Air Quality Cost-Benefit Analysis – Update

Review of the National Environmental Standards for Air Quality– Policy Options

Prepared for:
The Ministry for the Environment (MfE)

Date: 25 November 2019

m.e consulting

Document reference: MfE 012.19 Air Quality CBA 2019 update

Date of this version: 25/11/2019

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Date	Version	Changes
04/11/2019	Update	Preferred policy updated
25/11/2019	Final Draft	Updated to reflect feedback from the Ministry

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Contents

Tables

Figures

Abbreviations

ACC	Accident Compensation Corporation
AQ	Air Quality
BPO	Best Practicable Option
CAU	Census Area Unit
CBA	Cost-Benefit Analysis
CBR	Cost-Benefit Ratio
CHA	Cardiovascular Hospital Admissions
COMEAP	Committee on the Medical Effects of Air Pollutants
DALY	Disability Adjusted Life Year
EECA	Energy Efficiency and Conservation Authority
GA	Golder Associates (NZ) Limited
GLC	Ground Level Concentration
HAPINZ	Health and Air Pollution in New Zealand
HRAPIE	Health Risks of Air Pollution in Europe
LQI	Life quality index
M.E	Market Economics Limited
MfE	Ministry for the Environment
MoT	Ministry of Transport
NESAQ	National Environmental Standards for Air Quality
NIWA	National Institute of Water and Atmospheric Research
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter
PM_{10}	Particulate Matter (up to 10 micrometres in size)
$PM_{2.5}$	Particulate Matter (up to 2.5 micrometres in size)
QALY	Quality Adjusted Life Year
RAD	Restricted Activity Day
RHA	Respiratory Hospital Admissions
SNZ	Statistics New Zealand
SQ	Status Quo scenario
ULEB	Ultra-low emission burner
VLYL	Value of Life Years Lost
VOSL	Value of Statistical Life
VPF	Value of Preventing a Fatality
WHO	World Health Organisation
WTP	Willingness to Pay

1 Introduction

It is the Ministry for the Environment's responsibility, as the Government's principal advisor on environmental matters both nationally and internationally, to manage and improve air quality. This includes monitoring councils' compliance and/or steps taken to achieving compliance with the National Environmental Standards for Air Quality (NESAQ).

The Ministry for the Environment (MfE) is in the process of proposing amendments to NESAQ. Market Economics (M.E) and Golder Associates (GA) established a model to estimate the net gains of different policy options[1]. Subsequently, in 2019, M.E were approached to update the cost-benefit analysis, assessing the preferred policy option selected by MfE. This report forms part of the MfE's work in assessing the preferred policy option.

1.1 Aim and approach

The project aim was to develop a model to assess different policy options (in terms of costs and benefits). Having a flexible and robust model to analyse options is useful, as it can be used to better understand the trade-offs of different policy options. This report documents the process but only summarises the key findings of the selected (preferred) policy option as defined by MfE. Assessment results related to earlier policy options can be found in the 2017 report.

We understand that the findings informed MfE's decisions regarding the amendments and the selected proposal which will be used during the public consultation process. Crucially, this report is an update of the 2017 version. Only the relevant parts were updated, and does not include wholesale changes to either the model or the report. The update was completed in strict timeframes and many of the underlying datasets were not updated because more recent information is not available.

This assessment compares the preferred policy option **relative to** the baseline or Status Quo and the change is interpreted as follows:

- If the policy option results in less cost being imposed on (or spending incurred by) society, then that difference is interpreted as a **benefit**, or conversely
- If the policy option results in a greater total cost imposed on (or spending incurred by) society, then the difference is interpreted as a **cost**.

The National Institute of Water and Atmospheric Research (NIWA) was contracted by MfE to generate best estimates of annual-mean concentrations of PM[2] $_{2.5}$ at Census Area Unity (CAU) level for 2014. NIWA's input is further discussed in Section 2.2. Estimates were based on observations from 2014 where available, or older data in a few cases. They also provided the exposure response ratios that are used to calculate health costs in the CBA model. These ratios are in line with international approaches, e.g. Committee on the Medical Effect of Air Pollution (2010).

[1] This was part of a project for the MfE that was undertaken in during 2016/17.
[2] PM – particulate matter

Golder Associates (NZ) Limited (GA), as part of the project team in 2016/17, provided PM concentrations for airsheds in NZ, disaggregated by source (Domestic, Industry, Motor vehicles and Natural), and further broken down into the type of appliance (domestic) and per industry (48 sectors). GA provided a snapshot of concentrations every 5 years out to 2028, which is 'grown' in a straight line between the relevant years. More detailed information about GA's methodology can be found in Section 2.

The effect(s) of implementing different policy settings, e.g. setting emission limits for new home heating appliances, is then translated into a PM concentration reduction and ultimately health 'benefits' by using response ratios. At a high level this approach is consistent with the one used/developed during the HAPINZ process. The cost of implementing these options includes both private costs (replacing burners with a more costly option[3] than if the rules had not been established) as well as public costs (regulatory and enforcement costs).

The changes are distributed over a 10 year period and the costs/benefits are aggregated and expressed in discounted terms (NPV terms). Importantly, the results are for the 'relative position', i.e. policy induced change.

1.2 Assumptions, limitations and caveats

As mentioned, the cost-benefit analysis (CBA) examines the costs the policy setting imposes, **relative** to the costs under status quo. This is an important point. A reduction in cost is interpreted as a benefit.

1.2.1 General

This assessment is based on a wide number of assumptions. At a general level, the following points are highlighted:

1. All costs are estimated in NZ dollars.
2. All costs[4] in the CBA model have been discussed with and approved, by the Ministry for the Environment.
3. Air quality refers to the degree to which the air is free from particulate matter (PM), i.e. a lower concentration of PM implies an improvement of air quality and vice versa. This study did not consider any other pollutants in the air as contributing to air pollution (e.g. Ozone or noxious gasses).
4. When determining the 'cost' of a (compliant) heating source, the cost is seen as the difference between the current situation and the 'cheapest' compliant alternative. This is seen as the 'cost of compliance' imposed by the policy. Because a heat pump has zero $PM_{2.5}$ emission, it is compliant under all policy settings, and is seen as the cheapest alternative, since its 'total installation costs' (cost of the appliance and the cost of installation) is lower than that of a burner.

[3] Referring to 'one off' appliance cost rather than the cost-effectiveness of running the appliance.
[4] Private and public costs.

5. The analysis takes place at an airshed level, more specifically the urban airsheds (see Appendix 1 for a list of the airsheds represented in this report). Regional population located outside of these areas were aggregated and the area treated as one airshed – called '*Rest of Region Airshed*'. In these '*Rest of Region'* airsheds, only an emission limit of 1.5g/kg has been applied, implying that households will not be able to install a burner with an emission factor greater than 1.5g/kg when their current burner comes to the end of its life. However, they would not be forced to change their burner prematurely. Based on the current assumptions around the costs (of appliances), replacing the >1.5g/kg burners would be cost-neutral. The replacement/distribution patterns as discussed in Section 1.2.2, applies to these areas.

6. Because of the relative size of the population in the 'Rest of Region' airsheds, the results must be viewed with caution because it is weighted (influenced by) the large Rest of Region component, meaning that the total would be misleading in some of the regions.

7. Statistics New Zealand's Census 2013 population data and its population projections were used to determine the distribution of population in the airsheds. Some airsheds cut across CAUs, and therefore, we used meshblock level population data and then aggregated that to airshed level to address these 'cross boundary areas'. The population base and projections were kept consistent with the earlier studies, because at the time of updating this report, not all the required population data for Census 2018 had been released by SNZ. Also, SNZ changed the spatial resolution at which data is published, in 2018. Adjustments in the model would have been time consuming and costly while not changing the outcome in a material way, since we only report on the 'change'.

8. There are a number of uncertainties in estimating the burner count by airshed. The approach followed and its limitations are highlighted in the next section.

9. In terms of defining the solid fuel burners, we used the emission rates to group burners into discrete groups. The need for this evolved out of the 2016/17 assessment's latter stages. We used the following categories (the description in brackets refer to the original naming convention):

   - 0.5 g/kg (ULEB)
   - 1.0 g/kg (Pellet burner)
   - 1.5 g/kg (Compliant burner)
   - >1.5 g/kg (Includes Non-compliant burners, coal burners and open fires)

Section 2.8 contains the methodology of how the number of domestic heating sources were apportioned (as prepared by GA).

1.2.2 Policy Levers

The key assumptions with respect to policy settings for the CBA are as follows:

1. The following assumptions have been made, in consultation with MfE, with respect to retirement rates of solid fuel burners:
   - 0.5g/kg solid fuel burners:
     The lifespan of 0.5g/kg burners are assumed to be 20 years, and the first of these burners were installed around 2013, implying that they would be retired around 2033. Since this assessment effectively 'ends' in 2028, the retirement rate for 0.5g/kg burners has been set to 0.
   - 1.0g/kg solid fuel burners:
     Retirement rate of 6.5% per year.
   - 1.5g/kg solid fuel burners:
     Retirement rate of 6.5% per year.
   - >1.5g/kg solid fuel burners:
     Retirement rate of 1% per year for open fires and coal burning appliances.
     Retirement rate of 6.5% per year for wood burner with emissions greater than 1.5g/kg.
2. Re-installation rate of solid fuel burners: Where installation of a particular burner is restricted, we have assumed that the majority of households would install the 'next best' in terms of emissions (subject to the cost being the same or lower). However, it is expected a small portion of households would opt for a cleaner burning appliance, as a matter of environmental consideration. Subject to emission limits, the model adopts the distribution of heating sources as set out below, to guide the mix of choices likely to be made when installing a burner. On average these rates are:
   - Solid fuel burners: 83%
     - 1.0g/kg – 78%
     - 0.5g/kg – 5%
   - Heat pumps: 17%

   The above proportions may vary between airsheds, and also may not reflect future choices, but in the absence of other information, we use these splits. These assumptions reflect the currently available information.

   In addition, the following are assumed for certain airsheds (this applies to the current situation)[5]:

   - In Canterbury, a 0.5g/kg burner is installed in 30% of new homes. For every four new 0.5g/kg burners, one non-complying wood burner (i.e. >1.5g/kg) is replaced.
   - Southland (Breathe Easy scheme) coal phase-out scheme is applied to coal fires in Invercargill and Gore.
3. When a household is prevented from installing the burner of their choice because of policy, the cost being imposed is the **difference** in appliance cost of the compliant burner, over what they would have spent on a heating source in the absence of policy, i.e. a non-compliant burner.

[5] The update did not consider other councils that might have unique rules governing their air quality policies.

4. Emission limits cover all solid fuel heating devices. Under the assumption that all homes will have a heating source of some sort, it implies that **new homes** will choose between a compliant solid fuel burner and a heat pump[6]. We assume that the installation of heating sources in new homes follows the same distribution as replacement of burners already mentioned.
5. The model assumes private and local government costs are the same across regions, which means installation of a woodburner will cost the same in Northland as in Canterbury, for example. We acknowledge that this is unlikely to be the case. However, since it is likely the total cost in some areas will be lower and some higher, we deem this approach to be appropriate and will return a reasonable indication of the costs.
6. Included in Local government costs are the following:
   - Update of plan, editing, typesetting and printing,
   - Education cost, and
   - Evaluation of NESAQ.
7. Implementation of the policies is not done gradually, but rather all settings take effect immediately. This implies the burners retired/removed in a particular year will be replaced in that same year. This policy assumption causes an immediate change in the number of burners (by type) when the policy restricts burner types that can be installed, in the year it is implemented.

1.2.3 Health costs

1. In the CBA, health costs are aggregated across the population (instead of using fine age cohorts), because it is not possible to know how the effects are distributed among individuals. Health incidence rates were determined from base data provided in the HAPINZ[7] study. Exposure-response ratios were provided by NIWA[8] and are consistent with COMEAP and WHO studies (Appendix 2).

2. Value of Statistical Life (VOSL) is a transport risk based value, that is used to quantify the cost of premature mortality in various OECD countries. For this model the VOSL as at June 2015 prices[9] was used to determine the societal cost of mortality attributable to air pollution.

3. Value of Life Years Lost (VLYL) is an additional, alternative measure used by COMEAP (2010) in a study on the health effects of air pollution in the United Kingdom. VLYL was used as an alternative method of quantifying the cost of premature mortality. By using 'life' tables published by Statistics New Zealand (SNZ), we could calculate the number of life years that are lost due to premature mortality, per age cohort.

4. In VLYL calculations, we have assumed that the distribution of *mortality* per age cohort within an airshed is consistent with the distribution of *population* per age cohort within each airshed. This is to say that if 5% of the population in an airshed falls in the age group 5-9 years, then 5% of air pollution related deaths that occur, are among 5-9 year

[6] Or 'other' heating device such as electric or gas heater.
[7] HAPINZ Health Effects Model (2012).
[8] HAPINZ Update in progress (at time of writing).
[9] $4.06 million as updated by MoT.

olds. We acknowledge that some age cohorts could see a larger share of the health effects but due to information limitations, we are unable to provide a more granular distribution.

5. We have used the mid-point in each age cohort to determine the expected number of years left (thus lost as a result of dying prematurely). The value of a life year was set at $189,104 - consistent with measures used by ACC as described by O'Dea & Wren (2012).

6. We have assumed that the effect of long-term exposure to $PM_{2.5}$ and PM_{10} does not vary across age groups, but rather that the response ratio is consistent across all of the population. This might not be appropriate as we can expect that babies (0-1 years) and older individuals (75+ years) might react more 'strongly' to air pollution, i.e. more incidences could result. However, as a result of a lack of epidemiological evidence about the exposure-response relationship of different age groups, we opted to apply a consistent ratio across the population.

7. Cessation lag is a term referring to the time pattern of reductions in mortality hazards (i.e. health benefits), following a reduction in pollution. We have aligned our distribution of effects over time, with the US EPA cessation lag framework as specified in the COMEAP (2010) report – 30% of the risk reduction is realised in year 1 (after pollution reduction), 12.5% each in years 2-5 and the remaining 20% spread over years 6-20. There are several lag structures set out by different agencies, but consensus seems to be that all of the benefits of improved air quality, are realised within a twenty-year timeframe.

8. Cost per air pollution related hospital admission (for Cardiovascular Hospital Admissions and Respiratory Hospital Admissions abbreviated as CHA and RHA respectively) is a combination of the medical costs and the loss of output that occurs while the person is hospitalised. For CHA five days of hospitalisation has been assumed, and for RHA three days. This is consistent with current literature. The cost for RHA and CHA is calculated as $7,432 and $5,381 per incident, respectively. These values are consistent with HAPINZ and updated to current prices where appropriate.

1.2.4 Other Considerations

1. Retirement rates are drawn from studies based on Auckland and Christchurch. In essence they are relatively high[10], as the retirement rates in Auckland are probably higher than the rest of New Zealand. By the same token, reinstallation rates of solid fuel burners[11] are drawn from the Auckland studies and applied in the Status Quo and Policy Option scenarios (when other policy levers are silent). In the absence of better information, these rates have been discussed with MfE and deemed appropriate.

2. In this study, only the health benefits (i.e. avoided costs) of improved air quality primarily as a result of altering household heating arrangements, have been considered. However, in reality, the policy changes might generate other economic benefits, such as stimulus in the manufacturing, retail and tourism sectors. As more

[10] We acknowledged the potential implication of these assumptions and have communicated it with MfE.

[11] 0.5g/kg, 1.0 g/kg and 1.5g/kg.

compliant burners are needed, the manufacturing sector will have to increase production and more is expected to be sold, which flows through the retail sector. The technology sector is likely to get a boost as well, as consumers seek more cost-effective alternatives, along with imports.

3. Another component that has not been considered is the potential impact of improved air quality on inward tourism. Given NZ's *clean green* image, it can be expected that cleaner air in towns would encourage tourists to visit, leading to increased spending. This will flow through the local economy, and a portion of that is expected to flow through to the national economy.

4. A further aspect that is not considered is the potential effect of limiting households' choice of burner, which could (in some cases) result in higher fuel costs or households not replacing their burner, leading to cold homes. Cold homes have their own set of costs. There is limited information about these costs and the link to wood burners. This is a possible area where future research could add value.

1.2.5 Information availability

This study was undertaken using available information and in some instances the availability and quality of information was limited. Further, the update was undertaken in a short timeframe, limiting the ability to identify and verify any policy changes (at a local government level). This also limited our ability to review and update the parameters used in the modelling. Using more recent or more detailed information will change the results. This is especially the case for the key variables around the health costs and response rates as well as the information about the burners, including the current stage, replacement rates, market churn, costs and cost differences across the country, fuel costs and installation costs. We did not audit or review the information sets. We did however work with MfE to communicate the assumptions (and the potential implications of using the information).

1.3 Report Structure

This report is structured as follows:

- Section 1 outlines the overall approach and methods adopted for the Cost Benefit analysis (CBA).
- Section 2 summarises the approach taken to identify the volume of particulate matter in each airshed and the manner in which it is generated, and is likely to respond to policy settings.
- In section 3, the monetary basis for potential costs and benefits is outlined. They range from avoided health costs assessed via two methods, through to private costs for households. Central and local government costs are also included. We provide an indication of the ability to pay of different communities.
- Section 4 sets out the proposed policy option and its settings.
- Section 5 presents the key findings and results.
- Section 6 concludes the report by summarising the key points, and observations.

2 Particulate Matter

This section describes the air quality information and data used in this study. It outlines the sources, calculations and the assumptions required to generate home heating appliance numbers that was then used in the cost-benefit analysis (CBA) model. This section is based on the information and text provide to M.E by Golders Associates (as part of the 2016/17 study and is included for information). The associated model components were not updated for the 2019 assessment because of the constrained timeframe. M.E did not audit or review it for accuracy or technical robustness. The CBA relies heavily on these inputs. The results apply to present-day conditions for the base year 2013. The section outlines the assumptions used for changes in burner numbers in future years, under status quo conditions, that is, without new policy interventions. This provides a framework within which to test new NESAQ rules and their impacts on appliance numbers and air quality, to determine the costs of change and the benefits of improved air quality as emissions are reduced. As part of the process, the burner numbers are 'matched' to air quality emissions inventories to provide a usable starting point.

Air quality information, available at the 2013 census area unit (CAU) level, has been aggregated to provide data relating to NZ's urban air sheds. As a substantial proportion of New Zealand's population is not located in urban airsheds, and a proportion of road travel is between airsheds, it suggests that a large portion of areas falling within a Regional Council area, falls outside a gazetted airshed.

It is anticipated that new NESAQ rules will be aimed at reaching $PM_{2.5}$ targets. However, some of the calculations use parameters related to PM_{10}, as these are better-known. Hence the analysis has been carried out on both PM_{10} and $PM_{2.5}$. Nevertheless, the results are reported based on the changes in annual $PM_{2.5}$ concentrations and the effects thereof.

2.1 CAU to Airshed Mapping

A concordance showing the alignment between CAUs, airsheds, territorial authority, and council regions was generated by M.E. Note the following:

1. M.E utilised spatial mapping data[12] from a previous air quality related project, together with SNZ statistical boundaries to generate spatial definitions of the airsheds.
2. Beachlands and Maraetai in Auckland are gazetted as separate airsheds, as they are geographically separate. However, they are part of the same CAU so they have been combined into a single airshed.
3. There are some geographically separate urban areas in Christchurch, contained in the Styx CAU (which is mostly rural). They have been treated as one airshed.

[12] Meshblock level data aggregated into Airsheds.

4. The Wairarapa Valley was treated as a single airshed in this report, despite Masterton Urban airshed being gazetted in 2014.

5. Although not gazetted, Gisborne, New Plymouth, Hawera, Stratford and Auckland's North Shore have been treated as urban airsheds, separate from the rest of their regions. In the case of North Shore, this has been done to provide more flexibility and granularity of outcome. It is not the case that North Shore shares much in common with the Isthmus with respect to air quality given the lack of heavy industry and the (on average) newer housing stock.

6. We acknowledge that Mt Maunganui airshed has recently[13] been gazetted. However, given the lack of monitoring data, it has not been included as a separate airshed in this update.

7. In terms of the spatial scale, the modelling covers 96 airsheds, made up as follows:
   - 79 urban airsheds (a combination of the 72 gazetted airsheds and the other significant urban areas),
   - 16 airsheds covering the remaining parts of each region, and
   - 'Rest of Area' airshed[14].

2.2 Ambient PM_{10} and $PM_{2.5}$

The CBA requires ambient air quality data, as follows:

1. Typical annual-average concentrations of PM_{10} and $PM_{2.5}$ (that is, the likely average over several years, rather than the average of a specific year).

2. Apportionment of the annual concentrations according to anthropogenic source (home heating, industry, vehicles, outdoor burning) and natural levels.

3. Representative concentrations at the airshed level.

NIWA supplied annual-average PM_{10} and $PM_{2.5}$ data at the CAU level, based on monitored and modelled concentrations (NIWA 2016). In addition, the expected number of exceedances of $PM_{2.5}$ per year of a range of daily criterion concentrations were provided, as a function of the annual average. The annual averages were apportioned into natural and anthropogenic components. These ambient air quality data were taken from the year 2014, which was judged to be a good representation of typical air quality. A three-year average was not used.

The anthropogenic components were further apportioned into source types (domestic heating, motor vehicles, industry and outdoor burning) using estimates published by the Health and Air Pollution in New Zealand project. An update to the original project was carried out in 2012 (Kuschel et al., 2012), whose reports were accompanied by a health effects model and an

[13] 31 October 2019

[14] This covers population that Stats NZ records as 'Area Outside Region', and includes the surrounding small islands such as Chathams, Three Kings, Kermadecs, etc. It is included for statistical purposes.

exposure model. Source apportionment results have been taken from the exposure model and used here for the anthropogenic component of total PM_{10} and $PM_{2.5}$ only.

The concentration for each airshed was taken to be that of a representing CAU, determined by NIWA. This was the CAU containing the monitoring site, where available, or an alternative which could also be considered representative. Using $PM_{2.5}$ concentrations at the monitoring site enables determination of the predicted compliance of that airshed with new regulations, which, in reality, would be based on monitored data. Whilst this approach could possibly introduce some error, the best available information was used in this analysis.

2.2.1 Additional observations

There are several additional observations relating to the PM_{10} and $PM_{2.5}$ information, including:

1. It is a challenge to derive a concentration representative of the whole airshed. Alternatives may be averages over CAUs, or population-weighted averages, for instance. These could dilute the value at the monitoring site, making all airsheds appear to be compliant. NIWA's estimates of concentration at neighbouring urban CAUs are the same as the concentration at the representative CAU in a number of cases. It is assumed in the model that the specified CAU concentration would be representative of the whole urban area, and as such would respond to changes in emissions through the airsheds as described below. This would mean the costs of changes in emissions and benefits gained from reductions in $PM_{2.5}$ are accounted for by assuming the representative CAU concentration is typical of the urban airshed as a whole.

2. The apportionment of anthropogenic sources was based on a previous version of the exposure model, produced by the HAPINZ project. The 2012 update to the HAPINZ model, was based on source-apportioned PM_{10} calculated for the year 2006. There have been more recent updates to this, but they did not include source apportionment results. Therefore,

    - It has been assumed that the proportions are still relevant, and they have been applied to the current anthropogenic component of the ambient PM_{10}.
    - It has been assumed that the same proportions apply to $PM_{2.5}$ as PM_{10}.
    - The 2012 project was based on 2006 CAUs, some of which were different from the 2013 areas. The proportions for the 2013 CAUs have been assumed to be the same as the 2006 CAU for those that still exist, and to be nationally-averaged proportions for current 2013 CAUs that were not present in 2006.

The calculations outlined in this section thus provide source-apportioned annual-average PM_{10} and $PM_{2.5}$ concentrations representative of each airshed in New Zealand. The apportioned contributions can be used to estimate the total $PM_{2.5}$, from which the number of daily exceedances per year can be estimated.

2.3 Emissions of PM_{10} and $PM_{2.5}$ – All Sources

Emissions data for 2013 were taken from an inventory of home heating and other sources compiled and reviewed by Wilton et al (2015). The report and accompanying spreadsheet provided emissions of PM_{10} and $PM_{2.5}$ from domestic heating, motor vehicles, outdoor burning and industry, in tonnes per year and kilograms per winter's day, and these have been used here.

Emissions were summed over CAUs to provide airshed totals. The domestic heating emissions were apportioned into wood and coal burning in the Wilton et al. (2015) data. Further apportionment into wood-burning appliance types is described in Section 2.8.

2.4 Emissions of PM_{10} and $PM_{2.5}$ – Vehicles

In 2014, the Ministry for the Environment (MfE) and Statistics New Zealand (SNZ) published their Air Domain Report: Data to 2012. This report identified on-road vehicle emissions as a key pressure which has an impact on the state of air quality in New Zealand. According to the latest update (2018) vehicle emissions remain a pressure point in NZ. The 2014 report presented a trend analysis of vehicle emissions of PM_{10} and $PM_{2.5}$ between 2001 and 2012. The vehicle emissions were estimated using the methods detailed in the NIWA report 'Indicators for Environmental Domain Reporting' (2014).

In summary, NIWA estimated the emissions by multiplying vehicle kilometres travelled (VKT) for different vehicle types by the estimated emission factor (EF) for that vehicle class and the corresponding average speed. National VKT data were taken from warrant of fitness data summarised by the Ministry of Transport (MoT)[15]. NIWA took regional estimates of VKT, from the Road Assessment and Maintenance Management (RAMM) data set and scaled these to match the total National VKT. Vehicle fleet composition was also taken directly from MoT data. NIWA assumed vehicle fleet composition not to vary on a regional scale. NIWA assumed a non-congested vehicle speed for urban roads (of 50 km/h) and open roads (of 100 km/h). For some urban areas a congestion index was applied to reduce travel speeds to reflect the reality of travel in New Zealand's larger cities.

NIWA used the fleet composition and speed with the Vehicle Emissions Prediction Model (VEPM[16]) to predict the vehicle emission factors that were then used with the VKT to estimate the total emissions for PM_{10} and $PM_{2.5}$.

For this study the NIWA method was replicated to provide the base year data for 2013. This provided vehicle emission data on a regional level. The regional total vehicle emissions were then allocated to Census Area Units (CAU) by the method detailed in MfE's Home Heating Emission inventory and Other Sources Evaluation (Wilton et al 2015). Finally, the CAU data was grouped to provide vehicle emission data by airshed.

[15] Transport volume: Vehicle travel. http://www.transport.govt.nz/ourwork/tmif/transport-volume/tv034/. Accessed 29 June 2016.
[16] Vehicle Emissions Prediction Model (VEPM) http://air.nzta.govt.nz/predictions/nz-vepm. Accessed 29 June 2016.

The method used to estimate vehicle emissions for this study was adopted to ensure that, as far as practical, the CBA vehicle emission data was consistent with the national emission inventories previously prepared for MfE.

For future scenarios, the base year vehicle emissions were projected in increments of five years (2013, 2018, 2023, etc.) out to 2041. This is as far as VEPM will project. VKT was assumed to increase by 0.4 % per year. The VEPM default change in fleet composition with year was accepted. The split between urban/rural and free flowing/congested speeds was assumed to remain the same as that used for the base year (2013).

2.5 Emissions of PM_{10} and $PM_{2.5}$ – Industry

2.5.1 Boilers

Emissions data for boiler sources of PM_{10} and $PM_{2.5}$ for 2013 were taken from MfE's Home Heating Emission Inventory and Other Sources Evaluation (Wilton et al., 2015). The objective of this industrial emissions assessment was to identify industries throughout New Zealand, particularly those that emit significant amounts of PM_{10}. The industrial emissions assessment took a first-order approach with a priority on collating and summarising information from existing databases. These largely focused on combustion discharges and consequently, the assessment was limited with respect to process emissions.

The main databases used by Wilton et al (2015) were the Energy Efficiency and Conservation Authority (EECA) heat plant database (2014) and the 2008 industrial SO_2 emission inventory. Information from available local emission inventories (post-2009) was also integrated into the industrial emissions assessment including Industrial emissions data for Napier, Hastings, Taupo, Hamilton, Tokoroa, Nelson, Taihape, Taumarunui, Invercargill, Gore, Reefton, Blenheim and Richmond. The heat plant database contains information on over 4,000 heat plants. From the EECA database heat plants using coal, wood, heavy fuel oil and light fuel oil energy sources were included in the industrial emissions inventory. There were approximately 450 large scale heat plants that meet these criteria. Gas and oil combustion were largely excluded as were some small-scale solid fuel boilers (e.g. school boilers), except where these were included in local inventories. Emissions were estimated based on fuel consumption and boiler types (for coal fired boilers), where known.

Fuel consumption: The EECA database contained limited information on annual fuel consumption. Estimates of fuel consumption were made based on boiler heat outputs or other data where available. Fuel use estimates were ranked A, B or C for high, medium or low levels of uncertainty.

Emission factors: The solid fuel boiler emission factors are based on Wilton et al. (2007) and Wilton & Baynes, (2010). Other sources are based on USEPA AP42 emission factors. Some site-specific emissions test data for particulates were available. These data were used in preference to generic emission factors where available.

For the base year 2013, a total of 447 boilers were included in the inventory, each of these was associated with a region and an airshed. The regional distribution of boilers included in the inventory is shown in Table 2-1.

Table 2-1: Boilers by Region

Region	No. of Boilers
Northland	12
Auckland	24
Waikato	46
Bay of Plenty	19
Gisborne	4
Hawkes Bay	25
Wanganui-Manawatu	17
Taranaki	1
Wellington	7
Tasman	25
Nelson	28
Marlborough20	20
West Coast 22	22
Canterbury 81	81
Otago	43
Southland	73
Total	447

The base year 2013 emissions were increased for future year scenarios to match population growth and economic projections derived from Market Economics set of Economic Futures Models (EFMs). In addition, the best practical option (BPO) emission reduction for point sources was estimated. This is likely to involve end of stack treatments such as inertia cyclones, well-tuned boilers and good quality fuel. These systems and practices are only moderately effective at reducing emission ~ <20% removal for PM_{10} and <10% removal for $PM_{2.5}$. For the purposes of this study the BPO emission reduction was assumed to be taken up by 5 % of the sources each year – when applied.

2.5.2 Other sources

To estimate the contribution of non-boiler sources of particulate emissions, the economy was split into 48 sectors each of which was assigned as a zero, point or diffuse emission source type. BPO for point and diffuse sources was assumed to be <20% removal for PM_{10} and <10% removal for $PM_{2.5}$. As with the above, the BPO emission reduction was assumed to taken up by 5% of the sources each year.

Future estimates are predicated on economic growth in each sector – as above, the EFM is used to estimate future output from all sectors. The existing relationship between emission and economic output is assumed to hold for the next 12 years (with the exception of the BPO changes). In that way the uneven nature of growth and the regional concentration of different types of industry is reflected in projections of industrial emissions.

These BPO assumptions are intended to provide a high-level starting point estimate. But it must be acknowledged that for specific industrial activities the BAT and BPO reduction efficiencies can, and probably need to, be refined (as part of further research).

2.6 Emissions of PM_{10} and $PM_{2.5}$ – Outdoor burning

Outdoor burning rules in regional air plans were reviewed to ensure that, as far as possible, current and future predictions of this emission source in the model, are consistent with plan rules. This eliminates the risk of allocating emissions from this source to airsheds where it is currently banned. In 2016/17, nine of the 16 regional plans were reviewed in detail, with a focus on the regions that have the most significant air quality issues (see Table 2-2). This table was not updated in 2019.

Table 2-2: Outdoor burning regional planning documents (2016/17)

Region	Outdoor burning air plan rule number	Activity status in within airsheds	Activity status outside airsheds	Year of plan	Comments
Northland	10.3	Not permitted	Permitted	2003	
Auckland	4.5.11	Permitted	Permitted	2013	New plan currently proposed
Waikato	6.1.13.1	Permitted	Permitted	2011	
Bay of Plenty	5	Permitted	Permitted	2003	
Gisborne					
Hawkes Bay					
Wanganui-Manawatu					
Taranaki					
Wellington	19	Permitted	Permitted	2000	New plan currently proposed
Tasman					
Nelson	AQr.54	Permitted	Permitted	2008	New plan currently proposed
Marlborough					
West Coast					
Canterbury	AQL 28-35	Restricted in winter months within clean air zones.	Permitted	2011	New plan currently proposed
Otago	16.3.2	Permitted	Permitted	2009	
Southland	5	Permitted September to April Not permitted May to August.	Permitted		New plan currently proposed

The review showed that outdoor burning within airsheds is a permitted activity in all (of the reviewed) but one of the regions (Northland). The permitted activity status of the outdoor burning rule is subject to a number of generic conditions,

- no noxious effects, and
- restricting the materials burned to paper, untreated wood and some plastics.

In two regions (Canterbury and Southland) outdoor burning within airsheds is not permitted during winter months. It has been assumed that, given the regions reviewed all had outdoor burning as a permitted activity status, that it would be permitted in the regions not reviewed.

Outdoor burning emissions have been allocated in the model, consistent with the rules within the plans reviewed. An exception is airsheds within the Northland region. In theory, the Northland air plan has banned outdoor burning in urban areas, so ideally, we would remove all outdoor burning emissions from the airsheds within Northland and reallocate these emissions to the areas outside the airshed. However, the volume of work required to do that for the gains in accuracy suggest that the effort would not be justified (for the current project[17]).

2.7 Emissions of PM_{10} and $PM_{2.5}$ – Meteorological Factors

The results of the steps outlined in Sections 2.2 and 2.3 provide source-apportioned PM_{10} and $PM_{2.5}$, for both the annual-averaged ambient concentration, and total emissions. The ratio of ambient concentration to emission for each source type can then be used as a scaling factor to determine what the annual-average concentration of that component would change to if the emissions changed. The ratio has been labelled a 'meteorological factor', as the resulting ambient concentrations depend on the dispersion of emitted PM_{10} and $PM_{2.5}$ by meteorological effects. Note the following:

- The use of the meteorological factor is assumed valid when relating annual-average PM_{10} and $PM_{2.5}$ to annual-total emissions. It is more likely to hold true for long-term averages, but care should be taken when applying this to daily peaks or counts of exceedances.
- The meteorological factor arises from a simple relationship, but varies by source (for instance, discharges from tall industrial stacks may be better dispersed than discharges from residential chimneys, or motor vehicles at ground level).
- The meteorological factor varies between airsheds, due to the differing meteorological conditions they experience.
- As emissions and concentration information have been derived independently, separate meteorological factors have been used for PM_{10} and $PM_{2.5}$.
- Two meteorological factors arise for each source-PM combination, as emissions are provided as annual or winter's day totals. Either may be used for the calculation of new concentrations from changed emissions. The domestic heating component appropriately uses the winter's day total; other sources use the annual total.

2.8 Emissions of PM_{10} and $PM_{2.5}$ – Home Heating Appliance Numbers

2.8.1 Method

The proposed NESAQ rules will have their greatest influence on home heating methods used by households, leading to changes in the numbers of specific heater types. This means that numbers of individual heater types are needed for the base year 2013, and assumptions made

[17] This is a limitation in this study.

regarding how those numbers will change, under the current NESAQ, i.e. status quo, and under the proposed national policy intervention.

In the initial stages of model development, GA did not have data on numbers of burners of each type, so these have been inferred from the total home heating emissions, as follows. The winter's-day airshed-total emissions of PM_{10} and $PM_{2.5}$ from home heating were split into wood and coal use, according to Wilton et al. (2015). For wood burning, the home heating emissions were assigned proportions according to each appliance type as derived by Wilton et al. (2015), to provide per-airshed daily PM_{10} emission totals for each appliance (type). This information was supplemented by data on appliance numbers from the following emissions inventories, all prepared by Environet Ltd:

- Napier, Hastings and Havelock North 2015
- Blenheim 2005
- Hamilton and Tokoroa 2012
- Nelson and Richmond 2013
- Reefton 2013
- Taihape and Taumarunui 2010
- Taupo 2014.

PM_{10} emission factors and fuel use are combined for each appliance type to give the per-appliance daily PM_{10} emission totals, shown in Table 2-3. The number of appliances of each type in each airshed is thus the per-airshed emission divided by the per-appliance emission.

Table 2-3: Information used for appliance type apportionment

Appliance type	PM_{10} emission factor (g per kg of wood)	Fuel use (kg of wood per appliance per day)	Daily PM_{10} emission per appliance (g/day)
Open fires	7.5	20	150
Non-complying burners	10	20	200
Complying burners	4.5	20	90
Pellet burners	1.4	15	21
ULEBs	0.7	20	14

For coal burning, the number of coal-burning households from the 2013 census was taken from Wilton et al. (2015). This used a range of emission factors between 19 g/kg and 21 g/kg for open coal fires, but these parameters were not needed in the present analysis. Total airshed emission rate and the number of households sufficed to determine how emissions would change if coal fires were removed. Emissions of $PM_{2.5}$ were apportioned between sources in total, then if coal burning was restricted, the correct amount of $PM_{2.5}$ was removed from each airshed.

There are significant differences between estimates of the number of coal burning households drawn from the Census, and estimates derived by applying the burn rates to the quantum of coal produced in New Zealand. We were unable to reconcile these differences. Discrepancies between actual numbers of households with coal burners and households recorded as burning coal, may mean that the cost estimates of imposing an emission limit on burners, might be slightly misstated for the coal component of this report (we anticipate the margin of error to be relatively small). This is a caveat on the outcomes that cannot be eliminated without further research into coal burning households' actual practices.

Note the following:

1. For coal burning, no distinction has been made between open fires and enclosed burners.
2. PM_{10} emission factors for open fires, and other burners are as used by Wilton et al. (2015). The emission factor for ULEBs is taken from recent testing results (and used in resource consent applications in Christchurch). The factor for the wetback ULEB has been used here.
3. According to Wilton et al. (2015), the fuel use for wood burners and open fires takes a range of values between airsheds – 20 kg has been taken as a representative value.
4. There is much uncertainty in the numbers of appliance-types in each airshed. This information comes from telephone surveys of relatively small samples of households in some airsheds. The samples are sometimes large enough to determine the number of solid-fuel appliances in use, to within a reasonable margin of error, but not large enough to determine the number of appliances of each type.
5. Changes in $PM_{2.5}$ are based on changes in PM_{10}, using the ratio of total home heating emissions of $PM_{2.5}$ over PM_{10}, and the $PM_{2.5}$ meteorological factor. This assumes that the emission ratio of $PM_{2.5}$ to PM_{10} reported for the home heating total is the same for each appliance type.
6. It is assumed that the breakdown of ambient $PM_{2.5}$ among anthropogenic sources is consistent with the breakdown of emitted $PM_{2.5}$ among anthropogenic sources. This essentially means that if the proportion contributed (emitted) by one type shifts (up or down), then the share of ambient $PM_{2.5}$ (from that source) will also shift in the same proportion. There is likely to be some uncertainty around this assumption, as the breakdown of ambient $PM_{2.5}$ among the main source types is taken from HAPINZ data aligning with the 2006 census, while the breakdown of emissions in Wilton et al. (2015) takes 2013 as the base year. Also, some information on the breakdown into separate wood burning appliances is derived from inventories carried out over a range of years. Notwithstanding this, the information used in the model is the best available at present.

2.9 Summary for Base Year 2013 and implications of emission changes

The calculations in Sections 2.2 through to 2.7 have apportioned ambient PM_{10} and $PM_{2.5}$ and discharged PM_{10} and $PM_{2.5}$ into contributions from the main source types – domestic heating, motor vehicles, industry and outdoor burning. Linking these by the meteorological factors allows changes in PM_{10} and $PM_{2.5}$ to be calculated if the emissions of any of the source types changes. Section 2.8 further apportions the home heating emissions into appliance types and number of each type, so that if the number of appliances changes, the expected change in annual-average PM_{10} can be calculated, using the daily emissions per appliance and the home-heating meteorological factor for each airshed. Changes in $PM_{2.5}$ are calculated proportionally.

Under changed-emission scenarios, the components from each source and appliance type can be re-combined to produce predicted total annual-average PM_{10} and $PM_{2.5}$ in each airshed. From these totals, the number of exceedances of a daily threshold concentration can be calculated using the empirical formulas derived by NIWA (2016).

2.10 Projection of Source Activity, Emissions and Ambient $PM_{2.5}$

The air quality component of the CBA model provides a link between source activity (such as home heating methods, motor vehicle travel, industrial emissions and outdoor burning), such that changes in source activity can propagate through into the emissions, to changes in ambient $PM_{2.5}$ due to a particular source, and finally to changes in the total ambient $PM_{2.5}$. From this total, changes in public-health impacts and associated costs can be determined, ultimately as a function of changes in activities at a local, airshed level.

The projections of $PM_{2.5}$ and PM_{10} concentrations are also estimated under the chosen policy settings, as discussed later in this report. Further, there are changes that would happen, and are already happening, without the provision of new policies.

These include the retirement of old wood burners and their replacement by NESAQ -compliant heaters or other heating methods, implementation of bans on coal fires in some locations, and a gradual increase in the use of ultra-low emission burners (ULEBs). These effects have been implemented in the model as a status quo situation, upon which chosen policy options can be superposed.

It is important to note that the assumption is, changes in emissions occur evenly across each airshed, and that consequent changes in ambient $PM_{2.5}$ occur in proportion over the whole airshed, including at the representing CAU where the ambient $PM_{2.5}$ is defined.

3 Costs

This section outlines the costs used in the assessment. Where applicable we summarise the assumptions and approaches used to estimate the different costs.

3.1 Health Costs (social cost)

Our health impact assessment for exposure to $PM_{2.5}$ includes:

- the effect on mortality in all age groups,
- the effect on cardiac hospital admissions (CHA) and respiratory hospital admissions (RHA) respectively, in all age groups, and
- an estimate of restricted activity days (RADs) as a result of long-term exposure to $PM_{2.5}$.

In the health impact assessment for exposure to PM_{10}, data was not available on the exposure-response ratio for RADs, so the assessment only includes:

- the effect on mortality in all age groups, and
- the effect on CHAs and RHAs respectively, in all age groups.

Important: only the key findings and results of the $PM_{2.5}$-based CBA is reported.

The health costs are viewed as 'a cost to society'. This is because the costs accrue to the wider population and cannot be attributed to distinct (identifiable) parts of that population based on the population's attributes. For example, the benefit of heating a home with a burner can be linked to a particular residence but the health effects of the resulting air pollution are likely to be felt by someone in the wider community (who may or may not be contributing to air pollution).

This calculation is not an estimate of the number of people that will (actually) pass away due entirely to air pollution but it is an estimate, based on risk factors with air pollution a factor that increases deaths, i.e. a contributory factor. Like any other risk area, air pollution increases the risk of death to those exposed to the pollution. It is therefore reported that 'X' number of premature deaths attributable to $PM_{2.5}$ exposure, could be prevented by improving air quality by 'Y'.

The health costs were estimated using the HAPINZ approach. Essentially, this is done by translating the annual $PM_{2.5}$ and annual PM_{10} concentrations into health effects and then applying a health cost ($) to each 'new' incident. The relationships between PM_{10} or $PM_{2.5}$ concentrations and different health effects (i.e. the response ratios), are described in the various HAPINZ studies that have been done to date, and updated by NIWA in 2012, using the COMEAP report (2010) and the WHO HRAPIE project (2013) as reference. The cost per incident (health case) is consistent with the HAPINZ studies[18]. Where appropriate, costs have been updated to 2015-dollars from data released by the Ministry of Transport. Table 3-1 contains the values that were used to monetise the health effects.

[18] The different reports can be found on the HAPINZ website: www.hapinz.org.nz

Table 3-1: Health Effect and Cost per Case

Health Effect	Cost
Premature Mortality Effects (VOSL)	$4.06m
Premature Mortality Effects (VLYL)	$189,104 p.a.
Acute Respiratory Hospital Admissions (RHA)	$5,381
Acute Cardiovascular Hospital Admissions (CHA)	$7,432
Restricted Activity Day (RAD)	$70 per day

Source: HAPINZ 2010 and subsequent updates

Health benefits arise when as a result of the improved air quality, health incidences (and therefore health costs) decrease. This reduced cost (avoided cost) is interpreted as a benefit to society.

3.1.1 VOSL vs VLYL

The Value of Statistical Life (VOSL), also known as the Value of Preventing a Fatality (VPF), refers to the monetary value associated with each statistical death that is expected to be prevented through intervention (such as improving air quality). The official VOSL in New Zealand is a measure used by the transport sector (and many others) to reflect the total amount society is willing to pay for safety improvements that results in a reduction of the risk of premature death. It must be noted that it does not value the life of a specific person, of specific stature, age, etc., hence the term 'statistical life'. It refers to an 'incidence' of mortality.

The VOSL at June 2015 prices is $4.06 million as estimated by MoT. Originally the value was set at $2 million which was derived from a survey of adult New Zealand residents[19] undertaken in 1989/90 and successively updated in subsequent years by indexing to the average ordinary time wage rate. MoT sought to understand how respondents substitute between wealth and safety. This method of valuation is consistent with the HAPINZ study, but it is being debated whether VOSL is the most appropriate measure when estimating the cost of mortality, outside the transport sector.

Other life-year measures that have emerged from the health sector, which focuses on changes in longevity, have been gaining exposure in recent debates. These include:

- Life years lost (LYL) - a simple measure of changes in expected longevity, which can be assigned an economic value known as the value of statistical life year (VSLY) or the value of a life year lost (VLYL).
- Quality adjusted life years (QALY) and Disability adjusted life years (DALY) – changes in expected longevity is weighted by an index of quality of life and a disability weighting respectively. Disability weighting incorporates age weighting, therefore DALYs are regarded as less subjective than the quality weighting of QALYs.

[19] Value of Safety survey.

- Life quality index (LQI) – a method originating in Canada to weight life years by an assessment of quality but designed by engineers (rather than medical specialists as in QALY and DALY weightings).

As an alternative method of quantifying the social cost of mortality, the assessment included VLYL. We have assumed that the distribution of mortality per age cohort within the airshed is similar to the distribution of population per age cohort within the airshed. This is to say that if 5% of the population in an airshed falls in the age group 5-9 years, then 5% of air pollution related premature deaths that occur, are 5-9 year olds. By using the median age in each age group the model estimated the number of life years lost as a result of premature deaths attributable to air pollution. The value used in our model, i.e. $189,104[20], is consistent with the value used by O'Dea & Wren (2012), to estimate the human cost of accidents (for ACC).

3.1.2 Sensitivity analysis

Response ratios

NIWA provided a range of response ratios which was used as 'sensitivity settings' in the model measuring the sensitivity of health costs to different response ratios (incidences attributable to air pollution) – see Appendix 2 for the range of ratios. Switching to 'Low' ('High') response ratios decreased (increased) the health benefits by around a third, under the policy setting.

Burner costs

Under the current settings in the CBA, there is a cost differential of $1,500 for installing a 0.5g/kg burner, but no differential for other burners such as a 1.0g/kg burner. This implies that there is very little (additional) cost being imposed as a result of the emission limits set in the proposed policy. As part of testing the assessment's sensitivity to the cost differential, we included a $200 cost differential for installing a 1.0g/kg under the policy setting, versus installing a heating appliance in the absence of policy. This brings the CBR down to 2.8 (from 8.4). Our analysis shows that the CBR is highly sensitive to adjusting the cost differential.

Health costs – Value of Life

The VOSL method of valuing life, is used as the main measure of reporting on the benefit of preventing premature mortality in this report. However, as an additional method of monetising the value of life, M.E used the Value of Life Years Lost (VLYL) approach. The reasoning and details of both these approaches are discussed in the section above. Responding to feedback regarding the cost of mortality, M.E performed additional sensitivity analyses by decreasing the value of a statistical life year to $54,707 (as suggested by the peer reviewer[21]). Using this value reduces the CBR to 3.0 (from 14.0). While applying this cost to *discounted years*, marginally decreases the CBR, it still remains greater than one, suggesting that the benefits of implementing the proposed policy, is greater than the costs of doing so.

[20] $165,815 (2010-dollar terms) used by Wren & O'Dea inflated to 2015-dollar terms.
[21] During the original project. The review does not relate to the updated project.

Discount Rate

Using a discount rate of 8% for this CBA (as we have done in the analysis) returns a conservative approach (i.e. a higher discount rate reduces the values more than a small discount rate). Table 3-2 shows the CBRs under different discount rates – we used rates of 4% and 6%.

Table 3-2: Discount rates 4%, 6%, 8%

		VOSL Method			VLYL Method		
		4%	*6%*	*8%*	*4%*	*6%*	*8%*
NPV	*Costs: public and private costs ($'m)*	$123.4	$109.5	$97.7	$123.4	$109.5	$97.7
	Benefits: avoided health costs ($'m)	$1,062.8	$931.1	$820.2	$1,768.1	$1,550.2	$1,366.8
	CBR	**8.6**	**8.5**	**8.4**	**14.3**	**14.2**	**14.0**

3.2 Private Costs

The private costs, i.e. the cost to the homeowner, consists of one-off costs as well as ongoing costs. Private costs are listed in Table 3-3.

Table 3-3: Private Costs

One-off costs	$		Ongoing costs	
	0.5 g/kg	1.0 g/kg & 1.5 g/kg	Fuel costs*	$/hhld/annum
Removing a burner	400	400	Coal	492
Installation	900	900	Wood	970
New Appliance	3,500	2,000		
Council consent	500	500		

Source: M.E and MfE research.
*The fuel costs were used as part of assessing earlier policy options and are included for information purposes.

Commonly, ongoing burner costs relate to a household's spend on the wood burner during the life of the burner, e.g. fuel and maintenance. In the CBA model though, private costs are represented by the amount households would spend over and above what they would've spent anyway. This implies that maintenance cost would not be included, since we assume that the owner would have to pay for maintenance regardless of which appliance is operational. The cost differential between wood and coal, is considered in the analysis.

When a household is prevented/restricted from installing the burner of their choice because of policy, the cost being imposed is the difference in appliance cost of the compliant burner, over what they would've spent on their preferred (in a 'no-policy' situation) heating source.

It is important to note that the air quality modelling (of the policy option) assumes that households would be able to exercise their rights to install a new (or replacement) burner.

However, the probability of **all** (100%) households taking up this option is low. Factors limiting the potential uptake include:

- The affordability and ability to pay for a new/replacement burner,
- The desirability and attractiveness of a burner relative to other heating measures,
- The ongoing costs (perceived or real) of burners, specifically fuel costs, and
- The ability to install (or replace) a burner in the property given the property's attributes.

This report has not explored the trade-offs that households would make in order to pay for the replacement of a burner. There are questions around what a household would have to 'give up', in order to pay the cost differential between a compliant and non-compliant burner.

The relative price difference[22] between burners and heat pumps suggests that in the short to medium term, heat pumps may be favoured over burners – in total. This means that the burner numbers modelled in the scenarios might not be fully taken up. If, for some reason, the burner uptake rate is lower than that modelled, then the emissions and the health costs will be different from the ones reported here. This means that the health cost savings figures in this report are potentially on the conservative side.

3.3 Local Government ('Council') Costs

In addition to the health and household costs, Councils are also expected to incur additional costs to cover planning, regulatory and enforcement activities. These costs are 'in addition' to current spending and will be allocated to the 'new actions' associated with the regulatory, enforcement and/or community engagement activities.

Table 3-4: Regional Council Additional Costs

One-off costs	$	Annual Staff Costs[23]	$
Update Plan, editing, printing	25,000	Evaluation of NESAQ	25,000
Education Cost	50,000		
Monitoring Equipment	65,000		

3.4 Central Government Costs

Leading up to the implementation of the new policy, 'Policy development costs' to Central Government is estimated at $200,000, spread equally over 2 years. This is to cover the production of written guidance and policy workshops delivered by MfE staff. Policy implementation is estimated at an additional $100,000 for the year in which the policy is implemented.

[22] This is due to there being no council consent cost for installing a heat pump.
[23] Based on 0.2FTE per regional council for evaluation of NESAQ for each of the first 5 years.

3.5 Burden – Social Deprivation Index

When designing policy any unintended social impact must be carefully considered. To provide some context, we compared the private costs (in each airshed) with the social deprivation index (associated with the airshed). This provides a broad indication of the households' ability to pay (in the airsheds). This can be interpreted as a policy's cost burden on households (the burden of improving air quality). By using the NZ Social Deprivation score as a proxy for ability to pay (Atkinson et al., 2014) we aggregated meshblock level population to airsheds.

Appendix 4 lists the deprivation indices across the airsheds and provides some background information around how they are calculated.

As part of the assessment, we estimated the private costs per capita[24] as well as benefits per capita[25]. It is important to note that in areas where policies have a high net cost per capita, and there is also a high level of deprivation, a change in NESAQ could pose issues for policy makers, as the unintended social costs (not quantified here) could diminish the net benefits received from improved air quality. For example, if households cannot afford to change the burners but they still remove them, then those households are likely to run into 'cold home' issues.

Our analysis runs at an airshed level and reports the results at this level. It is not possible to assess the impacts at an individual household level. Aggregate assessment can only guide policy makers, but it would not show the finer, on the ground effects that some individual households might face.

[24] Total private costs to 2028 divided by 2018 population.

[25] Total benefits (avoided costs) to 2028 divided by 2018 population.

4 Policy options

In this Section, the details of the Status Quo, or *no change* option are outlined, followed by details of the proposed policy option.

4.1 Status Quo

The current NESAQ consist of regulations outlined in section 43 of the Resource Management Act 1991 (RMA), and those related to home heating include:

- standards set for ambient (outdoor) air quality – the current PM_{10} ambient air quality standard is a PM_{10} daily average of 50 ug/m^3, and
- emission limits set on wood burners installed on properties less than 2ha in area.

MfE views design standards for wood burners as fundamental to improving ambient (outdoor) air quality in urban areas of New Zealand. The NESAQ currently require that all wood burners installed on properties less than 2 hectares, have a discharge of less than 1.5 grams of PM10 for each kilogram of dry wood burnt, and a thermal efficiency of at least 65 per cent.

However, regional and local councils can enforce more stringent rules in an effort to improve air quality, such is the case in Christchurch and Nelson for example.

4.2 Preferred Policy

This policy requires councils to regulate the heating appliances households can install when their current burner comes to the end of its life. Existing regional rules are allowed to remain in force (if they support or strengthen the new rules). The main components of the proposed policy relevant to this assessment, are as follows:

1. Ambient air quality standards for both short-term and long-term $PM_{2.5}$ threshold concentrations.
   - Daily $PM_{2.5}$ limit at 25µg/m^3
   - Annual $PM_{2.5}$ limit at 10µg/m^3.
   - The daily $PM_{2.5}$ standards are to have the same provisions within the regulations as the existing PM_{10} regulations[26]
2. An airshed will be classified as 'polluted' if there has been an exceedance of either the daily or the annual $PM_{2.5}$ standard within the previous five years. Further, the airshed's current status existing under the NES PM_{10} standard will remain in place for the required 5 years, unless strong evidence can be provided by the council to have polluted status removed.

[26] Methods for monitoring and measuring, exceptional circumstances, and requirements triggered by an exceedance of either the daily or annual limit. The annual $PM_{2.5}$ standards are assumed to have similar provisions to the daily standard, with appropriate changes to reflect the different timeframe.

3. The NESAQ will require that all wood burners installed on properties smaller than 2 hectares, have a discharge of less than 1.0 grams of particles per kilogram of dry wood burnt, and a thermal efficiency of at least 65 per cent.

4. All types of new domestic solid fuel burners are included under the wood burner standards for emissions limits and thermal efficiency (i.e. coal burners, multi-fuel burners, pellet burners, open fires, cookers, water boilers, etc.).

5. Local rules already in place may continue where they are ‘stricter’ than the national rule or standard, and new rules may be established by councils.

5 Key findings/results

In this section we report on the key findings, focusing at a national level. Given that there are close to a 100 airsheds, we did not prepare a full write up of the effects at an airshed level. Summary figures showing some of the effects at an airshed level are included. We report on the total cost and total benefits. Total costs are made up of private costs and public costs, and benefits are mainly represented by avoided health costs.

5.1 Overall Result – CBR

Table 5-1 shows that implementing the preferred policy option is expected to deliver a cost-benefit ratio (CBR) of 8.4[27] using the VOSL method to value the cost of premature mortality. Using the VLYL method, the CBR increases to 14.0[28].

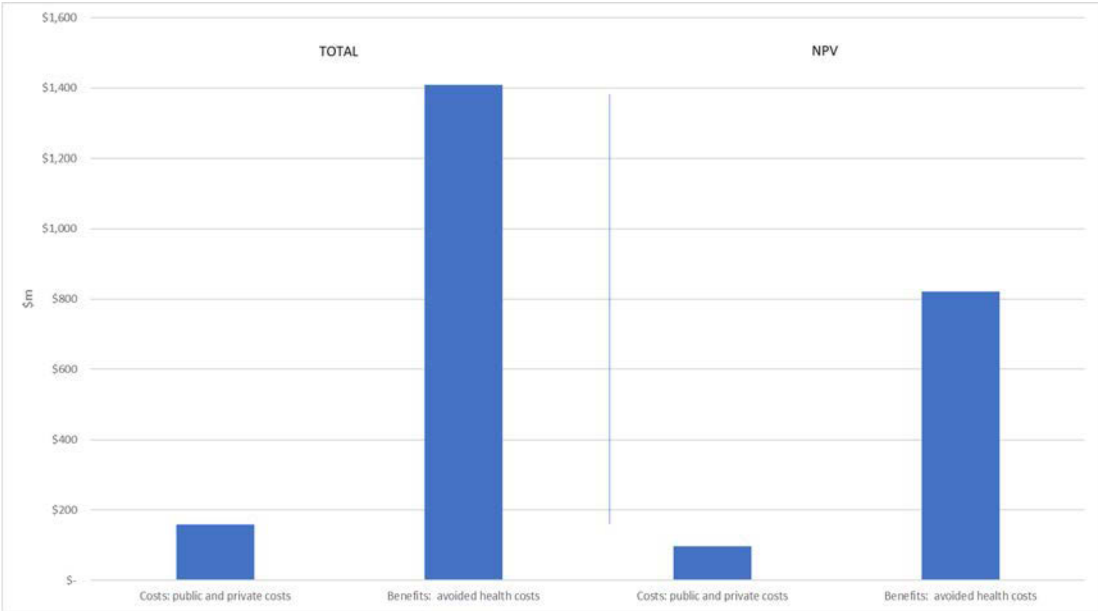
Table 5-1: Overall Results at a National level (VOSL method)

		$m	CBR
Total	Costs: public and private costs	$159.6	
	Benefits: avoided health costs	$1,409.4	
NPV	*Costs: public and private costs*	$97.7	8.4
	Benefits: avoided health costs	$820.2	

Figure 5.1 is a graphic representation of the table above, and it is clear that the avoided health costs, i.e. the benefits of improving air quality, is greater than the costs to do so under this policy option. A variation in costs might change the CBR, but we do not expect the costs of improving air quality to outweigh the benefits (health savings).

[27] $1 spent (cost) results in $8.40 of benefits/cost savings.
[28] $1 spent (cost) results in $14.00 of benefits/cost savings.

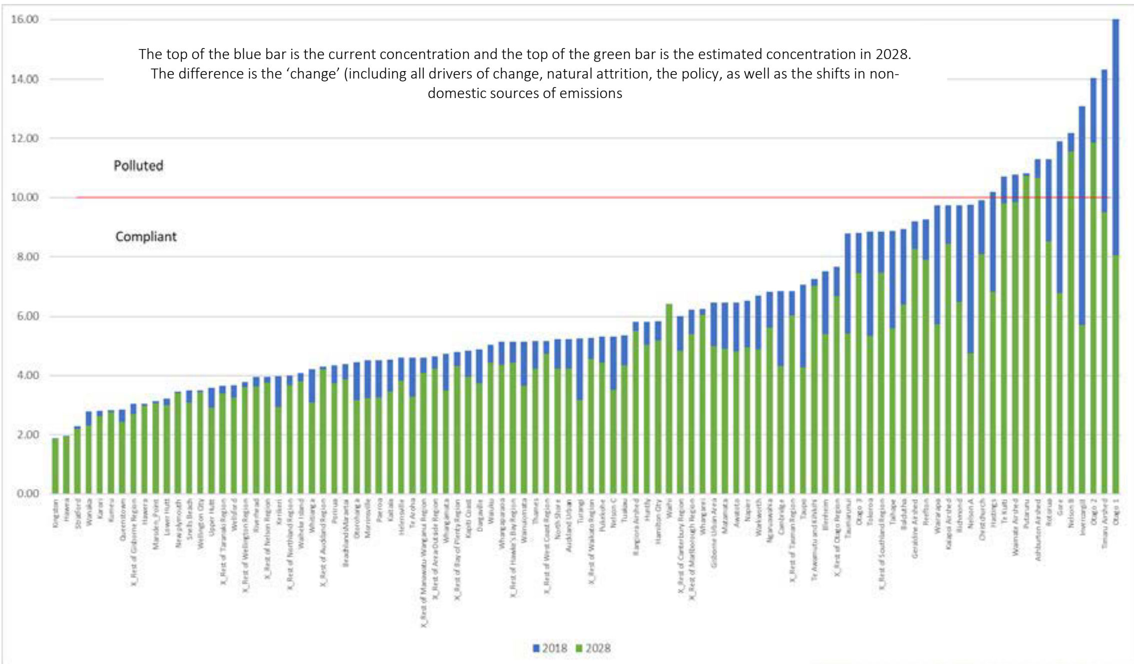
Figure 5.1: Costs vs Benefits at the National level (VOSL method)



5.2 $PM_{2.5}$ Concentration by Airshed

In Figure 5.2, each bar represents the average annual concentration of $PM_{2.5}$ in each of the 96 airsheds (Appendix 3 provides a larger version of this figure) in 2018 and 2028 (so it is possible to compare the trends over time).

Figure 5.2: Concentration of $PM_{2.5}$ by Airshed (ug/m3), 2018



It is clear that a key benefit of this policy is the nationwide improvement in air quality, to overall lower concentration of $PM_{2.5}$. The lower concentrations of PM2.5 are expected to lead to in fewer health incidences, resulting in societal benefit. Of the 12 airsheds that are classified as polluted in 2018, only four remain so by 2028[29].

5.3 Health Cost Savings

It is anticipated that implementing the proposed policy, will deliver a total, NZ-wide health cost saving of $820 million, with Auckland region responsible for the greatest savings - $158m, and the Waikato region contributing some $126m of health cost savings. All of these dollar values are reported in NPV terms. Table 5-2 shows the private costs incurred by households at the regional level. Auckland and Wellington households are shown to have the highest private costs when this policy is implemented. The modelling suggests that the biggest reduction in premature mortality will be in Auckland – 91 premature deaths attributable to $PM_{2.5}$ exposure, avoided. Nationally, a total of 468 premature deaths attributable to $PM_{2.5}$ exposure, are expected to be prevented over the period between 2018 and 2028. **Note**, *in Canterbury the current rules governing home heating, are stricter than those proposed by the policy, so no additional benefit or cost would result from implementation of the new policy.*

Table 5-2: Regional Net Health Cost Savings 2017 - 2028 ($m)

Regional Council	Cost Avoided*		Private Cost (Household)	Reduction in Mortality (lives)	Cost Benefit Ratio
	NPV	Undiscounted			
Northland	-$3.6	-$6.2	$5.7	2	1.1
Auckland	-$158.3	-$273.2	$36.0	91	7.3
Waikato	-$125.5	-$215.5	$16.9	72	12.3
Bay of Plenty	-$51.2	-$87.7	$3.9	29	21.5
Gisborne	-$19.7	-$33.8	$3.1	11	10.7
Hawke's Bay	-$74.9	-$128.5	$6.8	43	18.4
Taranaki	-$0.6	-$1.1	$4.6	0	0.2
Manawatu-Wanganui	-$2.9	-$5.0	$2.0	2	2.5
Wellington	-$110.6	-$189.6	$27.1	63	6.8
West Coast	-$0.3	-$0.6	$0.2	0	2.7
Canterbury	$0.0	$0.0	$-	0	-
Otago	-$110.0	-$188.7	$22.2	62	8.2
Southland	-$39.9	-$68.6	$10.3	23	6.5
Tasman	-$35.3	-$60.6	$1.2	20	50.4
Nelson	-$59.3	-$101.9	$3.5	33	28.0
Marlborough	-$28.2	-$48.4	$2.5	16	18.7
Area Outside	$-	$-	$-	0.0	-
TOTAL NZ	**-$820**	**-$1,409.4**	**$145.8**	**468**	

**The cost avoided (benefits) show how much 'less' is spent due to the health effects*

29 This differs from the figure in the latest NIWA report. We understand that this is due to different base years being used (see Section 2.9 for more detail).

The greatest areas of imbalance between benefits received (reduced health costs) and private costs, occur in the following airsheds, under this policy option:

- Ngāruawāhia: over 70% of the population in the top 3 most deprived categories, a very high cost per capita measure[30] (ranked 6 out of 96), and a relatively low benefit per capita (ranked 53 out of 96) implies a large imbalance.
- Taihape: more than half of the population in the 3 highest deprivation classes and a very high total private cost indicator, means a large imbalance between their cost per capita (highest of all the airsheds), and the benefits they receive (ranked 56 out of 96 airsheds).

This highlights the need for policy makers to look beyond the CBA ratios to also consider aspects such as households' ability to pay for the change.

[30] Total private costs to 2028 divided by 2018 population

6 Summary

While it is not known what the 'final' policy settings will be, this report presents the proposed policy option, relative to the status quo. The cost-benefit analysis (CBA) examines the costs (and benefits, i.e. reduced costs) of the policy **relative** to the costs (and benefits) under status quo. A reduction in cost under the implementation of policy, is interpreted as a benefit, e.g. avoidance of health costs. Some of the key findings are summarised as follow:

- Implementing this policy is expected to deliver a cost-benefit ratio (CBR) of 8.4[31] using the VOSL method to value the cost of premature mortality.
- A nationwide improvement in air quality, to lower concentrations of $PM_{2.5}$ is observed. Of the 12 airsheds[32] that are classified as 'polluted' in 2018, only four would remain so by 2028.
- It is anticipated that implementing the proposed policy, will deliver a total, NZ-wide health cost saving of $820m[33], with the Auckland region responsible for the greatest savings - $158m, and the Waikato region contributing some $125m of health cost savings.
- Of particular interest to policy makers, is the relationship between the populations being affected and the costs likely to be imposed upon them. A group's ability to pay or to meet the costs of burner upgrades is a strong indicator of a policy's potential success. While this study does not address directly the issue of ability to pay, it utilises Statistics New Zealand's Social Deprivation Index to profile the airsheds such that costs can be viewed in the context of the overall airshed's economic indicators. It is possible that airsheds classified as 'Polluted' has a large proportion of old burners, and low ability to pay for upgrades.
- While the assumption is that most households would replace their current burner with a (compliant) solid fuel burner when required to replace their heating appliance, a change in this preference will influence the results of the assessment. The relative price difference between burners and heat pumps suggests that in the short to medium term, heat pumps may be favoured over burners. This means that the burner numbers modelled in the scenarios might not be fully taken up. If, for some reason, the burner uptake rate is slower than the rate modelled in the scenarios, then the emissions and the health costs will be different from the ones reported here.

As with all modelling and assessments of this nature, the conclusions are subject to the inputs i.e. the policy settings and the assumptions. In addition to this, the timeframe over which any policy comes fully into effect, is critical in determining that policy's net position. This update was undertaken using available information and in some instances the availability and quality

[31] $1 spent (cost) results in $8.40 of benefits/cost savings.
[32] This differs from the figure in the latest NIWA report. We understand that this is due to different base years being used (see Section 2.9 for more detail).
[33] All results are presented In NPV terms, discount rate 8%.

of information, was limited. Using more recent or more detailed information will change the results.

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Appendix 1 – Airsheds

RC2013	Airshed # (GOLDER)	Airshed # (M.E)	Airshed Name
1	21	1	Kaitaia
1	24	2	Kerikeri
1	78	3	Whangarei
1	28	4	Marsden_Point
1	9	5	Dargaville
2	52	6	Snells Beach
2	73	7	Warkworth
2	75	8	Wellsford
2	37	9	North Shore
2	77	10	Whangaparoa
2	17	11	Helensville
2	50	12	Riverhead
2	26	13	Kumeu
2	2	14	Auckland Urban
2	66	15	Waiheke Island
2	5	16	BeachlandsMaraetai
2	44	17	Pukekohe
2	71	18	Waiuku
3	63	19	Tuakau
3	18	20	Huntly
3	36	21	Ngaruawahia
3	13	22	Hamilton City
3	7	23	Cambridge
3	58	24	Te Awamutu and Kihikihi
3	41	25	Otorohanga
3	59	26	Te Kuiti
8	55	27	Taumarunui
3	79	28	Whitianga
3	60	29	Thames
3	76	30	Whangamata
3	42	31	Paeroa
3	67	32	Waihi
3	30	33	Morrinsville
3	57	34	Te Aroha
3	29	35	Matamata
3	45	36	Putaruru
3	62	37	Tokoroa
4	51	38	Rotorua
3	56	39	Taupo
3	64	40	Turangi
6	3	41	Awatoto
6	31	42	Napier
6	14	43	Hastings
8	54	44	Taihape
9	22	45	Kapiti Coast
9	65	46	Upper Hutt
9	27	47	Lower Hutt
9	43	48	Porirua
9	69	49	Wainuiomata
9	74	50	Wellington City
9	23	51	Karori
9	70	52	Wairarapa
18	6	53	Blenheim
17	34	54	Nelson C
17	32	55	Nelson A
17	33	56	Nelson B
16	49	57	Richmond
12	48	58	Reefton
13	47	59	Rangiora Airshed
13	20	60	Kaiapoi Airshed
13	8	61	Christchurch
13	1	62	Ashburton Airshed
13	10	63	Geraldine Airshed
13	61	64	Timaru Airshed
13	68	65	Waimate Airshed
14	40	66	Otago 3
14	39	67	Otago 2

14	4	68	Balclutha
14	38	69	Otago 1
14	15	70	Hawea
14	46	71	Queenstown
14	72	72	Wanaka
15	12	73	Gore
15	19	74	Invercargill
14	25	75	Kingston
5	11	76	Gisborne Urban Area
7	35	77	New plymouth
7	53	78	Stratford
7	16	79	Hawera
99	80	80	X_Rest of Area Outside Region
2	81	81	X_Rest of Auckland Region
4	82	82	X_Rest of Bay of Plenty Region
13	83	83	X_Rest of Canterbury Region
5	84	84	X_Rest of Gisborne Region
6	85	85	X_Rest of Hawke's Bay Region
8	86	86	X_Rest of Manawatu-Wanganui Region
18	87	87	X_Rest of Marlborough Region
17	88	88	X_Rest of Nelson Region
1	89	89	X_Rest of Northland Region
14	90	90	X_Rest of Otago Region
15	91	91	X_Rest of Southland Region
7	92	92	X_Rest of Taranaki Region
16	93	93	X_Rest of Tasman Region
3	94	94	X_Rest of Waikato Region
9	95	95	X_Rest of Wellington Region
12	96	96	X_Rest of West Coast Region

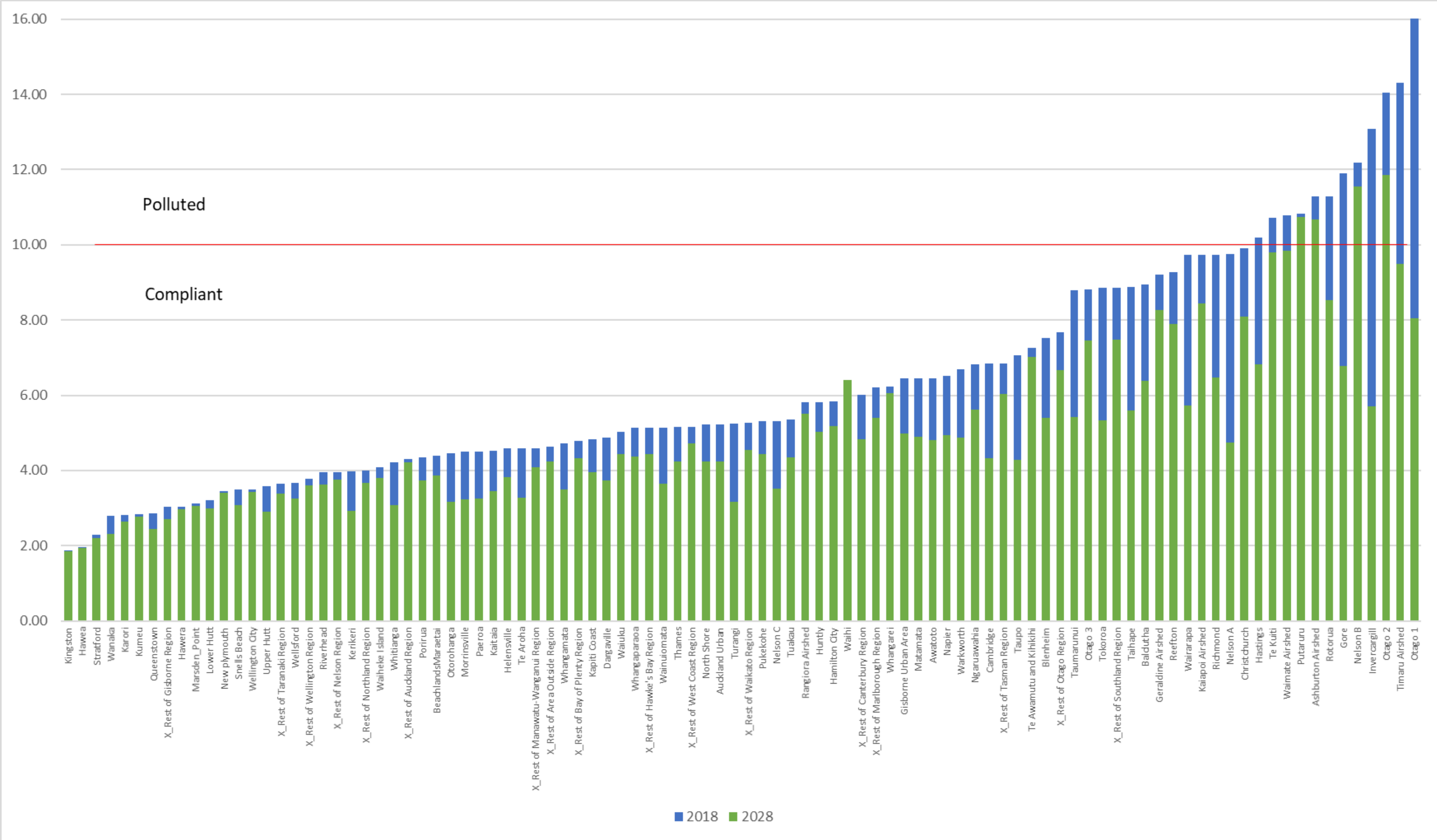
RC2013	Regional Council
1	Northland Region
2	Auckland Region
3	Waikato Region
4	Bay of Plenty Region
5	Gisborne Region
6	Hawke's Bay Region
7	Taranaki Region
8	Manawatu-Wanganui Region
9	Wellington Region
12	West Coast Region
13	Canterbury Region
14	Otago Region
15	Southland Region
16	Tasman Region
17	Nelson Region
18	Marlborough Region
99	Area Outside Region

Appendix 2: Exposure-response ratios

Morbidity & Mortality, exposure-response relationship, per 10 µg/m³ PM_{10}		$PM_{2.5}$		
1	Mortality	0.04	0.062	0.083
4	Cardiac Hospitalisation	0.0017	0.0091	0.0166
5	Respiratory Hospitalisation	-0.0018	0.019	0.0402
7	Restricted Activity Days	0.5	0.9	1.7

Morbidity & Mortality, exposure-response relationship, per 10 µg/m³ PM_{10}		PM_{10}		
1	Mortality	0.03	0.043	0.1
4	Cardiac Hospitalisation	0.003	0.006	0.009
5	Respiratory Hospitalisation	0.006	0.01	0.017
7	Restricted Activity Days			

Appendix 3: $PM_{2.5}$ Annual Average Concentration (ug/m3) under the proposed policy



Appendix 4 - NZ Social Deprivation Score

Details on the methodology and variables used to construct the NZDep2013 score can be found in the original report (Atkinson et al, 2014). Scores are available by meshblock[34] for the whole of NZ, which are then aggregated to provide a score for each airshed. The table below shows the distribution of population in each airshed across the scale is shown. By using colours to represent bands, we present a first glance picture of socioeconomic position in each airshed. Percentages are colour coded in a graded colour scale from dark green, through light green and yellow to red. The lower the share of population with a particular NZDep score (1-10), the greener the cell will appear, and the higher the portion of the population in a particular category, the closer to red the cell will appear. If a particular airshed has mainly red or orange cells on the high end of the spectrum (i.e. high deprivation scores), it is likely that, that airshed will find it harder to bear the burden of improving air quality. Conversely, if an airshed has a large portion of its population on the lower end of the spectrum (i.e. a number of orange cells on the left hand side of the table), it is to be expected that they will not find the burden as great.

It is also likely that the airsheds wherein a large portion of the population falls between 8 and 10 on the scale, such as Kaitaia and Huntly, will have a larger proportion of older or non-compliant burners.

The table is ordered based on deprivation, meaning the gazetted airsheds with the highest deprivation are listed at the top of the table. Gazetted airsheds are sorted separately from 'Rest of Region' airsheds.

[34] Meshblocks are the smallest administrative areas (geographical units) used by Statistics NZ, with a median population of approximately 81 persons (Census 2013).

	Least Deprived									Most Deprived
Airshed name	1	2	3	4	5	6	7	8	9	10
Kaitaia	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.3%	18.9%	6.7%	71.1%
Huntly	0.0%	0.0%	2.6%	0.0%	0.0%	2.4%	2.4%	16.4%	22.2%	53.9%
Waihi	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	10.6%	13.6%	36.2%	38.7%
Wellsford	0.0%	0.0%	0.0%	0.0%	0.0%	11.6%	0.0%	21.0%	45.1%	22.3%
Turangi	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	7.0%	10.9%	24.3%	52.7%
Putaruru	0.0%	0.0%	0.0%	0.0%	0.0%	8.8%	3.9%	29.5%	25.4%	32.5%
Paeroa	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	6.2%	7.7%	33.9%	44.3%
Tokoroa	0.0%	2.9%	0.0%	3.2%	3.2%	2.9%	2.6%	11.2%	31.5%	42.6%
Te Kuiti	0.0%	0.0%	0.0%	3.0%	0.0%	4.8%	7.4%	12.5%	47.2%	25.2%
Taumarunui	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	11.1%	11.8%	13.4%	57.1%
Otorohanga	0.0%	0.0%	0.0%	0.0%	3.5%	4.9%	13.7%	21.5%	37.2%	19.2%
Dargaville	0.0%	0.0%	0.0%	4.4%	6.0%	0.0%	13.6%	14.6%	34.1%	27.4%
Ngaruawahia	0.0%	0.0%	3.4%	0.0%	0.0%	5.7%	17.1%	7.9%	15.0%	51.0%
Whangamata	0.0%	0.0%	0.0%	0.0%	5.7%	14.1%	9.5%	51.7%	19.1%	0.0%
Whitianga	0.0%	0.0%	0.0%	3.1%	6.3%	15.3%	9.0%	39.8%	22.9%	3.6%
Whangarei	0.6%	3.3%	2.2%	5.1%	8.2%	7.8%	9.0%	18.6%	23.3%	21.9%
Gisborne Urban Area	5.0%	5.6%	2.0%	5.5%	4.0%	5.6%	9.1%	15.1%	18.2%	29.9%
Waimate Airshed	0.0%	0.0%	0.0%	3.5%	7.3%	6.2%	19.8%	28.4%	26.4%	8.3%
Hastings	2.4%	0.0%	0.8%	3.3%	4.9%	13.3%	14.0%	19.6%	23.3%	18.6%
Tuakau	0.0%	4.0%	2.8%	0.0%	12.2%	15.2%	6.3%	11.0%	31.2%	17.4%
Rotorua	4.6%	6.0%	5.2%	7.3%	8.2%	2.6%	8.2%	11.3%	19.2%	27.2%
Te Aroha	0.0%	0.0%	0.0%	7.6%	6.4%	11.6%	17.1%	35.4%	10.6%	11.3%
Napier	1.4%	2.7%	2.6%	5.5%	6.7%	11.2%	13.3%	20.1%	15.3%	21.1%
Nelson A	2.5%	0.0%	6.5%	5.0%	7.1%	8.5%	16.0%	15.8%	26.1%	12.5%
Thames	0.0%	0.7%	1.7%	3.1%	12.1%	10.1%	18.9%	17.5%	12.9%	23.2%
Taihape	0.0%	0.0%	0.0%	0.0%	9.5%	11.3%	28.3%	37.7%	13.2%	0.0%
Wainuiomata	0.0%	0.0%	1.0%	3.3%	7.9%	17.0%	20.9%	27.3%	19.4%	3.2%
Te Awamutu and Kihikihi	1.4%	1.3%	4.6%	4.0%	8.0%	18.1%	14.3%	17.1%	21.1%	10.1%
Stratford	0.0%	0.0%	5.7%	8.3%	5.6%	5.6%	29.7%	21.2%	23.9%	0.0%
Wairarapa	4.3%	9.5%	7.5%	10.1%	7.2%	9.3%	9.9%	19.1%	16.4%	6.5%
Matamata	3.3%	0.0%	3.9%	15.7%	8.6%	16.7%	9.9%	24.0%	10.0%	7.8%
Hamilton City	7.4%	8.9%	6.6%	7.5%	8.3%	10.2%	12.2%	13.1%	13.2%	12.6%
Morrinsville	1.1%	11.7%	6.9%	6.0%	2.7%	15.6%	17.0%	23.7%	6.8%	8.3%
Porirua	23.6%	8.6%	9.0%	4.4%	5.1%	5.9%	4.8%	5.7%	10.8%	22.1%
Auckland Urban	8.2%	9.3%	8.6%	9.6%	8.0%	8.8%	8.9%	10.7%	12.1%	15.7%
Otago 3	6.1%	7.4%	8.2%	8.3%	8.1%	12.2%	11.1%	19.3%	17.6%	1.6%
Invercargill	5.8%	5.3%	6.2%	8.6%	8.7%	12.0%	17.2%	12.6%	15.1%	8.5%
Pukekohe	5.0%	11.6%	8.2%	11.3%	12.3%	3.7%	12.8%	11.3%	6.7%	17.2%
Taupo	2.3%	4.4%	8.5%	18.4%	11.9%	8.9%	10.6%	12.0%	16.3%	6.7%
Hawera	1.3%	2.2%	5.8%	8.9%	10.8%	19.0%	17.5%	15.0%	14.9%	4.7%
Waiuku	0.0%	4.5%	0.0%	4.9%	23.9%	18.4%	14.0%	17.7%	7.9%	8.7%
Lower Hutt	11.8%	9.2%	9.8%	9.9%	9.2%	9.4%	8.1%	6.6%	12.3%	13.7%
Gore	10.4%	2.1%	10.3%	7.0%	17.8%	10.2%	11.7%	24.3%	6.4%	0.0%
Blenheim	11.0%	5.7%	2.5%	9.2%	10.0%	16.5%	17.3%	17.4%	8.0%	2.5%
Otago 2	14.1%	11.4%	8.0%	9.9%	11.2%	8.7%	9.1%	11.7%	9.5%	6.4%
Timaru Airshed	4.6%	10.5%	7.5%	8.0%	8.5%	17.4%	16.4%	12.6%	12.3%	2.3%
Marsden_Point	0.0%	4.4%	13.1%	14.1%	11.4%	10.5%	21.5%	7.7%	7.6%	9.6%
Upper Hutt	10.4%	8.0%	10.6%	8.8%	11.6%	12.2%	14.8%	11.9%	8.2%	3.5%
Kerikeri	4.4%	5.2%	5.8%	8.6%	12.6%	23.8%	16.0%	2.5%	6.1%	14.9%
New plymouth	10.4%	9.3%	10.9%	12.1%	7.8%	15.0%	11.0%	12.2%	6.8%	4.5%
Kapiti Coast	5.5%	9.0%	11.8%	15.0%	12.3%	11.0%	12.1%	9.4%	12.9%	1.0%
Christchurch	13.8%	11.1%	10.7%	10.4%	10.5%	10.1%	10.4%	10.1%	8.8%	4.1%
Balclutha	0.0%	10.4%	15.6%	16.8%	5.9%	19.6%	8.8%	10.6%	3.9%	8.3%
Kaiapoi Airshed	7.7%	4.2%	11.5%	14.7%	13.3%	9.9%	16.3%	20.6%	1.8%	0.0%
Ashburton Airshed	2.8%	8.6%	6.8%	11.8%	12.8%	17.9%	17.0%	11.4%	7.1%	3.8%
Wellington City	8.0%	8.9%	10.0%	15.1%	11.5%	12.1%	13.3%	9.9%	6.8%	4.6%
Helensville	0.0%	0.0%	0.0%	0.0%	19.1%	35.0%	25.6%	15.3%	0.0%	4.9%
Warkworth	0.0%	0.0%	18.0%	11.6%	19.6%	17.9%	13.7%	15.9%	3.4%	0.0%
Waiheke Island	0.0%	0.0%	0.0%	10.2%	10.1%	39.2%	22.0%	18.6%	0.0%	0.0%
Nelson B	7.0%	11.4%	10.2%	9.6%	17.5%	12.5%	15.1%	8.4%	6.0%	2.1%
Rangiora Airshed	10.1%	12.3%	6.9%	13.3%	13.7%	18.7%	9.0%	9.4%	6.5%	0.0%
Richmond	14.5%	8.3%	11.6%	12.0%	20.7%	11.4%	7.0%	8.8%	5.4%	0.5%
Cambridge	5.3%	11.8%	13.1%	10.6%	7.6%	16.9%	22.3%	9.1%	3.4%	0.0%
Nelson C	8.4%	10.8%	12.9%	16.5%	12.8%	17.6%	10.9%	3.5%	5.6%	1.1%
Snells Beach	0.0%	2.7%	6.9%	14.0%	21.5%	22.8%	24.5%	7.7%	0.0%	0.0%
Geraldine Airshed	0.0%	8.0%	9.8%	8.5%	8.7%	22.2%	35.5%	7.2%	0.0%	0.0%
Whangaparaoa	11.0%	12.1%	16.8%	17.2%	15.3%	10.0%	11.2%	5.2%	1.0%	0.2%
Reefton	0.0%	0.0%	0.0%	0.0%	43.1%	28.6%	24.0%	4.3%	0.0%	0.0%
Karori	35.2%	23.7%	15.3%	9.3%	12.1%	0.9%	0.0%	3.5%	0.0%	0.0%
Otago 1	10.6%	9.6%	16.3%	11.6%	17.3%	19.3%	11.9%	3.4%	0.0%	0.0%
North Shore	17.4%	18.3%	18.9%	15.2%	13.7%	9.3%	4.0%	1.5%	1.1%	0.8%
Queenstown	6.8%	9.8%	27.2%	27.3%	15.9%	9.2%	1.1%	0.0%	2.7%	0.0%
Riverhead	0.0%	19.7%	24.1%	22.8%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Awatoto	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%
Hawea	9.3%	51.9%	18.6%	0.0%	0.0%	20.2%	0.0%	0.0%	0.0%	0.0%
Wanaka	12.4%	19.6%	21.1%	17.4%	23.3%	6.1%	0.0%	0.0%	0.0%	0.0%
BeachlandsMaraetai	38.0%	19.8%	19.4%	16.9%	2.7%	3.2%	0.0%	0.0%	0.0%	0.0%
Kumeu	0.0%	9.3%	17.0%	44.8%	28.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Kingston	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rest of Gisborne Region	3.0%	6.3%	2.5%	13.9%	12.0%	6.3%	4.2%	6.3%	11.9%	33.8%
Rest of Northland Region	3.1%	5.3%	6.1%	8.7%	9.2%	11.2%	12.9%	11.4%	13.2%	19.0%
Rest of Manawatu-Wanganui Reg	5.0%	6.9%	6.0%	8.2%	9.4%	12.1%	12.0%	12.7%	13.9%	13.7%
Rest of Bay of Plenty Region	4.2%	7.9%	8.9%	9.1%	9.8%	12.2%	11.4%	11.5%	13.9%	11.2%
Rest of Taranaki Region	3.5%	7.1%	11.4%	13.7%	12.5%	12.8%	8.6%	12.8%	8.7%	8.9%
Rest of Hawke's Bay Region	10.9%	11.8%	10.7%	9.8%	7.7%	12.9%	7.8%	9.1%	6.3%	12.8%
Rest of West Coast Region	4.2%	5.2%	9.4%	9.1%	14.0%	19.3%	16.1%	11.8%	9.8%	1.0%
Rest of Area Outside Region	22.0%	10.9%	1.5%	1.7%	22.2%	15.7%	10.2%	13.4%	0.9%	1.6%
Rest of Waikato Region	8.1%	13.5%	10.3%	15.2%	13.6%	14.3%	9.5%	7.6%	4.7%	3.1%
Rest of Tasman Region	5.8%	10.4%	13.3%	19.5%	15.0%	11.4%	14.1%	5.3%	3.7%	1.4%
Rest of Marlborough Region	6.3%	12.1%	20.6%	17.5%	8.3%	17.1%	8.7%	5.3%	4.1%	0.0%
Rest of Southland Region	17.2%	15.7%	19.3%	12.8%	11.6%	8.3%	6.6%	3.3%	4.0%	1.1%
Rest of Auckland Region	15.7%	22.0%	18.4%	13.9%	11.0%	7.5%	4.6%	2.7%	3.3%	0.7%
Rest of Canterbury Region	27.0%	18.9%	15.7%	14.3%	10.8%	5.6%	3.9%	3.0%	0.7%	0.0%
Rest of Wellington Region	36.1%	19.3%	17.8%	11.0%	6.6%	4.9%	1.9%	1.7%	0.0%	0.4%
Rest of Otago Region	20.5%	20.3%	18.8%	15.8%	8.9%	7.1%	6.4%	1.8%	0.4%	0.0%
Rest of Nelson Region	15.4%	45.2%	25.3%	0.0%	0.0%	0.0%	14.1%	0.0%	0.0%	0.0%
Total NZ	423,942	435,915	424,035	445,611	411,624	432,549	408,255	421,479	423,201	415,521