in the calculations.
Table 12. Activity data of composting, data uncertainty and relevant emission factors. See text for details.

<table>
<thead>
<tr>
<th>Waste category</th>
<th>Added amount [%]</th>
<th>CH(_4) EF [g CH(_4)/kg waste]</th>
<th>N(_2)O EF [g N(_2)O/kg waste]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial sludge, dry matter</td>
<td>20</td>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>Municipal sludge, dry matter</td>
<td>30</td>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>Municipal solid waste</td>
<td>20</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>Household solid waste</td>
<td>20</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>Industrial solid waste, constr. waste</td>
<td>20</td>
<td>4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

The methane and nitrous oxide emissions are obtained using gas-specific emission coefficients. The composted waste amount is simply multiplied by the coefficient to obtain emissions. After this the emissions are expressed in CO\(_2\)e by using characterization factors 21 and 310 for methane and nitrous oxide, respectively.

5.4 Composting Scenarios

The emission scenarios of composting are only dependent on the estimates of the future amounts of waste composted. In other words, the amounts of composted waste by subcategories have been estimated and the calculation procedure described in Sec. 5.3 is used. The estimates have been based on expert opinions in agreement with SYKE and the Ministry of Environment.

The emission projections of composting during 1990-2050 are presented in Fig. 13.

Figure 13. Composting emissions in WEM and WAM scenarios during 1990-2050.
6  Projections for the Waste Sector

6.1  Variables influenced by Policies and Measures

In the model some variables can be adjusted to describe the effect of PAMs. These variables are collated in Tab. 13.

Fig. 14 shows where relevant policy measures can affect greenhouse gas emission. For example, Finland has PAMs affecting the amount of waste transported to landfills: Government decree on landfills (861/1997, revised 2006), Biowaste strategy (2006), and general reform of waste legislation. These measures intend to reduce the total waste amount and the amount of organic waste deposited in SWDS. These PAMs are showed in Fig. 14. In addition PAMs have been introduced to ensure that the SWDS are maintained properly in order to maximize the decomposition rate and methane recovery in the landfills.

Table 13. Variables that can be affected.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery shares</td>
<td>Amount of recovered CH$_4$</td>
</tr>
<tr>
<td>Waste fraction distribution</td>
<td>Effect on DOC content</td>
</tr>
<tr>
<td>Waste amounts</td>
<td>Amounts landfilled, composted etc.</td>
</tr>
<tr>
<td>DOC$_i$</td>
<td>Management of SWDS</td>
</tr>
<tr>
<td>popww(t)</td>
<td>Population that is connected to the sewage system, impact on wastewater treatment emissions</td>
</tr>
</tbody>
</table>

Figure 14. Policy measures affecting waste emissions.
6.2 Economic Assessments

So far there have been only separate analyses or assessments of economic impacts of waste policies, e.g. FCG (2010), Myllymaa et al. (2008), and Kauto et al. (2010). No comprehensive economic evaluations of the waste sector PAMs have been carried out. Available studies have evaluated costs of transportation and management of waste and the costs of equipment required for waste collection. In addition, the evaluation of the effect of the waste tax has been published in 2005 (Ministry of Environment, 2005). Some cost-related data that are collected regularly (Tab. 14).

Finnish customs collects landfill tax. Therefore Customs holds information about waste tax. Landfills provide Customs tax payment data every three months. Thus, annual and quarter year statistics can both be compiled. Annual data on waste tax can be e.g. accessed online in State Treasury reporting page (2011).

Statistics Finland compiles statistic about environmental and energy taxes annually. However, the taxation information is the aggregated value of energy, vehicle and other environment-related taxation (Statistics Finland, 2011b). Additionally, in the tax statistics the annual water and wastewater fees and waste management fee are given.

Table 14. Economic information in waste sector.

<table>
<thead>
<tr>
<th>Available economic information</th>
<th>Notes and relevance for evaluation of PAMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste tax, available at Netra-reporting page, on-budget entities’ revenue (State Treasury, 2011)</td>
<td>Partially a cost of PAMs for waste management, waste taxes are, however, also collected for other purposes (hygiene, public health, pollution control) than climate policy.</td>
</tr>
<tr>
<td>Water and wastewater fee, available at Statistic Finland</td>
<td>Annual data with one year delay. Fees are only partially related to climate PAM</td>
</tr>
<tr>
<td>Waste fees, available at Statistics Finland</td>
<td>Impacts on the amount of landfilled waste (recycling, waste combustion are alternatives) annual data with one year delay. Fees are only partially related to climate PAM</td>
</tr>
</tbody>
</table>
PART II: F-Gases

The emissions of F-gases account for approximately 1% of the total GHG emissions in Finland. However, the total emissions of F-gases have increased significantly since 1990 (Statistic Finland 2011a). Refrigerants are the main source of F-gas emissions (about 90% of total) (Alaja, 2009). HFC- or PFC-containing refrigerant gases are not manufactured in Finland.
7 Materials and Activity Data for Emission Inventories

At present, the activity data of F-gas inventories are obtained from annual electronic surveys of the Finnish companies operating in the different sectors defined as F-gas emission sources. Finnish Environment Institute SYKE is the responsible authority for these annual inventories. The survey to collect activity data for the inventory has been carried out annually since 2002 and the response rate has varied from 45% to over 70% (Statistics Finland 2011a). One should note that the companies have no legal obligation to report data on the use of F-gases. Based on the responses, the emissions (actual and potential) are calculated at SYKE. The data and calculations are processed in MS Excel. The calculation methods for each category are based on the IPCC (2000). Statistics Finland includes F-gas emissions in their annual reports to the EU and UNFCCC. The data collection, emission calculation and reporting processes are schematically presented in Fig. 15. Information about the electronic questionnaire forms used in the annual survey is summarized in Table 15.

Figure 15. Annual F-gas survey and emission calculation and reporting by Finnish Environment Institute. Illustration by Nufar Finel, SYKE.

Table 15. Electronic questionnaires about F-gases by Finnish Environment Institute.

<table>
<thead>
<tr>
<th>Questionnaire theme</th>
<th>Number of recipients in 2010, note that a company may receive several questionnaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration and air-conditioning equipment (RAC)</td>
<td>398</td>
</tr>
<tr>
<td>Foam blowing and use of foam products (FOAM)</td>
<td>22</td>
</tr>
<tr>
<td>Aerosols (AERO)</td>
<td>22</td>
</tr>
<tr>
<td>Manufacturing, use and disposal of electrical equipment (EE)</td>
<td>12</td>
</tr>
<tr>
<td>Fixed fire fighting systems</td>
<td>3</td>
</tr>
<tr>
<td>Semiconductor manufacturing</td>
<td>3</td>
</tr>
<tr>
<td>Mobile air conditioning equipment (cars) (MAC)</td>
<td>26</td>
</tr>
<tr>
<td>Other</td>
<td>9</td>
</tr>
</tbody>
</table>

1) Information obtained through email questionnaire.
Since survey responses are not received from all the targeted companies, the missing data is imputed or estimated. The main imputing methods and assumptions are as follows (Statistics Finland 2011a):

- Non-respondents behave similarly to the average respondents when it comes to installation and conversion of equipment and to destruction of refrigerants
- If a non-respondent is one of the largest manufacturers, importers or exporters, the activity data is estimated based on their previous responses
8 F-gas Emission Projections

The emission projections of F-gases in Finland were previously updated in the publication by Lindh (2010). These projections were also reported in 2011 PAMs reporting. Full description of the use of F-gases in Finland as well as the documentation with abatement costs are provided by Alaja (2009). Figure 16 illustrates the WEM and WAM projections made at SYKE by Päivi Lindh in 2010 for PAMs reporting of 2011. From this figure we clearly see the growing emission trend after 1990 until 2008.

The total F-gas emission projections are sums of the subsector emission scenarios (see Fig. 17). The main F-gas emission sectors are: refrigeration and air conditioning equipment, aerosols and other sources including electrical equipment. Each source category has a specific calculation method because of the differences in available data and background information. Refrigerant GWP values are provided by IPCC.

Figure 16. Projections of F-gas emissions in 2011 PAMs reporting.
The main sources of information in updating of F-gas projections for 2011 PAMs reporting were the following:

- Inventory of 2009 and 2008

The sources of information that have been used in order to form scenarios for each subsector are summarized in Tab. 16. The assumptions and sources of information are documented in the excel-file used for calculations.
Table 16. Sources of information in subsector scenarios.

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Sources for assumptions and inputs</th>
<th>Variables</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigeration and air-conditioning equipment (RAC), PFC</td>
<td>Oinonen 2001 surveys and estimates, AEAT 2004 Review on F-gas regulation, Elektroniikan tukkuakauppiat ry, 2008, Climate and Energy strategy 2008.</td>
<td>Number of new equipment, retirement of (old) equipment, consumption, fillings</td>
<td>PFC218 emissions in RAC-sector have decreased all the time. It is assumed that decreasing trend is according to the slope of 2002-2009.</td>
</tr>
<tr>
<td>Domestic refrigeration</td>
<td>Oinonen 2001*, surveys, estimations</td>
<td>Installed refrigerant amounts in new plants/shops, retirement of (old) equipment, consumption, equipment lifetimes</td>
<td>Annual growth in commissioning of equipment 2% or 1.8% according to the climate and energy strategy 2008.</td>
</tr>
<tr>
<td>Supermarket refrigeration systems</td>
<td>Oinonen 2001*, surveys, estimations</td>
<td>Installed refrigerant amounts in new plants/shops, retirement of (old) equipment, consumption, equipment lifetimes</td>
<td>One of the key input is Installed refrigerant amount in 1999 obtained from Oinonen (2001) and estimations about changes (percentages)</td>
</tr>
<tr>
<td>Food processing industry</td>
<td>Oinonen 2001</td>
<td>Installed refrigerant amounts in new plants</td>
<td>One of the key input is Installed refrigerant amount in 1999 obtained from Oinonen (2001) and estimations about changes (percentages)</td>
</tr>
<tr>
<td>Processing industry</td>
<td>Oinonen 2001</td>
<td>Installed refrigerant amounts in new plants</td>
<td>One of the key input is Installed refrigerant amount in 1999 obtained from Oinonen (2001) and estimations about changes (percentages)</td>
</tr>
<tr>
<td>Stand-alone commercial applications (Devices with an incorporated compressor unit, e.g. refrigerated cabinet)</td>
<td>Oinonen 2001</td>
<td>Fillings, installed amount of refrigerant, lifetime, installations of new equipment, retirement of (old) equipment</td>
<td>Key input is the annual amount of refrigerant during fillings (typically 2500 kg)</td>
</tr>
<tr>
<td>Professional kitchens</td>
<td>Oinonen 2001, according to Horeca, surveys, AEAT</td>
<td>Fillings, installed amount of refrigerant, lifetime, installations, retirement of (old) equipment</td>
<td>Key input is the annual amount of refrigerant during fillings (typically 3067 kg)</td>
</tr>
<tr>
<td>Transport refrigeration</td>
<td>LIPASTO, Oinonen 2001, ATP statistics</td>
<td>Fillings of vehicles, number or installed plants, shares of vans, lifetime, retirement of (old) equipment, usages</td>
<td>Key input is the number of new plants per year (ATP statistics)</td>
</tr>
<tr>
<td>Stationary air conditioning</td>
<td>Oinonen 2001, Park&amp;Jung 2007, surveys, IPCC2006GL</td>
<td>Installed amount of refrigerant, changes in equipment amounts, average fillings, usage, retirement of (old) equipment, lifetime</td>
<td>Key input is the annual amount of refrigerant filling in 1999 (Oinonen 2001) and estimations about changes (percentages)</td>
</tr>
<tr>
<td>Heat pumps</td>
<td>Finnish heat pump association (SULPU), Oinonen 2001</td>
<td>Amount of installed heat pumps, average filling, installations and use, retirement of (old) equipment, lifetime</td>
<td>Key input is the SULPU’s statistics. For projections, estimated growth of heat pumps in use is an important parameter.</td>
</tr>
<tr>
<td>Mobile air-conditioning systems (MAC)</td>
<td>Oinonen 2001, Transport Safety Agency (TraFi)</td>
<td>Annual numbers of registered vehicles, retirement of (old) equipment, HFC fillings per year</td>
<td>Passenger cars, vans, trucks and buses. Information available also in LIPASTO database and Liisa reports.</td>
</tr>
</tbody>
</table>

### Table 16. continued.

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Sources for assumptions and inputs</th>
<th>Variables</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam blowing and use of foam products (FOAM)</td>
<td>IPCC/TEAP2005/GL2006, activity data from surveys</td>
<td></td>
<td>Calculations according to inventory model.</td>
</tr>
<tr>
<td>Aerosols (AERO)</td>
<td>GSK 2007 inventory</td>
<td></td>
<td>WAM scenario same as WEM scenario.</td>
</tr>
<tr>
<td>Grouped emissions sources</td>
<td>Surveys, expert opinions at SYKE</td>
<td>Level of usage in fire fighting, semiconductor manufacturing processes</td>
<td></td>
</tr>
</tbody>
</table>
9 Summary

This report presents the materials and methods used for evaluating the climate impact of PAMs in the waste sector in Finland. In addition, the materials and methods of fluorinated greenhouse gases are briefly discussed in the second part. The waste sector includes solid waste, waste water, and composting. Both baseline assessment and policy scenario assessment are discussed.

The calculations and relevant assumptions of the waste emissions projections are explained in detail. The main data sources are summarized in Tab. 17.

Table 17. Summary of relevant information sources for waste sector.

<table>
<thead>
<tr>
<th>Category</th>
<th>Activity Data Sources</th>
<th>Comments (eg. updating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid waste disposal sites</td>
<td>VAHTI-database: waste to landfills (excluding Aland) Finnish Biogas Plant Register: landfill gas recovery</td>
<td>VAHTI data is updated annually and for some parts constantly Published annually</td>
</tr>
<tr>
<td>Wastewaters</td>
<td>VAHTI-database: BOD, COD, N input, efficiencies of wastewater treatment Water and Sewage Works Register Register for Industrial Water Pollution Control</td>
<td>see above National data are updated annually at SYKE</td>
</tr>
<tr>
<td>Composting</td>
<td>VAHTI-database Water and Sewage works register</td>
<td>see above</td>
</tr>
<tr>
<td>Population</td>
<td>Statistics Finland</td>
<td>So far update in every three years for the scenario. Essential initial data for waste scenarios.</td>
</tr>
</tbody>
</table>

The emission calculation steps of different waste types are summarized below.

The emissions of solid waste:
- The first step is to estimate waste amounts per year from different sectors. This includes MSW, ISW, municipal and industrial sludges, and CBW.
- Divide waste into different types according to the speed of decay. The waste is decaying, e.g. at the rate of slow, fast or default.
- Calculate the amount of emitted methane. This stage has three steps:
  - Calculate the amount of generated methane. For this employ the IPCC equations and guidance.
  - Calculate the amount of recovered methane.
  - Obtain emitted CH\(_4\) by substituting generated amount and recovered amount of methane into Eq. (27).

Wastewater emissions:
1. Calculate methane emissions of septic tanks, municipalities and industry using IPCC guidance.
2. Calculate nitrous oxide emissions of municipal, industry and fish farming.
3. Convert emissions into CO\(_2\)e by using characterization factors.
Emission calculations of composting are straightforward but require corrected input data from VAHTI system.

1. Make necessary corrections to initial activity data and obtain the amounts of composted waste.
2. Make use of gas-specific emission factors and multiply amounts of composted waste by emission factors.
3. Convert emissions into CO$_2$e by using characterization factors.

Emission projections for F-gases are made separately for each subsector and aggregated to obtain total emissions. Activity data is collected by Finnish Environment Institute through electronic surveys. However, the obtained activity data has to be further processed, e.g. missing data is imputed.
REFERENCES


### Abstract

The UN’s climate agreement and European Union necessitate evaluation of the policy sectors, the implementation of policy measures, and the achievement of the set goals. Last reporting about policies and measures for EU was done in 2011.

In this report the emission impact calculations of policies and measures targeting on waste sector and F-gases are described. Policy measures of these sectors fall in the remit of ministry of environment in Finland.

The procedure of calculations in waste sector is explained in detail from methods and required input data. The calculations include emissions related to solid wastes, waste waters and composting. The scenario calculations are done with the aid of Excel-spreadsheet at the Finnish Environment Institute. In addition, the report discusses briefly the economical assessment of waste sector that has been identified as a target for development.

In the second part of the report, the data collection, calculation and reporting process of the F-gases are explained. More detailed explanation of emission scenario calculations has been documented in two reports written at the Finnish Environment Institute. This report presents briefly the main sources in sub-sector emission scenarios and gives and overview about the calculations.

### Keywords
- greenhouse gases
- wastes
- F-gases
- emissions
- scenario
- policy measure
Calculations of greenhouse gas emissions of waste sector and F-gases for policy scenarios in Finland (Jätesektorin ja F-kaasujen kasvihuonekaasupäästöjen laskenta politiikkaskenarioita varten Suomessa)

Tiivistelmä

Tässä raportissa kuvataan jätesektorin sekä F-kaasuihin kohdistuvien politiikkatoimien vaikutusten arvioinnin liittyvää päästölaskentaa. Näihin molempiin kohdistuvat politiikkatoimet kuuluvat Suomessa ympäristöministeriön vastuualueeseen.


Raportin toisessa osassa osastetaan F-kaasuja koskevien datan kerua, laskentaa ja raportointia. Tarkempi päästöskenaarioiden laskenta on aiemmin dokumentoitu kahdessa eri Suomen ympäristökeskuksessa laaditussa raportissa. Tämä raportti esittelee tiivistäen käytetyt tiedot ja oletukset eri päästölähteiden skenaarioissa sekä yleiskuvauksen laskennasta.
**Sammandrag**


I denna rapport beskrivs utsläppsberäkningarna för politikåtgärder inom avfallssektorn och för F-gaser. Åtgärderna inom dessa områden hör i Finland till miljöministeriets ansvarsområde.


I rapportens andra del behandlas datainsamling, beräkningar och rapportering som gäller F-gaser. Den detaljerade beräkningen av utsläppsskenarier har publicerats i två skilda rapporter som gjorts upp vid Finlands miljöcentral. Denna rapport ger en översikt av beräkningarna och presenterar den information och de antaganden som de beräkningsmässiga skenarierna bygger på.

**Nyckelord**

växthusgaser, avfall, F-gaser, utsläpp, scenario, styrmedel
Finland is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. As a member of the European Union, Finland has reporting obligations also under the mechanism for monitoring European Community greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism, Decision 280/2004/EC of the European Parliament and the Council). According to the EU monitoring mechanism Member States have an obligation to prepare every two years a report including information on national policies and measures for the assessment of projected progress.

In this report the policy scenarios and greenhouse gas emission calculations of waste sector and F-gases are described. In the first part, the calculation procedure, main data sources and assumptions in waste sector are explained in detail. We also discuss briefly the economical assessment of waste sector that has been identified as a target for further development. In the second part, the data collection, calculation parameters and policy projection calculations of F-gases are explained briefly. More detailed description of methods and is available in reports of Finnish Environment Institute.