Options for setting particulate emissions criteria for home heating appliances

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Abstract

Environment Canterbury's draft Clean Heat Project as released for public consultation, proposed subsidies for the installation of electrical, gas-fired, and diesel-fired appliances, but not for the installation of solid fuel burners. This approach was based on the former understanding of the relative emissions performance of appliances fuelled by wood and other types of fuels.

Recent advances in solid-fuel burner technology, however, have led to substantial decreases in burner emissions. Emissions of particulate produced by solid fuel burners such as pellet fires are no longer substantially different from those generated by gas and diesel burners. This trend is evident in emission test results recently reviewed by Environment Canterbury.

Assessment of appliance emissions performance in the context of approval and eligibility processes is an important aspect of air quality management. Further consideration of qualifying criteria is warranted in light of these results. A number of broad options are available to define emission criteria, including differentiation by fuel type (as was originally proposed for the Clean Heat Project), setting a uniform particulate emission standard for all burner types (regardless of fuel), or setting a suite of standards based on fuel type.

This report discusses the implications of recent test results, options available for determining criteria and other associated issues.

Table of Contents

1 Introduction

1.1 Background

In recent years Environment Canterbury has been developing a plan for the management of air quality in the region (the Air Chapter of the proposed Canterbury Natural Resources Regional Plan). In its current form the plan has a particular focus on the management of suspended particulate (PM_{10}) emissions to the Christchurch air shed. In addressing this issue it proposes restrictions on the use of solid fuel as a method of home heating additional to those that apply currently. In recognition of the social and economic impacts of policy intervention in this area, Environment Canterbury has initiated an incentives and assistance programme to encourage households in Christchurch to move away from methods of solid fuel burning which produce high emissions of PM_{10}. The project, known as the "Clean Heat Project", includes amongst its objectives the encouragement of households to:

> "*…replace open fires and solid fuel burners with clean heating appliances such as heat pumps, nightstore heaters, flued gas heaters, flued diesel heaters, flued oil heaters, pellet fires and very low emission wood burners.*"

The inclusion of the latter type of wood burner was not originally encompassed by the scheme. As initially proposed, the programme was not to provide incentives and assistance for the installation of any kind of solid fuel burner[1] (Environment Canterbury, 2002a). At that stage, gas and diesel burners were considered to be cleaner burning than solid fuel burners, and were thus to be eligible for incentives, along with certain electrical heating appliances.

During the development phase of the scheme, however, testing commissioned by Environment Canterbury, together with a review of recent emission test results, indicated that selection of technology on the basis of fuel type might no longer be an appropriate approach. This was recognised in the final form of the Clean Heat Project in which eligibility was to be determined by emissions performance irrespective of fuel type (Environment Canterbury, 2002b).

In addition to the Clean Heat Project, consideration of emissions criteria may be an important aspect in the evaluation of appliances for a range of purposes. For example, approval of appliances for use in the Canterbury Clean Air Zones under section 369(11) of the Resource Management Act (1991) has for a number of years incorporated assessments of emissions performance (see section 2.3). In establishing criteria by which the emissions performance of different appliances can be compared, there is a range of approaches available. This report discusses those approaches in the light of recent emission test results and sets out the issues that need to be considered in defining criteria that might be used to distinguish between appliances for the purpose of managing emissions. The information contained in the report was presented to Environment Canterbury councillors during the course of their deliberations on the eventual form of the Clean Heat Project (Environment Canterbury, 2002b).

2 Background

2.1 Subsidy eligibility

The intention of the Clean Heat Project is to provide incentives and assistance for householders in Christchurch to install "clean heating". Data from overseas emission tests (for wood, gas, and diesel burners) and local emission tests (for solid fuel burners tested in accordance with AS/NZS 4012 and 4013) were assessed to determine which appliances were "clean burning". At the time the project was first proposed, emissions of particulate from gas and diesel-fired burners were significantly lower than emissions from solid fuel burners. Table 2.1 summarises the emission factors previously considered appropriate for different heating appliances.

[1] Also excluded from the programme were fixed electric resistance heaters, portable electric heaters and portable gas heaters

Table 2.1 PM_{10} emissions produced by domestic heating appliances

Appliance	Emission Factor g/kg	Fuel Used (kg/day)	Emissions g/day[1]
Gas burner	0.1	1.9	0.19
Diesel burner	1.3	1.4	1.82
Low emission wood burner	3.0	15.0	45
Coal burner	28	8	224

[1]Based on quantity of fuel used on a "typical winter's night" in Christchurch (Wilton, 2001a)

A recent review of up-to-date emission data conducted by Environment Canterbury, however, indicates that significant improvements have been made regarding low emission solid fuel burners. Appliances such as pellet fires, in particular, are producing similar levels of emissions to gas and diesel burners.

2.2 Quantification of emissions

Emissions from wood, gas and diesel-fired burners may be expressed using a variety of different units. From an ambient air quality management perspective, units that best represent the actual impact of burning on air quality over time should be used. The four main units that may be used are:

(i) g/kg - grams of particulate per kilogram of fuel burned
(ii) g/MJ_{in} - grams of particulate per megajoule of energy in the fuel
(iii) g/MJ_{out}, (or g/kW-hr) - grams of particulate per unit of "useful" heat emitted
(iv) g/hour - grams of particulate emitted per hour.

There are advantages and disadvantages associated with all units. These are discussed in greater detail in Section 3.2.1.

2.3 Emissions testing

The Resource Management Act allows Environment Canterbury to authorise or prohibit any class of fuel burning equipment (s369 (11) (b))[2]. Environment Canterbury requires solid fuel burners to be tested in accordance with AS/NZS 4012 and 4013 by an accredited testing agency. Gas and diesel burners have not been required to undergo emission testing. Consequently, local emission data for gas and diesel-fired appliances have not previously been available in New Zealand.

To address this, Environment Canterbury recently commissioned emission tests of three diesel-fired burners and a gas-fired burner. These test results have been compared to the latest low emission solid fuel burner test data. The results are outlined in Appendix 1 and summarised in Table 2.2, along with results from all solid fuel burners that currently meet the emission criteria in the NRRP (1 g/kg and 65% efficiency). The results indicate that emissions produced by low emission solid fuel burners when tested to NZS4013 are not substantially different to those produced by burners initially classified as "clean burning" for the purpose of the Clean Heat Project (i.e., gas and diesel). Table 2.2 ranks appliances from lowest emitting to highest, according to the average emission value for the different units used to express particulate emissions. Burner rankings vary depending on the units used to classify emissions. The burners have been classified by fuel type.

Although emission test results such as these may be used to quantify particulate emissions to air from various appliances, there are additional factors that need to be considered, when taking environmental impacts into account. Firstly, these data alone are not sufficient to estimate total emissions. Supplementary information such as the quantity of fuel consumed per night and the efficiency of the appliance must also be considered where appropriate. Further, these results are laboratory tests and do not

[2] This process is separate from that related to consideration of subsidies for appliances through the Clean Heat Project

Table 2.2 Ranking of appliances based on emissions

g/kg		g/MJ in		g/MJ out		g/hr	
Pellet A	0.33	Diesel A	0.012	Gas A	0.016	Diesel A	0.30
Pellet B	0.49	Gas A	0.013	Diesel B	0.018	Gas A	0.32
Diesel A	0.53	Diesel B	0.014	Pellet A	0.018	Diesel B	0.43
Wood A	0.56	Pellet A	0.017	Diesel A	0.021	Diesel C Wetback	0.50
Diesel B	0.60	Diesel C Wetback	0.019	Diesel C Wetback	0.029	Pellet A	0.52
Gas A	0.63	Pellet B	0.024	Pellet B	0.032	Pellet B	0.63
Pellet C	0.63	Wood A	0.028	Wood A	0.038	Pellet C	0.97
Diesel C Wetback	0.80	Pellet C	0.032	Pellet C	0.039	Wood A	1.01
Wood B	0.90	Wood B	0.045	Wood B	0.069	Pellet D	1.74
Pellet D	1.47	Pellet D	0.073	Pellet D	0.085	Wood B	2.10

necessarily reflect emissions produced in practice. For example, wood burners are likely to produce greater emissions than those indicated due to variations in fuel and operation (see Section 4.1). It is therefore necessary to apply "real-time" factors to the data to take into account operational variations when assessing the environmental impact of appliances.

3 Discussion of the options for setting criteria

The Clean Heat Project raised a number of issues about the way different types of appliances are compared on the basis of emissions. These issues highlight the importance of reviewing from time to time the way eligibility and/or approval criteria are defined, to ensure that they are relevant and appropriate. Broadly, there are three options that may be considered. These are:

1. Distinguish appliances on the basis of fuel type. For example, permitting or including gas and diesel burners, and excluding solid fuel burners.

2. Set a single particulate emission value with which all appliances must comply. This would require decisions to be made regarding appropriate emission units and the actual value to be selected. For example, if a value such as 0.03 g/MJ_{out} was selected as the eligibility criterion it would allow all tested gas and diesel burners, and at least one pellet fire to qualify. The assimilative capacity of the airshed would need to be taken into account when deriving this value.

3. Set a number of particulate emission values that varied depending on fuel used. For example, one could set a more stringent value for gas than wood burners; this would recognise that gas is an inherently cleaner fuel than wood, and would encourage the ongoing development of gas appliances that were as clean as was practicably possible.

3.1 Option 1 - Fuel type

Originally, the Clean Heat Project based eligibility on the type of fuel used - gas and diesel burners were to be eligible for the subsidy, solid fuel burners (including pellet, wood, and coal burners) were not.

There are advantages in using this type of criterion. It is easy to implement, there are no compliance costs for gas and diesel burner manufacturers, and it subsidises burners that are generally cleaner burning than solid fuel burning appliances.

The obvious disadvantage of this approach is that it does not take into account actual emission factors. For example, a higher emitting diesel burner would receive a subsidy whereas a lower emitting pellet burner would not (compare Pellet A and Diesel C in Table 2.2). Further, such an approach does not facilitate the development of improved burner technology. That is, technological improvements for gas and diesel burners would not be encouraged as these burners already qualify. There would be no incentive for improvements in pellet or solid fuel burner technology either, as this type of appliance would be automatically disqualified.

This criterion could possibly be amended to provide greater equity on the basis of air quality emissions produced by different burner types, by including pellet burners. Note, however, that the emission tests summarised in Table 2.2 indicate that not all pellet burners are clean burning. Burners such as Pellet D at 0.085 g/MJ out, would be eligible using this criterion yet it is one of the worst performing appliances in the table[3]. Unless all burners (classified by fuel) produce consistently low emissions then this approach is not optimal.

The likelihood that the different fuels and appliances would perform similarly in the home as in the laboratory is also an important consideration. This is discussed in greater detail in section 5.1.

[3] The test results for Pellet D highlight an additional issue that needs to be considered, that is performance under "real-life" conditions (discussed in Section 5.1). The laboratory test results for Pellet D indicate that the pellet fuel exceeded the standard moisture requirement of less than 8%. If pellets are not appropriately stored in the home then it is possible that emissions would be higher than those achieved during testing.

3.2 Option 2 - Set a uniform criterion ("level playing field")

An alternative is to set a numerical criterion for particulate emissions applicable to all burners regardless of fuel type. Burners that met the criterion would be eligible for a subsidy. Burners not meeting the criterion, even if they used gas or diesel, would not be eligible. Depending on the unit used a separate thermal efficiency criterion may also be required.

A number of issues are associated with this option. Firstly, the emission unit for the criterion would need to be selected. This would preferably be the unit that most adequately quantified the impact of emissions on ambient air quality. Secondly, the actual value of the criterion would need to be derived. Thirdly, gas and diesel burners are not subject to emission testing to NZS4012 or its equivalent under present legislation. Such testing may be required under this option with subsequent legislative and planning implications. These issues will be discussed in detail in sections 5 and 6.

3.3 Option 3 - Set individual criteria (based on "best available technology")

The third general option available for setting eligibility criteria is to specify a different numerical criterion for each fuel type. For example, if gas is cleaner burning than diesel, then a lower criterion than diesel could be set, even after allowing for differences in calorific value of the fuels. Depending on the unit used a separate thermal efficiency criterion may also be required. Although this approach does not treat each fuel equally, it is analogous to the "best practicable option" approach associated with the resource consent process. The separate criteria could take into account the different calorific values of the fuels, the expected quantity of emissions produced overnight based on fuel used on a "typical winter's night"[4] and the inherent "cleanness" of the different fuels.

[4] As indicated in Wilton (2001)

4 Setting criteria values

There are two decisions that must be made if a criterion value approach is adopted (options 2 and 3). Firstly, a decision regarding the unit to be used is required. As outlined in the following section, not all units allow direct comparison between burners of different fuel types.

Secondly, the numerical value(s) of the criterion need to be decided. Ideally consideration should be given to the air quality target, and the assimilative capacity of the airshed. This is not an easy task. The amount of "space" available for emissions from subsidised or approved burners is largely determined by the number of older burners in use at a given time in the future, and the number of people choosing electricity, gas, diesel etc. when changing from solid fuel heating. It is not possible to predict these numbers with any certainty.

Alternatively, air quality management could be directed at encouraging as many people as possible to replace their older solid fuel burners with zero or low emission options, thus increasing "space" in the airshed for low-emission burners.

4.1 Selection of emission units

The table attached at Appendix 1 outlines emission test results and reports them in different units. Reference to this table will aid in understanding differences between units and the implications of adopting a particular unit.

4.1.1 Grams per kilogram

The unit used historically to assess particulate emissions of wood burners and coal burners is "grams per kilogram" (g/kg). This provides a measure of the amount of particulate emitted, in grams, for each kilogram of fuel burned. This unit is relatively easy to measure, and is the unit used in the solid-fuel burner test method (AS/NZS 4013).

Expressing emissions in g/kg is not appropriate for comparing discharges from different fuels, as it does not take into account the amount of heat available per kilogram from different fuels. For example, a kilogram of diesel contains more than twice as much potential energy as a kilogram of wood (43 MJ vs 20.1 MJ), and a kilogram of gas contains even more energy (49.6 MJ). All else being equal, one would have to burn twice as many kilograms of wood per evening as diesel to get the same heat output, thus producing more emissions over time. Although g/kg is a useful unit for comparing burners using the same fuel, it makes little sense to use a single g/kg value to compare burners using different fuels.

Thermal efficiency is not taken into account in the g/kg unit; therefore the application of a separate efficiency criterion needs to be considered. Appliances with lower efficiencies will presumably use more fuel regardless of the potential energy contained within the fuel, as the heat output per unit of fuel burned would be less. One issue with the additional criterion approach (ie a g/kg value and a percentage efficiency value) is whether the burner would need to meet both requirements to meet an eligibility/approval threshold regardless of actual emissions produced, as proposed in the NRRP. For example, if a criterion of 1 g/kg and 65% efficiency was selected then Diesel A and Diesel C would be ineligible as they do not meet the efficiency requirement. Conversely, if emissions were assessed on the basis of heat output, both diesel burners produce significantly lower g/MJ_{out} (0.021 and 0.029 respectively) compared to Wood C (0.069). An alternative approach could be adopted however where a trade-off between efficiency and g/kg could be made based on an assessment of overall emissions.

Note that while a single g/kg unit is not appropriate for comparison between fuels, there is no reason why a separate g/kg criterion could not be set for each fuel reflecting the inherent differences in the calorific value of the fuel, e.g. 0.5 g/kg for gas, 0.6 g/kg for diesel, 0.3 g/kg for solid fuel burners.

4.1.2 Grams per unit of energy in the fuel - g/MJ_{in}

To take into account the energy content of the fuel, the emissions can be calculated as the amount of particulate emitted (in grams) per unit of potential energy in the fuel burned (in MJ). The resulting unit, "g/MJ_{in}", is more appropriate than g/kg for comparing appliances that burn different fuels.

To calculate the "g/MJ_{in}" it is necessary to know the calorific value of the fuel. This is reasonably straightforward for fuels with a consistent calorific value, such as gas (49.6 MJ/kg) or diesel (43 MJ/kg). For wood and coal the calorific value can be variable, though wood is generally quoted at 20.1 g/MJ (e.g. Baines, 1999). If burners are tested using fuels with different calorific values than those used in practice, emissions may be under or over estimated. Calorific values of coal mined in NZ, for example, range from 13.8 to 32 MJ/kg. If a lower calorific value coal or wood were burned in the home, then the grams per MJ would be higher, even if the g/kg was unchanged.

Again, this unit does not take into account efficiency associated with the appliance. A separate efficiency value would need to be considered. To meet eligibility/approval thresholds the burner could be required to meet both a "g/MJ_{in}" and a thermal efficiency criterion. Alternatively, a trade-off between efficiency and g/kg could be permitted.

4.1.3 Grams per unit of heat released into the room - g/MJ_{out}

As noted above, the preceding unit does not take into account the thermal efficiency of the appliance. One way to address this is to calculate the amount of particulate emitted per unit of useful heat emitted into the room - "g/MJ_{out}". This is essentially the "g/MJ_{in}" divided by the efficiency of the appliance.

This unit can also be expressed as grams of particulate per kilowatt-hour (kW-hr), by multiplying by 3.6 (1kW-hr = 3.6 MJ).

There are a number of advantages to the "g/MJ_{out}" unit over "g/MJ_{in}". Firstly, "g/MJ_{out}" does not require a separate efficiency criterion as "efficiency" is inherent in the derivation of the unit. Secondly, it allows appliance designers to balance particulate emissions with efficiency when designing the appliance to achieve the minimum emissions per unit of useful heat output. A third, limited, advantage arises in situations where the operator is able to exercise a high level of control over heat output, for example where appliances have a thermostatic control. In these circumstances "g/MJ_{out}" may reflect, to some extent, the actual emissions of particulate per evening better than the previous units, assuming that users choose to reduce fuel throughput when the desired temperature is reached. This is because this unit can be related directly to the householder's space heating requirements.

One of the disadvantages of this unit is that it requires measurement of the heat output from the burner. However, this would also be required with the previous two units if a separate efficiency criterion was to be applied.

4.1.4 Grams per hour - g/hour

A fourth possible unit is simply the grams of particulate emitted per hour, regardless of the fuel, the efficiency, or how clean burning the appliance is. All else being equal, a small heater will discharge less grams per hour than a large one. While this is ultimately the measure that directly affects the amount of particulate in the air, this approach raises a number of problems. One is that, depending on the value selected, it could almost be impossible for a large appliance to meet it, regardless of how clean burning it is. Conversely very small appliances may meet the criterion despite being neither clean burning nor efficient.

This unit does not take thermal efficiency directly into account. It could be assumed however, that to achieve the same heat output, a lower efficiency burner would need to burn more fuel and the g/hour would rise. A separate efficiency criterion could be established in addition to the g/hour criterion.

4.2 Air quality target and assimilative capacity of the airshed

The selection of a criterion value should take into account air quality objectives in the proposed NRRP and the assimilative capacity of the airshed to sustain burner numbers.

The targets outlined in the proposed NRRP include the following:

> *"By the Year 2012 there is a reduction in the concentration of PM_{10} to less than 50 $\mu g/m^3$, with no more than one annual exceedence…."*

"In the long-term, following a review of this chapter of the proposed NRRP in 2013, Environment Canterbury's target for PM_{10} will be 50 $\mu g/m^3$ (24-hour average) with no annual exceedences to be addressed."

Projected emissions, in accordance with the proposals contained in the NRRP, indicate that the first target may be attained if not more than 56% of households currently using solid fuel replace their appliance with a low emission woodburner. If more people replace their current burner with another woodburner then the target could be compromised.

In determining criteria, the capacity of the airshed to sustain projected burner numbers should be considered. At 2012 it is unlikely that there will be any capacity available for subsidised burners given that there will still be a large number of older burners being used in Christchurch. By 2021 the capacity for the airshed to sustain both subsidised and unsubsidised burners will be greater as the high emission burners will have been replaced.

Estimating the capacity of the airshed, however, is a difficult task. It is heavily reliant on assumptions made concerning the number of current solid fuel burning households that will change to electrical heating, or will install diesel or gas burners. Reliable information concerning potential uptake of subsidies is not presently available.

4.3 Further considerations

There are several approaches that may be adopted with regard to the selection of criterion values. In brief these include:

- select a value that some burners already meet
- set lower emission values to provide a challenge to designers and to encourage technological development
- select a single value or adopt a "staged" approach whereby the criterion could be lowered incrementally on a yearly basis
- require a burner's average emission to meet the criterion (current practice under AS/NZS4013), or require it to meet the criterion at each of the low, medium and high settings.

5 Additional issues

5.1 Operational factors

The degree to which laboratory conditions replicate appliance or fuel performance in the home is a critical factor requiring consideration. Laboratory tests (AS/NZS 4012 and 4013) are designed to compare one burner's performance with another rather than replicate operation/performance in the home. Factors which influence variability in emissions between laboratory tests and "real-time" operating conditions include the following:

- exclusion of emissions during start-up of the appliance or refuelling during the laboratory test
- variations in fuel loading, fuel type, fuel moisture and air supply
- appliance and flue maintenance
- inappropriate sizing and positioning of appliances.

Intuitively it seems likely that diesel and gas burners would perform similarly in the home as in the laboratory. Variations may occur, however, depending on tuning of the appliance. If, for example, installers were to tune "visible flame" gas appliances to operate with a yellow rather than the blue flame, emissions from this type of appliance would increase relative to the laboratory performance, as higher emissions are generally associated with a yellow flame. Variations in gas composition also affect emissions (e.g., propane to butane ratio). An additional unknown factor is how gas and diesel burners perform without regular maintenance.

It is considered less likely that solid fuel burners would perform similarly in the home as in the laboratory than their gas and liquid fuel counterparts. This is primarily due to the level of operational influence and the variable nature of the fuel. Characteristics such as sap content, presence of knots, size, moisture, and density of the fuel may influence emissions considerably. The degree to which this effect increases emissions is currently unknown. Further work has been proposed to investigate "real-life" solid fuel burner emissions.

Pellet burners, although classified as solid fuel burners, are considered to be in a category of their own. These appliances use an automatic feed system and burn fuel of a consistent shape and size. In this regard, it is likely that pellet fires would perform similarly in the home as in the laboratory. An issue that does require consideration, however, is the effect of moisture on pellets. It is unknown how much moisture may be reasonably absorbed during storage and the impact this has on emissions. The effect of varying damper settings also requires consideration.

5.2 Other pollutants

Pollutants emitted during the combustion of different fuels and on particular appliances can vary. This is reflected in the various emission factors used in the 1999 Emissions Inventory for Christchurch, for contaminants such as carbon monoxide, oxides of nitrogen, and oxides of sulphur (Wilton, 2001b).

Additional pollutants from wood smoke, as indicated in overseas studies, include dioxins and furans, and polycyclic aromatic hydrocarbons (PAH's) such as benzo(a)pyrene. These pollutants are produced under various combustion conditions and their concentrations may vary for different types of fuels and appliances. McCrillis *et al.* (1992) and Gras (2002) found that higher PAH concentrations were produced when burning softwoods (such as pine) versus hardwoods. Some studies have also shown that lower emission burners may produce more dioxins and furans (Environment Canada, 2000).

A greater focus has been given at a national level to some of these pollutants. The Ministry for the Environment has recommended guidelines for priority contaminants such as benzene and benzo(a)pyrene and has drafted a Dioxin Action Plan to target dioxin emissions (MfE, 2001 & 2002). Limited work has been undertaken in New Zealand with respect to these additional pollutants and further emission testing is required. In the interim, a review of past studies together with those conducted internationally would be desirable.

5.3 Uncertainties associated with test results

When the particulate emissions from a burner are measured, there are inherent uncertainties associated with the measurement. These arise from the accuracy limits of the various instruments used, including the mass balances, the air flow meters, and thermometers etc. Each instrument measures to within specified uncertainties, and these are combined to give the overall uncertainty of the result, whether it is g/kg or g/MJ. Applied Research Services Ltd (accredited to test burners in accordance with AS/NZS 4013), currently report the uncertainty as 19% for g/kg and 21% for g/MJ, for a “typical” wood burner on high setting. This corresponds to an uncertainty of about 0.3 g/kg for a 1.5 g/kg burner. As emission concentrations decrease, absolute uncertainty remains the same but the percentage uncertainty is higher. For the gas and diesel burners tested recently, the uncertainty may be of a similar magnitude to the test result.

5.4 Emission testing requirement for gas and diesel burners

Under the Transitional Regional Plan and the Proposed NRRP, the operation of gas and diesel burners are permitted activities. These appliances are not subject to the emission test requirements currently applicable to pellet fires and other solid fuel burning appliances. For consistency, adoption of a criterion value approach may require that these burners be tested in order to qualify for a subsidy, or approval for use.

6 Implications for the NRRP

The NRRP currently classifies emissions from diesel and gas burners as permitted in Christchurch. Solid fuel burners are permitted when replacing existing burners provided they meet the new emission criterion of 1 g/kg and 65% efficiency. These appliances, including pellet burners, are however prohibited in new houses and houses not currently heated by solid fuel burning. Subsidising appliances such as pellet fires or low-emission wood burners may be considered by some as inconsistent with the intention of the NRRP.

7 Conclusions

❖ The available laboratory test data indicate emissions produced by solid fuel burners such as pellet fires are not substantially different to those produced by gas and diesel burners. Air quality management eligibility or approval criteria that distinguishes appliances simply on fuel type, may not be appropriate. Any approach that differentiates by fuel type should consider operational aspects associated with the fuel and any additional pollutants produced.

❖ In light of recent emission results it may be preferable to use a quantitative criterion in assessing appliance eligibility for use or subsidy.

❖ A uniform standard could be applied which would be applicable to all burners regardless of fuel type. This is an equitable approach on an "emissions" basis but may require burners not currently tested (e.g. gas and diesel burners) to undergo particulate emission tests for eligibility.

❖ Different criteria could be set for each fuel type to take into account different calorific values of the fuels and to facilitate a best practicable option approach.

❖ Of the four main units available for setting numerical criterion:
- a single "g/kg" is not appropriate for assessing appliances using different fuels;
- "g/MJ_{in}" would be suitable, but it does not take account of the thermal efficiency of the appliance;
- "g/hour", while it is the most "effects based", is strongly influenced by the size (kW rating) of the appliance;
- "g/MJ_{out} " takes into account heat output and efficiency.

❖ Once a unit is selected it would be necessary to determine an appropriate value or values for the criterion. This value would need to consider the ability of the air shed to sustain burner numbers, and the long-term goals for air quality management. Setting a criterion below current emission levels would challenge manufacturers to develop technologies to meet this criterion.

❖ Additional considerations include:
- whether various fuels and burners produce similar levels of emissions in "real-life" as in the laboratory
- other air pollutants of concern, including toxic contaminants such as benzene, benzo(a)pyrene and dioxin.

8 Further investigations and monitoring

This investigation has highlighted a number of critical issues that require further investigation and clarification.

Firstly, it is desirable that "real-life" emissions from wood burners are measured, taking into account variations in operational behaviour and fuel. Environment Canterbury has recently received funding from the Ministry for the Environment through the Sustainable Management Fund (SMF) to undertake work in this area. The study proposes to conduct laboratory simulations of "real-life" burning cycles, determine the impact of wood type, moisture and size on emissions, and to undertake emission tests of burners in the home. Real-life emission factors will be derived and may provide greater certainty with regard to current and future emissions.

Secondly, further clarification is required regarding additional air pollutants (particularly HAP's) and the impact of various fuels and burner types on these emissions. It would not be desirable to subsidise or otherwise approve burners that may create significant pollution issues at a later date.

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Appendix 1 Particulate emissions from domestic heating appliances

Burner Type	MJ/kg	Setting	g/kg fuel[5]	g/MJ in	Efficiency	g/MJ out	g/hour	kW
GAS	**49.6**							
Gas A		Low	0.60	0.012	79	0.015	0.18	3.5
		Medium	0.60	0.012	84	0.014	0.30	5.6
		High	0.70	0.014	80	0.018	0.49	7.8
		average	**0.63**	**0.013**	**81**	**0.016**	**0.32**	**5.63**
DIESEL	**43**							
Diesel A		Low	1.00	0.023	61	0.038	0.40	2.8
8 inch pot		Medium	0.50	0.012	52	0.022	0.40	5.0
		High	0.10	0.002	58	0.004	0.10	6.8
		average	**0.53**	**0.012**	**57**	**0.021**	**0.30**	**4.87**
Diesel B		Low	0.50	0.012	77	0.015	0.20	3.7
10 inch pot		Medium	0.70	0.016	75	0.022	0.49	5.9
		High	0.60	0.014	77	0.018	0.60	9.3
		average	**0.60**	**0.014**	**76**	**0.018**	**0.43**	**6.30**
Diesel C		Low	1.10	0.026	64	0.040	0.44	3.2
10 inch wetback		Medium	0.60	0.014	66	0.021	0.36	5.0
		High	0.70	0.016	63	0.026	0.70	7.4
		average	**0.80**	**0.019**	**64**	**0.029**	**0.50**	**5.20**
PELLET	**20.1**							
Pellet A		Low	0.20	0.010	92	0.011	0.11	2.8
		Medium	0.10	0.005	92	0.005	0.10	5.0
		High	0.70	0.035	92	0.038	1.35	9.8
		average	**0.33**	**0.017**	**92**	**0.018**	**0.52**	**5.87**
Pellet B		**Low**	0.50	0.025	74	0.033	0.28	2.3
		Medium	0.43	0.021	69	0.031	0.44	3.7
		High	0.53	0.026	84	0.032	1.17	10.1
		average	**0.49**	**0.024**	**76**	**0.0320**	**0.63**	**5.37**
Pellet C		Low	0.70	0.035	78	0.045	0.56	3.6
		Medium	0.60	0.030	83	0.036	0.90	6.8
		High	0.60	0.030	79	0.038	1.44	10.6
		average	**0.63**	**0.032**	**80**	**0.039**	**0.97**	**7.00**
Pellet C		Low	0.60	0.030	71.8	0.042	0.48	3.6
Wetback		Medium	0.30	0.015	78.0	0.019	0.45	6.8
		High	0.50	0.025	71.9	0.035	1.20	10.6
		average	**0.47**	**0.023**	**74**	**0.032**	**0.71**	**7.00**
Pellet D		Low	1.75	0.087	95	0.092	0.88	2.7
NB - pellets did not comply with standard		Medium	1.19	0.059	81	0.073	1.43	5.7
		High	1.47	0.073	80	0.091	2.94	8.7
		average	**1.47**	**0.073**	**85**	**0.085**	**1.75**	**5.70**

[5] for pellets and wood, the unit is g/kg of oven-dry fuel

Burner Type	MJ/kg	Setting	g/kg fuel[6]	g/MJ in	Efficiency	g/MJ out	g/hour	kW
Pellet E		Low	0.97	0.048	90	0.054	0.78	3.9
		Medium	0.40	0.020	80	0.025	0.52	5.7
		High	0.57	0.028	85	0.033	1.54	12.4
		average	**0.65**	**0.032**	**85**	**0.037**	**0.95**	**7.33**
Pellet E		Low	0.60	0.030	84	0.036	0.48	4.0
Wetback		High	0.65	0.032	79	0.041	1.43	9.9
		average	**0.63**	**0.031**	**82**	**0.038**	**0.96**	**6.95**
WOOD	**20.1**							
Wood A		Low	0.70	0.035	73	0.048	1.09	6.4
		Medium	0.50	0.025	72	0.035	0.94	7.6
		High	0.47	0.023	71	0.033	1.00	8.7
		average	**0.56**	**0.028**	**72**	**0.038**	**1.01**	**7.57**
Wood B		Low	1.10	0.055	67	0.082	2.20	7.2
		Medium	0.80	0.040	65	0.061	1.84	8.6
		High	0.80	0.040	63	0.063	2.32	10.1
		average	**0.90**	**0.045**	**65**	**0.069**	**2.12**	**8.63**
Wood C		Low	0.80	0.040	71	0.056	1.36	6.8
		Medium	0.60	0.030	73	0.041	1.20	7.9
		High	0.70	0.035	69	0.050	1.47	8.2
		average	**0.70**	**0.035**	**71**	**0.049**	**1.34**	**7.63**
Wood D		Low	1.30	0.065	77	0.084	1.56	5.3
		Medium	0.80	0.040	71	0.056	1.44	7.3
		High	1.00	0.050	61	0.082	2.10	7.2
		average	**1.03**	**0.051**	**70**	**0.074**	**1.70**	**6.60**
Wood E		Low	0.70	0.035	71	0.049	1.33	7.7
		Medium	0.60	0.030	65	0.046	1.44	8.7
		High	0.60	0.030	59	0.051	1.80	9.7
		average	**0.63**	**0.032**	**65**	**0.049**	**1.52**	**8.70**
Wood F		Low	1.50	0.075	75	0.100	3.15	8.7
		Medium	0.70	0.035	68	0.051	2.24	12.0
		High	0.60	0.030	68	0.044	2.28	14.4
		average	**0.93**	**0.046**	**70**	**0.065**	**2.56**	**11.70**
Wood G		Low	1.20	0.060	75	0.080	2.64	9.3
		Medium	0.70	0.035	72	0.048	1.82	10.7
		High	0.70	0.035	69	0.050	2.10	11.7
		average	**0.87**	**0.043**	**72**	**0.059**	**2.19**	**10.57**
Wood H		Low	1.10	0.055	73	0.075	2.42	9.1
		Medium	0.60	0.030	70	0.043	1.68	11.3
		High	0.70	0.035	59	0.059	2.45	11.7
		average	**0.80**	**0.040**	**67**	**0.059**	**2.18**	**10.70**

[6] for pellets and wood, the unit is g/kg of oven-dry fuel