Multifuel burner emissions and air quality regulations at Reefton

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Multifuel burner emissions and air quality regulations at Reefton

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Executive Summary

Air quality monitoring for PM_{10} has been carried out in Reefton since 2005. During 2006, concentrations exceeded the National Environmental Standard (NES) of 50 µg m^{-3} (24-hour average) on 16 days. The maximum recorded 24-hour average PM_{10} concentration of 134 µg m^{-3} was observed in 2007. Based on the 2007 maximum, a 63% reduction in PM_{10} concentrations would be required to meet the NES limit of 50 µg m^{-3} (24-hour average).

A previous emission inventory for Reefton (Wilton 2006) showed that coal burning on multi fuel burners was responsible for 53% of the daily winter PM_{10} with 30% from wood burnt on multi fuel burners. While the NES contains a design standard for new woodburner installations that must be observed throughout New Zealand, there is no NES regulation concerning the installation of multi fuel appliances. Wilton's (2006) inventory also identified that woodburners contribute only 7% of PM_{10} emissions in Reefton during winter. Because of the much greater proportion of PM_{10} emissions from multi fuel appliances in Reefton, the ambient PM_{10} standard is therefore unlikely to be achieved in this airshed via the NES woodburner regulations alone.

The objective of this report was to investigate options for reducing PM_{10} to meet the NES, whilst retaining coal burning as a home heating choice for households in Reefton. This involved an evaluation of the potential for a low emissions coal burner and an assessment of the emission rate required to meet the NES for PM_{10} in Reefton.

Limited information is available on emissions from multi fuel burning appliances. Consequently, a key recommendation from this work is that additional testing of existing multi fuel burners be carried out, to assist with the development of policy options for Reefton and other areas of New Zealand where coal burning is prevalent and will continue.

Laboratory tests for two multi fuel burners using a mix of wood and coal have been undertaken in New Zealand. Emission test results between 2.56 g/kg and 3.9g/kg were achieved when tested to AS/NZS4013. Due to the differences between testing appliances in real life compared with the highly controlled AS/NZS4013 laboratory situation, it is believed that the actual emissions from these multi fuel burners may be considerably higher. While some coal-fired central heating appliances were identified that have lower emissions, the high cost of these systems means that they are unlikely to be realistic alternatives to multi fuel space heaters.

Examination of monitoring data, emissions inventory and projections modelling results shows that the NES regulations for ambient PM_{10} concentrations are unlikely to be met in Reefton without additional measures. Results from emissions projections indicate that a real life emission limit of less than 1 g/kg of PM_{10} for both wood and coal emissions from multi fuel burners may be required to achieve the NES for PM_{10} in Reefton. There currently does not appear to be a cost effective technology for multi fuel burners that could meet this limit. Discussions with appliance manufactures regarding the possibility

of developing a low emitting coal burner indicated that the production of such an appliance is unlikely due to the general movement away from domestic coal use in New Zealand. If technology was able to achieve an appropriate emission limit, an accelerated conversion programme would be necessary to achieve the NES by 2013.

1. Introduction

1.1. Background

Air quality monitoring for PM_{10} has been carried out in Reefton since 2005. During 2005, monitoring was based on a one day in three sample regime and only a small number of exceedences of the National Environmental Standard (NES) for PM_{10} were recorded. The maximum measured PM_{10} concentration during 2005 was 55 µg m^{-3}. However, during 2006 monitoring was carried out continuously and concentrations exceeded 50 µg m^{-3} (24-hour average) on 16 days. The maximum measured PM_{10} concentration in Reefton during 2006 was 86 µg m^{-3}. Monitoring results from 2007 show that up until mid August there had been 23 days with concentrations above 50 µg m^{-3} (24-hour average) and the highest recorded concentration was 134 µg m^{-3}. Based on the 2007 maximum concentration of 134 µg m^{-3}, a 63% reduction in PM_{10} concentrations would be required to reduce the maximum to 50 µg m^{-3}.

An emission inventory for Reefton (Wilton 2006) showed that coal burning on multi fuel burners was responsible for 53% of the winter PM_{10} emissions with 30% from wood burnt on multi fuel burners and 10% from wood and coal on open fires. A smaller proportion of PM_{10} emissions (7%) came from wood burners. Overall, 60% of households use coal on a multi fuel burner and 7% of households use coal on open fires in Reefton.

If the NES is not met by 2013, the West Coast Regional Council will be unable to grant resource consents for discharges of PM_{10} to air in Reefton. In addition, between September 2005 and 2013, consents for discharges to air can only be granted if Councils can demonstrate that the granting of the consent will not impinge on the "straight-line path" to compliance.

To assist in reducing PM_{10} emissions, the Ministry for the Environment introduced a NES design criteria for new installations of woodburners in urban areas. The NES specifies that new woodburners in urban areas must meet a laboratory emission test of 1.5 grams of total suspended particulate (TSP) per kilogram of fuel burnt. While the NES contains this performance standard for new woodburner installations, multi fuel appliances are exempt from NES design criteria. The impact of the woodburner design standard in reducing PM_{10} emissions in Reefton will therefore be minimal, in the absence of additional regulations, because of the large proportion of households in this area that install multi fuel burners. Under the NES, there are no requirements for multi fuel burners to meet a specified emission test.

In other urban areas of New Zealand, PM_{10} concentrations are being managed using methods such as the phasing out of open fires and wood burners that do not meet specific criteria, prohibitions on the installation of new appliances, prohibitions on the installation of new multi fuel burners and incentives to encourage householders to replace solid fuel with alternative, clean heating options. In most areas the proposed management options do not allow for the ongoing use of most existing coal burner types.

The Australian and New Zealand standard methods for testing thermal efficiency and particulate emissions from solid fuel burning appliances are AS/NZS4012 and AS/NZS4013. The particulate emission standard is expressed by an emission factor, which refers to a mass of total suspended particulate discharge (TSP) for every unit of fuel consumption or period of activity: i.e. grams of TSP per kilogram of fuel burnt (g/kg)[1] or grams of TSP per hour of combustion activity (g/hr). AS/NZS4012 and AS/NZS4013 apply to batch-fed domestic heating appliances with output less than 25kW. The testing requires the appliance to be installed in a calorimeter room, with emissions discharged into a dilution tunnel for emissions to be evaluated during nine test runs. Three runs are conducted for each of three burn rate settings: low, medium and high.

The standard method specifies: a required fuel load mass and geometry; a light up phase with testing started only after a specified mass of burning embers is established; a test fuel load equal to 16.5% of the chamber volume; and tests are conducted over one burn cycle only. For firewood loads, there are specifications to ensure free flow of air between logs, gaps sizes between logs and the firebox, and only high quality logs with specified proportions are allowed. When coal is burnt on its own, there is a specified volume and the load is required to be levelled. When burning mixed firewood and coal, the fuels are required to be equally apportioned with 50% mass of each. The firewood is to be loaded first, with coal loaded and levelled on top.

Along with comparing performance of different heating appliances, emission factors are used to underpin emission inventories and projections models, which are tools used by local authorities to identify and manage key sources of PM_{10} pollution in New Zealand. For these management tools to be effective, emission factors for domestic heating appliances must be representative of real life operating conditions. Emission factors from AS/NZS4012/3 are unlikely to be appropriate for use in emission inventories and management models, due to variation of the AS/NZS4012/3 fuel specifications and firing regime from real life operation.

[1] For g/kg, the mass of fuel consumed may expressed on a dry or wet fuel basis. Dry weight is used for comparing emission factors with AS/NZS4013 results, whereas wet weight is usually applied to emission factors used for emission inventories, because firewood in real life contains a percentage of moisture.

Under real life operation, there is no light-up phase exclusion, test fuel loads may be of unrealistically high volume and any geometry, air flow may be restricted by non-standard loading, and burning may include many loading cycles with variable state of embers prior to loading. Coal is also unlikely to be levelled out as required under standard testing conditions. When burning mixed firewood and coal on a multi fuel burner in real life, it is also unlikely that coal will be placed carefully on top of a precisely loaded bed of logs that have equal mass to the coal. All of these variations from the standard method are likely to cause greater emissions under real life operation of domestic multi fuel burners.

In situ emissions testing has shown that real life emissions from woodburners may be many times higher than emissions measured using the AS/NZS4013 standard procedure (Scott 2005, Kelly et al. 2007). Anecdotal accounts from testing of multi fuel burners suggests that emissions from coal burning are even more sensitive to operator variability than are woodburner emissions (*pers. comm.* Wayne Webley[2]). It is understood that coal fired appliances are especially susceptible to variability of emissions caused by the effects of load size variation and different coal sources. This observation is consistent with Butcher and Ellenbecker's (1982) study of emissions from a small coal stove that showed emissions using anthracite coal ranged from 0.33-0.62 g/kg but were 10.4 g/kg when operated using bituminous coal. While Butcher and Ellenbecker's (1982) testing could not strictly be regarded as either real life or AS/NZS4013 compliant, the results do highlight the order of magnitude difference that coal type can make to emission results under controlled conditions.

Due to the requirements of the calorimeter room and dilution tunnel, the AS/NZS4012/3 test method is undertaken in a laboratory and is physically not suitable for *in situ* testing of real life emissions in peoples' homes. AS/NZS4012/3 test methods were developed for comparing the performance of different heating appliances under controlled conditions and were not intended to provide emission factors[3] representative of real life operating conditions. However, Applied Research Services (ARS) in Nelson have been using a portable emissions sampler based on the Oregon Method 41 (OM41, or 'Condar' method) for *in situ* testing of woodburners, with results that correlate well with data from the AS/NZS4013 method (ARS 2005).

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[2] Personal communication with Dr Wayne Webley from Applied Research Services Ltd., July 2007.

[3] 'Emission factor' refers to a mass of particulate matter (PM) discharge for every unit of fuel consumption or period of activity: i.e. grams of PM per kilogram of fuel burnt (g/kg) or grams of PM per hour of combustion activity (g/hr). For g/kg, the mass of fuel consumed may expressed on a dry or wet fuel basis. Dry weight is used for comparing emission factors with AS/NZS4013 results, whereas wet weight is usually applied to emission factors used for emission inventories, because firewood in real life contains a percentage of moisture.

1.2. New technology and research on emissions from residential coal burning

The only emissions results that were obtained for domestic multi fuel appliances in New Zealand were for the Woodsman Matai RMF sold by WH Harris in Christchurch and two Logaire models: the Hestia and Kronos sold by Glen Dimplex Industries in Auckland.

Test results for the Woodsman Matai RMF show that emissions of 3.9g/kg were achieved when tested to AS/NZS4013 in 2002 using an equal mix of pine firewood and Ohai coal. While the Logaire test results were not sighted, advertising brochures claim emissions of 2.56 g/kg and 3.6 g/kg for the Hestia and Kronos respectively (Glen Dimplex Australasia Ltd. 2007). It is understood that the Hestia and Kronos emissions are based on AS/NZS4013 testing using an equal mix of firewood and coal. These results were confirmed by telephone with a Logaire representative, although the test results were not available at the time (*pers. comm*. Phil Allen[4]).

Other solid fuel burner manufacturers and the New Zealand Home Heating Association (*pers. comm*. Ed Hawkes[5]) were asked if there were any plans to develop a low emission multi fuel burner. Invariably the answer was that there isn't enough demand for domestic coal burning for the development of such an appliance to be considered economic. A representative from Solid Energy New Zealand advised that domestic coal supply was not being actively pursued by the organisation and there were no plans for developing any technology to facilitate low emission domestic coal burning (*pers. comm.* Dr Steven Pearce[6]). Solid Energy's focus for the domestic market is the supply of renewable energy sources; in particular, pellet fired home heating appliances and fuel supplied by subsidiary company Natures Flame.

Two domestic coal fired boilers were identified that had relatively low emissions. McKenzie Heating Design Ltd (Dunedin) manufacture an auto-stoker boiler unit that has been tested to have emissions of 1.46 g/kg. This testing was conducted to AS/NZS4013 with the exception that fuel is delivered by an automated process from a hopper. The automated fuel delivery is a very desirable feature in terms of reducing real life PM_{10} emissions, because it removes much of the operator variability responsible for elevated particulate emissions in real life. Provided that appropriate coal was used, the appliance could be expected to perform similarly in real life as it did during laboratory testing of emissions. However, the cost of the appliance is likely to be a constraint for most residents in Reefton. The central heating unit costs around

[4] Personal communication with Phil Allen from Glen Dimplex Australasia, Auckland, ph (09) 274 8265. July 2007.
[5] Personal communication with Ed Hawkes from NZHHA, Auckland, ph (09) 414 5076. July 2007.
[6] Personal communication with Dr Steven Pearce from Solid Energy, Christchurch, ph (03) 345 6000. August 2007.

$7,000 and, with further costs for radiators and plumbing, the system as it presently exists is unlikely to offer a universal solution to the air quality problem at Reefton.

The McKenzie Auto Stoker Boiler Unit is included in Otago Regional Council's list of burners approved under the Regional Plan: Air for Otago incorporating Proposed Plan Change 2 (NES) (ORC 2007). Also included on this list is the Ecomac Auto Coal Stoker and Boiler Unit manufactured by Allan's Sheet Metal & Engineering Ltd, Dunedin. The Ecomac has emissions of 1.49 g/kg. However, because the price for a complete installation is estimated at around $15,000 (pers. comm. Allan's Sheet Metal and Engineering Ltd[7]), the Ecomac is also unlikely to be universally accepted in Reefton.

While these central heating systems are relatively expensive heating options, the main attraction in terms of air quality is the air delivery and auto feed system that removes operator variability from the process of particulate emission production. A more affordable option might perhaps be a standalone space heater, similar to the domestic boiler units, that uses coal but has an auto feed operation similar to domestic pellet fires. This suggestion was put to representatives of both the Ecomac and McKenzie products, but they advised there was no intention to develop such a product as the market size was considered too small to be economic.

A research program was initiated in Australia during the late 1980s to develop a domestic heater capable of burning brown coal briquettes with good efficiency and low emissions (Environment Australia 2002). While the appliance was never developed commercially, technology including a gravity fed hopper and downdraught system were utilised to reduce emissions to a maximum of 3.8 g/kg. The relevant literature (Todd and Wingham 1988, Wingham 1990) was not available at the time of writing, so further details cannot be reported. However, this might be worth pursuing as the technology appears to minimise operator variability. Even though this particular appliance used processed coal briquettes, perhaps with some adaptation the technology might operate with West Coast coal that has been screened to a required size.

1.3. International management of residential coal burning emissions

There is a paucity of literature regarding regulation or management of domestic coal burning emissions in small urban areas the size of Reefton.

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[7] Personal communication with "Malcolm" from Allan's Sheet Metal and Engineering Ltd, Dunedin. ph (03) 455 2155. July 2007.

Coal emissions have mainly been managed in larger cities and usually involve prohibiting or restricting coal use. In Dublin, the marketing, sale, and distribution of bituminous coals were banned in 1990 (Clancy et al. 2002). After the coal ban, black smoke concentrations decreased by 70%. In London and other large urban areas in England, the Clean Air Act of 1956 was associated with a substantial reduction in ambient suspended particulate concentrations as domestic coal burning was restricted in favour of cleaner gas and electric heating options (Lawther and Waller 1976). In the United States, the use of coal as a heating fuel declined after the 1950s and gas and electric options steadily replaced solid fuels (Cullen and Bogen 2001).

Regulation of coal use per se has not been suggested as an option for mitigating PM_{10} pollution in Reefton. However, international approaches to managing residential coal burner emissions have invariably been to regulate the fuel source rather than appliances. Apart from Environment Australia's (2002) brief description of coal burner design from 1989, no international literature was identified that described successful management of residential coal emissions via regulation of coal burning appliances in the way that the NES regulates wood burner design to address PM_{10} emissions in New Zealand.

1.4. Objectives

The purpose of this report is to evaluate options for retaining coal burning as a home heating choice for households in Reefton whilst reducing PM_{10} to meet the NES.

2. Emission reductions required to achieve PM_{10} regulations

The reduction required in PM_{10} concentrations in Reefton was calculated by Wilton (2006) in 2006 as 9%. However, this was based on a limited amount of monitoring (one day in three) for PM_{10} carried out during 2005, which resulted in only a small number of recorded exceedences of the national environmental standards (NES) for PM_{10} and a maximum PM_{10} concentration of 55 $\mu g\ m^{-3}$.

More regular monitoring was carried out during 2006 and 2007, when a maximum PM_{10} concentration of 134 $\mu g\ m^{-3}$ was measured. Based on the maximum PM_{10} concentration for 2007, a 63% reduction of PM_{10} concentrations is required to meet the NES. Based on these data and the 2005 air emission inventory estimates of PM_{10}, the revised straight line path for Reefton is shown in Figure 2.1.

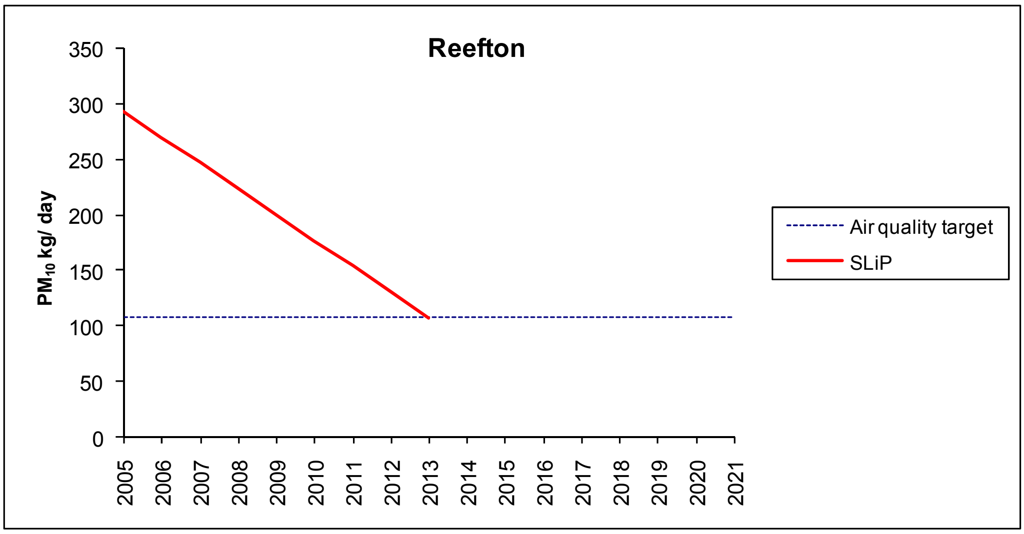

Figure 2.1: Revised straight line path for Reefton

3. A representative emission factor for multi fuel burners

The Reefton inventory emission factors (g/kg) from coal burners and open fires are those derived by Wilton (2001) for the Christchurch air emission inventory. Unlike most wood burning emission factors, the rates used for coal are based on only a very small pool of emission test data. This is not a major limitation for emission inventories in most areas, because coal burning is typically used by less than 10% of households. In Reefton, and a few other small urban towns, it does create a higher degree of uncertainty around the emission inventory estimates.

Wilton (2001) selected an emission factor of 21 g/kg for coal burning on an open fire, which was based on an average of tests carried out in New Zealand and weighted for more predominant use of bituminous coals. Previous emission factors used in the 1996 Christchurch air emission inventory (NIWA 1998) were around 33 g/kg. An emission factor of 28 g/kg was selected for PM_{10} from multi fuel burners burning coal, which was based on a weighted average of the test results available for different appliance types.

An additional uncertainty that arises when dealing with emission factors from coal burning is the proportion of the measured TSP that is in the PM_{10} size fraction. Little information is available on the relationship between PM_{10} and TSP emissions for domestic coal burning. For industrial coal burning in New Zealand, a relationship of around 70% is typically used (Wilton et al. 2007). However, it is uncertain whether domestic burners would show similar or different PM_{10} to TSP ratios.

The uncertainties in the emission factors for multi fuel burners create difficulties in establishing an emission limit for multi fuel burners. In our view, additional testing of emissions from multi fuel burners (both wood and coal) is required to provide an estimate of an emission limit for multi fuel burners that could be used for regulatory purposes.

4. Projections modelling for Reefton

A projections model was developed for Reefton to estimate changes in PM_{10} emissions from all sources under two scenarios: 1) the status quo; and 2) for the introduction of a regulated emission limit for multi fuel burners. The model is similar to those used in other areas of New Zealand (Wilton 2006; Scott 2002) and assumes a linear relationship between PM_{10} emissions and concentrations. Major assumptions underpinning the model for Reefton are described in Appendix A.

The base information for the modelling is the 2005 air emission inventory. Population related variables integrated into the model include the number of occupied dwellings from the 2006 census and a 1% decrease in population from 2001 to 2021[8]. The model has been developed to allow for easy integration of revised emission rates.

Figure 4.1 shows the estimated status quo impact, the introduction of an emission limit for multi fuel burners and the impact of the latter in combination with additional measures to achieve change over from older multi fuel burners to those meeting the emission limit. All are based on the assumption of an emission limit being effective from 2010 and the changeover option assumes all burners installed prior to 2005 are replaced.

The projections shown in Figure 4.1 rely upon on an assumed real life emission limit from multi fuel burners of 1 g/kg for both wood and coal. This is lower than emissions during recent tests of NES compliant wood burners (Kelly et al. 2007), which gave an average real life test of 3.9 grams of particulate per kilogram of fuel burnt (dry weight). It should be noted that the NES wood burner emission factor (Kelly et al. 2007) is expressed on a dry-weight basis, but emission factors for developing inventories are on a wet-weight basis. Hence, the real life equivalent emission factor for inventory purposes would be less, due to the moisture content of the wood.

[8] A 14% decrease in the Buller population has been predicted over this time, based on New Zealand Statistics population projections made in 2001. However, recent trends are not as extreme and the population has changed from 987 in 2001 to 948 in 2006. The estimated population for the period to 2021 was therefore based on the updated trends.

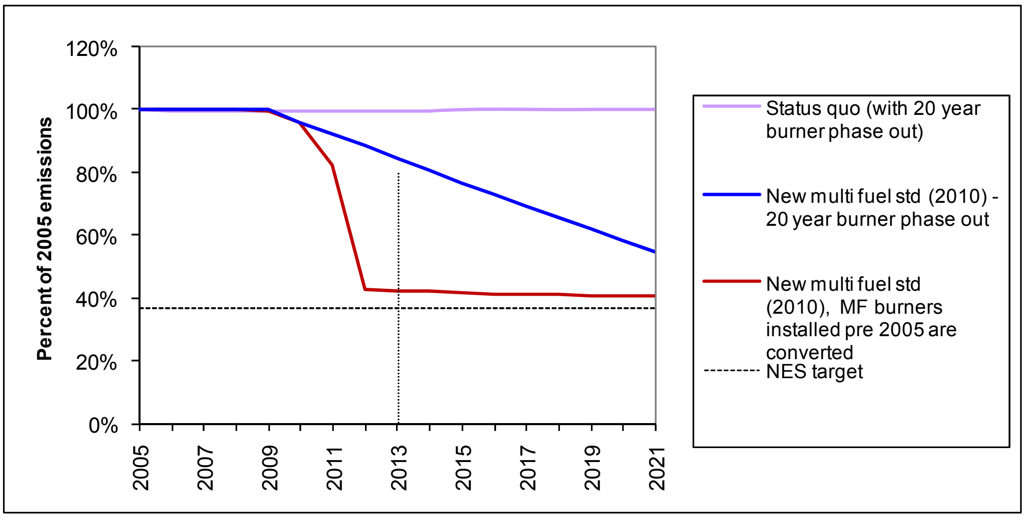

Figure 4.1: Projected emissions of PM10 for a new multi fuel burner emission limit of 1 g/kg PM10 (real life average).

Based on the current emission factors for coal burning, a real life emission limit of less than 1 g/kg of PM_{10} for both wood and coal emissions would be required to achieve the NES for PM_{10} in Reefton over time. Alternatively, a somewhat higher emission limit may be possible if additional regulatory measures were imposed, or if the limit were also applied to other heating devices. Irrespective of the emission rate chosen, an accelerated conversion programme would be necessary to achieve the NES by 2013. Because of significant uncertainties relating to the existing emission rates, it is recommended that further testing of emissions from multi fuel burners is conducted before any limit is used for regulatory purposes.

5. Summary and conclusions

The purpose of this report was to evaluate options for retaining coal burning as a home heating choice for households in Reefton whilst reducing PM_{10} to meet the NES.

Based on 2007 data, a 63% reduction in PM_{10} concentrations in Reefton would be needed to meet the NES requirement of 50 µg m^{-3} (24-hour average). Due to the high level of multi fuel burner use, the introduction of the 1.5g/kg standard for wood burners under the NES is unlikely to result in a significant downward trend in PM_{10} concentrations. Additional measures would therefore be required to meet the NES regulations for ambient PM_{10} concentrations.

The report has found that there is limited information supporting the current emission factors used and recommends further testing be done to determine accurate emission factors that could be used in the development of regulations that could be used in Reefton.

Results from emissions projections indicate that a real life emission limit of less than 1 g/kg of PM_{10} for both wood and coal emissions from multi fuel burners may be required to achieve the NES for PM_{10} in Reefton. A somewhat higher limit may be viable if additional regulations restricting emissions from other appliances are considered. There currently does not appear to be a cost effective technology for multi fuel burners that could meet this limit. Irrespective of the emission rate chosen, an accelerated conversion programme would be necessary to achieve the NES by 2013.

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Appendix A: Projections modelling

The following list outlines the key assumptions used in the Reefton projections modelling.

- A decrease in PM_{10} emissions from motor vehicles of around 40% by 2021. This is broadly based on reductions in tailpipe emissions as indicated in the NZTER database.
- The industry contribution to PM_{10} emissions is around 2% and there is a 10% increase in emissions from industry from 2001 to 2021.
- Current outdoor burning emissions occur throughout the week and weekend.
- Emission factors for burners as per the 2005 Reefton emission inventory.
- Average fuel use for wood burners of 27 kg per night as per the Reefton 2005 emission inventory survey.
- Average fuel use for coal burners of around 20kg per night as of 2005 emissions inventory.
- A proportional reduction in concentrations for any given reduction in emissions.
- No variations in the impact of emissions occurring at different times of the day.
- A 1 percent decrease in the number of households in Reefton.
- All new installations of wood burners from 2005 will meet an emission criterion of 1.5 g/kg when tested to NZS 4013.
- 79% of new burner installations will be multi fuel burners.
- The natural source contribution to PM_{10} in Reefton is 1% of the total anthropogenic emissions.