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Air Quality & IT Specialists

Management options for reducing PM_{10} concentrations in Reefton – Update 2012

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Executive Summary

This report updates a 2006 assessment of the effectiveness of management options in reducing PM_{10} concentrations in Reefton. There are a number of changes in this report including integrating revisions to the NES (timeframes for attainment), updated 2012 home heating methods and the impact of higher PM_{10} concentrations measured during 2012.

In 2012 PM_{10} concentrations measured in Reefton exceeded the ambient air quality guideline and National Environmental Standard (NES) concentration of 50 µg m^{-3} (24-hour average) on 27 occasions. This was the highest number of exceedences since continuous monitoring commenced at the site in 2006. More importantly, the second highest PM_{10} concentration (115 µg m^{-3}) was slightly higher than the previous concentration. The reduction in PM_{10} concentrations is typically assessed based on the second highest PM_{10} concentration and was previously calculated as a 52% reduction based on a concentration of 104 µg m^{-3}. Using the 2012 data, a 56% reduction in PM_{10} concentrations is required to meet the NES.

The main source of PM_{10} in Reefton during the winter months is solid fuel burning for domestic home heating. An emission inventory updated in 2012 found this source contributed around 96% of the anthropogenic PM_{10} within the inventory study area.

The effectiveness of different management options were evaluated using updated emissions and household heating data. Management measures evaluated included bans on the use of open fires, outdoor rubbish burning, phase outs of burners before the end of their useful life, no installations of new multi fuel burners and incentives to replace burners with non-solid fuel alternatives. Management options were evaluated based on an assumed wood and multi fuel burner life of 15 years and for an assumed burner life of 20 years.

Options to reduce PM_{10} concentrations in Reefton to meet the NES include:

- Prohibit outdoor rubbish burning and the use of open fires, no new installations of multi fuel burners and a 20% reduction in emissions occurs as a result of education measures.

- Prohibit outdoor rubbish burning and the use of open fires, no new installations of multi fuel burners and incentives to encourage 40% of household to replace solid fuel heating methods with cleaner heating options.
- Prohibit outdoor rubbish burning and the use of open fires and multi fuel burners.
- Compulsory use of secondary technology such as ESPs for all coal burners and wood burners not complying with the NES design criteria for wood burners, assuming on going effectiveness of technology can be maintained.

There may also be other technological solutions such as lower emission coal burners that may be available to assist with reducing PM_{10} emissions in the future.

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1 Introduction

National Environmental Standards (NES) require PM_{10} concentrations in Reefton meet a limit of 50 µg m^{-3} (24-hour average) with one allowable exceedence per year by September 2020 and three exceedences by 2016. The previous NES attainment date of 2013 was revised in 2011 to allow Councils more time to reduce PM_{10} concentrations. In 2012 concentrations of PM_{10} in Reefton exceeded 50 µg m^{-3} on 27 occasions during the winter months.

The reduction in PM_{10} concentrations required to meet the NES is typically based on the second highest PM_{10} concentration measured. The second highest PM_{10} concentration measured during 2012 was 115 µg m^{-3} and is higher than previously measured. This requires a re-evaluation of the reductions required in PM_{10} concentrations to meet the NES and the consequent management measures.

The 2005 emission inventory was also updated in 2012. Domestic heating was again found to be the main source of PM_{10} emissions during the winter months. This source is estimated to contribute 96% of the daily winter anthropogenic PM_{10} emissions within the Reefton inventory area (Wilton, 2013). The inventory excludes natural source contributions and contributions from areas outside of the urban area.

A previous management options report for Reefton was prepared for based on 2005 inventory data. That report provided a couple of options for meeting the NES. These were

1. The introduction of a multi fuel burner with a real life emission rate of 5g/kg, insulation measures to reduce coal consumption and a ban on outdoor burning and all multi fuel burners installed before 2005 would need to be replaced with low emission multi fuel burners.
2. A ban on the use of coal, open fires, and outdoor burning and a 15 year phase out of solid fuel burners from the date of installation.

The report also recommended that further testing of coal in multi fuel burners, in the laboratory, tested to AS/NZS4013 and AS/NZS4012 and real life testing be carried out to provide greater certainty on the emissions from burning coal in multi fuel burners and that the proportion of TSP that is PM_{10} be assessed for domestic coal burners in New Zealand.

These recommendations have not been carried out. Historical uncertainties with regards to coal burner emissions persist.

This report aims to update the previous management options assessment taking into account revisions to the NES, the updated air emissions inventory and PM_{10} concentrations measured since 2007.

2 Reductions required in PM_{10} concentrations

The reduction in PM_{10} concentrations required to meet the NES is typically calculated based on the second highest concentration in a year. This is because the NES allows for one exceedence of 50 µg m^{-3} annually. Prior to 2012 the largest second highest concentration was 104 µg m^{-3} and was measured during 2007. Consequently the reduction in PM_{10} had previously been calculated as 52% based on a concentration of 104 µg m^{-3}. The second highest PM_{10} concentration measured during 2012 was 115 µg m^{-3}.

Based on this concentration a reduction in PM_{10} concentrations in Reefton of around 57% is required. This has been calculated based on Equation 2.1:

$$R = 100(1 - \frac{t}{c}) \qquad \text{Equation 2.1}$$

where - R = the percentage reduction

t = the air quality target (e.g., 50 µg m^{-3})

c = the concentration identified as representing the reduction required (typically second highest PM_{10} concentration)

3 Sources of PM_{10} in Reefton

An emission inventory for Reefton was carried out in 2012 to provide updated information on the contributions of sources to PM_{10} (Wilton, 2013). The inventory included estimates of emissions from domestic heating, motor vehicles, industry and outdoor burning.

Figure 3.1 shows that domestic heating is the main contributor to daily winter anthropogenic PM_{10} emissions in Reefton (96%). Outdoor burning contributes 1% and industry contributes 3%.

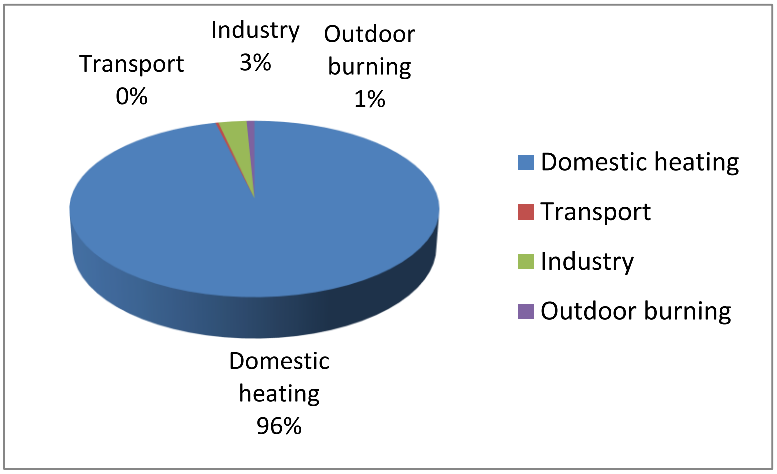

Figure 3.1: Sources of anthropogenic PM_{10} emissions in Reefton (2012).

The main method of home heating in Reefton for 2012 was multi fuel burners, with 54% of homeowners using this source. Around 26% of homeowners used electricity with the majority of these (51%) relying on heat pumps. Around 15% of households used wood burners. Only a small proportion used open fires or gas burners. Some households relied on more than one method of heating their main living area during the winter months.

The greatest amount of PM_{10} from domestic heating was found to come from multi fuel burners burning coal (63% of the domestic heating contribution). Multi fuel burners burning wood contributed 24% of the PM_{10} emissions from domestic home heating (Figure 3.2).

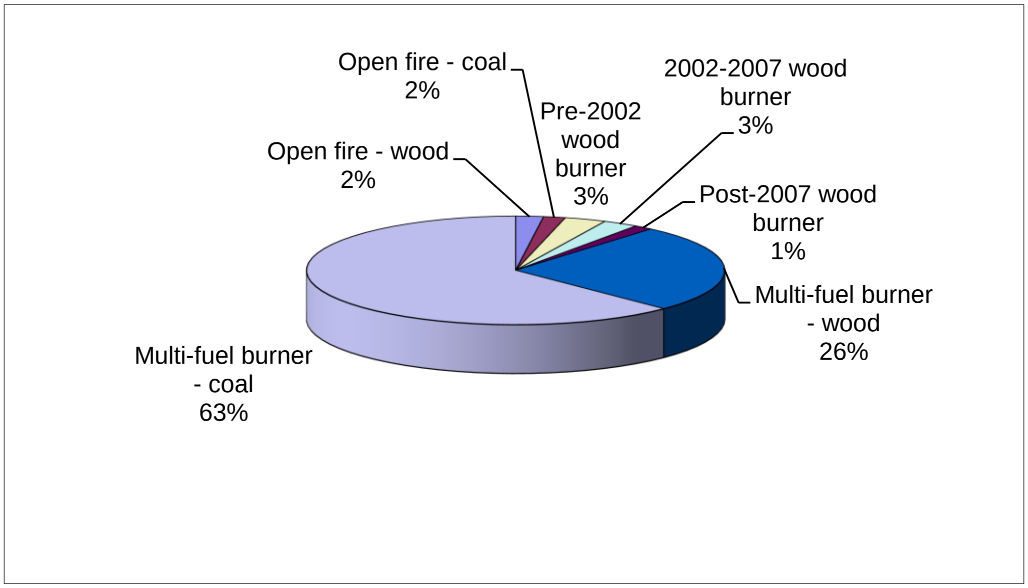

Figure 3.2: Relative contribution of different heating methods to PM_{10} from domestic heating in Reefton during 2012.

4 Managing PM_{10} concentrations in Reefton

4.1 Baseline projections

Baseline projections for domestic home heating were based on the following:

- No change in the Reefton population from 2012 to 2028.
- Emission factors and fuel factors used in the inventory apply across the whole life of the burner.
- Wood and multi fuel burners are replaced 15 and 20 years after installation (note because of uncertainties surrounding this variable both scenarios are modelled).
- The number of open fires decreases by 10% from 2012 to 2028.
- The number of new installations of solid fuel burners per year is equal to 100% of those removing burners.
- Around 67% of households with multi fuel burners burn wood and 88% burn coal.
- Around 90% of households with open fires burn wood and 70% burn coal (many households burn both wood and coal).

No increase in the contribution of industrial emissions, outdoor burning or motor vehicle emissions from 2012 to 2028.

4.2 Approach

The methodology used to assess the impact of different management options on PM_{10} emissions in Reefton relies on changing the variables within the projections frameworks for different sources. For example, if a management option aimed to examine the impact of a ban on outdoor rubbish burning from a particular year, the emissions from this source would be removed from the total PM_{10} emissions at the year the ban was assumed to be effective. Estimating the impact of management options for domestic heating is more complex as assumptions regarding replacement heating methods need to be made.

A number of other factors influence the analysis of the effectiveness of management options in reducing PM_{10} concentrations. These include:

1. The relative contribution of different sources to PM_{10} emissions (the emission inventory) and assumptions underpinning this assessment.

2. The potential contribution of sources of PM_{10} not included in the inventory or outside of the study area

3. Estimated projections in sources of emissions in the absence of additional controls.

4. The relationship between emissions and concentrations in Reefton.

The time of day impact relates to how emissions occurring at different times of the day influence the 24-hour average concentration. For example, emissions that occur when wind speeds are lowest and temperature inversions are present (typically evening and early morning) will have a greater impact on 24-hour average concentrations. A greater proportion of domestic heating emissions occur during this time, relative to other sources, and therefore this source may contribute slightly more to PM_{10} concentrations.

The relationship between emissions and concentrations for Reefton is assumed to be linear.

4.3 Management options

Management options included in this analysis include:

1. Status quo including the NES design standard for new installations of wood burners assuming a 15 year replacement rate for solid fuel burners, excluding open fires.

2. Prohibiting outdoor rubbish burning (modelling for both the 15 year and 20 year phase out scenarios).

3. Prohibiting outdoor rubbish burning and the use of open fires (modelling for both the 15 year and 20 year phase out scenarios).

4. No new installations of multi fuel burners and phase out solid fuel burners 15 years after installation.

5. Ban outdoor rubbish burning and open fires, no new installations of multi fuel burners and incentives to encourage 40% of household to replace solid fuel heating methods with cleaner heating options.

6. Improve burner operation and fuel quality through education and or other mechanisms.

7. Prohibit outdoor rubbish burning and the use of open fires and the installation of new multi fuel burners and reduce emissions by 20% through education or other mechanisms.

8. Prohibit outdoor rubbish burning and the use of open fires and multi fuel burners.

9. The option of introduction of a low emission coal burner meeting an emission limit of 5 g/kg (real life) was not included in this assessment. This option would require: the development or adoption of a real life testing regime for coal burners and the development/ importing of coal burners that may meet the limit.

Projections were modelled based on the assumption that solid fuel burners would be replaced 15 years and 20 years following installation. Although 15 years has been quoted by the New Zealand Home Heating Association as the average useful life of a wood burner, some burners may be used for longer periods. In some areas (e.g., Christchurch and proposed for Nelson), the uncertainty associated with burner replacement rates has been reduced by the proposed introduction of regulations requiring the replacement of burners 15 years following installation. It would seem likely that households may be more likely to retain their burners for longer periods in the current economic climate.

The status quo projections also include the introduction of the NES design criteria for the installation of new wood burners. This specifies new burners must meet an emission criteria of 1.5 grams of particulate per kilogram of fuel burnt when tested to NZS 4013. This criterion does not apply to the installation of new multi fuel burners (burners designed for both wood and coal).

4.4 Baseline projections by source

Figure 4.1 shows the estimated baseline projections in PM_{10} emissions from each source in the absence of additional management measures. These and subsequent projections are based on the assumptions outlined in Table 4.1.

These projections are based on the assumption that older burners are removed 15 years following installation. Because of the uncertainty surrounding this assumption, air management scenarios have been analysed for both a 15-year and 20-year phase out period.

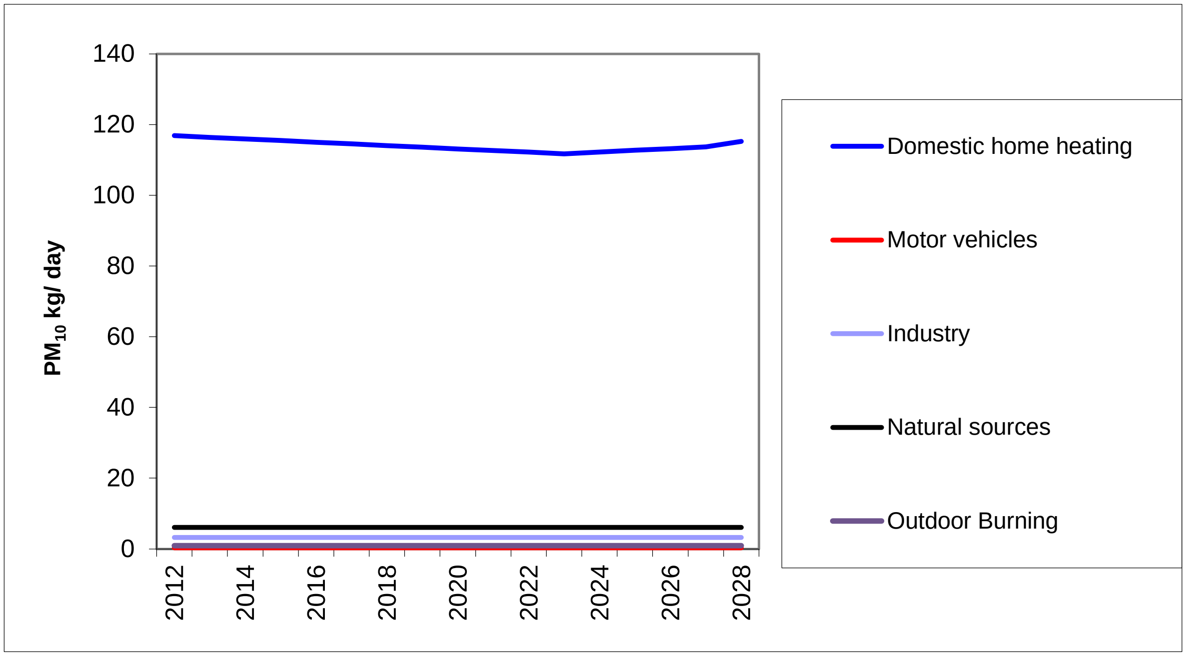

Figure 4.1: Baseline projections in PM_{10} emissions from all sources

Table 4.1: Assumptions underlying the assessment of the effectiveness of management options for reducing PM_{10} emissions

1	No change in emissions from motor vehicles.
2	The industry contribution to PM_{10} emissions does not increase from 2012 to 2028
3	Current outdoor burning emissions occur throughout the week and weekend.
4	Emission factors for burners as per the 2012 Reefton emission inventory.
5	Average fuel use for coal on multi fuel burners of 18 kg per night as per 2012 emission inventory survey.

6	A proportional reduction in concentrations for any given reduction in emissions.
7	No variations in the impact of emissions occurring at different times of the day.
8	Unless otherwise stated, 100% of households replacing older solid fuel burners or multi fuel burners will install solid fuel burners.
9	An emission factor for future installations of 1.5 g/kg wood burners of 5 kg.
11	As per the 2012 air emission inventory, 67% of households with multi fuel burners use wood and 50% use coal.
13	Natural sources contribute 5% of the daily PM_{10} emissions.
14	No significant change in natural sources, emissions from outdoor rubbish burning and industrial emissions from 2012 to 2028.

4.5 Status quo

Figure 4.2 shows the projected PM_{10} emissions assuming wood burners are phased out 15 years and 20 years following installation. This suggests that the NES for PM_{10} is unlikely to be met in Reefton in the absence of additional controls.

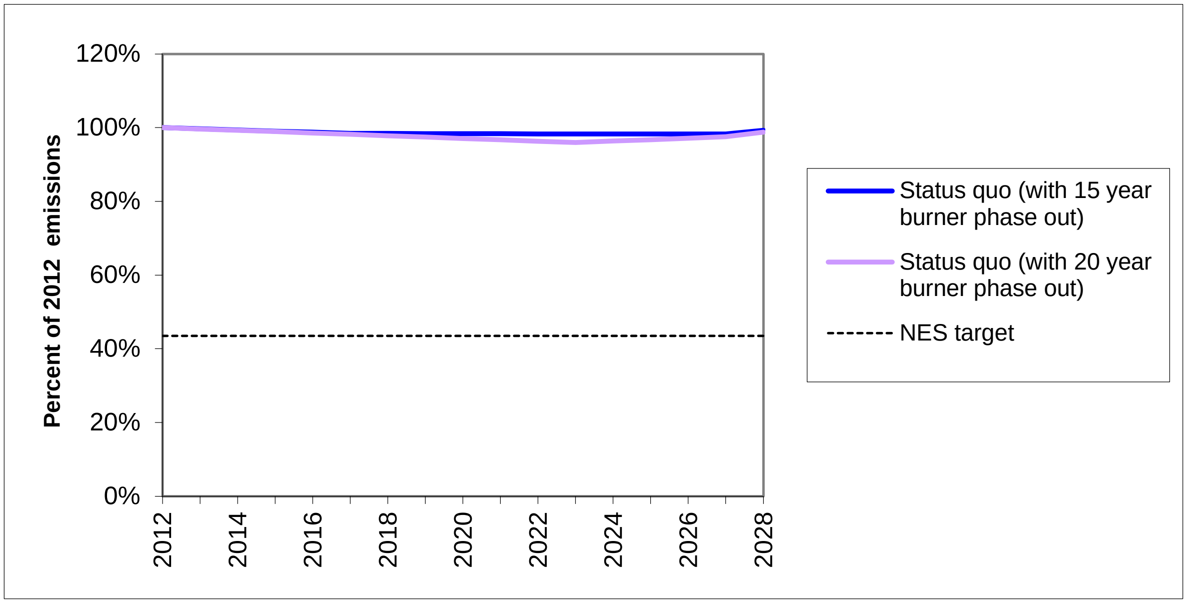

Figure 4.2: Status quo projections for PM_{10}

4.6 Ban on outdoor rubbish burning

Outdoor rubbish burning in Reefton is estimated to contribute around 1% of the daily anthropogenic PM_{10} emissions during the winter. Figure 4.3 shows the impact of a ban on outdoor rubbish burning during the winter months from 2014 on daily PM_{10} estimates from 2012 to 2028. Results suggest that the NES is unlikely to be met for both the burner phase out options.

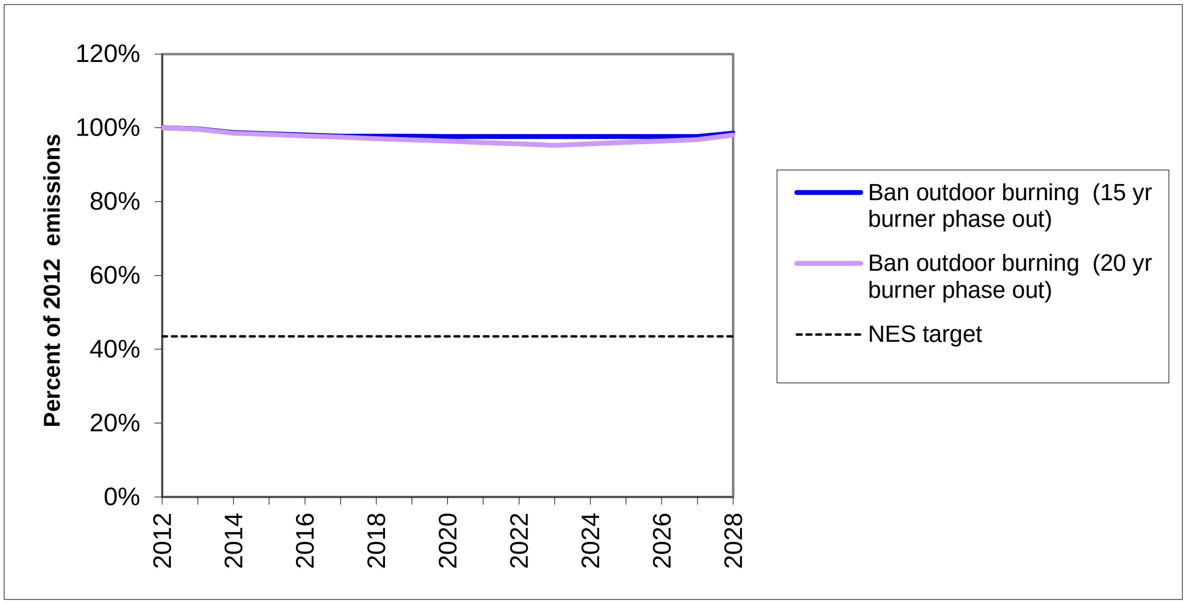

Figure 4.3: Ban on outdoor rubbish burning

4.7 Ban on outdoor rubbish burning and open fires

The addition of a ban on the use of open fires in Reefton is shown in Figure 4.4. Although there are only a small number of open fires regularly used in Reefton they are a very inefficient form of home heating because a good proportion of the heat available from the fuel goes up the chimney. Consequently they emit a disproportionate amount of PM_{10} for the amount of heat they produce. The analysis assumes open fires are not used beyond 2015 and that 50% of open fires are replaced with solid fuel burners.

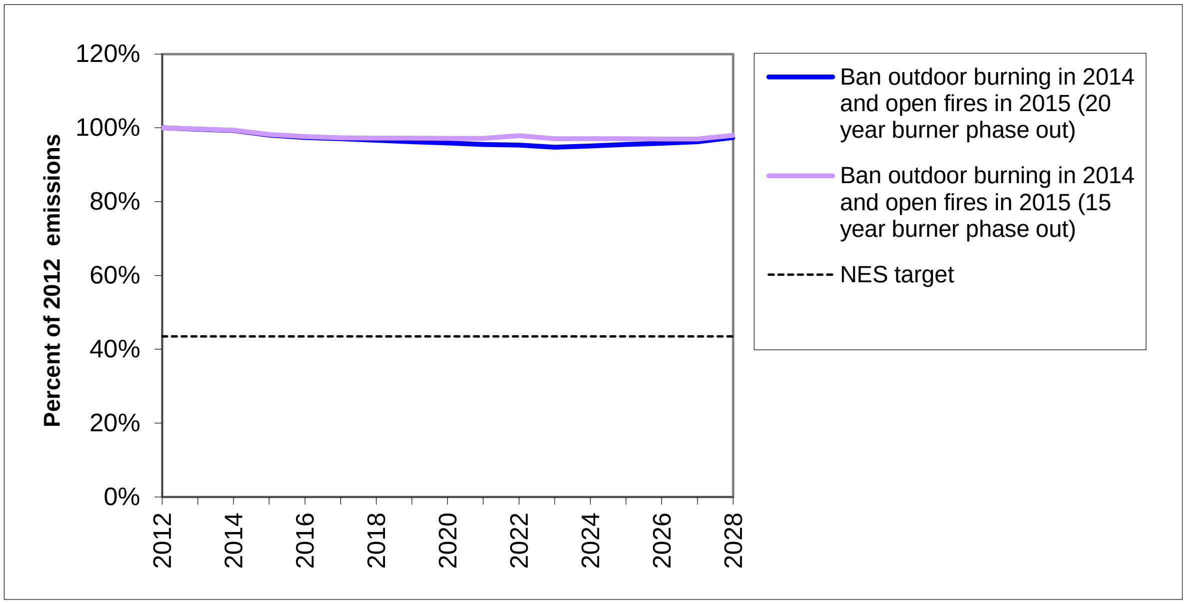

Figure 4.4: Ban on outdoor rubbish burning and prohibit the use of open fires.

4.8 No new multi fuel burner installations

The use of multi fuel burners is popular in Reefton owing to the availability of coal as a fuel. These burners emit more PM_{10} on average than wood burners and are the main contributor to PM_{10} emissions. Figure 4.5 shows the projections if the installation of new multi fuel burners were prohibited and households installed NES compliant wood burners instead.

Although significant reductions are predicated by 2028, the reduction by 2020 is unlikely to be sufficient to meet the NES.

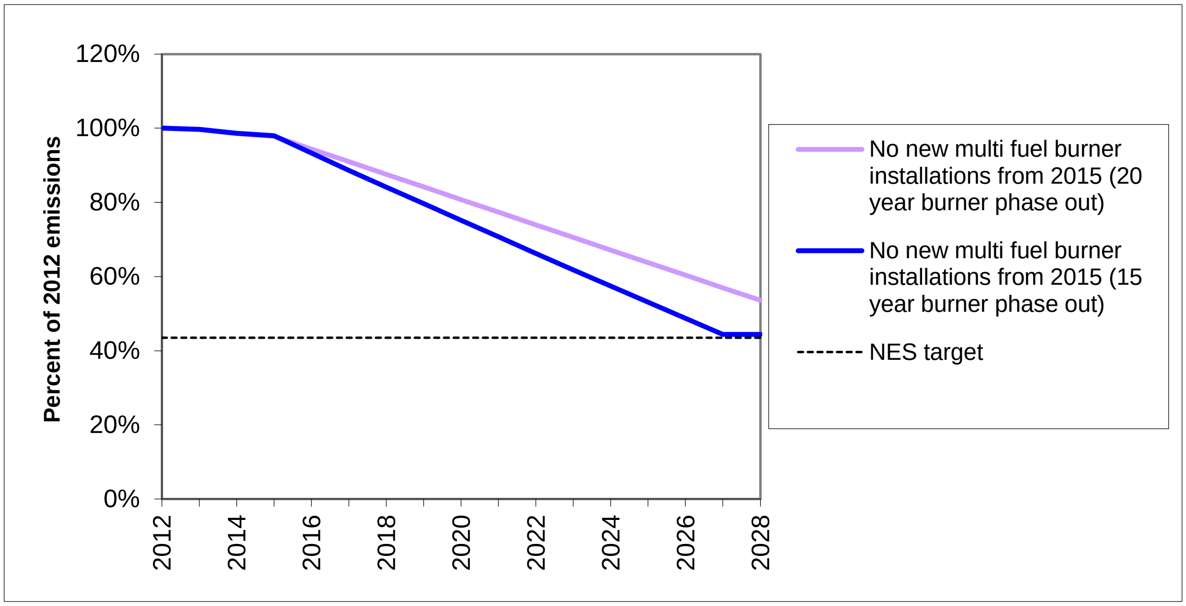

Figure 4.5: Prohibition on the installation of new multi fuel burners and existing burners are phased out after 15 or 20 years.

4.9 Prohibit the use of some types of coal

Assessing the impact of moving away from the more polluting coals is difficult as limited work has been carried out to quantify the difference between PM_{10} emissions from dirty versus cleaner coals. An indication of the potential feasibility of this approach could be made by making assumptions about the relative differences in PM_{10} emissions.

Around 14% of households who reported a coal type used bituminous (dirtier) coal. Assuming dirty coals produce 1.7 times the amount of PM_{10} as clean coals (i.e. relative emission factors of 18 g/kg versus 32 g/kg for multi fuel burners), a 9% improvement in PM_{10} may be achieved through conversion to cleaner fuel. If a similar assumption were made about the relative difference in emissions from households operating multi fuel burners poorly and the assumption that 10% of households do this a further improvement of 6% could be achieved if these households could operate their burners well.

4.10 Prohibit the use of coal and the installation of new multi fuel burners

Prohibiting the use of coal and the installation of new multi fuel burners in 2015 would result in a gradual decrease in PM_{10} emissions (Figure 4.6). For this option existing multi fuel burners could be retained for the burning of wood. However, reductions in PM_{10} are gradual and compliance with the NES 2020 is unlikely.

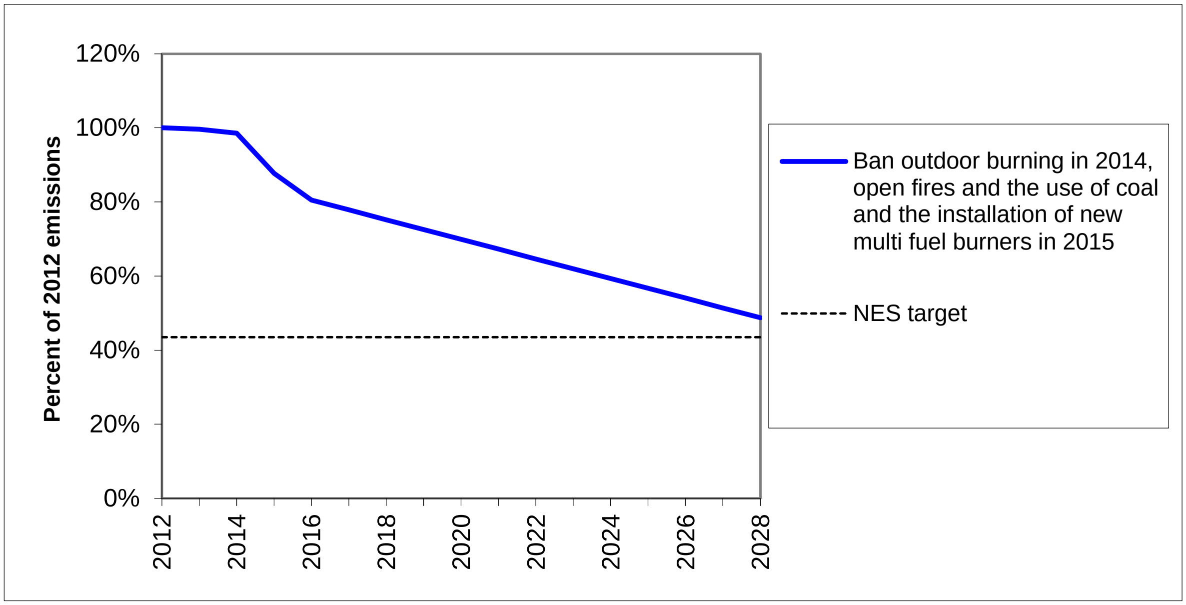

Figure 4.6: Ban outdoor rubbish burning in 2014 and open fires, the use of coal and the installation of new multi fuel burners in 2015 and a 20 year burner phase out.

4.11 Regulation and incentives to encourage the replacement of solid fuel with cleaner heat

Financial incentives can be used to encourage households away from solid fuel heating options. Figure 4.7 shows the estimated impact if 40% of households replacing wood burners or multi fuel burners at the end of their useful life converted to cleaner heating options such as electricity or gas heating with the remainder converting to NES compliant wood burners.

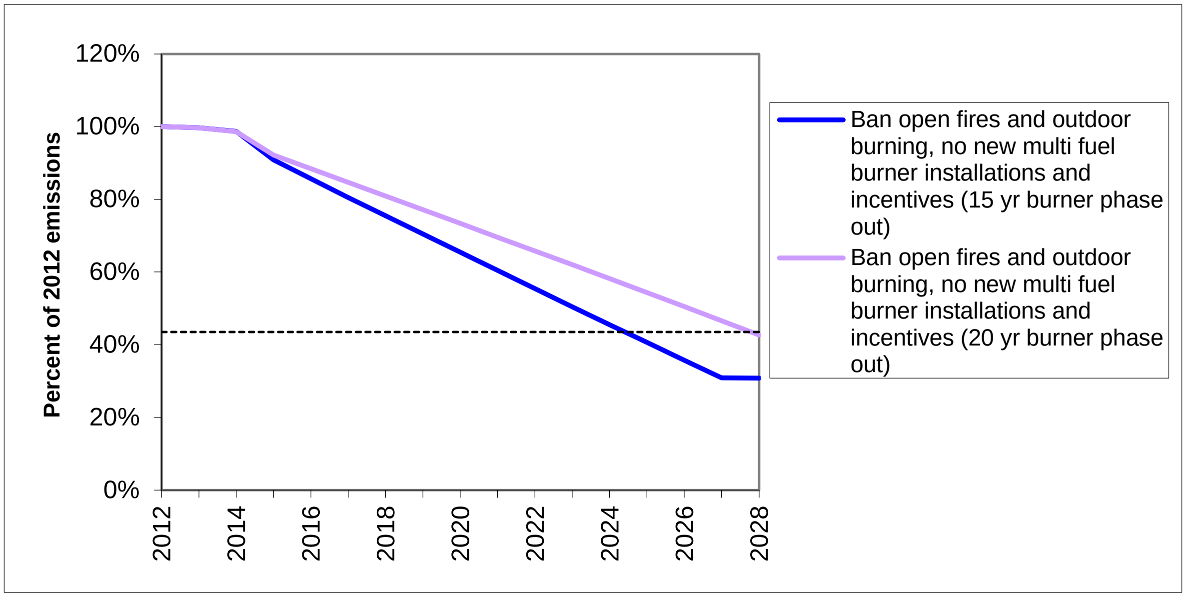

Figure 4.7: Ban outdoor rubbish burning and open fires, no new installations of multi fuel burners and incentives to encourage 40% of household to replace solid fuel heating methods with cleaner heating options.

4.12 Regulation and education

The combination of education and regulatory measures is another option that could be explored. Typically the impacts of education are difficult to quantify. Campaigns (e.g., good wood programmes) that result in a decrease in the use of wet wood are likely to be effective in reducing PM_{10} emissions. Other education programmes could target burner operation with an objective of removing gross emitters or those burning dirty coal. One limitation with relying on education is that impacts may not be sustained. That is households could revert to previous behaviours.

An estimate of the impact of changing burner behaviour and fuel type for different coal burners based on specific assumptions was made in section 4.9. Additional improvements, albeit smaller (around 5%) could be achieved through burning dry wood and improved wood burner operation. If education were effective in significantly improving burner operation and fuel quality, a reduction in PM_{10} emissions of around 20% may be possible.

Figure 4.8 shows the impact on PM_{10} emissions if education were able to reduce PM_{10} emissions by 20% combined with measures prohibiting outdoor rubbish fires, the use of open fires and phasing out wood burners 15 years after installation. Figure 4.9 shows the same scenario but with the addition of a regulation prohibiting the installation of new multi fuel burners.

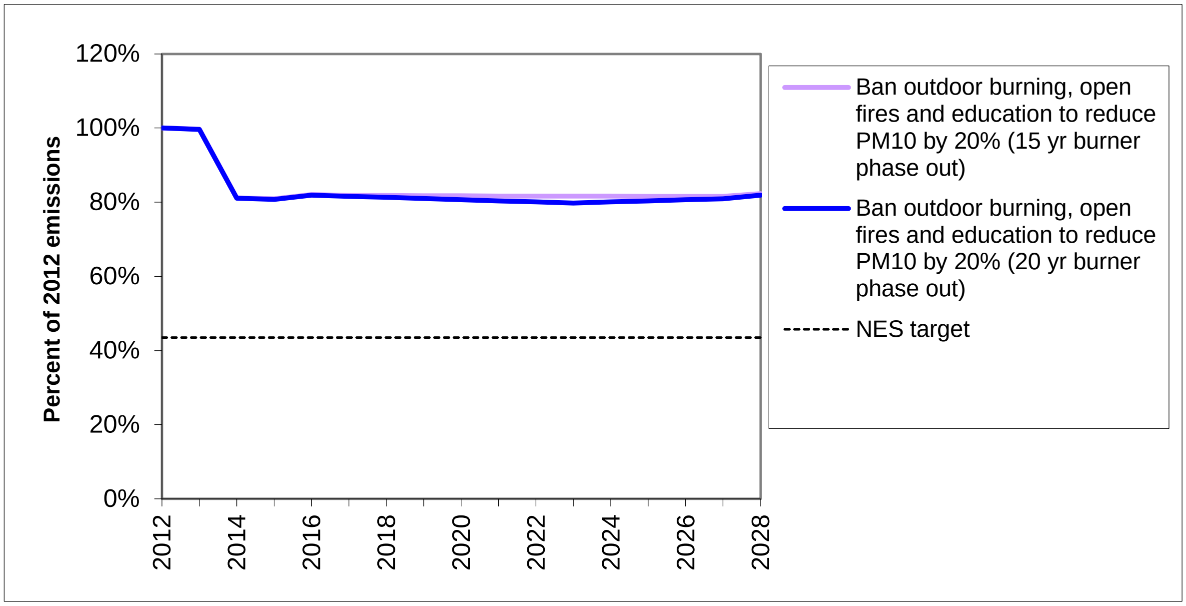

Figure 4.8: Ban outdoor rubbish burning and open fires and a 20% reduction in emissions occurs as a result of education measures.

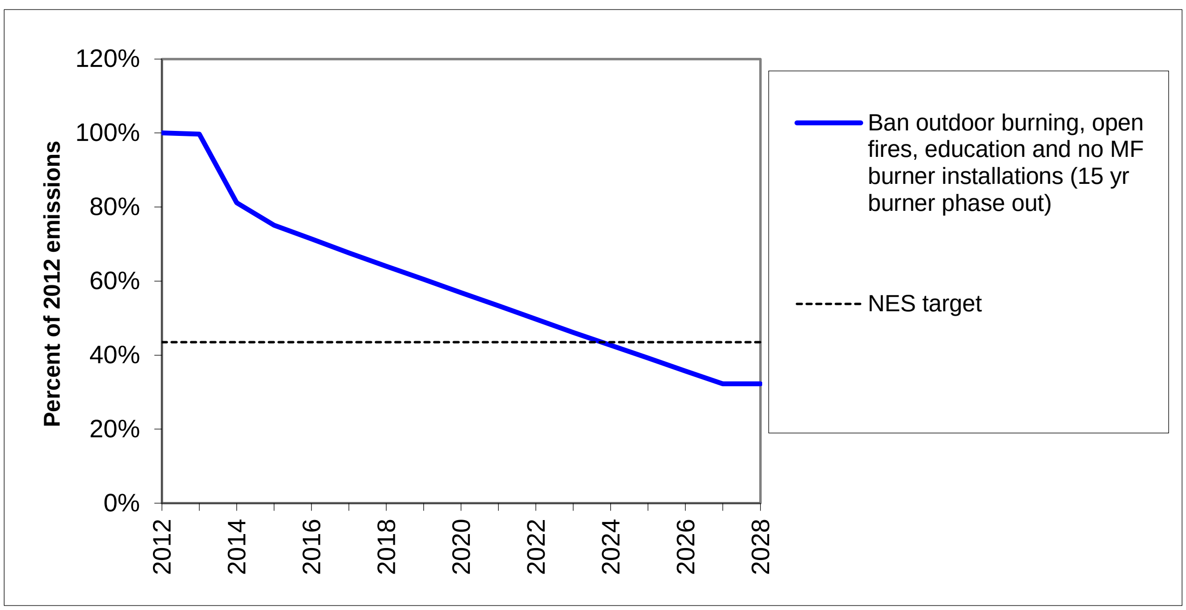

Figure 4.9: Ban outdoor rubbish burning and open fires, no new installations of multi fuel burners and a 20% reduction in emissions occurs as a result of education measures.

4.13 Ban outdoor burning and open fires and phase out multi fuel burners before the end of their useful life

The phasing out of multi fuel burners before the end of their useful life is not ideal but may be necessary to achieve the NES by 2020. Figure 4.10 shows the impact of phasing out all multi fuel burners in 2016. These burners could be as new as two years old depending on the length of advance warning given for the policy.

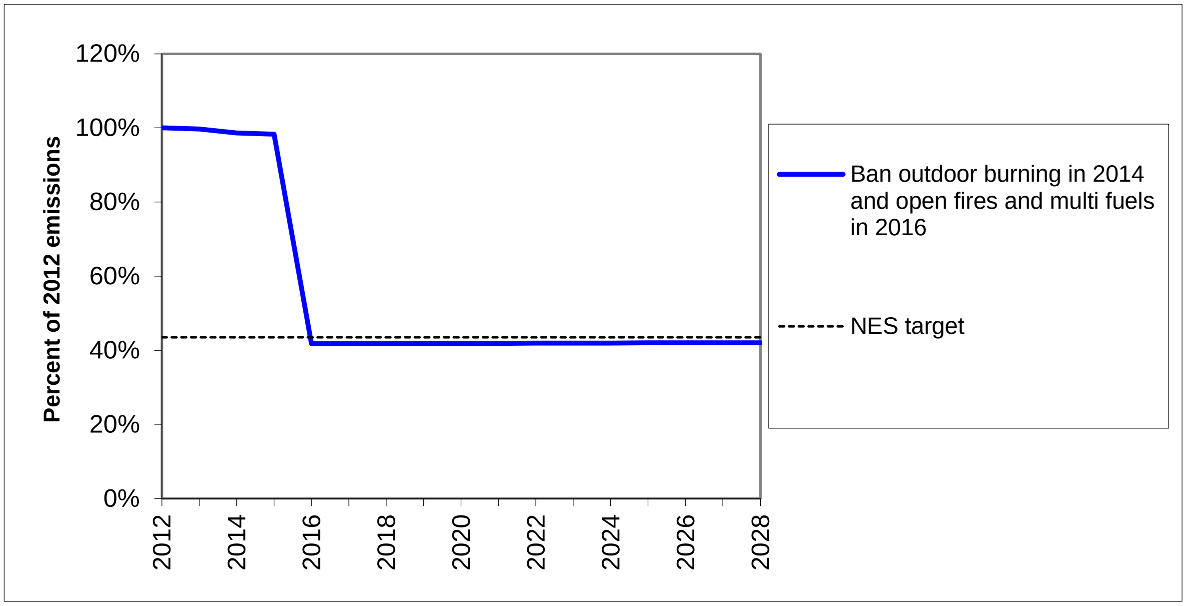

Figure 4.10: Ban outdoor rubbish burning and open fires and the use of multi fuel burners in 2016

4.14 Other options

The use of technology such as burners designed to minimise the impact of poor operation is likely to result in significant improvements in PM_{10} concentrations with time. Examples of such burners on the international market include Hass und Sohn and Rikatronic. These burners are not currently available in New Zealand, although a local manufacturer designed an appliance with similar features which is yet to reach the market because there is currently no suitable method for testing its emissions. It is difficult to quantify the impact of these burners on PM_{10} because of the nature of the emissions data available.

Further research into the availability of low emission coal burners is being carried out for Reefton. An earlier study (Wilton, Smith, & Baynes, 2007) identified a small number of lower emission coal central heating systems.

The use of secondary control measures has also been considered internationally. Technologies available include electrostatic precipitators, flue gas condensers, ceramic filters and catalytic converters. The ESP technology is considered the most promising for small-scale biomass combustion with existing ESPs (Obernberger & Mandl, 2011). However Obernberger & Mandl (2011) also note that a number of areas of on-going research are required with respect to the use of secondary measures, particularly in conjunction with older wood burner systems. It is likely some of the concerns – which relate to clogging of the electrodes would also apply to coal burners. There are a number of other issues with different ESP systems. Some have limits on the flue temperatures which limit their feasibility and many also report particulate collection efficiencies with regards to PM_1 as opposed to PM_{10} or TSP. Further investigations into this option are being carried out. Figure 4.11 shows the potential effectiveness of an ESP in reducing PM_{10} emissions in Reefton should an ESP be found to be effective in reducing PM_{10} from coal burning. This is based on a particle collection efficiency for PM_{10} of 65% and the assumption that the ESP is effective and maintained for the duration of the burners life.

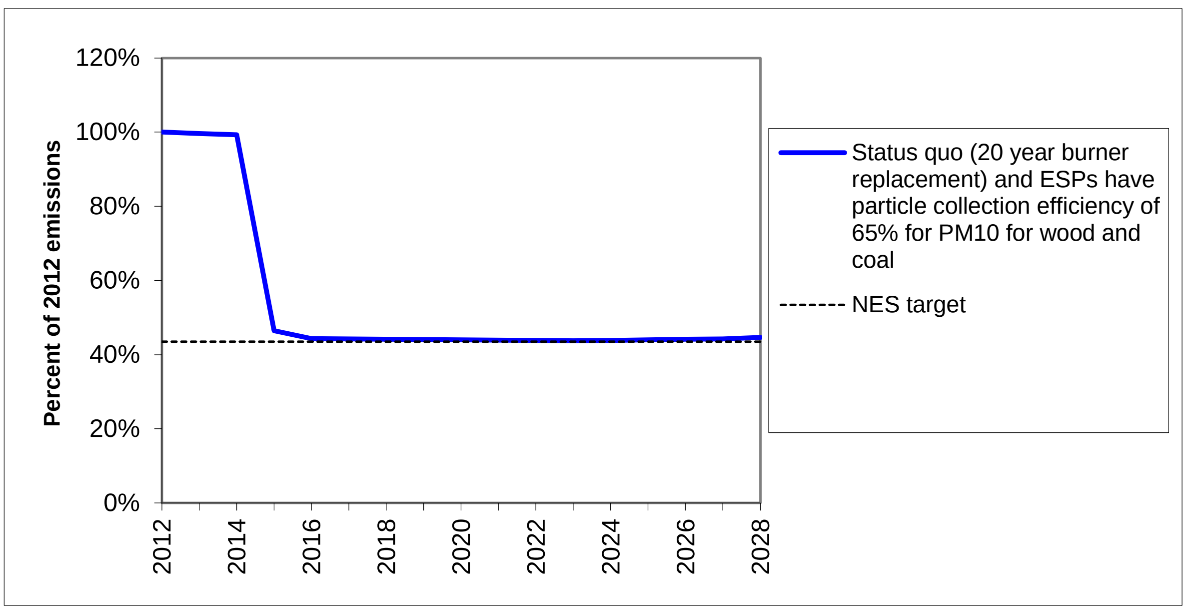

Figure 4.11: ESPs capable of reducing burner emissions by 65% are fitted to all multi fuel burners and older wood burners (not meeting the NES design criteria for wood burning)

5 Summary

Concentrations of PM_{10} measured during 2012 in Reefton are in excess of the NES and are the highest measured since routine monitoring commenced in 2006. Based on the 2012 data a reduction in PM_{10} emissions of 57% is required.

The effectiveness of different options in achieving reductions in PM_{10} has been assessed in this report relative to the revised NES timeframes for attainment and based on updated 2012 home heating methods. Management measures considered included bans on the use of open fires, outdoor rubbish burning, phase outs of burners before the end of their useful life, education and incentives to replace burners with non-solid fuel alternatives. Management options were evaluated based on an assumed wood burner life of 15 years and for an assumed burner life of 20 years.

Options to reduce PM_{10} concentrations in Reefton to meet the NES include:

- Prohibit outdoor rubbish burning and the use of open fires, no new installations of multi fuel burners and a 20% reduction in emissions occurs as a result of education measures.
- Prohibit outdoor rubbish burning and the use of open fires, no new installations of multi fuel burners and incentives to encourage 40% of household to replace solid fuel heating methods with cleaner heating options.
- Prohibit outdoor rubbish burning and the use of open fires and multi fuel burners.
- Compulsory use of secondary technology such as ESPs for all coal burners and wood burners not complying with the NES design criteria for wood burners, assuming on going effectiveness of technology can be maintained.

There may also be other technological solutions such as lower emission coal burners that may be available to assist with reducing PM_{10} emissions in the future.

References

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