Reducing Winter Air Pollution in Christchurch

A Independent Policy Review of Environment Canterbury's Proposed Draft Air Plan of April 2001

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1 Introduction

Temperature inversions in the atmosphere, still frosty nights, and the combustion of carbon fuels primarily for home heating combine to create visible smog in Christchurch during winter. The chief culprit is PM_{10}, tiny particles that measure less than 10 microns across.[1] Although winter air quality in Christchurch has greatly improved since the days when every home was heated with coal burned in an open fire, public concern has increased. This can be attributed to heightened environmental awareness and to stronger evidence for a causal link between PM_{10} and human health effects.

For some years, Environment Canterbury has been working to develop an Air Plan for Canterbury, to appear as *Chapter 3: Air Quality* in the Natural Resources Regional Plan (NRRP). Although Environment Canterbury must deal with many aspects of air quality in all of Canterbury, the greatest regional air quality challenge is the reduction of emissions of PM_{10} from home heating sources in Christchurch. The latest draft of the proposed Air Plan was released on 12 April, 2001.

The Christchurch City Council has long been a central player in efforts to reduce the city's winter smog, because of the impact of airborne particulates on public health and the aesthetic appeal of the city. On high pollution days in Christchurch, 90% of the PM_{10} in the air now comes from home heating sources, so no significant improvement in winter air quality can be achieved without substantial changes to the way homes are heated.

In the April draft of the proposed Air Plan, Environment Canterbury proposed a complete phasing out of the use of wood and coal for home heating in Clean Air Zones 1 and 2 by 2020. The complete phasing out of enclosed wood burners goes considerably further than earlier actions and proposed actions, and raises issues of concern to the city. Consequently, although the April draft of the proposed Air Plan has not been adopted as policy by Environment Canterbury, the City Council has commissioned this independent policy review of it. Eventually, Environment Canterbury will adopt a draft Air Plan and seek submissions on it. This review has been commissioned to assist City Council officers in providing advice to the Council during the preparation of their submission.

[1] Since the smallest particles are believed to be the most dangerous, some researchers have focussed on $PM_{2.5}$ – particles that measure less than 2.5 microns across. $PM_{2.5}$ is included in PM_{10} by definition.

2 A Condition not a Problem

Some policy issues are best framed as *problems* and others are best framed as *conditions*. Problems are amenable to solutions, whereas conditions are amenable to amelioration.

Environment Canterbury has framed the Christchurch smog issue as a *problem*. It is a central theme of this review that this is misguided, and that the smog issue should be framed as a *condition*. This theme is developed throughout this review, but the simple version is as follows.

Framing Smog as a Problem

Environment Canterbury has:

- framed the smog issue as a problem to be solved;
- set an "acceptable" level of pollution as an objective;
- proposed a set of policies intended to achieve that objective and solve the problem.

I term this approach *holistic*, since the intent is to deal with the *whole* problem in one plan.

Framing Smog as a Condition

The alternative approach is *incremental* and *strategic*.

- Frame the smog issue as a condition. On cold winter days, temperature inversions form in the atmosphere over Christchurch and trap air pollutants. Recognise that this is a condition that will always bedevil the city.[2]

- Decide to move in the direction of reducing the smog. The objective adopted as a standard that must be achieved above can still be adopted as a target.

- Design a sequence of steps that will ameliorate the smog condition incrementally.

This *incremental* approach has a number of advantages over the holistic "grand solution" approach. These include:

a) The most cost-effective steps can be taken first by "picking the low-hanging fruit".

b) Because the steps are spread over time, political resistance will also be spread over time, and at any one point in time will be weaker.

c) Predictions of PM_{10} reductions from various actions are very uncertain. An incremental approach has the advantage of flexibility. The effectiveness of an incremental step can be measured and the strategy changed accordingly.

3 The Switch from an Incremental to a Holistic Approach

Until recently, the Christchurch smog issue has been framed as a condition. Past actions have taken place as a series of incremental steps. These steps include the creation of Clean Air Zones, increasingly tighter control of industrial sources, the prohibition of backyard fires in winter, and a number of actions targeted at home heating sources.

[2] One might characterise winter smog as a comparative disadvantage for Christchurch in the same way as steep hills in Wellington make virtually all infrastructure relatively expensive.

Significant actions that have been taken to address *home heating sources* of PM_{10} are:

- A prohibition on the installation of open fires.
- Restrictions on moisture content in wood and sulphur content in coal.
- Emission standards for new enclosed wood burners expressed in terms of grams of total suspended particulate per kilogram of fuel burned. The first standard was 5 gram per kilogram and the current standard is 1.5 gram per kilogram.
- Financial incentives for home insulation and the replacement of open fires with enclosed wood burners.

Although some of these actions have taken place in the last decade, the framing of the issue has changed. The passage of the Resource Management Act in 1991 has triggered the current holistic approach, although this approach is not mandated by the Act.

In its Canterbury Regional Policy Statement, Environment Canterbury committed itself to: *"setting and maintaining minimum **standards** of ambient air quality in Christchurch*". These standards are to be based on based on the Ministry for the Environment's 1994 ambient air quality **guidelines** for New Zealand".[3]

This new approach required adopting an "acceptable" level of PM_{10} and devising a plan for reaching this standard. It is the *holistic* approach that follows from framing the smog issue as a *problem* for which a *solution* is to be sought.

Progress using this approach has been slow. There is still no Air Plan for Canterbury, and more importantly, there has been no significant improvement in winter air quality in the last decade.

In 1998, Environment Canterbury tried to make incremental progress by prohibiting the use of coal as a home heating fuel. Legal action taken by the Coal Association resulted in a High Court judgement that potentially affected parties must be provided with a proper opportunity to be heard.

This took place before a Hearing Panel comprising a retired judge and two Regional Councillors. They ruled that it was inappropriate to proceed with a domestic coal ban for several reasons. Tellingly, one of these reads:

"Coal should not be prohibited in isolation of other measures which may, or may not, in their present form, be part of an operative air plan."

The prohibition of coal would have been an *incremental* action, and as such, did not fit into the new *holistic* approach adopted for the preparation of the Air Plan. Unfortunately, the effect of the decision of the Hearing Panel was to sanction the holistic approach.

[3] Environment Canterbury, "Section 32 Report: Air Quality Chapter of the Proposed Canterbury Natural Resources Regional Plan", Draft, 12 April, 2000, part iii, p2.

4 The Policies Proposed in the April Draft Air Plan

In order to deal with winter air pollution in Christchurch, the draft Air Plan contains:

- an objective;
- a set of policies for the achievement of this objective; and
- a set of methods for implementing these policies.

The *objective* is to reduce the concentration of PM_{10} in ambient air to a 24-hour average of less than 50 µg/m^3 by the year 2013. One exceedance each year is allowed, averaged over three years.

Under the holistic approach, the policy development task has been to design a set of policies which will deliver this "acceptable" level of PM_{10}.

The *policies* that are directed at home heating sources of PM_{10} are given in Table 4.1. All apply to Christchurch Clean Air Zone 1, unless otherwise stated.

Table 4.1. Proposed policies for reducing PM_{10} from home heating sources.

Date	Policy	Policy Code
	Regulatory Policies for Open Fires	
Air Plan notified	• Extend the prohibition on the installation of open fires to Clean Air Zone 2.	AQ14
2005	• Prohibit the use of open fires.	AQ14
	Regulatory Policies for Enclosed Burners	
Air Plan notified	• Set emission standards for new enclosed burners of 1.5 grams of TSP per kg of fuel burned and a thermal efficiency of 65%.	AQ11
Air Plan notified	• Allow solid fuel burners to be installed only as replacements for older burners.	AQ13
2010 or 15 yrs after installing	• Prohibit the use of solid fuel burners that do not meet the standard of AQ11.	AQ15
2005	• Prohibit the installation of solid fuel burners that meet the standard of AQ11.	AQ16
	Other Policies	
	• Encourage cleaner forms of heating and increases in energy efficiency.	AQ13
	• Seek voluntary curtailment of solid fuel burning during periods of high pollution potential.	AQ16
	• Provide exemptions from rules for heritage buildings or in emergency situations.	AQ17
	• Mitigate adverse financial, social and health effects of clean air policies.	AQ18

Under the old *incremental* approach, distinctions were drawn between the more polluting and the less polluting forms of home heating, with priority given to reducing emissions from the more polluting sources.

Under the new *holistic* approach, a package of actions is planned that is to collectively deliver the desired reduction in PM_{10} emissions.

Key changes are:

- Coal is more polluting than wood, but in the proposed policies, no distinction is made between coal and wood.

- Uncontrolled burning in open fires is more polluting than combustion in enclosed burners, but in the proposed policies, the distinction between open fires and enclosed fuel burners is simply a matter of timing.

- Emissions of PM_{10} from enclosed wood burners vary over a wide range, and the incremental approach involved successive tightenings of standards. In the proposed policies, all use of wood as a fuel is to be phased out. It is implicitly assumed that technology for reducing PM_{10} to increasingly lower levels from wood burners cannot be developed.

5 Examination of the PM_{10} Objective

Duty to Examine the Objective

Since the set of proposed policies in the draft Air Plan are driven off the objective, it is logical to begin by examining the objective. Section 32 of the Resource Management Act is titled "*Duties to consider alternatives, assess benefits and costs, etc.*", and requires that a local authority *"be satisfied that any such objective… is necessary in achieving the purpose of this Act"*.

Recall that the objective is to reduce the concentration of PM_{10} in ambient air to a 24-hour average of less than 50 $\mu g/m^3$ by the year 2013, with one exceedance each year allowed, averaged over three years. This objective is based on the national PM_{10} guideline of a 24-hour average of 50 $\mu g/m^3$ set by the Ministry for the Environment.[4] The choice of a 24-hour average of 50 $\mu g/m^3$ has been made, because it is a reference level or target adopted in several other countries.

The Section 32 analysis conducted by Environment Canterbury does not go beyond this justification. There is no discussion of the economic cost and social impacts of achieving the objective, and no consideration of any other objective. It has taken on the aura of scientific truth and become non-negotiable.

The drawing of arbitrary "lines in the sand" as guidelines and targets is a common approach to pollution control. However, in this case, this "line in the sand" guideline has mutated into "a line drawn in concrete". It has been used as the basis for proposing a regulatory agenda that has implications extending far beyond local air quality.

The Objective Does Not Set a Safe Level

Guidelines setting target pollution levels are inevitably interpreted as marking the boundary between what is *safe* and what is *unsafe*. For example, a news item dated 25 June, 2001, stated that:

"So far this year Environment Canterbury has recorded 15 nights where pollution levels have exceeded safety guidelines".

However, such guidelines only have a scientific basis when the relevant dose-response curve has been shown by epidemiologists to have a threshold for damage. In the great majority of environmental toxicology studies, the shape of the dose-response curve (and therefore the existence or not of a threshold) is unknown, and probably unknowable. The lack of knowledge of a threshold for damage from PM_{10} is noted in the draft Air Plan.

Given the absence of a threshold, there is no sudden switch from *"safe"* to *"unsafe"* at 50 $\mu g/m^3$, or at any level except zero. A distinction between *"safe"* and *"unsafe"* is not correct and is misleading. The reality is that there are different degrees of safety.

There is a second arbitrary number in the target – *one* exceedance per year, averaged over three years. Again, there is nothing about one exceedance per year that makes it magically protective of human health. When environmental targets are couched in such success or failure terms, two exceedances per year appear to be as bad as ten or twenty exceedances.

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[4] In the draft NRRP, the target of 50 $\mu g/m^3$ is proposed as a first stage target and 33 $\mu g/m^3$ as a second stage target. The Ministry for the Environment has devised a set of assessment criteria that may be used by councils in setting regional criteria for air pollution. A level that is 66% of the national guideline is deemed to be just "acceptable"; 33 $\mu g/m^3$ is 66% of 50 $\mu g/m^3$. Note that 66% is an arbitrary number, with no basis other than being two thirds of the guideline level. For this discussion, a focus on the first stage target of 50 $\mu g/m^3$ will serve.

If the two arbitrary numbers – 50 µg/m^3 and one exceedance per year -- are considered together, a rigid interpretation of the target would imply that two days with an average PM_{10} concentration of 51 µg/m^3 are worse than ten days with an average PM_{10} concentration of 49 µg/m^3.

This nonsensical conclusion must lead to questioning the way in which the target is expressed. The achievement of only one exceedance per year of a 24-hour PM_{10} concentration of 50 µg/m^3 in the winter of 1999 would have required a reduction in emissions of about 70%. The target would be better expressed in terms of a weather-corrected percentage reduction from a base year, and then progress toward it could be measured sensibly.

An "Acceptable" Level of Risk?

Finally, behind the setting of a numerical objective lies the popular concept of an "acceptable" level of risk. This concept does not stand up to scrutiny.

When a risk is deemed acceptable or not, there is implicitly no middle ground because a risk is either acceptable or it is not acceptable. The reduction of a risk to an acceptable level suggests an exclusive focus on the benefits of the regulation. This is at odds with the balancing of benefits and costs required by Section 32 of the RMA.

The achievement of an acceptable level of one environmental health risk may lead to an unacceptable level of another. If the reduction of the PM_{10} risk leads to colder indoor environments and consequent illness, then there may well be a net health loss. This risk-risk tradeoff has been informally expressed as *"Must we choose whether to die by cough or by cold?"*[5].

"Is a risk acceptable or not?" is the wrong question.
The right question is: "*What is the best decision?"*

[5] Letter to Editor, Christchurch Press, 21 July, 2001.

6 Taking a Broader View

Measures taken to reduce PM_{10} emissions can create a series of other interlinked problems that have impacts on social goals beyond the reduction of smog in Christchurch. Some of these problems – and general methods to deal with them – are outlined in the draft Air Plan. But others are not mentioned.

The test of an environmental policy in the RMA is contained in Section 32. Under Section 32, the PM_{10} objective must be seen as necessary for achieving the *purpose* of the RMA.

The purpose of the RMA is *"to promote the sustainable management of natural and physical resources"*. Sustainable management includes enabling *"people and communities to provide for their social, economic and cultural well being and for their health and safety"*.[6] Human wellbeing, in a broad sense, matters.

Three general problems are potentially created by the proposed policies directed at home heating sources of PM_{10}.

- Alternative forms of home heating may not be affordable, especially by low income households.

- The reduction of the PM_{10} health risk may be outweighed by the health risk created by living in colder, damper houses.

- Alternative fuels may exacerbate other environmental problems. For example, emissions of carbon dioxide may rise, making it more difficult for New Zealand to achieve its climate change target.

Thus, the challenge is to devise local air quality initiatives that address these other problems simultaneously. This requires finding forms of home heating that reduce emissions of PM_{10}, *and* are affordable, keep houses warm and dry, and do not exacerbate other environmental problems.

Environment Canterbury intends to find such solutions by developing a Regional Energy Strategy, although it is not obliged to do so under the RMA. In the draft Air Plan, the Canterbury Regional Energy Strategy is described in broad terms. The flow-on effects of the PM_{10} policies are to be dealt with through the promotion of *clean heating* and *energy efficiency*. The next two sections of this report (7 and 8) contain observations and raise questions about forms of *clean heating* and *energy efficiency*.

In the proposed PM_{10} policies, solid fuel heating is to be phased out entirely, with no distinction made between coal and wood, or between the different ways of burning them. Solid fuel heating is discussed in section 9.

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[6] Resource Management Act 1991, Section 5(2).

7 Clean Heating

Three clean forms of heating are suggested in the draft Air Plan – *flued gas*, *electricity*, and *diesel*.

There is one problem shared by these three forms of heating – all are net emitters of carbon dioxide. The NZ Government is actively exploring ways of reducing carbon dioxide emissions. Although binding international commitments are some way off, concern about global climate change will remain with us in the foreseeable future.

It seems odd to describe electricity as a net emitter of carbon dioxide because South Islanders assume that the electricity they use in their homes comes from the hydro dams in the south. However, there is usually little excess hydroelectricity available in the South Island in winter for transmission to the North Island through the Cook Strait cable. There are plans for building three new large thermal generation plants in the North Island to meet the growing demand. Therefore, increased demand for electricity from hydro generation for heating in Christchurch will lead to less hydroelectricity being sent north, and hence the burning of more natural gas and coal in the North Island. Additional electricity used to heat homes in Christchurch will be, in effect, generated from burning natural gas.

Moreover, using thermally generated electricity to heat a home will result in more carbon dioxide being emitted to the atmosphere than burning LPG directly in a heating appliance in the home.

Fossil fuels, such as coal, natural gas, LPG, and diesel share a second undesirable characteristic – they are *non-renewable* forms of energy. The Energy Efficiency and Conservation Authority (EECA) has recently issued a national strategy for encouraging energy efficiency, conservation, *and* the use of renewable sources of energy. The strategy is not binding on local authorities, but will be influential and carry moral authority.

It is clear from the draft Air Plan that Environment Canterbury is well aware of the conflict between local environmental quality and global sustainability that is posed by the use of fossil fuels for home heating. But the “clean” forms of heating suggested in the draft Air Plan do not resolve this conflict.

The specific problems associated with each of the three “clean” forms of heating are now considered.[7]

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[7] Data in this section is taken from the Section 32 report, Part V.

Flued Gas

LPG gas heaters are popular because they provide large amounts of instant heat. Unlike electricity or piped gas, their operating cost is readily controllable. A further attraction after the winter of 2000 will be security of supply.

Unfortunately, *unflued* gas heaters have proved far more popular than the *flued* gas heaters advocated in the draft Air Plan.

In 1999, unflued gas heaters outnumbered flued gas heaters by five to one in the inner suburb area and nearly seven to one in the 25 suburb area. At least one in four households in Christchurch now owns an unflued gas heater. Unflued LPG heaters are particularly attractive to low income households because of the relatively low capital cost compared with flued gas heaters.

The rapid increase in ownership of unflued gas heaters is a most unfortunate trend because, beside being more dangerous, unflued gas heaters add as much as a litre of water per hour to indoor air.[8] This can lead to the vicious cycle of using the heater more in an effort to evaporate the water that condenses on cold surfaces, thus making the problem worse. There are two ways of getting rid of the water – venting which cools the interior of the house, and a dehumidifier which consumes more electricity.[9]

Compared with houses in other developed countries, New Zealand houses are damp due to both our climate and our building practices. The trend toward unflued gas heaters is making them damper, and damp houses are unhealthy houses. It may be that health gains from reducing PM_{10} may be more than outweighed by health losses from colder, damper indoor environments.

[8] Filling LPG bottles can be dangerous. Also, portable LPG heaters have been banned in some countries because after a few years of use they start to release dangerous gases like carbon monoxide (Environment Canterbury Fact Sheet “Home Heating on a Tight Budget”).

[9] Dehumidifiers do have the positive characteristic of operating as mini heat pumps. Because they release the latent heat of vapourisation of water in the room, they are more efficient converters of electricity to heat than resistance heaters.

Electricity

The supply and, consequently, the future cost of electricity must be considered if it is to be promoted as a clean fuel. The threat of major price increases due to low hydro lake levels this past winter has made this a salient political issue, but the problem goes deeper.

The phasing out of solid fuel burning would lead to a large increase in demand for electricity in Christchurch. This should to some extent be ameliorated by increased end use efficiency, and this is discussed in section 8. It is one thing for relatively few households "on the margin" to switch from solid fuel heating to electric heating, but it may be quite another if large numbers of households switch. Simple extrapolation from past marginal changes will not serve to assess the impact on electricity prices.

The impact of increased demand for electricity should be considered at all levels of the energy chain – generation, transmission, distribution, and end use.

Generation: As noted above, new electricity is likely to come from gas-fired power plants, unless carbon taxes, tradable permits or some other mechanism redirects investment to non-fossil energy sources. Either way, there is no reason for expecting the marginal cost of electricity to fall.

Transmission: The transmission line from Twizel to Christchurch has little spare capacity and the next increment will cost about $80M. About 20% of an electricity bill is paid to Transpower.

Distribution: The distribution network in central Christchurch is at capacity. Orion has sought to avoid major new expansion of capacity because of the impact it would have on line charges. Piping LPG around the city is theoretically a means of alleviating distribution constraints, but is prohibitively expensive even in new subdivisions.

End Use: If electricity becomes the sole heating fuel, the wiring in many houses may not be able to carry the wattage required for space heating.

Insecurity about the future supply and cost of electricity has risen to relatively high levels among domestic consumers for two reasons.

The first reason is the electricity supply crisis of the past winter; this came only eight years after the seriously dry winter of 1992. The construction of all-electric houses came to a halt in 1992. A very unfortunate feature of the Christchurch smog problem is that all the bad things happen together – a cold winter, little wind, low lake levels, temperature inversions, and poor health.

The second reason is consumer distrust of the electricity industry. The length of time it is taking for electricity retailers to get their billing systems right and the rejection of some new customers has left domestic consumers sceptical about the advantages of the restructuring of the electricity industry.

Increasing competition in the electricity industry can be expected to phase out seasonal cross-subsidisation. When this happens, the price of winter electricity will be about twice as much as the price of summer electricity.

Heat pumps use only half as much electricity as resistance heaters, but like flued gas heaters, have a high capital cost.

Diesel

In the data on methods of home heating, no households are recorded as using diesel for a home heating fuel. Presumably, diesel can be burned in a home heating appliance such that the combustion gases contain virtually no solid particles. However, if the diesel contains a high level of sulphur, as diesel in New Zealand currently does, droplets of corrosive sulphuric acid will be formed in the atmosphere. Like LPG, diesel is a fossil fuel, and therefore a source of carbon dioxide and nonrenewable.

8 Energy Efficiency

Arguably, the most important approach to reducing PM_{10} emissions lies in improving the efficiency of home heating and thereby reducing the amount of energy that is required. This is typically done by increasing the thermal resistance of the building shell – insulating the ceiling, walls, and floor, sealing air gaps, installing curtains and double-glazing windows.

Not all of these efficiency measures will be good investments for the homeowner, but in virtually every house, there will be some measures that are economic. Because of the poor winter air quality in Christchurch, there is a case for requiring energy efficiency measures that are not economic from the householder's perspective, but are economic from a societal perspective.

While improvements in energy efficiency will reduce PM_{10} emissions, care should be taken not to overstate what can be achieved.

Compared with other developed countries, New Zealand houses are cold. People feel comfortable in an indoor temperature range of 18 to 26^{o}C. The World Health Organisation recommends 18^{o}C as the minimum indoor temperature, with rooms for the elderly, children and handicapped people kept warmer. The limited information that is available on the actual temperatures in New Zealand houses suggests that average winter indoor temperatures are below 18^{o}C and often below 16^{o}C.[10]

Thus, the benefit of insulating Christchurch houses will be experienced in two ways:

- a decrease in the energy used for space heating, and
- an increase in thermal comfort.

The colder a house is, the more likely it is that the energy used for space heating will not fall at all, and may even increase as thermal comfort becomes within reach.

A second "reality check" is in order. The energy savings from retrofitting an existing house with insulation are not as great as those from incorporating insulation into a new house. In fact, an old house can only ever be made about half as energy efficient as a new house can be.

[10] Isaacs, Nigel P. "Poverty and Comfort?". Building Research Association of New Zealand, Conference Paper No.59. Presented at the Fourth National Food Bank Conference, Wellington, November 13, 1998.

9 Reconsidering Solid Fuel

Since there are energy supply, environmental, and health problems associated with the suggested clean heating methods, solid fuel should be reconsidered.[11]

Salient changes in the inner suburb area between 1996 and 1999 are:

- The *use* of open fires increased by 31%.
- The number of households using coal in either open fires or enclosed burners decreased by 20%.
- The number of enclosed wood burners increased by 38%.
- The number of households using electricity as the only “fuel” stayed constant.
- The number of households using more than one fuel increased by 33%.

The message about coal appears to be getting through, but the message about open fires has not. Clearly, wood has become more popular as a heating fuel, particularly in enclosed burners, and the proposed prohibition on its use is in the opposite direction from this trend.

The relative environmental merits of wood and coal are as follows.

- Wood combustion produces less PM_{10} than coal combustion. For example, an open fire burning wood produces only two thirds of the PM_{10} from an open fire burning coal.

- Appliances for burning wood that reduce PM_{10} emissions to much lower levels than from an open fire exist. A new standard wood burner emits only one fifth the PM_{10} as does an open fire burning wood. In contrast, other existing appliances for burning coal are little better or worse than open fires, although there may be potential for this to change.

- Wood is “greenhouse neutral”, that is, the carbon dioxide emitted during combustion has been absorbed relatively recently from the atmosphere.[12] In contrast, coal is a fossil fuel, and per unit of energy, emits about twice as much carbon dioxide as natural gas.

- Wood is a renewable resource and coal is not.

There is clearly a trend toward the use of wood, especially in enclosed wood burners, and PM_{10} emissions from these are relatively low. Previously, efficient enclosed wood burners were seen as a major way to reduce PM_{10} emissions, as evidenced by the increasingly strict standards.

But two concerns appear to have caused the change in perspective.

First, post-1994 wood burners burn 30% more fuel than older burners, undermining the gains from the stricter limits on emissions. It could be said that these new burners are oversized, but perhaps it could equally well be said that we are seeing a trend away from the underheating of New Zealand homes. Only a few affluent New Zealand householders have discovered central heating, but this could change quite rapidly. That enclosed wood burners have enough “grunt” to heat a whole house may explain their popularity.

Second, the PM_{10} emissions produced in test conditions can be very different from those produced when the burners are operated in houses. The practice of loading up the burner at night, and damping it down so that the fire can be easily revived in the morning, leads to very poor combustion performance.

The consideration of alternative means for achieving the air quality objective in the Section 32 analysis includes only *existing technology*. Consequently, the only way of achieving the one annual exceedance of 50 $\mu g/m^3$ by 2013 appears to be the complete phasing out of all solid fuel.

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[11] The data in this section is taken from the Section 32 report, Part V.
[12] This is not entirely true because of the fuel used in transport and processing.

Given the popularity of enclosed wood burners, it seems politically unwise to abandon too readily the earlier approach of sequential improvements to combustion efficiency and consequent lower PM_{10} emissions.

The current route to reducing the particulate emissions from enclosed wood burners is better two-stage burning, with separate air supplies to each of the two chambers, and the chambers separated by a solid partition.

The discrepancy between testing conditions in the laboratory and actual operation is greatest at start-up. LPG self-starters are a possible technical fix. The wood burners that deliver the most consistent results burn pelletised sawdust. A few pellet-burning wood burners have been imported from Canada where they have been used for thirty years.

10 Effectiveness and Economic Efficiency -- Section 32 of the RMA

Environment Canterbury's Section 32 Analysis

Section 32 of the Resource Management Act requires that the methods chosen to achieve an environmental objective be both *effective* and *efficient*.

Recall that the environmental objective is to reduce the concentration of PM_{10} in ambient air to a 24-hour average of less than 50 µg/m^3 with one exceedance each year by the year 2013. It has been argued in section 5 that the numerical target is arbitrary and, rather than trying to achieve the target by adopting a "complete" package of policies, it is much more sensible to embark on a sequence of incremental gains.

Environment Canterbury has prepared a Section 32 report to accompany its draft Air Plan.[13] In this report, the proposed methods and alternative methods are examined each in turn with respect to its effectiveness and efficiency.

The effectiveness of each method is rated as ineffective, low, moderate, or high on the basis of "bulletpoint" discussion. For some methods, graphs are presented showing how much the method is expected to reduce PM_{10} emissions over time. Interestingly, there are no estimates of PM_{10} reductions expected from gains in energy efficiency.

The efficiency of each method is rated similarly by comparing its benefits with its costs. Environmental, social and economic costs and benefits are compared. For some methods, the net economic benefit is presented, using the results of a cost-benefit analysis.

The results of the Section 32 analysis have been used to select a set of methods that *collectively* are expected to deliver the environmental objective. A consequence of applying the *holistic* approach is that it is virtually impossible to get the contribution of each method into perspective. Such perspective is essential for the *incremental* approach advocated in this paper. The low-hanging fruit must be identified before they can be picked.

A Section 32 Analysis Using the Incremental Approach

The type of Section 32 analysis advocated in this report consists of two stages. The first stage identifies "what to do"; the second stage identifies "how to do it".

The first stage is the measurement of the effectiveness and efficiency of possible technical options for making physical changes to fuels, to heating appliances, and to buildings that would reduce the emission of particulates. Air pollution is a physical problem and it is logical to begin policy development with a clear assessment of the technical potential for improvement.

The second stage is the assessment of different ways in which desired technical changes might be accomplished – through rules, incentives, and so on. It is appropriate at this stage to consider the social and environmental costs and benefits of different policies, since part of the policy design task will be the amelioration of adverse social and environmental impacts.

The Section 32 analysis performed by Environment Canterbury jumps straight to the second stage. Moreover, some of the "methods" are odd. It is not clear how "Precautionary Approach", "Regional Energy Strategy", or "Sustainable Living Strategy" could be methods. "Enforcement", and "Response to Complaints and Inquiries" are listed separately from a number of specific Regional Rules, but are surely part of the successful implementation of such rules.

[13] Environment Canterbury, "Section 32 Report: Air Quality Chapter of the Proposed Canterbury Natural Resources Regional Plan", Draft, 12 April, 2000.

The first stage of the policy design task can be achieved by the creation of a “supply curve of reduced PM_{10} emissions”. This powerful graphical aid enables each technical option to be readily compared with respect to both effectiveness and efficiency with all the other technical options.

The supply curve approach was originally developed for assessing different energy efficiency interventions by the generation of “supply curves of conserved energy”.[14] It has recently been used in New Zealand to assess a sequence of controls for reducing dioxin emissions from medical waste incinerators by the generation of a “supply curve of reduced dioxin emissions”.[15]

In order to generate a “supply curve of reduced PM_{10} emissions”, the effectiveness and efficiency of each technical option must be estimated.

The calculation of economic efficiency is done relatively simply using a form of economic analysis known as cost-effectiveness analysis. The difference between cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) is that in a CEA, there is no need to express benefits in dollars.

Under the incremental approach, once the decision has been made to take action on Christchurch smog, a full cost-benefit analysis is a waste of resources. Costly exercises such as the highly uncertain estimates of the number of lost work-days due to pollution and the dollar value of a lost work–day are unnecessary, since such benefits will scale directly with effectiveness.

The result of a cost-effectiveness analysis for reducing winter smog in Christchurch would be a set of cost-effectiveness ratios, one for each technical option. An appropriate physical unit for measuring effectiveness must be chosen. One option for this physical unit is “kilogram of PM_{10} *not* emitted to air”. The cost-effectiveness ratios would then be measured in dollars per kilogram of PM_{10} not emitted to air. The lower the ratio for a technical option, the cheaper it is to reduce PM_{10} emissions by one kilogram, and the more cost-effective the technical option is.

The supply curve is generated by plotting the cost-effectiveness ratios against the cumulative effectiveness of the sequence of incremental technical options.

A supply curve is a graph showing the relationship between the price of a good and the quantity that can be supplied. Supply curves rise as higher prices enable greater quantities of the good to be supplied. In a supply curve of reduced PM_{10} emissions, a price is a cost-effectiveness ratio for an option and a quantity is the effectiveness of that option.

The supply curve is shown as a step function, where each step represents one technical option for reducing PM_{10} emissions. A wide step is relatively effective and a low step is relatively cost-effective. **Therefore, a wide, low step is both effective and cost-effective; a narrow, high step is the opposite.** Hence, the supply curve depiction allows **simultaneous** assessment of both effectiveness and efficiency.

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[14] Meier, A., Wright, J, and Rosenfeld, A.H. 1983. “Supplying Energy through Greater Efficiency: The Potential for Conservation in California’s Residential Sector.” Berkeley: University of California Press. 196p.
[15] Wright, J.C., Millichamp, P. and Buckland, S.J. 2001. “The Cost-Effectiveness of Reductions in Dioxin Emissions to Air from Selected Sources: Economic Analysis for Section 32 of the Resource Management Act” NZ Ministry for the Environment.

11 Economic Analyses of Options

Two economic analyses of options for reducing Christchurch smog have been commissioned by Environment Canterbury. The first was done in 1998[16] and an updated version completed at the end of 2001[17].

The two analyses are based on different sets of options, although all are targeted at the burning of solid fuel. **A significant omission in both is improved energy efficiency.** Increased energy efficiency is a policy in the draft Air Plan (policy AQ13), yet neither economic analysis attributes any cost nor any effectiveness to it.

A major difference between the two economic analyses is the cost of expanding Orion's distribution system. In 1998, this cost was thought to be small and it was not included, but the assessment taken in 2001 has shown this not to be so. As can be seen by comparing the two figures in this section, costs are roughly an order of magnitude greater in the 2001 study than in the 1998 study.

The 1998 Economic Analysis

The 1998 analysis supports delaying a decision about whether or not to phase out all solid fuel.

"The results show that there is a wide variation in economic efficiency between options. The phase-out of open fires, the introduction of the new emission criteria for enclosed burners and the introduction of a coal ban, achieve substantial emission reductions for relatively little cost. These are all very cost-effective measures for reducing emissions. In contrast, the phasing out of burners installed after 1992 has a high cost relative to the emissions reductions achieved and is a relatively inefficient means of reducing emissions. This means that, from an economic perspective, options such as the phase-out of low emission burners should only be implemented after the more cost-effective options have been introduced." (Ball, 1998, p.17)

This result can be seen dramatically in the supply curve (Figure 11.1) which has been constructed from data in the report. The supply curve exhibits typical "diminishing returns" pollution control behaviour; it rises slowly at first, and then increasingly steeply.

[16] Ball, Richard. May 1998. "An Economic Analysis of Options to Reduce Suspended Particulate from Domestic Burning in Christchurch". Environment Canterbury, Report R98/9.
[17] Greer, Glen and Bicknell, Katie. November 2001. "Updated Economic Analysis of Options to Reduce Suspended Particulate from Domestic Burning in Christchurch". Environment Canterbury, Report U01/88.

Table 11.1 gives effectiveness and cost-effectiveness ratios for seven technical options taken from the 1998 economic analysis. These have been used to construct the supply curve in Figure 11.1.

The unit of effectiveness is a 1% reduction in discounted cumulative emissions to 2021.[18] Thus, cost-effectiveness is measured in millions of dollars per 1% reduction in discounted cumulative emissions to 2021.

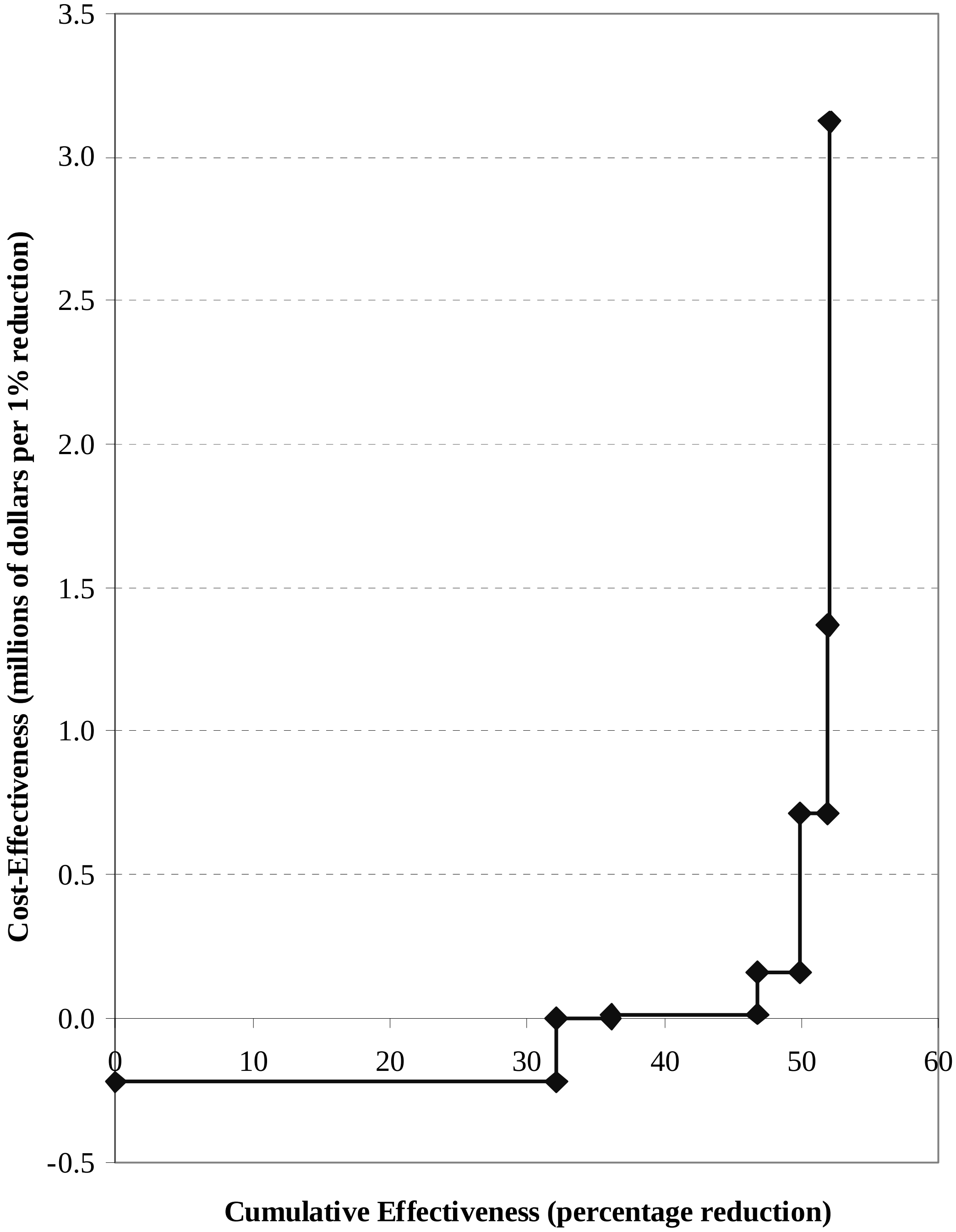
Table 11.1. Effectiveness and cost-effectiveness of options for reducing PM_{10} emissions. (Taken from Ball, 1998, Table 3.)

Technical Option	**Effectiveness** (% reduction)	**Cost-Effectiveness** ($ per % reduction)
Ban open fires in 2001[19]	32.1	-222,000
Introduce 3g/kg PM_{10} limit in 1997	4.0	0
Ban domestic coal burning in 1998	10.7	14,000
Introduce 1.5g/kg PM_{10} limit in 2000	3.1	161,000
Ban pre-1989 appliances from 2002	2.0	714,000
Ban 1989-92 appliances by 2007	0.08	1,369,000
Ban appliances > 1.5g/kg limit by 2012	0.15	3,123,000

The calculation of cost-effectiveness has not been performed incrementally, because the overlap between the banning of open fires and the banning of coal has not been removed. There is some double counting that will have led to an exaggeration of the effectiveness and cost-effectiveness of both. Nevertheless, it is clear that the lowest-hanging fruit is open fires. The last two technical options achieve so little, their effectiveness does not register on the graph.

[18] In a CEA, streams of costs and effectiveness are converted to their value in the present through the mechanism of discounting.
[19] The cost-effectiveness of the open fire ban is negative because in this study the **net** cost of banning open fires and replacement with other forms of heating was found to be negative. Open fires are a very inefficient, and therefore expensive, form of heating.

Figure 11.1 Supply Curve of Reduced PM10 Emissions based on Ball, 1998



The 2001 Economic Analysis

In the 2001 study, the costs, benefits, and effectiveness of seven policies and seven scenarios (various combinations of the seven policies) are presented. The fifth scenario is the draft Air Plan, and is the combination of the first, third, fourth and fifth policies. This allows for an incremental approach and, thus, the construction of a supply curve which will allow simultaneous assessment of the effectiveness and efficiency of the four component policies.

Table 11.2 gives effectiveness and cost-effectiveness ratios for the four policies that together form the draft Air Plan scenario. These have been used to construct the supply curve in Figure 11.2.

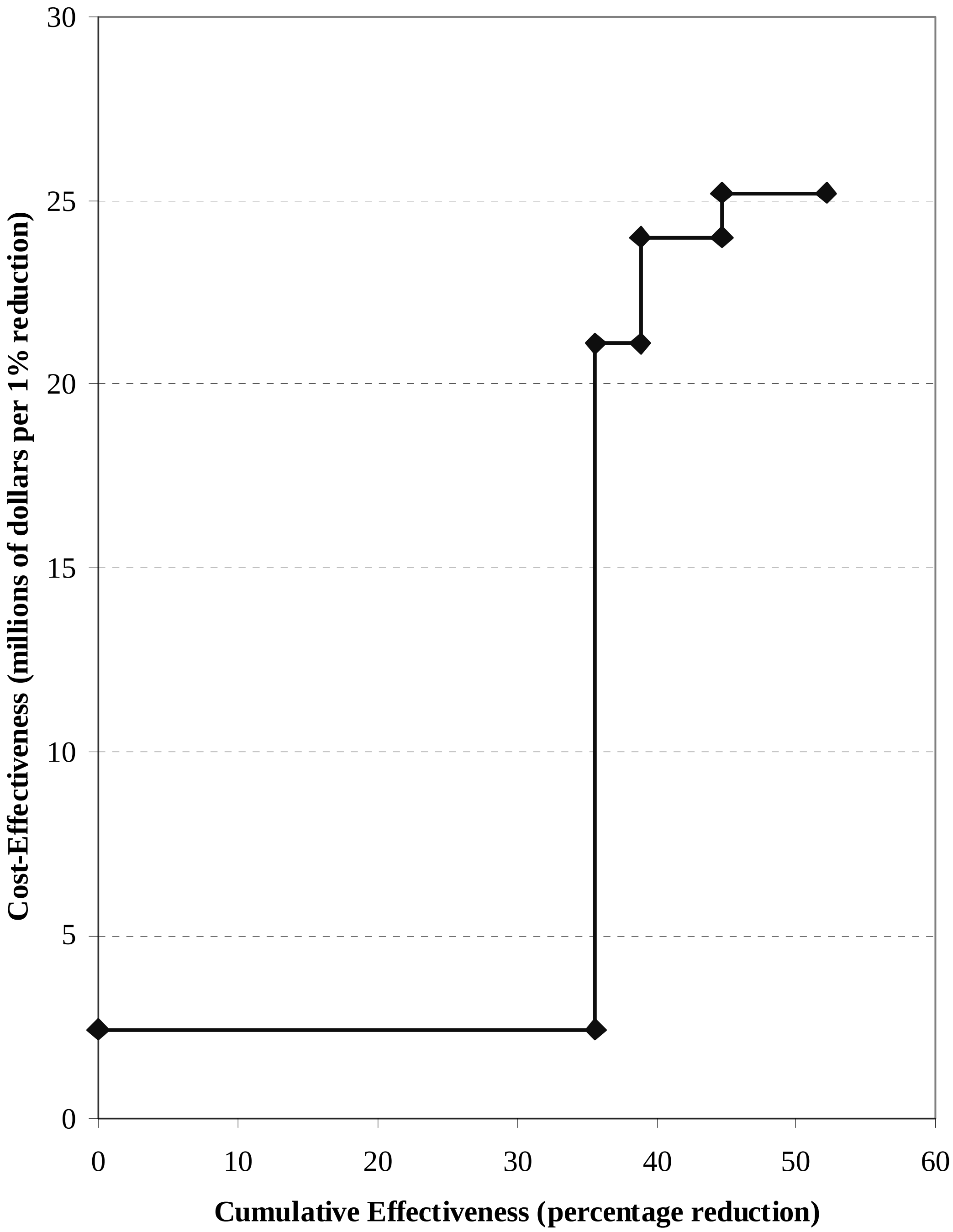
As for the 1998 analysis, the unit of effectiveness is a 1% reduction in discounted cumulative emissions to 2021. Thus, cost-effectiveness is measured in dollars per 1% reduction in discounted cumulative emissions to 2021.[20,21]

Table 11.2. Effectiveness and cost-effectiveness of four policies in draft Air Plan for reducing PM_{10} emissions. (Taken from Greer & Bicknell, 2001, Tables 2 and 8.)

Technical Option	**Effectiveness** (% reduction)	**Cost-Effectiveness** ($ per % reduction)
Ban open fires by 2005	35.6	2,430,000
No burners into new houses or into existing houses using other heating methods from 2005	3.22	21,100,000
Phase out non-complying burners from 2010	5.83	23,990,000
Prohibit the installation of replacement solid fuel burners from 2005	7.47	25,200,000

[20] The cost-effectiveness ratios in this table are the averages of those under the two sets of assumptions for the capital costs of replacement appliances.
[21] The second and third policies in this table (and in Table 11.3) are in reverse order from that given in Greer & Bicknell, 2001, because in an incremental analysis, cost-effectiveness ratios should monotonically increase.

Figure 11.2 Supply Curve of Reduced PM10 Emissions based on Greer & Bicknell, 2001



The supply curve in Figure 11.2 shows cost-effectiveness ratios for the enclosed burner policies to be about ten times higher than the cost-effectiveness ratio for the open fire ban. The elimination of open fires gives ten times as much “bang for the buck” than the enclosed burner policies.

As noted above, the cost-effectiveness ratios in the 2001 study are much higher than those in the 1998 study. Presumably, this is mostly attributable to the inclusion of the costs of the Orion expansion in the later study.

In the 2001 analysis, effectiveness is also expressed in a second form, namely, the expected PM_{10} emissions in 2021 as a percentage of the levels in 2000. This would be a preferable basis for the supply curve because it can be more directly related to the PM_{10} objective in the draft Air Plan.

More importantly, an examination of the increasing effectiveness of sequential policies measured in this way shows that **the status quo alone is expected to reduce PM_{10} emissions in 2021 to 75% of PM_{10} emissions in 2000**.

Thus, the supply curve in Figure 11.2 should contain an initial step showing the significant effectiveness from the status quo policies at a cost-effectiveness ratio of zero.

Table 11.3 shows that the results of the cost-benefit analysis (CBA) in which the benefits of averted deaths, illness, and lost work-days are quantified into dollars is consistent with the cost-effectiveness analysis. The net present value of the draft Air Plan is only positive because of the ban on open fires.[22]

Table 11.3. Net present value of the four policies and the draft Air Plan for the base case assumptions.[23]

Policy	**Net Present Value** (million $s)
Ban open fires by 2005	306
No burners into new houses or into existing houses using other heating methods from 2005	- 33
Phase out non-complying burners from 2010	- 76
Prohibit the installation of replacement solid fuel burners from 2005	- 106
TOTAL: Draft Air Plan	**68**

[22] The value of life used for quantifying the benefit of averted deaths in dollars is the $2.25 million used in the transport sector in New Zealand. In fact, because road safety projects are not funded unless the benefit-cost ratio equals 4, the effective value of life is $0.56 million. This is still about five times larger than Pharmac's cut-off of $10,000 per year. Thus, the monetary benefit from averted deaths estimated in the 2001 economic analysis is high compared with that used elsewhere in the public sector.

[23] 6% discount rate, 25% of deaths are harvest deaths, i.e. hastened by only a few days or weeks. Results in the report are presented for both lower cost replacement appliances and higher cost replacement appliances; these have been averaged in Table 11.3.

12 Thoughts on the Way Ahead

Major Recommendations

The objective set by Environment Canterbury for reducing the concentration of PM_{10} in ambient air should be viewed as a line in sand, not a line in concrete. It must not be allowed to dictate the composition of the package of policies aimed at reducing winter smog in Christchurch. The important thing is to make steady progress in the right direction.

There is no good reason for taking a holistic approach and trying to “solve” the problem of winter smog. Instead, an incremental approach should be adopted in which the low-hanging fruit are first picked. This lends itself to a positive measure of success in which a steady decrease in the number of days each year on which the target concentration is exceeded can be celebrated, in contrast with bemoaning that the number of annual exceedances is not yet down to the arbitrary one.

It is crucial that Environment Canterbury be very clear about which types of fuels and appliances it wishes to discourage and which types it wishes to encourage. There is no avoiding some environmental impacts if the citizens of Christchurch are to be warm in winter.

There is no doubt about the primary villain – open fires. The elimination of this primitive form of heating is clearly both very effective and very cost-effective. This should be one major focus of action.

The second major focus should be the increasingly efficient use of energy. There is no question about whether this should be done; New Zealand lags behind most of the rest of the developed world in this regard. Some thoughts on how it might be done are given below. It may well be that Environment Canterbury’s PM_{10} objective can be achieved by the elimination of open fires and significant upgrading of the thermal integrity of houses.

The proposed about-turn on enclosed wood burners is not helpful; indeed it may lead to a lack of public confidence in policy-makers. Both economic analyses show that the gain from banning the efficient appliances now on the market is relatively small. There are problems with enclosed wood burners associated with starting up and damping down behaviours, and possibly with excessive size. But technical solutions can be found. No policy can be effective if political opposition prevents its adoption. Coal burners should be subjected to the same PM_{10} standards as wood burners.

Increasing Energy Efficiency in Homes

A major effort to increase the thermal integrity of houses in Christchurch would be a win-win policy on three dimensions – warmer drier homes, reduced environmental impacts (including particulate emissions), and employment creation. In addition, reducing the demand for energy is often more economic than buying more energy, even from a narrow economic perspective that does not take into account externalities such as the social costs of winter smog.

Although Environment Canterbury includes the encouragement of energy efficiency as a policy in its draft Air Plan, its potential to reduce PM_{10} emissions is ignored. Neither economic analysis contains any quantification of the costs or effectiveness of improvements in energy efficiency.

Christchurch is already recognised within New Zealand as the city most conscious of the benefits of energy efficiency due to the efforts of the City Council, Orion, and Community Energy Action. To achieve further gains, a joint working group could be established with the task of identifying the problems to be solved, and then designing solutions. The encouragement of energy efficiency has moved beyond the standards and subsidy approach to what is known as “market transformation”, in which it becomes commercially rational to invest in energy efficiency. Standards and subsidies still have a place, but markets must be reorganised for energy efficiency to realise its huge potential.

A "block-and-tackle" framework could be used for organising discussion within the joint working group – identify the blocks, and then work out how to tackle them. A first run through this exercise has led to the identification of five blocks and some initial thoughts on how to tackle them.

- **To the homeowner the benefit of energy efficiency is "invisible", and the risk of "getting it wrong" is too great.**

It can be difficult for homeowners to believe that the benefits of investing in energy are real. The savings in energy costs are spread out through time, and masked by seasonal variation and changing prices. The Wellington School of Medicine will soon begin a large study in which a test group of houses will be retrofitted and compared with a control group. A large number of variables will be measured beside energy consumption – indoor temperature, mildew, medical records – in order to quantify the benefits of thermal comfort, building preservation, and improved health.

A second problem from the homeowner's perspective is choosing a "best practice" contractor. In the same way as a contractor may use timber in a renovation that is not treated to the right level, insulation can be installed so it performs well below specification.

The Building Research Association of New Zealand (BRANZ) tests and sets standards for insulation, and issues guidelines for installation as do some manufacturers. Tasman Insulation, the manufacturer of Pink Batts, is so concerned about installation standards that it is developing a list of approved installers.

The Energy Efficiency and Conservation Authority (EECA) funds a two week training course. However, training in retrofitting houses for energy efficiency does not fit well with any of the Industry Training Organisations (ITOs), so formal accreditation is difficult to establish.

Housing New Zealand has recognised the value of energy efficiency in state houses, and it is possible that a national standard of best practice may evolve from this growing commitment to energy efficiency.

- **The capital investment required is too great for some homeowners.**

The general solution to this block is the provision of capital from a third party, with repayments affordable because of reduced energy bills.

If a home is heated electrically, the ideal third party is a company that both generates and retails electricity, so that the tradeoff between increasing supply through generation and reducing demand through investment at the retail end can be made directly. However, such an arrangement could make it difficult for the householder to switch retailers. Moreover, the time it is taking to get billing systems running smoothly in the competitive retail market makes it hard to be confident that retrofit payments would be correctly billed.

The restriction of Orion to a lines company has been a setback for energy efficiency in Christchurch. Although Orion has a commercial interest in reducing demand in order to delay costly infrastructure investment, it has no direct contractual relationship with householders.

The third party need not be an energy company. The Christchurch City Council or Environment Canterbury could make energy efficiency loans available at a cheaper rate than that available to homeowners. Final repayment could be required when the house is sold.

- **The value of energy efficiency is not reflected in real estate prices.**

For many homeowners, investment in an energy retrofit would be over-capitalisation. EECA is developing a Home Energy Rating Scheme (HERS) in which the energy efficiency of a house would be scored between 1 and 10. If a high score leads to a higher price for the house, the repayment of an energy efficiency loan at time of sale would, in theory, be painless.

In some US states, an energy rating must be obtained when a house is sold.

- **When a rented house is retrofitted for energy efficiency, the landlord pays and the tenant benefits.**

Recent research has shown that this is not as much of a barrier as previously thought. Benefits do accrue to landlords from energy efficiency upgrades.

If a house is warm and energy bills are low, tenants will stay longer. The occupancy rate will be higher and the transaction costs of changing tenants incurred less often. If energy bills are low, tenants will be more likely to pay rent on time. There will be less mildew and decay, and less repainting required. All this should eventually translate into the ability to charge higher rents.

As for privately-owned houses, capital could be made available by local government. There is a case for funneling it through the not-for-profit sector, since government agencies may be viewed as prey by landlords, unlike, for instance, Community Energy Action.

- **The Building Code is “weak” on energy efficiency and based on a narrow economic perspective.**

The Building Code has recently been updated and takes climate into account in a crude way by requiring more insulation for South Island houses than North Island houses. An economic argument can be made for a local variation, namely, that greater investment in energy efficiency is justified in Christchurch because of the social costs of winter smog.

Section 7(2) of the Building Act says “*… no person … shall be required to achieve … criteria … more restrictive … than … specified in the building code*”. Local variations are only permitted where specifically identified in the Building Code. There are two options for making progress.

The first option is to recommend higher insulation levels within the city and to communicate why this will add to the value of the house – lower energy bills, greater thermal comfort, less condensation and mildew. Selwyn District Council has taken this path by strongly recommending snow-loading provisions in mountainous areas more stringent than required by the Building Code, and warning of the possible consequences of not adopting the recommendation. The Building Industry Authority (BIA), which administers the Building Code, has not challenged this practice.

The second option is to use Section 14 of the Building Act to persuade the Government to issue directions to the BIA to allow local variations for thermal integrity. If Christchurch was designated as a special zone for thermal integrity in the Building Code, the city would be able to enforce a new standard.

The Christchurch City Council may also wish to investigate whether there is significant evasion of the current insulation standard. Currently, building inspectors visit after framing and after cladding, and cannot see whether insulation has been properly installed in walls. If such evasion is occurring it is not easily rectified. In most cases, ceiling and floor insulation can be easily retrofitted to an existing building, whereas retrofitting wall insulation requires the removal of exterior cladding or internal lining.