



Review of Default Emissions
Factors in Draft Stationary
Energy and Industrial
Processes Regulations:
Waste Combustion for the
Purpose of Generating
Electricity or Industrial Heat





Report to the Ministry
for the Environment

7 May 2009

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Task	Responsibility	Signature
Project Manager:	M Wells	
Prepared by:	M Wells	
Reviewed by:	J Thiele	
Approved for Issue by:	M Taylor	

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Prepared by:

Duffill Watts Ltd
 Level 1, John Wickliffe House
 265-269 Princes Street
 PO Box 910
 Dunedin 9054
 New Zealand
 Telephone: +64 3 477 7133
 Fax: +64 3 477 4236
 E-mail: dunedin@duffillwatts.com

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TABLE OF CONTENTS

EXECUTIVE SUMMARY		1
1.0 INTRODUCTION		1
2.0 OBJECTIVES OF REPORT AND OVERVIEW OF CONTENT		1
3.0 EMISSION FACTOR DATA AND REVIEW APPROACH		2
3.1 EF Units, Calorific Values, Biomass		3
4.0 RESULTS – REVIEW OF EMISSION FACTORS		5
4.1 Overview of EF Classifications and Associated Energy Sector		5
4.2 Emission Factor Review		6
5.0 DETERMINATION OF UNIQUE EMISSION FACTORS		7
5.1 Summary of Accepted Methods		7
5.2 Description of Methods		7
5.3 Method Choice and Reliability		9
5.4 Methods Implementation – Data Requirements, and Collection		9
5.4.1 Stack Testing of Emissions (CEM and Periodic Source Testing)		10
5.4.2 Fuel Sampling and Analysis (All Methods)		11
5.5 Calculations		14
5.5.1 Stack Rate of Mass Emissions Formula		15
5.5.2 Calculated Mass Emissions Formula (CO ₂ only)		15
5.5.3 Calculation of EFs		16
5.5.4 Example Calculations		16
5.6 Quantification of Uncertainty		18
5.7 Reporting, QA/QC and Verification		19
6.0 CONCLUSIONS		20
7.0 REFERENCES		20
APPENDIX 1		
Data Sheets		

List of Common Acronyms

API	American Petroleum Institute
AS	Australian Standard
ASTM	American Society for Testing and Materials
BANZ	Bioenergy Association of New Zealand
CEN/TS	Comité Européen de Normalisation (European Committee for Standards – Technical Specification)
EF	Emission Factor
ETS	Emission's Trading Scheme
GCV	Gross Calorific Value
GHG	Greenhouse Gas(es)
GHGI	Greenhouse Gas Inventory
GPA	Gas Processors Association
GPG	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
IPCC	Intergovernmental Panel on Climate Change
IPCC Guidelines	Revised 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual
ISO	International Standards Organisation
kt/PJ	kilotonne per PetaJoule
MSW	Municipal Solid Waste
NAEI	National Atmospheric Emission Inventory (United Kingdom)
NCV	Net Calorific Value
NZS	New Zealand Standard
PDF	Probability Density Function
PEM	Predictive Emission Modelling
SEIP	Stationary Energy and Industrial Process
TDF	Tyre-derived fuel
UEF	Unique Emission Factor
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

This report sets out the results of a work programme to review default emission factors (EF) in the Draft Stationary Energy and Industrial Processes Regulations with regard to waste combustion generating electricity or industrial heat. In addition, the report outlines the methods available for New Zealand Emissions Trading Scheme participants to use for development of unique emission factors. Though waste combustion represents a relatively small proportion of New Zealand's energy use, this proportion is growing and likely to continue given the increasing importance of alternative fuels and sustainability.

1.0 INTRODUCTION

Climatic change and how it impacts sustainability is one of the most important global issues of our time, and increasingly governments and the private sector alike will need to demonstrate responsibility for greenhouse gas (GHG) emissions. The Ministry for the Environment (MfE) is New Zealand's principal adviser on environmental sustainability and related international matters that affect the environment and is interested to facilitate emissions trading incentives for New Zealanders to develop and apply GHG-friendly processes and technologies. As part of the development of a New Zealand Emissions Trading Scheme (ETS), Draft Climate Change Regulations have been developed to set out methods for those involved in Stationary Energy and Industrial Process (SEIP) sectors to monitor and calculate emissions from their activities. Calculating emissions requires an emission factor (EF), which expresses the emission of GHGs relative to the intensity of a specific activity. In the SEIP sector, one area of activity is the combustion of waste to produce electricity or industrial heat. Such activities include, for instance, combustion of waste oil, combustion of used tyres (notably in cement kilns), and combustion of wood wastes.

In order to obtain accurate and up-to-date estimates of emissions, it is necessary to periodically review emissions factors. In 2003, the Energy Modelling and Statistics Unit of the Ministry of Economic Development (MED) commissioned a review of energy sector GHG emission factors (Hale & Twomey, 2003) and the information from this work was used to include a schedule of default EFs for calculation of emissions from waste combustion. A recent NZ ETS Bulletin (No. 8, MfE, 2008) reports that the proposed approach to emissions calculations in the Draft Climate Change (SEIP) Regulations provide flexibility for use of default EFs, while also allowing ETS participants to apply for unique EFs (UEFs) specific to their own particular activities. Following on to this, the MfE has identified a need to review default EFs for waste combustion activities and to develop appropriate mechanisms for participants to apply for UEFs. This strategy will best assist companies to identify risks and challenges associated with the evolving climate change arena, as well as opportunities to develop proactive business opportunities.

2.0 OBJECTIVES OF REPORT AND OVERVIEW OF CONTENT

As per the participant-responsive strategy discussed above, the objectives of the present work are 1) to review default emissions factors for updating the NZ-ETS draft Climate Change (SEIP) Regulation's methods and 2) to review ways in which participants can apply for UEFs. With regard to the default EFs, the existing values are assessed against existing and new information with regard to combustion technology, fuel type, and GHG. The specific GHGs under

consideration here are carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄). With regard to UEFs, the overarching goal is to identify robust and participant-responsive methodologies for arriving at acceptable UEFs for use in lieu of the defaults. Discussed separately, but integral to the effort for both objectives, there is an overview of tests that can be done to estimate greenhouse gas emissions from combustion of different waste types for electricity or heat, including measurement methods and calculations and accuracies and uncertainties of same. This report covers SEIP activities, and hence explicitly does not consider waste disposal (e.g. landfilling, incineration, etc.).

The information in this report is designed to further enhance the MfE's and MED's elucidation of a flexible ETS for New Zealand that will also ensure consistency and completeness in emission estimations. There are a number of acronyms that appear repeatedly through this report, and the most common of these are summarised above.

3.0 EMISSION FACTOR DATA AND REVIEW APPROACH

The point of departure in EF review was to examine existing default emission factor documentation. The document "Review of Energy Sector Greenhouse Gas Emissions Factors – Report to Energy Modelling and Statistics Unit, Ministry of Economic Development" (Hale & Twomey, 2003) was provided by the MED, along with all associated appendices and an updated (2007) MED spreadsheet (K. Tsui, Personal Communication, March, 2009) with the most recent EFs. These materials provided background on the original sources of all extant EFs, and any relevant calculations/unitary conversions. A review of this information was undertaken with regard to comparable emission factors from national and international sources. Key review factors included:

- Data Applicability
 - Applicable to the conditions associated with the emission source
 - Consistent with New Zealand source categories
- Data Quality
 - Accuracy and uncertainty
- Transparency
 - Identification of data sources
- Accepted practice (vide infra)
 - Intergovernmental Panel on Climate Change (IPCC)
 - United States Environmental Protection Agency's (US EPA) AP-42 documentation

Standards for data applicability and quality are evolving. Published default EFs represent an average, from a source designated as typical or representative, and therefore generally applicable to other similar emission sources. The Intergovernmental Panel on Climate Change (IPCC) distinguishes EFs according to three Tiers, with Tier 1 representing EFs across a very broad grouping of fuel type, sector, etc., and Tier 3 representing the highest level of disaggregation and specificity. The Tier system relates to applicability, but higher applicability also ensures an enhanced level of data quality with respect to emissions quantification. By analogy the US EPA (AP-42, US EPA, 1997) has a quality rating system for EFs, and grades range from 'A' (highly reliable) to 'E' (least) according to the reliability of tests used to develop the EFs and the amount and quantity of data employed in their derivation.

The fuels considered in the present report are highly heterogeneous, and emissions likewise highly variable with equipment type, efficiency, vintage, and operational conditions. Emissions of CH₄ and N₂O are particularly sensitive to factors that influence combustion efficiency. As possible, EFs were scrutinised with respect to applicability and quality and relevant notations given. With regard to transparency, data sources are cited as appropriate throughout this report. In all cases an attempt was made to obtain primary reports documenting EF derivation, however, due to time constraints, primary reports were not always obtainable; citations are made to the source material from which data was extracted.

Best/accepted practices have been a further consideration in EF review and preparation of this report. Key documents include:

- IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories publication (IPCC, 2000)
- US EPA Procedures for Preparing Emission Factor Documents (US EPA, 1997)

3.1 EF Units, Calorific Values, Biomass

The IPCC GPG dictates that EFs should be based on net calorific values (NCVs), however, New Zealand employs gross calorific values (GCVs) for energy statistics. This report utilises the convention that

$$\begin{aligned} \text{NCV} &= 0.95 * \text{GCV} && \text{– for coal and liquid fuels} \\ \text{NCV} &= 0.90 * \text{GCV} && \text{– for gas} \end{aligned}$$

This convention was adopted in the 2003 EF review report following OECD / IEA assumptions (Organisation for Economic Cooperation and Development / International Energy Agency). Similarly, that report recommended the use of kilotonne/PetaJoule (kt/PJ) as the standard unit of expression for emission factors, and this unit is used here.

Most published EFs used in national GHG Inventories (GHGIs) are reported in units of mass GHG/energy. However, most EFs published for use in ETSs are reported in units of mass/mass, specifically tonnes CO₂-e/tonne fuel. The existence and persistence of the two types of units relate to different sets of needs and perspectives. Both units are likely to remain in common use. On one hand, mass/mass units are typically more accessible to ETS participants. On the other hand, a realistic emissions inventory demands units in mass/energy because energy is the ultimate driver of emissions. Though fuel is, for instance, imported in terms of mass or volumes for which the associated mass is readily quantified, it is consumed according to the amount of energy obtained and needed. Therefore, accurate understanding of global emissions depends on mass/energy units, and this practice emerges as common.

As a result of having two different types of EF unit in common use, any comparison of EFs from multiple data or publication sources will require the use of a single unit, i.e. any values not reported in the unit of choice will require conversion. Mass/mass units are converted to mass/energy using a calorific value (and vice versa). Therefore, in order to obtain an accurate conversion, the calorific value used must itself be accurate and representative of the fuel in question. If a weighted average of calorific values can be obtained for any given fuel, then the conversion will be, on average, correct. However, for any particular emissions source or facility, if the average calorific value is quite different from actual, i.e. the specific case at hand, this will result in considerable inaccuracy in the source emissions inventory. Further, uncertainties in calorific value and emissions factor can propagate in the conversion and magnify differences in compared emissions factors (particularly problematic for CH₄ and N₂O EFs, as in the case of wastes there is considerable uncertainty in both EF and average calorific value). To address

this issue it is necessary to ensure that the calorific value of fuels are measured, and increasingly this is required as routine for ETS participants (e.g. Australia).

With respect to calorific values, GCV is measured with confidence using bomb calorimetry. As with the discussion of units above, GCV may be accessible inasmuch as it is easy to measure, but it is not representative of the dynamics of energy use and emissions because it does not reflect the actuality of energy lost in a stack due to vaporisation of water. The conversion factors listed above are rough rules of thumb, but could potentially introduce errors of up to 5% for fuels with highly variable water content, e.g. wood (wet vs. dry) and certain solid organic wastes. Thus for instance, in one report, the World Business Council has acknowledged “the importance of using site specific lower heating values, due to the changing composition of fuels over regions and time”, and certainly this practice is not only more realistic, but obviates in large part the need to have highly disaggregated emissions factors as a result of the increased variability that can result from use of GCVs. Though New Zealand and Australia presently use GCVs and EFs based on GCVs, most other countries with similarly developed GHGI practices use NCVs and this report recommends that New Zealand revisit this issue.

Due to the heterogeneity of some fuels considered here, and the need to convert between mass/mass and mass/energy units and between GCV and NCV EFs, it is usual to expect higher variability in reviewed EFs than for other fuels whose properties are less variable and also known with greater confidence. For the purpose of EF comparison, all calculations/conversions reflect the appropriate use of significant figures where uncertainties are known or estimated. Round-off occurs after calculation to avoid round-off error. In all other instances or in the absence of further information, data is reported without alteration.

A potentially confounding issue with respect to EFs for certain wastes is whether the EF is to be integrated over waste composition and how biogenic carbon is considered. So, for instance, the present default factors for New Zealand distinguish between organic and non-organic wastes, with the former default EF corresponding to the IPCC designation for municipal solid waste (MSW) – biomass. Instead of having a biomass and non-biomass EF for MSW, some countries require reporting of average waste stream contributions, such that a single MSW combustion EF is multiplied by a factor representing the non-biogenic contribution. Similar international practices pertain to fuels such as tyre-derived fuel (TDF), though again, New Zealand explicitly separates this. The issue of how biomass is handled potentially adds an additional component of data to be collected in some cases – i.e. the percentage of biogenic carbon must be determined for exclusion of short-cycle CO₂ from emissions. Two methods for determination of biogenic carbon, recognised by the Australian Government Technical Guidelines (2008) are Comité Européen de Normalisation (European Committee for Standards – Technical Specification) (CEN/TS) 15440:2006, and ASTM D6866-06a. The latter method is more accurate, but as it involves carbon-14 measurements is restricted to specialised facilities. Regarding the Draft Regulations, the question of determination of biomass fraction relates to emissions inventory and does not influence the practices necessary for participants to apply for UEFs (i.e. since the biomass fraction is explicitly subtracted from emissions in the present Draft Regulations). Due to varying international practices however, procedural differences in biomass accounting at an international level (i.e. biomass/non-organic aggregated EFs) will result in higher variability in published EFs for certain waste classes.

4.0 RESULTS – REVIEW OF EMISSION FACTORS

4.1 Overview of EF Classifications and Associated Energy Sector

The current classification of waste combustion (SEIP) activities in New Zealand, by EF, is (corresponding IPCC categories listed in parentheses).

- Used oil and waste oil
 - Non-organic used or waste oil (“Waste Oils”)
 - Organic used or waste oil (“Municipal Wastes – biomass fraction”)
 - Blended organic or non-organic used or waste oil (“Waste Oils”)
- Used tyres (“Industrial Wastes”)
- Non-organic waste (“Municipal Wastes – non-biomass fraction”)
- Organic waste
 - Wood (“Wood/ Wood Waste”)
 - Biogas (“Biogas”)
 - Organic waste other than wood or biogas (“Municipal Wastes – biomass fraction”)

Based upon review of international EFs and waste combustion activities in New Zealand, this represents a level of aggregation that largely exceeds the scope of present national activity, but is in keeping with the IPCC categories and probable future needs. For instance, used tyres and/or tyre-derived fuel (TDF) are a material utilised elsewhere, particularly as a fuel supplement to cement kilns, but is not yet a fuel in use in New Zealand. Similarly, in the category of non-organic waste, the German Federal Environment Agency (2007) provides an EF for combustion of polystyrene, but background research for this report did not reveal any New Zealand activity for combustion of non-organic wastes. Most of the present New Zealand EFs are set at IPCC defaults, though as noted in Data Sheets (vide infra) there are apparently some minor deviations.

At present, waste combustion is a very small percentage of New Zealand energy use for electricity and heat. According to data from the New Zealand Energy Data File (MED, 2008), the total New Zealand contribution of “other” renewables and waste heat” is less than 7% of the national primary energy supply for 2007; as this figure includes solar, wind power, and wood energy (inclusive of non-waste materials), the actual figure for the wastes considered here is much lower. For electricity generation, data from this report indicates that ~ 0.1, 0.47, and 1.3 % of energy in 2007 was sourced from waste heat, biogas, and wood, respectively. Data from the Bioenergy Association of New Zealand’s (BANZ) heat plant database (2008), also cited in the New Zealand Energy Data File, indicates that heating fuel is sourced at 29.5, 0.36, 0.03, and 1.46 %, respectively, for wood/wood byproducts, biogas, “other” organic waste (e.g. tallow, husks), and oil/diesel (data for heat plants > 100 kW thermal capacity in the following sectors: wood processing, dairy, metal processing, food and beverage processing, hospitals, other manufacturing). These numbers represent the percentage of heating fuel in aggregated categories. The entire aggregated category of oil/diesel (1.46 %) is small, hence the share for waste oil will be negligible. For wood and wood byproducts, the percent share for wood waste is negligible for all sectors surveyed with the exception of the wood processing sector. For the wood processing sector, wood waste is about 40% of the sector share, or ~16% of the total. In summary, none of the wastes in consideration here represent a key source category at this time; wood waste may be poised to become a more substantial source of future emissions, but biomass is counted as carbon neutral with reference to CO₂.

4.2 Emission Factor Review

Per the 2003 EF report, Appendix 1 contains Data Sheets for each EF considered in this review; these data sheets matrix EFs by GHG and by fuel type; any information relating to combustion technology is listed on each form. The original template has been adapted slightly and details all the relevant considerations and findings pertinent to each individual EF, and the detailed findings outlined in the Data Sheets are summarised here.

Generally at the international level, and compared to other categories of activity in the energy sector, there is not a great deal of data on waste combustion. This appears to be a logical consequence of two considerations – first, there is apparently no instance of a country wherein both GHGI reporting activities are mature and waste combustion is a key source category. Hence, data acquisition in this area is relatively lower in priority. Second, some waste materials exhibit considerably more heterogeneity than conventional fossil fuels, and so there is a certain amount of data available but not comparable/standardised; levels and approaches to aggregation vary as well. At the international level, data is available via publications in the peer-reviewed literature and via selected agencies. For New Zealand however data for waste combustion is even more sparse. Some private entities nationally are potentially gathering test data on emissions and a number were contacted during preparation of this report. These contacts typically resulted in one of three outcomes: the individual or organisation contacted 1) did not have relevant data, 2) declined to share data, or 3) did not respond to requests. In two instances industrial contacts were quite helpful in assisting with information and/or information about source materials but requested anonymity and confidentiality of their information. It is anticipated that, in future, the ability for ETS participants to apply for UEFs will partially rectify the absence of publically obtainable data.

The greatest amount of data found was for combustion of oil products, either similar to waste oil or explicitly designated as waste oil. For one of these EF categories, the New Zealand defaults are on the low side, hence not conservative. On the other hand, for TDF the New Zealand default appears to be high. Despite such differences in reviewed EFs and the present New Zealand defaults, this report recommends retention of the default values as such in all cases. This recommendation is made based upon the rationale that deviation from the IPCC defaults should be empirically justified and is most critical for key source categories. At present, no key source category is implicated and uncertainties associated with the EFs in question are relatively high.

High uncertainties, where quantifiable, are observed even for CO₂. Carbon content and fuel calorific value can be determined with high precision for individual samples, but uncertainties associated with the variability in fuel composition can be high. As both of these values (carbon content and fuel calorific value) may be used in determination of CO₂ EFs, error in each can exacerbate EF error via error propagation.

With regard to EF reporting units, this report follows the convention, also increasingly used internationally and recommended in the 2003 EF report, of using mass/ energy units, specifically kt GHG/PJ is used for EFs throughout this report. Most participants will be utilising fuel on a mass or volumetric basis, and emissions can be quantified in mass or volumetric basis as well. Thus the Draft Regulations EFs in mass/mass terms (with the simple conversion for global warming potential) is highly practical. However, converting from the IPCC units (mass/energy) for the defaults then requires a fuel calorific value. As noted in Section 3.1, the process of averaging, i.e. use of averaged values, can lead to high uncertainty associated with the average, and this uncertainty is propagated through the unit conversion. Propagated error is quantifiable by mathematical first principals (as discussed in the IPCC GPG) and as a statistical measure of uncertainty does not arise from a flaw in performance of calculations. Since approximately half the comparison EFs shown in the data sheets were reported in mass/mass, the other half in mass/energy, uncertainties in fuel calorific values will continue to be an issue in EF uncertainty

and EF review no matter what units are chosen as standard. Probability density functions (PDFs) have been reported for most of the source categories (Norwegian Pollution Control Authority, 2006), and, as possible were employed to calculate EF uncertainty. These results are noted as appropriate on Data Sheets.

5.0 DETERMINATION OF UNIQUE EMISSION FACTORS

5.1 Summary of Accepted Methods

As with EFs themselves, considerations for methods for EF determination revolve around specific GHG, fuel type, and combustion technology. Carbon dioxide from fuel combustion is effectively determined by fuel carbon content, and this can be measured with reasonable accuracy. Non-CO₂ emissions (CH₄ and N₂O) from combustion are typically vanishingly small compared to CO₂ but are subject to much greater uncertainty and variability. Comments on these general considerations are offered as useful in detailed consideration of methods below.

Two common hierarchies relating to emission estimation approaches are published by the American Petroleum Institute (API, 2004) and the US EPA (AP-42), respectively. While there are some differences between the two, there is a general correspondence. Figure 1 combines and summarises these with respect to the methods for determining emission factors and a brief description of each follows in the next section.

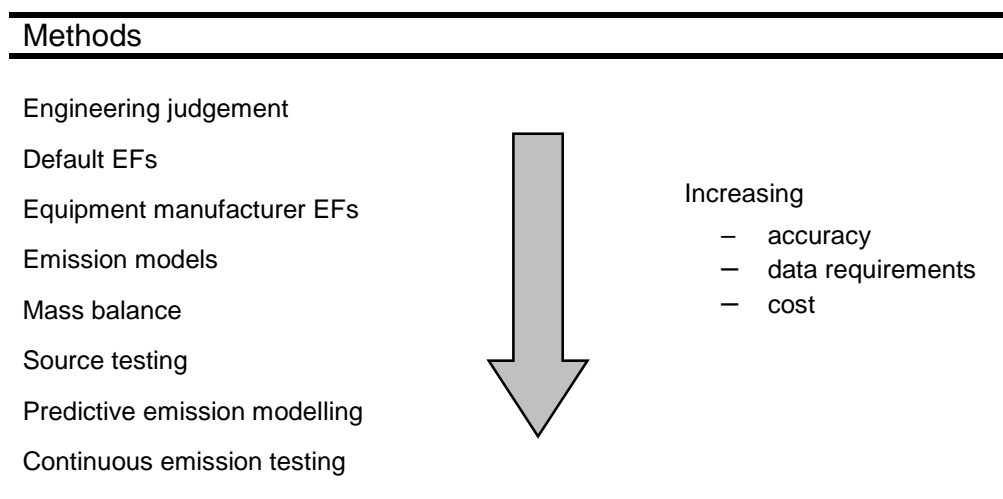


Figure 1 – Hierarchy of methods for EF determination.

5.2 Description of Methods

Engineering Judgement

EFs are estimated from basic principles of engineering, chemistry and physics, expert judgement, site-specific knowledge of the chemical and physical processes involved, and knowledge of design features of the combustion technology.

Default EFs

The reliability of default estimates depends on combustion process complexity and variability of site/process/industry specific emission characteristics; default EFs are derived from testing of

representative sources, but the term representative is relative and thus not applicable to many specific installations.

Equipment Manufacturer EFs

Increasingly emissions characteristics are measured by equipment manufacturers; the reliability of these will vary depending upon the duration of testing and the accuracy of methods used. To derive emissions factors, information on the quantity and composition of fuel is also needed, and actual fuel used at specific installations may differ substantively. Generally speaking actual EFs from manufacturers are not commonly available.

Emission Models

Algorithms or correlations developed to estimate emissions are available for some industry sectors or specific equipment from process designers, government agencies and others; these require detailed data input such as equipment specifications and process conditions. Examples include U.S. EPA TANKS and Water9. No such models are presently in routine use for waste combustion.

Mass Balance

As the term implies, this approach requires accounting for all of the materials going into and coming out of the combustion process. Mass balance can vary greatly in reliability, depending upon material combusted and combustion product of interest. In general, mass balances are appropriate for use in situations where a high percentage of material is lost in combustion and where the gas emitted is not substantially consumed or chemically recombined during the process, i.e. *it is very suitable for CO₂, but inferior to default EFs for CH₄ and N₂O.*

Source testing

A volume of the stack/flue gas is collected and the corresponding exhaust flow rates, moisture content, temperature and other parameters are measured, usually via standard test methods as possible, and this information is used to calculate emissions. At the same time, the fuel composition and quantity must be measured; EFs are calculated from fuel input leading to the measured emissions. Since the resulting EFs extrapolate a few hours' snapshot testing to a relatively long-term use EF, it is important that representative operating conditions are used.

Periodic Source Testing

As with source testing, but repeated periodically.

Predictive Emission Modelling (PEM), not to be confused with periodic emission measurement)

This is an emerging method, not yet in frequent use, but a subject of increasing research and likely to provide a less expensive and robust tool after the initial expense of development and validation. The approach typically hybridises emission modelling (above, tendency toward more theoretical) with continuous monitoring (most accurate). In this approach, modelling is combined with long-term accurate monitoring to develop a mathematical relationship between emissions and some measurable operating parameters or predictors (e.g. fuel use). The approach has the potential to be very accurate if model development employs data that reflect the range of actual operating conditions; to be effective a predictor is required that can be reliably measured.

Continuous Emission Monitoring (CEM)

Similar to source testing albeit with continuous measurement of stack/flue gas composition, flowrate, etc. May require adherence to stringent protocols to ensure accuracy of continuous measurements and is therefore comparatively expensive. To derive EFs, fuel composition and quantity must also be monitored and recorded with some degree of regularity. Though nominally considered most accurate for emissions testing, the API has questioned the suitability of CEM for GHG emissions applications, noting however that the CEM approach is still preferable to default EFs.

5.3 Method Choice and Reliability

Of the methods listed above, reliability of any single approach will vary greatly from scenario to scenario. The United States Department of Energy's (US DOE's) Office of Policy and International Affairs recently published updated technical guidelines for voluntary reporting of GHGs, and this document contains a method rating system that is generally representative of approaches internationally. Ratings 'A' to 'E' are assigned ordinal values (4 to 1), with 4 representing the most reliable (highest accuracy, verifiability) and 1 the least. In this scheme, emissions must be determined with an average rating at the level of 3 or higher for any reporting year in order for recorded reductions or sequestration to qualify as "registered" reductions. EFs based on a single measurement (single source test) rank as 2, therefore are not appropriate for ETSS. In the New Zealand context, emission modelling and PEM are not mature enough to be promising for near-term adoption with respect to waste combustion. This leaves mass balance (for CO₂ only) and periodic source testing or CEM as suitable methods for UEF development. Methods specifically rating 4 and 3, as designated by the US DOE, are consistent with assessments made in method review for the present report, and this report's recommendations for methods to be used for UEF applications are as follows:

- For CO₂
 - CEM or mass-balance derived EFs (actual fuel composition), regulatory agency supervised (best)
 - Publicly documented and widely reviewed EF adopted by public agency, standards organisation or industry group (good)
- For CH₄ and N₂O
 - CEM derived EFs (best)
 - Unit-specific EFs based on periodic and site-specific measurements (good)
 - Publicly documented and widely reviewed EF adopted by public agency, standards organisation or industry group (good)

Choice of method will depend on the level of reliability deemed acceptable and ease of method implementation. To ensure optimal flexibility for users, the US DOE accepts submissions from individual users that document alternate practices for evaluation and possible acceptance. In return for this flexibility the agency reserves the right to incorporate alternate methods into future revisions of programme documentation.

5.4 Methods Implementation – Data Requirements and Collection

In all cases, to calculate an EF users will require:

1. Their emissions of each GHG (stack testing, or in the case of CO₂ this may be calculated) and
2. The amount of energy associated with these emissions (determined from fuel quantity and energy content).

An overview of the data to be collected for the methods recommended above is

- For CEM
 - A sensor monitoring GHG concentration
 - A flow monitoring system to determine stack/flue gas flow
 - Fuel quantity measurements
 - Fuel calorific values
- For periodic source testing
 - Same as for CEM, averaged over appropriate measurement period

- For mass balance
 - Carbon content based on energy units, or
 - Carbon content of fuel and fuel heat value

Additionally there will in most cases be unit conversions and physical factors needed, particularly for gas stream calculations where a defined physical standard is needed (see for instance API). Except for unit conversions and standard conventions, taken as exact, for every datum collected there is an associated uncertainty that must also be collected for uncertainty analysis. A specific summary of representative methods follows here. This summary is consistent with the Australian standard (2008), which is well suited to New Zealand.

5.4.1 Stack Testing of Emissions (CEM and Periodic Source Testing)

Stacks may be monitored by CEM or by periodic stack testing according to the directives below. For a UEF application to qualify, the documented UEF uncertainty should not exceed the relative uncertainties associated with DEF values for the particular fuel class involved.

Stack Frequency of Measurement

Measurements must be taken frequently enough to ensure that data is representative and accurate. CEM enables more frequent measurement and the number of readings should reflect this. CEM equipment must operate for more than 90% of the period for which it is used to monitor emissions, and measurements for any single GHG should be made at least every 30 minutes during operation. Downtime for calibration of CEM equipment may be excluded, and if the CEM equipment is not operating for a period (within the 90% constraint), readings taken during periods when the equipment was operating may be used to estimate data on a pro rata basis for the period that the equipment was not operating.

The method of periodic stack testing may also be used as long as the principle of sufficiency is demonstrated. Sampling must be undertaken during the year for a sufficient duration to produce representative data that may be reliably extrapolated to provide estimates of emissions across the full range of operating conditions for that year. Participants are required to document the testing frequency and to provide demonstrated justification of same.

Sampling Positions for Stack Testing Equipment

Sampling positions for stack measurements must be selected according to a recognised standard or set of standard specifications as published by a standards organisation. Acceptable standards for sampling positions are:

- AS 4323.1—1995. *Stationary Source Emissions - Selection of Sampling Positions.*
- AS 4323[1].1—1995 Amdt 1-1995. *Stationary Source Emissions - Selection of Sampling Positions.*
- ISO 10396:2007. *Stationary Source Emissions - Sampling for the Automated Determination of Gas Emission Concentrations for Permanently Installed Monitoring Systems.*
- ISO 10012:2003. *Measurement management systems - Requirements for Measurement Processes and Measuring Equipment.*
- USEPA – *Method 1 – 2000. Sample and Velocity Traverses for Stationary Sources* (2000).

Measurement of Stack Flow Rates

The volumetric flow rate for stacks must be taken according to a recognised standard or set of standard specifications as published by a standards organisation. Acceptable standards are:

- ISO 10780:1994. *Stationary source emissions — Measurement of Velocity and Volume Flowrate of gas streams in ducts.*
- ISO 14164:1999. *Stationary Source Emissions — Determination of the Volume Flowrate of Gas Streams in Ducts – Automated Method.*

USEPA – Method 2 – 2000. *Determination of Stack Gas Velocity and Volumetric Flowrate (Type S Pitot tube)* (2000).

USEPA – Method 2A – 2000. *Direct Measurement of Gas Volume Through Pipes and Small Ducts* (2000).

Measurement of GHG Concentrations in Stacks

GHG gas concentrations must be taken according to a recognised standard or set of standard specifications as published by a standards organisation. Acceptable standards are:

ISO 12039:2001. *Stationary Source Emissions — Determination of Carbon Monoxide, Carbon Dioxide and Oxygen — Performance Characteristics and Calibration of Automated Measuring System.*

USEPA – Method 3A – 2006. *Determination of Oxygen and Carbon Dioxide Concentrations in Emissions from Stationary Sources (Instrumental Analyzer Procedure)* (2006).

USEPA – Method 3C – 1996. *Determination of Carbon Dioxide, Methane, Nitrogen, and Oxygen from Stationary Sources* (1996).

Performance Characteristics of Equipment

Performance characteristics of stack testing equipment must be verified by an independent third party that is:

- An accredited laboratory, or
- A laboratory that meets requirements equivalent to ISO 17025.

Calibration gases used in characterisation of stack testing equipment must be certified by an accredited laboratory accredited to ISO Guide 34:2000 as being within 2% of the concentration specified on the cylinder label.

5.4.2 Fuel Sampling and Analysis (All Methods)

Note – carbon content analysis is only necessary for calculated CO₂ EFs.

Requirements for Sampling Solid Fuels

Samples of solid fuel should be composites of solid fuel combusted (composited with sufficient frequency to constitute a representative sample) and such composite samples should be collected at minimum monthly. Values obtained from samples must only be used with reference to a consignment of fuel sampled. If a delivery of fuel lasts for a month or less, analysis must be conducted on a delivery basis, however exceptions may be made if the participant can demonstrate that fuel properties do not change significantly between deliveries. Similarly, if a consignment lasts from more than a month, and the participant can demonstrate that uncertainties in fuel properties are low, the participant may apply for less frequent sampling. Appropriate sampling standards should be used, as noted below, and bias should be eliminated per standard directives. Sampling standards include:

- Industrial materials derived from fossil fuels, tyres and TDF – CEN/TS 14778 - 1:2005; CEN/TS 15442:2006
- Non-biomass municipal materials – CEN/TS 14778 - 1:2005; CEN/TS 15442:2006
- Dry wood – CEN/TS 14778 - 1:2005; CEN/TS 15442:2006
- Green and air dried wood – CEN/TS 14778 - 1:2005; CEN/TS 15442:2006
- Biomass municipal and industrial waste materials – CEN/TS 14778 - 1:2005; CEN/TS 15442:2006
- A solid fuel may also be sampled in accordance with a standard that is equivalent to a standard set out above.

Measurement of Solid Fuel Consumption

Solid fuel combusted at a facility during the course of a year must be estimated. Suitable methods included inventory or measurement. Measurements should always be performed with equipment calibrated to a measurement requirement and inventories must be documented by delivery invoices and stockpile records.

Fuel quantities must be obtained in terms of mass and stockpiles in either mass or volume must be measured in accordance with recognised industry practice. If fuel stockpiles are measured in volumes, then the bulk density of the stockpile must be measured:

- In accordance with the procedure ASTM D/6347/D 6347M-99.
- If the stockpile does not exceed 10% of the annual solid fuel combustion from the operation of a facility a sample can be extracted from the stockpile using a mechanical auger in accordance with ASTM D 4916-89.
- If the stockpile exceeds 10% of the annual solid fuel combustion, the stockpile may be sampled by coring, measurement of the sample mass and core volume and subsequent determination of fuel density. Fuel mass is obtained given the fuel volume and density.

Analysis of Solid Fuels

Fuel samples should be analysed at minimum monthly using a suitable standard for analysis. For the combustion of waste materials including

1. industrial materials derived from fossil fuels, tyres and TDF
2. non-biomass municipal materials
3. dry, green or air dried wood, and
4. biomass municipal and industrial waste materials,

suitable methods are CEN/TS 15400:2006 (energy content) and CEN/TS 15407:2006 (carbon content). Participants may apply to use other standards with demonstrated equivalency, and all analyses should be performed by an accredited laboratory or a laboratory that meets requirements equivalent to ISO 17025.

Requirements for Sampling Gaseous Fuels

Samples of gaseous fuel should be taken at minimum monthly as derived from composites amounts of fuel combusted or sampled with a frequency to compensate for lack of compositing. Values obtained from samples must only be used with reference to a consignment or discrete source of fuel sampled. Appropriate sampling standards should be used, as noted below, and bias should be eliminated per standard directives. Sampling standards include:

- ASTM D5287 - 08 (2002) – *Standard Practice for Automatic Sampling of Gaseous Fuels*
- ASTM F307 – 02 (2007) – *Standard Practice for Sampling Pressurized Gas for Gas Analysis*
- ASTM D5503 – 94 (2003) – *Standard Practice for Natural Gas Sample-Handling and Conditioning Systems for Pipeline Instrumentation*
- GPA 2166-86 – *Methods of Obtaining Natural Gas Samples for Analysis by Gas Chromatography*
- ISO 10715:1997 – *Natural Gas Sampling Guidelines*.

Measurement of Gaseous Fuels and Consumption

Gaseous fuel use must be characterised as specified below. Participants may apply to use other methods with demonstrated equivalency. Equipment used in measurements must meet specified equipment requirements.

Compliant gas measuring equipment includes flow devices, flow computers and gas chromatographs. The following standards relate to flow devices and ensure that the maximum uncertainty in measurement is less than 1.5%:

- For orifice plate measuring systems — the publication entitled *American Gas Report No. 3* published by the American Gas Association or Parts 1 to 4 of the publication entitled *API 14.3* published by the American Petroleum Institute.
- For turbine measuring systems — the publication entitled *American Gas Association Transmission Measurement Committee Report No. 7* published by the American Gas Association.
- For positive displacement measuring systems — ANSI B109.3—1986.

Flow computers used for measuring purposes must record the instantaneous values for all primary measurement inputs and must also record instantaneous corrected volumetric flow, cumulative corrected volumetric flow, instantaneous uncorrected volumetric flow (for turbine and positive displacement metering systems), cumulative uncorrected volumetric flow (for turbine and positive displacement metering systems) and super-compressibility factor.

Gas chromatographs must be capable of performing gas composition analysis with an accuracy of $\pm 0.15\%$ for use in calculation of gross calorific value and $\pm 0.25\%$ for calculation of relative density, and include a mechanism for re-calibration against a certified reference gas.

All flow devices that are used by measuring equipment should, wherever possible, be calibrated for pressure, differential pressure and temperature to respective uncertainties of 0.25, 0.25, and 0.5 % (facilities using < 3500 GJ gas/day) or 0.1, 0.1, 0.25% (facilities using > 3,500 GJ gas/day or more). The calibrations must take into account the effects of static pressure and ambient temperature. The New Zealand Standard NZS 5259:1999 for gas measurement should be followed, or alternately a demonstrably equivalent standard.

For the purposes of gas measurement, standard conditions are taken as an air pressure of 101.323 kilopascals, an air temperature of 15.0 degrees Celsius; and an air density of 1.225 kilograms per cubic metre.

Analysis of Gaseous Fuels

Fuel samples should be analysed at minimum monthly using a suitable standard for analysis. For the combustion of gases including

1. landfill biogas
2. sludge biogas
3. other biogas, for electricity or heat,

suitable methods are ASTM D1826 — 94 (2003) ASTM D7164 – 05, ISO 6974 parts 1-6 (2000-2002), ISO 6976:1995, and GPA 2172 – 96 (energy content) and ASTM D1945 – 03, ASTM D1946 – 90 (2006), ISO 6974 parts 1-6 (2000-2001), GPA 2145 – 03, and GPA 2261 – 00 (gas composition). Participants may apply to use other standards with demonstrated equivalency, and all analyses should be performed by an accredited laboratory or a laboratory that meets requirements equivalent to ISO 17025:2005.

The density of a gaseous fuel must be analysed in accordance with ISO 6976:1995 or in accordance with a standard that is equivalent to that standard.

Requirements for Sampling Liquid Fuels

Samples of liquid fuel should be composites of liquid fuel combusted (composited with sufficient frequency to constitute a representative sample) and such composite samples should be

collected at minimum quarterly. Values obtained from samples must only be used with reference to a consignment of fuel sampled. If a delivery of fuel lasts for a quarter or less, analysis must be conducted on a delivery basis, however exceptions may be made if the participant can demonstrate that fuel properties do not change significantly between deliveries. Similarly, if a consignment lasts from more than a quarter, and the participant can demonstrate that uncertainties in fuel properties are low, the participant may apply for less frequent sampling. Appropriate sampling standards should be used, as noted below, and bias should be eliminated per standard directives. Sampling standards include

- ASTM D4057 - 06 – *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*
- ASTM D4177 – 95 (2005) – *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*
- ISO 3170:2004 – *Petroleum Liquids: Manual Sampling*

Measurement of Liquid Fuel Consumption

Liquid fuel combusted at a facility during the course of a year must be estimated. Suitable methods included inventory or measurement. Measurements should always be performed with equipment calibrated to a measurement requirement and inventories must be documented by delivery invoices and facility records.

Fuel quantities must be obtained in terms of mass and either mass or volume must be measured in accordance with recognised industry practice. If fuel quantity is measured in volume, then the bulk density of the fuel must be measured as well (ASTM D1298-99 2005). The density used for obtaining fuel mass must reflect fuel density at the temperature at which the fuel volume was measured.

Analysis of Liquid Fuels

Fuel samples should be analysed at minimum quarterly using a suitable standard for analysis. For the combustion of petroleum based oils, suitable methods are ASTM D240-02 2007 (energy content) and ASTM D 5291-02 2007 (carbon content). Participants may apply to use other standards with demonstrated equivalency, and all analyses should be performed by an accredited laboratory or a laboratory that meets requirements equivalent to ISO 17025:2005.

5.5 Calculations

Calculations will require users to have a basic math proficiency, knowledge of the units and unit conversions, and knowledge of the process represented, or to contract a suitable entity with such skills. Subsequent to general approaches, two example calculations are given below. These are representative of examples provided in, for example, API and US DOE (Department of Energy, 2007) documentation. Due to the varied nature of scenarios possible, the calculations included below are intended only as representative examples. In all cases, the basic recommended process is the same:

1. Emissions – determine mass of emissions in kt **or** determine mass of emissions in tonnes CO₂-e
2. Fuel – determine quantity of fuel combusted as energy (PJ) **or** as mass (tonnes)
3. Fuel – determine fuel calorific value for reporting
4. EFs – calculate EF in kt GHG/PJ fuel and convert to tonnes CO₂-e/tonne fuel **or** calculate EF in tonnes CO₂-e/tonne fuel
5. Sum EFs to obtain single EF for all emissions (carbon dioxide, methane, nitrous oxide)

Items 2 and 3 result from sampling and analysis as described in the previous section, and EFs are calculated as described below. Item 1 is calculated from sampling and analysis as described in the previous section and subsequent calculations as described below.

5.5.1 Stack Rate of Mass Emissions Formula

For CO₂, CH₄, or N₂O, the following formula should be used for stack data:

$$mr_{\text{gas type}} = \frac{mw_{\text{gas type}} \times P \times F \times C}{8.314 \times T}$$

where

$mr_{\text{gas type}}$ is the rate of GHG emitted in tonnes of gas type released per second,

$mw_{\text{gas type}}$ is the molecular mass of the GHG in tonnes per kilomole,

P is the pressure of the gas stream in kilopascals,

F is the flow rate of the gas stream in cubic metres per second,

C is the proportionate amount or concentration of the GHG in the gas stream (either in volume GHG/total volume or mass GHG/total mass units, but not in volume/mass or mass/volume), and

T is the temperature, in degrees Kelvin, of the gas.

The formula above assumes that all parameters are measured at the same time for any given measurement interval. Since for CEM measurement intervals are contiguous, i.e. measurement is continuous, the results from each measurement interval are averaged. The same is true for periodic source testing, though fewer values will contribute to the average.

Values for $mw_{\text{gas type}}$ are

44.01×10^{-3} for carbon dioxide and nitrous oxide, and
 16.04×10^{-3} for methane.

A mass of emissions, $m_{\text{gas type}}$, is obtained by multiplying the mass rate by the time interval of measurement, t , in seconds:

$$m_{\text{gas type}} = mr_{\text{gas type}} \times t$$

The result above is in tonnes GHG, which can be converted to kt GHG/s (divide by 1000) or this is converted to CO₂-e/s (for methane and nitrous oxide) as follows:

$$m_{\text{CO}_2\text{-e}} = 21 \times m_{\text{CH}_4}, \text{ and}$$

$$m_{\text{CO}_2\text{-e}} = 310 \times m_{\text{N}_2\text{O}}.$$

5.5.2 Calculated Mass Emissions Formula (CO₂ only)

Calculate CO₂ emissions from fuel quantity and carbon content according to the following formula:

$$m_{\text{CO}_2} = m_{\text{fuel}} \times \frac{m_{\text{carbon}}}{m_{\text{total}}} \times \frac{44}{12}$$

where

m_{CO_2} is the mass of CO₂ in tonnes,

m_{fuel} is the mass of fuel in tonnes,

$m_{\text{carbon}}/m_{\text{total}}$ is the fraction of carbon in the total amount of fuel (ranges from 0 to 1), and

44/12 is the ratio of how much CO₂ is produced per tonne carbon combusted.

For calculations in kt, this value in tonnes is divided by 1000.

5.5.3 Calculation of EFs

EFs are calculated as follows:

$$EF_{\text{GHG}} = \frac{m_{\text{GHG}} \text{ (tonnes CO}_2\text{-e)}}{m_{\text{fuel}}} = \frac{m_{\text{GHG}} \text{ (kt)}}{E_{\text{fuel}}}$$

where

EF_{GHG} is the emission factor for a particular GHG,

m_{GHG} is the mass of GHG emitted in tonnes CO₂-e or kt,

and E_{fuel} is the energy of fuel combusted in PJ.

If the EF is calculated in kt/PJ, this is converted to tonnes CO₂-e/tonne fuel by 1) for CO₂, multiplying by the calorific value (in GJ/t), 2) for methane, multiplying by the calorific value (in GJ/t) times 21, 3) for nitrous oxide, multiplying by the calorific value (in GJ/t) times 310.

The total emissions EF is

$EF_{\text{total}} = EF_{\text{CO}_2} + EF_{\text{CH}_4} + EF_{\text{N}_2\text{O}}$; the value for EF_{CO_2} is only added for fossil-based fuels, and not for biomass or organic fuels.

5.5.4 Example Calculations

Mass Balance Example:

Sample Calculation for CO₂ UEF for Combustion of Tyre Derived Fuel

Input Information:

A cement company combusts of 14,000 metric tonnes (14 kt) per year of used tyres or TDF in cement kilns (considered complete combustion). The carbon content and heat content (gross) of the specific TDF averages 69%, by weight, 29.0 MJ·kg⁻¹, respectively (Courtemanche and Levinis, 1998). The company will calculate their EF in kt/PJ in order to compare their obtained EF with internationally reported values, and will also calculate the EF in t CO₂-e/t for ETS inventorying.

Calculation Methodology:

1. Calculation of emissions output – the total amount of carbon dioxide released from complete combustion is

$$m_{CO_2} = 14 \text{ kt TDF} \times \frac{69 \% \text{ carbon}}{100 \% \text{ total}} \times \frac{44 \text{ kt CO}_2}{12 \text{ kt carbon}} = 35.4 \text{ kt CO}_2.$$

2. Calculation of energy input – this is calculated using the material input, material heat content, and appropriate conversion factors to obtain a final result in PJ:

$$14,000 \text{ tonnes TDF} \times \frac{1000 \text{ kg}}{1 \text{ tonne}} \times \frac{29.0 \text{ MJ}}{1 \text{ kg}} \times \frac{1 \text{ PJ}}{1,000,000,000 \text{ MJ}} = 0.406 \text{ PJ}$$

3. Calculation of emission factor – the emission factor is calculated as the output divided by the input, or

$$\frac{35.4 \text{ kt}}{0.406 \text{ PJ}} = 87.2 \text{ kt} \cdot \text{PJ}^{-1}.$$

This value is considerably lower than the default value of 135.85 kt/PJ, so the cement company should consider application for a UEF. In units of CO₂-e/t, the emissions in 1 are divided by the tonnes fuel used with appropriate unit conversions (i.e. 35.4 kt = 35,400 tonnes CO₂):

$$\frac{35,4000 \text{ t CO}_2}{14,000 \text{ t TDF}} = 2.53 \text{ t CO}_2 - \text{e} \cdot \text{t}^{-1} \text{ fuel}.$$

Periodic Source Testing Example:

Sample Calculation for CH₄ UEF for Combustion of Wood Waste

Input Information:

A sawmill company combusts 3600 metric tonnes (3.6 kt) per year of shavings in a grate fired boiler to produce heat. The following is known from limited stack testing under representative operational conditions: Flow rate = 0.283 m³·min⁻¹; Pressure = 1 atm (101.3 kPa); Temperature = 15°C (273 K); CH₄ content = 49 ppmv; Heating value = 21 MJ·kg⁻¹ (HHV, softwood, Ragland et al. 1991).

Calculation methodology:

1. Calculation of emissions output – the stack emissions formula is used, converting cubic meters per minute to cubic meters per second (0.0047 m³/s)

$$mr_{CH_4} = \frac{(16.04 \times 10^{-3}) \times 101.3 \times 0.0047 \times \left(\frac{49}{1,000,000} \right)}{8.314 \times 273} = 1.649 \times 10^{-10} \text{ t/s}$$

The rate is expressed in seconds, so to obtain an estimate of yearly emissions corresponding to this rate

$$m_{CH_4} = \frac{1.649 \times 10^{-10} \text{ t CH}_4}{\text{s}} \times \frac{31,536,000 \text{ s}}{1 \text{ year}} = 0.00520 \text{ t/year}$$

In CO₂-e this is

$$m_{CO_2-e} = 0.00520 \text{ tonnes} \times 21 = 0.109 \text{ tonnes CO}_2 - \text{e}.$$

Note that although the rate is in units of seconds, this will typically represent a measurement integrated or averaged over some discrete time period. However, this time period itself may not be long (e.g. 15 minutes) and so each individual measurement embodies the uncertainty of basing a year's emissions on 15 minutes worth of data. If the measurement is taken over a longer time period, then the result truly represents an average over the measurement period, but an average lacking information on variations about the average. The optimal solution is to take many measurements over discrete time periods to yield both an average and associated variations over time.

2. Fuel is expressed in mass as 3600 metric tonnes
3. Calculation of emission factor – the emission factor is then

$$\frac{0.109 \text{ tCO}_2 \cdot \text{e}}{3600 \text{ t}} = 0.00003 \text{ tCO}_2 \cdot \text{e} \cdot \text{t}^{-1}.$$

In this example the estimated UEF is approximately three orders of magnitude lower than the default; deviation in this degree would represent a discontinuity flag and hence special care in verification. For N₂O, the calculation would be performed identically, save for use of the appropriate molecular weight and the factor 310 instead of 21 in step 1.

5.6 Quantification of Uncertainty

In order to determine uncertainty in emissions calculations, EF uncertainty is needed. This in turn can be determined via 1) descriptive statistics on repeated EF determinations, or 2) propagation of error of average uncertainties associated with each variable quantity used in calculating EFs. For fuel use measurements, if the amount of fuel combusted is directly measured before use, then the resulting uncertainty should be fairly low, however, other methods of fuel measurement may not be (e.g. purchase or inventory records for waste oils). Though great emphasis is often placed on uncertainty in stack measurements, fuel calorific value can also be another source of high uncertainty for heterogeneous or composition variable fuels, thus the common practice of using country specific averages for fuel calorific values may be a source of error in some cases. There is a strong tendency to convolute problems with accuracy and problems of precision, as the two are inextricably linked with regard to emissions. While precision is straightforward to quantify, given the appropriate level of data collection, determination of accuracy requires a true value and hence injection of systematic errors (affecting accuracy) are a greater source of concern and difficult to detect. Use of published rather than measured fuel heat values then are an example of a practice that is liable to inject systematic error. Therefore, this should be avoided as possible if doubt exists as to their relevance to a specific fuel source.

There are a number of very good standards for measurement of relevant quantities as outlined in Section 5.4, and the use of direct measurements via standardised procedures will greatly reduce concerns associated with injection of systematic error. Similar remarks pertain to random measurement errors. Generally, various categories of sampling error contribute substantially to uncertainty, therefore, the use of standardised methods for sampling, in addition to analysis, are important to understand and quantify statistical uncertainty. The issue of fuel heterogeneity requires both a sampling method (to capture a suitable sample for analysis) and sampling programme (to capture fuel heterogeneities over large masses and over time) to sufficiently capture uncertainties inherent in carbon content and calorific value. Stack testing is a mature field and thus there are a number of standardised methods for both sampling and testing (representative examples above). As the results from stack testing involve use of

multiple collected data (i.e. least direct), propagated error is typically large. All of these considerations argue strongly for restriction of UEFs to those based on data obtained following standard methods whenever possible (i.e. the majority of applications considered here), as standard methods incorporate validated directives for determination of uncertainty.

5.7 Reporting, QA/QC and Verification

Reporting should fully document all data collected, any calculations, and all assumptions made in estimations (e.g. aggregation, averaging, time periods of measurement, etc.).

There are a number of components that can be included in QA/QC and verification. For QA/QC, full and transparent documentation must be the foundation of any programme. For standardised procedures for measurements, QA/QC procedures to be followed are given, as well as directives for quantification of uncertainty. Guidance documents such as the US EPA's Climate Leaders series (2008) further provide specific information on QA/QC relating to data treatment and calculations at a very detailed level (e.g. data entry, unit checks, evaluation of calculation results, etc.). Organisations that have established quality programmes such as ISO 9001, or similar, will be able to institute necessary procedures for documentation and data checking within that framework.

With respect to verification, common avenues include:

- Examination of QA/QC documentation for all measurement associated EFs on a site specific and fuel specific basis.
- Examination of QA/QC documentation for all UEF calculations by an external examining expert.
- Assessment of fuel consumption data against purchasing and/or inventories, as appropriate
- Cross validation of method UEF by alternate method.
- Comparison of relative UEF value to defaults; trend (lower, higher, magnitude of difference) should agree with qualitative expectations.
- Comparison of UEF to those calculated or obtained from the fuel supplier or other (related or comparable) industry group.
- Comparison of UEF over time for consistency and/or reasonable trends in variation.
- For site-specific or technology specific UEFs, intercomparison with like facilities nationally.

The various verification activities should produce a self-consistent result. Any lack of consistency represents a discontinuity flag, which then requires further examination to determine the underlying cause for inconsistency. Though participants may wish to engage in their own verification procedures, verification should in all cases be supervised or overseen by an independent third party.

6.0 CONCLUSIONS

Findings and recommendations from this report are as follows:

- In reviewing the present default EFs, no justification was found to warrant deviation from IPCC defaults.
- NZ-ETS participants may in some cases benefit from application for an UEF, and such application should be based on mass balance (CO₂ only), periodic source testing, or CEM.
- Standardised methods should be utilised in sampling, analysis, data collection, record keeping and reporting, and verification should involve external oversight.
- While Draft Regulations are given in terms of tCO₂-e/t fuel, aggregated for carbon dioxide, methane and nitrous oxide, most international sources publish EFs in units of mass/energy, which is a functional or fit-for-purpose unit with regard to the end process of energy or heat production. This report recommends retention of the use of kt/PJ as a base or absolute unit, per the previous Hale and Twomey report.
- Units of tCO₂-e/t fuel are more likely to be accessible to users, and are typical for ETSs. This report recommends the retention of these units for ETS guidelines.
- It is recommended that users test fuel for energy content a matter of course according to appropriate methods, as detailed in this report. This is in keeping with Australian practice and highly desirable for accurate, complete, and transparent records in New Zealand.
- Regarding calorific value, NCVs represent the functional unit of interest (again, linking end-product or energy use with actual emissions) and are more widely used internationally than the New Zealand standard use of GCVs. This report recommends that New Zealand revisits and reevaluates this issue.

7.0 REFERENCES

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APPENDIX I

Data Sheets

Section 1.1

Carbon Dioxide

- 1. Non-organic used or waste oil**
- 2. Organic used or waste oil**
- 3. Blended organic or non-organic used or waste oil**
- 4. Used tyres**
- 5. Non-organic waste other than non-organic used or waste oil or used tyres**
- 6. Organic waste, other than biogas or wood**
- 7. Biogas**
- 8. Wood**

GHG	CO ₂	
Emission Source	Used Oil, non-organic	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
69.6	IPCC/NZ MED
73.8	NAEI, fuel oil
72.6	NAEI, lubricant
72.1	NAEI, burning oil
73.8	Canadian GHGI, lubricants and greases
69.9	Norwegian GHGI, light fuel oil (boiler)
74.9	Norwegian GHGI, heavy fuel oil (boiler)
70.4	Statistics Finland, gas oil (light fuel oil, heating fuel oil)
72.0	CORINAIR, residual oil
72.8	"
74.1	"
70.3	German Federal Environment Agency, heating oil
74.1	"
69.0	"
69.9	Australian GHGI Methods, lubricants and greases
71.0	US EPA Climate Leaders, residual oil

Current NZ Emission Factor	69.6 kt/PJ
Suggested Emission Factor	69.6 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Changes due to fluctuating nature of source composition with time; not key category, however.

Comments
 Internationally waste oil is typically blended. Since blended oil represents a different NZ emission source category, comparison is made here to materials that are representative of the non-organic oil waste precursor. New Zealand EF is slightly low relative to comparison values, however, other EFs given are not for strictly comparable materials and the present default value is reasonable given uncertainty, nature of comparison values, non-key source category, and in view of aggregate uncertainty across blended and non-organic waste oil categories. Note that CI for blended/waste oil (see separate sheet) is 63.3-77.2 kt/PJ, i.e. high uncertainty for waste oils.

Uncertainty Issues
 PDF – normal; CI ($p < 0.1$) is 68.5-75.2 kt/PJ; IPCC default CI is 68.6-70.7 kt/PJ.

New Zealand Specific Information
 Country specific variability – function of imports, NZRC processes, post-use reprocessing, etc.

GHG	CO ₂	
Emission Source	Organic used and waste oil (IPCC MSW – biomass)	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
111	IPCC / NZ MED
121	US State of Iowa GHGI biofuel data, seed corn
83.8	“ high carbon ash
97.9	“ oat hulls
115	“ seed corn
84.6	Cement Sustainability Initiative, animal meal
53.3	Statistics Finland, biomass

Current NZ Emission Factor	111 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogenous and fluctuating nature of source composition with time.

Comments


Present NZ value sourced from upper limit of IPCC category for MSW – biomass. Despite high uncertainty, this is not a key source category and hence default could be used. This is a recent IPCC emission source category and hence comparable data is sparse due to varying practices in treatment of waste streams and aggregation EFs.

Uncertainty Issues

PDF – normal, insufficient data for quantitative uncertainty; IPCC default CI is 80.4-111 kt/PJ.

New Zealand Specific Information

Country specific and regional variability due to waste stream treatment; very small source at present in New Zealand.

GHG	CO ₂	
Emission Source	Used Oil, blended	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
69.6	IPCC / NZ MED
69.2	NAEI, waste oil
63.2	US EPA / FIRE, waste oil (liquid, atomised, vaporised)
74.9	Statistics Finland, recycled waste oil
70.3	Cement Sustainability Initiative, waste oil
73.2	UK GHGI, waste oil
69.5	UK GHGI, lubricants, waste

Current NZ Emission Factor	69.6 kt/PJ
Suggested Emission Factor	69.6 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Changes due to fluctuating nature of source composition with time; not key category, however.

Comments


New Zealand EF is representative. Waste oil is a new IPCC category and not disaggregated as non-organic and blended. Uncertainties are high.

Uncertainty Issues

PDF – normal; CI ($p < 0.1$) is 65.6-77.9 kt/PJ (incorporating CSI data for which $n = 90$); IPCC CI for waste oils is 68.6-70.7 kt/PJ.

New Zealand Specific Information

Country specific variability, function of imports, NZRC processes, post-use reprocessing, etc.

GHG	CO ₂	
Emission Source	Used tyres	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
136	IPCC / NZ MED (IPCC category industrial waste)
107	US EPA Climate Leaders, waste tyres
49.5	NAEI, waste tyres
81.6	Australian GHGI Methods, recycled tyres
77.3	US DOE, tyres
80.8	Cement Sustainability Initiative, tyres
79.9	Australian Energy Reporting Guidelines, tyres
81.6	UK GHGI, scrap tyres, cement
89.5	UK GHGI, scrap tyres, manufacturing

Current NZ Emission Factor	136 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogeneous (e.g. steel content) and fluctuating nature of source composition with time.

Comments


IPCC default for industrial waste is highly conservative, though uncertainties are high; the HHV used for weight/weight CO₂ EFs in Draft Regulations (10.5 TJ/Gg) is likely low by roughly a factor of three, hence erring in the non-conservative side for Draft Regulation EF (literature and industry values of 29.0 kt/PJ, 31. kt/PJ 1, 32.0 kt/PJ, 36.7 kt/PJ from this review). Additionally, Draft Regulation EFs do not account for tyre biomass carbon (14 and 15% respectively based on literature and industry communication).

Uncertainty Issues

PDF – likely normal based on analogous sources, CI is 50.0-110 kt/PJ assuming normal PDF and omitting IPCC non-specific industrial waste default; IPCC industrial waste (non waste-stream specific) default CI is 105-174 kt/PJ.

New Zealand Specific Information

Nonexistent source at present in New Zealand.

GHG	CO ₂	
Emission Source	Non-organic waste other than used oil or tyres	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
115	IPCC/NZ MED
70.4	Statistics Finland, plastics
80.4	German Federal Environment Agency , polystyrene
71.3	Cement Sustainability Initiative, plastics
76.0	“ other fossil-based wastes
28.9	NAEI, municipal solid waste
22.7	Norweigan GHGI, municipal solid waste
85.4	Australian Energy Reporting Guidelines, non-biomass municipal waste
76.0	UK GHGI, non-biomass packaging waste
76.0	UK GHGI, waste solvents
76.0	UK GHGI, waste solvents

Current NZ Emission Factor	115 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogeneous and fluctuating nature of source composition with time

Comments
 Present NZ value sourced from upper limit of IPCC category for MSW – non-biomass. Despite high uncertainty, this is not a key source category and hence default could be used. As with MSW-biomass fraction, this is a recent IPCC emission source category and hence comparable data is sparse due to varying practices in treatment of waste streams and aggregation EFs.

Uncertainty Issues
 PDF – normal; CI ($p < 0.1$) is 23-120 kt/PJ; IPCC default CI is 69.6-115 kt/PJ.

New Zealand Specific Information
 Country specific and regional variability due to waste stream treatment; uncertain/very small source at present in New Zealand.

GHG	CO ₂	
Emission Source	Biomass, not biogas or wood	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
111	IPCC / NZ MED (IPCC category MCW - biomass)
121	US State of Iowa GHGI biofuel data, seed corn
83.8	“ high carbon ash
97.9	“ oat hulls
115	“ seed corn
84.6	Cement Sustainability Initiative, animal meal
53.3	Statistics Finland, biomass

Current NZ Emission Factor	111 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogeneous and fluctuating nature of source composition with time.

Comments


Present NZ value sourced from upper limit of IPCC category for MSW – biomass. Despite high uncertainty, this is not a key source category and hence default could be used; as well, default appears reasonable from limited data.

Uncertainty Issues

PDF – unknown, data insufficient for quantitative uncertainty; ; IPCC default CI is 80.4-111 kt/PJ.

New Zealand Specific Information

Small but emerging source at present in New Zealand.

GHG	CO ₂	
Emission Source	Biomass, biogas	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
101	NZ MED
51.9	IPCC, 2006, landfill gas, sludge gas, other biogas
104	Statistics Finland, biogas
52.4	US State of Iowa GHGI biofuel data, biogas/landfill gas
53.9	Canadian GHGI, landfill gas

Current NZ Emission Factor	101 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	infrequent
Changes Over Time	Only dependent upon fuel methane content.


Comments

Source of present default not clear vis a vis IPCC default.

Uncertainty Issues

IPCC default CI is 41.6-59.4 kt/PJ.

New Zealand Specific Information

GHG	CO ₂	
Emission Source	Biomass, wood	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
104	NZ MED
106.4	IPCC, 2006, wood/wood waste
89.0	US EPA Climate Leaders, wood/wood waste
84.0	US EPA / FIRE, boiler, dry wood, wet wood, bark
86.2	"
95.7	"
94.0	Australian GHGI Methods, wood/wood waste
91.0	AEA Technology, wood, furnace
100	"
92.2	Canadian GHGI , wood fuel
105	Norwegian GHGI , wood waste
87.8	US State of Iowa GHGI biofuel data, wood
104	Statistics Finland, wood fuel

Current NZ Emission Factor	104 kt/PJ
Suggested Emission Factor	104 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively source and condition dependent.

Comments


Uncertainty Issues
PDF – unknown, IPCC default well accepted; IPCC default CI is 90.3-125 kt/PJ.

New Zealand Specific Information
Country specific and fuel source/condition dependent.

Section 1.2

Methane

- 1. Non-organic used or waste oil**
- 2. Organic used or waste oil**
- 3. Blended organic or non-organic used or waste oil**
- 4. Used tyres**
- 5. Non-organic waste other than non-organic used or waste oil or used tyres**
- 6. Organic waste, other than biogas or wood**
- 7. Biogas**
- 8. Wood**

GHG	CH ₄	
Emission Source	Used Oil, non-organic	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC/NZ MED
0.002	NAEI, fuel oil
0.0021	NAEI, lubricant
0.0021	NAEI, burning oil
0.0008	Australian GHGI Methods, residual oil, boiler, electrical
0.0028	Australian GHGI Methods, residual oil, boiler, energy
0.0013	Australian GHGI Methods, residual oil, boiler, commercial
0.00067	CORINAIR, residual oil
0.000095	"
0.0029	"
0.0095	CORINAIR, petroleum oil

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments
See comments for CO₂ regarding comparable sources.

Uncertainty Issues
PDF – truncated normal; data insufficient for PDF type; IPCC default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information
Country specific variability – function of imports, NZRC processes, post-use reprocessing, etc.

GHG	CH ₄	
Emission Source	Organic used and waste oil (IPCC MSW – biomass)	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC / NZ MED
0.29	NAEI, straw
0.003	US State of Iowa GHGI biofuel data, seed corn
0.003	“ high carbon ash
0.039	Australian Energy Reporting Guidelines, biomass MSW

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Effectively dependent upon heterogeneous fuel composition, combustion technology and conditions.

Comments


No comparable data found.

Uncertainty Issues

PDF – lognormal; IPCC default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information

Country specific and regional variability due to waste stream treatment; very small source at present in New Zealand.

GHG	CH ₄	
Emission Source	Used Oil, blended	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC / NZ MED
0.002	NAEI, waste oil

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments

Uncertainty Issues
PDF – truncated normal; IPCC default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information
Country specific variability, function of imports, NZRC processes, post-use reprocessing, etc.

GHG	CH ₄	
Emission Source	Used tyres	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC / NZ MED (IPCC category industrial waste)
0.029	NAEI, waste tyres
0.00095	Australian Energy Reporting Guidelines, tyres

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogeneous (e.g. steel content) and fluctuating nature of source composition with time and combustion conditions.

Comments

Uncertainty Issues
 PDF – likely normal based on analogous sources; IPCC industrial waste (non waste-stream specific) default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information
 Non-existent source at present in New Zealand.

GHG	CH ₄	
Emission Source	Non-organic waste other than used oil or tyres	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC/NZ MED
0.31	NAEI, municipal solid waste
0.021	Norwegian GHGI, non-organic waste
0.029	Australian Energy Reporting Guidelines, non-biomass MSW

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Effectively dependent upon heterogeneous fuel composition, combustion technology and conditions.

Comments

Uncertainty Issues
PDF – lognormal; IPCC default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information
Country specific and regional variability due to waste stream treatment; uncertain/very small source at present in New Zealand.

GHG	CH ₄	
Emission Source	Biomass, not biogas or wood	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.03	IPCC / NZ MED (IPCC category MCW - biomass)
0.29	NAEI, straw
0.003	US State of Iowa GHGI biofuel data, seed corn
0.003	“ high carbon ash
0.039	Australian Energy Reporting Guidelines, biomass MSW

Current NZ Emission Factor	0.03 kt/PJ
Suggested Emission Factor	0.03 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Function primarily of combustion technology and conditions.

Comments

Uncertainty Issues
PDF – lognormal, data insufficient for quantitative uncertainty; IPCC default CI is 0.01-0.1 kt/PJ.

New Zealand Specific Information
Small but emerging source at present in New Zealand.

GHG	CH ₄	
Emission Source	Biomass, biogas	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.001	IPCC / NZ MED
0.0006	US State of Iowa GHGI biofuel data, biogas/landfill gas
0.011	Canadian GHGI, landfill gas

Current NZ Emission Factor	0.001 kt/PJ
Suggested Emission Factor	0.001 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Only dependent upon fuel methane content and combustion conditions.

Comments

Uncertainty Issues
PDF – normal; IPCC default CI is 0.0003-0.003 kt/PJ.

New Zealand Specific Information

GHG	CH ₄	
Emission Source	Biomass, wood	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.014	NZ MED
0.001	IPCC, 2006, wood/wood waste
0.033	NAEI, wood
0.009	US EPA / FIRE, boiler, dry wood, wet wood, bark
0.0048	“ stoker bioler
0.0042	Australian GHGI Methods, wood/wood waste
0.005	Canadian GHGI, wood fuel
0.015	Norwegian GHGI, wood waste
0.0035	US State of Iowa GHGI biofuel data, wood
0.0038	Australian Energy Reporting Guidelines, dry wood

Current NZ Emission Factor	0.014 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments

Source of current default not clear.

Uncertainty Issues

PDF – lognormal, CI ($p < 0.1$) is 0.0009-0.035 kt/PJ; IPCC default CI is 0.01-0.1 kt/PJ.


New Zealand Specific Information

Country specific and fuel source/condition dependent.

Section 1.3

Nitrous Oxide

- 1. Non-organic used or waste oil**
- 2. Organic used or waste oil**
- 3. Blended organic or non-organic used or waste oil**
- 4. Used tyres**
- 5. Non-organic waste other than non-organic used or waste oil or used tyres**
- 6. Organic waste, other than biogas or wood**
- 7. Biogas**
- 8. Wood**

GHG	N ₂ O	
Emission Source	Used Oil, non-organic	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC/NZ MED
0.0006	Australian GHGI Methods, residual oil, boiler, electrical/energy/commercial
0.00066	Norwegian GHGI Inventory, light fuel oil, boiler
0.0007	Norwegian GHGI Inventory, heavy fuel oil, boiler
0.043	CORINAIR, residual oil
0.0006	NAEI, fuel oil
0.00063	NAEI, lubricant
0.00063	NAEI, burning oil

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments
See comments for CO₂ regarding comparable sources. Note: CORINAIR value represents high in range, no median given.

Uncertainty Issues
PDF – beta; IPCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
Country specific variability – function of imports, NZRC processes, post-use reprocessing, etc.

GHC	N ₂ O	
Emission Source	Organic used and waste oil (IPCC MSW – biomass)	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC / NZ MED
0.0038	NAEI, straw
0.00039	US State of Iowa GHGI biofuel data, seed corn, high carbon ash
0.0039	Australian Energy Reporting Guidelines, biomass MSW

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Effectively dependent upon heterogeneous fuel composition, combustion technology and conditions.

Comments


No comparable data found.

Uncertainty Issues

PDF – beta; PCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information

Country specific and regional variability due to waste stream treatment; very small source at present in New Zealand.

GHG	N ₂ O	
Emission Source	Used Oil, blended	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC / NZ MED

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments
 No comparable data found.

Uncertainty Issues
 PDF – beta; IPCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
 Country specific variability, function of imports, NZRC processes, post-use reprocessing, etc.

GHG	N ₂ O	
Emission Source	Used tyres	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC / NZ MED (IPCC category industrial waste)
0.00064	Australian Energy Reporting Guidelines, tyres

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Changes due to heterogeneous (e.g. steel content) and fluctuating nature of source composition with time and combustion conditions.

Comments

Uncertainty Issues
 PDF – likely normal based on analogous sources; IPCC industrial waste (non waste-stream specific) default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
 Nonexistent source at present in New Zealand.

GHG	N ₂ O	
Emission Source	Non-organic waste other than used oil or tyres	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC/NZ MED
0.004	NAEI, municipal solid waste
0.001	Norwegian GHGI
0.0039	Australian Energy Reporting Guidelines, non-biomass MSW
0.0091	CORINAIR, municipal solid waste

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Effectively dependent upon heterogeneous fuel composition, combustion technology and conditions.

Comments
No comparable data found.

Uncertainty Issues
PDF – beta; IPCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
Country specific and regional variability due to waste stream treatment; uncertain/very small source at present in New Zealand.

GHG	N ₂ O	
Emission Source	Biomass, not biogas or wood	


Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	IPCC / NZ MED (IPCC category MCW - biomass)
0.0038	NAEI, straw
0.00039	US State of Iowa GHGI biofuel data, seed corn, high carbon ash
0.0039	Australian Energy Reporting Guidelines, biomass MSW

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	very infrequent
Changes Over Time	Function primarily of combustion technology and conditions.

Comments

Uncertainty Issues
PDF – beta; IPCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
Small but emerging source at present in New Zealand.

GHG	N ₂ O	
Emission Source	Biomass, biogas	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.002	NZ MED
0.0001	IPCC
0.00001	US State of Iowa GHGI biofuel data, biogas/landfill gas
0.0011	Canadian GHGI, landfill gas
0.0001	Norwegian GHGI, landfill gas

Current NZ Emission Factor	0.002 kt/PJ
Suggested Emission Factor	see comments
Future Review Necessary	very infrequent
Changes Over Time	Only dependent upon fuel methane content and combustion conditions.


Comments

Source of present default not clear.

Uncertainty Issues

PDF – beta; IPCC default CI is 0.00003-0.0003 kt/PJ.

New Zealand Specific Information

GHG	N ₂ O	
Emission Source	Biomass, wood	

Emission Factor Comparison	
Factor (kt/PJ)	Source of EF
0.004	NZ MED
0.0044	NAEI, wood
0.0056	US EPA / FIRE, boiler, dry wood, wet wood, bark
0.0096	“ fluidised bed
0.0019	“ stocker boiler
0.0041	Australian GHGI Methods, wood, boiler
0.0019	Canadian GHGI, wood fuel
0.00029	Norwegian GHGI, wood waste
0.00047	US State of Iowa GHGI biofuel data, wood
0.00039	Australian Energy Reporting Guidelines, dry wood

Current NZ Emission Factor	0.004 kt/PJ
Suggested Emission Factor	0.004 kt/PJ
Future Review Necessary	infrequent
Changes Over Time	Effectively dependent upon combustion technology and conditions.

Comments

Uncertainty Issues
PDF – beta; IPCC default CI is 0.0015-0.015 kt/PJ.

New Zealand Specific Information
Country specific and fuel source/condition dependent.



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