Notes and comments:
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Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Guidance for local authorities
PM_{10} emissions from wood fuels





Inspiring energy efficiency · advancing renewable energy

Contents

Introduction

Woody biomass is a renewable and carbon neutral source of energy. It can be derived from forestry residues, clean material such as joinery and arboriculture wastes, and the sawmilling industry. The advantages of being both renewable and carbon neutral, as well as the increasing price of fossil fuels, are drivers for the conversion to woody biomass from other fuels for heating and energy.

The potential for the increased use of woody biomass to contribute to particulate matter emissions, in particular, those smaller than ten microns in diameter (PM_{10}), is of concern to local authorities with responsibility for managing air quality and ensuring compliance with the National Environmental Standards for Air Quality.

This document sets out to provide a source of information to local authorities to assist them when considering both regulatory provisions in plans and individual applications for resource consent for discharge to air. The focus of this guidance is on small scale thermal plants for burning woody biomass that may be sited for example within office buildings, schools, sports centres, hospitals, up to industrial scale thermal plant applications. Woody biomass combustion processes for domestic use within homes is outside the scope of this review and the sector is already covered under national regulations.

The following approach was taken to gathering information for this review:

- An international literature review on the available technology and particulate matter emission limits for woody biomass combustion.
- Regional air plan provisions for woody biomass compiled and summarised for the thresholds and general conditions currently operative for this sector.
- PM_{10} emission measurement data obtained principally via contact with stack emission testing companies, equipment suppliers and local authorities.

From the information available, potential approaches to managing and regulating biomass appliances have been developed for the New Zealand context. While the intention of this document was to have specific emphasis on PM_{10} emissions, overseas data is based on total particulate matter (TPM[1] or dust) and there appears to be insufficient New Zealand data to establish meaningful emission rates for PM_{10} here. Using TPM provides a conservative approach from a regulatory perspective and is consistent with European certification schemes reviewed.

Note: "dust" is the word by word translation of "Staub".
"Staub" in this case refers to the total suspended particulates TSP hence TPM is the better translation.
E.g. the German word for particulates is "Feinstaub" which means "fine dust".

1 Total particulate matter (TPM) in this report is equivalent to total suspended particulate matter, which is the terminology generally used for emission monitoring of particulate in New Zealand.

1. Legislative context

The Resource Management Act 1991 (RMA) is the applicable overarching legislation for decision making around managing discharges to air. The National Environmental Standards for Air Quality provide an absolute baseline for acceptable effects. Regional councils provide the next level of regulation in their regional plans and associated policy statements. Relevant provisions of the regulatory framework are discussed below.

1.1 The RMA

The purpose of the RMA is to promote the sustainable management of natural and physical resources, including air. Under Section 30 of the RMA, consenting authorities have a statutory responsibility to control discharges of contaminants into air. Section 15 of the RMA restricts the discharge of contaminants into air, while discharges to air from industrial and trade premises require a resource consent unless specifically provided for by a rule in a regional plan or by regulation.

Section 88 of the RMA requires an assessment of environmental effects to accompany an application for discharge consent, while Schedule Four is specific as to the matters that should be included. The relevant provisions are set out in the Ministry for the Environment's *Good Practice Guide for Assessing Discharges to Air from Industry* (2008). To assess discharges to air in support of an application for consent, the rate of emissions to air is included in the information requirements. Sources of information to estimate emissions are typically: manufacturer's data, actual emission test data for the plant if already in operation and/or emission factors from a published source. The emission rate ultimately determines the effect on the environment in terms of overall loading on an airshed and the contribution to concentrations directly downwind of the source.

Of particular relevance to biomass as an energy source, Section 7 of the RMA requires that:

> *"In achieving the purpose of this Act, all persons exercising the functions and powers under it, in relation to managing the use, development, and protection of natural physical resources, shall have particular regard to – (ba) the efficiency of the end use of energy, and (j) the benefits to be derived from the use and development of renewable energy."*

Burning of wood fuels satisfies sub-sections (ba) and (j) of Section 7 of the RMA, which supports using wood fuels, provided the environmental effects are acceptable overall.

1.2 National Environmental Standards for Air Quality

The *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* (SR2004/309) amended as at April 2011[2] (NESAQ) specifies ambient air quality standards for certain contaminants. The NESAQ includes concentration thresholds and permissible excursions, as listed in Table 1.

Table 1: Ambient Air Quality Standards (Schedule 1 of the NESAQ)

Contaminant	Threshold concentration (µg/m³)	Permissible excess
Sulphur dioxide	350 as a 1-hour mean	9 in a 12-month period
	570 as a 1-hour mean	None
Particulate matter (PM_{10})	50 as a 24-hour mean	One in a 12-month period
Nitrogen dioxide	200 as a 1-hour mean	9 in a 12-month period
Carbon monoxide	10,000 as an 8-hour running mean	One in a 12-month period

Airshed

The NESAQ uses the term *airshed*, which defines where air quality must be monitored and determines the basis for certain decisions on resource consents. Regulation 15 requires that if the standard is likely to be breached the council must conduct monitoring in the part of the airshed where the standard is breached by the greatest margin or the most frequently.

2 www.mfe.govt.nz/issues/air/

Thus the worst case site is used to be representative of air quality in the airshed.

A key focus of the NESAQ is to address particulate matter that is smaller than ten microns in diameter (PM_{10}). The NESAQ sets a concentration limit for PM_{10} of 50 µg/m^3 as a 24-hour average. Airsheds have been established for managing PM_{10} around New Zealand, particularly around areas where there are non-compliances or suspected non-compliances with the NESAQ for PM_{10}. Regulation 17(4) of the Amendment Regulations (2011/103) define a "polluted" airshed as of 1 September 2011 or any later day, as where the average exceedances for an airshed, where there is meaningful data, is more than one per year for the preceding 5-year period.

Non-complying airsheds

At the start of 2011, there were 15 airsheds identified as non-complying with the NESAQ for PM_{10} and being in a position where they would not be able to comply with the requirement to meet the ambient air limit by 2013. The Amendment Regulations (2011/103) extended the date for compliance for the worst airsheds to 1 exceedance by 2020. The peak measurements in one airshed was up to around 120 µg/m^3 as a 24-hour average and up to 60 or more exceedances of the limit value per year.

The NESAQ has a new provision relating to granting consents in polluted airsheds. Under regulation 17(1) for a new discharge the application must be declined if the discharge would be likely to, at any time, increase the concentration of PM_{10} by more than 2.5 µg/m^3 as a 24-hour average in any part of the airshed, unless offsets are provided. An SKM report, *Generic Application for Wood-fired School and Commercial Heating Boilers in Auckland Region* (2008), used a screening air dispersion modelling study to investigate the potential effects for a 720 kW KOB, specifically designed, low emission wood-fired boiler. The predicted maximum increase in PM_{10} was 7 µg/m^3 as a 24-hour average. Another boiler rated 1.3 MW converted from coal was also considered in the assessment and had a predicted maximum ground level concentration of 16 µg/m^3 as a 24-hour average. These boilers do not appear to meet the requirements of Regulation 17 (1) unless they are replacing a boiler or existing appliance with one that has the same or lower level of emissions. It is noted, however, that the generic consent application was necessarily conservative. The rate of particulate matter emissions utilised for the converted boiler was based on 150 mg/Nm^3 at 12% CO_2 and was affected by building downwash. When the model was rerun without building downwash[3] (21 m high stack) the ground level concentration was predicted to be 0.7 µg/m^3 as a 24-hour average, which would be acceptable in a polluted airshed under the NESAQ.

Any conversions of appliances where a well-designed wood-fired plant is replacing an existing coal plant would be expected to meet the regulation. An entirely new facility in a polluted airshed, however, may be less well placed to gain consents without providing for offsets.

Improving air quality

It will probably depend on the area / airshed if the main source of PM10 emissions are from domestic or industrial boilers, won't it?

Action is being taken to improve air quality such as via the requirements on domestic woodburners within the NESAQ and some regional plan provisions on domestic home heating emissions, which are generally responsible for the majority of the wintertime PM_{10} in affected areas. The potential for growth in the use of woody biomass plant in the commercial and industrial sectors has implications for managing PM_{10}, particularly within polluted airsheds. This is because, depending on the source being replaced, growth may compromise the ability of councils to achieve compliance with the PM_{10} standard and further or amended controls may be appropriate. Options for controls on these sources through regional plans are the subject of this document. More stringent requirements are likely to be appropriate in polluted as compared to non-polluted airsheds.

1.3 Regional plans

All local authorities with responsibilities for air management have regional plans that regulate air discharges. These may be at different stages of the planning process i.e. proposed, operative, or operative with proposed changes. Appendix A summarises the regional plan thresholds for rules applicable to woody biomass combustion and the status of the plan as reviewed, although it is recommended that the relevant plan be consulted because plans are subject to change. Appendix A cannot be viewed as an authoritative reference. In addition, plans contain specific provisions relating to the information requirements that must met for consent applications within the particular region.

3 Ron Pilgrim, e-mail, July 2008.

Historically, many regional plans classified thermal plants such as boilers over 5 MW (gross heat output) as activities requiring air discharge consent. Activities below this threshold were generally permitted with relatively general conditions. Some plans have differentiated rules based on fuel type with rules being more permissive (i.e. higher thresholds) for a permitted activity for gas combustion. Coal and wood are generally aggregated into one rule with the same threshold, although plans (such as Auckland's) have a middle threshold that applies to wood, with coal being more restrictive and gas less restrictive. Tasman District has specified limits for wood pellets that are equivalent to gas and light fuel oils, although the rule framework is complicated and also varies according to zone/airshed. Specifying wood separately allows for more specific (relevant) permitted activity conditions to be developed. This approach will allow for setting emission limits on particulate matter that are achievable with a purpose-designed low emission wood fired unit, potentially allowing a higher activity threshold compared to coal.

Some regional plans have a permitted activity threshold for woody biomass as low as 40 kW being permitted and anything above this requiring consent.

The Auckland regional plan

Air Land Water (operative in part October 2010) makes the combustion of wood not exceeding a total generating capacity of 5 MW[4] a permitted activity. The conditions of the permitted activity however, include that the wood is less than 25% moisture by weight (dry basis) and that a particulate control measure such as a bag filter or electrostatic precipitator must be used. Other conditions relate to the stack height and the efflux velocity requirements. We understand that the efflux velocity requirement is very difficult to comply with for small scale plants and that the moisture content is not achievable unless the wood fuel has been purposely dried (SKM, 2008) therefore the default position will be that many sites will require consent as a discretionary activity by default.

The Canterbury natural resources regional plan[5]

The Canterbury natural resources regional plan[6] has rules depending on whether the facility is in a Clean Air Zone i.e. polluted airshed or not. Outside a Clean Air Zone wood (and coal or light fuel oil) between 40 kW up to 1 MW is a permitted activity, with conditions including stack height requirements and a concentration limit on total particulate matter of 500 mg/m^3 at standard temperature and pressure adjusted to 8% O_2 or 12% CO_2. Environment Canterbury also requires that the wood moisture content not exceed 25% dry weight and that the quantity of fuel burnt is recorded and reported to the council annually. Within the Clean Air Zone woody biomass appliances are, at a minimum, classified as controlled activities.

Note:

12% CO2 and 8%O2 are different reference points!
It is unclear why you can chose between two different reference points? (8% O2 is stricter)

In general: on biomass boiler plants a O2 reference makes more sense than a CO2 reference point.

The Otago Regional Council also differentiates on the basis of air zones, with all fuel burning appliances up to 1 MW being permitted inside a polluted airshed and 5 MW outside.

Environment Bay of Plenty

Some councils have developed thresholds within the permitted activity status i.e. a stepped approach, where more stringent conditions apply to larger appliances still within the permitted status. For example, Environment Bay of Plenty, which has a Ringelmann smoke requirement for appliances up to 500 kW and an emission limit of 400 mg/m^3 (STP, 8% O_2), that applies in the range 500 kW to 5 MW. Overall where emission limits are specified by councils in permitted activity rules they range from 125 mg/m^3 up to 500 mg/m^3, with a common requirement being 250 mg/m^3. Councils generally aggregate the combustion of wood with coal, hence emission limits may be being set higher (and therefore thresholds set lower) than desirable. In addition, facilities with permitted activity status are not typically monitored, thus there are no guarantees that the emission limits set in plans are being achieved.

As discussed in Sections 4 and 6 of this report, using best practice, purpose designed woody biomass fired appliances has the potential to result in lower emission levels than those provided in current regional plans. The regional plan provisions are in themselves highly variable as to scale of appliance and conditions to be met. A New Zealand certification scheme could be developed for small to mid-sized woody biomass appliances, which would support more consistency around future rule development and provide more certainty around compliance with permitted activity rules.

? …what is small, what is mid-sized?

4 While not explicit in many plans, it is assumed that the megawatt rating (MW) is the gross heat output as calculated by the higher heating value of the fuel.
5 Operative in Part, October 2009/June 2011
6 Operative in Part, October 2009/June 2011

2. Wood fuel parameters

The Bioenergy Association of New Zealand (BANZ, 2010)[7] has a classification system for properties of woody biomass fuel which helps to ensure a consistent quality fuel is supplied. BANZ also discusses the differing types of wood fuels as suitable for various thermal heat appliances. A description of the classification system and types of fuel and their suitability for different applications is outlined below.

2.1 Wood fuel classification

The BANZ classification system for wood fuels is based upon specifications for: size, moisture content, ash content, actual bulk density; and energy density. Wood fuel classification is relevant to the application of wood fuels in various combustion systems. The parameters are discussed below.

Size: *The main factor for a boiler design is the calorific value.*
Fuel size will be considered but effects mainly the fuel handling system.
It's unlikely that larger fuel pieces will increase the emissions of a purpose built boiler.
Why should they?

Size (S): thermal heat plants are generally designed for a particular fuel size. The size distribution of the fuels has a direct effect on the combustion and emission performance of the appliance. Fuels with fines content exceeding what they are designed to handle or fuel pieces larger than what the system was designed will reduce the performance considerably resulting in higher emissions.

Moisture: *That is wrong.*
Purpose build boilers (designed for high moisture content fuels) will have an excellent combustion performance. Most Polytechnik boilers operate at CO levels <10 mg/m3 at MCR.

Moisture (M): thermal heat plants are generally specified to burn wood of certain moisture content. High moisture content results in lower combustion performance and lower thermal efficiency.

Ash (A): manufacturers generally specify certain ash levels for the fuels to be burned in their appliances. Excessive ash reduces the efficiency of the appliance and increases maintenance and disposal costs. Ash is non-combustible material, which directly impacts on particulate matter emissions.

Bulk density (BD): bulk density is useful when considering the sale of wood fuels, since it is generally more practical to measure the volume of wood for sale rather than to weigh it. When the bulk density is combined with the moisture content, wood fuels can be measured and sold on an energy basis simply by measuring the volume of wood. Bulk density is reported as kg of wood per unit volume of the wood (kg/m^3).

Energy density (ED): wood fuels being sold with a specific classification have consistent energy content rather than one that varies by weight or volume. The importance of energy content of the fuel relates to the efficiency of the boiler or stove design and the tuning of the appliance to optimise combustion conditions. Energy density is reported as the energy value per kg of wood (MJ/kg).

≤ 35%

For example, wood chips may be classified as **S30 M35 A1 BD200 ED18**. This classification means the wood chips must be 30 mm in size, with a moisture content of 35% by weight, ash content of 1% by weight, bulk density of 200 kg/m^3, and an energy density of 18 MJ/kg.

≤ 1% *NCV, dry matter?*

7 www.eecabusiness.govt.nz/node/14982, Wood Fuel Classification Guidelines (2010)

2.2 Wood chips

The quality wood chip for fuel supply is dependent on:

- moisture content
- contamination
- particle size distribution.

All wood chips for fuel supply must be made from untreated timber and must be free from non-wood contaminants. Wood chips are classified according to the BANZ *Wood Fuel Classification Guidelines* as:

- fine wood chips (S30)
- medium wood chips (S50)
- coarse wood chips (S100)
- wood chips unsorted.

Wood chips of S30 classification can be utilised in all biomass specific chip boilers, provided other specifications are right.

Wood chips unsorted is the lowest quality of wood chips available and is sold without reference to size, moisture content and degree of contamination. It is recommended that unsorted woodchips are used in larger industrial scale applications having a greater degree of combustion control and pollution abatement.

? - if larger means >250 kW then OK

Note: all of Polytechnik's boilers ≥300kW will utilize unsorted wood chips very efficiently (size and blend will be agreed with the costumer)

2.3 Hog fuel

Hog fuel is primarily sourced from wood processing residues and comprises: pulverized *?* bark, shavings, sawdust, and low-grade lumber and lumber rejects from the operation of such processes as pulp mills, saw mills and plywood plants. As with wood chips, all hog fuel categories must be made from untreated timber and must be free from non-wood contaminants.

Due to the nature of the wood and its source, it is recommended that hog fuel is used in larger industrial scale applications having a greater degree of combustion control and pollution abatement.

? - if larger means >250 kW then OK

Note: all of Polytechnik's boilers ≥300kW will utilize hog fuel very efficiently (size and blend will be agreed with the costumer)

2.4 Wood pellets

Wood pellets are produced from high quality wood and their production is standardised according to the wood feedstock used. Heat plants using wood pellets can be categorised according to size:

What is - small -medium - large ?

- Small – generally domestic for home heating
- Medium – generally for small to medium sized commercial or industrial boilers
- Large – generally for large industrial process heat boilers. *...and power plants*

When considering small to medium scale heating appliances, controlling the fuel quality such as with wood fuel pellet standards provides a means of controlling the emissions from combustion. This avoids the need for ongoing monitoring of emissions providing the specified fuel quality is used.

When considering larger scale combustion plants, where a resource consent for air discharges may be required, the quality of the fuel inputs can also be an important consideration in the combustion plant being able to meet its emission limit requirements. The BANZ guidance note recommends that:

> *"When a resource consent is applied for, the boiler supplier must clearly state what category of pellet is capable of being used in the appliance. This must also be stated in the warranty conditions of the boiler. This requirement will give confidence to the consent issuer that the appropriate technology and fuel are being used. Testing of the fuel and boiler technology in advance is likely to lead to a more efficient consenting process."*

This approach is endorsed and recommended for adoption by the consenting authorities for processing applications for resource consents for pellet fuelled appliances. The BANZ recommendation is also applicable more generally to other wood fuels, and a more general recommendation is provided in Section 8 of this report.

The three categories of pellet fuel are described in the BANZ guidance as described below.

2.4.1 Category A – premium pellets

Category A premium pellets are suitable for use in any residential or commercial boiler, and must be made from virgin wood, untreated and free from contamination. Ash levels are low (less than 1% of the mass of the pellet) and as a result so are the subsequent ash emissions levels. These pellets are suitable for use in appropriate appliances in degraded airsheds. Category A Premium Pellets must be around 6mm in diameter and less than 6 times the diameter in length (thus less than around 36 mm).

2.4.2 Category B – large premium pellets

Category B premium pellets must be made from virgin wood, be untreated and free from contamination, and BANZ states, may be used in smoke control areas (degraded airsheds). The only difference between these and the Premium A pellets is the size of the pellet; the pellet quality remains largely unchanged from Category A Premium Pellets with ash content also being less than 1% of the mass of the pellet. These are most suitable for larger scale combustion processes such as school or hospital boilers and industrial applications. Category B Large Premium Pellets must be around 10 mm in diameter and less than 6 times the diameter in length (thus less than around 60 mm).

2.4.3 Category C – industrial grade pellets

Category C industrial grade pellets may be used in selected boilers subject to resource consent and boiler manufacturer specifications. BANZ recommends that these pellets are used for larger scale appliances outside smoke control areas (degraded airsheds) or subject to individual air discharge consent. This grade of pellet offers the benefit of ease of fuel handling but does not offer the advantages offered by Category A and Category B pellets, such as low ash content and inherently low ash emissions levels (the ash content requirement being less than 5% of the mass of the pellet compared to less than 1%).

2.4.4 European certification of pellet quality

The two main certifications of quality for pellets in the European market are the German *DIN51731*[8] and the Austrian *Ö-Norm M-1735*. Pellets conforming to these standards will have less than 10% water content, are uniform in density, have good structural strength, and low dust and ash contents as set out in Table 3.1.

Table 3.1: European Pellet Quality Standards

	Ö-Norm	DIN-Norm	DINplus
Thermal Value	18 MJ/kg	18 MJ/kg	18 MJ/kg
Density	1.12 kg/dm^3	1.0 - 1.4 kg/dm^3	1.12 kg/dm^3
Water content	Max. 10.0%	Max. 12.0%	Max. 10.0%
Ash content	Max. 0.5%	Max. 1.5%	Max. 0.5%
Length	Max. 5 x diameter	Max 50 mm	Max. 5 x diameter
Diameter	4 – 10 mm	4 – 10 mm	4 – 10 mm
Abrasion	Max. 2.3%		Max. 2.3%
Composition	natural wood	natural wood	natural wood

8 Testing of solid fuels - Compressed Untreated Wood - Requirements and Testing

The German Institute for Standardisation (DIN[9]) publishes national standard for wood pellet classification, which is being adopted in the main within a new European Standard on wood pellets to be published in 2011. In addition, a European standardisation committee is presently developing requirements for quality assurance of the production and supply of solid fuels, based upon the requirements for the "DINplus" Quality Mark for wood pellets.

To achieve the DINplus quality mark monitoring and quality assurance, specified requirements must be met including an annual inspection by an external, third-party who conducts random tests.

2.5 Construction and demolition waste timber

In Germany/Europe: four (4) classes acc. to Regulation on Waste Wood:

AI: *Waste timber in its natural state or only mechanically worked which, during use, was at most insignificantly contaminated with substances harmful to wood*

AII: *Waste timber which has been bonded, coated, painted,lacquered or treated otherwise without halogen-organic compounds in the coating and without wood preservatives*

AIII: *Waste timber with halogenated organic compounds in the coating, without wood preservatives*

AIV: *Waste timber treated with wood preservatives, s.a. sleepers, poles, hop-poles, vineyard-poles and other waste timber which cannot be classified in one of the classes AI – AIII*

Construction and demolition wastes are often considered as one waste stream although they can produce quite different wastes as follows:

- Construction – off cuts from structural and finishing timber, timber packaging, scaffolding, wooden hoardings, concrete form work
- Demolition – used structural and other timber, e.g. floorboards, joists, beams, staircases and doors.

Categories in terms of waste arising are:

- treated wood waste
- untreated wood waste
- contaminated wood waste (reconstituted or coated wood products).

It is noted that refurbishment activities can lead to a mixture of both demolition and construction wastes.

In Europe[10] construction and demolition (C&D) materials are treated as wastes and combustion systems receiving this material must meet the Waste Incineration Directive (WID). The definition of biomass includes:

> *"...wood waste with the exception of wood waste which may contain halogenated organic compounds or heavy metals as a result of treatment with wood preservatives or coating, and which includes in particular such wood waste originating from construction and demolition waste."*

Combustion processes burning wood that may contain treated or coated wood wastes must comply with the requirements for waste incineration plants. The WID has strict operational standards such as a residence time of 2 seconds at 850°C or higher (as necessary), after the last injection of combustion air to ensure destruction of the contaminants, as well as strict emission limit values requiring an emissions abatement plant.

EU
Directive 2000/76/EC on the Incineration of Waste

In the UK, any combustion process that burns C&D materials must meet the requirements as for incineration because it has been deemed too difficult to establish a clean wood supply from the C&D waste stream.

Germany:
Ordinance on Incineration Plants and other Combustible Substances: 17th BImSchV (Seventeenth Ordinance on the Implementation of the federal Emission Control Act – 1990/2003)

BANZ identifies that untreated demolition wood can be hogged and should be classified as hogged wood fuel. Caution is warranted with this approach as based on European experience, material may be contaminated and may cause issues both operationally (e.g. nails) and with air emissions (e.g. lead-containing paint and other undesirable coatings). BANZ recommends that the manner in which the wood is assessed or analysed to ensure the absence of treated timber be documented and should withstand evaluation under the RMA consent process. In practice, separation and documentation of adequate separation may be very difficult to achieve in New Zealand such as has been the case in Europe, where all construction and demolition wood is considered to be contaminated and thus subject to the requirements of the WID. If material is obtained from C&D waste, both the applicant and the consent authority need to satisfy themselves that the level of separation is sufficient to avoid contamination.

Burning contaminated woody biomass is outside the scope of this review, and would be the subject of individual resource consent or regional rules. Local authorities, however, need to be confident that combustion of contaminated C&D materials is not occurring in small scale combustion appliances.

9 Deutsches Institut für Normung
10 European Directive 2010/75/EU of the European Parliament and of the Council of 24th November 2010 on Industrial Emissions (Integrated Pollution Prevention and Control) (recast), known as the Industrial Emissions Directive (IED) which incorporated and updated the requirements of European Directive 2000/76/EC of the European Parliament and the Council of 4th December 2000.

2.6 Compressed fibrelogs and briquettes

Compressed fibrelogs refer to artificially produced logs. Both fibrelogs and briquettes are generally made from sander, router or process sawdust and or wood shavings.

BANZ states that:

- all fire log categories (and briquettes) must be made from untreated timber
- wood fuels must be free from non-wood contaminants.

BANZ makes no determination as to the types of combustion appliances that this fuel type can be used in.

2.7 Firewood

Firewood is has been classified by BANZ in Table 8 of their guidance. It is not proposed to discuss this fuel type further because it is understood that this relates principally to domestic appliances.

3. Emission limits values

In order to help meet air quality objectives, many countries have set emission limit values on particulate matter emissions from industrial processes. Emissions limits have, however, generally been set for Total Particulate Matter (commonly referred to in New Zealand as Total Suspended Particulate Matter) and not for the fine particulate component (PM_{10}) even though ambient air guidelines relate to PM_{10}. There are methods available for measuring PM_{10} emissions (as described by Nussbaumer (2008) *Particulate Emissions from Biomass Combustion in IEA Countries*), but they have not generally been adopted in industrial emissions monitoring for a variety of reason, not least of which is their complexity.

impractical?
...just for small boilers?
(e.g. <100 kW?)

Eco-label schemes focus on both: efficiency and emissions

Emission limits for industrial and commercial combustion appliances are generally monitored through a stack emission testing requirement. The cost of regular stack emissions monitoring for small industrial and commercial applications is an impractical ongoing requirement. An alternative is to require in-house testing of a representative number of appliances before sale, as is required for domestic scale activities under the NES for air in New Zealand; and as occurs for eco-labelling schemes in Europe. Appliance emission standards are guaranteed at the point of sale where they can be readily regulated and monitored, although there are concerns that point of sale emissions may not be matched by actual day-to-day performance, particularly if the fuel quality and combustion conditions are outside of the scope of the approval.

For small biomass-fired appliances: 10 to 13% oxygen not 6 to 13%

Emission limits that are set based on the concentration are typically set specifying an oxygen or carbon dioxide percentage as a correction factor. This correction factor allows the setting of pollutant emission concentration limits on a standardised basis avoiding the effects of different rates of excess combustion air. The actual rate of excess combustion air depends on the nature of the fuel and the appliance type. As excess air increases, the concentration of emitted pollutants decreases but not the mass of emission. Unfortunately, various jurisdictions use various standardising levels for oxygen or carbon dioxide concentrations. For small biomass-fired combustion appliances, European practice for reference oxygen in combustion gases range from 6 to 13% oxygen. A lower oxygen percentage will give a higher equivalent mass emission rate for the same concentration value.

3.1 European union emission limits

see note on page 4

Emission limits in Europe are set by the Industrial Emissions Directive (IED). The IED sets emission limit values for "dust", which is equivalent to total particulate matter from industrial processes including combustion for variable scales of activity.

The IED differentiates between existing processes and new processes by setting differing emission limits. Table 4.1 sets out the emission limit values, which are set at a standard temperature and pressure (STP) of 273.15 K (0°C) and 101.3 kPa, dry basis and at a standardised oxygen (O_2) concentration of 6% for solid fuels.

Table 4.1 IED Emission Limit Values for Particulate Matter from Biomass Combustion

Total rated thermal input (MW)	mg/Nm^3 (STP, 6% O_2)	
	Existing plant	New plant
50 – 100	30	20
100 – 300	20	20
> 300	20	10

- check: 20 for biomass and peat?

Note: the table above is for large power plants and utility boilers - bigger than 50 MW! hence the 6% O2 - might be irrelevant for New Zealand?

3.2 Ecolabel emission limit values and EN standards

3.2.1 EN 303 Part 5

The main standard for heating boilers of up to 300 kW output in the European Union is EN 305 Part 5, originally drafted in 1999. This standard is currently being reviewed and a draft was produced in 2010[11]. EN 303 Part 5 has not been harmonised in the European Union, meaning that each country has the opportunity to set their own standards, which can be tighter than the EN 303 Part 5 requirements.

The Emission limits set within EN 303 Part 5 (1999) are based upon the classification of the device. There are 3 classifications: Class 1, Class 2 and Class 3, and hand stoked verses automatic fuel feed. The classification covers the thermal efficiency of the boiler and is based on the useful heat delivered by the boiler from the fuel as follows:

- Class 3 = 73% to 82%
- Class 2 = 63% to 72%
- Class 1 = 53% to 62% *see note on page 4*

Table 4.2 sets out the emission limits for "dust" for each class of appliance. It is noted that the draft review of EN 303 Part 5 in 2010 would appear to be lowering these limits, although no confirmation can be obtained at this point in time. Individual countries within the EU, and in the wider European setting, have set or are setting tighter emission limits at a national level for particulate matter, in particular through "eco labelling" schemes. Examples of these are outlined in the following subsections.

Table 4.2 Emission Limits for "Dust" set within EN 303 Part 5 (1999)

Stoking	Nominal heat output (kW)	Total particulate matter (mg/m³)*		
		Class 1	Class 2	Class 3
Manual	≤ 50	200	180	150
	> 50 – 150	200	180	150
	> 150 to 300	200	180	150
Automatic	≤ 50	200	180	150
	> 50 – 150	200	180	150
	> 150 to 300	200	180	150
* = referred to dry exit flue gas, 0°C, 1013 mbar 10% O_2				

3.2.2 Swiss Standards *only for coal and wood boilers <350 kW!*

Relevant for Switzerland is the LRV: (LRV= Luftreinhalteverordnung)

<120kW: 100 mg/Nm3 @ 13% O2
120-500kW: 50 mg/m3 @ 13% O2
500kW-1MW: 20mg/m3 @ 13% O2
1MW-10MW: 20mg/m3 @ 11% O2
>10MW: 10mg/m3 @ 11% O2

referred to dry gas, STP

Please note: capacity is net fuel heat input not gross boiler heat output!

Table 4.3 sets out the Swiss emission limits for particulate matter concentration for biomass appliances effective from 1 January 2011.

Table 4.3 Swiss Emission Limits for Biomass Appliances

Type of installation	Total particulate matter (mg/m³) (13% O_2)
Log wood boiler	50
Automatic chip boiler	60
Automatic pellet boiler	40
Pellet stove	40
Wood stove	90

3.2.3 Austrian Standards

Table 4.4 sets out the Austrian standards for small scale wood-fired boilers of up to 300 kW, which are set on a basis of milligrams of particulate matter per mega joule of fuel (mg/MJ).

Table 4.4 Austrian Particulate Matter Emission Limits for Biomass Appliances <300 kW

Device type	Limit (mg/MJ)
Manually Fed	60
Automatically Fed	60

11 It has not been possible to obtain a copy of this revised draft of EN 303 Part 5 2010, which will provide emission limits from smaller scale combustion processes.

*EG-K & LRV-K for steam boilers whereas FAV is for all boilers, hence the **FAV** is the leading ordinance!*

Please note: capacity is net fuel heat input not gross boiler heat output!

Since 19.9.2011 new FAV!

<1MW:150mg/m3
1-2MW:50mg/m3
>2MW: 20mg/m3

values referred to dry gas, STP and 11 vol% O2

In addition, Austria has set emission limits for "dust" emissions for small boilers, recovery boilers and fluidised bed boilers as laid out in Table 4.5. All emission limit values are given in mg/Nm³.

EG-K: 150kW-2MW
LRV-K: 50kW-2MW
120 not 150

Table 4.5 Austrian Particulate Emission Limits for Larger Biomass Appliances

Capacity		mg/Nm³		
		< 2 MW	2 – 5 MW	> 5 MW
EG-K	Wood, wood chip, bark, peat (13% O_2)	150	150	50
LRV-K	Wood, bark, saw dust, wood chips (13% O_2)	150	50	
FAV	Untreated wood, chips or bark (13% O_2)	150	50	

superseded!

All emission values are related to dry exhaust gas at 0°C and a pressure of 1.013 bar
EG-K: Emissionsshuutzgesetz für Kesselanlagen (BGBI. 2004/150) Emission Protection Act
LRV-K: Luftreinhlateverordnung für Kesselanlagen (BGBI. 1989/19 i.d.F. BGBI. II 1997/324 Clean Air Ordinance for Steam Boilers
FAV: Feuerungsanlagenverordnung (BGBI. II 1997.661) Ordinance for Firing Installations

Spelling: Emissionsschutzgesetz Luftreinhalteverordnung

3.2.4 Austrian Ecolabelling

The Austrian Ecolabelling Scheme[12] sets the emission limits for biomass appliances as presented in Table 4.6. These are tighter limits than the Austrian National Standards. The Ecolabelling Scheme differentiates between automatically stoked and manually loaded appliances. The standards are set on the basis of mg/MJ and "dust" is used synonymously with total particulate matter.

Table 4.6 Austrian Ecolabelling "Dust" Standards for Biomass Appliances

for up to 400kW fuel heat input

Fuel	Dust emission (mg/MJ)	
	Boiler	Space heater
Pellets (automatically stoked)	15	20
Woodchips (automatically stoked)	30	20
Manually loaded	30	30

3.2.5 German Ecolabel Standard

Germany has introduced an ecolabel standard (Blauer Engel or Blue Angel) for wood-fired appliances burning wood pellets as set out in Table 4.7.

Table 4.7 German Particulate Matter Ecolabel Standards

Device type	Particulate matter (mg/Nm³) (13% O_2)
Pellet ovens	20
Pellet stoves	25

3.2.6 Nordic Swan

Nordic Swan is the ecolabelling scheme for all the Nordic countries (Norway, Sweden, Finland, Denmark and Iceland). Table 4.8 sets out the Nordic Swan emission limits for particulate matter.

Table 4.8 Nordic Swan Particulate Matter Emission Standards (mg/m³ dry gas, 10° O_2)

Automatic feed boiler	Manual feed boiler	
≤ 300 kW	≤ 100 kW	100 to ≤ 300 kW
40	70	

12 Österreichisches Umweltzeichen 37

4. Appliance types

Wood chip and pellet fuelled appliances are the focus of The London Energy Partnership (LEP) guidance "*Biomass for London – Wood Fuels Guide*".[13] The LEP Guide covers systems for both existing buildings and new developments for appliances above the individual domestic scale. The LEP Guide covers the option for small scale Combined Heat and Power Plant (CHP) under 2 MW as these are becoming more commercially feasible in the UK. The smallest wood-fired CHP unit currently available in the UK is 100 kW electrical (200 kW thermal).

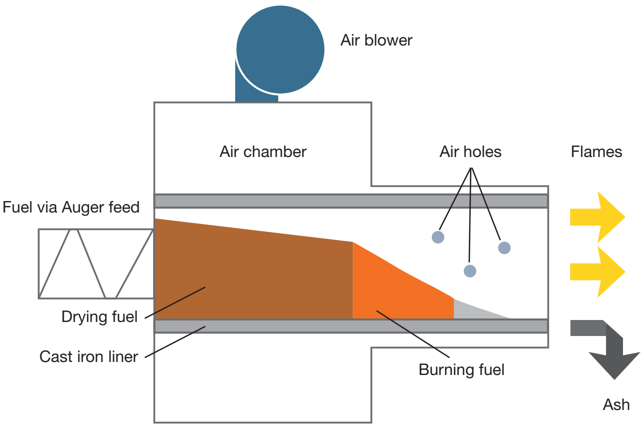
There are three main boiler types that are generally considered suitable for smaller scale biomass combustion for heating applications. These are: stoker burners; underfed hearths; and moving grates.

4.1 Stoker burners

Fuel is introduced into a stoker burner using an auger feeding into a burner head. Figure 1 is a diagram of a typical stoker burner system. The burner head is lined to reflect heat back onto the fuel and air is introduced into the fuel space via small holes. The burner head produces a "vigorous flame" that passes into the boiler.

Figure 1 Typical Stoker Burner System14

Out of curiosity:
- Controls? no fine tuning?
- Emissions?
- Efficiency?
- Safety?
- just for small boilers
< 50 kW?



One advantage of this type of system is that it is possible to retrofit this type of burner onto existing boilers as long as the combustion chamber is large enough and that there is provision for ash removal.

Ash is pushed into the ash pan from the burner head by the incoming fuel. De-ashing is often manually undertaken, especially in smaller units. The stoker burner is a low cost form of wood burning but does have limitations as follows:

- The fuel must be dry, preferably below 25% and no greater than 35% moisture content.
- The particle size and moisture content must be consistent.
- There is no provision for primary and secondary air limiting the opportunity for fine tuning combustion conditions to the needs of the fuel.

The advantages of stoker burners are:

- the small physical size of the fire, which is a function of the small quantity of fuel within the burner at any one time. This allows rapid response to load swings because the small fire means the changes in fuel supply have an immediate effect.
- very low heat generated on "slumber" mode when the boiler is not on demand (i.e. during the night).

13 Creative Environmental Networks, BioRegional, and SEWF, Biomass for London: Wood Fuels Guide, January 2009.
14 www.woodfuelwales.org.uk/boilers.php

4.2 Underfed hearths

In an underfed hearth fuel is pushed up through the base of the hearth using an auger. Fuel wells up into the combustion chamber and spreads out to the sides. Primary air is fed into the fuel from below whilst secondary air is fed from above the fuel.

The ability to feed secondary air allows for fine tuning of the combustion conditions to the fuel requirements. These appliances are generally not suitable for fuels with a moisture content above approximately 30%. This is due to the fact that there is no drying of the fuel by radiant heat in the feed system. Some designs of underfed hearth may be able to accept wetter fuels, but the moisture content of the fuel suitable for each appliance must be specified.

Depends inter alia on the combustion air temperature

De-ashing of underfed hearths can be either manual or automatic.

4.3 Moving grate

Only in comparison to 4.1 and 4.2! E.g. BFB boilers would be more expensive than moving grate boilers

falls - ?

Moving grates are generally the most versatile, but are the most expensive combustion systems suitable for woody biomass. Fuel is delivered to the grate by an auger or a ram stoker. The fuel falls onto the top of the grate and is moved by the grate though the combustion chamber. The grate is made of several panels of fire bars which are moved sequentially encouraging the fuel to move along the grate through each of the phases of combustion. *FYI - advanced systems (>200kW) have water-cooled moving grates*

The fuel sequentially passes through drying, volatilisation (where the volatile components of the fuel are driven off and combusted), and char burnout. Ash falls off the end of the grate and is removed mechanically. Primary combustion air is supplied under the grate and secondary air is fed into the combustion chamber above the fuel.

The sequenced combustion is one of the main strengths of moving grate appliances allowing a wide range of fuels to be burned, and due to the ceramic arch over the grate reflecting heat back onto the fuel allowing fuels of up to 70% moisture to be burned. These types of appliance are generally over 100 kW in output.

70% moisture?
I'd seriously doubt that someone can burn 70% MC (wet base) fuel with a moving grate system!

Without combustion air-preheater typically up to 50% MC and with air-preheater up to 60%. (BFBs up to 63 maybe 65% MC)

The advantages of moving grate technologies are:

- the ability to burn a wide range of fuel types of varying particle size and moisture content
- the avoidance of clinkering and blockages due to the enforced movement of material along the grate
- high combustion efficiency arising from the ability to control combustion closely.

Note: listed advantages and disadvantages are debatable and depend on the boiler supplier.

The disadvantages are:

- slow response times to load swings arising from high fuel inventories on the grate
- the complex design leading to higher capital cost
- a long warm up arising from the amount of ceramic, up to 2 hours for wet wood
- the slumbering heat output being relatively high ranging from 10% to 30% on wet fuels.

Moving grate from the Fogarty Industries FT-185 Wood Chip Boiler

5. Design and control considerations

The Industrial Emissions Directive (IED, 2011) incorporates the Large Combustion Plant Directive (LCPD). Smaller scale industrial and commercial boilers (less than 20 MW thermal) are not regulated under European legislation. The LCPD sets out emissions levels and technologies and techniques identified as Best Available Techniques (BAT) for combustion processes. BAT for combustion processes is identified in the Integrated Pollution Prevention and Control Reference Document on Best Available Techniques for Large Combustion Plants (the LCP BREF).

Some of the BAT's technologies and techniques for minimising pollution from combustion are suitable from smaller scale combustion processes. While many of the technical requirements for the LCPD would be cost prohibitive for smaller scale boiler plant, there are combustion techniques within it that can be applied to smaller scale plant and can be adopted to improve combustion efficiency, thus reducing emissions of PM_{10} as discussed below.

5.1 Fuel quality and storage

For clarification:
Coarse fly ash particle emissions increase with ash content, boiler load, etc, whereas PM10 emissions (mainly aerosols <1μm) depend on the chemical composition of the fuel! E.g. wood chips, bark, waste wood. etc. see page - 22

The ash content of the fuel directly contributes to particulate matter emissions. Fuel moisture also affects combustion conditions and efficiency. The fuel moisture content and ash content are therefore important factors for minimising the emission of particulate matter.

Incorrect!
Purpose build boilers (designed for high moisture content fuels) will have an excellent combustion performance. Most Polytechnik boilers operate at CO levels <10 mg/m3 at MCR and very low particulate emissions.

Wetter fuels may well lead to higher emissions of particulate matter, including PM_{10}, as a result of inefficient combustion. It is therefore important that the design of the fuel storage area ensures that the wood fuel is kept dry to maintain optimum combustion and perform as designed. Water seepage into the fuel bunker or feed auger (where used) can lead to expansion of pellet fuels, which can lead to potential blockages.

BANZ has produced a guide for converting solid fuel boilers from coal to wood fuel (*Guidelines for the Conversion of Solid Fuels from Coal to Wood Pellet Firing – BANZ, 2010*). The Guide makes recommendations on the storage of wood pellets. The same principles should be considered for storage of all woody biomass fuels, where appropriate, to minimise PM_{10} emissions as follows:

- The fuel hopper or bunker must be moisture proof, both from direct moisture, such as rain, as well as general dampness.
- Existing concrete coal bunkers should be imperviously lined to ensure no absorption of moisture from the concrete.
- The floor of the bunker must be angled towards the fuel feed auger (or ram as may be the case) at an angle of at least 40° to ensure complete delivery of all the fuel in the bunker to the boiler. There must be no dead spots where material can lie. A shallower angle may be used if the materials of construction of the bunker are smooth.
- If there is any possibility of water ingress into the fuel bunker, it must be fitted with sump pump, at the lowest point in the floor with angled drainage to it, with an alarm to warn of its failure.

Wood chips have a tendency to “bridge” and remain in place even when chips underneath are moved, thus wood chip requires more than a sloping floor to ensure that it reaches the fuel feed auger. Typically this is done mechanically and could involve a moving floor or an arm to push the chip into the auger.

5.2 Co-combustion with coal

Possible further issues:
- fouling
- clinkering
- corrosion
- increased CO and OC/VOC

Co-combustion of wood with coal is relatively common practice in New Zealand. Co-combustion with good quality coal may have advantages allowing for burning lower grade biomass fuels with increased efficiency. Issues may arise with co-combustion because of the relatively high ash content of coal compared with good quality wood fuel (less than around 1% by mass), thus the rate of particulate emission will increase. Accordingly, co-firing with coal is best handled on a case-by-case basis via the resource consent process.

Emission limits for CO, PM10 and NOx might be required?

5.3 Fuel feed systems

Manual feeding of fuel to combustion chambers is recognised as leading to inefficient combustion conditions resulting in higher particulate emissions. Automatic feed systems are recommended for commercial and industrial scale applications to ensure fuel is applied at the appropriate rate for efficient combustion. Appropriately designed automated systems prevent overload or insufficient supply of fuel and thereby reduce the risk of increased PM_{10} emissions through poor combustion conditions.

In addition, automatic fuel feed systems are generally enclosed systems limiting the ingress of air. Manual loading systems require the combustion chamber to be opened, or to remain open, therefore allowing the ingress of air, which has the potential to unbalance the air to fuel ratio leading to inefficient combustion and increased emissions. Auger or ram types of fuel feed system may be used dependent upon the fuel type used and the boiler design.

In order to ensure the safety of the system, and to prevent burn back along the feed conveyor system to the fuel storage bunker or silo, burn back protection should be installed for all woody biomass combustion plant. This prevents the risk of the fire in the combustion chamber burning back along the fuel feed systems. To prevent fire in the fuel store area, a primary control is achieved via a break within the fuel feed through the provision of two augers (or similar) one feeding from the day bunker or main fuel storage to the second auger (or similar) which then feeds the combustion chamber. Best practice would incorporate a burn-back flap, a water dousing system and sensors triggering auger emptying. Further information on burn back protection is available in the BANZ *Guidelines for the Conversion of Solid Fuel Boilers from Coal to Wood Pellet Firing* (2010).

Note: this is for auger fed systems. Hydraulic stokers have different features!

5.4 Combustion air

Wood fuel pellets require less primary (or under fire) air and considerably more over fire (secondary air) for complete combustion compared with coal. Very old stokers only supply air from beneath the fuel bed providing insufficient secondary air for efficient pellet combustion according to the BANZ Guide for conversions from coal (2010).

Incorrect injection of combustion air will lead to inefficient combustion of the fuel and hence increased PM_{10} emissions. Individual solutions for woody biomass boiler units are needed to accommodate combustion air requirements, particularly for conversions, and should include automated combustion control devices that automatically trim the air flow requirements necessary for efficient combustion.

Some stoker designs may be able to accommodate the change in air flow requirements from coal to wood pellet combustion by adjusting the air dampers. Where such stokers cannot accommodate these requirements there are three alternatives:

- Replace the entire stoker with a modern unit, in essence a specifically designed woody biomass combustion unit
- Modify the secondary air ducting to provide more air
- Install an additional fan, ducting and secondary air nozzles to provide the necessary air.

Such conversions are practicable and can lead to satisfactory results. Modifications should, however, only be undertaken after the proper design of the system by a competent engineer conversant with the combustion process.

Note: as soon as wood chips and forest or sawmill residues are utilized it is likely that the existing furnace volumes and the grates are too small.
(compare fuel volatiles coal vs biomass and ash softening temperatures)

5.4.1 Under-fired boilers

Under-fired boilers of an appropriate design can burn logs of specified size and woodchips, although wood briquettes can be used as well. Wood pellets are not suitable for combustion within these types of appliance due to the high density and small particle size of the pellets.

Gasification and partial combustion of the fuel occurs in a small fraction of the fuel at the base of the fuel pile, with complete combustion occurring in a secondary chamber. Natural draft is normally used to supply combustion air, although some models do incorporate an air blower or flue gas fan. Combustion within under fire boilers tends to be more stable than in over-fire boilers normally resulting in lower emissions. We are not aware of these burners being available in New Zealand.

5.4.2 Down-draught boilers

Down-draught boilers are the latest innovation in wood log combustion appliances. The flue gases are forced to flow down through the ceramic grate, with secondary combustion air being introduced at the grate or in the secondary combustion chamber. Final combustion takes place at high temperatures.

Due to the flow resistance of the flue gases being high, a combustion air fan or a flue gas (induced draught) fan is required. The fan also allows the precise introduction and distribution of primary and secondary air within the combustion chambers. This allows a very well controlled combustion leading to reduced emissions, including particulate matter.

Due to the well controlled combustion and reduced emissions, these boilers are being introduced to help meet the stricter emissions limits being set in some countries. Coupled with the technology of the down-draft boiler, automatic control systems such as lambda control probes (measuring flue gas oxygen levels) allow precise control of combustion air and staged-air combustion. In some models fuzzy logic control has been used to control combustion to lower emissions even further. Due to the advanced technology used, these boilers are more expensive than simple over-fired and under-fired boilers.

5.5 Operation manuals and operator training

It must be noted that unless the boiler is installed in an industrial complex, the operation of these boilers will be by undertrained people whose main job will not be the maintenance and management of the boiler. Hence clear, concise, simple to read operating manuals should be provided and include sections on:

- Efficient combustion
- Safe operations
- Action plan for malfunctioning or broken down systems

After the installation of a new, dedicated woody biomass boiler system, or following conversion from a coal-fired boiler system, ensure that the individuals who will have responsibility for the operation and maintenance of the system are trained in the new system. Following the training the competence of the individual to operate and maintain the system should be assessed, and where necessary additional training provided.

The provision of clear, concise, simple to read operating manuals and operator training can be considered as best practice, even where a trained dedicated boiler operation has been involved.

5.6 Combustion control

"Good quality wood fuels" to be specified?
- dry wood chips, pellets, etc., or
- low ash content, low moisture, etc.
- or low alkaline, etc.
- ?

The main cause of elevated particulate emissions from combustion processes is the incomplete combustion of the fuel. Incomplete combustion gives rise to a larger proportion of particulate matter made up of the combustible fraction of the fuel. Good control of combustion and using good quality wood fuels are principal methods for minimising particulate matter emissions.

5.7 Insulation

Insulation of housing and buildings in general reduces the amount of fuel burned to produce heat required to keep the building warm. Thus, well insulated buildings reduce the fuel demand, thus reducing the emissions from combustion.

5.8 Cyclone and multicyclone

Just for coarse fly ash as they are inefficient when it comes to PM10 emissions.

Boilers of greater than 50 kW output often incorporate a cyclone or a series of cyclones (multicyclone) to control particulate matter emissions. Cyclones are useful for removing particulate matter but predominantly remove coarser particles rather than the finer particles. Dependent upon the required emission limit cyclones and multicyclones can be used as a pre-cleaning system prior to other abatement technologies.

5.9 Electrostatic precipitators

The Beth Mini ESP range is for small boilers only.
The ESP technology is worldwide used for boilers from 100 kW to several hundred MW.

Advantages:
- low operating costs
- very low pressure drop
- less fire risk

Electrostatic precipitators (ESP or EP) are widely used in industrial applications and EP units are available, at least in Europe and in the USA, for boilers above 100 kW output. ESPs have an electrical field to capture the particulate matter and require a large volume to reduce the flue gas velocity so the electrical field can be effective capturing particulate matter of all sizes. Weis Environmental market the BETH mini ESP in the range of 900 to 4800 m^3/hour range, which are claimed to be suitable for small boilers up to a heat release of 1 MW. To our knowledge, small ESPs are available in New Zealand for control of emissions from small combustion appliances.

5.10 Fabric filters

Fabric filters or bag filters are commonly used across industry and offer a very effective method for particulate removal. Modern materials have allowed this technology to operate at relatively high temperatures, but at a higher cost. Bag filters can capture a wide range of particle sizes but may require a pre-cleaning system, such as cyclones or multicyclones, where significant amounts of particulate matter are present, and especially if there is a significant amount of carbon in the particulate matter as this will represent a fire risk. Carbon would only be present in large amounts in an inefficient and poorly controlled combustion appliance. Pre-cleaning systems also minimise the carryover of hot particles and sparks which can damage filter bags or cause ignition of carbon and condensed volatile organic matter on bag surfaces.

Note:
if CO is low and with proper furnace/combustor design there are no VOCs, unless the boiler starts and stops several times a day.

It is noted that fabric filters offer a surface upon which condensable particulates can condense, and thus offer some abatement for this fraction of particulate matter which can lead to PM_{10} concentrations in the ambient air. However, because condensed VOCs substantially increases the fire risk, condensation of condensable particulate on filter bags should be avoided by good operation of the combustion process and by insulating the fabric filter. There is generally reluctance in New Zealand to equip sold fuel-fired combustion plant of any size with fabric filters because of cost but more importantly because of fire risk.

Bag filters can be affected by moisture, and may require pre-heating or the use of fabrics that do not clag with moisture. Due to the large volume and large pressure drop across the filters, they require additional fan power. In addition fabric filters will require either replacement, or some form of cleaning mechanism (reverse jet pulses, shakers, etc) to ensure continued efficient operation.

5.11 Ceramic filters

Ceramic filters have similar features to fabric filters but can operate at very high temperatures. Ceramic filters are available for appliances of 50 kW or more in capacity. Ceramic filters are commercially available overseas for use within non-domestic applications and are as efficient at particulate removal as fabric filters.

High-porosity solid ceramic foam filters are available in Europe to capture particulate from wood-burning stoves. The filter can be integrated in the stove directly above the combustion chamber to provide continuous oxidation at high temperature to burn-off carbonaceous particulate. The HARK Company in Germany has introduced a new generation of the ECOPlus furnace which features an integrated ceramic foam filter to minimise the emission of particulate to meet the second stage of the Germany Federal Immission Control Act which is expected to be in force in 2015.

We are not aware of the use of ceramic filters in New Zealand.

5.12 Effectiveness of abatement technologies

The LCP BREF describes the efficiencies of particulate control devices in Table 3.2.6 of Chapter 3, an extract of which is presented in Table 6.1 below. With these technologies in place, it is understood that manufacturers in Europe will generally guarantee emission limits of less than 20 mg/Nm^3, although in reality particulate matter concentrations of less than 10 mg/Nm^3 are achievable. The Table does not mention ceramic filters, this is most likely because the LCPD caters for combustion plant greater than 50 MW thermal, where standard fabric filters will generally be used.

Table 6.1 General Performance of Particulate Matter Control Devices

Technology	Removal efficiency %			
	< 1µm	2 µm	5 µm	> 10 µm
ESP	> 96.5	> 98.3	> 99.95	> 99.95
Fabric filter*	> 99.6	> 99.6	> 99.9	> 99.95
Cyclone	85 – 90%. The smallest diameter of the dust trapped is 5 – 10 µm			
* The efficiency of ceramic filters is known to be similar or equal to that of fabric filters, however they are not represented within the LCP BREF, Table 3.2.6.				

85 to 90% cyclone efficiency is misleading (just with poor combustion systems)
Cyclones separate just coarse particles.

Typical efficiencies:
particulates <1µm no separation
particulates of 5µm less than 50%
particulates of 10µm less than 85%

Note: 85 to 98% of the PM10 emissions will be smaller than 1µm hence a cyclone is inefficient for PM10 emissions! - see:

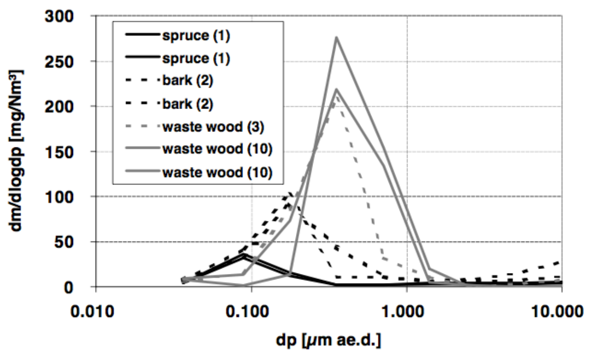


Figure 3: PSD of aerosols formed during the combustion of different biomass fuels in grate fired boilers

Explanations: emissions related to dry flue gas and 13 vol.% O_2; ae.d.: aerodynamic diameter; numbers in () indicate the fuel numbers (see Table 1)

6. New Zealand data

6.1 Emission factor development

Emission factors for fuel combustion sources generally relate to the mass of pollutant produced per unit of fuel consumed (either on a mass or energy basis). Emission factors are used in air emission inventories to calculate the total mass of pollutant discharges in an airshed and also to calculate the emissions discharged from an individual source, particularly in the absence of actual emission data for that source, such as for a new facility. The US EPA AP42 has comprehensive emission factors for many industrial processes. Particulate matter emission factors for external combustion sources fired on wood residue are specified by fuel type and control device type but not by boiler type[15].

Environet Ltd (2010) has prepared two reports *Improving PM_{10} Emission Factors from Industrial Boilers in New Zealand – Stage 1 and Improving PM_{10} Emission Factors from Industrial Boilers in New Zealand – Stage 2*. These reports incorporate US EPA emission factors for considering the PM_{10} component of Total Suspended Particulate (TSP) matter from woody biomass appliances. The Environet report states the emission factors are suitable for estimating total daily TSP in an airshed such as would be done for emission inventory development.

Emission inventories are used to build up a picture of the main contributors of emissions within the airshed, and provide a tool to decide on appropriate strategies to manage discharges either to maintain air quality or achieve compliance with the required air quality standards. Environet also states that the factors are suitable for a Tier 2 assessment, of discharges from a source under the Ministry for the Environment's (2008) *Good Practice Guide for Assessing Discharges to Air from Industry* i.e. for preparing assessments of environmental effects to support individual resource consent applications. A Tier 3 assessment would presumably require a more reliable assessment of emission rates, specific to the source.

From monitoring data collected, and applying the US EPA factors for the PM_{10} component, Environet indicates emission factors for particulate matter from biomass boilers from the Stage 2 study. These are summarised in Table 7.1. The table also includes data for coal fired appliances, which provides a comparison with wood, although wood was not generally shown in the Environet study to have lower emissions by comparison with coal technologies. Environet recommends the emissions database on which the factors in Table 7.1 are based is regularly updated with available test data. Given the difficulty encountered in obtaining data for this study, SKM would support such an initiative.

Table 7.1 Updated New Zealand Emission Factors (June 2010)[16]

Appliance	Emissions factor TSP (g/kg)	Emissions (mg/m³) (STP and 12% CO_2)	Number of boilers tested	PM_{10} equivalent factor g/kg
Underfeed Stokers	2.8	300	18	2.0
Underfeed Stokers with cyclones	1.1	120	2	No data
Chain Grate Boilers with multicyclones	1.9	200	27	1.3
Vekos Boilers (Coal)	5.4	569	7	1.7
Wood-fired boilers	2.0	309	6	1.8
Boilers with bag filters	1.0	106*	16	No data
* = Bag filters typically achieve results of around 50 mg/m³				

FYI:
Emissions of biomass boiler plants depend inter alia on:
- fuel type (moisture, size, alkaline, etc.)
- grate heat release rate
- furnace volume
- fuel feed mechanism
- flue gas recirculation
- ratio primary air / secondary air
- emission control system
- boiler control system
- boiler load and condition
- etc.

15 www.epa.gov/ttn/chief/ap42/ch01/bgdocs/b01s06.pdf
16 Improving PM_{10} Emission Factors from Industrial Boilers in New Zealand – Stage 2 (June 2010)

6.2 Available PM_{10} emissions monitoring data

Is the available data really PM10 and not TPM?
PM10 monitoring is very complex (and expensive) hence it is assumed that all test results are actually TPM and not PM10?

Emissions monitoring data for PM_{10} from woody biomass was gathered in this study in attempt to provide better estimates of emission rates in New Zealand. SKM approached equipment suppliers, regional councils, unitary authorities and stack emission testing companies to obtain data. The best source of information was that held by the councils, as this was publicly available. The PM_{10} emissions monitoring data gathered in this study is summarised in Appendix B.

Overall, there was a relatively limited amount of PM_{10} emissions monitoring data available. As was the case for the review of European limits, there is currently no requirement to monitor PM_{10} source emissions in all jurisdictions in New Zealand; rather monitoring of total suspended particulate matter is more prevalent. There were also limitations in the level of information supplied in stack emission testing reports. Generally, the data is not directly useful for confirming or developing PM_{10} emission factors, considering the variable factors involved including: appliance type, fuel feed and grate system, fuel classification and emission control.

See page 23 for main factors for emissions.

A reference to a boiler make might not be meaningful?

E.g. The "best" boiler on poor quality fuel, lots of load swings, etc. might be worse than a "bad" boiler on high quality fuel running at constant load?

The appliances for which data was obtained ranged in scale from 1 MW at maximum continuous rating (MCR) up to 54 MW. Thus the majority of the data is not representative of the scale of activities that are the focus of this report. Only the largest facility was reported as having a baghouse filter for particulate emission control. Emission concentrations of less than 10 mg/Nm^3 were achieved for this site. The Visdamax boiler with no control and those with high efficiency cyclones and/or a water scrubber achieved concentrations of around 100 mg/Nm^3 or less. The highest emissions of PM_{10} reported were for the Vekos boilers, which were of the order of 400 mg/Nm^3.

Given the very low emission rates that are achievable (<20 mg/Nm^3) with good quality fuels, well designed and automated appliances and the best practice emission control, we consider it is generally appropriate to assume all particulate matter emitted from low emission appliances is PM_{10}. The PM_{10} fraction is more likely to be of relevance for larger appliances, with relatively high rates of particulate matter emission. In such cases, some advantage may lie with the consent applicant if actual PM_{10} fractions are known and emission testing for PM_{10} would be recommended.

7. Summary and recommendations

Recognition of the potential health effects of PM_{10} in air has led the World Health Organisation and many countries worldwide to set air quality objectives for ambient concentrations of PM_{10}. The New Zealand NES for ambient PM_{10} of 50 µg/m^3 as a 24-hour average is consistent with international standards. The worst affected of the polluted airsheds in New Zealand have until 2020 to comply with a requirement for one exceedance of the NES for PM_{10} per year, although in one airshed the current level of non-compliance is up to around 60 exceedances per year.

One source of PM_{10} in the ambient air is combustion processes, of which woody biomass is likely to increase with carbon taxes on fossil fuels and rising fossil fuel prices. Woody biomass is increasing in smaller scale commercial and industrial settings with applications such as in hospitals, glasshouse heating and school boilers. Local authorities are naturally cautious about a potential increase in particulate matter emissions from the woody biomass sector and in general have been reducing the threshold for permitted activity status in plans and/or increasing the requirements in permitted activity conditions.

Some regional plans have differentiated the scale of the permitted activity dependent on the status of the airshed i.e. more restrictive, lower scale of appliance in polluted airsheds. This approach would appear prudent given the emphasis on managing PM_{10} to achieve compliance under the NESAQ.

Note:
All emissions after bag houses and EPSs are PM10 emissions hence TPM and PM10 on those applications is the same.

Emission limits and measurement data for combustion appliances, including woody biomass still tend to refer to total particulate matter rather than PM_{10}. TPM provides a more conservative approach from a regulatory perspective and is consistent with European certification schemes reviewed in this report. Larger scale facilities with relatively high mass emission rates may have advantages to the site if PM_{10} is measured to provide more realistic data for dispersion modelling when assessing the environmental effects.

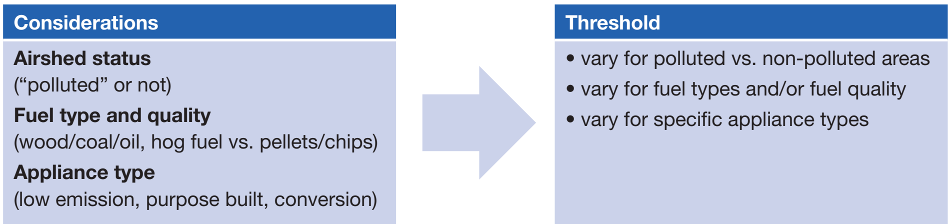
The mass per unit energy of particulate matter produced as a result of combustion is dependent upon the combustion conditions, the fuel burned and the efficiency of the combustion technology. In general, the better the fuel quality, the higher the efficiency of combustion and the better the combustion control, the less particulate matter is produced and emitted for all sizes of appliance.

Key findings from this study are:

- There is insufficient data to develop PM_{10} based emission factors or limits for the sector. International practice is to set total particulate matter emission limits (generally as "dust") and these can be considered as a surrogate for PM_{10}, particularly for low emission and well controlled systems. *see note on page 4*
- Each local authority needs to consider the actions required to ensure future compliance with the NES for PM_{10}, both in terms of maintenance of environments with existing good air quality and where air quality improvements are required. Equipment that meets emission limits in line with the eco-labelling schemes and the IED should be considered for adoption in areas where improvement in air quality is required.

Figure 5 sets out the considerations for councils when developing rules for woody biomass as an energy source. A primary consideration is whether the discharge will take place in an airshed that is polluted, where tighter restrictions may be applicable. If councils develop more specific rules for fuel types, rather than aggregating them, there may be justification to increase the level at which the permitted activity thresholds are set.

Figure 5 Considerations for Rule Development for Woody Biomass



Considerations for conditions relating to permitted activities particularly in polluted airsheds based on best practice as per this review include:

Why 12% O2?
- why not 11% O2
- or 12% CO2
- or ?

- manufacturer guaranteed emission levels e.g. 30 mg/Nm^3 adjusted to 12% O_2 (NB. For a non-polluted airshed a limit of 90 mg/Nm^3 adjusted to 12% O_2 may be more appropriate to provide for a wider range of appliances as permitted activities.)
- mass discharge limits relevant to the gross output of the appliance
- automatically fuel feed and ash removal
- automated oxygen control
- fuel of guaranteed quality in accordance with boiler design
- fuel storage and reception appropriately designed to prevent water ingress
- operation in accordance with operating manuals and the manufacturer's specifications.

- what is small?
- waht is medium?

A certification scheme for small to medium scale appliances would be beneficial to support growth in woody biomass as an energy source. Such a scheme could be used to underpin permitted activity status for biomass fired appliances in regional plans and create more consistency and certainty in the future development of plan rules for the sector.

Any rules relating to combustion should be supported by policies that reduce the amount of fuel burned, such as insulation of buildings and heat storage technologies. These measures will ultimately reduce the amount of particulate matter produced through combustion by raising the efficiency of the heat use from combustion.

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Appendix A. Regional plan biomass combustion thresholds

Consenting authority	Date	Permitted
Environment Waikato	28/09/2007	≤5 MW (existing activities), ≤2 MW (new activities)
Auckland Council	21/10/2010	≤5 MW
Otago Regional Council	01/01/2003	Air Zones 1 and 2: ≤1 MW Air Zone 3: ≤5 MW
Bay of Plenty Regional Council	15/12/2003 as amended 2006	≤5 MW
Hawke's Bay Regional Council	August 2006	≤100 kW
Horizons Regional Council	Proposed as amended by decisions August 2010	≤500 kW
Taranaki Regional Council	Proposed as amended by decisions August 2010	≤400 kW (250 mg/m³, NTP) 400 kW and 5 MW (125 mg/m³, NTP)
Greater Wellington Regional Council	13/04/2000	≤2 MW
West Coast Regional Council	July 2002	≤40 kW
Northland Regional Council	March 2003	≤2.5 MW
Gisborne District Council	14/01/2008	≤2.5 MW
Environment Southland	March 1999	≤ 5 MW
Environment Canterbury In Christchurch Clean Air Zones 1 & 2:	27/10/2009	
Outside Christchurch Clean Air Zones 1 & 2, Rangiora Clean Air Zones a & 2, Kaiapoi Clean Air Zones 1 & 2 and Ashburton Clean Air Zones 1 & 2		
Nelson City Council	03/11/2008	
Tasman District Council Not in Richmond Airshed	26/02/2011	≤5 MW for untreated wood, (existing activities outside Residential Zone) ≤1 MW for untreated wood or ≤ 2MW for pellets (new activities within Residential or Mixed Business Zone) ≤2 MW for untreated wood or ≤ 5 MW for pellets (new activities in not in Residential or Mixed Business Zone)
Within Richmond Airshed		≤2 MW for pellets (existing activities) ≤1 MW for pellets (new activities)
Marlborough District Council	09/03/2009	≤40 kW

	Controlled	Restricted discretionary	Discretionary
		>5 MW (existing activities), >2 MW (new activities)	
		In the range of 5-20 MW	>20 MW
			Air Zones 1 and 2: >1 MW Air Zone 3: >5 MW
			>5MW
	≤10 MW		>10 MW
			>500 kW
	> 5 MW - ≤10 MW		>5 MW
	2 to 5 MW		>10 MW
	≤10 MW		>10 MW
			>2.5 MW
			>2.5 MW
			>5 MW
	≤500 kW (replacement of existing solid fuel burner with pellet burner)	1 MW (existing activities, or replacement of existing solid fuel burner with pellet burner) 500 kW (replacement of existing non-solid fuel burner with pellet burner)	>1 MW (new activities)
	>5 MW (existing activities)		
		≤200 kW	>200 kW
	≤5 MW (existing activities within Residential Zone or Mixed Business Zone) ≤20 MW (existing activities outside Residential or Mixed Business Zone) ≤2 MW for untreated wood or ≤ 5 MW for pellets (new activities within Residential or Mixed Business Zone) ≤5 MW for untreated wood or ≤20 MW for pellets (new activities outside Residential or Mixed Business Zone)	>2 MW for untreated wood or >5 MW for pellets (new activities within Residential or Mixed Business Zone)	>5 MW for untreated wood or >20 MW for pellets (new activities outside Residential or Mixed Business Zone)
	≤5 MW for pellets (existing activities)		
	≤10 MW (Industrial Zone only)		

For clarification: NR means no or nominal rating?

really PM10 and not TPM?

Appendix B. PM_{10} Source test data for biomass boilers in New Zealand

Location	Boiler type	Emissions control	MW at MCR	% MCR during test	Emission test data	
					PM_{10}, mg/Nm^3	PM_{10}, kg/hr
Nelson	Vekos	Cyclone	4.5	58% 55% 100%	360 378 425	1.6 1.7 1.5
Nelson	Scott Combustor	Cyclone	6	85% 70%	244 229	1.4 1.4
Paraparaumu	Binder Model RRK500	Cyclone	0.5	62% 62% 62%	16.8 10 11.9	0.04 0.03 0.03
Waimea	Scott Combustor	Cyclone	2	NR	81 301 88	0.20 0.68 0.22
Waimea	Vekos	Cyclone	6	NR	215 269 235	0.67 1.38 0.22
Wairoa	Fogarty Boiler #1	High efficiency Cyclone	2.7	<45%	57 61 60	0.087 0.81 0.10
Wairoa	Fogarty Boiler #2	High efficiency Cyclone	2.7	<45%	73 72 79	0.085 0.099 0.094
Wairoa	Fogarty	High efficiency cyclone	2.5	NR	57 61 60	0.087 0.81 0.10
Wairoa	Fogarty	High efficiency cyclone	2.5	NR	73 72 79	0.085 0.099 0.094
Wairoa	Morrow WWVC	Multicyclone	5	NR	105 125 113	0.45 0.59 0.52
Nelson	John Thompson	Multicyclone	20	NR	18 36	0.51 1.2
Nelson	John Thompson	Multicyclone	20	NR	129 105	3.2 2.0
Nelson	Konus	Multicyclone	35	NR	74 82 78	2.7 2.6 2.7
Nelson	Easteel	Multicyclone	20	NR	140 210	4.2 5.7
Blenheim	Vekos	Multicyclone	7.5	NR	433 425 419	2.0 2.3 2.0
Whangarei	Visdamax Bio-T Burner	4 primary cyclones plus 1 multi-cyclone	7.5	60% 47%	92 83	0.9 0.9
Whangarei	Visdamax Bio-T Burner	4 primary cyclones plus 1 multi-cyclone	7.5	60% 60%	65 77	1.0 1.3
Whangarei	Visdamax Bio-T Burner	4 primary cyclones plus 1 multi-cyclone	7.5	47% 47% 60%	100 111 94	1.0 1.1 1.3
Whirinaki	Foster Wheeler Boiler	Multicyclone and wet scrubber	28	NR	49 48 44	3.3 3.4 2.9
Whirinaki	Easteel	Baghouse	54	NR	4.8 7.4 2.5	0.3 0.5 0.2
Auckland	Vekos	None	4	NR	340 151 499	1.9 0.9 3.0
Auckland	Vekos Powermaster	None	2.5	NR	392 326 257	0.9 0.8 0.7
Masterton	Visdamax	NA	1	NR	97 80 101	0.12 0.10 0.16

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