Ministry for the Environment
Manatū Mō Te Taiao

Quantification of Air Quality Co-Benefits from Climate Change Mitigation Measures

New Zealand Government

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Contents

Appendices

Figures

Tables

Executive Summary

New Zealand, along with the rest of the global community, faces a number of environmental problems that require actions from governments and citizens. Two of these problems are: poor air quality, leading to public health effects, and greenhouse gas emissions that affect the climate.

Scope

A number of measures exist to address these problems, and many are being enacted in New Zealand. They generally have costs and consequences – and in particular with these two emissions issues, what is beneficial for one, might be deleterious for the other, and vice versa. There are also measures that have positive gains for both issues: the co-benefits. This study examines a range of possible measures and assesses the potential co-benefits for both reducing greenhouse gas emissions, and reducing public health effects and costs through lower air pollution emissions.

Methodology

The air pollution health effects are based on the outcomes of a recent large study (The HAPiNZ study – *Health and Air Pollution in New Zealand*, 2007, available at www.hapinz.org.nz). This has quantified the effects associated with various sources of air pollution, in three major categories: domestic heating emissions (mainly from wood burners), vehicles emissions, and industrial emissions.

The greenhouse emissions are based on data in the 2006 official New Zealand reporting mechanism prepared by the Ministry for the Environment: *New Zealand's Greenhouse Gas Inventory 1990–2005* (MfE, 2007b).

Economics

To make the quantitative comparison, both effects have been costed and put in dollar values. It would otherwise be very difficult to compare the benefit of a tonne of carbon emission reduced, with say the reduced hospital admissions for air pollution effects. The public health costs for air pollution are taken from the HAPiNZ study, which are of the order of $1.14 billion (B) per year for all effects throughout the country. These comprise costs from premature mortality (at $750,000 each), for additional hospital admissions (at around $3,000 each), down to lower-level 'restricted activity days' (at $92 each). The cost of carbon emissions has been selected at $25 per tonne carbon dioxide-equivalent (CO_2-e). This is slightly higher than the $21 per tonne CO_2-e used by The Treasury in its December 2007 valuation of New Zealand's Kyoto liability, and possibly lower than expectations, but the results can be scaled appropriately if desired. The 2007 benefit-cost analysis for the New Zealand Energy Strategy used values of $15, $25 and $50.

There is a high degree of subjectivity in determining the costs of the air pollution health effects and the greenhouse gas emissions.

Results

The focus of the analysis has been on those sectors of the economy that have emissions of both air pollution and greenhouse gases. The analysis has been almost entirely upon activities producing CO_2, since other greenhouses gases have little or no air quality impacts. The analysis has thus focused on energy use in three main sectors – domestic, vehicle, and industry (where industry includes two main sub-categories – thermal electricity production and energy use in industrial processes).

Several assumptions have had to be made, to account for lack of specific data, and for regional differences. The analysis has been conducted using a number of scenarios, designed to be plausible, although not necessarily easy to achieve, such as "... what if general vehicle use was reduced by 10%?", or "... what if 25% of wood burner users switched to heat pumps?".

Domestic heating emissions

Increasing the use of wood burners by 25% has a health effect cost of up to $70 million (M) per year depending on the type of wood burner used. As wood is considered 'carbon neutral' there is no direct greenhouse gas benefit. There is only a greenhouse co-benefit, of up $12M, if users have switched from electricity and use new low-emissions wood burners, associated with thermal electricity generation. This includes a slight extra cost ($1M) due to the extra methane emissions from using wood as a fuel.

Conversely, if 25% of current wood burner users switch to efficient electricity (specifically heat pumps), there is a benefit in air pollution costs of up to $183M, with an increase in greenhouse costs of $3M from the extra electricity generation required.

Overall, for any move to increase wood burner use there is a small greenhouse emissions benefit (mainly due to offsets from thermal electricity generation), but a significantly larger air pollution cost.

Vehicle emissions

Almost any measure to reduce vehicle trips (by say 10%) will have benefits for both greenhouse gas emissions ($11–32M per year) and local air quality effects ($43–49M per year). The only increase (a modest $6M) occurs if bus use increases significantly, using buses with current emissions rates. In practice this is an overestimate, since many bus fleet operators are meeting new lower emission standards. Any switches to biofuels for transport (say 3–10% uptake) have a strong gain in reducing greenhouse emissions ($8–24M per year), roughly in proportion to the amount of imported petrol and diesel replaced. Biodiesel blends could also have a significant air quality benefit (up to $99M per year for 20% blend – although this is not well validated by current research). Ethanol in petrol blends probably does not have strong air quality benefits since (a) petrol vehicles are responsible for a small fraction of particulate pollution (associated with the main health effects), and (b) probably result in increased oxides of nitrogen emissions which can exacerbate the health effects (by up to $2M per year for E10, a blend with 10% ethanol). This latter factor has not yet been fully researched in New Zealand.

Overall, biofuels appear to offer strong co-benefits, although the research backing the air quality gains is by no means solid, and much depends on the formulations and types of biofuels used.

Industry emissions

As would be expected, any measures to reduce fossil fuel energy use in the industrial sector (say 5–20%) will have benefits for greenhouse gas emissions reductions ($6–26M per year). These also have modest air quality health effects gains (up to $28M per year), but only if the process does not involve industry switching to using wood, in which case the health costs increase (by up to $7M per year). Some of this wood combustion emissions effect could be reduced if processes were fitted with modern emissions control technology – but this would only be applied to the larger emitters, and needs substantial financing.

Summary

It is possible with existing data to make quantitative estimates in both physical and monetary terms, of the health co-benefits and co-costs (via changes in air quality) associated with measures to reduce emissions of greenhouse gases. They are indicative only because such estimates:

- do not cover all aspects of air quality
- are sensitive to a number of the assumptions made (eg, greenhouse gas (GHG) emission factor for electricity; level of 10-micron Particulate Matter (PM_{10}) emissions from an expanded population of wood burners)
- involve a high degree of subjectivity with regard to the monetary estimates.

The scenarios examined show that co-benefits are possible, but so are contrary outcomes. The clearest gains are obtained in the transport sector, with either (a) reducing the amount of general vehicle use, or (b) increasing biofuel use. Having people use wood burners more – ie, with a carbon neutral fuel – can have gains for reducing greenhouse gas emissions. However, these gains are almost certainly offset, and exceeded, by the larger cost rises in public health effects, even with new low emissions burners. Improving energy efficiency across the industrial sector also has modest gains and co-benefits for both greenhouse gases and air quality.

Using different values for key factors would change the relative benefits and costs, and the total net benefits, of the scenarios examined. Examples are the GHG emission factor for electricity; or the level of PM_{10} emissions from an expanded population of wood burners; and different values for the cost of GHG emissions on the cost of health effects.

1 Introduction

The New Zealand Government, at the highest levels, has become committed to being a leader in the global efforts to mitigate climate change by reducing greenhouse gas emissions. There are many possibilities, but these most come with some cost to the economy and to individual citizens and companies. Whilst 'zero-cost' initiatives and policies are obviously favoured, some of the other options can also generate co-benefits. One of the more obvious is in reducing energy consumption – thereby reducing the demand for fossil fuel use in transport, industry, power stations, and to some extent in the domestic heating sector. Such reductions in consumption have their own obvious co-benefits: for example, consumers can lower their energy bills. There are other co-benefits as well. For instance, reducing the use of fossil fuels will also reduce the incidence of air pollution; this results in health benefits to the community and reduced costs in the health system.

The initiatives analysed in this study seek to simultaneously address climate change and air quality through reductions of greenhouse gases (GHG) and air pollutants, respectively. The co-benefit measures addressed in this report allow for a more cost-effective use of scarce natural, financial, technical and human resources.

Co-benefits strategies that integrate air quality management with climate change mitigation can result in effective and sustained approaches towards the improvement of air quality – on the local, national and global scales.

Any new policies implemented should address the underlying causes of air pollution as well as GHG emissions.

2 Greenhouse Gas Mitigation – General

The goal of this study is to quantify the economic benefits of positive health impacts due improved air quality through various greenhouse gas mitigation options. The focus is on the domestic, transport and industrial energy sectors, since it is known that these sectors have the largest health effect with respect to air pollution (Fisher et al, 2007). The energy sector represents the second largest source of greenhouse gas emissions in New Zealand, after agriculture. Agriculture is responsible for about half of all New Zealand's greenhouse gas emissions; since few air quality benefits beyond odour can be achieved through reductions in agricultural emissions, they will not be addressed in this study. According to New Zealand's latest UNFCCC greenhouse gas inventory 1990–2005 (MfE, 2007b) the energy sector collectively represents 42.4% of all greenhouse gas emissions. Table 2.1 shows the sources of greenhouse gas emissions within the energy sector in New Zealand.

The focus of this study is on carbon dioxide (CO_2), which accounts for about half of New Zealand's total emissions – the rest being mainly methane from agricultural processes. Agricultural processes that generate methane do not generally emit other contaminants with health effects; consequently they have no significant public health cost associated with air pollution.

The majority of the figures from Table 2.1 are sourced from the greenhouse gas inventory (MfE, 2007b) with the exception of the road transport and residential heating breakdowns. The breakdown in emissions by vehicle type was achieved using the Vehicle Kilometres Travelled (VKT) from Transit's New Zealand Dynamic On-Road Transport (DOT) Model Fleet Hub. Similarly the residential heating breakdown was achieved using heating statistics from the Ministry for the Environment's Warm Homes Project. Emissions from biomass (wood and biogas) are included in the greenhouse gas inventory (MfE, 2007b) and are not included in totals, whereas here they have been included in the analysis, but excluded in the final accounting. Note that, with more recent data (Warm Homes) it is possible that the greenhouse gas inventory (MfE, 2007b) slightly underestimates the emissions from residential sources.

Table 2.1: Breakdown of annual greenhouse gases in the energy sector (2005)

Source of greenhouse gas emissions by sector	CO_2–e (kilotonnes)		Summary commentary Actions that may have a co-beneficial effect on air quality and greenhouse gas emissions reductions
Energy industries	**7,184**		There is potential for reducing the need for existing and new thermal power generation. Phasing out thermal power generating plants would reduce both GHG emissions and air pollution. However, air pollution from thermal generation affects relatively few people, so the health benefits are small. Measures such as large-scale use of solar hot water and domestic-scale renewable energy, use of energy efficient appliances, and reducing the use of electrical space heating, all have potential to decrease the demand for new and existing thermal power stations. Substituting heat pumps for electrical resistance heating could reduce the peak winter heating load. Some of the gains could be offset by increased use of air conditioning in summer.
Public electricity and heat production		6,066	
Petroleum refining		824	
Manufacture of solid fuels and other energy industries		294	
Manufacturing industries, building and construction	**5,093**		Substantial energy savings could be achieved through co-generation or by making use of the waste heat produced at various industrial and electricity generating and heating operations. Similarly industrial symbiosis could be examined. These initiatives involve industries working together to engage traditionally separate industries and other organisations in a collective approach, to add competitive advantage involving physical exchange of materials, energy, water and/or by-products together with collaboration on the shared use of assets, logistics and expertise.
Transport	**14,313**		Pollution and GHG emissions from personal transport could be decreased by reducing the total number of vehicle kilometres travelled (VKT). This could be achieved through a number of social, technical, and economic initiatives. Use of ethanol and biodiesel represent one such technical solution, however careful analysis of the 'embodied energy' is required to ensure an overall net positive GHG effect. Overseas research indicates that wide-scale use of biodiesel, more so than ethanol, can result in reductions in particulate emissions. Heavy commercial vehicles represent 16.6% of all toad transport GHG emissions in New Zealand (or 3.0% of total GHG emission); they are also major emitters of air pollution. Greater utilisation of rail for transporting freight represents a possible method to prevent HCV from entering heavily populated areas.
Road transport		12,602	
a Cars (petrol)	8,645		
b Cars (diesel)	598		
c LCV (petrol)	76		
d LCV (diesel)	723		
e HCV (petrol)	99		
f HCV (diesel)	2,096		
g Buses (petrol)	68		
h Buses (diesel)	298		
Civil aviation		1,203	
Railways		172	
Marine		336	
Other sectors	**6,333**		The need for domestic heating can be reduced by improving building envelopes (eg, better insulation, weatherproofing, etc). There is evidence to suggest that some efficiency gains will be negated by increased home temperatures. Measures aimed at reducing humidity levels in homes would allow for lower indoor temperatures with no impact on comfort levels. Biomass fuel represents a renewable energy supply with little or no net greenhouse gas emissions. However, air pollution due to large-scale burning in populated areas has serious health implications. Pellet burners and low-emission wood burners represent one possible solution.
Commercial/institutional		1,705	
Residential		3,457	
a Open-fire wood	386		
b Open-fire coal	74		
c Pre-1994 wood burner	1,097		
d 1994–1999 wood burner	836		
e Post-1999 wood burner	291		
f Multi-fuel burner – wood	371		
g Multi-fuel burner – coal	289		
h Gas	114		
Agriculture/forestry/fisheries		1,170	
Fugitive emissions from fuels	**1,582**		Not covered in this study

3 Air Pollution – General

Any assessment of the health effects due to air pollution is extraordinarily complex. Firstly, assessing the level of air pollution is not a trivial exercise, as it is highly variable in space and time, affected by the weather, by what is being emitted through various activities, and by very location-specific features such as valleys and where people live and work in relation to the sources. The major source categories are summarised in Table 3.1, with further details provided in Appendix A.

Secondly, although the concept that 'dirty air' is bad for people has been known since ancient times, it is only within the last decade that the mechanisms have started to be identified. Furthermore, a great number of large-scale epidemiological studies have shown that effects can occur at quite low levels of pollution, over a wide range of people due to a number of different exposure scenarios – eg, which pollutant, over what time period, under which activity.

Finally, there is no one measure of 'air pollution'. It is a common public perception that air pollution is a single thing – and most evidenced by visible pollution such as smoke. However air pollution comprises many components, not all of which are obvious or even detectable by people, and each of which can have different effects:

- Particulates (commonly assessed as PM_{10}) – very fine particles that can be visible, but are often not obvious – affects pre-mature mortality, and exacerbates a number of respiratory problems.
- Carbon monoxide – a colourless gas – affects mortality slightly, but exacerbates heart disease, causes drowsiness and learning difficulties. Is strongly correlated with PM_{10} in cities.
- Nitrogen dioxide – a slightly brown gas (only detectable when present over large areas) – causes breathing problems, exacerbates asthma and other respiratory problems. Tends to be well correlated with PM_{10}.
- Sulphur dioxide – a pungent gas – causes sore throat and eyes, and can have an effect on mortality. Not usually present in high concentrations in New Zealand.
- Ozone – a colourless gas – present naturally, but can cause severe breathing problems in high concentrations. Not presently a serious problem in New Zealand.
- Benzene – a component of petrol (along with numerous other hydrocarbons) – can lead to cancer.
- Toxics – a whole range of other toxic compounds, including complex organic chemicals, process chemicals, and heavy metals. Little is known about many of these.

In summary, whilst some health effects are well known, others are not, and the state of knowledge is still developing rapidly.

This report treats air pollution and greenhouse gases as two separate entities. In addition to the source linkages between climate change and air quality, evidence exists which shows that air pollutants, especially troposphere ozone and particulate matter, play an important role in the climate system (Heywood and Shine, 1995). Air pollutants may affect climate in different ways. Tropospheric ozone is a greenhouse gas (GHG) and thus has a warming effect on the atmosphere. Particles have either a cooling effect on the atmosphere through scattering of shortwave radiation (sulphate and organic carbon particles) or a warming effect through absorption of shortwave radiation (black carbon particles). In addition to the direct effects of scattering or absorption, particles may indirectly influence climate by affecting clouds and the albedo of snow and sea ice.

Table 3.1: Breakdown of sources of air pollution (PM_{10}) emissions (2005)

Source of emissions	Emissions (kilotonnes per year)	Commentary
Domestic	13.5	Domestic sources are primarily emissions from the use of wood and coal in home-heating appliances. Home heating is the major source of winter air pollution in New Zealand's towns and cities. Christchurch experiences 25 to 30 days on which the particles standard is exceeded each winter. In many areas (on both the North and South Island) domestic heating can contribute around 80–90% of the daily winter particle emissions. Other domestic sources can include: • surface coating and thinners • aerosols • service stations / refuelling • fuel combustion • lawn mowing • cutback bitumen • natural gas leakage • off road vehicles • dry cleaning • domestic waste combustion (burn-offs) • other unaccounted for industrial/commercial emissions.
Industry	3.2	Large industrial installations can generate considerable quantities of air contaminants from a single source. Industrial sources include major industries such as power generation, the pulp and paper industry and dairy processing. Power generation from the burning of fossil fuels is a significant source of air pollutants. Reducing consumption of electricity has an immediate effect on air quality by reducing emissions. However, New Zealand has relatively few large industrial emitters; these are often located at some distance from heavily populated areas and are subject to local authority discharge rules. Other industrial sources can include: • food manufacture • mining and quarrying • chemical manufacture • non-metallic minerals • metal manufacture • can coating • fabricated metals • printing • fuel storage.

Source of emissions	Emissions (kilotonnes per year)	Commentary
Transport	2.1	Transport sources are primarily from internal combustion engines (vehicles) on the national roads, using petrol and diesel. Diesel effects are greatest, and are classed as cars, light commercial vehicles, heavy commercial vehicles and buses. Key generic issues of importance also effecting vehicle emissions include the composition of the fleet, the state of tuning of vehicles, congestion levels, weather factors and road design features. New Zealand has one of the highest vehicle ownership rates in the world. Other transport sources can include: • marine pleasure craft/ shipping • rail • aviation.
Biogenic sources	n/a	• Vegetation. • Soil • Sea spray.

3.1 Calculating air pollution emissions

The emissions figures given in Table 3.1 are estimates. There is currently no national emissions inventory, although a project is underway to develop the first one for New Zealand. Most regional councils have developed air pollution emissions inventories for their regions or for the major towns within their regions. These are used to track reductions measures and as input to air pollution studies such as airshed modelling (see summary in Appendix A). Some these are very detailed and have gone through several iterations. However there has been no serious attempt to accumulate all of the information and there are still regions of the country where a detailed emissions inventory has not been completed. The analysis is further complicated since different councils have used different categories – for example there is no consistent view on what sources should be included in the 'industrial' category, or whether the 'transport' category should include off-road vehicles or not, or aviation, etc.

For the purposes of this analysis, an estimate has been made on an adjusted population basis, using emissions data from those places where specific analyses have been done (listed in Appendix A). These include the major population centres of Auckland, Wellington and Christchurch as well as several other smaller towns and regions. There are regional variations that have been accounted for – such as the heavier traffic density in Auckland, the greater use of wood burning for home heating in more southern towns and those near forests, and the distribution of industries. This is a similar methodology that was used in the HAPiNZ Study (Fisher et al, 2007) to estimated PM_{10} concentrations in 67 cities and towns throughout New Zealand. It has proved reasonably robust for that purposes.

It should be noted that the kilotonnes per year figures given are for indicative purposes only – they are not used further in the co-benefits analysis, which is based on actual pollution concentrations in the air rather than on emissions *per se* (of course the two factors are closely related, but in a complex way that depends on the local meteorology and topography).

4 Overseas Research

A similar study on air pollution / GHG reduction co-benefits for Canada has been conducted by the David Suzuki Foundation. The study which examined a number of measures chose the following six for an indepth analysis:

- vehicle fuel economy standards
- fuel taxes
- increased public transit
- fuel switching in electricity generation
- more renewable resources in electricity generation
- community building energy efficiency improvement retrofits.

These measures, which assumed a significant degree of uptake, produced a 9% reduction in GHGs, a 9% reduction in SOx, a 7% reduction in NOx, a 1.4% reduction in VOCs, and a 1% reduction in PM by 2010. This is an example of co-benefits, but is not directly transferable to New Zealand. In many northern hemisphere countries (including Canada) there are significant air quality effects due to SOx, NOx and VOC (through secondary effects due to ozone). New Zealand does not have any similar significant effects due to SOx or VOCs. It does have effects due to NOx and PM_{10}, so it is possible that gains of a similar order to the Canadian assessment could be made.

In the United Kingdom the Department for Environment Food and Rural Affairs (Defra) commissioned the Air Quality Expert Review Group (AQEG) to examine the linkages between climate change and air quality pollutants and their potential mitigation policies (AQEG, 2007).[1] This data could be considered in further assessing the relationships relevant in New Zealand, taking into account that the key air pollution issues will be different.

In addition, the Royal Society, the United Kingdom's National Academy of Science, began a major study into the impact of climate change on global air quality in January 2007. The study looks at how ground-level ozone, a major pollutant and greenhouse gas, may interact with the climate system to affect air quality and possibly influence climate change over the next century. It will also consider the impact of ground-level ozone on human health and the environment. Their study was to be made available towards the end of 2007.[2]

Some published work has an analysis of the potential impacts of increasing global temperatures on people's behaviours and potential emissions of local air pollutants in New Zealand. Examples are greater use of air conditioning in summer and decreased use of heating in winter, and the potential increase in evaporative emissions from petrol. These secondary effects have not been included here as they would require a substantial degree of analysis; they may also introduce a level of uncertainty into the results that is not warranted, simply because the basic underlying research has not been conducted in New Zealand.

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1 http://www.royalsoc.ac.uk/news.asp?id=5830

2 ibid.

The Campaign for Clean Air in London recently (August 2007) commented:

> *Air pollution needs to be tackled holistically with sensible judgments being made in the inevitable trade-offs between air quality and climate change. A classic example is the latest Department for Transport 'Act on CO_2' calculator which is likely to encourage people to choose cars with diesel engines because of their small CO_2 (ie, climate change) advantage even though that generates substantially more of the hazardous particulate matter and nitrogen oxides. We should question whether there is still a place for diesel engines in large cities while there is such a serious public health problem. Instead, we recommend a simple approach to these complicated air pollution trade-offs in cities [through] an 'Air Pollution Trade-off Principle'.*
>
> *Treating air pollution holistically requires difficult trade-off decisions between air quality and climate change issues. The Campaign for Clean Air in London encourages policy makers to accept a dis-benefit of up to 5% in climate change terms provided there is an associated benefit of over 50% in air quality terms (and vice versa) ie, one to 10. Such an approach to trade-offs should be considered acceptable since large benefits may be hard to find and small dis-benefits can be rectified relatively easily through other policy measures.*[3]

Such a 'trade-off' policy could be explored for use in New Zealand, but its implications have not been explored here.

In Europe, on 10 January 2007 the European Commission set out proposals and options for keeping climate change to manageable levels in its Communication *Limiting Global Climate Change to 2° Celsius: The way ahead for 2020 and beyond*. This document also considers the potential impacts of climate change reduction measures on air pollution. It states:

> *Action on climate change also reduces air pollution. For example, reducing CO_2 emissions in the EU by 10 % by 2020 would generate enormous health benefits (estimated at € 8 to 27 billion). Such policies will therefore make it easier to attain the objectives of the EU's strategy on air pollution.*

The impact assessments[4] for this Communication contain some useful information about how these figures were calculated.

In general there is little relevant overseas research and many of the results are not directly applicable to New Zealand. Of what little research is available, one of the features is lack of consistency, and authors make repeated points about the need for further, more detailed research and analysis. For instance, several studies from the USA and Australia (discussed in detail in Appendices B and C) show that the implementation and uptake of biofuels can have variously positive or negative effects on air quality and greenhouse emissions.

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[3] http://www.bbc.co.uk/dna/actionnetwork/A25804262

[4] http://www. ec.europa.eu/environment/climat/pdf/ia_sec_8.pdf

5 Methodology – Air Pollution Health Effects

The methodology required for quantifying the health effects of air pollution is derived from the *Health and Air Pollution in NZ* (HAPiNZ) study, a joint initiative from the Health Research Council, the Ministry for the Environment and the Ministry of Transport (Fisher et al, 2007). This study represents the most comprehensive analysis of air pollution, its health implications, and the resulting societal costs conducted in New Zealand. The research evaluated the effects of specific source categories of emissions from vehicles (including private petrol cars, diesel cars, and diesel trucks), industry, domestic and total sources in New Zealand.

The research encompassed five interconnected components:

- air quality, meteorology and emissions data analysis
- air pollution exposure assessment
- health impact assessment
- economic impact assessment
- preventative policy assessment.

A more detailed explanation of the methodology can be found in the HAPiNZ report. Tables 5.1, 5.2 and 5.3 summarise the health effects of air pollution from domestic, transport, and industrial sources, respectively.

Table 5.1: Annual health effects associated with domestic sources, including from particulate matter (PM_{10}) and carbon monoxide (CO)

	Premature mortality (PM_{10})	Premature mortality (CO)	Bronchitis	Respiratory and cardiac admissions	Cancer	Restricted activity days (000s)
Auckland	50	10	125	57	3	155
Wellington	7	1	17	8	0	22
Christchurch	89	18	222	101	5	276
Dunedin	11	2	27	12	1	34
Hamilton	11	2	27	12	1	34
Rest of North Island	107	21	267	121	6	332
Rest of South Island	81	16	202	92	4	251
All of New Zealand	**356**	**70**	**887**	**404**	**19**	**1,105**

Table 5.2: Annual health effects associated with transport sources, including from particulate matter (PM_{10}) and carbon monoxide (CO)

	Premature mortality (PM_{10})	Premature mortality (CO)	Bronchitis	Respiratory and cardiac admissions	Cancer	Restricted activity days (000s)
Auckland	183	38	239	109	10	297
Wellington	12	2	16	7	1	19
Christchurch	45	9	59	27	2	73
Dunedin	6	1	8	4	0	10
Hamilton	17	4	22	10	1	28
Rest of North Island	126	26	165	75	7	204
Rest of South Island	25	5	33	15	1	41
All of New Zealand	**414**	**85**	**542**	**247**	**22**	**672**

Table 5.3: Annual health effects associated with industry, including from particulate matter (PM_{10}) and carbon monoxide (CO)

	Premature mortality (PM_{10})	Premature Mortality (CO)	Bronchitis	Respiratory and cardiac admissions	Cancer	Restricted activity days (000s)
Auckland	51	9	45	21	2	56
Wellington	6	1	5	2	0	7
Christchurch	17	3	15	7	1	19
Dunedin	5	1	4	2	0	6
Hamilton	6	1	5	2	0	7
Rest of North Island	34	6	30	14	2	38
Rest of South Island	12	2	11	5	1	13
All of New Zealand	**131**	**22**	**116**	**53**	**6**	**145**

Monetary estimates of the air quality benefits are based on the assumptions made in the HAPiNZ study, which was based on previous research in New Zealand (described in detail in Fisher et al, 2007), and results from overseas studies adjusted for New Zealand conditions. Table 5.4 gives a summary of the specific health effects and their cost per case as was used in the HAPiNZ study. These are not personal costs, but costs to the NZ economy – the external costs of air pollution.

Table 5.4: Summary of costs of events used in the analysis

Effect	Cost per unit
Mortality	$750,000
Bronchitis	$75,000
Other admission (respiratory)	$2,700
Other admission (cardiovascular)	$3,675
Cancer	$750,000
Restricted activity day	$92

These figures have a degree of subjectivity, and are estimates only. There is no international agreement on how to apply economic analysis – and the values used in various countries can differ widely. For instance the premature mortality is argued to be as low as $50,000 to as high as $6,000,000, with the New Zealand Ministry of Transport adopting $2,700,000 for road crash death costs. The figures used here are reasonably conservative estimates, calculated for New Zealand circumstances. Different studies may apply different costs. In addition, there are some effects that are not studied, nor explicitly costed, mainly because the research results are not available. These include asthma cases, short-term effects, and toxic effects. Similarly some effects will incur additional costs that are difficult to quantify, including costs of extra doctors visits and medication, lower-level effects due to mild but perhaps widespread effects from drowsiness, headaches, loss of attention, and quality of life that may not be included in the restricted activity day analysis. Finally the general economic effect of perceptions of 'poor air quality' on tourism and recreation are not negligible, although beyond the scope of this study.

5.1 Air pollution health effects summary

The total costs of health effects of air pollution can be estimated from the health effect and the cost per case of that effect, shown in Table 5.5. The largest component of the 'economic health burden' is the loss of life-years as a result of premature mortality, followed by restricted activity days, and then chronic bronchitis.

Table 5.5: Summary valuation of annual health effects in New Zealand due to domestic, industrial and transportation related air pollution ($ million)

Effect	Domestic	Vehicle	Industrial	Total
Mortality (due to PM_{10}, NO_2)	267.0	310.5	98.3	675.8
Mortality (due to CO)	52.5	64.5	16.5	133.5
Bronchitis and related	66.5	40.6	8.7	115.8
Respiratory/cardiac admissions	1.2	0.7	0.2	2.1
Cancer	14.3	16.5	4.5	35.3
Restricted-activity days	101.7	61.7	13.3	176.7
Total	**503.2**	**494.6**	**141.5**	**1,139.2**

These costs are used to make a basic comparison with the greenhouse costs, although there remains a high degree of subjectivity in determining these costs (as with the greenhouse gas costs).

6 Methodology – Greenhouse Gas Emissions

There are several sources of information on greenhouse gas emissions, but here the data from the latest New Zealand Government greenhouse gas inventory are used (MfE, 2007b).

These are grouped here into the same three categories as the air pollution health effects calculations. These categories are not completely consistent with those used for the greenhouse gas emissions assessments, and the data have been re-grouped to fit this categorisation. It has been done this way – rather than trying to re-group the air pollution data – since it is the easier of the two methodologies. It also reflects the priority areas and those sectors most likely to be identified for co-benefits.

6.1 Data sources

The main data source for sector greenhouse gas emissions is the national emissions inventory, updated in 2007, but there are several other sources and not all of the figures are consistent. Another source referenced is the Ministry of Economic Development's latest report on greenhouse emission from the energy sector (MED, 2007). This gives more detailed information on emissions from various energy sources and is updated annually. Other sources used include the IPCC for emission factors and various related and recent studies carried out on detailing emissions.

One problem in using some of these data sources is that the sectoral breakdowns are not equivalent, making comparison between data sources difficult, and leaving the co-benefit analysis open to alternative interpretations.

Most of the figures used are reasonably consistent across the various data sources. For instance the Ministry for the Environment national greenhouse gas inventory gives the 2005 CO_2 emissions from land transport as 12.6 Mt/year (when all the relevant categories are summed). The Ministry of Economic Development energy use figure gives this as 12.7 Mt/year. The difference is not fully accounted for, and is likely to result from the two methodologies not including exactly the same categories. However this level of difference is very minor and will not alter the outcomes of this co-benefit analysis significantly.

A greater level of discrepancy can be found in the estimates of CO_2 emissions from wood burners used for home heating. In one sense these can be listed as zero, since there is judged no net release of CO_2 from biofuels, but the emissions are included in the analysis here since they have a major impact of local air pollution and health effects. The Ministry of Economic Development figures are substantially lower than those used by the Ministry for the Environment (as well as those used by Regional Councils in various regional emissions inventories). The reasons for this have not been fully investigated – they may include factors such as the large fraction of unreported, self-collected wood that is known to be used for home heating. The analysis here has adopted to follow the emissions figures from the Ministry for the Environment inventory, which are consistent with the Regional Council data. These data are judged to be more reliable since they are based on much more detailed and specific survey data than that used by the Ministry of Economic Development.

6.2 Domestic heating

The source of data on fuel used (and hence emissions) in New Zealand is the Household Energy Efficiency Programme (HEEP) (BRANZ, 2006). Having run for 10 years, this gives a comprehensive view of energy use in this sector, summarised in Table 6.1.

This shows that for heating, 57% of households use electricity, 52% use wood (many households will have multiple fuel sources), 34% gas, 7% coal, and a negligible amount of other fuels (such as oil). The total domestic heating consumption on an average winter's day in July is 15,490 tonnes of wood, 1,442 tonnes of coal, and 375 tonnes of gas. These 'average day' figures are derived by tracking the consumption through the winter months (defined as June, July and August) and taking an average daily figure.

Table 6.1: Domestic home heating methods and fuels used, New Zealand

	Households		Winter fuel use (July)	
	%	Number	Tonnes per day	%
Electricity	57%	816,907	–	–
Total gas	34%	487,278	375	2%
Flued gas	9%	134,939	–	–
Unflued gas	24%	352,339	–	–
Oil	2%	28,663	0	0.0%
Open fire	6%	85,990	–	–
Open fire: wood	6%	85,990	2,080	12%
Open fire: coal	2%	28,663	295	2%
Total wood burner	38%	544,605	11,412	66%
Pre-1994 wood burner	16%	235,724	5,915	34%
1994–1999 wood burner	12%	178,825	4,077	24%
Post-1999 wood burner	9%	130,055	1,420	8%
Multi-fuel burners	8%	114,654	–	–
Multi-fuel burners: wood	8%	114,654	1998	12%
Multi-fuel burners: coal	5%	78,824	1,149	7%
Pellet burners	0%	0	0	0%
Total wood	52%	745,249	15,490	89%
Total coal	7%	107,488	1,443	8%
Total	**100%**	**1,440,336**	**17,308**	**100%**

Source: Reproduced from the Warm Homes Technical Report (MfE, 2005).

The greenhouse gas emissions from these sources are calculated using the emissions factors in Table 6.2, with the overall result shown in Table 6.3. The data in this table is given in terms of CO_2 emissions per winter day. In most of the country, these emissions will be close to zero on summer days. The resulting total emission for home heating, at 25.3 kilotonnes per day, is broadly consistent with the 'other sectors' greenhouse gas inventory total of 3,437 kt/year, if it assumed there are 136 days in winter, and wood is used evenly throughout these days (25.4 kt/day). This is not unreasonable, since 'winter' is often defined in the South Island as lasting up to 180 days, but in the warmer North Island might be only 90 days or less. For the purposes of this study, a figure of 140 days has been used for the length of 'winter'. It is assumed that amounts of wood used outside of the winter period, whilst not zero, are very small relative to the winter amounts

Table 6.2: Home heating CO_2 emissions factors, gross calorific values (2005)

Fuel type	kt CO_2/PJ	kt CO_2/PJ	MJ/kg	Emission rate used[2]
Wood	104.2	108.5	12.8	1,350 g/kg
Bituminous coal[1]	88.8	92.7	22.6	2,000 g/kg
Sub-bituminous coal[1]	91.2	94.1	29.9	2,600 g/kg
Oil	68.7	73.3	46.0	3,000 g/L
Gas/LPG	60.4	62.8	49.7	2,700 g/kg

Data sources: Energy GHG Emissions for NZ (MED), IPCC, Energy Data File (MED).

Notes:

1 Assume that 58% coal is sub-bituminous – therefore average emission rate of 2,350 g/kg used.

2 The emissions rates used in this analysis are calculated using the MED figures, and rounded. The analysis is not greatly sensitive to these figures, since the uncertainties in other parts of the analysis are larger than the emission rate uncertainties.

Table 6.3: Home heating CO_2 emissions totals, day in winter (2005)

Fuel	Amount used (tonnes)	Emission factor (kg/tonne)	Total emission CO_2 (kilotonnes)
Wood	15,490	1,350	20.9
Coal	1,443	2,350	3.4
Gas	375	2,700	1.0
Oil	<1	3,000	<0.001

So far it has been assumed that emissions of non-CO_2 greenhouse gases are negligible from this sector. The data in Table 6.3 define the baseline emissions of CO_2 for the domestic heating sector. However the emissions of other greenhouse gases, whilst small in relative terms, are not negligible and need to be included as they are not judged greenhouse neutral. Table 6.4 shows the CO_2 equivalent emissions from home heating due to methane (CH_4). The emissions of nitrous oxide (N_2O) are much smaller, and less than 1%.

Table 6.4: Home heating methane emissions totals, day in winter (2005)

Fuel	Amount used (tonnes)	Emission factor CH_4 (kg/tonne)[1]	Total emission $CO_{2\text{-}e}$ (kilotonnes)
Wood	15,490	77.5	1.2
Coal	1,443	156	0.2
Gas	375	0.9	<0.001
Oil	<1	0.9	<0.001

1 Takes account of the greenhouse warming potential factor of 21. The emissions factors are taken from the MED 2007 NZ Energy Greenhouse Gas Emissions data.

GHG emissions and air pollution resulting from residential heating can be reduced by a variety of technical, political and social initiatives. In general, the emissions can be reduced by the following:

- reducing the demand for heating:
  - improved building envelope
  - insulation
  - improved building design (passive solar)
  - smaller homes
- improving the efficiency of the heating:
  - heat pumps
  - reduce the number of open fires
- switching to less pollution methods of heating:
  - low-emissions wood burners
  - pellet burners
  - heat pumps.

6.3 Transport

Only land transport is assessed here. Marine and aviation do not generally contribute anything significant to air quality effects. Similarly off-road vehicle emissions (including farm vehicles) are insignificant contributors. The basic land transport fleet emissions profile is given in Table 6.5, reproduced from the greenhouse gas inventory (MfE, 2007b).

Table 6.5: Annual greenhouse gas emissions from the land transport fleet (2005)

Category[1]	CO_2 (t/yr)	CH_4 (t/yr)[2]	N_2O (t/yr)[2]	Total (t/yr)[2]	Percentage of GHG emissions[1]	Percentage of VKT[1]
Cars (petrol)	8,590,470	3,653	641,037	9,235,160	68.6%	72.2%
Cars (diesel)	634,499	1,042	3,354	638,895	4.7%	5.7%
LCV (petrol)	75,503	32	5,634	81,169	0.6%	6.3%
LCV (diesel)	767,095	1,260	4,055	772,410	5.7%	6.9%
HCV (petrol)	100,549	26	5,563	106,138	0.8%	0.5%
HCV (diesel)	2,186,968	1,960	50,442	2,239,370	16.6%	7.1%
Buses – petrol	68,519	18	3,791	72,327	0.5%	0.3%
Buses – diesel	310,358	278	7,158	317,794	2.4%	1.0%

1 LCV = light commercial vehicle; HCV = heavy commercial vehicle;
GHG = greenhouse gas, VKT = vehicle kilometres travelled.

2 Estimates are reported in units of CO_2 equivalents using Global Warming Potentials published in the IPCC Second Assessment Report. The emission factors are substantially the same as those given in the Third IPCC Assessment report. Any uncertainties in these totals will be dominated by uncertainties in determining the fleet profile rather that in the emissions factors themselves.

Table 6.5 shows that the largest source of transport emissions is petrol cars (68%), followed by heavy-duty diesel trucks (17%), and then diesel cars and light commercial vehicles (10%). Because of their prevalence on the road network, and their air pollution emissions, diesels are also the vehicles responsible for the greatest air quality health effects (diesel vehicles have on average 25 times higher emission rates of PM_{10} than petrol vehicles).

There are two types of petroleum used in New Zealand – locally refined and imported. All New Zealand petroleum refining takes place at the NZ Refining Company Ltd plant at Marsden Point. All of the fuel processed there is consumed in New Zealand, and all associated emissions are assumed covered above. The refinery itself produces air pollution and greenhouse gas emissions, but these are a relatively small fraction of the total. Imported fuel is a small portion of the total and is included in the figures in Table 6.5.

As with the domestic heating emissions, there are a number of options available for reducing emissions from the transport fleet:

- reducing total vehicle-kilometres of travel by:
  - improving sustainable transport, including through encouraging high occupancy vehicle use and promoting walking, cycling and public transport
  - promoting rail as an alterative method for transporting freight
- reducing fuel consumption per kilometre by:
  - encouraging or mandating fuel-efficient and environmentally friendly vehicles and technologies
- reducing pollution/GHGs emitted per unit of fuel consumption by:
  - implementing wide-scale biofuel use
  - improving fuel quality
  - improving engine performance (ie, encouraging all vehicles to be properly tuned).

Some progress on the initiatives discussed can be made through driver education and public awareness campaigns. However, it is likely that regulations, or economic incentives, will need to be implemented at the national, regional, and local levels to make significant headway in reducing the environmental impacts of road transport.

6.3.1 Biofuels

In principle, the burning of biofuels represents an approximately carbon neutral process. However, factoring in the energy required to plant, tend, harvest, process and transport the finished product can make the equation less favourable. There is currently a debate within the scientific community regarding just how much input energy is required to produce, process, and transport biofuels. Given the wide range of feedstocks available (such as tallow, cereals, soybean, rape seed oil, sugar cane and palm oil) and the variety of growing conditions, as well as the various fuels that can be used to process and transport, there is no clear cut answer. Much of the research on ethanol has been conducted in the USA and is based on corn-based ethanol. Appendices B and C provide data on the major studies exploring the net energy balance for corn-based ethanol in the USA and Canada. Studies located above the ‘zero line’ found that ethanol had a positive net fossil energy value (ie, less fossil energy is used to produce ethanol than the energy that is available in ethanol). Studies below the ‘zero line’ found that ethanol had a negative fossil energy value. This may not be directly transferable to the New Zealand situation, since the assessment is sensitive to:

(a) the biofuel feedstock used

(b) the process employed to produce the biofuel

(c) indirect effects such as transport and land use.

The conclusions of a US EPA study which examined the results of 80 studies related to the tailpipe emissions from biodiesel (US EPA, 2002) indicate that a blend containing 20% biodiesel and 80% conventional diesel by volume would have an approximate 10.1% reduction in tailpipe PM_{10} emissions. Since biodiesel burns hotter, nitrogen oxide (NOx) emissions are actually higher than conventional diesel. However not all studies agree with this conclusions. In Australia, one study concluded there was no benefit at all (Beer et al, 2004). Most studies recommend further research before any strong conclusions can be drawn.

American and European studies on biofuels can not easily be adapted to New Zealand conditions, hence life-cycle GHG emissions of biofuels in New Zealand are still very much unknown. In addition, the impact that biofuels will have on air pollution is still uncertain, including its potential negative impacts on new pollutant emissions such as acetaldehyde. Before large-scale biofuels targets are implemented, a full analysis on the costs and benefits should be conducted. It is also suggested that research is conducted to determine which of the available energy crops (and waste streams) are able to produce the biofuels most efficiently and with minimal environmental impact in New Zealand. While imported biofuel will not require a large amount of input energy from a New Zealand perspective, an understanding of the embodied GHG emissions should still be required to ensure sustainability.

Ethanol-burning cars will emit fewer carcinogens such as benzene and butadiene, but they can emit 20 times as much acetaldehyde as those using conventional fuel. Acetaldehyde can react with sunlight to form ozone, one of the main constituents of smog (Jacobson, 2006). A further problem, indicated by many of the emissions studies, is that while emissions of some pollutants (such as PM_{10} and CO) can go down, others (such as NOx) can go up because the fuel is burning hotter. This makes a health effects analysis difficult, since the gains from reduced PM_{10} may be offset by the losses from increased NOx.

For the purposes of this study, it is assumed that:

1. all biofuel is carbon neutral, resulting in a greenhouse gas emissions saving
2. the government target 3.4% blend results in a PM_{10} emissions reduction of 5%
3. E10 ethanol blends in petrol result in a PM_{10} emissions reduction of 10%
4. B20 biodiesel blends result in a PM_{10} emissions reduction of 20%.

These figures are very preliminary, indicative only, and should not be regarded as having a great deal of scientific rigour (see summary in Appendix B).

6.4 Industry

The energy industries sub-sector comprises public electricity and heat production, petroleum refining, and the manufacture of solid fuels and other energy using industries. The air pollution resulting from these operations is generally localised, for the most part, affecting only the communities within the immediate vicinity of the plant.

6.4.1 Electricity generation

All of the major thermal electricity producers in New Zealand are listed in Appendix D. Assessing the greenhouse emissions accurately from these sources is difficult since they run on different fuels, with widely different capacity factors.

For the purposes of this study, the following estimates have been made:

1. Thermal stations with a total theoretical maximum generation capacity of 2,621 MW run with an overall average capacity factor of 50% (some like Southdown are base load and operate close to 100%, others like Whirinaki are emergency and operate close to 0%).
2. The fuels used are a mixture of gas, oil and coal. Electricity generated from these fuels has different emissions factors, with coal-fired electricity ranging from 6.8 to 7.6 kt/MW-year depending on the calorific value, electricity from natural gas being 5.0 kt/MW-year and electricity from oil 7.1 kt/MW-year. In this analysis an overall average factor of 6 kt/MW-year has been used for the annual emissions, based on the approximate current balance of fuel use – about 2/3 gas, 1/3 coal and negligible oil.

This gives a total CO_2 emission from the sector of 6.5 Mt/year.

6.4.2 Manufacturing and construction

Estimating these emissions independently requires a great deal of detailed work. Even in the air pollution effects study (HAPiNZ) this was done by making area-based estimates. This is a valid approach, provided there is reasonable confidence that the sector is fully covered both in the air pollution exposure methodology, and in the greenhouse gas emissions methodology.

Thus the total CO_2 emissions from this sector including an allowance for medium to small dischargers are 5.1 Mt/year, as per the greenhouse gas inventory (MfE, 2007b).

6.4.3 Other

The major emissions categories covered already – domestic heating, transport, manufacturing, thermal electricity generation, – account for large fraction of the air pollution associated with health effects. As discussed previously, this analysis has focused on these sources.

There are other sources of both air pollution and greenhouse gases that can have air quality effects. These are mainly medium to small industrial sources, principally those using some combustion process such as boilers. Also included here are a reasonably large number of small emitters (fish and chip shops, panelbeaters, etc). These have not been explicitly included as there is very little specific data on either their air pollution emissions or greenhouse gas emissions. However they are largely included in the major manufacturing and construction category above – being the balance of emissions unidentified by specific analysis.

6.5 Greenhouse emissions summary

All of the calculations above are summarised in Table 6.6 and compared with the emissions assessment detailed in Table 2.1. This is done to ensure consistency, given that most of the two sets of figures have been derived independently.

Table 6.6: Summary of annual greenhouse emissions from the key sectors

Sector	Emissions estimate (from Table 2.1) (Mt/yr)	Estimate calculated here (Mt/yr)	Comment
Domestic heating	3.5	3.5	Assuming an average winter period of 140 days
Transport	12.8	12.7	Excludes marine and aviation
Industry			The 'other' sector is assumed to be fully covered (ie, has not been independently calculated)
Electricity	6.1	6.5	
Other	5.1	5.1	

The level of agreement, whilst not perfect, is encouragingly good. Not included in this comparison are the increased methane emissions from domestic heating, at 1.4 kt/day, or 0.2 Mt/year. These are not included in Table 2.1, but do need to be accounted for in the analysis.

6.6 Economics

Having made an assessment of the quantities of greenhouse gases emitted by each of the sectors being considered, these are now 'priced' in order to make a comparison with the health effects costs.

It is difficult to put a sensible price of CO_2. International free market trading has existed for several years, with current trading in range of $12–$15 per tonne. Under various Kyoto target reduction schemes, it has traded in the past for over $200 for high quality European credits, to below $0.50 for Russian 'hot air' credits.

The NZ government, in their Preferred Climate Change Policy Package (2004), set a cap on the price of CO_2 at $25 per tonne. This is the price used for the comparative analysis. It is slightly higher than the NZ$21 per tonne CO_2-e used by the Treasury in its December 2007 valuation of New Zealand's Kyoto liability.

7 Co-benefits Analysis

This section examines the co-benefit initiatives in more detail, providing specific data on the potential changes in both GHGs and air pollution, along with analyses to determine the potential health and economic implications of the initiatives. In order to do this, certain scenarios have been developed. These are based on changes within the sector activities, rather than arbitrary percentage emissions changes. They range from modest through to ambitious. The results are all shown in the tables by prefixes, a plus sign indicating there is a cost, and the minus sign indication a negative cost, ie, a benefit.

7.1 Assumptions

In conducting this analysis, a number of simplifying assumptions have been made on the details on how emissions (and effects) would change from the various sources analysed. The test has been made on a range of options, all of which are reasonably significant in order to show the scale of the effects possible. For instance ± 10% changes in fuel use, or ± 25% changes in wood burner use. These percentages should not be interpreted too literally and are simply designed to show the effects associated with changes of this order. In the real world there are several more detailed factors to consider. For instance, changes of this magnitude would only occur over several years, or in the face of very dramatic policy or economic drivers. Furthermore there will be strong regional differences, particularly in the case of wood burner effects. Finally, there is a lack of detailed information on some important factors, such as just how might any change in wood burner or industrial boiler use occur in relation to efficiency, model, fuel type etc. Thus the results presented in this section should be taken as preliminary and indicative, designed to show the order of magnitude of the effects and their interrelationship, rather than be used as any definitive measure of a specific co-benefit.

7.2 Domestic heating

Three scenarios were examined, based on a range of changes to peoples' fuel usage, mainly in switching to wood burners, to alternative fuels, or to electricity (shown in Table 7.1). In this analysis wood is assumed to be carbon neutral with respect to CO_2 – that is the CO_2 gas emissions attract zero cost, even though the changes within the scenarios are significant. However wood use also leads to an increased emission of methane, which is included in the costs, although this is not a major factor.

The scenarios are somewhat simplistic as they assume simple displacement features – that is switching fuels. For instance scenario 1 in Table 7.1 assumes an increase in wood burner use will result in reduced thermal electricity generation at the average rate described previously (6 kt/MW-year). The opposite displacement occurs in scenario 3. The assumption is that the fraction of the electricity supply sourced from thermal generation is 30%. It has been lower in the past, but is increasing.

7.2.1 Wood burner emission factors

Determining the appropriate wood burner PM_{10} emissions factor for use in this analysis is a difficult task. There are a very wide range of wood burner types and ages throughout New

Zealand, with PM_{10} emissions factors that can range from less than 1 g/kg to over 30 g/kg. The variation is due to appliance type, appliance age, fuel type and operation method. The Ministry for the Environment and numerous Regional Councils have conducted extensive tests for various purposes, such as compiling emissions inventories and testing mitigation policies. Ideally, a detailed analysis could be conducted to use these tests and build a very detailed scenario of the effects of the various options involving change of wood burner usage patterns. However this would be inordinately complex and still subject to numerous assumptions about replacement rates, types etc.

For the purposes of this analysis the following assumptions have been made:

1. The average national current PM_{10} emission factor for wood burners is taken as 12 g/kg. This was derived from the weighted average values in the two main emissions inventories from Auckland and Christchurch. The figure is reasonably consistent with that used by the Ministry for the Environment – based on a wider selection of burners – of 14–16 g/kg.
2. The average national PM_{10} emission factor for newly installed wood burners (2008 and beyond) is taken as 4.6 g/kg. This is based on recommendations made by the Ministry for the Environment in a 2007 report on the Warm Homes project (MfE, 2007a). A recommendation is also made that this should be the emissions figure used in any airshed modelling (unless more accurate data are available).
3. The average PM_{10} emissions factor for a 'low-emissions' burner is taken as 1.0 g/kg. This is an extreme case constructed for the purpose of the scenario. It is unrealistic in the sense that it is probably unachievable in practice, but it is included as an example of the theoretical optimum emissions levels that could be achieved with 100% compliant new low-emissions burners.

Table 7.1: Cost effects of various scenarios for domestic heating

Scenario option	Details	Annual impact GHG (CO_2 and CH_4 only)		Annual impact air pollution (PM_{10} only)[1]		Net
1 Wood burners	25% increase in the number of wood burners (with current models) and associated reduction in electricity usage	+730kt +42kt[3] –162kt[4] +610kt	$0 [2] +$1M [3] –$4M –$3M	+1.3kt	+$70M	+$67M (cost)
2 Low-emissions wood burners (eg, pellet burners)	25% of electricity users and 25% of gas users switch to low-emissions wood burners	–523kt +42kt [3] –481kt	–$13M +$1M [3] –$12M	+0.5kt	+$27M	+$15M (cost)
3 Electricity	25% of existing wood burner users switch to electricity (heat pumps)	–730kt [5] –42kt [3] +162kt [4] –610kt	$0 [2] –$1M [3] +$4M +$3M	–3.4kt	–$183M	–$180M (benefit)

1 This impact is due to PM_{10} alone, which dominates the health effect. A more in-depth analysis would include changes in emissions of other pollutants, but these are either essentially neutral (eg, CO), or not enough is known about the effects (eg, acetaldehyde and NOx – see text).

2 If wood assumed 'carbon neutral' for carbon dioxide, but not for methane.

3 This is due to the methane emissions, which are considered as the same for all wood burner types. In practice they are not and depend on usage efficiency, fuel type and operating method.

4 This is the estimated change (±) in CO_2 from thermal electricity generation.

5 This is the saving in CO_2 from wood burners, but not counted.

The calculations in Table 7.1 assume that:

a) the 'existing models' of wood burners have an average PM_{10} emission rate of 12 g/kg

b) the 'current models' of wood burners have an average PM_{10} emission rate of 4.6 g/kg

c) the 'low emissions' wood burners have an average of 1.0 g/k or $1/12^{th}$ the PM_{10} emission rate as the existing models

d) 50% of the total electricity consumption goes into space heating.

The GHG emissions analysis is also somewhat simplistic and contains the following simplifying assumptions. It is assumed that a 25% increase in wood burner use results in a simple 25% increase in the current rate of GHG emissions (scenario 1). This may not be realistic, since newer burners are likely to be more efficient than the existing models, consequently burning less wood and emitting less CO_2 than current models. The data on this is not clear, and so this simple assumption is used. Conversely, it is assumed that if 25% of wood burners are decommissioned (scenario 2), the reduced CO_2 emissions will be 25% of the total. In practice this might not occur since older, less efficient, wood burners are likely to be preferentially replaced. Thus the '25%' should not be interpreted too literally. The 'real' effect on emissions might be somewhat higher or lower, but probably not be more than a few percent. A good deal more real-world data would need to be analysed to improve this estimate. However the point of the scenario is to show in crudely quantitative terms what can happen to the various emissions if wood burner usage is altered by a reasonably sized factor – in this case a nominal 25%.

A similar situation exists with the consequent decrease or increase in electricity usage. This factor is smaller, but again the point of the analysis is to show the order of magnitude shifts that are possible, and their scale compared to shifts in wood burner usage. These assumptions are simplistic, but need to be made in order to make the comparison with the shifts in health effects associated with each scenario.

The results show that a 25% increase in use of wood burners has a health effect cost ranging up to $70M depending on the type of wood burner used. There is only a greenhouse co-benefit, of up to $12M if low-emissions wood burner users have switched from electricity and gas.

If 25% of wood burner users switch to electricity (heat pumps, say), there is a benefit in air pollution costs of $183M, and an increase in greenhouse costs of $3M. This air pollution benefit is probably underestimated, since any practical measures taken by government to encourage users to switch to cleaner fuels would almost certainly be targeted at older, high-emissions burners. That is, rather than simply reducing the number of 'average' emission burners (12 g/kg), the measures would likely reduce emission further (more from burners > 12 g/kg). Without analysing specific policies it is not possible to calculate this explicitly, but such a replacement measure would have greater air pollution health benefits than are calculated here.

7.3 Transport

Three simple transport scenarios are examined. These can be very complex in detail, because subtle adjustments in the fleet profile, in regional differences, in fuel types, and in evolving technology can make significant differences. The scenarios given here can thus only be used as broad-scale indicators.

Table 7.2: Cost effects of various scenarios for transport

Scenario option	Details	Annual impact GHG (CO_2 only)		Annual impact air pollution (PM_{10} only)[1]		Net
1 Generally reduce travel	All vehicles VKT reduced by 10%	–1,260kt	–$32M	–0.21kt	–$49M	–$81M (Benefit)
2 Displacement	Car VKT reduced by 10% and bus VKT increased by 5%	–908kt	–$22M	*+0.03kt*	*+$6M* [2]	–$16M (Benefit)
3 Heavy trucks to rail	HCV VKT reduced by 20% and rail emissions increase by 20%	–440kt	–$11M	–0.23kt	–$43M [3]	–$54M (Benefit)

1 This impact is due to PM_{10} alone, which dominates the health effect. A more indepth analysis would include changes in emissions of other pollutants, but these are either essentially neutral (eg, CO), or not enough is known about the effects (eg, acetaldehyde and NOx – see text).

2. Although buses are a small fraction of the fleet (1%), they emit more pollution per VKT (Vehicle Kilometres Travelled – about 8 times the fleet average). Such impacts can be avoided through retrofitting catalysts.

3. This figure is an estimate only, since rail emissions were not explicitly evaluated in the HAPiNZ study. The increase in rail is assumed to be either (a) electric, or (b) new low-emissions diesel rolling stock.

The results in Table 7.2 show that almost any measure to reduce vehicle trips will have benefits for both greenhouse gas emissions and local air quality effects. The only increase (a modest $6M) occurs if bus use increases significantly (5%), using buses with current emissions rates. In practice this is an overestimate, since many bus fleet operators are meeting new lower emission standards. For instance if the bus fleet were to substantially meet the latest Euro 4 standard (a policy being enacted in Auckland), then the cost figure would go down, and perhaps even turn into a benefit.

7.3.1 Biofuels

A separate calculation has been made for various scenarios involving switching portions of the transport fleet to biofuels. This is a trend in many parts of the world, with considerable interest from the public, since biofuels are seen as a sustainable and carbon neutral resource. However it is not as simple as it may seem, and this report shows the results from a number of studies that can be used to analyse these scenarios (see Appendices B and C). Table 7.3 shows some summary results.

Table 7.3: Cost effects of various scenarios for switching to biofuels

Scenario option	Details	Annual impact GHG (CO_2 only)		Annual impact air pollution (PM_{10} only)[1]		Net
Government target 3.4%	3.4% of all petrol and diesel is replaced with ethanol and biodiesel, respectively	–323kt	–$8M	–0.07kt	–$17M	–$25M (Benefit)
E10	All petrol has 10% blended ethanol	–950kt	–$24M	*+0.01kt* [2]	*+$2M* [2]	–$22M (Benefit)
B20	All diesel sold in New Zealand has 20% blended biodiesel	–720kt	–$18M	–0.42kt	–$99M	–$117M (Benefit)

1 This impact is due to PM_{10} alone, which dominates the health effect. A more in-depth analysis would include changes in emissions of other pollutants, but these are either essentially neutral (eg, CO), or not enough is known about the effects (eg, acetaldehyde and NOx – see text).

2 This figure is low because petrol is responsible for only a small fraction of total PM_{10} emissions from transport (compared to diesel). According to the Ministry of Transport standard emissions model – NZTER – this factor is approximately 25. That is for a given sized vehicle, the diesel version emits 25 times more PM_{10} than the petrol version. On this basis all of the PM_{10} health effects are assumed to be due to diesel emissions. The use of E10 is estimated to have a slight negative effect due to an increase in NOx emissions because of its higher combustion temperature.

The results in Table 7.3 show that any switches to biofuels have a strong gain in reducing CO_2 emissions, roughly in proportion to the amount of imported petrol and diesel replaced. Biodiesel blends also have a significant air quality benefit (although as discussed above, this is not well validated by current research). Ethanol in petrol blends probably does not have strong air quality benefits since (a) petrol vehicles are responsible for a small fraction of PM_{10} (the main health effects), and (b) probably result in increased NOx emissions which can exacerbate the health effects. This latter factor has not yet been fully researched in New Zealand.

7.4 Industry

The analysis for industry (categorised basically as all other combustion processes that are not (a) domestic heating, (b) transport, or (c) thermal electricity generation, is difficult. This is because there are so many different processes that have a great variability on both greenhouse gas emissions and local air pollution. The greenhouse gas inventory is calculated mainly on fuel use, but with some additional emissions information in certain industries because of the process involved. The air pollution emissions are estimated from resource consents and area/ population-based estimates.

Table 7.4: Cost effects of various scenarios for industry

Scenario option	Details	Annual impact GHG (CO_2 only)		Annual impact air pollution (PM_{10} only)[1]		Net
1 Thermal electricity generation	Reduced by 10% (say through use of renewable sources)	–610kt	–$12M	–0.32kt	–$2M[1]	–$14M (benefit)
2 Industrial efficiency	Energy efficiency in industry, including combined heat and power, giving 20% less fuel demand	–1,020kt	–$26M	–0.64kt	–$28M	–$54M (benefit)
3 Fuel switching	Switching from gas/coal/electricity to wood as fuel – 5% of usage[3]	–255kt	–$6M	+0.16kt	+$7M[2]	+$1M (cost)

1 This is a very modest gain since although air pollution emissions are reduced, they mostly occur in areas where few people live, and so the public health exposure is low.

2 This increases since most of these industries will be in urban areas where PM_{10} will increase public exposure.

3 This assumes a simple 5% CO_2 emission reduction which obviously represents different amounts of coal or gas.

The analysis for industrial sources is based only on CO_2 for GHG, and only on PM_{10} for air pollution. It is accepted that there may be effects due to other GHGs and other air pollutants, but these are not included here since (a) the effects are relatively minor relative to the main CO_2/PM_{10} emissions, and (b) there is not enough data available on the quantum of emissions, and in many cases their effects.

The results in Table 7.4 indicate that, as would be expected, any measures to reduce fossil fuel energy use in the industrial sector will have benefits for CO_2 emissions reductions. These also have modest air quality health effects gains, but only if the process does not involve industry switching to using wood, or wood waste. (Some of this wood combustion emissions effect could be reduced if processes were fitted with modern emissions control technology – but this would only be applied to the larger emitters, and comes with a substantial financial cost.)

8 Discussion

8.1 Wood as carbon neutral

The analysis to this point has assumed that all sources of greenhouse gases contribute to the total emissions. In particular, solid fuel used for home heating has been ascribed a significant amount of CO_2 emissions. However, in the current carbon accounting systems, biofuels such as wood are considered renewable and carbon neutral. That is it is assumed that the wood consumed is replaced with new growth. This has made the increased use of wood a popular option for reducing CO_2 net emissions. However this can be an overly simplistic assumption since it is not a given that wood consumed will be replaced with like wood. Alternative scenarios include (a) the wood consumed is not replaced but the land cleared ends up being used for other purposes, (b) heavily forested land (with high carbon sequestered amounts) is cleared for more lightly grown wood-as-fuel, or in extreme cases (c) wetlands are drained for wood-as-fuel usage with consequent high loss rates of carbon to the air.

However as shown above, the increased use of wood can lead to increased health effects, unless very clean burning appliances and fuels are used. This is a dilemma, since it leads to contradictory outcomes:

A) Use more wood for heating = displacing gas and thermal electricity generation = lower CO_2 emissions. *Good* for the *global* environment.

but

B) Use more wood for heating = increased air pollution emissions = increased health effects on urban populations. *Bad* for the *local* environment, and increased health effects.

This is difficult to resolve, and reverts to a policy choice rather than a scientific analysis.

8.2 Achieving the gains

The study conducted here has focused on quantifying the effects of various scenarios for changes in energy use that might occur, because of the growing concern for reducing greenhouse gas emissions, and improving air quality. There has been no significant analysis on how these might be achieved.

For instance it is relatively easy to show the gains from reducing the number of trips taken in vehicles, but achieving this in practice is a whole separate issue. In this case there are a wide range of options, including (a) public education to encourage walking/cycling, (b) improved urban planning to reduce the distances between work-home-leisure activities, (c) tighter vehicle emissions standards, (d) financial instruments such as incentives, or taxes. A number of these measures are being pursued by government agencies such as the Ministry of Transport and Regional Councils (for a more in-depth discussion see the HAPiNZ Study: Fisher et al, 2007).

There are difficulties of a different nature with any fuel switching that involves burning more wood. Apart from the dilemma of the conflicting effects noted above, there are also very strong regional differences and economic factors. The analysis used here has assumed an average national picture, however what occurs in a smaller rural community close to a forest, with cold winters, is very different to what happens in a larger or warmer urban centre. The degree of uptake will depend on fuel prices, wood availability and the rate of installation of new burners (this is covered in much more details in report for the Ministry for the Environment's Warm Homes project, MfE, 2007).

8.3 Secondary factors

Also not covered to any extent here are a number of secondary factors, and how these might affect the overall emissions and effects.

For instance no attempt has been made to calculate the increased emissions that would result from transporting wood around if its use was to increase. This could offset the CO_2 emissions benefits, perhaps by several percent. There is no data available on this subject. This could also increase health costs associated with emissions from the trucks and vans transporting the wood.

Anecdotal evidence also suggests that there may be co-benefits from improving domestic energy efficiency use through insulation and lower costs for more easily obtained fuels (ie, wood). People then keep their homes warmer, and suffer fewer winter health problems. However research on this is New Zealand has only just begun (Wellington School of Medicine and Health Sciences) and suitable data are not available

In addition, no attempt has been made to assess the possible increased emissions associated with producing new biofuels. The overseas studies indicate that these can be substantial.

Likewise, there has been no attempt to analyse the effects of increased forestry plantations that occur for carbon offsetting. These can have co-benefits in some obvious ways, in terms of land use, water quality, aesthetic values, recreation, but they do not generally have any significant or direct benefits in terms of improving air quality.

Finally, no attempt has been made to assess either greenhouse gas emissions or local air pollution effects that might be associated with switching land use to produce biofuels. Internationally, this is being recognised as a growing problem, with the distinct possibility: that in many circumstances using land for biofuel production can result in an increase in the overall greenhouse gas emissions over what it might have been previously.

9 Conclusion

It is possible with existing data to make quantitative estimates in both physical and monetary terms, of the health co-benefits and co-costs (via changes in air quality) associated with measures to reduce emissions of greenhouse gases. They are indicative only, because such estimates do not cover all aspects of air quality, are sensitive to a number of the assumptions made (eg, GHG emission factor for electricity; level of PM_{10} emissions from an expanded population of wood burners) and because a high degree of subjectivity attaches to the monetary estimates.

An analysis has been made of the potential co-benefits between measures to reduce greenhouse gas emissions and measure to improve public health through reducing air pollution.

This has been conducted using the data available on air pollution health effects from the HAPiNZ Study (*Health and Air Pollution in New Zealand*) and from the national greenhouse gas inventory (*New Zealand's Greenhouse Gas Inventory 1990–2005*).

The focus has been on those emissions which have significant effects in both these areas, and thus are more significant for potential co-benefits, or costs. These are essentially activities and processes that involve combustion of fossil fuels – domestic heating using wood burners, transport, thermal electricity generation, and energy use in industry. The analysis has been based mainly on CO_2, since processes generating other greenhouse gases have little if any health effects. Some smaller changes in methane emissions are also included. The main contaminant associated with health effects is particulates (as PM_{10}), with associated emissions of carbon monoxide and oxides of nitrogen.

A number of plausible scenarios have been examined involving changes in the key sectors that result in either a reduction in air pollution emission, a reduction in greenhouse gas emissions, or both – domestic heating, transport, and industry.

The scenarios examined show that co-benefits are possible, but so are contrary outcomes. The best gains are obtained in the transport sector, with either (a) reducing the amount of general vehicle use, or (b) increasing biofuel use. Whilst having people use wood burners more – with a carbon neutral fuel – can have gains for reducing greenhouse gas emissions, these are almost certainly offset by the larger cost rises in public health effects, even with new low emissions burners. Improving energy efficiency across the industrial sector also has modest gains and co-benefits for both greenhouse gases and air quality.

The largest individual benefit identified ($180M net) was having 25% of wood burner users convert to electricity (heat pumps), but this did not create a significant co-benefit as the increased thermal electricity generation required produced an additional greenhouse gas cost ($3M).

Clear and consistent co-benefits occur with almost any measure to reduce the use of fossil fuels in transport. Even modest 10% reductions in travel demand resulted in significant net co-benefits ($81M net).

The largest co-benefit identified was the introduction of 20% of biodiesel into the transport sector ($18M in greenhouse and $99M in health effects, giving $117M net). However this result needs to be interpreted with caution, as the research on air quality benefits from biodiesel are not confirmed, and further research on New Zealand specific features is needed.

Different values for factors such as the GHG emission factor for electricity or the level of PM_{10} emissions from an expanded population of wood burners, and different values for the cost of GHG emissions or the cost of health effects would change the relative benefits and costs, and the total net benefits, of the scenarios examined.

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Appendix A: Air Pollution Emissions

An assessment of the amount of PM_{10} from different sources across the whole of New Zealand was carried out in 1998 (NIWA, 1998). Sources included in the national emission inventory were broken down into the following categories: area based emissions (predominantly domestic home heating, small scale boilers, lawn mowing, off-road vehicles, open burning), transport, industry and natural emissions. The methodology was less complex than the majority of the regional emissions assessments, with estimates based on broader assumptions. For example, emissions from domestic home heating were assessed based on the results from existing inventories (Auckland and Christchurch for the North and South Islands respectively) and scaled based on population for each area.

The transport emissions assessment in the Total Emission Inventory for New Zealand estimates annual PM_{10} motor vehicle emissions of 197, 694, 317, 71, 146, 225 and 368 t/year for North Shore City, Auckland City, Manukau City, Wellington and Christchurch respectively. Collectively, estimates for the Auckland area (excluding Rodney District and Franklin) total 1,425 t/year or around 3.9 t/day, compared to around two tonnes per day given in the 1996 Auckland Regional Emission Inventory (includes parts of Franklin and Rodney). Results from the national inventory assessment for Wellington (around 0.6 t/day) were relatively low compared to the regional estimates for 1997 of 1.2 tonnes. For Christchurch estimates were a bit closer with around 1 t/day for the 1996 national assessment compared to around 0.8 t/day for the 1996 motor vehicles assessment.

The comparability of the total PM_{10} emission estimates in the national emission inventory assessments to the regional assessments varies with area. In Wellington estimates of around 2,500 tonnes per year for the national emission inventory compare to around 1,500 tonnes in the Wellington region emission inventory.

In Hamilton annual estimates of around 590 tonnes of PM_{10} from the regional assessment compare to around 578 in the national emissions inventory. In Taupo, regional assessments indicate around 400 tonnes of PM_{10} are likely to compare to an estimated 249 tonnes in the national inventory assessment. In Auckland, the regional assessment for 1993 indicates annual emissions for TSP of less than 6,000 tonnes per year. This is similar to the national inventory assessment when the areas of Franklin and Rodney are excluded from the assessment. However, if these areas are included, the national assessment indicates around 9,000 tonnes of PM_{10} per year. The regional data includes parts of these areas.

For Christchurch, the national emissions inventory estimate of 3,086 tonnes of PM_{10} per year is greater than around 2000 estimated based on the Christchurch emission inventory 1996 back-cast. A better comparison is observed in Nelson with regional estimates of around 300 tonnes per year compared to 455 in the national emissions inventory.

The methodologies used to calculate these various inventories are different. The national inventory was completed using general information available from statistics, whereas the regional inventories are calculated using more specific tools such as local surveys. However it is not possible to use regional inventories here since (a) they are compiled using different categories in different regions (there is no standard), and (b) not all regions have inventories.

Table A1: Breakdown of PM emissions

PM	Domestic	Industry	Transport
Auckland – wintertime TSP 1995	67	24	9
Taupo – wintertime PM_{10} 2000	30	64	6
Hamilton – wintertime PM_{10} 2001	90	1	9
Bay of Plenty – annual particles 1997	52	31	17
Taranaki – annual PM_{10} 1998	55	16	29
Wellington – wintertime PM_{10}	57	18	25
Timaru – wintertime PM_{10} 2001	91	3	6
Christchurch – wintertime PM_{10} 1999	80	10	10
Waimate – wintertime PM_{10} 1997	97	2	1
Nelson – wintertime PM_{10} 2001	83	13	4
Dunedin – wintertime PM_{10} 1999	61	37	2
Mosgiel – wintertime PM_{10} 1999	53	47	0
Balclutha – wintertime PM_{10} 1999	93	6	1
Northland – winter daytime PM_{10} 1996–2000	55	34	11

Source: Emission Inventories in New Zealand – http://www.mfe.govt.nz/publications/air/air-quality-tech-report-38-aug03/html/page5.html.

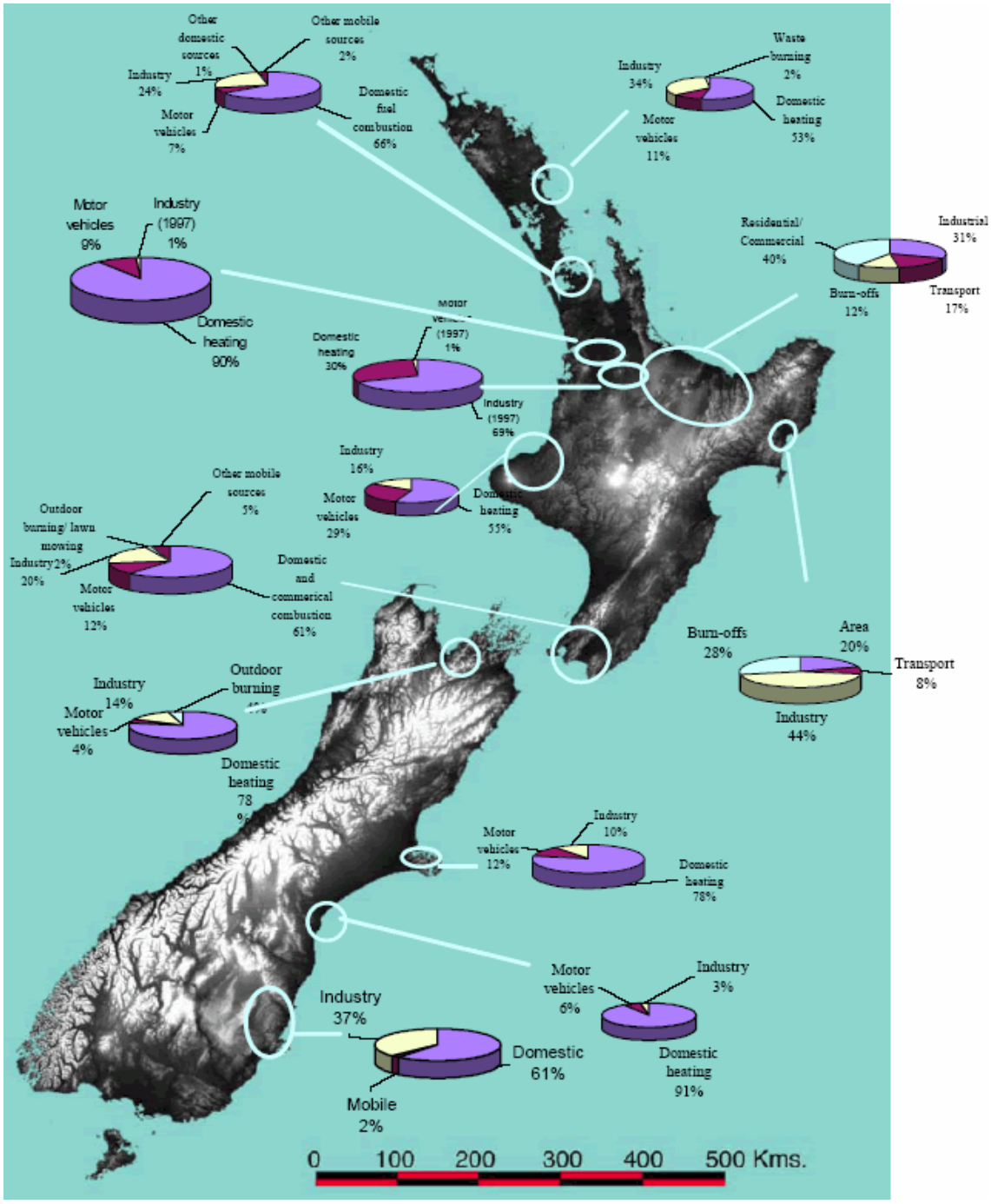
Table A2: Comparison of PM_{10} emissions estimates for different regions of New Zealand

	Domestic kg/day	Mobile sources kg/day	Industry kg/day	Total kg/day
Alexandra	264	4	114	382
Arrowtown	120	0.5	14	135
Balclutha	250	4	17	271
Clyde	63	0.5	8	72
Cromwell	127	1	48	176
Milton	174	2	43	219
Mosgiel	325	3	290	618
Oamaru	870	17	236	1,123
Queenstown	586	31	143	760
Wanaka	147	1	68	216
Dunedin	3,174	101	1,933	5,208

	Domestic heating kg/day	Motor vehicles kg/day	Industry kg/day	Other domestic kg/day	Other mobile kg/day	Total kg/day
Christchurch	7,929	991	1,027			9,947
Rangiora	543	8	61			612
Kaiapoi	334	12	5			351
Ashburton	897	18	106			1,021
Waimate	285	1	6			292
Timaru	1,124	61	41			1,226
Hamilton	3,600	371	39			4,010
Taupo	409	77	866			1,352
Tokoroa	1,232	58	2,866			4,156
Nelson	1,486	78	264	85		1,912
Northland	3,028	633	1,915	103		5,679
Auckland	18,900	2,000	7,100	300	700	29,000
Wellington	6,160	1,200	2,000	180	490	10,030

	Domestic t/year	Mobile sources t/year	Industry t/year	Burn-offs t/year	Total t/year
Taranaki	490	251	138		879
BOP	1,110	455	849	323	2,737
Gisborne	151	58	340	210	759

Figure A1: Relative contribution of sources of particles within New Zealand



Source: http://www.mfe.govt.nz/publications/air/air-quality-tech-report-38-aug03/html/figure5-1.html). With the exception of Bay of Plenty, Taranaki and Gisborne, these data represent average wintertime emission sources.

Appendix B: Tailpipe Emissions of E10

Below are some studies been conducted examining the effect of emissions when E10 replaces traditional petrol (without oxygenates). Table B.1 shows a summary of the overall results.

Table B1: Summary of studies examining the effect of E10 on tailpipe emissions

Study details	Location	Effect on emissions	Relevant information
1 Ragazzi, et al (1999) *The Impact of 10% Ethanol Blended Fuel on Exhaust Emissions of Tier 0 and Tier 1 Light Duty Vehicles at 35 Degrees*, CO DPHE 1999	Colorado, USA	An overall PM reduction of 36.0% was achieved	Cold weather study
2 AEA Technology (2004). *Ethanol emissions testing*. Prepared for United Kingdom Department of Transport, Local Government and the Regions, E&E/DDSE/02/021 Issue 3	UK	95% probability that the 10% ethanol addition leads to a reduction in PM emissions of between 33 and 57%	
3 Malawa, et al, Effect of ambient temperature and E-10 fuel on primary exhaust particulate matter emission from light duty vehicles, *Environmental Science & Technology* 31(5): 1302–7	USA	Older vehicles burning 10% ethanol produced up to 22% less soot particulate pollution than those burning regular fuel	Cited in another paper – unable to obtain original
4 Beer T, Grant T, Morgan G, Lapszewicz J, Anyon P, Edwards J, Nelson P, Watson H, and Williams D (2001) *Comparison of Transport Fuels: Final Report (Ev45a/2/F3c) to the Australian Greenhouse Office on the Stage 2 Study of Life-Cycle Emissions Analysis of Alternative Fuels for Heavy Vehicles*. Australian Greenhouse Office, EV45A/2/F3C	Based on Australian and overseas research	No change in E10 PM emissions compared to Premium Unleaded Petrol	Unsure of original research – E10 information seems dependent on MacLean HL and Lave LB (2000) Environmental implications of alternative fuelled automobiles: air quality and greenhouse gas tradeoffs, *Environmental Science & Technology* 34: 225–31
5 Modelling the Effects of E10 Fuels in Canada – Robert Vitale, J Wayne Boulton*, Mike Lepage, Martin Gauthier, and Xin Qiu from RWDI West Inc and Serge Lamy Health Canada	Canada	Emission rates unchanged by the addition of E10 ($PM_{2.5}$)	Study based on modelled data

Further summary details on these studies are available from the authors upon request.

Appendix C: Tailpipe Emissions of Biodiesel

Biodiesel is promoted as a fuel that has significant greenhouse benefits, but the air quality benefits are not as clear.

Similar to the biofuels/greenhouse gas debate, there is research which seeks to determine the life-cycle emissions of biofuels. These studies examine both the upstream and downstream emissions resulting from the manufacturing and combustion of alterative fuels. This paper focuses on the tailpipe emissions only, and is intended to determine the impact of large-scale alternative fuel use in populated areas around New Zealand. This is a valid assumption especially as the vast majority of the health effects experienced from motor vehicle emissions occur in populated areas.

Even without full scale life cycle analysis there is a high degree of variability in the results of studies of tailpipe emissions. Part of this variability is due to factors such as engine temperature, driving and/or testing conditions, type of vehicle, age of vehicle, and type of biofuel (ie, feedstock). Two studies are summarised (Table C1).

Table C1: Studies on the air quality befits of biodiesel

Study details	Location	Effect on emissions	Relevant information
1 EPA – A comprehensive analysis of biodiesel impacts on exhaust emissions (2002)	Various	Use of B20 would result in a 10.1% reduction in PM for the heavy duty vehicle emissions on highways	Heavy duty (highway) vehicles only. A review of 80 studies was conducted – 39 of which were selected and included. Primarily based on pre-1997 engines.
2 Newcastle City Council Biodiesel Trial: Emissions Testing Program	Newcastle, Australia	Use of B20 resulted in a 39% reduction in PM emissions	The 12 vehicles tested including light duty four-wheel drives, light and medium duty trucks and garbage collection vehicles.

Further summary details on these studies are available from the authors upon request.

Appendix D: Thermal Electricity Generation Status

Overall the air pollution and resulting health impacts of thermal electricity generation in New Zealand is relatively small. One reason for this that most thermal generation uses natural gas. While natural gas generation can cause elevated levels of NOx, particulate emissions are generally very low.

Currently, the coal power plant at Huntly is the only large operational coal plant in New Zealand (some smaller co-generation facilities are operated by the industry sector and can run on coal) (Table D1). However, there are two coal stations in the initial planning and consenting phases in Waipara, Auckland and Buller, West Coast (Table D2). Some stations can, and do, operate on fuel oil (for instance New Plymouth and Whirinaki).

Table D1: Existing thermal power stations 10 MW or over

Plant name	Location	Plant type	Fuel [1]		Capacity (MW)
			Primary	Secondary	
Huntly	Waikato	Steam turbine	Coal	NG	972
Huntly	Waikato	Gas turbine	NG	Distillate	48
Kinleith	Waikato	Steam turbine with Cogen	Wood waste	Coal/gas	40
Te Awamutu	Waikato	Gas turbine with Cogen	NG		54
Southdown	Auckland	Combined cycle gas turbine	NG		122
Otahuhu A*	Auckland	Gas turbine	Distillate		40
Otahuhu B	Auckland	Combined cycle gas turbine	NG		365
Te Rapa	Hamilton	Gas turbine with Cogen	NG		42
New Plymouth*	New Plymouth	Steam turbine	NG	Oil	200
Taranaki CC	Stratford	Combined cycle gas turbine	NG		357
Whirinaki*	Napier	Gas turbine	Diesel		155
Kiwi Cogen	Hawera	Co generation of electricity	Kapuni gas	Distillate	69
Kapuni Cogen	Kapuni	Co generation of electricity	Kapuni gas		25.3
Edgecumbe Cogen	Edgecumbe	Gas turbine with Cogen	NG		10
Glenbrook Cogen	Auckland	Generation of steam and/or electricity from waste heat	Waste heat and gas		122
Total estimate		Allowing for average capacity factor of 50%			1,300

[1] NG = natural gas, Cogen = co-generation.

* These stations run with a low capacity cycle (for instance Whirinaki is for peaking only and has rarely been run).

Table D2: Proposed new thermal power stations

Plant name	Location	Plant type	Fuel[1]		Capacity (MW)
			Primary	Secondary	
Huntly (E3P)	Huntly	Combined cycle gas turbine	NG		385
West Coast	Buller	Steam turbine	Coal		320
Huntly P40 CCGT	Huntly	Combined cycle gas turbine	NG		85
Otahuhu C	Auckland	Combined cycle gas turbine	NG		380
Taranaki CC 2	Taranaki	Combined cycle gas turbine	NG		380
Tasman	Kawerau	Steam turbine with Cogen	HOG/NG		100
Waipara	Auckland	Steam turbine	Coal		400

[1] NG = natural gas.

There are also eight geothermal power generations in New Zealand with a combined generating capacity of around 400 MW with another four plants in various planning stages. Geothermal plants emit approximately a third of the CO_2 as would a power plant of the same capacity on gas, or about one-fifth that on coal. The main pollutants of concern resulting from geothermal power plants are hydrogen sulphide and mercury. Emissions of mercury are rarely sufficiently high to warrant monitoring, but are generally well below New Zealand guidelines. While hydrogen sulphide is toxic at high concentrations, geothermal emissions of H_2S generally represent more of an odour nuisance than a health risk, and these emissions are not considered here.