Australian Government
Department of Sustainability, Environment, Water, Population and Communities

National Pollutant Inventory

Emission estimation technique manual
For

Combustion in boilers
Version 3.6
December 2011

First published in August 1999
Version 3.6 published December 2011

ISBN: 978-0-642-55386-7

Disclaimer
The manual was prepared in conjunction with Australian states and territories according to the *National Environment Protection (National Pollutant Inventory) Measure.*

While reasonable efforts have been made to ensure the contents of this manual are factually correct, the Australian Government does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this manual.

Emission Estimation Techniques
For
Combustion in Boilers

Table of Contents

List of Figures, Tables, Equations and Examples

FIGURES

TABLES

EQUATIONS

EXAMPLES

1 Introduction

The purpose of all Emission Estimation Technique (EET) manuals is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This manual describes the procedures and recommended approaches for estimating emissions resulting from combustion in boilers.

Note that the ANZSIC code is part of NPI reporting requirements. The NPI Guide contains an explanation of the ANZSIC coding system.

EET MANUAL	Combustion in boilers
ANZSIC 2006	Any industry sector where combustion is used in the production of steam for energy and/or hot water, i.e. ANZSIC 2006 Divisions A – S.

NPI substances are those that, when emitted at certain levels, have potential to be harmful. Australian, state and territory governments have agreed, in response to international requirements, that industry will report these emissions on an annual basis. Reportable NPI substances are listed in the NPI Guide and are classified into six categories with different reporting thresholds. If your facility trips a threshold in a reporting year for a substance on the reporting list, all the emissions of that substance from your facility must be reported. The NPI Guide is available on the NPI website at www.npi.gov.au

This manual has been developed through a process of national consultation involving state and territory environmental authorities and key industry stakeholders. Particular thanks are due to the HRL Technologies Pty Ltd for their assistance in developing this manual.

2 Process description

The first step in estimating emissions of NPI substances from your facility is to create a process flow diagram, highlighting points in the process where emissions may occur. In the case of combustion in boilers, this involves identifying fuels burnt onsite and the boiler types. When considering the fuel usage onsite it is important to note:

> *for fuel, 'usage' indicates the amount of fuel burnt onsite, not 'usage' as applies to individual NPI substances (receipt, storage, handling, manufacture, import, processing, coincidental production or other uses), and fuels burnt in both boilers and engines need to be considered for the total fuel usage.*

2.1 Fuel types

The most common fuels used in boilers in Australia include:

- diesel;
- black coal;
- natural gas;
- bagasse;
- residual fuel oil;
- wood and wood waste;
- coal by-products;
- brown coal briquettes;
- synthetic biofuels;
- tallow;
- various process gasses; and
- waste oil.

2.2 Expected emissions

All fuels emit substances when combusted, many of which may be harmful and therefore of interest to the NPI. A large number of industrial processes and facilities use industrial boilers to produce hot water and steam energy. Industrial boilers use a range of fuels depending on boiler size and design characteristics and on the availability/proximity of fuel. In many cases the fuel is a by-product or waste product from other processes.

The volume and nature of emissions from combustion in boilers differ depending on fuel composition, fuel consumption, boiler design and operation and pollution control devices used. Independent of fuel used, the general process of combustion is as follows:

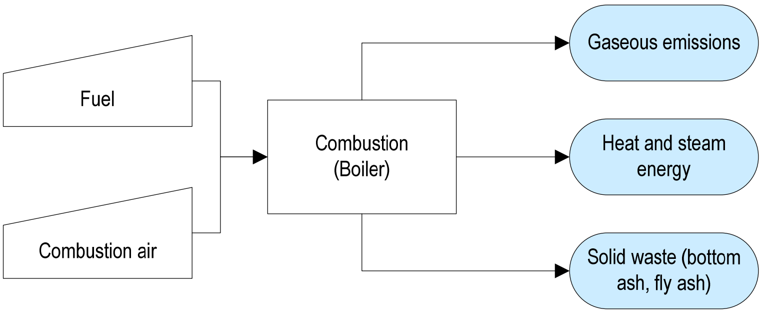

Figure 1: Process for combustion in boilers

When fuels burn they are converted to various substances, some of which are NPI listed substances. The non-combustible portion of the fuel remains as a solid waste. The coarser, heavier waste is called 'bottom ash' and is extracted from the boiler and the lighter, finer portion is 'fly ash' and is usually emitted as particulates through the stack. Products of incomplete combustion include carbon monoxide, sulfur oxides, oxides of nitrogen, acid gases and organic compounds. Metals and their compounds may also be entrained (carried forward by a stream of gas or vapour of fine liquid droplets). A number of techniques exist to assist complete combustion and to reduce some emissions.

2.3 General boiler types

2.3.1 Combustion of solid fuels

There are three basic modes of burning solid fuels:

- in suspension
- resting fuel on a grate/bed (fuel bed firing) – the fuel bed may be moved slowly through the furnace by the vibrating action of the grate or by being carried on a travelling grate, and
- in a fluidised bed.

Although many variations of the above have been developed, the fundamental characteristics of equipment and procedures are the same.

a. Suspension firing

Suspension firing of pulverised coal (PC) is more common than fuel-bed or fluidised bed firing of coarse coal. This mode of firing affords higher steam generation capacity, is independent of the caking characteristics of the coal, and responds quickly to load changes. It is rarely used on boilers of less than 45.4 t/h steam capacity as economic advantage decreases as size decreases. Therefore, suspension fired boilers are more common for power generation or large steam raising boilers rather than for smaller industrial boilers.

b. Fuel-bed firing (stoker)

Fuel-bed firing is accomplished with mechanical stokers, which are designed to achieve continuous or intermittent fuel feed, fuel ignition, proper distribution of the combustion air, free release of the gaseous combustion products and continuous or intermittent disposal of the unburned residue.

An advantage of stoker-fired furnaces is the adaptability to fire almost any unsized solid fuels (e.g. bark, bagasse, refuse). There are two classes of stoker, which are distinguished by the direction of fuel feed:

- overfeed stokers, and
- underfeed stokers.

c. Overfeed stokers

There are two general types of overfeed stokers, which are distinguished by the relative direction of fuel and air flow, as well as by the manner of fuel feed.

c.i. Cross-feed stokers

In cross-feed stokers, the fuel is dumped by gravity from a hopper onto one end of a moving grate, which carries the fuel into the furnace and down its length. Cross-feed stoker boilers are also termed travelling-grate stoker boilers. In the cross-feed stoker the fuel flows at right angles to the air flow.

Cross-feed (travelling-grate) boilers are more commonly used with smaller scale industrial boilers

c.ii. Spreader stokers

In spreader stokers, the fuel is propelled into the furnace. A portion of the fuel burns in suspension while the rest burns on the grate. In most units, the fuel is pushed off a plate under the storage hopper onto revolving paddles (either overthrow or underthrow), which distribute the fuel on the grate. The largest fuel particles travel the furthest, while the smallest become partially consumed during their trajectory and fall on the forward portion of the grate. The grate may be stationary or travelling. Fuel and air flow in opposite directions.

Spreader stoker boilers are typically used for larger industrial boilers.

d. Underfeed stokers

For an underfeed stoker, both the fuel and air have the same relative direction. Underfeed stokers can be of single-retort and multiple-retort designs.

In the single-retort side-dump stoker, a ram pushes the solid fuel into the retort toward the end of the stoker and upward toward the tuyere blocks (the nozzle that the air is forced through), where the air is admitted to the bed (of fuel).

In multiple-retort stokers, the solid fuel is fed by rams to the top of sloping grates between banks of tuyeres. Auxiliary small sloping rams perform the same function as the pusher rods in the single retort. Air is admitted along the top of the banks of tuyeres, and on the largest units the tuyeres are given a slight reciprocating action to agitate the bed further.

e. Fluidised-bed combustion

In fluidised-bed combustion (FBC), fuel is burned in a bed of particles supported in an agitated state by an upward flow of air introduced via an air distributor. The bed may be sand or ash derived from the fuel. In some cases, sulfur sorbent like limestone or dolomite may also be used. Fluidised beds have inherently good heat-transfer characteristics that ensure even temperatures within the combustor and high heat flux rates to steam/water cooling circuits.

The good gas-solids contacting promotes effective sulfur capture by sorbents and allows high combustion efficiency to be achieved at significantly lower temperatures than would be required by, for example, a pulverised coal (PC) fired furnace. These lower temperatures result in reduced slagging and fouling problems and significantly lower NOx formation.

There are two types of FBC units, distinguished by their operating flow characteristics:

- bubbling, or
- circulating fluidised-beds.

Bubbling FBC units operate with a relatively low gas velocity within the fluidised-bed and have distinct bed and freeboard regions with the majority of the combustion reaction occurring within the bed. By comparison, circulating FBC units operate with a higher gas velocity and combustion occurs throughout the reactor and unburnt particles that are carried out of the reactor are captured and returned to the bottom of the bed. Both types of FBC combustors can be designed to operate at atmospheric pressure or at elevated pressure.

An advantage of FBC is fuel flexibility; however, the unit must be designed for the range of fuels. A single FBC unit can burn a wider range of materials that a PC furnace.

2.3.2 Combustion of liquid fuels

Oil is typically burned as a suspension of droplets generated by atomising the fuel. As the droplets pass from the atomiser into the flame zone, they are heated both by radiation from the flame and by convection from the hot gases that surround them. The light fuel components vaporise and mix with surrounding air and ignite. Depending on the fuel type, the fuel droplet may be completely vaporised or it may be partially vaporised, leaving a residual char or coke particle.

Atomisers can be classified into two broad groups: pressure atomisers in which fuel oil is injected at high pressure, and twin-fluid atomisers in which fuel oil is injected at moderate pressure with a compressible fluid (steam or air) to assist in the atomisation process.

Many oil burners are designed as combination gas/oil burners.

2.3.3 Combustion of gaseous fuels

Gas burners may be classified as premixed or non-premixed. The flow rate of gas and / or combustion air can be regulated to achieve the required flame characteristics and level of excess air. Many forms of flame stabilisers are employed in gas burners.

The use of gaseous fuels with heating values lower than that of natural gas, e.g. coke oven gas, results in a low flame temperature and, therefore, an increased heat transfer surface area to capture an equivalent amount of heat is required.

2.4 Emission controls

A number of pollution control techniques are available to reduce emissions from boilers.

Primary measures to reduce emissions at the source or during combustion include:

- switching to fuels with a lower levels of sulfur, nitrogen, metals etc;
- combustion modifications which could include capacity de-rating, burner and in-furnace modifications, air and fuel modifications; and
- a range of combustion control mechanisms for the reduction of oxides of nitrogen.

These mechanisms are referred to in Appendix B, Table 34: Efficiency rates for different control devices, and include:

- low excess air (LEA)
- staged combustion (SC) including burner out-of-service (BOOS), biased burner firing (BBF), over-fire air (OFA) and fuel staging (FS)
- flue gas recirculation (FGR)
- reduced air preheat (RAP), and
- low NOx burners (FGR, RAP, FS).

Secondary measures to reduce emissions include a number of processes and physical devices to reduce particulate, sulfur dioxide, oxides of nitrogen and metal emissions. Among the devices used are:

- electrostatic precipitators (ESP) for removal of particulate matter ($PM_{2.5}$ and PM_{10})
- fabric filtration (baghouse) for removal of particulate matter ($PM_{2.5}$ and PM_{10}) and substances that resist ESPs
- cyclones and multicyclones for pre-cleaning, generally to remove PM, although it is most effective for particles larger than 10μm
- wet and dry scrubbers for the removal of a number of pollutants which may include some particulates however this is dependent on the design of the scrubber, and
- techniques for the removal of sulfur dioxide (common flue gas desulfurisation (FGD)); and oxides of nitrogen (selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR)).

3 Emission sources

General information regarding emission sources can be located in the NPI Guide. However, it is important to note that emissions from combustion in boilers will generally be directed through an air stack unless there is a breach in the exhaust system.

3.1 Emissions to air

Air emissions may be categorised as fugitive emissions or point source emissions.

3.1.1 Fugitive emissions

Fugitive emissions are not released through a vent or stack. Examples of fugitive emissions include emissions from vehicles, dust from stockpiles, volatilisation of vapour from vats and open vessels, or spills and materials handling. Emissions emanating from ridgeline roof-vents, louvers, and open doors of a building as well as equipment leaks, such as from valves and flanges are also examples of fugitive emissions. The nature of fugitive emissions does not lend itself to the use of control devices.

Emission factor EETs are the usual method for determining losses from fugitive emission sources.

It is expected that most emissions from boilers would not be fugitive emissions, although fugitive emission may occur at other parts of a facility such as from fuel storage.

3.1.2 Point source emissions

Point source emissions are directed into a vent or stack and emitted through a single point source into the atmosphere. Most boiler emissions would be point source emissions and have the potential for monitoring activities, although these would not be commonly used.

Air emission control technologies such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers are commonly installed to reduce the concentration of particulates in processing off-gases before emission through a stack. The collection efficiency of the abatement equipment needs to be considered where such equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimations. Equation 9 for applying collection efficiencies is shown on page 15.

3.1.3 Emissions to water

Emissions of substances to water can be categorised as discharges to:

- surface waters (lakes, rivers, dams, estuaries)
- costal or marine waters, or
- stormwater runoff.

Emissions of toxic substances to waterways may pose environmental hazards. Most facilities emitting NPI-listed substances are required by their state or territory environment authority to closely monitor and measure these emissions. The existing sampling data can be used to calculate annual emissions to the NPI. The discharge of NPI listed substances to a sewer or tailings dam is not regarded as an emission but a transfer and as such is reportable to the NPI as a transfer (refer to Section 6: Transfers of NPI substances in waste, page 23).

3.1.4 Emissions to land

Emissions of substances to land include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids, and such emissions may contain NPI-listed substances. Emission sources can be categorised as:

- surface impoundments of liquids and slurries, or
- unintentional leaks and spills.

4 Threshold calculations

The NPI Guide outlines detailed information on thresholds and identifying emission sources. The NPI Guide can help identify NPI substances that may be used by your facility, or are components of materials used by your facility, and then calculate whether the quantity used exceeds an NPI threshold. If the threshold is exceeded for any NPI substance, then all emissions of that substance from your facility must be reported.

Table 1: Category 2a and 2b substances

Category 2a & 2b substances	Category 2b only substances
• Carbon monoxide • Fluoride compounds • Hydrochloric acid • Oxides of Nitrogen • Particulate matter 10 micrometres or less in diameter (PM_{10}) • Particulate matter 2.5 micrometres or less in diameter ($PM_{2.5}$) • Polycyclic aromatic hydrocarbons (B[a]Peq) (PAHs) • Sulfur dioxide • Total Volatile Organic Compounds (Total VOCs)	• Arsenic and compounds • Beryllium and compounds • Cadmium and compounds • Chromium(III) compounds • Chromium(VI) compounds • Copper and compounds • Lead and compounds • Magnesium oxide fume • Mercury and compounds • Nickel and compounds • Polychlorinated dioxins and furans (TEQ)

The threshold for Category 2a is the burning of 400 tonnes or more of fuel in the reporting year. If your facility trips this threshold, you must estimate and report any emissions of all Category 2a NPI substances listed in Table 1.

The threshold for Category 2b is the burning of 2,000 tonnes or more of fuel in the reporting year. If your facility trips this threshold, you must estimate and report any emissions of all Category 2a and Category 2b NPI substances listed in Table 1 Many fuels are not commonly measured in tonnes. Table 2 provides approximate amounts of fuel required to be burnt in order to trip Category 2a and 2b thresholds, using alternative units of measure.

Table 2: Calculating how much fuel is burnt

Fuel type	Category 2a per reporting year	(min limits) per hour	Category 2b (min limit) per reporting year	Conversion factor
Gaseous Fuels				
Biogas	367,000 (m^3)	917 (m^3)	1,830,000 (m^3)	1.09 (kg/m^3)
LPG	784,000 litres	1,960 litres	3,920,000 litre	0.510 kg/L
Natural Gas	17,800,000 MJ	44,400 MJ	88,800,000 MJ	0.0225 kg/MJ
Liquid Fuels				
Diesel	478,000 litres	1,200 litres	2,390,000 litres	0.836 kg/L
Fuel Oil	444,000 litres	1,110 litres	2,220,000 litres	0.9 kg/L
Petrol	541,000 litres	1,350 litres	2,710,000 litres	0.739 kg/L
Solid Fuels				
Explosives (eg ANFO)	400 tonnes	1 tonne	2,000 tonnes	N/A
Solid Fuel (eg coal, wood or waste)	400 tonnes	1 tonne	2,000 tonnes	N/A

a) Conversion factors taken from the NPI Guide - Version 5.1, February 2010

Example 1

Example 1

Example of a threshold calculation

A facility burns 6,000 tonnes of virgin wood products and 300 tonnes of black coal in a year. A volume of 15,000 L of LPG (butane) is used as a fuel source for onsite forklifts. The process for calculating whether the facility trips NPI thresholds is set out below:

Wood and coal usage does not need to be converted as the data is provided in tonnes. LPG, on the other hand, requires conversion:

Table 2 indicates that the conversion rate for LPG is 0.510 kg/litre.

To calculate the weight of 15,000 L of LPG:

15,000 L × 0.510 kg/L = 7 650 kg

Converting to tonnes:

7,650 ÷ 1,000 = 7.65 tonnes

Thus the total fuel burnt is 6,000 tonnes of wood fuel, 300 tonnes of black coal and 7.65 tonnes of LPG: 6,308 tonnes in total. This quantity of fuel exceeds both Category 2a and 2b thresholds as set out in the NPI Guide. Hence all Category 2a and 2b substance emissions must be estimated and reported.

5 Techniques for estimating emissions

If you have established under Section 4 that the quantity of fuel burnt at your facility meets or exceeds the Category 2a or Category 2b threshold, you will need to estimate the emissions to air, land and water of each tripped NPI substance.

5.1 Techniques

There are five approved approaches to estimating emissions for NPI purposes:

- mass balance
- fuel analysis or engineering calculations
- sampling data or direct measurement
- emission factors, and
- an approved alternative.

Generally, facilities that burn fuel in boilers would report emissions for NPI substances using emission factors, these are described in Sections 5.1.1 to 5.3.

As outlined above, a range of EETs can be used to calculate emissions. In the case of boiler fuel emissions, local point source measurements (including 'sampling', 'direct measurement', and 'fuel analysis' techniques) have the potential to provide the best results. However, these techniques are complex, and rely on consistency and expert assumptions. They are only beneficial when they are science-based and applied rigorously and with expertise. You may wish to use either of these techniques in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. Information in relation to these techniques is detailed in the manual. Direct measurement is described in Section 5.25.2 and fuel analysis is described in Section 5.3.1.

You will need to select the EET (or mix of EETs) that is most appropriate for your purposes. You can choose a mix of techniques depending on the application.

If you estimate emissions using any of the above mentioned EETs, data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of an EET not outlined in this manual, your data will also be displayed as being of acceptable reliability.

This manual seeks to provide the most effective EETs for the NPI substances relevant to combustion in boilers. However, the absence of an EET for a substance in this manual does not imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains wherever reporting thresholds have been exceeded. Where an emission cannot be reported due to absence of emission factors, the emissions section should be left 'blank', not entered as 'zero'. If a blank emission is included in a report for an NPI substance where usage has tripped the reporting threshold, a reason is required. A statement such as 'no emission factor is available' is appropriate.

EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (e.g. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission [the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed immediately (within 24 hours) during clean up operations].

5.1.1 Emission factors

As discussed previously, emission factors are commonly used tools in industry to estimate emissions to the environment. In this manual, they relate to the quantity of substance emitted from a source to some common activity associated with the emissions. Emission factors are usually expressed as the weight of a substance emitted per activity. To calculate the emission, multiply the substance specific emission by the activity.

You should be aware that there is uncertainty associated with emission factors relating to the degree of difference between the equipment/process from which the factor was derived and the equipment/process to which the factor is being applied. An A or B rating indicates a greater degree of certainty than a D or E rating.

The EFR system is:

- A (Excellent)
- B (Above Average)
- C (Average)
- D (Below Average)
- E (Poor)
- U (Unrated)

Emission factors applicable to this manual are listed in Appendix B. You must ensure emissions are estimated for all substances where a threshold has been exceeded.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. For example, a company may have several units of similar model and size, if emissions were measured from one facility, an emission factor could be developed and applied to similar sources. If you wish to use a site-specific emission factor, you should first seek approval from your state or territory environment authority before its use for estimating NPI emissions.

5.2 Direct measurement

As indicated above, you may wish to use direct measurement to estimate emissions, particularly if you already do so to meet other regulatory requirements. For sampling data to be accurate and suitable to be used for NPI reporting purposes, it would need to be collected over a period of time and be representative of operations for the whole year.

5.2.1 Sampling data

Stack sampling test reports often provide emissions data in terms of kg per hour or grams per cubic metre (dry). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (i.e. normal) operating conditions. You should be aware that some tests undertaken for a state or territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

This section shows how to calculate emissions in kg per hour based on stack sampling data, and how to convert this to an annual emissions figure. Calculations involved in determining particulate matter (PM) emissions are used as an example, although the same calculations are applicable for most of the substances listed on the NPI.

Equation 1 indicates how to calculate the concentration of a substance from the weight of the substance and the volume of air sampled:

$$C_{PM} = C_f \;/\; V_{m,\,STP} \qquad \textbf{Equation 1}$$

where:

C_{PM} = concentration of PM or gram loading, g/m^3
C_f = filter catch, g
$V_{m,STP}$ = metered volume of sample at STP, m^3

Equation 2 can be used to convert the concentration of a substance calculated in Equation 1 to an hourly emission of the substance:

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273 \;/\; (273 + T)] \qquad \textbf{Equation 2}$$

where:

E_{PM} = hourly emissions of PM, kg/hr
C_{PM} = concentration of PM or gram loading, g/m^3
Q_d = stack gas volumetric flow rate, m^3/s, dry
3.6 = 3,600 seconds per hour multiplied by 0.001 kilograms per gram
T = temperature of the gas sample, °C

The information from some stack tests may be reported in grams of particulate per cubic metre of exhaust gas (wet). Use Equation 3 to calculate the particulate emissions in kg/hr.

$$E_{PM} = Q_w \times C_{PM} \times 3.6 \times (1 - moist_R/100) \times [273 \;/\; (273 + T)] \qquad \textbf{Equation 3}$$

where:

E_{PM} = hourly emissions of PM, kg/hr
Q_w = wet cubic metres of exhaust gas per second, m^3/s
C_{PM} = concentration of PM or gram loading, g/m^3
3.6 = 3,600 seconds per hour multiplied by 0.001 kilograms per gram
$moist_R$ = moisture content, %

273 = 273 K (0°C)
T = stack gas temperature, °C

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM_{10} from total PM emissions, a size analysis may need to be undertaken. The weight PM_{10} fraction can then be multiplied by the total PM emission rate to produce PM_{10} emissions. Alternatively, assume that 100% of PM emissions are PM_{10}; i.e. assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less i.e. ≤10µm.

To calculate moisture content use Equation 4:

Moisture percentage = 100 % * weight of water vapour per specific volume of stack gas/ total weight of the stack gas in that volume

$$\text{moist}_R = \frac{(100\% \times g_{moist} / (1{,}000 \times V_{m,STP}))}{(g_{moist} / (1{,}000 \times V_{m,STP}) + \rho_{STP})} \qquad \textbf{Equation 4}$$

Where

moist_R = moisture content, %
g_{moist} = moisture collected, g
$V_{m,\,STP}$ = metered volume of sample at STP, m^3
ρ_{STP} = dry density of stack gas sample, kg/m^3 at STP {if the density is not known a default value of 1.62 kg/m^3 may be used. This assumes a dry gas composition of 50% air, 50% CO_2}

An example of test results is summarised in Table 3 The table shows the results of three different sampling runs conducted during one test event. The source parameters measured as part of the test run include gas velocity and moisture content, which are used to determine exhaust gas flow rates in m^3/s. The filter weight gain is determined gravimetrically and divided by the volume of gas sampled, as shown in Equation 4 to determine the PM concentration in grams per m^3. Note that this example does not present the condensable PM emissions.

Table 3: Example - Stack sample test results

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (sec)		7,200	7,200	7,200
Moisture collected (g)	g_{moist}	395.6	372.6	341.4
Filter catch (g)	C_f	0.0851	0.0449	0.0625
Average sampling rate (m^3/s)		1.67E-04	1.67E-04	1.67E-04
Standard metered volume (m^3)	$V_{m,\,STP}$	1.185	1.16	1.163
Volumetric flow rate (m^3/s), dry	Q_d	8.48	8.43	8.45
Concentration of particulate (g/m^3)	C_{PM}	0.0718	0.0387	0.0537

a) Source: Queensland Department of Environment and Heritage 1998

Example 2:

Using stack sampling data

PM emissions have been calculated using Equation 1 and Equation 2, and the stack sampling data for Test 1 (as presented in Table **3**), and an exhaust gas temperature at 25°C (298K). This is shown below:

$$\begin{aligned} C_{PM} &= C_f / V_{m,STP} \\ &= 0.0851 / 1.185 \\ &= 0.072 \text{ g/m}^3 \end{aligned}$$

$$\begin{aligned} E_{PM} &= C_{PM} \text{ x } Q_d \text{ x } 3.6 \text{ x } [273 / (273 + T)] \\ &= 0.072 \text{ x } 8.48 \text{ x } 3.6 \text{ x } [273/423\text{K}] \\ &= 1.42 \text{ kg/hr} \end{aligned}$$

5.2.2 Continuous Emission Monitoring System (CEMS) data

A Continuous Emission Monitoring System provides a continuous record of emissions over time, usually by reporting pollutant concentration.

Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

It is important to note that prior to using CEMS to estimate emissions, a protocol should be developed for collecting and averaging the data to ensure the estimate satisfies the relevant environmental authority's requirement for NPI emission estimations.

Table 4: Example - CEMS output

Test	O_2 (% by volume)	Concentration [b]				Gas flow rate (Q)	Combustion rate (tonnes/hour) a
		SO_2	NO_x	CO	VOC		
		(ppm_{vd})					
1	10.3	150.9	142.9	42.9	554.2	8.52	290
2	10.1	144	145.7	41.8	582.9	8.48	293
3	11.8	123	112.7	128.4	515.1	8.85	270

a) Source: Queensland Department of Environment and Heritage, 1998.

b) *ppmvd = parts per million volume dry

Hourly emissions can be based on concentration measurements as shown in Equation 5.

$$E_i = (C \text{ x } MW \text{ x } Q \text{ x } 3{,}600) / [22.4 \text{ x } \{(T + 273) / 273\} \text{ x } 10^6] \qquad \textbf{Equation 5}$$

where:

E_i = emissions of pollutant i, kg/hr
C = pollutant concentration, $ppm_{v,d}$
MW = molecular weight of the pollutant, kg/kg-mole
Q = stack gas volumetric flow rate, m^3/s
3,600 = conversion factor, s/hr
22.4 = volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m^3/kg-mole

T = temperature of gas sample, °C

Actual annual emissions can be calculated by multiplying the emission rate (kg/hr) by the number of actual operating hours per year (OpHrs) as shown in Equation 6 for each typical time period and summing the results.

$E_{kpy,i} = \Sigma (E_i \times OpHrs)$ **Equation 6**

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr
E_i = emissions of pollutant i, kg/hr (from Equation 5)
OpHrs = operating hours, hr/yr

Emissions in kilograms of pollutant per tonne of oil consumed can be calculated by dividing the emission rate (kg/hour), by the oil consumption rate (tonnes per hour) during the same period as shown below (Equation 7). It should be noted that the emission factor in Equation 7 assumes the selected time period (hourly) is representative of annual operating conditions and longer time periods should be used for NPI reporting where available. Use of Equation 7 is shown in Example 3.

$Ekpt_{,i} = E_i / A$ **Equation 7**

where:

$E_{kpt,i}$ = emissions of pollutant i per tonne of oil consumed, kg/t
E_i = hourly emissions of pollutant i, kg/hr
A = oil consumption rate, t/hr

Example 3 illustrates the application of Equation 5, Equation 6 and Equation 7.

Example 3:

Using CEMS Data

This example shows how SO_2 emissions can be calculated using Equation 5 based on the CEMS data for Time Period 1 shown in Table 4, and an exhaust gas temperature of 150°C (423 K).

$$\begin{aligned} E_{SO2,1} &= (C \times MW \times Q \times 3{,}600) / [(22.4 \times (T+273/273) \times 10^6] \\ &= (150.9 \times 64 \times 8.52 \times 3{,}600) / [22.4 \times (423/273) \times 10^6] \\ &= 296{,}217{,}907 / 34{,}707{,}692 \\ &= 8.53 \text{ kg/hr} \end{aligned}$$

For Time Period 2, also at 150°C
$E_{SO2,2}$ = 8.11 kg/hr

For Time Period 3, also at 150°C
$E_{SO2,3}$ = 7.23 kg/hr

Say representative operating conditions for the year are:

Period 1 = 1,500 hr
Period 2 = 2,000 hr
Period 3 = 1,800 hr

Total emissions for the year are calculated by adding the results of the three Time Periods using

Example 3:

Equation 6:

$$E_{kpy,SO2} = E_{SO2,1} \text{ x OpHrs} + E_{SO2,2} \text{ x OpHrs} + E_{SO2,3} \text{ x OpHrs}$$
$$= (8.53 \text{ x } 1{,}500) + (8.11 \text{ x } 2{,}000) + (7.23 \text{ x } 1{,}800) \text{ kg}$$
$$= 42{,}021 \text{ kg/yr}$$

Emissions, in terms of kg/tonne of oil consumed when operating in the same mode as Time Period 1, can be calculated using Equation 7:

$$E_{kpt,SO2} = E_{SO2} / A$$
$$= 8.53 / 290$$
$$= 2.94 \text{ x } 10\text{-}2 \text{ kg } SO_2 \text{ emitted per tonne of oil consumed}$$

When the boiler is operating as in Time Periods 2 or 3, similar calculations can be undertaken for emissions per tonne.

5.3 Engineering calculations

An engineering calculation is an estimation method based on physical/chemical properties of the substance (e.g. vapour pressure), and mathematical relationships (e.g. ideal gas law).

5.3.1 Fuel analysis

Fuel analysis is a particular type of engineering calculation and can be used to predict SO_2, metals, and other emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

$$E_{kpy,i} = Qf \text{ x pollutant concentration in fuel/100 x } (MW_p/EW_f) \text{ x OpHrs} \qquad \textbf{Equation 8}$$

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr
Q_f = fuel use, kg/hr
OpHrs = operating hours, hr/yr
MW_p = molecular weight of pollutant emitted, kg/kg-mole
EW_f = elemental weight of pollutant in fuel, kg/kg-mole
i = Concentration of pollutant i in fuel expressed as weight percent, %

For instance, SO_2 emissions from fuel oil combustion can be calculated based on the concentration of sulfur in the fuel oil. This approach assumes complete conversion of sulfur to SO_2. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO_2 (MW = 64) are emitted. The application of this EET is shown in Example 4.

Example 4:

Calculating sulfur dioxide emissions using fuel analysis

This example illustrates how SO_2 emissions can be calculated from oil combustion based on fuel analysis results and the fuel flow information from a boiler. The boiler is assumed to operate 1,500 hours per year.

Fuel flow = 2,000 kg/hr
Weight percent sulfur in fuel = 1.17

$E_{kpy,SO2}$ = Qf x pollutant concentration in fuel / 100 x (MW_p / EW_f) x OpHrs
= (2,000) x (1.17 / 100) x (64 / 32)
= (46.8 kg/hr x 1,500 hr/yr)
= 70,200 kg/yr

5.4 Approved alternative technique

You are able to use EETs that are not outlined in this document. You must, however, seek the consent of your state or territory environmental authority. For example, if your company has developed site-specific emission factors as a result of monitoring and testing, you may use these if they have been approved by your local environmental authority.

5.5 Calculating emissions

The general equation below uses emission factors to estimate a facility's emissions.

$$E_{(s)} = A \times EF_{(s)} \times (1-CE) \quad \textbf{Equation 9}$$

where;

$E_{(s)}$ = the annual emission level for a NPI substance (s) – e.g. Carbon monoxide in kg/yr
A = the activity rate over a year (e.g. operating hours or tonnage used)
$EF_{(s)}$ = the uncontrolled emission factor for the substance as set out in this manual at Appendix B.
CE = the control efficiency of the emission (%) and reflects the impact of any devices or processes that control the level of emissions. For example if you had a control device with an efficiency of 90% then the value of CE would be 0.9.

5.5.1 Emission factors for boiler fuel

Emission factors for NPI substances known to be components of boiler fuel are calculated in terms of kilograms of substances per tonne (or similar unit) of fuel. Appendix B provides emission factors to estimate emissions of NPI listed substances for various fuels and process configurations.

Table 34 in Appendix B sets out control efficiencies (CEs) for a number of techniques and devices that can be used to calibrate emission factors when estimating emissions. Please note that control efficiencies should only be applied to the substance outlined in Table 34, and can only be used for uncontrolled emissions.

An example to demonstrate how emission factors can be used to determine emissions is shown in Example 5.

Example 5:

Reporting NPI emissions from a facility using steam for its operations

A facility has a boiler (Underfeed Stoker) and burns 450 tonnes of black coal per year. A fabric filter with a collection efficiency of 95% for PM_{10} and $PM_{2.5}$ is used.

A. Determine whether / what NPI substances are used at the facility and whether they trip NPI thresholds.

From the threshold for reporting based on combustion of coal is 400 tonnes (Category 2a) and 2,000 tonnes (Category 2b). The mass of black coal used exceeds the Category 2a threshold, therefore reporting is expected for all Category 2a substances

B. Determine the level of emissions

The facility has determined that emission factors are the best approach to estimating emissions for the site. Table 16: Emission factors for black coal (underfeed stoker) provides emission factors for uncontrolled boilers;

For this site, the sulfur content of black coal has been determined to be approximately 0.5%. As S = 0.5, the sulfur dioxide emission factor is 7.75 kg/t

Using Equation 9:

Carbon monoxide: 5.50E+00
$E_{(CO)}$ = A × $EF_{(Carbon\ monoxide)}$
= 450 t × 5.50E+00
= 2475 kg/yr
Fluoride compounds: 7.50E-02
$E_{(F)}$ = A× $EF_{(Fluoride\ compounds)}$
= 450 t × 7.50E-02
= 33.75 kg/yr
Hydrochloric acid: 6.00E-01
$E_{(HCl)}$ = A × EF(Hydrochloric acid)
= 450 t × 6.00E-01
= 270 kg/yr
Oxides of nitrogen: 4.80E+00
$E_{(NOx)}$ = A × EF(Oxides of nitrogen)
= 450 t × 4.80E+00
= 2160 kg/yr
PM_{10}: 3.10E+00
E($_{PM<10}$) = A × EF($PM_{\leq}10$) × ($CEPM_{\leq}10$)
= 450 t × 3.10E+00 × (1-0.95)
= 69.75 kg/yr
$PM_{2.5}$: 1.90E+00
$E_{(PM\leq2.5)}$ = A × EF(PM≤2.5) × (CEPM≤2.5)
= 450 t × 1.90E+00 (PM2.5) × (1-0.95)
= 42.75 kg/yr
Polycyclic aromatic hydrocarbons (B[a]Peq): 9.49E-06
$E_{(PAH(B[a]Peq))}$ = A × EF(Polycyclic aromatic hydrocarbons (B[a]Peq))
= 450 t × 9.49E-06
= 4.27E-03 kg/yr

Example 5:

Sulfur dioxide: 7.75E+00

$E_{(SO2)}$ = A × EF(Sulfur dioxide)
= 450 t × 7.75E+00
= 3487.5 kg/yr

Total VOC: 6.50E-01

$E_{(\text{Total VOC})}$ = A × EF(Total VOC)
= 450 t × 6.50E-01
= 292.5 kg/yr

C. What needs to be reported?

Threshold data:
450 tonnes of black coal

Emissions data:

Carbon monoxide	= 2475 kg/yr
Fluoride compounds	= 33.75 kg/yr
Hydrochloric acid	= 270 kg/yr
Oxides of nitrogen	= 2160 kg/yr
PM_{10}	= 69.75 kg/yr
$PM_{2.5}$	= 42.75 kg/yr
PAH (B[a]Peq)	= 4.27E-03 kg/yr
Sulfur dioxide	= 3487.5 kg/yr
Total VOC	= 292.5 kg/yr

Pollution Control Equipment (Voluntary)
Fabric Filter

6 Transfers of NPI substances in waste

The NPI requires the mandatory reporting of NPI substances that are transferred in waste to a final destination if a Category 1, Category 1b or Category 3 reporting threshold is exceeded. Transfers to voluntary reporting transfer destinations can also be reported if desired. Refer to the NPI Guide for further details on the various categories and the relevant thresholds.

There is no requirement to report transfers of substances that are exclusively Category 2a or 2b in the event that they have been tripped only by the fuel and energy use threshold (i.e. there is no requirement to report transfers of oxides of nitrogen, particulate matter ≤10 µm, particulate matter ≤ 2.5 µm, polychlorinated dioxins and furans, or polycyclic aromatic hydrocarbons).

In the specific context of combustion in boilers, the quantities of NPI substances contained in waste moved onsite or offsite to landfill or other final destination will need to be reported as they are considered to be mandatory transfers. As stated previously, the transfer of waste need only be reported if it contains an NPI substance that your facility has triggered in Categories 1, 1b or 3. For example, waste from combustion in boilers includes 'bottom waste' from the combustion process as well as sludge and waste from desulfurisation and other boiler cleaning. These wastes are likely to contain unburnt substances similar to the emissions from combustion, and pollutants from the cleaning process.

The transfer of NPI substances to a destination for reuse, recycling, reprocessing, purification, partial purification, immobilisation, remediation or energy recovery can be reported voluntarily. This is an opportune way for facilities to promote their efforts to reduce their 'environmental footprint' to their local community.

7 Next steps for reporting

This manual has been written to reflect the common processes employed by facilities using fuel for steam energy and hot water in boilers. To ensure a complete report of the emissions and transfers from your facility, it may be necessary to refer to other EET manuals such as, but not limited to:

- Fuel and organic liquid storage
- Combustion in engines,
- Fugitive emissions, and
- Other industry-specific emission estimation technique manuals.

When you have a complete report of substance emissions and transfers from your facility, report these emissions and transfers according to the instructions in the NPI Guide.

8 References

1. Australian Bureau of Statistics and Statistics New Zealand, ANZSIC: *Australia and New Zealand Standard Industrial Classification*, ABS Catalogue 1292.0.
2. Department of Environment and Heritage (now Department of Environment, Water, Heritage and the Arts), *Emission Estimation Technique Manual for Combustion in Boilers, Draft Version* 2.0, December 2003,
3. Eastern Research Group (US), *Preferred Alternative Methods for Estimating Air Emissions from Boilers*, January 2001, Paper prepared for the USEPA.
4. HRL Technologies Pty Ltd, *NPI Development of Emission Factors for Combustion in Boilers*, Report #: HLC/2007/075, August 2007 and references contained therein.
5. United States Environment Protection Agency, *Compilation of Air Pollutants and Emission Factors, Stationary Point and Area Sources*, Volume 1, fifth edition, USEPA, AP-42, January 1995, Chapters 1 and 13
6. United States Environment Protection Agency, Technical Background Document for the Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization, March 15, 1999, http://www.epa.gov/epaoswer/other/fossil/ffc2_399.pdf

9 Appendix A: Definitions and abbreviations

AP- 42	USEPA compilations of air pollution emission factors
BOOS	Burning out of service
Desulfurisation	The removal of sulfur compounds from petroleum fractions using hydrogen in the presence of a catalyst
EET	Emission estimation technique
EF	Emission factor
EFR	Emission factor rating
ESP	Electrostatic precipitator
FBC	Fluidised bed combustion
FGD	Flu gas desulfurisation
FGR	Flue gas recirculation
LEA	Low excess air
LNB	Low NOx burner
LPG	Liquid petroleum gas
PAH	Polycyclic aromatic hydrocarbons
NG	Natural gas
NPI	National Pollutant Inventory
OFA	Over fired air
PC	Pulverised coal
PF	Pulverised fuel
RAP	Reduces air preheat
SCR	Selective catalytic reduction
SDA	Spray dryer absorbers
SNCR	Selective non-catalytic reduction
Total VOC	Total Volatile Organic Compounds
U/C	Uncontrolled (i.e. no pollution control device used)

10 Appendix B: Emission factor tables

The following tables provide emission factors for various fuel, process and control configurations for certain NPI listed substances. Not all NPI substances are listed, as emission factors have not been developed for all possible combinations of process, fuel and pollution control devices used at Australian facilities. If this is the case, you may wish to consult other NPI resources, such as the NPI Emission Estimation Technique Manual for Fossil Fuel Power Electric Power Generation (where emission factors for Victorian brown coal can be located. These factors have not been reproduced in the Combustion in Boilers manual as use of this fuel is typically limited to power generation facilities in Victoria).

In the event you have a requirement to report an NPI substance for which there are no emission factors, you should attempt to estimate the emission using one of the other accepted EETs. If you have any questions or are in doubt over which approach to take, please contact the NPI office in your state or territory.

BAGASSE

Table 5: Emission factors for bagasse boilers (uncontrolled)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.61E+00	1,2a,2b	B	a
Oxides of Nitrogen	7.60E-01	2a,2b	B	a
Particulate matter ≤10.0 µm	6.15E+00	2a,2b	U	a, b
Particulate matter ≤2.5 µm	3.51E+00	2a,2b	U	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	5.00E-04	2a,2b	U	a
Sulfur dioxide	2.50E-01	1,2a,2b	C	a, d
Polychlorinated dioxins and furans (TEQ)	4.75E-10	2b	U	c

a) *Source: Table 32, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Source: US EPA AP-42, Chapter 1.8*
c) *Source: Table 4.45, Pacific Air & Environment, National Dioxins Program, Technical Report 3, a consultancy prepared for the Department of the Environment and Heritage.*
d) *Assuming sulfur content of between 0.02-0.1%*
e) *Bagasse has an energy to weight value of 18-21 GJ/t*
f) *Bagasse has a bulk density of 120-200 kg/m^3, Sugar Cane Trash has a bulk density of 70-150 kg/m^3*

Table 6: Emission factors for bagasse boilers (dry scrubber)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.61E+00	1,2a,2b	B	a
Oxides of Nitrogen	7.60E-01	2a,2b	B	a
Particulate matter ≤10.0 µm	7.50E-01	2a,2b	A	a, b
Particulate matter ≤2.5 µm	4.34E-01	2a,2b	U	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	5.00E-04	2a,2b	U	a
Sulfur dioxide	2.50E-01	1,2a,2b	C	a, d
Polychlorinated dioxins and furans (TEQ)	4.75E-10	2b	U	c

a) *Source: Table 32, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Source: US EPA AP-42, Chapter 1.8*
c) *Source: Table 4.45, Pacific Air & Environment, National Dioxins Program, Technical Report 3, a consultancy prepared for the Department of the Environment and Heritage.*
d) *Assuming sulfur content of between 0.02-0.1%*
e) *Bagasse has an energy to weight value of 18-21 GJ/t*
f) *Bagasse has a bulk density of 120-200 kg/m^3, Sugar Cane Trash has a bulk density of 70-150 kg/m^3*

Table 7: Emission factors for bagasse boilers (wet scrubber)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.61E+00	1,2a,2b	B	a
Oxides of Nitrogen	7.60E-01	2a,2b	B	a
Particulate matter ≤10.0 µm	2.20E-01	2a,2b	A	a, b
Particulate matter ≤2.5 µm	1.26E-01	2a,2b	U	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	5.00E-04	2a,2b	U	a
Sulfur dioxide	2.50E-01	1,2a,2b	C	a, d
Polychlorinated dioxins and furans (TEQ)	4.75E-10	2b	U	c

a) *Source: Table 32, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Source: US EPA AP-42, Chapter 1.8*
c) *Source: Table 4.45, Pacific Air & Environment, National Dioxins Program, Technical Report 3, a consultancy prepared for the Department of the Environment and Heritage.*
d) *Assuming sulfur content of between 0.02-0.1%*
e) *Bagasse has an energy to weight value of 18-21 GJ/t*
f) *Bagasse has a bulk density of 120-200 kg/m^3, Sugar Cane Trash has a bulk density of 70-150 kg/m^3*

VICTORIAN BROWN COAL BRIQUETTES

Table 8: Emission factors for brown coal briquettes (uncontrolled)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	4.79E+00	1,2a,2b	D	a
Fluoride compounds	3.12E-03	2a,2b	U	b, c
Hydrochloric acid	2.99E+00	2a,2b	U	b, c
Oxides of Nitrogen	2.68E+00	2a,2b	D	a
Particulate matter ≤10.0 µm	7.80E-01	2a,2b	E	a, d
Particulate matter ≤2.5 µm	7.00E-02	2a,2b	E	a, d
Polycyclic aromatic hydrocarbons (B[a]Peq)	8.00E-07	2a,2b	U	b
Sulfur dioxide	4.79E+00	1,2a,2b	D	a, e
Total volatile organic compounds (Total VOC)	3.32E+00	1a,2a,2b	U	a
Arsenic and compounds	1.95E-05	1,2b	E	b, c
Beryllium and compounds	1.11E-05	1,2b	E	b, c
Cadmium and compounds	1.63E-05	1,2b	E	b, c
Chromium (III) compounds	5.85E-05	1,2b	E	b, c
Chromium (VI) compounds	3.97E-05	1,2b	E	b, c
Copper and compounds	4.03E-05	1,2b	E	b, c
Lead and compounds	5.27E-05	1,2b	E	b, c
Mercury and compounds	1.04E-05	1b,2b	E	b, c
Nickel and compounds	2.21E-04	1,2b	E	b, c
Polychlorinated Dioxins and Furans (TEF)	2.32E-10	2b	U	b

a) *Source: Table 32, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Source: Pacific Power International 2002, as provided by the Victorian electricity generators*
c) *Calculation based on 65% moisture in brown coal and 10% in briquettes*
d) *Calculation based on 92% of total PM is PM_{10}*
e) *Assuming sulfur content of between 0.25-0.38%*

Table 9: Emission factors for brown coal briquettes (baghouse)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	4.79E+00	1,2a,2b	D	a
Fluoride compounds	3.12E-03	2a,2b	U	b, c
Hydrochloric acid	2.99E+00	2a,2b	U	b, c
Oxides of Nitrogen	2.68E+00	2a,2b	D	a
Particulate matter ≤10.0 µm	3.10E-01	2a,2b	E	a, d
Particulate matter ≤2.5 µm	3.00E-02	2a,2b	E	a, d
Polycyclic aromatic hydrocarbons (B[a]Peq)	8.00E-07	2a,2b	U	b
Sulfur dioxide	4.79E+00	1,2a,2b	D	a, e
Total volatile organic compounds (Total VOC)	3.32E+00	1a,2a,2b	U	a

Table 9: Emission factors for brown coal briquettes (baghouse)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Arsenic and compounds	1.95E-05	1,2b	E	b, c
Beryllium and compounds	1.11E-05	1,2b	E	b, c
Cadmium and compounds	1.63E-05	1,2b	E	b, c
Chromium (III) compounds	5.85E-05	1,2b	E	b, c
Chromium (VI) compounds	3.97E-05	1,2b	E	b, c
Copper and compounds	4.03E-05	1,2b	E	b, c
Lead and compounds	5.27E-05	1,2b	E	b, c
Mercury and compounds	1.04E-05	1b,2b	E	b, c
Nickel and compounds	2.21E-04	1,2b	E	b, c
Polychlorinated Dioxins and Furans (TEF)	2.32E-10	2b	U	b

a) Source: Table 32, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Source: Pacific Power International 2002, as provided by the Victorian electricity generators

c) Calculation based on 65% moisture in brown coal and 10% in briquettes

d) Calculation based on 92% of total PM is PM_{10}

e) Assuming sulfur content of between 0.25-0.38%

BLACK COAL

Table 10: Emission factors for black coal (cyclone furnace)

Process Configuration ∟ Substance ∟ *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.50E-01	1,2a,2b	A	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen				
Bituminous	1.65E+01	2a,2b	A	a, b, c
Sub Bituminous	8.50E+00	2a,2b	C	a, b, c
Particulate matter ≤10.0 µm				
Uncontrolled	0.13 x A	2a,2b	E	a, b, c, e
Multiclones	0.056 x A	2a,2b	E	a, c, e
ESP	0.055 x A	2a,2b	E	a, c, e
Particulate matter ≤2.5 µm				
Uncontrolled	0.055 x A	2a,2b	E	a, b, c, e
Multiclones	0.055 x A	2a,2b	E	a, c, e
ESP	0.003 x A	2a,2b	E	a, c, e
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide				
Bituminous	19 x S	1,2a,2b	A	a, b, c, d
Sub Bituminous	17.5 x S	1,2a,2b	A	a, b, c, d
Total volatile organic compounds (Total VOC)	6.00E-02	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) *Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) *Additional collection efficiencies for these devices can be found in Table 34.*

c) The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.

d) Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value

e) Coal ash content as percent by weight (as fired), Value of A used in the calculation tools is 0.17

Table 11: Emission factors for black coal (fluidised bed)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	9.00E+00	1,2a,2b	D	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen				
Circulating Bed	2.50E+00	2a,2b	D	a, b, c
Bubbling Bed	7.60E+00	2a,2b	D	a, b, c
Particulate matter ≤10.0 µm				
Uncontrolled	6.45E+00	2a,2b	E	a, b, c
Particulate matter ≤2.5 µm				
Uncontrolled	2.06E+00	2a,2b	U	a, b, c
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide	$19.8 \times S \times (Ca / S)^{-1.9}$	1,2a,2b	E	a, b, c, d, e
Total volatile organic compounds (Total VOC)	2.50E-02	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Additional collection efficiencies for these devices can be found in Table 34.

c) *The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.*

d) *Ca/S = Molar Calcium to sulfur ratio in the fluidised bed. This equation may be used when Ca/S is between 1.5 and 7, in other cases use the emission factor for underfed stokers and consider the emission factor rating to be E*

e) *Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value*

Table 12: Emission factors for black coal (overfeed stoker)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	3.00E+00	1,2a,2b	B	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen	3.80E+00	2a,2b	A	a, b, c
Bituminous	3.80E+00	2a,2b	A	a, b, c
Sub Bituminous	3.80E+00	2a,2b	A	a, b, c
Particulate matter ≤10.0 µm				
Uncontrolled	3.40E+00	2a,2b	E	a, b, c
Multiclones	2.90E+00	2a,2b	E	a, c
Particulate matter ≤2.5 µm				
Uncontrolled	1.10E+00	2a,2b	E	a, b, c
Multiclones	1.10E+00	2a,2b	E	a, c
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide				
Bituminous	19 x S	1,2a,2b	A	a, b, c, d
Sub Bituminous	17.5 x S	1,2a,2b	A	a, b, c, d
Total volatile organic compounds (Total VOC)	3.00E-02	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c

Table 12: Emission factors for black coal (overfeed stoker)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Selenium and compounds	6.50E-04	1	A	a, c

a) Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Additional collection efficiencies for these devices can be found in Table 34.

c) The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.

d) Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value

Table 13: Emission factors for black coal (Pulverised coal, dry bottom)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.50E-01	1,2a,2b	A	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen				
Bituminous, Dry Bottom, Walled Fired	1.09E+01	2a,2b	A	a, b, c
Bituminous, Dry Bottom, Tangential Fired	7.50E+00	2a,2b	A	a, b, c
Sub-Bituminous, Dry Bottom, Wall Fired	6.00E+00	2a,2b	C	a, b, c
Sub-Bituminous, Dry Bottom, Tangential Fired	4.20E+00	2a,2b	A	a, b, c
Particulate matter ≤10.0 µm				
Dry Bottom, Uncontrolled	1.15 x A	2a,2b	C	a, b, c, e
Dry Bottom, Multiclones	0.29 x A	2a,2b	E	a, c, e
Dry Bottom, Scrubber	0.21 x A	2a,2b	D	a, c, e
Dry Bottom, ESP	0.27 x A	2a,2b	D	a, c, e
Dry Bottom, Baghouse	0.011 x A	2a,2b	E	a, c, e
Particulate matter ≤2.5 µm				
Dry Bottom, Uncontrolled	0.3 x A	2a,2b	C	a, b, c, e
Dry Bottom, Multiclones	0.03 x A	2a,2b	E	a, c, e
Dry Bottom, Scrubber	0.15 x A	2a,2b	D	a, c, e
Dry Bottom, ESP	0.012 x A	2a,2b	D	a, c, e
Dry Bottom, Baghouse	0.005 x A	2a,2b	E	a, c, e
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide				
Bituminous	19 x S	1,2a,2b	A	a, b, c,d
Sub Bituminous	17.5 x S	1,2a,2b	A	a, b, c,d
Total volatile organic compounds (Total VOC)	3.00E-02	1a,2a,2b	B	a, c

Table 13: Emission factors for black coal (Pulverised coal, dry bottom)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Additional collection efficiencies for these devices can be found in Table 34.

c) The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.

d) Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value

e) Coal ash content as percent by weight (as fired), Value of A used in the calculation tools is 0.17

Table 14: Emission factors for black coal (Pulverised coal, wet bottom)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.50E-01	1,2a,2b	A	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen				
Bituminous, Wet Bottom, Walled Fired	1.55E+01	2a,2b	D	a, b, c
Bituminous, Wet Bottom, Tangential Fired	1.07E+01	2a,2b	U	a, b, c
Sub-Bituminous, Wet Bottom, Wall Fired	1.20E+01	2a,2b	E	a, b, c
Sub-Bituminous, Wet Bottom, Tangential Fired	7.00E+00	2a,2b	E	a, b, c
Particulate matter ≤10.0 µm				

Table 14: Emission factors for black coal (Pulverised coal, wet bottom)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Wet Bottom, Uncontrolled	1.3 x A	2a,2b	E	a, b, c
Wet Bottom, Multiclones	0.65 x A	2a,2b	E	a, c, e
Wet Bottom, ESP	0.021 x A	2a,2b	E	a, c, e
Particulate matter ≤2.5 µm				
Wet Bottom, Uncontrolled	0.74 x A	2a,2b	E	a, b, c, e
Wet Bottom, Multiclones	0.43 x A	2a,2b	E	a, c, e
Wet Bottom, ESP	0.011 x A	2a,2b	E	a, c, e
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide				
Bituminous	19 x S	1,2a,2b	A	a, b, c,d
Sub Bituminous	17.5 x S	1,2a,2b	A	a, b, c,d
Total volatile organic compounds (Total VOC)	2.00E-02	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) *Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) *Additional collection efficiencies for these devices can be found in Table 34.*

c) *The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.*

d) *Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value*

e) *Coal ash content as percent by weight (as fired), Value of A used in the calculation tools is 0.17*

Table 15: Emission factors for black coal (spreader stoker)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	2.50E+00	1,2a,2b	A	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen				
Bituminous	5.50E+00	2a,2b	C	a, b, c
Sub Bituminous	4.40E+00	2a,2b	B	a, b, c
Particulate matter ≤10.0 µm				
Uncontrolled	6.60E+00	2a,2b	E	a, b, c
Multiclones	3.90E+00	2a,2b	C	a, c
Multiclones with fly ash re-injection	6.00E+00	2a,2b	E	a, c
ESP	2.20E-01	2a,2b	E	a, c
Baghouse	4.00E-02	2a,2b	E	a, c
Particulate matter ≤2.5 µm				
Uncontrolled	2.30E+00	2a,2b	E	a, b, c
Multiclones	1.60E+00	2a,2b	C	a, c
Multiclones with fly ash re-injection	2.30E+00	2a,2b	U	a, c
ESP	1.50E-01	2a,2b	E	a, c
Baghouse	2.00E-02	2a,2b	E	a, c
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide				
Bituminous	19 x S	1,2a,2b	A	a, b, c,d
Sub Bituminous	17.5 x S	1,2a,2b	A	a, b, c,d
Total volatile organic compounds (Total VOC)	3.00E-02	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) *Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Additional collection efficiencies for these devices can be found in Table 34.*
c) *The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis.*
d) *Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value*

Table 16: Emission factors for black coal (underfeed stoker)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	5.50E+00	1,2a,2b	B	a, c
Fluoride compounds	7.50E-02	2a,2b	B	a, c
Hydrochloric acid	6.00E-01	2a,2b	B	a, c
Oxides of Nitrogen	4.80E+00	2a,2b	A	a, b, c
Particulate matter ≤10.0 µm				
Uncontrolled	3.10E+00	2a,2b	C	a, c
Particulate matter ≤2.5 µm				
Uncontrolled	1.90E+00	2a,2b	C	a, c
Polycyclic aromatic hydrocarbons (B[a]Peq)	9.49E-06	2a,2b	D	a, c
Sulfur dioxide	15.5 x S	1,2a,2b	D	a, b, c,d
Total volatile organic compounds (Total VOC)	6.50E-01	1a,2a,2b	B	a, c
Arsenic and compounds	2.05E-04	1,2b	A	a, c
Beryllium and compounds	1.05E-05	1,2b	A	a, c
Cadmium and compounds	2.55E-05	1,2b	A	a, c
Chromium (III) compounds	1.30E-04	1,2b	A	a, c
Chromium (VI) compounds	3.95E-05	1,2b	D	a, c
Copper and compounds	4.92E-04	1,2b	U	a, c
Lead and compounds	2.10E-04	1,2b	A	a, c
Mercury and compounds	4.15E-05	1b,2b	A	a, c
Nickel and compounds	1.40E-04	1,2b	A	a, c
Polychlorinated dioxins and furans (TEQ)				
Uncontrolled, or with ESP, or with baghouse	2.97E-10	2b	D	a, c
Antimony and compounds	9.00E-06	1	A	a, c
Cobalt and compounds	5.00E-05	1	A	a, c
Manganese and compounds	2.45E-04	1	A	a, c
Selenium and compounds	6.50E-04	1	A	a, c

a) *Source: Table 35-41, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*
b) *Additional collection efficiencies for these devices can be found in Table 34.*
c) *The emission factors that have been developed for black coal are based on a Gross Specific Energy content (or higher heating value, HHV) of 23.4 GJ/t. If a facility knows that the energy content of the coal they are using is different from 23.4 GJ/t, the*

emission factors should be scaled according to the ratio of energy content, i.e. by the ration of (H/23.4), where H is HHV of the fuel used, eg the emission factor for CO from the combustion of black coal with a HHV of 25.0 GJ/t is equal to 2.50 × (25/23.4) = 2.67 kg/t. The HHV of the coal is sometimes also referred to as the Gross Calorific Value. The energy content should be on an as-fired basis

d) *Default value of S used in the NPI tools is 0.8, if your facility has different coal properties, you should use the that information instead of the default value*

BLAST FURNACE GAS

Table 17: Emission factors for blast furnace gas

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	1.60E-01	1,2a,2b	U	a
Oxides of Nitrogen	1.10E+00	2a,2b	U	a
Particulate matter ≤10.0 µm	2.50E-02	2a,2b	U	a
Particulate matter ≤2.5 µm	2.50E-02	2a,2b	U	a
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	2a,2b	U	b, c
Sulfur dioxide	2.50E-03	1,2a,2b	U	a
Total volatile organic compounds (Total VOC)	9.00E-03	1a,2a,2b	U	a
Mercury and compounds	5.00E-08	1b,2b	U	a
Polychlorinated dioxins and furans (TEQ)	1.00E-11	2b	U	a

a) *Source: Table 55, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) *Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

c) *Emission factor is taken from that derived for the combustion of natural gas.*

COKE OVEN GAS

Table 18: Emission factors for coke oven gas

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	6.40E-01	1,2a,2b	U	a
Oxides of nitrogen	6.90E-01	2a,2b	U	a
Particulate matter ≤10.0 µm	1.10E-02	2a,2b	U	a
Particulate matter ≤2.5 µm	1.10E-02	2a,2b	U	a
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	2a,2b	U	b, c
Sulfur dioxide	8.7 × S	1,2a,2b	U	a, d
Total volatile organic compounds (Total VOC)	9.00E-03	1a,2a,2b	U	a
Mercury and compounds	9.90E-07	1b,2b	U	a
Polychlorinated dioxins and furans (TEQ)	2.00E-11	2b	U	a

a) *Source: Table 56, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.
c) Emission factor is taken from that derived for the combustion of natural gas.
d) S = sulfur content,an approximate range is 0.1-0.5%.

LANDFILL GAS

Table 19: Emission factors for landfill gas boilers (uncontrolled)

Substance Process Configuration *Subtype*	Emission Factor (kg/MJ)	CAT	EFR	Notes
Carbon monoxide	3.08E-06	1,2a,2b	U	c
Oxides of Nitrogen	1.80E-05	2a,2b	U	c
Particulate matter ≤10.0 µm	1.08E-06	2a,2b	U	c
Particulate matter ≤2.5 µm	1.08E-06	2a,2b	U	c, e
Sulfur dioxide	6.39E-08 × S	1,2a,2b	U	d, f
Total volatile organic compounds (Total VOC)	8.67E-07	1a,2a,2b	U	b
Arsenic and compounds	1.86E-09	1,2b	U	b
Cadmium and compounds	2.61E-09	1,2b	U	b
Chromium (III) compounds	1.03E-08	1,2b	U	b
Copper and compounds	3.44E-09	1,2b	U	b
Lead and compounds	2.86E-09	1,2b	U	b
Mercury and compounds	3.56E-11	1b,2b	U	b
Nickel and compounds	3.44E-08	1,2b	U	b
Polychlorinated dioxins and furans (TEQ)	1.33E-13	2b	U	c
Manganese and compounds	1.02E-07	1	U	b, h

a) It is recommended that to calculate all of the potential emissions from the operation of a municipal solid waste facility, the methodology in municipal solid waste landfills NPI manual be followed.
b) Source: Table 58, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.
c) Source: Background information document for updating AP42 Section 2.4 for estimating emissions from municipal solid waste landfills
d) Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.
e) Based on assumption that all particulate matter less than 10 micron will also be less than 2.5 micron based on gaseous fuel type.
f) S = sulfur content, as a percentage %, a default value of 0.5 is used in the NPI tool.
g) A emission factor for Landfill gas (methane content of 55%) has been calculated based on the methane content and a comparison with natural gas (methane content of 94%) emission factors.
h) Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion

NATURAL GAS

Table 20: Emission factors for natural gas (tangential fired)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/Gj)	CAT	EFR	Notes
Carbon monoxide					
Uncontrolled	5.20E-01	1.17E-02	1,2a,2b	D	a, b
Flue Gas Recirculation	2.12E+00	4.77E-02	2a,2b	D	a, b
Oxides of Nitrogen					
Uncontrolled	3.68E+00	8.28E-02	2a,2b	A	a, b
Flue Gas Recirculation	1.64E+00	3.69E-02	2a,2b	D	a, b
Particulate matter ≤10.0 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Particulate matter ≤2.5 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	3.11E-07	2a,2b	E	a, b
Sulfur dioxide	2.84E-03 × S	6.39E-05 × S	1,2a,2b	A	a, b, c
Total volatile organic compounds (Total VOC)	1.19E-01	2.68E-03	1a,2a,2b	C	a, b
Arsenic and compounds	4.33E-06	9.74E-08	1,2b	E	a, b
Beryllium and compounds	2.60E-08	5.85E-10	1,2b	E	a, b
Cadmium and compounds	2.38E-05	5.36E-07	1,2b	D	a, b
Chromium (III) compounds	3.03E-05	6.82E-07	1,2b	D	a, b
Copper and compounds	1.84E-05	4.14E-07	1,2b	C	a, b
Lead and compounds	1.08E-05	2.43E-07	1,2b	D	a, b
Mercury and compounds	5.62E-06	1.26E-07	1b,2b	D	a, b
Nickel and compounds	4.54E-05	1.02E-06	1,2b	C	a, b
Polychlorinated dioxins and furans (TEQ)	1.07E-10	2.41E-12	2b	E	a, b
Cobalt and compounds	1.76E-06	3.96E-08	1	D	a, b, e
Manganese and compounds	8.24E-06	1.85E-07	1	D	a, b, e
Selenium and compounds	5.13E-07	1.15E-08	1	E	a, b, e
Zinc and compounds	6.21E-04	1.40E-05	1	E	a, b, e

a) Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Converted from kg/106 m^3 using a natural gas specific volume of 1.30E+06 L/t

c) S = sulfur concentration in natural gas in mg/m^3. Average Australian value is 8.4mg/m^3

d) All gaseous fuel particulate emissions are assumed to be PM_1, hence falling into both PM_{10} and $PM_{2.5}$ categories.

e) Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion

Table 21: Emission factors for natural gas (≤30MW wall fired)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/Gj)	CAT	EFR	Notes
Carbon monoxide	1.82E+00	4.10E-02	1,2a,2b	D	a, b
Oxides of Nitrogen					
Uncontrolled	2.16E+00	4.86E-02	2a,2b	D	a, b
LNB	1.08E+00	2.43E-02	2a,2b	D	a, b
Flue Gas Recirculation + LNB	6.90E-01	1.55E-02	2a,2b	C	a, b
Particulate matter ≤10.0 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Particulate matter ≤2.5 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	3.11E-07	2a,2b	E	a, b
Sulfur dioxide	2.84E-03 × S	6.39E-05 × S	1,2a,2b	A	a, b, c
Total volatile organic compounds (Total VOC)	1.19E-01	2.68E-03	1a,2a,2b	C	a, b
Arsenic and compounds	4.33E-06	9.74E-08	1,2b	E	a, b
Beryllium and compounds	2.60E-08	5.85E-10	1,2b	E	a, b
Cadmium and compounds	2.38E-05	5.36E-07	1,2b	D	a, b
Chromium (III) compounds	3.03E-05	6.82E-07	1,2b	D	a, b
Copper and compounds	1.84E-05	4.14E-07	1,2b	C	a, b
Lead and compounds	1.08E-05	2.43E-07	1,2b	D	a, b
Mercury and compounds	5.62E-06	1.26E-07	1b,2b	D	a, b
Nickel and compounds	4.54E-05	1.02E-06	1,2b	C	a, b
Polychlorinated dioxins and furans (TEQ)	1.07E-10	2.41E-12	2b	E	a, b
Cobalt and compounds	1.76E-06	3.96E-08	1	D	a, b, e
Manganese and compounds	8.24E-06	1.85E-07	1	D	a, b, e
Selenium and compounds	5.13E-07	1.15E-08	1	E	a, b, e
Zinc and compounds	6.21E-04	1.40E-05	1	E	a, b, e

a) *Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) *Converted from kg/106 m^3 using a natural gas specific volume of 1.30E+06 L/t*

c) *S = sulfur concentration in natural gas in mg/m3. Average Australian value is 8.4mg/m3*

d) *All gaseous fuel particulate emissions are assumed to be PM_1, hence falling into both PM_{10} and $PM_{2.5}$ categories.*

e) *Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion*

Table 22: Emission factors for natural gas (>30MW wall fired)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/Gj)	CAT	EFR	Notes
Carbon monoxide	1.82E+00	4.10E-02	1,2a,2b	D	a, b
Oxides of Nitrogen					
Uncontrolled	5.95E+00	1.34E-01	2a,2b	A	a, b
LNB	3.03E+00	6.82E-02	2a,2b	A	a, b
Flue Gas Recirculation + LNB	2.16E+00	4.86E-02	2a,2b	D	a, b
OFA/LEA	4.11E+00	9.25E-02	2a,2b	A	a, b
Particulate matter ≤10.0 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Particulate matter ≤2.5 µm	1.60E-01	3.60E-03	2a,2b	D	a, b, d
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	3.11E-07	2a,2b	E	a, b
Sulfur dioxide	2.84E-03 × S	6.39E-05 × S	1,2a,2b	A	a, b, c
Total volatile organic compounds (Total VOC)	1.19E-01	2.68E-03	1a,2a,2b	C	a, b
Arsenic and compounds	4.33E-06	9.74E-08	1,2b	E	a, b
Beryllium and compounds	2.60E-08	5.85E-10	1,2b	E	a, b
Cadmium and compounds	2.38E-05	5.36E-07	1,2b	D	a, b
Chromium (III) compounds	3.03E-05	6.82E-07	1,2b	D	a, b
Copper and compounds	1.84E-05	4.14E-07	1,2b	C	a, b
Lead and compounds	1.08E-05	2.43E-07	1,2b	D	a, b
Mercury and compounds	5.62E-06	1.26E-07	1b,2b	D	a, b
Nickel and compounds	4.54E-05	1.02E-06	1,2b	C	a, b
Polychlorinated dioxins and furans (TEQ)	1.07E-10	2.41E-12	2b	E	a, b
Cobalt and compounds	1.76E-06	3.96E-08	1	D	a, b, e
Manganese and compounds	8.24E-06	1.85E-07	1	D	a, b, e
Selenium and compounds	5.13E-07	1.15E-08	1	E	a, b, e
Zinc and compounds	6.21E-04	1.40E-05	1	E	a, b, e

a) Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.

b) Converted from kg/106 m^3 using a natural gas specific volume of 1.30E+06 L/t

c) S = sulfur concentration in natural gas in mg/m^3. Average Australian value is $8.4 mg/m^3$

d) All gaseous fuel particulate emissions are assumed to be PM_1, hence falling into both PM_{10} and $PM_{2.5}$ categories.

e) Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion

PETROLEUM REFINERY GAS

Table 23: Emission factors for petroleum refinery gas

Process Configuration Substance *Subtype*	Emission Factor kg/m^3	CAT	EFR	Notes
Carbon monoxide	5.61E-04	1,2a,2b	U	a
Oxides of Nitrogen	2.24E-03	2a,2b	U	a
Particulate matter ≤10.0 µm	4.81E-05	2a,2b	U	a, b
Particulate matter ≤2.5 µm	4.81E-05	2a,2b	U	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.38E-05	2a,2b	E	a, d
Sulfur dioxide	1.52E-02 × S	1,2a,2b	U	a, c
Total volatile organic compounds (Total VOC)	4.49E-05	1a,2a,2b	U	a
Polychlorinated dioxins and furans (TEQ)	1.07E-10	2b	E	a, d

a) *Source: Table 57, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*

b) *All gaseous fuel particulate emissions are assumed to be PM_1, hence falling into both PM_{10} and $PM_{2.5}$ categories*

c) *S = sulfur concentration in gas in mg/m^3. Average Australian value is 8.4mg/m^3*

d) *Source: Table 51-53, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts*

LIQUID PETROLEUM GAS (LPG)

Table 24: Emission factors for LPG (industrial butane)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Carbon monoxide	7.60E-01	4.32-01	1,2a,2b	E	a, b
Oxides of Nitrogen	4.43E+00	2.52E+00	2a,2b	E	a, b
Particulate matter ≤10.0 µm	2.40E-01	1.36E-01	2a,2b	E	a, b
Particulate matter ≤2.5 µm	1.30E-01	7.39E-02	2a,2b	E	a, b
Sulfur dioxide	3.5E-03 × S	2.0E-03 × S	1,2a,2b	E	a, b, c
Total volatile organic compounds (Total VOC)	5.00E-02	2.84E-02	1a,2a,2b	E	a, b
Polychlorinated dioxins and furans (TEQ)	9.92E-11	5.64E-11	2b	E	a, b
Mercury and compounds	4.96E-07	2.82E-07	2a,2b	E	a, b

a) *Source: Table 54, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of the Environment, Water, Heritage and the Arts.*

b) *Converted to kg/1,000L using a Butane density of 1760 L/t.*

c) *S = Sulfur concentration as mg/kg. The Australian standard is 100 mg/kg*

Table 25: Emission factors for LPG (industrial propane)

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Carbon monoxide	7.50E-01	3.80E-01	1,2a,2b	E	a, b
Oxides of Nitrogen	4.46E+00	2.30E+00	2a,2b	E	a, b
Particulate matter ≤10.0 µm	2.60E-01	1.33E-01	2a,2b	E	a, b
Particulate matter ≤2.5 µm	8.00E-02	4.08E-02	2a,2b	E	a, b
Sulfur dioxide	4.1E-03 × S	2.09E-03 × S	1,2a,2b	E	a, b, c
Total volatile organic compounds (Total VOC)	6.00E-02	3.06E-02	1a,2a,2b	E	a, b
Polychlorinated dioxins and furans (TEQ)	9.92E-11	5.06E-11	2b	E	a, b
Mercury and compounds	4.96E-07	2.53E-07	2a,2b	E	a, b

a) Source: Table 54, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts. Converted from kg/1,000L using a propane density of 1960 L/t.

b) S = sulfur concentration as mg/kg. The Australian standard is 100 mg/kg

RESIDUAL OIL

Table 26: Emission factors for residual oil (≤30MW)

Substance Process Configuration *Subtype*	Emission Factor kg/t	Emission Factor kg/kL	CAT	EFR	Notes
Carbon monoxide	6.70E-01	6.03E-01	1,2a,2b	A	a, b
Fluoride compounds	4.96E-03	4.46E-03	2a,2b	D	a, b
Oxides of Nitrogen	7.32E+00	6.59E+00	2a,2b	A	a, b
Particulate matter ≤10.0 µm	1.90E-01	1.71E-01	2a,2b	D	a, b
Particulate matter ≤2.5 µm	1.20E-01	1.08E-01	2a,2b	D	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.58E-04	1.42E-04	2a,2b	E	a, b
Sulfur dioxide	2.09E-02	1.90E-02	1,2a,2b	A	a, b
Total volatile organic compounds (Total VOC)	4.00E-02	3.60E-02	1a,2a,2b	A	a, b
Arsenic and compounds	6.99E-04	6.29E-04	1,2b	E	a, b
Beryllium and compounds	3.70E-06	3.33E-06	1,2b	C	a, b
Cadmium and compounds	5.29E-05	4.76E-05	1,2b	C	a, b
Chromium (III) compounds	1.12E-04	1.01E-04	1,2b	C	a, b
Chromium (VI) compounds	3.30E-05	2.97E-05	1,2b	C	a, b
Copper and compounds	2.34E-04	2.11E-04	1,2b	C	a, b
Lead and compounds	2.01E-04	1.81E-04	1,2b	C	a, b
Mercury and compounds	1.50E-05	1.35E-05	1b,2b	C	a, b
Nickel and compounds	1.12E-02	1.01E-02	1,2b	C	a, b
Polychlorinated dioxins and furans (TEQ)	2.34E-10	2.11E-10	2b	E	a, b
Antimony and compounds	6.99E-04	6.29E-04	1	E	a, b, c
Cobalt and compounds	8.01E-04	7.21E-04	1	D	a, b, c

Manganese and compounds	4.00E-04	3.60E-04	1	C	a, b, c
Selenium and compounds	9.10E-05	8.19E-05	1	C	a, b, c
Zinc and compounds	3.87E-03	3.48E-03	1	D	a, b, c

a) *Source: Table 42-45, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*

b) *Converted from kg/1,000L using a density of 1,110 L/t*

c) *Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion*

Table 27: Emission factors for residual oil (>30MW)

Substance Process Configuration *Subtype*	Emission Factor kg/t	Emission Factor kg/kL	CAT	EFR	Notes
Carbon monoxide	6.70E-01	6.03E-01	1,2a,2b	A	a, b
Fluoride compounds	4.96E-03	4.46E-03	2a,2b	D	a, b
Oxides of Nitrogen					a, b
Tangential firing, uncontrolled	4.26E+00	3.83E+00	2a,2b	B	a, b
Tangential firing, LNB	3.46E+00	3.11E+00	2a,2b	E	a, b
wall fired, uncontrolled	6.25E+00	5.63E+00	2a,2b	B	a, b
wall fired, LNB	5.32E+00	4.79E+00	2a,2b	B	a, b
Particulate matter ≤10.0 µm	1.90E-01	1.71E-01	2a,2b	D	a, b
Particulate matter ≤2.5 µm	1.20E-01	1.08E-01	2a,2b	D	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.58E-04	1.42E-04	2a,2b	E	a, b
Sulfur dioxide	2.09E-02	1.90E-02	1,2a,2b	A	a, b
Total volatile organic compounds (Total VOC)	4.00E-02	3.60E-02	1a,2a,2b	A	a, b
Arsenic and compounds	6.99E-04	6.29E-04	1,2b	E	a, b
Beryllium and compounds	3.70E-06	3.33E-06	1,2b	C	a, b
Cadmium and compounds	5.29E-05	4.76E-05	1,2b	C	a, b
Chromium (III) compounds	1.12E-04	1.01E-04	1,2b	C	a, b
Chromium (VI) compounds	3.30E-05	2.97E-05	1,2b	C	a, b
Copper and compounds	2.34E-04	2.11E-04	1,2b	C	a, b
Lead and compounds	2.01E-04	1.81E-04	1,2b	C	a, b
Mercury and compounds	1.50E-05	1.35E-05	1b,2b	C	a, b
Nickel and compounds	1.12E-02	1.01E-02	1,2b	C	a, b
Polychlorinated dioxins and furans (TEQ)	2.34E-10	2.11E-10	2b	E	a, b
Antimony and compounds	6.99E-04	6.29E-04	1	E	a, b, c
Cobalt and compounds	8.01E-04	7.21E-04	1	D	a, b, c
Manganese and compounds	4.00E-04	3.60E-04	1	C	a, b, c
Selenium and compounds	9.10E-05	8.19E-05	1	C	a, b, c
Zinc and compounds	3.87E-03	3.48E-03	1	D	a, b, c

a) *Source: Table 42-45, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*

b) *Converted from kg/1,000L using a density of 1110 L/t*

c) *Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion*

DISTILLATE (DIESEL) OIL

Table 28: Emission factors for distillate (diesel) oil (≤30MW)

Substance Process Configuration *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Carbon monoxide	6.80E-01	5.68E-01	1,2a,2b	A	a, b
Oxides of Nitrogen	2.72E+00	2.27E+00	2a,2b	D	a, b
Particulate matter ≤10.0 µm	1.40E-01	1.17E-01	2a,2b	E	a, b
Particulate matter ≤2.5 µm	3.00E-02	2.51E-02	2a,2b	E	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	2.25E-04	1.88E-04	2a,2b	E	a, b
Sulfur dioxide	1.93E-02	1.61E-02	1,2a,2b	A	a, b
Total volatile organic compounds (Total VOC)	2.72E-02	2.28E-02	1a,2a,2b	A	a, b
Arsenic and compounds	7.72E-05	6.45E-05	1,2b	E	a, b
Beryllium and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Cadmium and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Chromium (III) compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Copper and compounds	1.16E-04	9.70E-05	1,2b	E	a, b
Lead and compounds	1.74E-04	1.45E-04	1,2b	E	a, b
Mercury and compounds	5.79E-05	4.84E-05	1b,2b	E	a, b
Nickel and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Polychlorinated dioxins and furans (TEQ)	4.49E-10	3.75E-10	2b	E	a, b
Manganese and compounds	1.16E-04	9.70E-05	1	E	a, b, c
Selenium and compounds	2.92E-04	2.44E-04	1	E	a, b, c
Zinc and compounds	5.79E-05	4.84E-05	1	E	a, b, c

a) *Source: Table 46-49, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*
b) *Converted from kg/1,000L using a density of 1,110 L/t*
c) *Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion*

Table 29: Emission factors for distillate (diesel) oil (>30MW)

Substance Process Configuration *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Carbon monoxide	6.80E-01	5.68E-01	1,2a,2b	A	a, b
Oxides of Nitrogen					
uncontrolled	3.26E+00	2.73E+00	2a,2b	D	a, b
LNB	1.36E+00	1.14E+00	2a,2b	D	a, b
Particulate matter ≤10.0 µm	1.40E-01	1.17E-01	2a,2b	E	a, b
Particulate matter ≤2.5 µm	3.00E-02	2.51E-02	2a,2b	E	a, b

Table 29: Emission factors for distillate (diesel) oil (>30MW)

Substance Process Configuration *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Polycyclic aromatic hydrocarbons (B[a]Peq)	2.25E-04	1.88E-04	2a,2b	E	a, b
Sulfur dioxide	1.93E-02	1.61E-02	1,2a,2b	A	a, b
Total volatile organic compounds (Total VOC)	2.72E-02	2.28E-02	1a,2a,2b	A	a, b
Arsenic and compounds	7.72E-05	6.45E-05	1,2b	E	a, b
Beryllium and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Cadmium and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Chromium (III) compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Copper and compounds	1.16E-04	9.70E-05	1,2b	E	a, b
Lead and compounds	1.74E-04	1.45E-04	1,2b	E	a, b
Mercury and compounds	5.79E-05	4.84E-05	1b,2b	E	a, b
Nickel and compounds	5.79E-05	4.84E-05	1,2b	E	a, b
Polychlorinated dioxins and furans (TEQ)	4.49E-10	3.75E-10	2b	E	a, b
Manganese and compounds	1.16E-04	9.70E-05	1	E	a, b, c
Selenium and compounds	2.92E-04	2.44E-04	1	E	a, b, c
Zinc and compounds	5.79E-05	4.84E-05	1	E	a, b, c

a) *Source: Table 46-49, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*
b) *Converted from kg/1,000L using a density of 1,110 L/t*
c) *Category 1 substances, If your company uses 10 tonnes or more of cobalt, manganese, selenium or zinc and their compounds, you are required to report emissions of these metals from all processes, including fuel combustion*

Table 30: Emission factors for waste oil (uncontrolled)

Substance Process Configuration *Subtype*	Emission Factor (kg/t)	Emission Factor (kg/kL)	CAT	EFR	Notes
Carbon monoxide	6.30E-01	5.68E-01	1,2a,2b	A	a, b
Oxides of Nitrogen					
uncontrolled	2.39E+00	2.15E+00	2a,2b	D	a, b
Particulate matter ≤10.0 µm	6.42E+00	5.78E+00	2a,2b	E	a, b
Particulate matter ≤2.5 µm	3.62E+00	3.26E+00	2a,2b	E	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	3.70E-05	3.33E-05	2a,2b	E	a, b
Sulfur dioxide	1.67E-01	1.50E-01	1,2a,2b	A	a, b
Total volatile organic compounds (Total VOC)	1.30E-01	1.17E-01	1a,2a,2b	A	a, b
Cadmium and compounds	1.17E-03	1.05E-03	1,2b	E	a, b
Chromium (III) compounds	2.52E-03	2.27E-03	1,2b	E	a, b
Lead and compounds	6.92E-02	6.23E-02	1,2b	E	a, b
Nickel and compounds	1.38E-03	1.24E-03	1,2b	E	a, b

a) Source: Table 50, HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts
b) Converted from kg/1,000L using a density of 1,110L/t

TALLOW

Table 31: Emission factors for tallow

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide				
uncontrolled	1.80E-01	1,2a,2b	E	a
flue gas recirculation	2.70E-01	1,2a,2b	E	a
Oxides of Nitrogen				
uncontrolled	1.77E+00	2a,2b	E	a
flue gas recirculation	1.52E+00	2a,2b	E	a
Particulate Matter ≤10.0 µm	1.90E-01	2a,2b	E	a, c
Particulate Matter ≤2.5 µm	2.00E-02	2a,2b	E	a, c
Sulfur dioxide	1.10E-01	1,2a,2b	E	a, d
Total Volatile Organic Compounds (Total VOC)	2.72E-02	1a,2a,2b	U	a, b

a) Source: HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.
b) Based on similiarity between diesel and tallow, the diesel emission factor for Total VOC's has been used.
c) Assumes 92% of total PM is PM_{10}
d) Sulfur content assumed to be between 0.01 and 0.2%

WOOD AND BARKFIRED BOILERS

Table 32: Emission factors for bark fired boilers

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide				
generic barkfired boiler	4.08E+00	1,2a,2b	D	a
fluidised bed combustion	7.00E-01	1,2a,2b	D	a
dutch oven	3.30E+00	1,2a,2b	D	a
Oxides of Nitrogen				
generic barkfired boiler	1.49E+00	2a,2b	D	a
fluidised bed combustion	1.00E+00	2a,2b	D	a
dutch oven	1.90E-01	2a,2b	D	a
Particulate matter ≤10.0 µm				
uncontrolled	8.40E+00	2a,2b	D	a
Dry electrostatic granular filter	1.20E-01	2a,2b	D	a
multiclones with fly ash reinjection	5.50E+00	2a,2b	D	a
multiclones without fly ash reinjection	1.62E+00	2a,2b	D	a
Wet Scrubber	1.25E+00	2a,2b	D	a
Fluidised Bed	8.40E+00	2a,2b	D	a, b

Table 32: Emission factors for bark fired boilers

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Dutch Oven	1.20E-01	2a,2b	D	a, b
Particulate matter ≤2.5 µm				
uncontrolled	5.00E+00	2a,2b	D	a
dry electrostatic granular filter	1.00E-01	2a,2b	D	a
multiclones with fly ash reinjection	2.80E+00	2a,2b	D	a
multiclones without fly ash reinjection	8.60E-01	2a,2b	D	a
Wet Scrubber	8.10E-01	2a,2b	D	a
Fluidised Bed	8.10E-01	2a,2b	D	a, b
Dutch Oven	1.00E-01	2a,2b	D	a, b
Polycyclic aromatic hydrocarbons (B[a]Peq)	8.94E-04	2a,2b	U	a
Sulfur dioxide	1.70E-01	1,2a,2b	A	a
Total volatile organic compounds (Total VOC)	1.20E-01	1a,2a,2b	D	a
Arsenic & compounds				
uncontrolled	1.49E-04	1,2b	U	a
controlled	4.27E-05	1,2b	U	a, c
Beryllium & compounds				
uncontrolled	7.47E-06	1,2b	U	a
controlled	1.64E-07	1,2b	U	a, c
Cadmium & compounds				
uncontrolled	2.79E-05	1,2b	U	a
controlled	1.06E-05	1,2b	U	a, c
Chromium (III) compounds				
uncontrolled	1.43E-04	1,2b	U	a
controlled	7.80E-05	1,2b	U	a, c
Chromium (VI) compounds				
uncontrolled	2.38E-05	1,2b	U	a
controlled	2.30E-05	1,2b	U	a, c
Copper & compounds				
uncontrolled	3.33E-04	1,2b	U	a
controlled	1.87E-04	1,2b	U	a, c
Lead & compounds				
uncontrolled	3.26E-04	1,2b	U	a
controlled	2.23E-04	1,2b	U	a, c
Mercury & compounds				
uncontrolled	2.38E-05	1b,2b	U	a
controlled	2.58E-06	1b,2b	U	a, c
Nickel & compounds				
uncontrolled	2.24E-04	1,2b	U	a
controlled	3.45E-05	1,2b	U	a, c
Polychlorinated dioxins and furans (TEQ)	5.29E-10	2b	U	a

a) Source: HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.
b) Uncontrolled particulate emissions
c) Controlled emissions include, Dry electrostatic granular filters, multicyclones with and without fly ash reinjection and wet scrubbers

Table 33: Emission factors for wood/bark fired boilers

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
Carbon monoxide	4.08E+00	1,2a,2b	D	a
Oxides of Nitrogen	1.49E+00	2a,2b	D	a
Particulate matter ≤10.0 µm				
uncontrolled	3.24E+00	2a,2b	D	a
ESP	1.20E-01	2a,2b	D	a
multiclones with fly ash reinjection	2.73E+00	2a,2b	D	a
multiclones without fly ash reinjection	8.60E-01	2a,2b	D	a
wet scrubber	2.20E-01	2a,2b	D	a
Particulate matter ≤2.5 µm				
uncontrolled	2.74E+00	2a,2b	D	a
ESP	1.00E-01	2a,2b	D	a
multiclones with fly ash reinjection	1.62E+00	2a,2b	D	a
multiclones without fly ash reinjection	4.30E-01	2a,2b	D	a
wet scrubber	2.20E-01	2a,2b	D	a
Polycyclic aromatic hydrocarbons (B[a]Peq)	1.78E-03	2a,2b	U	a
Sulfur dioxide	1.70E-01	1,2a,2b	A	a
Total volatile organic compounds (Total VOC)	1.20E-01	1a,2a,2b	D	a
Arsenic & compounds				
uncontrolled	1.49E-04	1,2b	U	a
controlled	4.27E-05	1,2b	U	a, b
Beryllium & compounds				
uncontrolled	7.47E-06	1,2b	U	a
controlled	1.64E-07	1,2b	U	a, b
Cadmium & compounds				
uncontrolled	2.79E-05	1,2b	U	a
controlled	1.06E-05	1,2b	U	a, b
Chromium (III) compounds				
uncontrolled	1.43E-04	1,2b	U	a
controlled	7.80E-05	1,2b	U	a, b
Chromium (VI) compounds				
uncontrolled	2.38E-05	1,2b	U	a
controlled	2.30E-05	1,2b	U	a, b
Copper & compounds				
uncontrolled	3.33E-04	1,2b	U	a
controlled	1.87E-04	1,2b	U	a, b
Lead & compounds				

Table 33: Emission factors for wood/bark fired boilers

Process Configuration Substance *Subtype*	Emission Factor (kg/t)	CAT	EFR	Notes
uncontrolled	3.26E-04	1,2b	U	a
controlled	2.23E-04	1,2b	U	a, b
Mercury & compounds				
uncontrolled	2.38E-05	1b,2b	U	a
controlled	2.58E-06	1b,2b	U	a, b
Nickel & compounds				
uncontrolled	2.24E-04	1,2b	U	a
controlled	3.45E-05	1,2b	U	a, b
Polychlorinated dioxins and furans (TEQ)	5.29E-10	2b	U	a

a) Source: HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.

b) Controlled emissions include, Dry electrostatic granular filters, multicyclones with and without fly ash reinjection and wet scrubbers

EFFICIENCY RATES FOR DIFFERENT CONTROL DEVICES

Table 34: Efficiency rates for different control devices

Substance ↳ Control	Efficiency rate (%)	Notes a
Mercury		
Wet scrubber	55-65	b
Wet scrubber with conditioning agent	76-82	b
Spray absorbers & Fabric Filter (limestone)	44-52	b
Spray absorbers & Fabric Filter (absorbent)	87-94	b, c
ESP or Fabric filter with carbon injection	50-90	b
ESP or Fabric filter & polishing wet scrubber	85	b
Oxides of nitrogen		
SCR	70 - 90	a
SNCR	30 - 50	a
SNCR with LNB	65 - 75	a
LEA	10 - 44	a
LNB (Air staged)	25 - 35	a
LNB (Flue gas recirculation)	0 - 20	a
LNB (fuel staged)	50 - 60	a
Sulfur dioxide		
Wet scrubber	90 - 98	a
Semi-dry scrubber	80 - 90	a
Dry scrubber	50 - 80	a
PM_{10} (Particulate Matter ≤10μm)		
ESP	90 - 99.9 (new equipment 99 and above)	a
Fabric filter	95 - 99.9 (new equipment 99 and above)	a
Single high throughput cyclone	10- 40	a
Single conventional cyclone	30 - 90	a
Single high efficiency cyclone	60 - 95	a
Multi cyclones	80 - 92.5	a
Venturi scrubber	70 - 99	a
Condensation scrubber	99 - 99.9	a
Impingement scrubber	50 - 99	a
Orifice scrubber	80 - 99	a

continued on next page.

Table 34: Efficiency rates for different control devices

Substance ↳ Control	Efficiency rate (%)	Notes a
$PM_{2.5}$ (Particulate Matter ≤2.5μm)		
ESP	90 - 99.9 (new equipment 99 and above)	a
Fabric filter	95 - 99.9 (new equipment 99 and above)	a
Single high throughput cyclone	0 - 10	a
Single conventional cyclone	0 - 40	a
Single high efficiency cyclone	60 - 95	a
Venturi scrubber	20 - 70	a
Condensation scrubber	70 - 99	a
Impingement scrubber	50 - 99	a
Orifice scrubber	80 - 99	a

a) *Source: HRL Technology Pty Ltd, NPI – Development of Emission Factors for Combustion in Boilers, a report prepared for the Department of Environment, Water, Heritage and the Arts.*

b) *Source: Review Mercury in waste incineration, Waste Management Research 2002*

c) *Special absorbents may be absorbents impregnated with sulfur or sulfur compounds or active carbon based absorbents, which increase the sorption of mercury particles.*

Appendix C: Erratum to the Combustion in boilers EET manual

Version 3.6 - December 2011

Page	Outline of alteration
Table 26 and 27	Corrected incorrect emission factors, decreased sulfur dioxide emission factor from 2.09E+01 to 2.09E-02

Version 3.5 - June 2011

Page	Outline of alteration
Table 19	Corrected emission factors, updated category for manganese and compounds
Tables 20-23	note: Increased average sulfur content of gas used in the NPI calculation tool from 4 to 8.4mg/m^3
Table 30	Renumbered to include table for waste oil
Table 32, 33	Restored trace metal emission factors which were removed from Version 3.2
Table 34	Add information on control efficiencies for mercury emissions

Version 3.3 - September 2010

Page	Outline of alteration
Table 28, 29	Correction to Zinc emission factor from 5.79e-02 to 5.79e-05
Page 15	Correction to control efficiency equation 9,
Page 16	Correction to example - changed fuel description from natural gas to black coal
Table 31, 32	Restored trace metal emission factors which were removed from Version 3.2
Table 20 - 23	note: Increased average sulfur content of gas used in the NPI calculation too from 4 to 8.4mg/m^3

Version 3.2 - February 2010

Page	Outline of alteration
Table 2	Removal of table 5 and addition of table 2, so as to align thresholds information with the NPI Guide.
throughout	Revised emission factors for PM≤2.5. Revised emission factors for Polychlorinated dioxin and furans (TEQ) Revised layout of tables to reflect category 2a and 2b thresholds Additional background information and details of assumptions underpinning emission factors provided accompanying emission factor tables. Revised emission factors for sulfur dioxide to improve accuracy. New factors require the user to incorporate sulfur content of fuel specific to the location of the facility. Emission factors published in version 3.1 of the manual had assumptions incorporated.
Page 7	Removed Petroleum products from list of fuels
Page 13	Updated conversion factors for common boiler fuel types.
Page 20	Updated Example 5
Pages 29-30	Split bagasse fuel table into multiple tables based on process configuration. Revised emission factors for Polycyclic aromatic hydrocarbons (B[a]Peq)
Pages 30-31	Split brown coal briquette fuel table into multiple tables based on process configuration.
Pages 32-38	Split black coal fuel table into multiple tables based on process configuration.
Pages 41-42	Split natural gas fuel table into multiple tables based on process configuration.
Pages 44	Split LPG fuel table into multiple tables based on process configuration.
Pages 45-46	Split residual oil fuel table into multiple tables based on process configuration.
Pages 46-47	Split distillate oil fuel table into multiple tables based on process configuration.
Page 49	Corrected missing emission factors for wood combustion

Version 3.1 - (March 2008)

Page	Outline of alteration
throughout	Version 3.1 follows the new standard format for Emission Estimation Techniques Manuals.
1	Removed Section 1.1, which duplicated information in the NPI Guide.
	Version 3.1 makes use of new emission factors which are additional or modifications of those used in earlier versions of the manual, based on further research reports. Published emission factors have either been developed based on Australian data, or have been drawn from USEPA AP42, where that data has been accessed as acceptable for Australian industrial applications.
	Emission factors for sulfur dioxide for Natural Gas combustion purposes have been updated to correct an anomaly in version 3.0 of the manual.
	Version 3.1 incorporates the changes to the National Environmental Protection Measure (NEPM) by state and federal Ministers from June 2007.