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Cost Effectiveness of Policy Options for Air Quality Management in Tokoroa

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Disclaimer

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Executive summary

Air quality in New Zealand by OECD standards is generally good. However, poor air quality, largely attributable to domestic heating, exists in some areas. Tokoroa has been identified as one of these areas.

National environmental standards (NES) developed by the Ministry for the Environment (MfE) in 2005 included air standards to be achieved by 2013.

The air standards target small (less than 10 microns in diameter) air particles defined as PM_{10}, which in most developed countries come from motor vehicles.

New Zealand PM_{10} standards specify a daily limit for emissions of 50μg/m^3 over 24 hours and 20/m^3 annually.

Tokoroa exceeds the daily limit on some days in winter by up to 55 per cent. This information comes from measurements made over a seven year period which also identifies the primary source of PM_{10} emissions as domestic wood burners.

Policy options addressing this problem, including regulations and incentives, were analysed for cost effectiveness (heating, health and productivity losses) on the basis of daily and winter emissions. Under regulatory policies it is generally the user who pays, in contrast to incentive policies which may be government funded. This dichotomy is addressed by measuring policy acceptance by the community.

Policy acceptance probabilities were estimated from two surveys of representative stakeholder groups.

The permutations of 36 individual factors for each policy were analysed using a decision support tool developed for this project.

None of the options investigated would achieve the emissions target reduction as stand alone policies. The greatest emission reduction was through a regulatory policy, achieving a 32 per cent reduction – well short of the 55 per cent required.

It is recommended that a policy incorporating regulation and incentives is the best option, providing the potential to include a large proportion of the community and therefore achieve higher emission reductions than any stand alone policy.

Social and economic implications of inadequately heated homes and homes heated with unflued gas appliances are discussed along with a bulk purchase scheme of suitable heating appliances. The reliability of new compliant heating is questioned and unquantifiable costs identified.

The role of the decision support tool was seen as pivotal in being able to assimilate new information pertaining to the assessment of policy cost effectiveness. The tool should be invaluable for other communities addressing similar policy issues.

1 Introduction

New Zealand's air quality is generally good by OECD standards, mostly due to the country's low population density, island nature and distance from other countries and sources of air pollution. However, poor air quality does exist in some urban areas.

Fine particulate matter occurs naturally in our environment at low levels. PM_{10} (particulate matter less than 10 microns in diameter) is also produced by transport, industry and domestic heating. In many developed countries, vehicular traffic is the major cause of PM_{10} pollution, however, in many of New Zealand's urban centres domestic heating in the form of solid fuel burners is the main contributor.

The Ministry for the Environment (MfE) has developed a series of national environmental standards (NES) for pollutants, including particulate matter. Domestic heating tends to be time-specific in terms of time of day and seasonality, prompting MfE to introduce a 24-hour PM_{10} limit in addition to an annual standard (Fisher et al. 2005). The PM_{10} standards specify a daily limit of 50µg/m^3 (24 hour average)[1], and an annual daily limit of 20µg/m^3. These standard concentrations should be achieved no later than 2013 (MfE, 2005).

1.1 Policy context

Meeting the NES for PM_{10} concentrations in Tokoroa will require an estimated 55 per cent reduction in peak winter PM_{10} emissions from anthropogenic sources (Kim, 2007). This reduction is higher than an earlier estimate of a 33 per cent reduction requirement (Wilton, 2006a), with the latter method including a calibration correction, then the reassessment of existing air quality data for Tokoroa (Kim, 2007).

The Proposed Waikato Regional Plan (appeals version), while listing PM_{10} limits in the ambient air quality guidelines as 50µg/m^3 in a 24 hour period, or 20µg/m^3 as an annual average, states that an airshed will be considered degraded if PM_{10} levels are between 66-100 per cent of this guideline. It is therefore assumed that a policy response that takes Tokoroa air quality beyond what is essential in the short-term will be of greater value than policy designed just to achieve the 2013 requirements.

Consistent with many New Zealand towns, domestic heating is the major source of PM_{10} emissions in Tokoroa, estimated to make up 89 per cent of total PM_{10} emissions (Wilton, 2006). Woodburners are popular for home heating partly because of availability of fuel at a low cost in close proximity to the town. An estimated 65 per cent of the stock of solid fuel burners are pre-2000, and inefficient by today's standards. Cleaner alternatives in terms of PM_{10} emissions include electric fixed and portable systems, gas fixed and portable systems, low-emissions woodburners and pellet burners.

This report describes the cost effectiveness of regulation and incentives as discrete policy options for reducing PM_{10} concentrations in Tokoroa by 2013. The baseline is assumed to be the situation that would exist in Tokoroa should no policy intervention be undertaken (natural attrition). It is expected that there would be some adoption of cleaner technologies over time, but this would be insufficient to achieve the air quality objectives: intervention policy will be required. This analysis compares natural attrition with two options: regulation designed to phase out non-clean technologies, and incentives aimed at encouraging the adoption of cleaner technologies.

This cost effectiveness analysis studies the costs of regulation and incentive policies (resource costs, health costs and productivity losses) taking into account their likelihood of achieving the policy objective – in this case, a 55 per cent reduction of

[1] With one allowable exceedance per year.

peak winter time PM_{10} emissions in Tokoroa (Kim, 2007). A decision support tool[2] was developed to facilitate the process of choosing policy to reduce PM_{10} concentrations. The tool incorporates survey data from a domestic heating inventory of the Tokoroa community, air quality monitoring data, and estimates of community responses to possible policies. Outputs of the tool include estimates of mortality rates, hospitalisation rates, restricted activity days,[3] and resource costs associated with changing health and productivity outcomes.

Calculations of levels and costs of health outcomes, such as increased mortality, hospital admissions, and restricted activity days (and the resulting lost productivity) are dependent upon the overall level of particulate emissions. Costs of the heating systems (capital and operating) are dependent on individual household choices. As a result, while it is possible to calculate the expected cost of the technology per household, the analysis must consider the health impact on the Tokoroa community as a whole.

Tokoroa has an average of 1.3 heating appliances per household (Wilton, 2005a). These appliances may be fixed or portable systems, using oil, gas, electricity or solid fuel (wood, coal and pellets). The current low purchase costs of portable heating make it likely that many households use 'back-up' portable electric or gas units. This analysis studies how households are likely to respond to policies that target their main heating system, if that system is one of the solid fuel burners contributing to the current poor air quality experienced in Tokoroa.

Policy options being considered to move the Tokoroa community towards cleaner domestic heating include regulation and provision of incentives. These options are explored here as discrete policies, and compared to natural attrition as the baseline option. Each policy option, including natural attrition, is assumed to have the same level of education regarding the negative health impacts related to poor air quality.

1.2 Natural attrition

Natural attrition relies on the replacement of woodburners at the end of their useful life.

Estimates of the life expectancy of woodburners are wide ranging and determined by many factors including model, usage and fuel quality. Woodburner performance may worsen as the appliance ages. The ability to 'recondition' existing appliances is recognised in household decision making.

1.3 Regulation

Regulation includes the following.

- The banning of open fires (in place in 2012).
- Adherence to the new national design standards and thermal efficiency standards for woodburners (no more than 1.5g of PM_{10} per kg of wood burnt; ratio of useable heat energy output to energy input not to be less than 65 per cent).
- All households with woodburners installed prior to 2000 would be expected to comply with central government emission standards by 2013. This would mean replacement of pre-2000 woodburners with compliant models.
- Monitoring and enforcement actions would be at a low level.

Two regulation options have been considered. The first excludes multifuel burners from regional council regulations, while the second option applies all regulations for woodburners to multifuel burners.[4]

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[2] Refer Environment Waikato document #1220187.

[3] A restricted activity day is a day where a person is affected enough by air pollution to take time off work, or not undertake activities they otherwise would have (Fisher et al., 2005).

[4] Multifuel burner exclusion is based around the fact that national woodburner design standards and thermal efficiency standards do not apply to multifuel burners. Refer to Appendix 3 for more detail on the treatment of multifuel burners in the modelling.

1.4 Incentives[5]

The incentive option includes the following.

- Households using open fires and solid fuel burners prior to 1 June 2000 would be offered a financial incentive to encourage replacement with a low emission woodburner, pellet burner or other cleaner form of heating such as a heat pump, night store heater, flued gas heater or flued oil heater.
- Owner-occupied households where the owner has a Community Services Card would be eligible for a 100 per cent subsidy for an approved heating system (a low emission woodburner, pellet burner or other approved form of electric or gas heating).
- Landlords would be eligible for a 40 per cent subsidy or a 10-year interest-free loan towards an approved heating system (a low emission woodburner, pellet burner or other approved form of electric or gas heating).
- All other households would be eligible for a $600 subsidy or a 10-year interest-free loan towards replacing their pre-2000 open fire or woodburner with an approved form of heating (a low emission woodburner, a pellet burner, or other approved form of electric or gas heating).

In terms of the broader policy context, decisions relating to the NES should be considered in the light of other environmental, social and economic objectives. For example, the New Zealand Government's climate change solutions website (www.climatechange.govt.nz) highlights woodburners as a potential solution for reducing household electricity usage, with the message: 'It can be cheaper to burn firewood in an efficient woodburner than to pay for electric or gas heating'.

A more immediate consideration would be the capacity of the electricity system to provide electricity to heat all homes that were once heated by solid fuel combustion.

2 Methods

To facilitate the multiple decisions needed to be taken to achieve the air quality objectives for the Tokoroa community, a decision support tool was developed. Using a decision tree and starting with the current heating inventory, daily fuel use and PM_{10} emission factors, community responses for each policy were gauged, outcomes identified, resource costs estimated and PM_{10} reductions calculated. This tool relies on the following inputs in the form of assumptions and data.

2.1 Quantifying PM_{10} output

Daily PM_{10} output from heating systems the current Tokoroa domestic heating inventory was calculated from fuel used (kg) and emissions factors per kg of fuel use. The decision support tool utilises heating inventory information (Wilton, 2005a)[6], combining it with independently collected information on probable community responses to the different policies, leading to a projected future heating system inventory. The projected inventory, again multiplied by fuel used (kg) and emissions factors per kg of fuel, creates a new level of PM_{10} emissions, allowing analysis of the effectiveness of differing policies in reducing PM_{10} emissions, and the comparison of outcomes and resource costs. However, it must be highlighted that the same woodburner is unlikely to yield the same level of emissions in every household. Factors that produce variability in household emissions include the type of wood used, moisture levels in wood and human input (operation). Results from testing of low emission burners have shown that these factors contribute to a high level of variability in emissions (Scott, 2005). This variability, plus the fact that we make assumptions on

[5] Based on the Christchurch Clean Heat programme options (http://www.cleanheat.org.nz/why-clean-heat.html).
[6] The decision support tool result for current emissions was consistent with Wilton's average and worse-case results (2005a).

when and how the heating systems are used, suggests that the calculated outputs should be taken as an indication, rather than an exact measure.

2.2 Projected PM_{10} levels to determine outcomes

Two measures for reductions in PM_{10} levels were required to calculate the cost effectiveness of prospective policies. The first measure was based on the total daily winter PM_{10} emissions (852,000 kg) and the calculated contribution of domestic heating to winter emissions of 89 per cent (Wilton, 2005a). From these measures a comparison was made between the 2005 emissions (based on the inventory at that time (Wilton, 2005c)) and the projected emissions following policy implementation and community response. This measure has been used to determine the likelihood of reaching the 55 per cent reduction target through a specific policy and is based on the peak winter emissions – on the coldest days when virtually all of the heating systems in Tokoroa are likely to be being used.

The second measure is based on monitored daily levels of PM_{10}, and takes into account the seasonal use of heating systems and their contribution to daily emissions levels. When calculating future annual emissions levels for different policy choices, the projected percentage reduction in domestic heating emissions is deducted at 100 per cent from the domestic heating contribution in the peak winter months (May, June, July and August), at a 50 per cent rate in the ‘shoulder’ months (April, September and October), and at a nil rate in the remaining months. The annual average measure is relevant to calculating health impacts.

The calculation of health outcomes was based on earlier investigations of the relationship between annual average PM_{10} levels and mortality (Kunzli et al., 2000), cardio and respiratory admissions (McGowan et al., 2002) and restricted activity days (American Lung Association, 1995).[7] While these initial calculations were relatively straight-forward, the division of restricted activity days into major and minor restrictions was more complex.

In terms of restricted activity days, major restrictions result in time away from work or school, while a minor restriction suggests that a person can still attend their usual activities, but performance is likely to be somewhat impaired. Fisher et al., (2005) used 10 per cent and 90 per cent respectively for major and minor levels of restriction, but there was no clear reason given for this choice. This study uses 20 per cent and 80 per cent for major and minor levels of restriction. Visits to general practitioners (GPs) have been based on restricted activity days, with the assumption that 33 per cent of major restricted activity days result in a GP visit.[8] Table 1 summarises the outcomes and costs.

2.3 Resource costs

Where practicable, outcomes involving resource costs have been monetised, including productivity losses, GP visits, hospitalisation and replacement and operating costs of heating systems. As a general rule, costs related to the policy outcomes have been able to be estimated, however the estimation of benefits has been more complex. The benefits of changes in air quality can be divided into outcomes with resource costs (direct and indirect), and those with quality of life outcomes, where benefits are complex and difficult to quantify (Table 1).

[7] Refer Appendix 1 for models of these relationships.

[8] This assumption is based on the 2005/06 study of housing, heating and health where for adults with asthma, the mean number of sick days was 5.9, and GP visits 2 (Howden-Chapman et al., 2006).

Table 1: Summary of outcomes related to unsafe PM_{10} levels

Quality of life outcomes
Decreases in life expectancy – premature death
Hospitalisations
Morbidity
Restricted activity days
Other losses – such as less pleasant environment
Economic costs
Productivity losses – days off work (or impaired performance) or usual activities
Hospitalisation – respiratory diseases
Hospitalisation – cardio-pulmonary diseases
Primary health care – GP visits, pharmaceuticals
Replacement heating system costs – capital costs, running costs

2.3.1 Economic costs

Health costs

Direct health costs include hospital admissions, GP visits, pharmaceutical costs and restricted activity days (Table 1). Hospital admission cost data based on average length of stay and daily cost for cardio-vascular and respiratory illnesses, and was sourced from the Waikato District Health Board (Table 2).[9] The cost per visit to a general practitioner was provided by Brown (personal communication). Pharmaceutical costs have not been included in the analysis because of difficulties sourcing this information.

Table 2: Health impacts and costs

Health impact	Costs	Cost base	Source
Cardio admission	8583	Per admission	Waikato DHB
Respiratory admission	3466	Per admission	Waikato DHB
GP visit	38	Per visit	
Restricted activity day – 15 yrs +	111	Per day	Dept of Labour
Restricted activity day – less than 15 yrs	48	Per day	

Restricted activity days occur for both adults and children, and include days of major restriction (inability to attend work/school) and minor restriction (inability to perform work tasks at usual standard). For adults, time absent from work was based on average hourly earnings. These earnings were discounted by 33 per cent because of disutility of work avoided and ability of the worker and of co-workers to make up for time away.[10] For under-15 year olds, the minimum youth rate has been used to calculate the cost of time absent from school.[11] It is recognised though that days absent from school are difficult to value, with real costs including foregone education and possibly parents losing work time to provide at-home care (Chapman et al., 2004).

Heating system costs

The regulation and incentive-based policies assume that households changing from non-compliant woodburners purchase a new heating system (Table 3). To equalise as much as possible the differences between health and wellbeing related to different levels of domestic warmth, all heating system outputs have been equated to a

[9] Cardio-vascular diagnosis categories: I48, I200, I208-14, I219-20, I229, I253, I255, I259, I469, I471-2, I490, I495, I498, I500-1, I509, I2511-2. Respiratory diagnosis categories: J13-4, J40, J46-7, J069, J111, J150-2, J154, J180-1, J189, J208-9, J440-1, J448-9, J459.

[10] New Zealand average hourly earnings (excluding Auckland, Wellington and Christchurch) $20.72/hour www.dol.govt.nz/publications/lmr/ 5 March 2007.

[11] Differing from Chapman et al., (2004) where the Minimum Youth Rate was used for teens, and half that rate for primary aged children, however, the results differ little for this change. The Minimum Youth Rate is $9.00/hour www.dol.govt.nz 18 July 2007.

minimum of 6 kilowatts (kW) of output.[12] For example, 2.5 portable 2.4kW electric heaters would be required to make up to 6kW. The 6kW minimum output also allows discrepancies between initial costs and operating costs to be taken into account, while annualising costs has accounted for different life expectancies and maintenance costs. The annual hours of heater operation used were 646.4 for electric and gas, and 860.6 for solid fuel burners.[13]

Table 3: Heating systems purchase and operating costs

Heating system	Purchase cost $	Life yrs[14]	Efficiency %	Annual maintenance $	Operating cents/kWh	Output (kW)
Electric portable	125	2	100	0	17.5	2.4
Heat pump	3500	20	300	10	7.5	5.0
Woodburner	3500	20	60	40	7.0	15.0
Pellet burner	4000	20	80	40	8.0	10.5
Gas portable	300	10	85	250	21.0	3.5
Flued gas	2000	20	80	20	17.0	4.0
Oil heater	125	5	100	0	17.5	2.4
Multi fuel burner	3000	20	60	40	8.0	17.0
Open fires	4500	50	15	40	25.0	2.0

Source: South Waikato District Council. Home Heating Options Pamphlet No. 6.

2.3.2 Exclusions

Health-related costs exclude costs related to no heating and to health effects from indoor toxic emissions because of lack of availability of these costs. These costs are likely to be important, particularly nitrogen dioxide (NO_2) emissions from unflued gas heating. Other health-related costs not included in this analysis are costs of pharmaceuticals, and costs of foregone education for children absent from school due to ill health.

The capacity of the electricity generation and distribution systems to cater to the additional demand on its resources has not been considered.

2.4 Probability estimates

To generate data for probability estimates, two workshops were held with Tokoroa community representatives – hereafter referred to as 'the stakeholder group'. The stakeholder group comprised 12 people representing the following organisations:

- Raukawa Trust
- South Pacific Islands Health Committee
- South Waikato District Council
- Waikato District Health Board
- Housing New Zealand
- Environment Waikato.

In the initial workshop in August 2006 the stakeholder group was structured with the objective of estimating community response to policy. The group was provided with an

[12] Based on the 6-8kW output of heating systems installed in the Housing, Heating and Health Study (Housing and Health Research Programme, 2005).
[13] Based on unpublished survey work by Wilton (2005c). Gas heater use hours were used as representative of electric and gas heating. Log burner use hours were used as representative of all solid fuel burners.
[14] Life expectancy of individual heating systems estimated by author.

information pack briefly summarising the policy options, the current home heating inventory, home heating options, efficiency and costs, and housing tenure in Tokoroa. The group was then led through the decision trees for each policy, and asked to discuss then 'vote' on a single slip of paper the response of the community using a scale of 1-5. For example, for the regulation policy, the question was posed: 'Of those households choosing to change to a new heating system, how likely are those households to purchase a new woodburner?'

A second workshop was held in May 2007 to confirm the earlier preference estimates, and consider the differences between actions of owner-occupiers and landlords in each policy scenario. This workshop was a focus-group style, with discussion the main input. Agreement between participants was not required: the variation between estimates was used to identify high and low values around a point estimate (refer Appendix 2). Some earlier estimates were altered by the group.

Averages of estimates from the stakeholder group were used as point estimates in the decision support tree, with the range used for sensitivity analysis.

2.5 Assumptions

Assumptions applying to policies

- Education is a part of each policy.
- No households change from clean systems (post-2000 woodburners, pellet burners, NES burners, electricity or gas) to solid fuel burners.
- The housing stock in Tokoroa (and associated new woodburners) is not growing sufficiently to unduly influence findings. This assumption was based on recent growth, where 96 new dwellings were built in the entire South Waikato district in the year to March 2007. This was a one per cent increase in total dwellings (9225 as at March 2007). In addition to this, the use of wood and coal for domestic heating has decreased both in number and as a percentage of total privately owned homes over the past 10 years (Table 4).

Table 4: Number and proportion of South Waikato households using wood and coal for domestic heating

Year	Wood		Coal		Total privately occupied homes
	Number	*% of total*	Number	*% of total*	
1996	5,667	*68.0*	645	*7.7*	8,328
2001	5,265	*64.8*	465	*5.7*	8,121
2006	5,016	*61.4*	369	*4.5*	8,163

Source: Statistics New Zealand, Census 1996, 2001, 2006.

While insulation of homes has not been considered as part of this cost effectiveness analysis, in the 2007/08 year it is anticipated that EECA funding will become available to commence insulation of owner-occupied homes in Tokoroa. Most of the Tokoroa housing stock is pre-1980, and much of it not fully insulated. EECA funding for insulation is available to owner-occupied homes only, and with more than 30 per cent of homes rented, and 75.3 per cent of those using solid fuel for heating, the market for funded insulation is restricted, as is its ability to make a difference for the poorer families.

Local government policy costs are not considered within this analysis.

2.6 Sensitivity analysis

Sensitivity analysis was used to vary the responses and identify where small changes in responses could lead to widely varying outcomes. The main areas of concern were:

- variability of emissions from NES-compliant woodburners
- variability of emissions from pellet burners
- estimates of housing tenure and age of heating systems
- impact of households without heating
- levels of unflued gas heating
- households moving from clean heat to solid fuel burning
- bulk purchases under incentives schemes.

2.7 Information/data sources

Base information and data for existing heating systems, emission factors, fuel/s used and community statistics was collected through previous air quality studies, the Waikato District Health Board and Statistics New Zealand (Table 5).[15]

Table 5: Sources of information for decision support tool

Type of information/data	Source
Current inventory of heating systems	Wilton (2005a) and Wilton (2005c)
Emission factors	Wilton (2005a) and Wilton (2006a)
Fuel consumed	Wilton (2005a) and Wilton (2006b), Statistics New Zealand
Health and hospitalisation data	Waikato District Health Board
Housing tenure	Statistics New Zealand
Community Services Card holders	Estimates based on Statistics New Zealand data on income levels, family size and housing tenure

3 Results

Using the decision support tool, two possible policy platforms have been analysed to determine the most cost effective option to achieve the objectives. The two policy platforms are regulation and incentives, which are compared with natural attrition. All results are given as annual resource costs or outcomes.

3.1 Natural attrition

3.1.1 Outcomes

The PM_{10} component of outdoor air quality is expected to reduce gradually as households replace aging woodburners with cleaner heating technologies. These improvements will reduce peak and annual average PM_{10} levels, and consequently projections of annual mortality, hospital admissions, GP visits, and restricted activity days (Table 6). However, the improvement due to natural attrition is expected to reduce peak emissions by 13 per cent between 2007 and 2013, far short of the 55 per cent estimated to be required to meet the NES.

Table 6: Comparison of annual outcomes of the status quo and natural attrition

Outcome	Current	Natural attrition	*% change*
Mortality (deaths)	5.6	5.0	*-9.6*
Cardio admissions	1.8	1.6	*-10.2*
Respiratory admissions	7.0	6.3	*-10.2*

[15] Refer to Appendix 2 for a complete list of variables and sources.

Restricted activity days	16,000	14,410	*-8.7*
GP visits	1053	961	*-8.7*

The inability of natural attrition to achieve the 55 per cent required is partly due to assumptions about woodburner turnover. Early assumptions were that the life span of a woodburner was 15 years (Wilton, 2004). This was later increased to 20 years (Wilton, 2006). However, anecdotal reports suggest that woodburners of 20-30 years are not uncommon, and can be 'reconditioned' for continued use. This is supported by Peterson (2007), and by focus-group participants – some of whom had woodburners still operating after approximately 30 years of use. Wilton (2006) reported that approximately 10 per cent of new woodburner installations in Tokoroa involve second-hand burners, and questioned whether all installations were consented.

3.1.2 Resource costs

The natural attrition scenario assumes people will make changes to their heating system as the old heating system expires. The ability to foresee the need for a new system means that households are likely to be able to plan the transition and are therefore financially prepared. There is a general trend in the South Waikato district towards fewer households burning wood and coal for warmth. From 1996 to 2001, 7.1 per cent (402 households) and 27.9 per cent (180 households) fewer households burnt wood and coal respectively. This downward trend continued through the 2001-2006 period with reductions of 4.7 per cent (249 households) and 26.0 per cent (96 households). These falls are possibly related to falls in population in the district. If population were to stabilise or to increase, then reliance on natural attrition in achieving reductions in PM_{10} emissions would be questionable at best.

The natural changes expected in heating stock over time will result in falling annual resource costs. The largest resource gain is related to improved health, with increased productivity reducing the total annual cost of days off work and school (and impaired performance), resulting in a $55,000 gain (Table 7). This same gain in health lead to a decrease in costs associated with cardiac and respiratory hospital admissions and GP visits.

Table 7: Annual resource costs: Status quo and natural attrition

Resource cost	Current $000	Natural attrition $000	Difference $000	*% change*
Direct – households				
- Heating system purchase	NA	902.1	NA	*NA*
- Heating system operation	1,265.2	1,245.1	-20.1	*-1.6*
- GP visits	40.0	36.6	-3.5	*-8.7*
Direct – health costs				
- Cardio admissions	15.7	14.1	-1.6	*-10.2*
- Respiratory admissions	24.4	21.9	-2.5	*-10.2*
Indirect – productivity				
- Restricted activity days	631.1	576.1	-55.0	*-8.7*

Under the natural attrition scenario, the net annual operating costs for heating systems decreases by $20,000 (1.6 per cent) from current levels (Table 7). While increases in electric and gas heating systems have increased operating costs, falls in costs for other heating systems have produced a net decrease. This is mainly related to a reduction in open fires. Open fires are the most inefficient form of home heating, taking three open fires to produce the 6.0kW used in the model as the baseline for heating required for an average household. Although households with open fires are not expected to actually use three, using the model in this way allows us to account for the negative health effects of inadequate heating.

Under natural attrition, 45 per cent of owner-occupiers and 30 per cent of landlords with houses with older woodburners are predicted to change their heating system by 2013, with around 40 per cent of owner-occupiers and 20 per cent of landlords to electricity or gas. Projected changes lead to a 15 per cent reduction in PM_{10} emissions. To reach the 55 per cent PM_{10} reduction required to meet the NES, large and unlikely changes would have to occur. For example, if *all* households with pre-1995 woodburners and open fires changed their heating systems to electricity or gas, then we would expect to achieve a 50 per cent reduction in PM_{10} emissions.

The stakeholder group predicted that of tenanted households with aging woodburners, 30 per cent of those woodburners would be replaced by 2013. Eighty per cent of those replacements were expected to be new woodburners, the balance with non-solid fuel heating systems. Factors thought to influence landlords' decisions were low rental returns, suggesting landlords would only replace heating if they 'absolutely had to'. Landlords living outside Tokoroa were considered to be less likely to replace aging heating systems.[16] Approximately half the landlords replacing existing woodburners were expected to replace with portable gas or electric heating. Rising house values were considered a positive contributor to investment in new heating systems. Tenanted homes may provide the market for the second-hand woodburners referred to by Wilton (2006).

The decision tree for the natural attrition scenario is shown in Figure 1.

[16] Peterson (2007) confirmed these expectations.

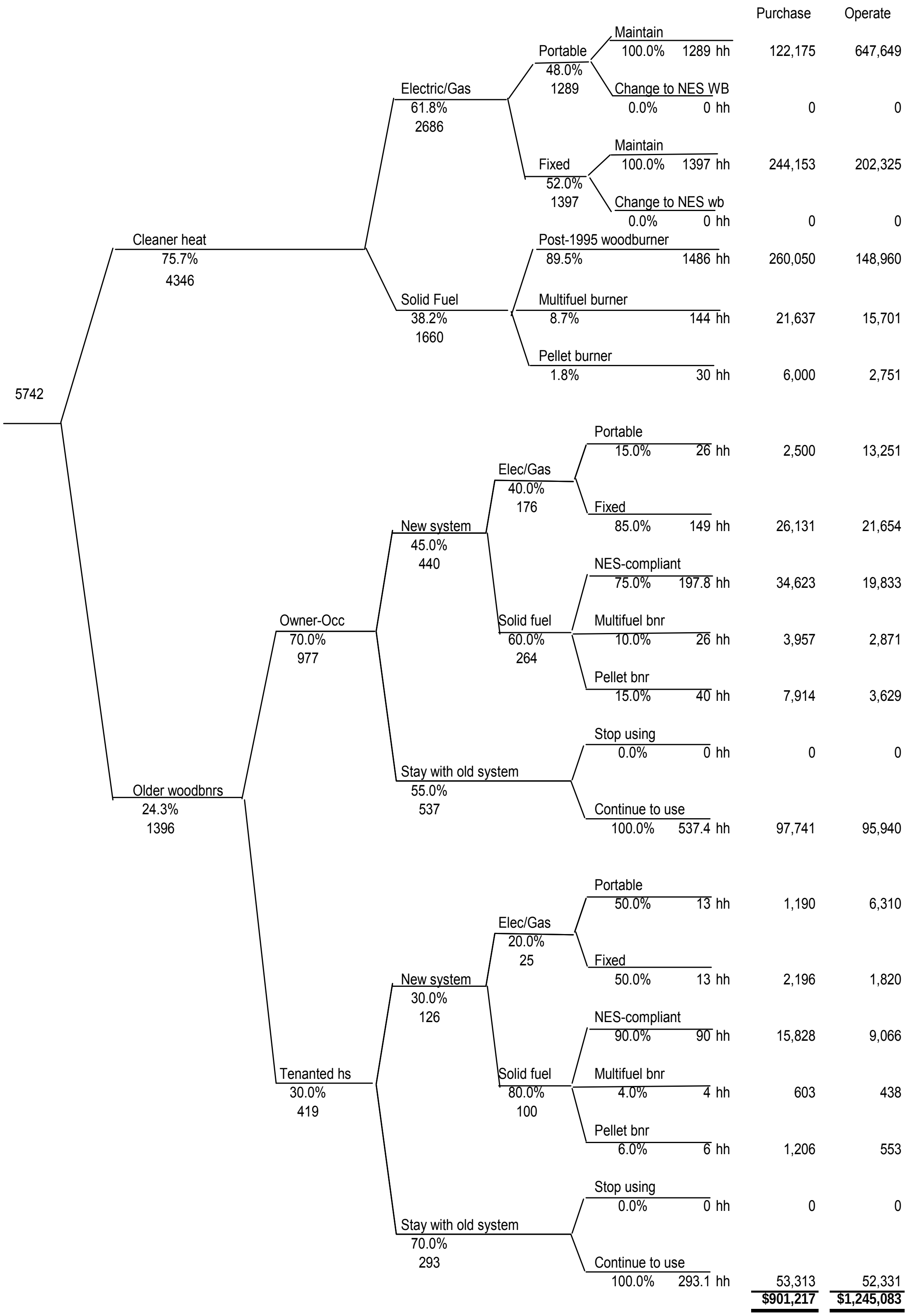

Figure 1: Natural attrition scenario – decision tree

3.2 Regulation

The decision support tool was used to compare two regulation scenarios: the first where multifuel burners are excluded from any regulation (Regulation 1), and the second where multifuel burners are subject to the same emission limits as woodburners (Regulation 2).[17]

3.2.1 Outcomes

The outcomes of both Regulation 1 and Regulation 2[18] compare favourably with those of natural attrition, and are projected to reduce the highest winter PM_{10} emissions by 30 per cent and 32 per cent respectively. With both regulation scenarios the rates of mortality, hospital admissions and restricted activity days are 12-16 per cent lower than those for natural attrition (Table 8).

Table 8: Comparison of the outcomes of natural attrition and regulation policy scenarios, with percentage change between natural attrition and regulation

Outcomes	Natural attrition	Regulation 1	*% change*	Regulation 2	*% change*
Mortality	5.0	4.4	*-13.2*	4.3	*-15.3*
Cardio admissions	1.6	1.4	*-14.0*	1.4	*-16.2*
Respiratory admissions	6.2	5.4	*-14.0*	5.3	*-16.2*
Restricted activity days	14,400	12,800	*-11.7*	12,600	*-13.6*
GP visits	951	848	*-11.7*	831	*-13.6*

The results for the Regulation 2 scenario are slightly more positive than those for Regulation 1 because of the multifuel burner inclusion. In the Tokoroa community, multifuel burners make up just four per cent of the total domestic heating stock, so their inclusion makes only a small contribution to positive outcomes. In communities where multifuel burners form a larger proportion of the total heating stock, their inclusion in policy may be vital to achieving air quality objectives. If multifuel burners are not included in regulation, it may encourage their use and they may become a larger proportion of the heating stock, requiring regulation at a later date.

A reasonable lead-in time was suggested by the stakeholder group as a requirement for the success of any regulation, allowing time for households to plan for change. As would be expected, the level of response was considered to be positively related to the level of monitoring, enforcement and penalties.

3.2.2 Disadvantages

The main disadvantage of regulation is that households using non-compliant woodburners are expected to replace them, but may not have the financial means to do so. Alternatives available to households with insufficient means to replace their woodburner with a regulation-compliant solid fuel burner or a fixed (non-portable) electric or gas system include:

- buying what can be afforded – which may be portable electric or unflued gas heating
- choosing to ignore the regulation and continuing to use an existing non-compliant woodburner
- stopping using their non-compliant woodburner and having no home heating.

[17] Under central government legislation, woodburners are required to meet specific emission and efficiency standards should they be installed on properties of less than two hectares. These standards do not apply to multi fuel burners (www.mfe.govt.nz/publications/air/national-wood-burner-review-jun07/html/page2.html).

[18] Regulation 2 assumes that the age profile of multifuel burners is similar to that of woodburners.

These options are equally applicable to tenants whose landlords are unwilling or unable to replace non-compliant domestic heating.

3.2.3 Resource costs

Under the regulation scenarios, the net annualised costs of purchasing new heating systems and operation costs are similar to those under the natural attrition scenario. The annualised purchase costs of regulation are held at a similar level to natural attrition, in part reflecting a trend towards portable heating, which is expected to become more popular under regulation. Operating costs under regulation show a sharp increase, again related to the increase in portable heating, which is generally more expensive to run than fixed systems, although the up-front purchase price is more affordable.

The costs of all health-related outcomes are lower for the regulation scenarios than for natural attrition, particularly where multifuel burners are included in the regulation framework (Regulation 2) (Table 9). This is an expected result as external air quality improves. Similarly costs of lost productivity due to poor health are expected to be around 12-14 per cent lower with regulation than with natural attrition. However, it must be remembered that this analysis may not adequately include the costs of inadequate home heating, and does not attempt to measure costs related to poor indoor air quality related to unflued gas heating.[19]

Table 9: Resource costs: Natural attrition versus regulation, total costs and percentage difference

Resources	Natural attrition	Regulation 1		Regulation 2	
	$ 000	$ 000	%	$ 000	%
Direct costs – households					
- Heating system purchase	901.2	895.4	*-0.6*	899.6	*-0.2*
- Heating system operation	1,245.1	1,250.9	*0.5*	1253.6	*0.7*
- GP visits	36.6	32.2	*-11.7*	31.6	*-13.6*
Direct costs – health					
- Cardio admissions	14.1	12.1	*-14.0*	11.8	*-16.2*
- Respiratory admissions	21.9	18.8	*-14.0*	18.3	*-16.2*
Indirect costs - RADs					
- Lost productivity	576.1	508.6	*-11.7*	498.0	*-13.6*
TOTALS	**2,794.9**	**2,718.0**	***-2.7***	**2,712.9**	***-2.9***

The extent to which the community 'buy-in' with any regulatory policy, and therefore the amount of monitoring and enforcement required, will have an impact on the final costs of the policy option. Recent evaluation work suggests a high level of local awareness of poor air quality in the Tokoroa community, coupled with a persisting belief that the Carter Holt Pulp and Paper Plant at Kinleith is a major contributor to the issue (Peterson, 2007). This belief may adversely influence the success of any regulation policy.

[19] As a proxy for inadequate heating, the costs of purchase and operation of all heating systems have used 6.0kW as a minimum. No appropriate measure of the costs of poor indoor air quality related to unflued gas heating has been found.

3.2.4 Operating costs

In addition to one-off costs of purchasing new heating systems, moving away from wood burning heating is likely to directly increase household expenses. The costs of operating a wood burning heating system are estimated at 5.0-7.5 cents per kilowatt hour (Table 3). Further, some households in Tokoroa collect their own firewood, and would consider it 'free'. Shifting low income households from wood burning to other heating methods will change household budget priorities. For example, for a household operating a woodburner for 861 hours per year at 5 cents per kilowatt hour, the total annual cost would be $387 (assuming 15kW output at 60 per cent efficiency – Table 3). To achieve the same level of warmth from portable electric heating the household would have to purchase 3.75 electric portable heaters (at 2.4kW each – Table 3). Using the average hours per year of woodburner use (861) at 17.5 cents per kilowatt hour, the total annual cost would be $1356. It is perhaps unlikely that a household would purchase three heating units and run them for the 861 hours as described above – it is more likely that the household would purchase just one unit and be colder. The cost difference is therefore a useful proxy for the diminished utility of the household.

3.2.5 Unflued gas heating

The 2005 Tokoroa heating system survey found that unflued gas comprised 52 per cent of all gas heating systems (Wilton, 2005a). If we assume that unflued gas is also portable, and therefore that 52 per cent of the electric systems are portable, then 22 per cent (1289) of the community's heating systems are either portable and/or unflued gas. Some of these will be secondary heating systems. Under regulation, 85 per cent of owner-occupiers and 20 per cent of tenanted households with aging woodburners are expected to change to a new heating system (that is, 80 per cent of landlords are expected not to respond to the regulatory changes). Of those households making changes, 40 per cent of owner-occupiers and 20 per cent of tenanted households are expected to move to electricity or gas. Of those, 15 per cent of owner occupiers and 60 per cent of tenanted households are expected to move to portable systems. This higher proportion of tenanted homes with portable heating systems is a concern in terms of increasing social inequity.

Projected changes in the numbers of portable heating systems under a regulatory regime have implications in terms of the health and wellbeing of the Tokoroa community. In the recent study on the effect of portable electric and unflued gas heating (Housing, Heat and Health Research Programme, 2007), portable electric and unflued gas heating appliances were replaced with 'more effective and less polluting heaters' in homes across five New Zealand communities, for families where children had asthma. Reported results included:

- less mould and mouldy smells
- levels of nitrogen dioxide halved
- an association between nitrogen dioxide and coughing in asthmatic children
- children reporting fewer episodes of cold and 'flu
- children with asthma reporting less coughing and wheezing
- one day less off school during winter (on average)
- fewer visits to the GP for children (on average).

In more deprived communities such as Tokoroa, regulatory policies that lack financial support for community change can be expected to increase levels of inadequate heating and therefore increase negative health impacts, having the greatest impact on the poorest households. The New Zealand Deprivation Index lists five of the 10 area units in the Tokoroa urban area as falling into New Zealand's two highest deprivation categories, with 75 per cent of Tokoroa households living within these two area units.[20]

[20] Dimensions of deprivation measured are access to telephone, employment, qualifications, housing tenure, access to car, living space and income (Salmond, et.al. 2007).

3.2.6 Implications for rental accommodation

The outcomes and costs for regulation (Tables 8 and 9) are based on the expectation that most (70 per cent) landlords with non-regulation woodburners will ignore the new regulations. If this were the case, and tenants wanted to be part of the solution for cleaner air, they are left with the option of no home heating, or purchasing a portable unit themselves. The stakeholder group felt that given the level of community awareness of the relationship between woodburners and clean air, 10-30 per cent of rented households would stop using their non-complying woodburners even with no replacement heating. The implications of this are discussed in the sensitivity analysis.

3.2.7 Achieving the reduction in PM_{10} with regulation

Under regulation, a high and perhaps unlikely level of compliance would be required for the Tokoroa community to reach the 55 per cent PM_{10} reduction objective (Table 10). For both Regulation 1 and Regulation 2, if 100 per cent compliance by owner-occupiers was achieved (that is, *all* households stopped using non-compliant solid fuel heating), and then *all* of those complying households chose electric or gas home heating, the estimated reduction would be close to 50 per cent. This assumes that tenanted households make changes as determined within the stakeholder workshops.

Table 10: Regulation 2: Level of change required to reach target PM_{10} reduction

	% complying households	Number of complying households	% changing to electricity or gas	Number changing to electricity or gas	% reduction in peak PM_{10} emissions
Landlords	30	195	20	39	55
Owner-occupiers	100	1513	100	1513	

Obviously there are alternative combinations of owner-occupier and tenanted households making heating changes, and of the type of heating systems chosen, however, Table 10 illustrates the scale of the change required for Tokoroa to reach the level of reduction required.

The decision tree for the Regulation 1 and Regulation 2 scenarios is shown in Figures 2 and 3.

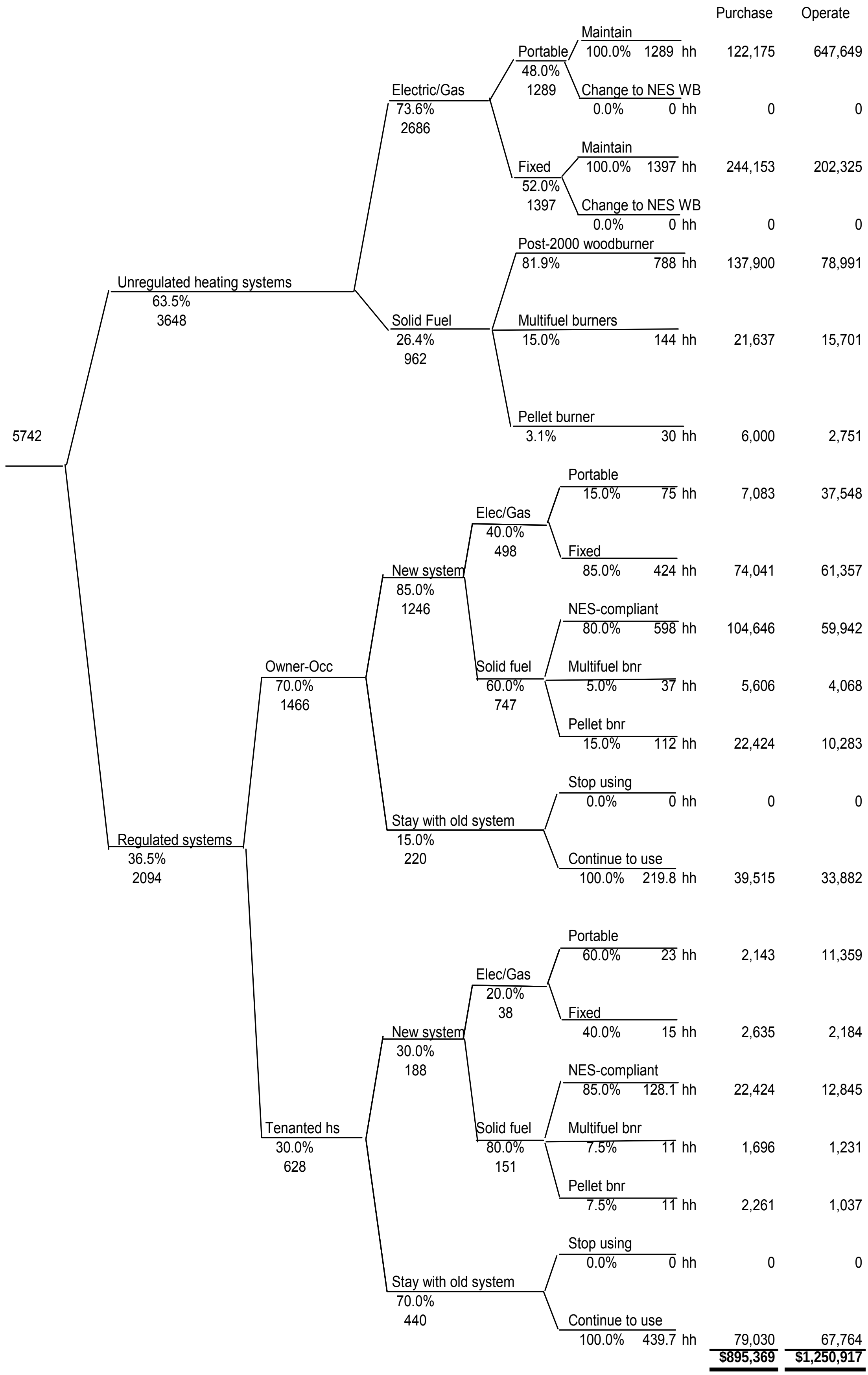

Figure 2: Regulation 1 scenario – decision tree

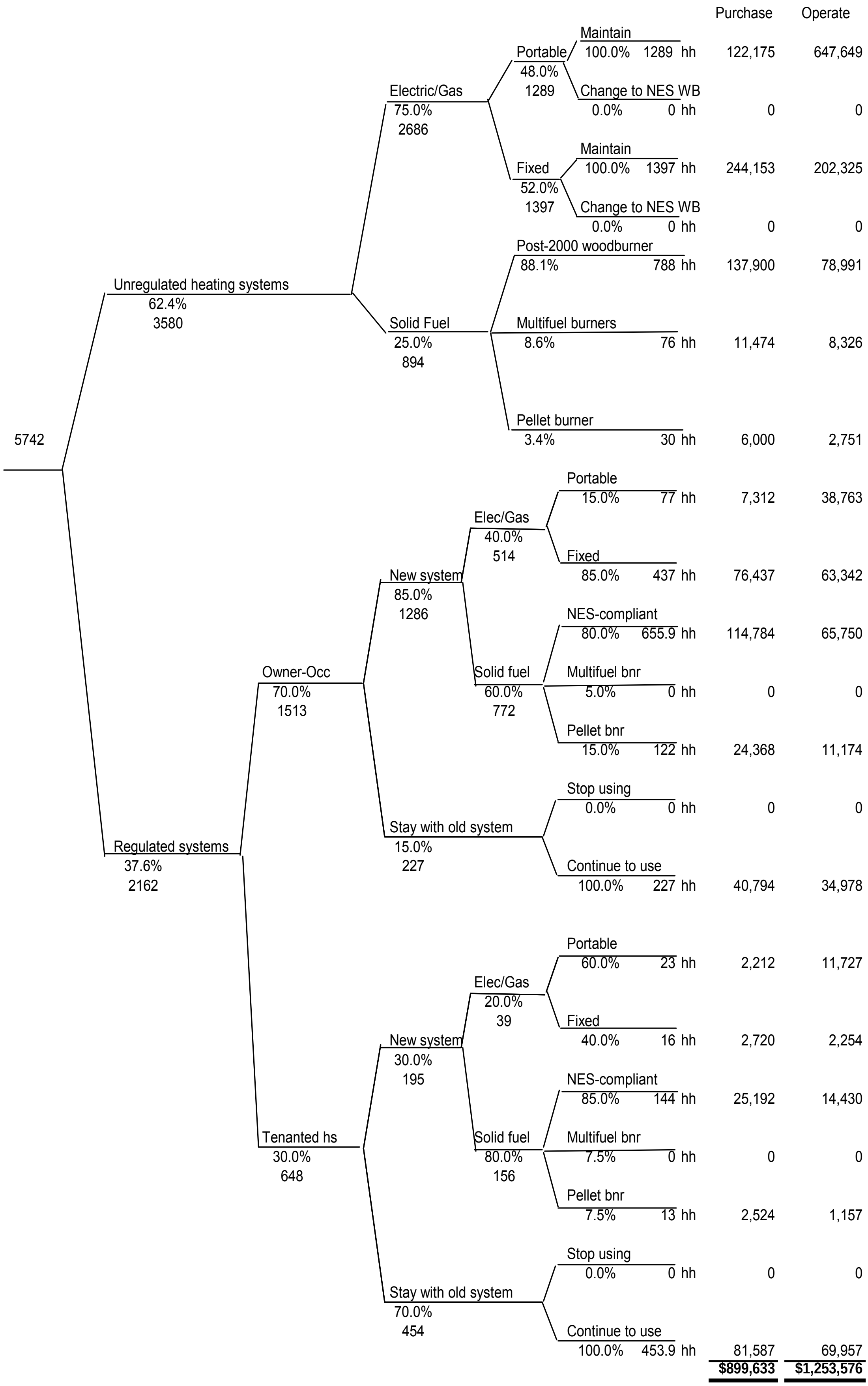

Figure 3: Regulation 2 scenario – decision tree

3.3 Incentives

In this section the incentive scenario is explored, with outcomes and resource costs analysed and compared with those for the natural attrition and regulation scenarios.

3.3.1 Outcomes

The decision support tool indicates that the incentive policy (as described in Section 1) could achieve a 28 per cent reduction in peak winter PM_{10}. This is considerably greater than the expected 13 per cent reduction achieved through natural attrition, but falls far short of the 55 per cent reduction objective because given the choice, most Tokoroa households are expected to replace their current woodburner with another woodburner. Although newly installed woodburners must meet new standards as specified by central government, the difference between emissions from NES-compliant and older woodburners is uncertain at best (Scott, 2005; MfE, 2007a), and may not be sufficient to reduce total emissions. Greater shifts towards electricity or gas, or higher levels of uptake by non-CSC holders and landlords would be required to reach the PM_{10} reduction required.

Health outcomes under an incentives policy are expected to be better than those under natural attrition, with lower levels of mortality, hospital admission and general ill health (Table 11). However, health outcome levels are projected to be slightly worse under incentives than under regulation. At this point it must be remembered that health outcomes from no heating or from poor indoor air quality due to unflued gas heating have not been included. Inclusion of these, if it were possible, would change the profile of health costs for these scenarios.

Table 11: Comparison of the outcomes of natural attrition with incentive policies

Outcome	Natural attrition	Incentives	*% difference*
Mortality	5.0	4.5	*-11.5*
Cardio admissions	1.6	1.4	*-12.2*
Respiratory admissions	6.3	5.5	*-12.2*
Restricted activity days	14,600	13,100	*-10.2*
GP visits	961	863	*-10.2*

Under regulation, replacing aging woodburners with portable electric and gas systems is an option for less affluent households. The decision support tool reveals differences in groups expected to purchase portable heating under the different policy scenarios. While there is little or no expected increase in the number of households dependent on portable systems under an incentive policy, under regulation, portable systems become an option for complying with regulation while on a low income: approximately half of both owner-occupied and tenanted households are expected to change from non-complying systems to portable electric or gas heating.

3.3.2 Resource costs

As in the natural attrition and the regulation scenarios, the health outcomes under the incentive scenario translates into lower resource costs for cardio and respiratory admissions, GP visits, and time away from usual activities due to illness. All of these health related resource costs are 10-12 per cent lower under an incentive scenario than under natural attrition (Table 12). The annualised costs of heating system purchase are similar under both natural attrition and incentive scenarios, however, operation costs are lower for incentives because of an expected trend towards fixed systems, which are generally less expensive to operate.

Another major difference is who pays – under natural attrition and regulation, the household pays, under incentives the cost is shared between the households and government (the wider community). Under an incentive scheme, the opportunity to purchase in bulk potentially reduces purchase costs of heating systems still further, although this is excluded in the following table.[21]

Table 12: Resource costs: Natural attrition versus incentives

Resource cost	Natural attrition $000	Incentives $000	*% change*
Direct – households			
- Heating system purchase	901.2	907.0	*0.5*
- Heating system operation	1,245.1	1,230.0	*-1.2*
- GP visits	36.5	32.7	*-10.2*
Direct – health costs			
- Cardio admissions	14.1	12.4	*-12.2*
- Respiratory admissions	21.9	19.2	*-12.2*
Indirect – productivity			
- Productivity	576.1	517.2	*-10.2*
TOTALS	**2,794.9**	**2,718.6**	***-2.7***

For the incentives scenario, the quantifiable health costs are within one per cent of those for the regulation scenarios. As previously noted, the health costs associated with indoor emissions from unflued gas heating have not been included, but would increase the costs associated with regulation.

3.3.3 Achieving the reduction in PM_{10} emissions

The decision support tool allows many contributing factors to policy outcomes to be changed to indicate the likelihood of achieving the PM_{10} emissions goal. As with regulation, under an incentive scenario a relatively high level of uptake of new heating systems would be required to reach the PM_{10} reduction objective. For example, if *all* home owners moved to new heating, with the current preferences for solid fuel and electric/gas, a 43 per cent reduction in emissions would be expected. Alternatively, if uptake of subsidies was as was expected by the stakeholder group (at 80 per cent, 38 per cent and 36 per cent of owner-occupier CSC holders, owner-occupier non-CSC holders and landlords respectively) and all of those making changes moved to electric or gas heating systems, the reduction expected would be around 36 per cent. Clearly it will be important to get high levels of uptake of subsidies, should incentives be part of the policy mix.

The decision tree for the incentive scenario is shown in Figure 4.

[21] For example, Environment Canterbury was able to supply a Mitsubishi heat pump installed at a cost of $2156 plus GST. The same heat pump retailed (installed) for $2999 plus GST (Gaudin, personal communication). In this case this is a price reduction on 28.1 per cent. The impact of bulk purchasing is explored further in Section 4.

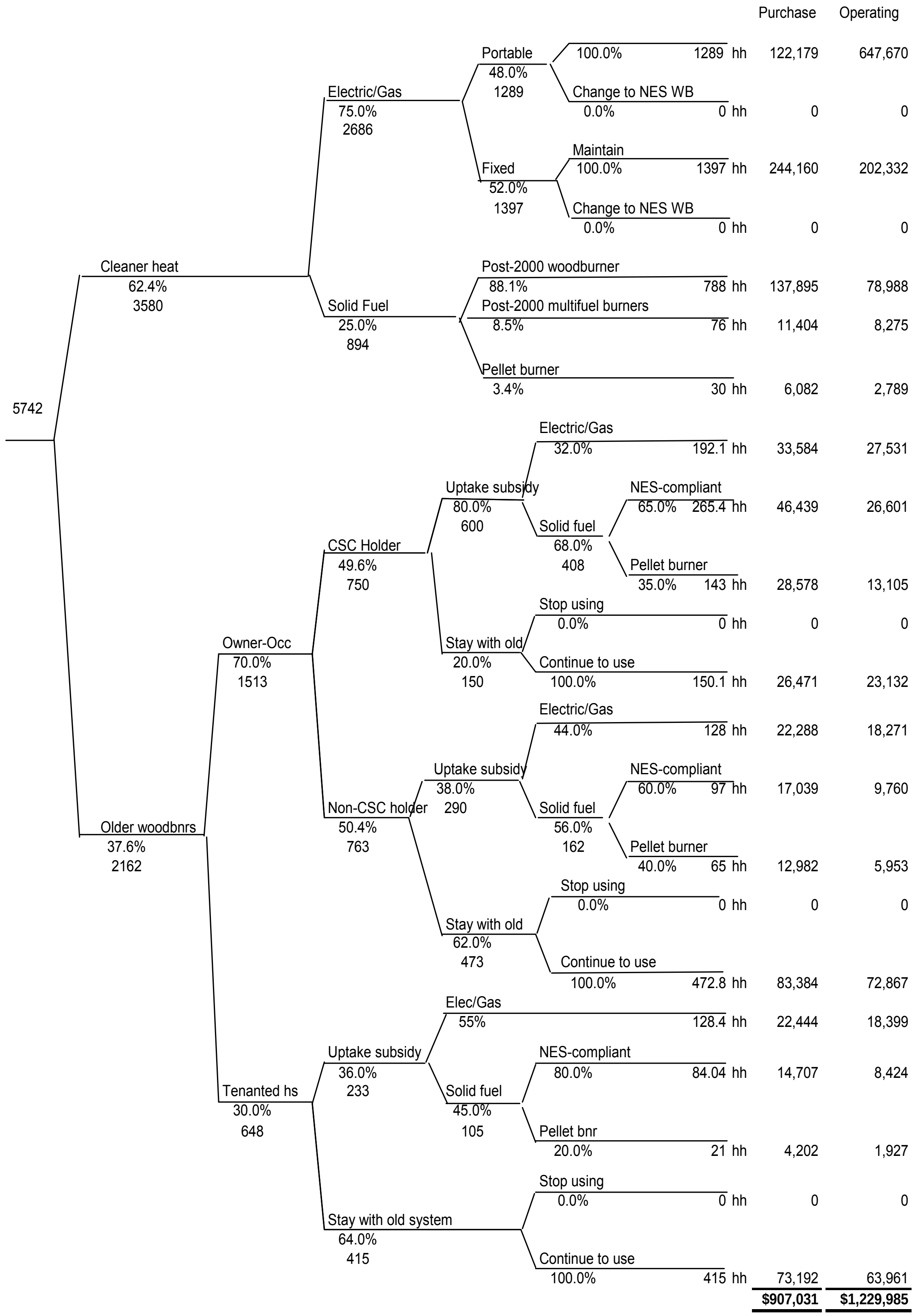

Figure 4: Incentivising heating systems – cost outcomes

3.4 Overall

Outcomes and costs of different policies

The current annual costs relating to health impacts from PM_{10} pollution are significant. The 2006 costs for hospital admissions, productivity losses and GP visits in Tokoroa were estimated to be $711,000. Prospective policies bring expected improvements in health and wellbeing, with reduced annual rates of mortality, hospital admissions, restricted activity days, and associated public and private costs.

Natural attrition is expected to bring about an improvement to the current levels of mortality, hospital and restricted activity days, with all rates falling between 8-10 per cent. The introduction of policies to further reduce PM_{10} levels bring about much greater improvements in relation to current levels (Table 13).

Table 13: Improvement in health outcomes from current status

Health outcome	Regulation 1 %	Regulation 2 %	Incentives %
Mortality	21.5	23.4	20.0
Hospital admissions – cardio	22.8	24.7	21.2
Hospital admissions – respiratory	22.8	24.7	21.8
Restricted activity days	19.4	21.1	18.1

Using natural attrition as a baseline level, Regulation 2, with the inclusion of multifuel burners, shows the greatest improvements in health outcomes, with each measure (mortality, hospital admissions and restricted activity days) falling by 14-16 per cent on the same measures for natural attrition. Regulation 1 records 12-14 per cent reductions, and incentives 10-12 per cent reductions. The decision tree shows results of health outcomes to be close, with incentives slightly higher (within two per cent of Regulation 1 and four per cent of Regulation 2, across all health related outcomes) than regulatory policies. Remembering that effects from unflued gas are not accounted for, and that regulatory policies are most likely to increase the number of unflued gas heating units in the community, it is likely that health outcomes are much closer.

These reductions in health outcomes transfer to lower health-related costs.[22] Even with natural attrition, we would expect that costs would be around nine per cent lower than current costs by 2013. The Regulation 1, Regulation 2 and incentives policies lower current health related costs by 20 per cent, 21 per cent and 18 per cent respectively. Comparisons between natural attrition and Regulation 1, Regulation 2 and incentives show that these latter policies can be expected to reduce health related costs to 12 per cent, 14 per cent and 10 per cent lower than those achieved under natural attrition. Again taking into account the higher uptake of unflued gas heating expected with regulatory policies, these figures are likely to be much closer that the decision tree shows.

All potential policies show similar levels of purchase costs when annualised (Table 14), however, the low initial costs of portable heating mean that under a regulatory regime many households are likely to opt for these units with their low up-front costs. When a purchase discount is applied to the incentives option, the annualised purchase costs drop to $880,000. A discount is likely with the bulk buying that occurs with funding of incentives (Gaudin, M., personal communication).

[22] Mortality costs have not been quantified, remaining as a qualitative measure.

Table 14: Improvement in health outcomes from current status

Annualised cost	Natural attrition $000	Regulation 1 $000	Regulation 2 $000	Incentives $000
Purchase	901	895	900	907
Operation	1,245	1,251	1,254	1,200

4 Sensitivity analysis

4.1 Variability of emissions from NES-compliant woodburners

Woodburners will continue to be part of the home heating stock in Tokoroa in the foreseeable future and certainly to 2013. By law, replacement woodburners must be NES-compliant and it is assumed their emissions are lower than the aging woodburners they replace. This is critical to achieving PM_{10} reductions.

'Real life' testing for PM_{10} emissions from NES-compliant woodburners has revealed that the average PM_{10} per kilogram of wood burnt was 4.6g/kg ± 2.0g/kg (95 per cent confidence interval). This is three times more than the initial factory test results, and potentially compromises policy outcomes.[23] The report on real life emissions concluded by advising caution because of the small sample (nine), the narrow range of burner designs and the test methodology (MfE, 2007a). In terms of the test methodology, the selection process for participants was not random. Households were selected on the basis that they had a suitable heating system and were willing to participate. The selection process indicates that the sample is unlikely to be representative of the community. Each household in the above study burned the wood they would usually burn. Results revealed a clear relationship between moisture in firewood and emissions, with one household burning wood with a moisture content of 40 per cent and producing 11.2g/kg of PM_{10} emissions.[24]

Currently no information exists as to the quality of individual household firewood storage facilities, and although people appear to know of the importance of burning dry wood, buying early and storing in dry conditions is not always an option (Peterson, 2007). At least one major supplier of split firewood in Tokoroa stores the split wood uncovered in a large yard (Arthur, personal communication). Any policy that includes replacement with NES-compliant woodburners must consider the implications of burning wood with high moisture content. Some regulation of wood supplier storage conditions may be worth considering.

Within the decision support tool a 6.0g/kg point estimate (average) was used, with comparison of low and high values of 4.0 and 8.0.[25] The potential reduction in PM_{10} emissions drops steeply as the average PM_{10} from NES-compliant woodburners increases (Table 15). The risk is that the total PM_{10} emissions from compliant woodburners will be in excess of what has been assumed, jeopardising the chances of meeting air quality goals. Clearly this risk must be considered when making policy.

[23] Earlier testing of NES-compliant woodburners by Scott (2005) concluded that in some circumstances, PM_{10} emissions may be as high as 12 to 15g/kg of wood burnt.
[24] This household was also using a native wood species.
[25] 6g/kg was a figure suggested Wilton (2006).

Table 15: Per cent PM_{10} reduction with varying NES-compliant woodburner emissions

PM_{10} range g/kg fuel	Per cent reduction in PM_{10} emissions			
	Natural attrition	Regulation 1	Regulation 2	Incentives
4.0	15	34	37	30
6.0	13	30	32	28
8.0	11	25	27	25

Adding to the complexity, the ability of NES-compliant burners to deliver target emission levels may be partly determined by retailer support for regulation. A recent informal survey of three retailers revealed that all offered or explained options for altering the 'damping' mechanism of the NES-compliant woodburner which would allow the fire to be damped down to burn more slowly, emitting more PM_{10}.[26]

Incentives used in conjunction with regulation may enhance retailer support, allowing a list of 'trusted retailers' to be compiled, and those retailers who do not follow agreed process to be excluded (Gaudin, personal communication).

4.2 Variability of emissions from pellet burners

Field testing of pellet burners was carried out in 2007 (MfE, 2007b). The sample was small (4), and one burner was found to be faulty. Excluding the faulty burner from the sample, the average PM_{10} emissions were 1.4g/kg. The robustness of this figure assumes no faulty burners in the population. Including the four burners in the sample, the average would be 3.9g/kg, ± 7.9g/kg (95 per cent confidence interval). Pellet burners have a relatively low uptake to date, with projected uptake limited according to stakeholder group. The implications are that the faulty pellet burners may emit as much as 11.8g/kg of fuel burnt.

The decision support tool uses 1.4g/kg as the average emissions figure for pellet burners. Altering this to a higher level has little impact on total emissions due to the low expected uptake, however, if pellet burners became more popular then the possibility of higher emissions may be significant. Inspection of pellet burners for faults, possibly using regulation to do so, may assist in solving this.

4.3 Housing tenure and aging woodburners

The relationship between housing tenure and age of woodburners is important. An assumption in the decision support tool is that 70 per cent of pre-2000 woodburners are in owner-occupied households with the balance in rented homes. This assumption is based on work by Wilton (2005c), and is supported by the 2006 Census to the extent that similar percentages of rental and owner-occupied homes have wood burning appliances, although the age and type of wood burning appliance is not included in the latter. It is reasonable to suppose that the 2005 survey data may have overstated the number of pre-2000 woodburners in owner-occupied homes, given that it was a telephone survey, and rented households may be less likely to have access to a land-based telephone. When the ownership structure assumption is altered to 60 per cent of pre-2000 woodburners in owner-occupied homes and 40 per cent in rented homes, each policy is less likely to meet the required emission reduction (Table 16).

Table 16: PM_{10} emissions reductions with proportions of pre-2000 woodburners in owner-occupied housing

Pre-2000 woodburners in owner-occupied homes %	Natural attrition %	Regulation 1 (2) %	Incentives %
60	13	30 (32)	28

[26] This informal survey by Sandra Barns (author) was undertaken in Whakatane, June 2007.

	70	13	27 (29)	26

4.4 Unheated households

In 2006, 42 households in the Tokoroa urban area were recorded as not using any home heating, with 79 per cent of these being rented accommodation (Statistics New Zealand, 2007c).[27] Growing awareness of the relationship between woodburners, air quality and health may prompt people to stop using woodburners, and the prevalence of households with no heating is expected to alter with the policy chosen (Table 17). If change is forced, then those households without the financial means to make a positive change may end up with no heating. Some of those included in Table 17, if renting, may move to portable gas or electric heating, which raises other health issues, as discussed earlier in this section.

Table 17: Tokoroa households with no heating – current and projected

Current	Natural attrition	Regulation 1 (2)	Incentives
42	66	156 (160)	77

4.5 Levels of unflued gas heating

Wilton (2005a) estimated that 1558 houses used gas, made up of 748 flued and 810 unflued appliances. Upon this work by Wilton is based the estimations of portable and fixed systems in the decision support tool, with the general assumption that unflued systems are portable, and flued systems are fixed.

In the 2006 Census 1782 households were recorded as using gas, with 1128 (63.3 per cent) using bottled gas. Incorporating the 2006 Census data into the decision support tool (63 per cent portable systems; 37 per cent fixed systems), the following changes occur.

- The annualised purchase costs of heating systems are approximately 3-4 per cent lower for all scenarios.
- The annual operating costs are approximately 10-12 per cent higher for all scenarios.
- There is no change within health costs.
- Although costs have risen, there is no change in the relationships between the scenarios.

These are changes to current stock, not to future decisions, so all scenarios change similarly and relationships remain the same. Although the health related costs do not change in the model, in reality an increase in unflued gas heating would negatively impact on health, but again because these are current stock, the changes would affect each scenario similarly.

4.6 Households changing from clean heat to solid fuel

Some households currently using electricity or gas to heat their homes may decide in the future to install an NES-compliant woodburner. Drivers of this may be increases in the costs of electricity or gas, or fears about ongoing supply. It is useful to examine how these types of household decisions would impact on the likelihood of meeting the PM_{10} emission standards. A five per cent movement towards woodburners by households currently using electric or gas heating results in a small change in total emissions reductions (Table 18). If the number of households making this move is

[27] The 2006 Census figure for households with no heating may be lower than the actual number. Across ethnicities, the national net undercount for Maori and Pacific peoples was estimated to be 3.1 per cent and 2.3 per cent respectively in the 2006 Census, which is higher than for the majority European population (1.4 per cent) (Statistics New Zealand, 2007b).

higher, at say 10 per cent, then the impact on reaching the emissions reductions target will be greater. Monitoring trends in this area would be worthwhile.

Table 18: PM_{10} emissions reductions with conversion to NES-compliant woodburners[28]

Percentage change to woodburners %	Natural attrition %	Regulation 1 (2) %	Incentives %
0	13	30 (32)	28
5	11	27 (30)	25
10	8	24 (27)	22

4.7 Bulk purchase under incentives

The ability to bulk-purchase heating systems at preferential prices has been a feature of the Nelson and Christchurch incentive programmes. In the baseline case (in the decision support tool), approximate retail prices have been used. When discounts for bulk purchase are included for the incentives scenario, the purchase costs of heating systems and therefore total costs fall. In the baseline case the incentives scenario has the highest overall costs, although costs are very similar between regulation and incentives. Applying a discount of 20 per cent to purchases of new heating systems decreases total costs for this scenario, making it the least expensive of all options (Table 19).

Table 19: Resource costs with bulk purchase discounts applied to incentives scenario

Policy	Heating system purchase cost $000	Total costs $000
Natural attrition	901.2	2794.1
Regulation 1	895.7	2718.0
Regulation 2	899.6	2712.9
Incentives	907.0	2718.6
Incentives with 10% discount	893.9	2705.5
Incentives with 20% discount	880.9	2692.4

5 Discussion

Poor air quality is an environmental issue, but many of the outcomes relate to health effects.

An interesting aspect of this study is that while households may make environmentally ‘clean’ choices at an individual level, the choices made by the balance of the community can still negatively impact on the household. That is, members of a household using clean technology can still suffer negative health outcomes – some of the benefits of using clean technology are public goods. So while it is possible to calculate the expected cost of the technology per household, the analysis must consider the health impact on the Tokoroa community as a whole. The negative externality of polluted air makes a clear case for public authority intervention.

Options to solve the problem of poor local air quality in Tokoroa include solutions that improve outdoor air quality at the expense of indoor air quality (moving from solid fuel burning to unflued gas heating, for example), or improving indoor air quality while potentially reducing global air quality (exchanging wood burning for electric heating options). The latter may be less important over time as New Zealand continues to adopt renewable energy sources such as wind and sun, in addition to its current 70 per

[28] Assumes a 6g/kg of wood burnt for PM10 emissions from NES-compliant woodburners.

cent annual electricity production from renewable sources (hydro, geothermal, wind and sun) (MED, 2004).

Using the decision support tool to calculate the likely reduction in PM_{10} emissions with different policy options, it was found that natural attrition, the unassisted gradual change of heating systems over time, will not achieve the PM_{10} reduction required by 2013. This finding is supported by the slow changes seen in the Statistics New Zealand figures for 'fuel used to heat dwelling' in the 2001 and 2006 censuses. Regulatory and incentives policies could be expected to achieve more than twice the reduction of natural attrition, each at around 30 per cent. However, as discrete policies, these both fall short of the estimated 55 per cent required to reach the NES air quality targets for PM_{10}.

Outcomes and costs of different policies

The current annual costs relating to health impacts from PM_{10} pollution are significant. The 2006 costs for hospital admissions, productivity losses and GP visits in Tokoroa were estimated to be $711,000. Prospective policies bring expected improvements in health and wellbeing, with reduced annual rates of mortality, hospital admissions, restricted activity days, and associated public and private costs. All policies, including natural attrition are expected to bring about improvements in the status quo; however, the greatest improvements are from active policies of regulation or incentives.

Who pays?

One of the major differences between the regulatory and incentives policies is who pays. Under the regulatory policy, the user of the heating is expected to carry the cost. If regulation is adhered to and households make changes, then clearly this is the case. If households do not respond positively to regulation, and high levels of monitoring and enforcement are required, then the costs to the wider community would be expected to increase positively with the amount of monitoring and enforcement activity.

Incentives might be funded by other government agencies (for example EECA), thus the wider tax paying public is contributing. Funding might also be by the individuals via rates, or by the wider local or regional community.

Choices by households

The stakeholder workshops revealed that the drivers influencing choices made by households in the Tokoroa community are affordability in terms of purchase costs and operating costs (the availability of 'free' firewood is a key factor) and the desire of many in the community to comply with regulations.

Regulation-based policies without financial support to assist change may increase the difficulties for low-income households. Portable heating systems tend to have low purchase costs but high operating costs, so while initially attractive, household budgeting may be more difficult, houses colder, and indoor air pollution more of an issue (this latter relating to unflued gas heating). A move from wood burning will have a negative impact on households previously dependent on freely gathered firewood, but unable to afford the purchase price of an NES-compliant burner.

In the 2006 census (Statistics New Zealand), 42 households in Tokoroa were recorded as using no heating fuel. Regulation as a stand-alone policy is expected to increase this figure more than other policy alternatives. Households living in rented accommodation are expected to be the most affected.

Investment in new, good quality heating systems in rental properties is a business decision. Whether this investment increases the capital value or rental return of the property is debatable, and will depend on the location of the property. Therefore some (and in some cases all) of the benefits of such investments are a public good – so landlords are likely to under-invest.

Using the decision support tool to take a closer look at the regulation and incentive scenarios reveals that it is likely the two policies will draw positive responses from different segments of the community. Under regulation, 30 per cent of tenanted households with older woodburners are expected to replace them with compliant heating. When incentives are offered, the response rate climbs to 36 per cent. Conversely, under the regulation scenario, 85 per cent of owner-occupied homes are expected to replace non-compliant heating systems, while with incentives this figure is lower, at 60 per cent. Probing further, under the incentives scenario, of those expected to uptake the subsidy, 67 per cent are Community Services Card holders. This, along with the results from tenanted homes (above), suggests that if incentives are offered, the 'lower income' segments of the community are more likely to participate in the solution to air quality issues.

Reliability of NES-compliant heating

Consistently low figures on PM_{10} emissions from NES-compliant woodburners continue to be elusive, with reasons for poor performance including human-controlled factors such as wet wood and interference with the woodburner design. These types of issues may find an answer within policy, for example, if wood storage can be identified as a major contributor to high levels of PM_{10}, then some support to change the ability of the community to store wood may be useful to changing outcomes. Alternatively, if changes to manufacturer design was a large enough problem, then clearly the community and retailers are not 'on board' with the issue of air quality, and more work is required in that area. Given the expected preference of Tokoroa households for wood-burning heating, there appears to be a very real risk of replacing aging woodburners with NES-compliant woodburners that prove to be little better in the long run.

Recent testing has shown that faulty pellet burners can produce PM_{10} emissions in excess of levels from 'old' woodburners. Unlike poor storage of wood or tampering with woodburner design, faulty pellet burners may be difficult to identify, but could be tested through a quality control program. If they were to become a popular heating system in Tokoroa, an issue of quality control must be addressed to ensure target emissions can be achieved.

Unquantifiable costs

Arguably the greatest costs associated with emissions from, and/or inadequacies of, home heating may be in areas where the values are unable to be quantified, such as loss of life, loss of ability to fully enjoy life through illness and time away from school for children, resulting in loss of education and opportunities. Stress associated with cold, damp homes may also be significant, and should be taken into account in considering policy measures.

Natural attrition

The rate at which households replace their aging woodburners and the type of heating systems they choose as replacements was determined by the stakeholder group, as described in Section 2.4. Using this method, approximately 14 per cent (201) of older wood burners are expected to be replaced with a range of electric and gas heating options between 2007 and 2013. This is slightly fewer than the number of households ceasing to use wood for home heating in the five years to 2006 – 216 households (Statistics New Zealand). This suggests figures for this section of the natural attrition scenario are likely to be reasonably reliable.

In addition to this gains in reduced emissions will be made from households switching from aging woodburners to NES-compliant woodburners, but these have been unable to be verified.

6 Conclusions

To meet the NES for PM_{10} concentrations it is estimated that peak winter emissions in Tokoroa will need to be reduced by 55 per cent. With 89 per cent of PM_{10} emissions in Tokoroa from home heating, policy must be focused on reducing the number and use of polluting domestic solid fuel burners.

PM_{10} emissions from home heating are the cause of a local air quality problem, which in turn contributes to health problems in the community. An understanding of the wider costs of prospective policy choices is necessary to make an informed decision, such as trading better outdoor air quality for poorer indoor air and warmth or trading local air quality issues for global air quality issues (moving from solid fuel burning to electricity-based options). This study has attempted to provide information on the former, but the latter requires more science-based information.

While a natural improvement is occurring over time as people change their aging woodburners for newer and more efficient heating, natural attrition is not expected to achieve the 55 per cent reduction objective, in part because woodburners have a longer useful life than first thought. The presence of non-consented woodburners in Tokoroa may also contribute to this. It is therefore necessary to consider other policies to enable the Tokoroa community to meet the NES, and to take it further, as described in the Proposed Waikato Regional Plan.

6.1 Regulation

Two regulatory approaches and an incentives approach have been considered as discrete policies in this analysis.

Overall, regulation is expected to improve air quality in Tokoroa, increasing health and wellbeing of the community, both in terms of current levels and those under the natural attrition scenario. These results rely on a high level of compliance from owner-occupied homes (85 per cent), although tenanted homes are not expected to reach such levels (30 per cent). However, without monitoring, enforcement and penalties, regulation is unlikely to shift households who cannot afford to or do not want to make changes. Further, for households who cannot afford to, but elect to change (wanting to keep within the regulations), options are portable heating, no home heating or increased debt. These choices increase the health-related costs of regulation, which tend to fall more heavily on poorer households.

Of the regulatory responses, Regulation 2 provides a level of 'future-proofing', meaning that the inclusion of multifuel burners in the initial policy will ensure the policy wouldn't have to be revisited at a later date, should they prove a problem.

6.2 Incentives

The regulation policy appears on the face of it to be marginally more attractive than incentives, especially with the inclusion of multifuel burners. Mortality, hospital admissions and days of restricted activity are slightly lower than those for the incentives scenario. However, when the purchase and operating costs for home heating are included, the total costs for regulation and incentive scenarios are within one per cent of each other. In addition, costs relating to no home heating or to harmful indoor pollutants from unflued gas heating – which are issues of an unsupported change regime – would increase costs in the regulation scenario.

Like regulation, the incentives scenario is expected to reduce PM_{10} emissions, thereby increasing the health and wellbeing of the Tokoroa community. A high expectation of subsidy uptake, particularly within the low income/owner-occupier section of the community (80 per cent) is the major reason for the air quality improvement. One of the potential benefits of the incentives policy is the ability of policy makers to influence outcomes through subsidy design. For example, larger incentives for cleaner burning alternatives.

Unlike regulation, issues of inadequate heating and indoor pollution are not expected to be exacerbated by an incentives policy because low income households are supported to make changes to clean heat. Similarly the numbers of households with no heat are likely to be lower than with regulation.

6.3 Regulation and incentives… together

The regulatory and incentives policies draw positive responses from different segments of the community. Under regulation, 30 per cent of tenanted households are expected to replace older woodburners with compliant heating. For incentives the response rate is 36 per cent. The stakeholder group expected that landlords would respond more positively to a combination of incentives and regulation, where the regulation had a lead-in time, with incentives available.

Under the regulation scenario, 85 per cent of owner-occupied homes were expected to replace non-compliant heating systems, while with incentives this figure was lower, at 60 per cent. Probing further, under the incentives scenario, of all households expected to uptake the subsidy, 67 per cent were Community Services Card holders.

If we assume that the main reason for owner-occupiers not responding positively to regulation is financial inability, then a combination of regulation and incentives should achieve a better result than either policy on its own. This, along with the results from tenanted homes (above), suggests that if incentives are offered, the 'lower income' segments of the community are more likely to participate in improving air quality in Tokoroa.

Another benefit of an incentives-regulatory approach is the ability to build relationships with retailers supplying heating appliances, increasing their support for regulations.[29]

Individually, policies of regulation and incentives are each likely to fall well short of the target for reduction in PM_{10} concentrations for the Tokoroa community. A combination of regulation and incentives is likely to come closer to reaching the reduction of PM_{10} required.

6.4 Uncertainty of NES-compliant burner emissions

In spite of testing, PM_{10} emission levels for NES-compliant woodburners remains uncertain, as do those for pellet burners. A policy whose outcome was the replacement of aging woodburners with similar numbers of NES-compliant woodburners would be risky. Similarly, if the popularity of pellet burners was greater than currently expected and the incidence of faulty pellet burners was significant, this too could be problematic. While pellet burner concerns could be addressed by a careful inspection regime, judicious design of policy around woodburner replacement may be needed to ensure the risk of replacing current woodburners with similarly polluting woodburners is reduced or eliminated.

6.5 Quality-of-life impacts and immeasurable dimensions

Not all costs can be monetised. Early death, quality of life impacts through ill health, loss of enjoyment of the local environment due to air pollution, lost education and opportunities for children because of time away from school – all these outcomes should be considered alongside resource costs when making decisions about policy.

[29] This has been an important aspect of the Christchurch Clean Heat Project (Gaudin, pers.comm).

6.6 Other policies…

There are potentially other partial solutions to reducing PM_{10} emissions. Testing of NES-compliant woodburners highlighted the importance of well-stored wood. As well as relaying this message to the community, there may be more practical ways to assist households, such as provision of storage containers. Dry wood also provides an avenue for renting households to be involved with the helping to reduce PM_{10} pollution in the community.

6.7 The decision support tool

The decision support tool has proven invaluable in identifying the key drivers of community response to policy and identifying cost impacts. Its versatility lies in that as new information on the various drivers becomes available these may be factored in and the outcomes measured. The decision support tool is a work-in-progress, in the sense that not all resource costs are able to be quantified at this time. As better data becomes available it can be included in the tool to provide more robust results. The possible impacts of pharmaceutical costs and other costs relating to no home heating, inadequate heating and toxic indoor emissions should be considered by decision makers.

7 Limitations

This study has worked with a stakeholder group representing the Tokoroa community to estimate the probabilities needed for the decision support tool. Sensitivity analysis was used to determine which probabilities were of particular importance to results. Unfortunately not all groups within the Tokoroa community were represented in the stakeholder group – one notable exception was the elderly. A more thorough approach to gathering probability data could be made through a community survey.

Although qualitative information is available on negative health impacts of inadequate heating and toxic emissions from unflued gas heating, quantitative data that can be used in the decision support tool is not. This absence means that health-related costs are likely to be understated, particularly those scenarios where problems of inadequate heating, no heating and indoor pollution are exacerbated.

More general quality of life impacts, such as those related to loss of enjoyment of the local environment, ill health, and lost educational opportunities through time away from school are all outcomes with costs that are not easily quantifiable, and have not attempted to be quantified within this work. The decision support tool cannot account for quality of life aspects of decision making.

8 Recommendations

Recommendations arising from this study are as follows.

- A policy that provides for continuous lowering of PM_{10} levels is likely to offer the best value in the longer term, in view of the likelihood of continued pressure to reduce air pollution. The Proposed Waikato Regional Plan (www.ew.govt.nz/regionalplan) Section 6.3 lists the guideline for PM_{10} concentrations as 50µg/m^3 as a 24 hour average, and 20µg/m^3 as an annual average, and states that these guidelines are not ‘pollute up to’ levels, and that PM_{10} concentrations of 66-100 per cent of these levels are considered ‘degraded’.
- Investigate further the issues relating to moving from solid fuel domestic heating to electric heating – local air quality versus global air quality. Is there an issue? Will it change over time as New Zealand moves toward cleaner electricity generation?

- If regulation is introduced for woodburners, multifuel burners should be included within the regulatory framework, as being good economically and future-proofing policy.
- A mix of regulation and incentives is indicated as the best approach to a policy to reduce PM_{10} pollution in Tokoroa. Potentially achieving a higher reduction in PM_{10} concentrations, this two-pronged approach would capture a wider group within the community, and allow low-income households to participate in the air quality solution.
- Incentives for landlords should be part of an incentives programme, increasing the participation of this group.
- It may be necessary to monitor the level of solid fuel based uptake in order to achieve the NES objective for PM_{10} concentrations. Policy should be designed so that the level of woodburners replaced with NES-compliant woodburners is at a sufficiently low level to ensure policy success. Uncertain levels of PM_{10} emissions from NES-compliant woodburners and the expectation that many Tokoroa residents will want to remain with woodburners are two strong factors that could contribute to policy failure.
- Quality of life values should be considered alongside economic considerations, because although not possible to monetise, they have a strong influence on the value of people's lives.
- Other policy approaches, such as the inspection of pellet burners to ensure no faults and availability of bins for dry wood storage would be useful to be considered alongside main policies.
- A community survey to ground-truth the community response to policies is recommended. This study used a stakeholder group to assess probabilities in the decision support tool, and sensitivity analysis to examine the effect of variability in these probabilities. The ground truthing of earlier work will add credibility to the work done by the stakeholder group, and highlight areas where the stakeholder group may have erred in their deliberations.
- The decision support tool should be used to examine other policy alternatives prior to implementation. It has proved a useful tool for understanding the cost effectiveness of different policy choices, and for highlighting aspects of the policy which contribute to its failure or success both in achieving the air quality objective and in outcomes and costs of doing so.

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Appendices

Appendix 1: Models of health outcomes

i. RAD due to PM_{10}

Estimates of restricted activity days are based on the interpretation by the American Lung Association (ALA) of a study by Ostro (1987), which found 91,200 RAD each year for every 1 million population. Both Wilton (2005b) and Fisher et al. (2005) applied a dose-response relationship in calculations of RAD. The equation is:

$$Annual\,RAD = population * (91200/1000000) * annual\,average PM_{2.5}$$

As in Fisher et al. (2005) a 3.8μg/m^3 was applied, and Wilton's assumption of $PM_{2.5}$ being equal to 60 per cent of PM_{10}. For Tokoroa the average PM_{10} for 2005 was 25μg/m^3.[30]

ii. Hospitalisations

The relationship between particulate air pollution and hospital admissions (in Christchurch) with cardio-respiratory diseases was explored by McGowan et al. (2002). Findings of this study were that cardiac and respiratory admissions increased by 0.85 per cent and 2.28 per cent respectively with each 10μg/m^3 increase in daily PM_{10}. These figures represent the average over all age groups. Following Fisher (2005)[31], the annual number of hospital admissions is calculated as follows:

$$N_r = (DR/100) * H * Sum(E_i - B)$$

Where:

N_r = Annual number of respiratory hospital admissions attributed to PM_{10};
DR = the percentage increase in daily hospital admissions per 1μg/m^3 increase in PM_{10};
H = the baseline average number of hospital admissions per day;
Ei = the daily PM_{10} level;
B = the threshold PM_{10} level for its effects on hospital admission;
Sum = the summation of each of the 365 days into an annual number.

iii. Primary health care

Data on primary health care for PM_{10} related health effects is not readily available, and therefore the outcomes in terms of GP consultations and pharmaceuticals have not been established in the New Zealand studies undertaken by Wilton (2005a) or Fisher et al. (2005). However, the Fisher et al. study does estimate costs based on an assumption that primary health care costs are equal to 25 per cent of the costs for acute hospital admissions.

iv. Mortality

Assume that these outcomes are calculated even if not monetised…

Kunzli et al. (1999) estimated the effects of air pollution on public health, and the relationship between air pollution and sickness and death in Europe. Kunzli et al. estimated that the dose response relationship between PM_{10} and mortality was an increase in mortality of 4.3 per cent per 10μg/m^3 increase in PM_{10}. Kunzli's formula to calculate mortality was used by both Wilton (2005a) and Fisher (2005) for areas within New Zealand.

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[30] 2001 Census population for area units of Mangakaretu, Kinleith, Paraonui, Parkdale, Matarawa, Stanley Park, Tokoroa Central, Aotea, Strathmore and Amisfield 14,620 (Statistics New Zealand).
[31] Wilton (2005a) also based her figures for hospitalisations on McGowan's work.

Following Fisher (2005), the formula (Kunzli, et al.) for calculation of mortality is:

$$P_0 = \frac{P_e}{1 + [(RR - 1)(E - B)/10]}$$

Where:

- P_0 = baseline mortality per 1000 people, after deducting the air pollution effect (this will depend on the other variables).
- P_e = the crude mortality rate per 1000 people for the selected age group.
- E = PM_{10} exposure level in the area of interest.
- B = threshold PM_{10} exposure level for mortality effect (3.8µg/m^3 was applied for Christchurch).
- RR = the epidemiologically derived relative risk for a 10µg/m^3 increment of PM_{10}, assuming a linear dose-response relationship above the threshold (B).

The increased mortality is then calculated:

$$D_{10} = P_0 * (RR - 1)$$

Where:

- D_{10} = the number of additional deaths per 1000 people onto the baseline mortality for a 10µg/m^3 increase in PM_{10}.
- P_0 = baseline mortality per 1000 people, after deducting the air pollution effect
- RR = the epidemiologically derived relative risk for a 10µg/m^3 increment of PM_{10}, assuming a linear dose-response relationship above the threshold (B).

And then:

$$N_c = D_{10} * P_c * (X_c - B)/10$$

Where:

- N_c = the number of deaths due to PM_{10}
- D_{10} = the number of additional deaths per 1000 people onto the baseline mortality for a 10µg/m^3 increase in PM_{10}.
- P_c = the population (000)
- X_c = the PM_{10} exposure level.
- RR = the epidemiologically derived relative risk for a 10µg/ m^{-3} increment of PM_{10}, assuming a linear dose-response relationship above the threshold (B).

Appendix 2: Variables and sources

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
Households	Total dwellings	4451				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2005
Heating stock in Tokoroa	Total heating systems	5861	100 per cent			Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2006
	Electricity	1098	19 per cent	1043	1153	
	Open fires - wood	148	3 per cent	141	155	
	Open fires - coal	30	1 per cent	29	32	
	Multi-fuel burners - wood	252	4 per cent	239	265	
	Multi-fuel burners - coal	119	2 per cent	113	125	
	Oil	30	1 per cent	29	32	
	Gas (total)	1558	27 per cent	1480	1636	
	- Flued	748	48 per cent	711	785	
	- Unflued	810	52 per cent	770	851	
	Pre-1995 woodburners	1110	19 per cent	1055	1166	
	1995-2000 woodburners	698	12 per cent	663	733	
	Post-2000 woodburners	788	13 per cent	749	827	
	Woodburners (total)	2596	44 per cent	2466	2726	
	Pellet burners	30	1 per cent	29	32	
Emission Factors PM10 (g/kg)	Electricity	0	0 per cent			Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2006
	Open fire - wood	10				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2007
	Open fire - coal	21				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2008
	Multi-fuel - wood	13				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2009
	Multi-fuel - coal	28				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2010
	Oil	0.3				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2011
	Gas	0.03				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2012
	Pre-1995 woodburners	11				Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2013
	1995-2000 woodburners	8				Wilton, E (2006) Tokoroa Projections Model - Outputs and Assumptions.

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
	Post-2000 woodburners	7				Wilton, E (2006) Tokoroa Projections Model - Outputs and Assumptions.
	NES-compliant burners	6		4	8	Warm Homes Technical Report (June 2007) ME:813
	Pellet burners	1.4		0.7	3.9	Warm Homes Technical Report (June 2007) ME:814
Fuel Use (kg/day/unit)	Electricity	0.0			0.0	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2013
	Open fire - wood	17.6			24.3	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2014
	Open fire - coal	18.0			18.0	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2015
	Multi-fuel - wood	15.5			20.2	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2016
	Multi-fuel - coal	8.9			9.2	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2017
	Oil	3.3			3.3	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2018
	Gas	0.6			0.8	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2019
	Pre-1995 woodburners	26.5			30.4	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2020
	1995-2000 woodburners	26.5			30.4	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2021
	Post-2000 woodburners	26.4			30.3	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2022
	NES-compliant burners	26.0			30.4	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2023
	Pellet burners	8.0			8.0	Wilton, E (2005) Seasonal Variations in PM10 Emissions in Tokoroa 2024
COMMUNITY PREFERENCES						
Natural attrition	Owner-occupier making change		45 per cent	40 per cent	52 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to electric/gas		40 per cent	30 per cent	50 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		15 per cent	10 per cent	20 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- fixed system		85 per cent	80 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
	Owner-occupier to NES-compliant burner		75 per cent	70 per cent	80 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to pellet burner		15 per cent	10 per cent	20 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to multi-fuel burner		10 per cent	8 per cent	12 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier not changing system		55 per cent	50 per cent	60 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		5 per cent	0 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Rental home owners		30 per cent			Statistics New Zealand. 2006 Census.
	Landlord making change		30 per cent	10 per cent	35 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to electric/gas		20 per cent	10 per cent	30 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		50 per cent	45 per cent	55 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- fixed system		50 per cent	45 per cent	55 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to NES-compliant burner		90 per cent	85 per cent	95 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to pellet burner		6 per cent	5 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to multi-fuel burner		4 per cent	0 per cent	5 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord not changing system		70 per cent	65 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		5 per cent	0 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
Regulation	Owner-occupier making change		85 per cent	80 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to electric/gas		40 per cent	30 per cent	50 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		15 per cent	10 per cent	66 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- fixed system		85 per cent	34 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to NES-compliant burner		80 per cent	60 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier to pellet		15 per cent	7 per cent	30 per cent	Stakeholder workshop (August 2006). Updated

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
	burner					May 2007
	Owner-occupier to multi-fuel burner		5 per cent	3 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Owner-occupier not changing system		15 per cent	10 per cent	20 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		10 per cent	5 per cent	15 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord making change		30 per cent	20 per cent	40 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to electric/gas		20 per cent	10 per cent	30 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		60 per cent	50 per cent	70 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- fixed system		40 per cent	30 per cent	50 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to NES-compliant burner		85 per cent	80 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to pellet burner		7.5 per cent	0 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord to multi-fuel burner		7.5 per cent	0 per cent	10 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Landlord not changing system		80 per cent	70 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		20 per cent	10 per cent	30 per cent	Stakeholder workshop (August 2006). Updated May 2007
Incentives	Households with Community Services Cards		50 per cent	45 per cent	55 per cent	Estimate based on data from
						Statistics New Zealand (2006 Census). Work and Income NZ
	CSC - uptake subsidy		80 per cent	65 per cent	85 per cent	Stakeholder workshop (August 2006). Updated May 2007
	CSC-holder to electric/gas		32 per cent	22 per cent	42 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		0 per cent	0 per cent	0 per cent	Portable systems not subsidised
	- fixed system		100 per cent	100 per cent	100 per cent	Portable systems not subsidised
	CSC-holder to NES-compliant burner		65 per cent	55 per cent	75 per cent	Stakeholder workshop (August 2006). Updated May 2007
	CSC-holder to pellet		35 per cent	30 per cent	40 per cent	Stakeholder workshop (August 2006). Updated

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
	burner					May 2007
	CSC-holder to multi-fuel burner		0 per cent	0 per cent	0 per cent	Assume these are not subsidised
	CSC-holder not changing system		20 per cent	15 per cent	35 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		5 per cent	0 per cent	10 per cent	Assume similar to natural attrition values
	Non-CSC(owner) uptake subsidy		38 per cent	28 per cent	48 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Non-CSC (owner) to electric/gas		44 per cent	39 per cent	49 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		0 per cent	0 per cent	0 per cent	Portable systems not subsidised
	- fixed system		100 per cent	100 per cent	100 per cent	Portable systems not subsidised
	Non-CSC (owner) to NES-compliant burner		60 per cent	50 per cent	70 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Non-CSC (owner) to pellet burner		40 per cent	30 per cent	50 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Non-CSC (owner) to multi-fuel burner		0 per cent	0 per cent	0 per cent	Assume these are not subsidised
	Non-CSC (owner) not changing system		62 per cent	52 per cent	72 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating appliance		5 per cent	0 per cent	10 per cent	Assume similar to natural attrition values
	Rental - uptake subsidy		36 per cent	26 per cent	46 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Rental to electric/gas		55 per cent	45 per cent	65 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- portable system		0 per cent	0 per cent	0 per cent	Portable systems not subsidised
	- fixed system		100 per cent	100 per cent	100 per cent	Portable systems not subsidised
	Rental to NES-compliant burner		80 per cent	70 per cent	90 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Rental to pellet burner		20 per cent	10 per cent	30 per cent	Stakeholder workshop (August 2006). Updated May 2007
	Rental to multi-fuel burner		0 per cent	0 per cent	0 per cent	Assume these are not subsidised
	Rental not changing system		64 per cent	54 per cent	74 per cent	Stakeholder workshop (August 2006). Updated May 2007
	- Stopping using heating		5 per cent	0 per cent	10 per cent	Assume similar to natural attrition values

Category	Variable	Point est.		Low value	High value	Source
		Number	Per cent			
	appliance					
Resource costs	Cardio admission (avg)	8583				Waikato District Health Board
	Resp. admission	3466				Waikato District Health Board
	General Practitioner visit	38				Paul Brown (pers. Comm 4/05/07)
	Pharmaceutical costs					No figures found
	Work day lost	110.51				Chapman et al. (2004)
	Heater output for avg house (kW)	6				University of Otago and Wellington School of Medicine (2005)
Heating systems purchase	Electric portable	125				South Waikato District Council (2007) Home Heating Options
	Heat pump	3500				South Waikato District Council (2007) Home Heating Options
	Woodburner	3500				South Waikato District Council (2007) Home Heating Options
	Pellet burner	4000				South Waikato District Council (2007) Home Heating Options
	Gas portable	300				South Waikato District Council (2007) Home Heating Options
	Flued gas	2000				South Waikato District Council (2007) Home Heating Options
	Oil heater	125				Author assumed similar to electric portable
	Multi fuel burner	3000				South Waikato District Council (2007) Home Heating Options
	Open fires	4500				South Waikato District Council (2007) Home Heating Options
Heating systems operating	Electric portable (cents/kW)	17.50				South Waikato District Council (2007) Home Heating Options
	Heat pump (cents/kW)	7.50				South Waikato District Council (2007) Home Heating Options
	Woodburner (cents/kW)	8.00		0		South Waikato District Council (2007) Home Heating Options
	Pellet burner (cents/kW)	8.00		8	10?	South Waikato District Council (2007) Home Heating Options
	Gas portable (cents/kW)	21.00				South Waikato District Council (2007) Home Heating Options
	Flued gas (cents/kW)	17.00				South Waikato District Council (2007) Home Heating Options
	Oil heater (cents/kW)	17.50				Author assumed similar to electric portable
	Multi fuel burner	8.00				South Waikato District Council (2007) Home

Category	Variable	Point est.		Low value	High value	Source
		Number	**Per cent**			
	(cents/kW)					Heating Options
	Open fires (cents/kW)	25.00		0		South Waikato District Council (2007) Home Heating Options
	Hours operated per day	Variable				Based on survey work by Emily Wilton (2005).
PM10 in Tokoroa	Domestic Heating	853.00	89 per cent			SMITH, J (2007) Air Quality in the Waikato Region. Presentation to Councillors
	Outdoor burning	48.00	5 per cent			SMITH, J (2007) Air Quality in the Waikato Region. Presentation to Councillors
	Transport	48.00	5 per cent			SMITH, J (2007) Air Quality in the Waikato Region. Presentation to Councillors
	Industry	10.00	1 per cent			SMITH, J (2007) Air Quality in the Waikato Region. Presentation to Councillors
Demographics	Population	14260				Statistics New Zealand (2001 Census)
	Owner-occupied houses		70 per cent			Statistics New Zealand (2006 Census).
	Tenanted houses		30 per cent			Statistics New Zealand (2006 Census).
	Community Services Card					Based on Statistics NZ data for housing tenure,
	in owner occupied houses					family size and income (2006 Census)
	with older solid fuel bnrs		49.6 per cent		55 per cent	
	Tokoroa mortality data					New Zealand Health Information Service
	Respiratory admissions					Waikato District Health Board
	Cardio Admissions					Waikato District Health Board

Appendix 3: Multifuel burners

Two options for the treatment of multifuel burners are modelling. In the first (Regulation 1), multifuel burners are not regulated (as is their current status), while in the second (Regulation 2) applies as it does to woodburners. This differing treatment calls for different treatment within the model. In the following table, figures and explanations are given. In all cases, the age profile of multifuel burners is assumed to be the same as that of woodburners, that is 43 per cent pre-1995, 27 per cent 1995–2000, and 30 per cent post-2000.

	Clean/ unregulated heat	Solid fuel heating	Multi-fuel heaters	Explanation and assumptions
Regulation 1	63.5 per cent	26.4 per cent	15.0 per cent	Multifuel burners are unregulated regardless of age, however, it is assumed that pre-1995 burners have been replaced by 2013.
	3648	962	144	
Regulation 2	62.4 per cent	25.0 per cent	8.5 per cent	Pre-2000 multi-fuel burners are regulated, so are excluded from the unregulated heating mix.
	3580	894	76	
Natural attrition	75.7 per cent	38.2 per cent	8.7 per cent	Multifuel burners installed post-1995 are assumed still to be in operation and are included in the cleaner heat mix, along with woodburners of that vintage. Multifuel burners installed prior to 1995 assumed to have been updated.
	4346	1660	144	
Incentives	62.4 per cent	25.0 per cent	8.5 per cent	Households with pre-2000 solid fuel multifuel burners are offered a subsidy to replace with clean heating. Post-2000 multifuel burners included in clean heat figures.
	3580	894	76	