



Australian Government

Rural Industries Research and
Development Corporation



RURAL INDUSTRIES

Research & Development Corporation

Wood Pellet Stoves for Pollution and Greenhouse Gas Reduction



MARCH 2013

RIRDC Publication No. 12/O65



Australian Government

**Rural Industries Research and
Development Corporation**

Wood Pellet Stoves for Pollution and Greenhouse Gas Reduction

By David Carr, Ian Reeve, Shane Andrews and Dorothy Robinson

March 2013

RIRDC Publication No. 12/065
RIRDC Project No. PRJ-006538

© 2013 Rural Industries Research and Development Corporation.
All rights reserved.

ISBN 978-1-74254-408-3
ISSN 1440-6845

Wood Pellet Stoves for Pollution and Greenhouse Gas Reduction
Publication No. 12/065
Project No. PRJ-006538

The information contained in this publication is intended for general use to assist public knowledge and discussion and to help improve the development of sustainable regions. You must not rely on any information contained in this publication without taking specialist advice relevant to your particular circumstances.

While reasonable care has been taken in preparing this publication to ensure that information is true and correct, the Commonwealth of Australia gives no assurance as to the accuracy of any information in this publication.

The Commonwealth of Australia, the Rural Industries Research and Development Corporation (RIRDC), the authors or contributors expressly disclaim, to the maximum extent permitted by law, all responsibility and liability to any person, arising directly or indirectly from any act or omission, or for any consequences of any such act or omission, made in reliance on the contents of this publication, whether or not caused by any negligence on the part of the Commonwealth of Australia, RIRDC, the authors or contributors.

The Commonwealth of Australia does not necessarily endorse the views in this publication.

This publication is copyright. Apart from any use as permitted under the *Copyright Act 1968*, all other rights are reserved. However, wide dissemination is encouraged. Requests and inquiries concerning reproduction and rights should be addressed to the RIRDC Publications Manager on phone 02 6271 4165.

Researcher Contact Details

David Carr
Southern New England Landcare Ltd
PO Box 85
Armidale NSW 2350

Email: mail@snelcc.org.au

Ian Reeve
Institute for Rural Futures
University of New England
Armidale NSW 2351

Email: irf@une.edu.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600

PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: <http://www.rirdc.gov.au>

Electronically published by RIRDC in March 2013
Print-on-demand by Union Offset Printing, Canberra at www.rirdc.gov.au
or phone 1300 634 313

Foreword

Domestic space heating in many cold regions of Australia is usually supplied by heaters running on solid wood, gas or electricity. All three fuel sources usually emit large quantities of greenhouse gases. Firewood collection for wood heaters has serious impacts on biodiversity. Wood heaters emit smoke and other gases which cause serious health problems. This research looked at pellet heaters as an alternative home heating option, to see if they could reduce wood smoke pollution, greenhouse gas emissions and biodiversity impacts, using the Northern Tablelands of NSW as a case study.

The research looked at existing literature and conducted social surveys to find that pellet heaters are a suitable home heating option with lower emissions and lower impacts on biodiversity than other options. Pellet heaters will be slightly more expensive to purchase and operate, so options for providing incentives for their uptake were examined. There are public benefits from pellet heaters (public health, biodiversity and climate), and so there may be a case for policy intervention to encourage their uptake.

Pellet supply was identified as a disincentive to the uptake of the heaters. The research found that there are suitable local sources of waste wood or silvicultural by-products to support pellet manufacture in the region. An efficient pellet plant would need to produce in the vicinity of 50,000 tonnes per year to be viable. Such a plant would over-supply the Northern Tablelands under the most optimistic scenario, so a market would need to be created for pellets outside the region.

Additional funding and support for this project was provided by the NSW Environmental Trust through the High Country Urban Biodiversity project and by Armidale Dumaresq Council.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our Bioenergy, Bioproducts and Energy R&D program.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns

Managing Director

Rural Industries Research and Development Corporation

About the Authors

David Carr (Southern New England Landcare).

Ian Reeve (Institute for Rural Futures – University of New England),

Shane Andrews (Southern New England Landcare), and

Dorothy Robinson (Department of Primary Industries).

Acknowledgments

The assistance of Euan Belsen and Carol Davies from Armidale Dumaresq Council in the research leading to this report is gratefully acknowledged. ADC staff also assisted with preparing wood samples for ash analysis and in establishing the firewood and biomass trial. Patsy Asch and Kate Boyd from Sustainable Living Armidale assisted the project throughout as participants in the Steering Committee. Rod Bailey from Pellet Heaters Australia generously explained the operation of a pelleting process and provided pellets for our public events. Ferg Lister of Parkwood Fires, NZ assisted with the display at SLEX by providing a pellet heater. David Freudenberger from Greening Australia gave a presentation to a firewood forum in Armidale in 2010 which helped trigger the project.

Additional funding for the project was provided by the NSW Environmental Trust through the High Country Urban Biodiversity Project and by Armidale Dumaresq Council.

A public forum held in Armidale in May 2012 provided feedback leading to the recommendations contained in the report.

Abbreviations

ABS	Australian Bureau of Statistics
ADC	Armidale Dumaresq Council
ANZLECC	Australia New Zealand Environment and Conservation Council
AUD	Australian Dollar
BaP	Benzo[a]Pyrene
BREAZE	Ballarat Renewable Energy and Zero Emissions Group
CHP	Clean Heat Program (Christchurch, NZ)
COP	Coefficient of Performance
FAA	Firewood Association of Australia
GhG	Greenhouse Gas
kWh	kilowatt hour
NPV	Net Present Value
NZD	New Zealand Dollar
OEH	NSW Office of Environment and Heritage
PAH	Polycyclic Aromatic Hydrocarbons
PM 2.5	Fine particulate matter less than 2.5 microns.
PM 10	Fine particulate matter less than 10 microns.
PNF	Private Native Forestry
PVP	Property Vegetation Plan
RDANI	Regional Development Australia Northern Inland
SLA	Sustainable Living Armidale
SLEX	Sustainable Living Expo, Armidale
UNEP	United Nations Environment Program

Contents

Foreword.....	iii
About the Authors	iv
Acknowledgments.....	iv
Abbreviations.....	v
Executive Summary	x
1 Introduction.....	1
2 Objectives	3
3 Methodology	4
3.1 Literature review	4
3.2 Community survey	4
3.3 Biomass audit.....	5
4 Literature review	7
4.1 Features of pellet stoves.....	7
4.2 Types of pellet heater and installation options	11
4.3 Biodiversity and firewood harvesting.....	12
4.4 Biomass pellet production processes	13
4.5 Biomass pellet storage, handling and distribution.....	17
4.6 Pellet heater market penetration and growth	18
4.7 Factors known to influence pellet heater uptake	19
4.8 Transformative technologies.....	21
4.9 The role of public policy.....	24
5 Current Situation in Armidale	35
5.1 The wood smoke problem.....	35
5.2 Biodiversity and firewood harvesting.....	44
5.3 Biomass resources.....	47
5.4 Pellet heaters	56
5.5 Biomass pellet availability	59
5.6 Heating costs in Armidale.....	59

5.7	State and local government policy initiatives	63
6	Discussion of Results.....	66
6.1	The need for policy action in Armidale	66
6.2	Policy options.....	66
6.3	Public and private benefits and costs of heater replacement	70
6.4	Producing wood pellets in the New England.....	71
6.5	Concluding remarks	74
7	Implications	76
7.1	National and State governments	78
7.2	Local government	79
7.3	Local home heating retailers, plumbers and electricians.....	79
7.4	Pellet manufacturers	80
8	Recommendations.....	81
9	Appendices.....	83
	Appendix 1. Communications	83
	Appendix 2. Survey questionnaire.....	84
	Appendix 3. Sources and characteristics of a variety of different biomass samples collected in the southern New England region of NSW.....	96
	Appendix 4. Wood pellet manufacturing scenarios for southern New England region – an economic comparison.	99
	Appendix 5. Personal communication sources.....	102
10	Bibliography	103
	Footnotes.....	108

Tables

Table 3.1	Comparison of respondent household tenure with 2006 Census.....	5
Table 4.1	Distribution of emissions ratings for pellet heaters approved by Environment Canterbury, NZ.	10
Table 4.2	Emissions levels for a number of pellet heaters available in Australia.....	10
Table 4.3	Typical quality standards for wood pellets suitable for domestic wood pellet heaters...	13
Table 4.4	Estimated annual health costs of air pollution in Christchurch.....	26
Table 4.5	Cost (Net Present Values, NPV) of various policy options (including costs to industry compared to the health benefits)	31
Table 5.1	Percentages giving “True”, “False”, or “Unsure” for two questions about the health impacts of wood smoke.	39
Table 5.2	The results of ash and energy analysis for a variety of different biomass samples collected in the Southern New England region of NSW.....	48
Table 5.3	The type, estimated volumes and current end use of sawmill waste produced by some of the timber processors in the wider New England region of NSW.....	53
Table 5.4	A summary of the current and potential sources of biomass that occurs in the southern New England of NSW that might provide raw material for a wood pellet manufacturing plant.	55
Table 5.5	Survey estimates of average annual heating costs for three types of household, according to the mix of heating types.....	60
Table 5.6	Comparative per kWh heating costs for a range of heating costs calculated for Armidale, with published figures for New Zealand for comparison.....	62
Table 5.7	Estimated annual heating costs and fuel use for Armidale.....	63
Table 6.1	Summary of heating options.....	69
Table 6.2	Heating substitution matrix – public benefits and costs.	70
Table 6.3	Heating substitution matrix – private benefits and costs.....	71
Table 6.4	Summarises the results of the economic comparisons of various local wood pellet manufacturing scenarios for the southern New England examined via a spread sheet model (Appendix 4).....	72
Table 7.1	Comparison of characteristics of different heat sources	77
Table 7.2	Benefits or otherwise of changing to pellet heaters from existing heat sources.	77

Figures

Figure 3.1	Comparison of respondent age and household type with 2006 Census.	5
Figure 4.1	Examples of pellet heaters available in Australia.	7
Figure 4.2	Schematic cross-section of a Parkwood pellet stove. ⁱⁱ	8
Figure 4.3	Schematic diagram of a pellet plant.	16
Figure 4.4	Example of a masonry heater.	21
Figure 4.5	Examples of ultra-low emissions wood boilers.....	22

Figure 4.6	An example of a New Zealand low emissions wood heater, the Pyroclassic IV.	23
Figure 4.7	United Nations Environment Projections for global temperatures with and without a package of 16 measures (including phasing out log-burning heaters in developed countries in favour of pellet heaters) to reduce methane and black carbon emissions ...	27
Figure 4.8	Daily average PM2.5 levels in Libby, Montana, USA, before and after virtually all old wood stoves were replaced by new ones.....	33
Figure 4.9	Results of CSIRO modelling of 24-average PM2.5 levels, which decrease steadily over time as wood heater uses declines.	34
Figure 5.1	Daily average PM2.5 Pollution in Armidale and Sydney 2008-2010, and photo of pollution in May, 2011	35
Figure 5.2	Average winter PM2.5 Pollution (June, July, August), Council Chambers, Armidale NSW	36
Figure 5.3	Air pollution in Armidale, NSW in 1996 (source Robinson et al, 2007).....	37
Figure 5.4	Perceptions of the importance of various contributory sources to winter haze in Armidale.	38
Figure 5.5	Perceptions of the level of risk to self or family of a range of possible health risks.	39
Figure 5.6	Proportions of respondents with various types of heating.	40
Figure 5.7	Comparison of the types of heating among those with no wood heating who intended to buy a wood heater in the next few years, and those who did not.	41
Figure 5.8	Comparison of the importance of wood heater attributes in the purchase decision, between those who currently have wood heating and those who do not.....	42
Figure 5.9	Proportion of house owner respondents with various types of insulation.....	43
Figure 5.10	Distribution of tonnes of firewood used per year.....	45
Figure 5.11	Density plot showing the amount of firewood use per year compared to the insulation score for houses.	46
Figure 5.12	Distribution of the proportion of firewood collected from roadsides and paddocks.	47
Figure 5.13	Sources from which respondents had heard about pellet heaters.....	56
Figure 5.14	What respondents who had heard of pellet heaters knew about them.....	57
Figure 5.15	Proportion of respondents naming various pellet heater attributes as important in a purchase decision.....	58
Figure 5.16	Distributions of annual heating costs for households with wood heating only, wood and other heating, and no wood heating.	61
Figure 5.17	Levels of support for various policy approaches given by respondents with wood heating and those without.....	65

Executive Summary

What the report is about

This research was carried out in the Northern Tablelands of NSW to determine whether pellet heaters could provide an alternative form of domestic space heating without the environmental and health costs of current space heating options. Wood heaters, for example, can cause severe wood smoke pollution and have high impacts on biodiversity due to firewood collection. Reverse cycle air conditioners, gas heaters and electric radiators have high greenhouse gas emissions. The research looked at barriers to adoption of pellet heaters and opportunities to increase their uptake. This included an examination of options for manufacturing pellets locally from a range of sustainable sources.

Who is the report targeted at?

The research is targeted at: consumers of domestic space heating, particularly in cold areas of eastern Australia; local government; suppliers and installers of domestic home heating; firewood suppliers; State and Commonwealth Government policy makers.

Where are the relevant industries located in Australia?

This research is particularly relevant to the Northern and Southern Tablelands of NSW; the ACT; Tasmania and the Victorian Alps. These areas consume large quantities of energy for domestic space heating, including firewood.

Aims/objectives

The broad, long-term objectives of this project are to:

- reduce woodsmoke and greenhouse gas emissions from wood heating, and
- reduce the impact on biodiversity from unsustainable firewood collection.

The project objectives are to:

- examine the barriers stopping people swapping to, or buying, a pellet heater rather than a conventional wood heater for domestic space heating;
- review the mix of incentives available to encourage greater uptake of pellet heaters;
- Examine the options and economic viability of developing a supply chain of pellets from sustainable sources;
- Use the knowledge gained from the project to educate about sustainable use of pellet heaters as an alternative to wood heaters; reducing air pollution; the environmental damage and threats to biodiversity from non-sustainable firewood collection; and the substantial contribution to global warming from methane emissions of conventional log heaters.

Methods used

The project used a literature review and a survey to research the objectives. Suppliers of pellet heaters and pellets, manufacturers of pellets and potential suppliers of raw material for pellet manufacture were contacted by phone or visited in person.

Results/key findings

Any substitution of wood heaters by pellet heaters will have a net positive impact on biodiversity, wood smoke and greenhouse gas emissions.

Availability and perceived cost of purchasing and operating a pellet heater and security of pellet supply are the key barriers to adoption of pellet heaters on the Northern Tablelands.

There are a range of species and sources of material to support a pellet production plant in the region.

There is local interest in pellet heaters and some willingness to purchase them should they become available.

Implications for relevant stakeholders

The implications for local government are that pellet heaters provide a feasible alternative to wood heaters to encourage lower emissions.

The establishment of pellet manufacturing in the region will depend on private investment, support from Government would be required using silvicultural waste from regional plantations.

Simple steps such as a bulk-buy scheme, heater demonstrations and establishment of a cooperative for pellet buyers would enable pellet heaters to gain a foothold in the domestic heating market in the region.

Recommendations

The report contains recommendations:

- for potential retailers of pellets and pellet heaters,
- on policy for local, state and commonwealth governments,
- on opportunities for potential manufacturers of pellets or investors, and
- for community organisations on ways to increase adoption of pellet heaters.

1 Introduction

Wood-burning stoves are a popular form of home heating in many developed countries, particularly those with cooler climates. In Australia, wood is an energy source in 10.2 per cent of households, providing 60 petajoules in 2007-08 (Australian Bureau of Statistics, 2010, 2011). Although the proportion of households burning wood for space heating declined for much of the last 12 years (Australian Bureau of Statistics, 2008, 2011), perceived advantages related to comfort, affordability, and the renewable nature of wood have ensured that there remain sufficient numbers of wood-burning stoves in many residential areas to create smoke pollution at levels harmful to health (NSW Government Health, 2003). In fact, a NSW Government-commissioned report in 2011 concluded that woodsmoke is an \$8 billion health problem just in NSW (NSW OEH 2011). This works out at more than \$22,000 for every wood heater in NSW, over its working life.

The rural city of Armidale (population, approximately, 25,000), situated on the northern tablelands of NSW, at an altitude of 980m above sea level, has an annual heating degree-day requirement between 1,000 and 1,500 (Bureau of Meteorology, 2012). The city's position within a shallow valley creates surface inversion conditions on many nights in winter, with resulting high levels of particulate air pollution. In 2011, PM_{2.5} (fine particulate matter less than 2.5 microns) levels exceeded the Australian National Environmental Protection Measure advisory level on 26 days (Armidale Dumaresq Council, 2011). Approximately 85% of winter air particulates in Armidale originate from wood heaters (NSW Environment, Climate Change and Water, 2010).

It is widely accepted that the particulates and gases in wood smoke cause a range of health problems in humans (Naeher et al, 2007). In Armidale, measured wintertime PM_{2.5} pollution is much higher than Sydney, with woodsmoke exposure estimated to increase mortality by about 7%, costing approximately \$4,270 per wood heater per year (Robinson et al., 2007). Recent research has linked PM_{2.5} and Polycyclic Aromatic Hydrocarbon (PAH) exposure to reduced ability of the placenta to supply nutrients to the foetus, genetic damage in babies, reduced IQ, and behavioural problems when children start school (Edwards, 2010; Siddiqui, 2008; Munroe, 2012; Yang, 2011). If public awareness of these impacts grows, it may discourage people from moving to Armidale, and/or from living in the low lying parts of the city. Ultimately, there is a risk to property values in the low lying residential areas of Armidale if those with the financial means move to the higher areas, or out of town. In contrast, a solution to Armidale's woodsmoke problem could attract 'tree-changers' to a city that could be justifiably proud of its clean, country air.

The collection and use of firewood in heating stoves also has a direct and negative impact on biodiversity. Most firewood in the region comes from standing or fallen dead native trees. Dead timber is an important component of habitat for many native animals, is a valuable source of soil carbon, and provides sheltered microclimates and grazing protection for native plants. Many birds and bats, including threatened species, rely on dead timber for roosting and breeding sites, utilising hollows and cracks. Threatened birds, such as the Bush Stone Curlew, use logs and sticks on the ground to hide amongst and to protect their nests. The type of hollows and cracks used by wildlife can take up to 120 years to develop, so are not readily replaced by regeneration or revegetation.

Approximately half of the firewood used in New England is collected by people for their own use, mostly from roadsides and Travelling Stock Reserves. Ecosystems in these areas often have high conservation values because of irregular grazing patterns, and support populations of threatened fauna and flora. Therefore firewood collection has a disproportionate impact on biodiversity.

There are currently few alternatives to the use of dead native trees for firewood in the region. While other sources, such as pine plantations and woody weeds exist, only limited amounts are converted into dry, seasoned firewood for domestic use (Heathcote, 2003). In addition, current Australian wood heaters are not designed to burn softwood and have high levels of emissions if they do (Gras, 2002).

Pellet heaters, which mostly use waste products from sawmills, provide an opportunity to reduce the reliance on unsustainable firewood collection. Moving some of the domestic space heating fuel from firewood to pellets made from sawmill waste and plantation thinnings would have a direct positive impact on biodiversity in the region. Pellet heaters also have much lower emission levels and so have the potential to reduce the health impacts of wood stoves.

New policy initiatives stemming from the economic analysis of these health impacts are likely to increase public awareness of the health effects of air pollution and the recommendations of health authorities, e.g. the Australian Lung Foundation and the American Lung Association not to use wood heating when alternatives are available.

The aim of this report is to investigate the potential of pellet stoves to meet the space heating needs of households with wood stoves in rural cities such as Armidale that are facing growing air pollution problems from woodsmoke, while offering the possibility of supporting local pellet manufacture that utilises wood or other biomass waste.

While pellet boilers for hydronic heating do exist, this form of heating comprises only a small fraction of domestic heating in Armidale, and since the majority of these hydronic heating systems use gas firing or an electric heat pump, this form of heating makes negligible or no contribution to air pollution problems in Armidale. For this reason, this report does not consider pellet fired boilers, but is restricted to pellet stoves that could potentially substitute for space heating wood stoves located in living spaces.

Wood cooking stoves also comprise a small fraction of the wood burning appliances in Armidale, and as pellet cookers are relatively rare and expensive, this report does not consider pellet cookers.ⁱ

2 Objectives

The broad, long-term objectives of this project are to:

- reduce woodsmoke and greenhouse gas emissions from wood heating, and
- reduce the impact on biodiversity from unsustainable firewood collection.

The project objectives are:

- Using the Northern Tablelands of NSW as a case study, examine the barriers stopping people swapping to, or buying, a pellet heater rather than a conventional wood heater for domestic space heating;
- Using the Northern Tablelands of NSW as a case study, review the mix of incentives available to encourage greater uptake of pellet heaters. Incentives to be examined include: policy (regulations), financial (subsidies, levies etc) and suasive (education, demonstrations, appeals to altruism);
- Examine the options and economic viability of developing a supply chain of pellets from sustainable sources including local (farm, garden and silvicultural waste) and existing Australian pellet manufacturers. The research will also examine options for processing wood on farms and as part of Council operations;
- Use the knowledge gained from the project to educate about sustainable use of pellet heaters as an alternative to wood heaters; reducing air pollution; the environmental damage and threats to biodiversity from non-sustainable firewood collection; and the substantial contribution to global warming from methane emissions of conventional log heaters. Relevant information will be distributed to industry bodies, landcare groups, local Councils, broader community groups directly and through the media, a public forum and Armidale's Sustainable Living Expo.

3 Methodology

3.1 Literature review

An initial scoping review was conducted using the bibliographic databases to which UNE subscribes, including Australian Public Affairs, JSTOR, ProQuest, SpringerLink, Taylor and Francis, Web of Science, and Wiley Online Library, as well as Google. A number of specialist websites were located and these were investigated in greater detail, beyond the level to which pages were referenced by Google.

3.2 Community survey

A questionnaire for householders was developed with a view to gaining an understanding of the incidence of wood heating, the age of wood heaters, the amount of firewood used, the proportion of firewood collected by the householder, intentions for wood heater replacement or purchase, opinions about pellet heaters and opinions about woodsmoke issues. A copy of the questionnaire is provided in Appendix 2.

Two community surveys were conducted in the southern New England Region using the questionnaire, one in which questionnaires were delivered to letter boxes and one in which potential respondents were contacted by email and invited to participate in an online survey. The questionnaires for the two surveys were identical, apart from the street survey questionnaire carrying a code which identified the town in which it had been delivered, and the email survey having a question which asked in which town the respondent lived.

3.2.1 Street survey

A printed version of the questionnaire was hand delivered to letterboxes in a selection of streets in Armidale (600) and Uralla (200). The streets were chosen with reference to a map of the ABS 2006 SEIFA index (Index of Relative Socio-Economic Advantage/Disadvantage) to ensure that each street spanned the full range of the Index in the two towns. The questionnaire offered respondents the choice of using the online survey or reply-paid envelope. A response rate of 8 per cent was obtained.

3.2.2 Email survey

An invitation to participate in the online survey was emailed to subscribers to the following email discussion lists and e-newsletters: UNE-Events, Talloires and UNEGreens email lists, and to recipients of e-newsletters sent to supporters of Southern New England Landcare and Sustainable Living Armidale. A total of 244 respondents filled in the online survey.

3.2.3 Representativeness of survey sample

The surveys carried questions on respondent age, type of household and household tenure, structured similarly to the ABS Census questions in 2006. Comparison of the Census figures for Armidale and hinterland (Armidale State Suburb (SSC 16089), showed that the sample of responses obtained significantly over-represented those in middle aged and older age groups, family households and households owning their house (chi-square goodness of fit tests shown in Figure 3.1, Table 3.1).

Figure 3.1 Comparison of respondent age and household type with 2006 Census.

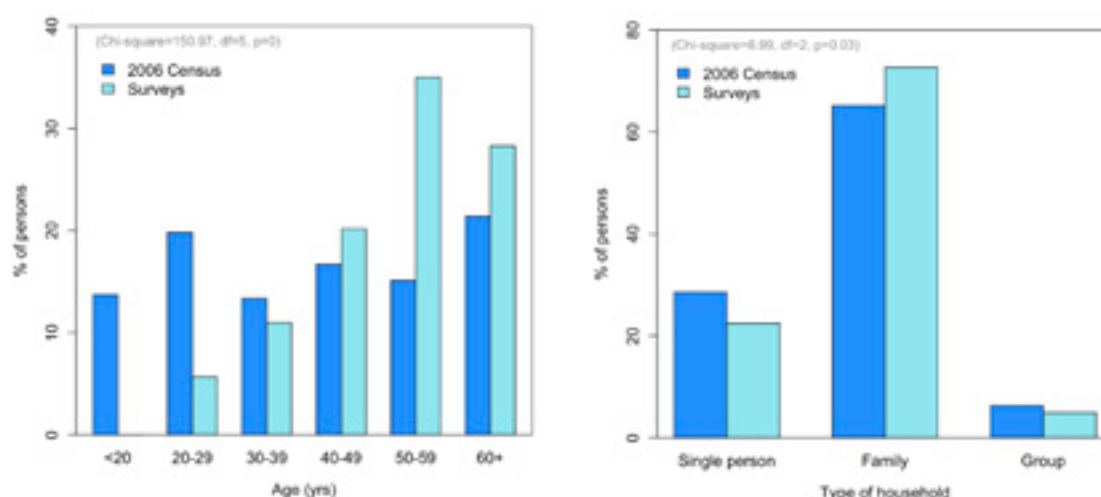


Table 3.1 Comparison of respondent household tenure with 2006 Census. (Chi-square=77.37, df=1, p=0)

	% households owning house	% households renting house
Surveys	87.4	12.6
2006 Census	62.1	37.9

Wood heater ownership in the sample was 63.4 per cent. A previous random survey of wood heater use and attitudes to woodsmoke reported that 53.3% of Armidale households used wood heating (Khan, 2002).

From these results, it is apparent that, although the survey sample is not representative of the Armidale region adult population as a whole, it is likely to be reasonably representative of those households with wood heaters which potentially could be using pellet heaters.

3.3 Biomass audit

A desk top assessment was made of the biomass resources of southern New England to determine the potential viability of local wood pellet manufacture. The assessment also included a brief review of pellet production and their costs and supply from outside the region.

The principal sources of information came from: unpublished and published reports into the regional timber industry; data from unpublished and published reports of farm tree species trials and biomass assessment studies; and from direct contact with saw millers, waste managers, transport companies, government agencies, foresters and forestry consultants.

Direct contact was also made with wood pellet manufacturers in a nearby region and from New Zealand. Wood Pellets Australia kindly provided a tour of their wood pellet factory at Woodburn on the NSW north coast.

The wider literature and internet resources were also consulted to determine the general state of the wood pellet industry world –wide and to provide current information on wood pellet quality standards.

A laboratory assessment was carried out using samples from a number of the common timber and farm tree species as well as some of the waste biomass resources of the region. This assessment aimed to indicate the suitability of common biomass sources of the region for the manufacture of wood pellets.

A simple spread sheet economic model was constructed to examine the viability of wood pellet manufacture in the local region given indicative feedstock, transport and manufacturing costs of a number of feedstock sources and pellet mill locations.

4 Literature review

4.1 Features of pellet stoves

4.1.1 Construction

Pellet stoves resemble a wood heating stove in appearance (Figure 4.1)

Figure 4.1 Examples of pellet heaters available in Australia.

Left: Canadian made Enviro Fire. Right: New Zealand made Parkwood.ⁱⁱ



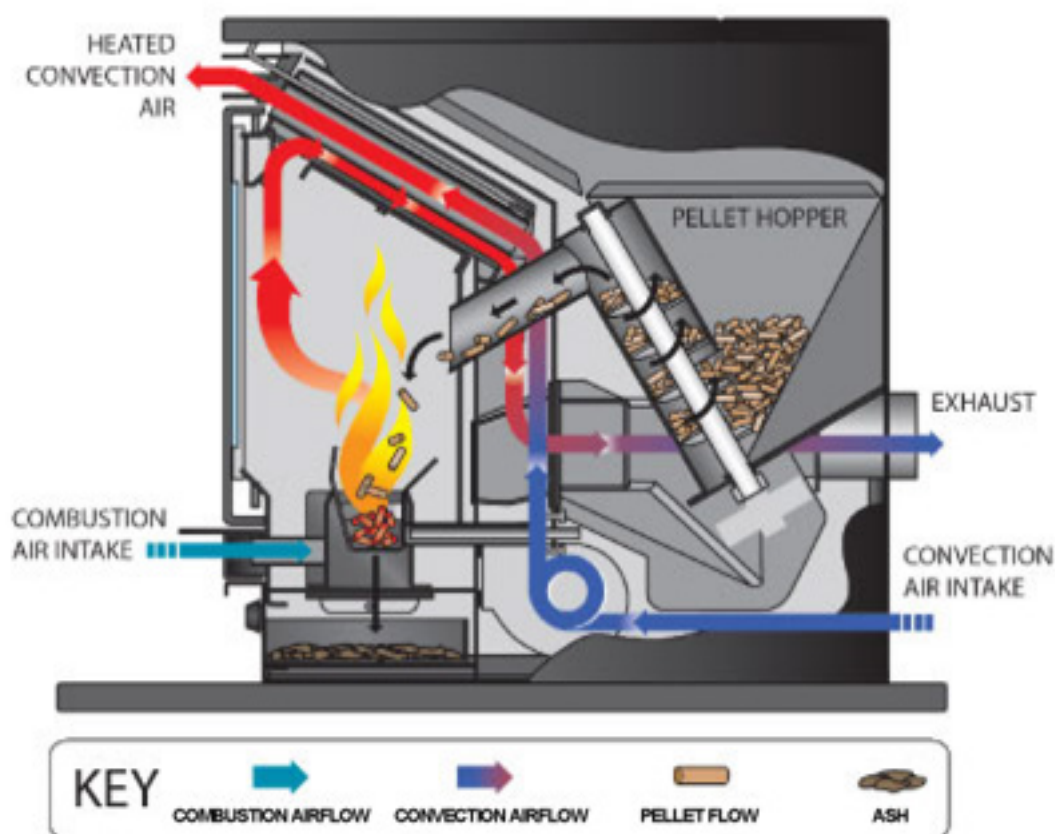
Pellet stoves are much more complex than wood stoves, with components such as the pellet hopper, pellet feed auger, one or more blowers, combustion pot and air feed, front glass air screen, printed circuit board with controller electronics, and a range of sensors, such as a flue pressure sensor, a fire sensor, and a flue temperature sensor. A 12V battery back-up and inverter to power the stove during power outages may also be included. Some models with advanced electronics include a diagnostics port. Some of these components are shown in Figure 4.2.

4.1.2 Operation

The screw auger transfers wood pellets to the combustion pot, which sits in the base of the fire box. The combustion pot is surrounded by fine air nozzles which may be supplied by a blower, or by air drawn in by the convection of flue gases up the flue. The blower, which draws its air from the room, also passes air over the top and/or around the fire box, and back into the room. Pellet ash drops through the bottom of the combustion pot into an ash tray in the base of the stove. Ignition and draft may be controlled by a micro-processor.

A major advantage of pellet heaters is their wide range of burn rates from about 2.0 to 10.5 kW, with optional thermostatic control, so that the desired temperature is maintained. Timer control also enables heaters to be turned off when the family is in bed or out for the day, but still have a warm house when they return or get up in the morning.

Figure 4.2 Schematic cross-section of a Parkwood pellet stove.ⁱⁱ



4.1.3 Emissions

Real-life emissions vs laboratory emissions

Most, if not all, of the emissions data cited by heater manufacturers is measured in the laboratory with optimal operating conditions. Measurements from heaters installed in people's homes and in everyday operation show that laboratory emissions ratings can seriously underestimate real-life performance, particularly if the heater is mainly used at low burn rates. Fisher et al. (2000) measured real-life emissions of USEPA Phase II certified stoves, required to have lab-test emissions of 7.5 g/hr or less (non-catalytic stoves) and 4.1 g/hr (stoves with catalysts). After some years of use, real-life emissions were 10.3 g/hr (9.2 g/kg) for the non-catalytic stoves and 12.8 g/hr (10.8 g/kg) for catalytic stoves. The average burn rate in this study was 1.07 kg/hr.

The same problem was noted in NZ for log-burning heaters. Average real life emissions of 4 models with mean AS4013 rating of 1.0 g/kg was 15.5 g/kg (Scott 2005).

The Australian and New Zealand standard for wood stoves (excluding cookers and central heating boilers), AS/NZS 4013, is 4g of emissions per kg of firewood burnt. Real-life emissions of AS4013 heaters installed in people's homes in Australia were also found to be much higher than the AS4013 rating. Meyer et al. (2008) recommended 10 g/kg for use in the Australian National Pollutant Inventory. Other researchers have suggested an even higher figure of 12.5 g/kg (Robinson 2011). Very poor operation (which is not uncommon) can lead to even higher emissions. On Australian researcher noted: "*The worst smoke emissions I was able to achieve in the laboratory were about 100g/kg of particles*" (Todd 2003).

Real-life emissions tests of four pellet heaters reported an average of 1.4 g/kg for 3 heaters that were in correct working order. Two of these heaters were Sherwood Industries EF2 (USANorth American manufacture) which has a rating of 1.3kg/hr (Oregon Department of Energy, n.d.).. and the third a Sherwood Industries EF3 Meridian. The relativity of the measured emissions in g/kg and the specification in g/hr would suggest the measurement was made at a fairly high burn rate. One of the four heaters was identified as faulty, with emissions of 11.4 g/kg (Kelly et al 2007).

Unless otherwise noted, the emissions data cited in the remainder of this report is as advertised by manufacturers, i.e. based on laboratory measurement under optimal operating conditions. These emissions will mostly be less than emissions under real-life conditions. In some cases the advertised emissions levels may bear no relationship to levels under real-life conditions (Todd, 2008).

US Emissions Data

Analysis of the emissions characteristics of the 897 wood stove models in the USA that qualify for tax credits when purchased suggests that the emissions and efficiency performance of US pellet stoves is generally better than the emissions of either catalytic or non-catalytic wood stoves. The average emission levels for US pellet stoves is 1.99 g/hr, compared to emissions of 4.42 g/hr for non-catalytic wood stoves.ⁱⁱⁱ

An independent study of an American pellet heater by Bowman et al. (2011) found the heater had mean emissions of 23 mg/MJ on high (5.7kW) and 40 mg/MJ on low (2 kW).

European Emissions Data

There are a small number of non-catalytic wood stoves with efficiency equal to that of pellet stoves, and emissions within the upper part of the range of emissions for US pellet stoves, e.g. the wood stoves manufactured by the MCZ Group in Italy, many of which achieve emissions levels of 3.9g/hr and efficiencies up to 81 per cent.^{iv} There are also a number of European ceramic-lined wood boilers with downdraft combustion that use high burn rates and heat storage tanks to achieve low emissions averaging about 36 mg/MJ (about 0.6 g/kg).

A Swedish study compared the new designs with older style wood fuelled boilers, some of which had very high particle and methane emissions, noting that an *“old-type wood boiler may have more than twice as high an impact on climate change as an oil boiler, besides high emissions of particles and unoxidised gaseous compounds.”* The most polluting of the older style wood fuelled boiler was found to emit 35 g of PM2.5 and 77 g of methane per kg of firewood (Johansson et al. 2004).

An independent study of a Scandinavian pellet heater by Bowman et al. (2011) found the heater had mean emissions of 16 mg PM2.5 MJ (about 0.26 g/kg) on high burn (5 kW) and 34 mg/MJ on low burn (1.7kW).

Australian and NZ Data

As mentioned at the beginning of this section, wood heater emissions may be much higher than the AS/NZS 4013 level of 4g/kg.

A number of NZ District Councils set an AS/NZS 4886 emissions limit of 0.8 g/kg for pellet heaters (Ministry for the Environment, 2011). Environment Canterbury provides a list of 25 approved pellet heaters (Environment Canterbury Regional Council, 2012). A summary of their emissions ratings is shown in the table below. The average emissions rating was 0.6 g/kg and the mean efficiency 79.5%, with some models achieving 88% efficiency.

Table 4.1 Distribution of emissions ratings for pellet heaters approved by Environment Canterbury, NZ.

AS/NZS 4886 emissions rating (g/kg)	0.3	0.4	0.5	0.6	0.7
Number of stoves with this emissions rating	2	7	12	3	1

The emissions ratings above for NZ are comparable to the independent test results of a modern Scandinavian and North American pellet stoves tested by Bowman et al. (2011).

Emissions ratings for models currently available in Australia

Emissions levels in g/kg for a small number of NZ-made pellet heaters available in Australia range from 0.5 g/kg to 0.7 g/kg (Table). US and Canadian made heaters have higher emissions ratings.

Table 4.2 Emissions levels for a number of pellet heaters available in Australia

Australian seller or agent	Brand and model (country of manufacture)	Emissions*	Certification/Source
Ipswich Skylights	Osburn Hybrid 45MF (USA)	4.5g/hr	EPA Method 28
Firemakers	Parkwood Maxi (NZ)	0.6g/kg	Manufacturer website
Firemakers	Parkwood Compact (NZ)	0.5g/kg	Manufacturer website
Firemakers	Parkwood Insert (NZ)	0.6g/kg	Manufacturer website
Firemakers	Enviro EF2 (Canada)	1.3g/hr (1.9g/kg)	Seller website pelletstovefires.com
Firemakers	Enviro EF3 (Canada)	2.0g/hr (3.6g/kg)	US EPA tax credit list
Pellet Fires Australia	Masport Storm 2 Freestanding (NZ)	0.7g/kg	Applied Research Services Ltd, NZ

4.1.4 Efficiency

The efficiency characteristics of the 897 wood stove models in the USA that qualify for tax credits when purchased show that almost all pellet stoves fall in the 78 per cent efficiency group, while almost all wood stoves fall in the 68 per cent efficiency group (US EPA, n.d.). This suggests that, if all the heat energy is needed to keep the house at a comfortable temperature, substitution of pellet heaters for wood heaters would reduce wood consumption by 13 per cent,

There is evidence, however, that much of the heat generated by log-burning heaters is in excess of requirements. A study of air quality in Launceston (Atech, 2001) noted that:

...there is considerable anecdotal evidence to suggest that thermal comfort in wood heated homes often borders on the stifling... Excess heat from wood heaters is sometimes managed by opening a window rather than turning the heat down.

In NZ, the estimate was that about a third of the heat from the average wood heater was surplus to requirements and so wasted. (Gilmour & Walker 1995).

Poorly insulated houses may also encourage excessive heat generation by wood heaters, since the temperatures that people perceive in heated rooms are generally somewhere between the actual air temperature and the mean radiant temperature of the room. The latter is the area-weighted mean of the temperatures of room surfaces and, in a poorly insulated house, the mean radiant temperature can be well below the air temperature, resulting in a perceived temperature lower than the actual air temperature.

4.2 Types of pellet heater and installation options

4.2.1 Top and horizontal feed

Top feed pellet heaters have a pellet delivery auger arranged such that it drops pellets into the combustion pot from above. This arrangement provides a physical break between the fire and the pellets, which minimises the possibility of fire burning back into the pellets. Top feed pellet heaters require low ash pellets, so that the small amounts of ash can drop out of the combustion pot into the ash hopper below. Horizontal feed pellet heaters have a horizontal delivery auger which pushes pellets horizontally onto the fire from the rear or side. This has the advantage of allowing poorer quality pellets to be used, as excess ash is pushed out of the combustion pot by the pellets being pushed into the combustion pot. However, the system does not have the clear physical separation between the fire and the unburnt pellets in the auger and hopper.

4.2.2 Free standing and fireplace insert

As the names suggest, free standing pellet heaters are designed to stand at any distance from the walls of the room. The flue passes up through the ceiling and the pellet hopper is on the top and/or rear of the heater. A fireplace insert heater is designed to go in an existing fireplace with the flue passing some distance into the existing chimney. If the fireplace height is restrictive, a horizontal feed pellet heater is more likely to fit than a top feed heater.

4.2.3 Roof and wall vented

In some countries, such as the USA, the exhaust gases from the pellet heater are permitted to be vented through a short flue, horizontally through an exterior wall adjacent to the heater. This is feasible due to the very low emissions of pellet heaters. However, such installations require the heater to have an exhaust fan to create the draught through the flue. In the event of a power outage, and if the heater does not have a back-up battery, this arrangement can result in fumes entering the room as the fire is extinguished. Positive pressurised flues also require a high standard of sealing between flue sections to prevent flue gas leakage.

The more common arrangement is to vent pellet heaters vertically through the roof, as for wood heaters. No exhaust fan is required as convective forces are sufficient to move combustion gases up the flue. The flue draught will remain in the event of a power outage.

4.2.4 Positive and negative air pressure

The majority of pellet heaters that use a fan to drive combustion air through the heater are negative pressure systems, in that the fan is on the exhaust side of the fire and draws air into the fire and pushes combustion gases out the flue. This means that the area around the fire in the heater is at negative pressure relative to the room and any leaks that develop will draw air into the stove, rather than leak combustion gases into the room. The disadvantage of negative air pressure systems is that the fan requires periodic cleaning, as it is operating in the flue gases and particulates. Positive air pressure systems situate the fan between the fire and the combustion air source, so that the area around the fire in the heater is at positive pressure relative to the room, with the result that any leaks that develop will allow combustion gases into the room.

4.2.5 Outside air intake

With increasing air tightness of houses with improved energy efficiency standards, the point can be reached where the air tightness of the building envelope is controlling the draught to the pellet fire, rather than the heater itself. Some pellet heaters manufacturers require outside air intakes be fitted as

part of heater installation. Some pellet heater models have spigots on the rear to take both a flue and a connection to an outside air intake.

4.2.6 Incorporated or external pellet hopper

The majority of pellet heaters have a hopper incorporated in the heater itself. This has a capacity of up to 30kg, sufficient for several days use at a low setting. Some firms sell accessory storage equipment, such as bulk hoppers that can be installed on the other side of a wall which has a pellet heater against it. The bulk hopper can either feed directly via an auger and a port in the wall, or the bulk hopper may have a delivery point from which a bucket can be filled and carried inside to replenish the hopper on the heater. Use of a bulk hopper enables heating costs to be reduced as pellets delivered in bulk are generally cheaper than bagged pellets.

4.2.7 Auto ignition

Some stoves are equipped with auto ignition, which works in a similar way to cigarette lighters in cars. Under normal usage, the auto ignition, augers and fans use up to 100kWh per month during the heating season (US Dept Energy, 2011).

4.2.8 Thermostatic and timer control

There is a gradation in pellet heater models in the amount of control the user has over the operation of the heater, ranging from three or four auger and fan speeds, to thermostatic control with a room temperature sensor on the heater, to thermostatic control with wireless temperature sensors located remotely from the heater, to thermostatic control combined with a timer to allow temperature settings to be varied throughout the day.

4.3 Biodiversity and firewood harvesting

The collection and use of firewood has a direct and negative impact on biodiversity. Most firewood in the region comes from standing or fallen dead native trees. Dead timber is an important component of habitat for many native animals; is a valuable source of soil carbon; and provides sheltered microclimates and grazing protection for native plants.

Many threatened species of birds and bats rely on dead timber for roosting and breeding sites, utilising hollows and cracks. Microbats live in small colonies and use tree hollows and cracks in standing dead trees for roosting during the day. Hollows and cracks provide shelter from predators and the weather. In order to stop parasites building up in roost sites, many bat species change roosting sites frequently (Tidemann and Flavel, 1987). This means that they require many hollows and cracks within their home ranges.

The Bush Stone Curlew, use logs and sticks on the ground to hide amongst and to protect their nests on the ground (DECC, 2007). The Brown Treecreeper uses hollows in dead and live standing trees for nesting and fallen dead timber is important for foraging (NSW Scientific Committee, 2001). Hooded Robins use fallen branches for perching before pouncing on insects, while Speckled Warblers build their nests among fallen timber on the ground or amongst grass tussocks. In Australia there are 21 bird species directly threatened by firewood collection of which 15 are woodland species and one a temperate forest species (Garnett and Crowley, 2000). In New England the great majority of our firewood is collected from woodland or temperate forests.

In surveys in River Red Gum forests in south eastern Australia MacNally et al (2000) found significant links between the amount of fallen timber (coarse woody debris) and different wildlife groups. At 20 t/ha they found an increase in the diversity of bird species, while 45 t/ha was required

before an increase in small native mammals was detected. In similar forest types, West et al (2008) found that in areas where firewood harvesting regularly occurred, an average of 3 t/ha of coarse woody debris remained. Where firewood harvesting did not occur, coarse woody debris levels were >20 t/ha on average.

The type of hollows and cracks used by wildlife can take up to 120 years to develop, so are not readily replaced by regeneration or revegetation (Munro et al, 2007). Artificial nest boxes can act as a substitute for hollows but they are expensive to make and install and must be made in high numbers and a diversity of styles to replace the natural range of hollows lost when old and dead trees are removed from an ecosystem. As a result, artificial nest boxes are rarely deployed. Even though trees are a renewable resource, the long replacement times for the habitat values of standing and fallen dead wood means that firewood is not a sustainably-managed resource.

Approximately half of the firewood used in Australia is collected by people for their own use, with a significant amount coming from roadsides and Travelling Stock Reserves (Freudenberger et al, 2000).

4.4 Biomass pellet production processes

4.4.1 Quality standards

To ensure the adequate performance of wood pellet heaters and minimize maintenance issues, high quality pellets are required as fuel. Common problems resulting from poor fuel include: poor combustion due to low physical or energy density or high pellet moisture content; auger blockage due to high levels of fines/moisture; and build-up of clinkers/sinter (silicate slag material) in the combustion pot, fire box and flue due to too much ash in the fuel. Low ash content (<1% by weight) is a critical fuel characteristic for domestic room-size wood pellet heaters. The narrow air flow apertures in the combustion pot are easily blocked by clinkers. Larger commercial pellet heaters/boilers are more tolerant of the above issues due to the generally higher usage rates of fuel and the larger size of the combustion chamber, fuel conveyors and flues. Larger wood pellet boilers can tolerate fuel with ash content as high as 3%.

Wood pellet standards vary across the world and standards for domestic heater wood pellets have yet to be developed in Australia and New Zealand. A brief review of various standards in regions of New Zealand and in other countries occurs at www.woodpellets.org.nz, the listed values from this review are summarised below.

Table 4.3 Typical quality standards for wood pellets suitable for domestic wood pellet heaters

(source www.woodpellets.org.nz).

Parameter	Range in values
Diameter	6 to 10mm
Length	20 – 40mm
Bulk density	>600kg/m ³
Energy content	>16.5 - 18 MJ/kg
Ash	< 0.5 – 1%
Moisture	< 8 – 10%
Fines	< 0.5 – 1%
Chlorine	< 0.02%

The latest European standard DIN – EN 1496-2(Quality A1) is the benchmark that current pellet manufacturers are likely to aim for. In New Zealand, pellets that meet this European standard are considered to be of high quality (www.woodpellets.org.nz).

4.4.2 Biomass sources

Wood pellet manufacture requires considerable breakdown of the original source material to shavings/sawdust consistency, thorough drying, and then compression to a consistent density via a pelletiser (see below). Therefore the initial moisture content, wood structure and density of the source material is no longer important in determining burn characteristics of the manufactured fuel (in contrast to solid wood fuel used in conventional log heaters). Additionally, variations in energy content of a wide array of woody biomass sources are usually small when measured on a dry weight basis (e.g. a range of between 19 to 20mj/kg net of moisture and ash for 26 Australian tree species reported by Olsen *et.al.* 2004). Ash content is therefore often the most critical measure when considering biomass sources for wood pellets. Provided ash content is low enough, woody material from virtually any tree species is suitable for the manufacture of wood pellet fuel.

The simplest route for pellet manufacture is to use waste wood that is already substantially broken down into small fibres i.e. sawdust/shavings. Sawdust is a waste material from sawmills and can often be acquired at relatively low cost. World-wide, sawdust is the most common source material for the manufacture of wood pellets (IEA Bioenergy, 2009). Other potential woody materials suitable for wood pellet manufacture include: other sawmill waste (e.g. wood chips, offcuts and flitches); urban green waste, woody weeds and waste timber; silvicultural thinnings and low quality logs from timber production forests and agro-forests; and purpose grown biomass tree crops. Each of these other biomass sources will require some form of harvesting, pre-treatment (debarking, sieving, sorting), and grinding/hammer milling to sawdust consistency prior to use within a pellet mill. Each additional transport and pre-processing step creates extra cost in the manufacturing process.

4.3.3 Wood pellet mills and pelleting processes

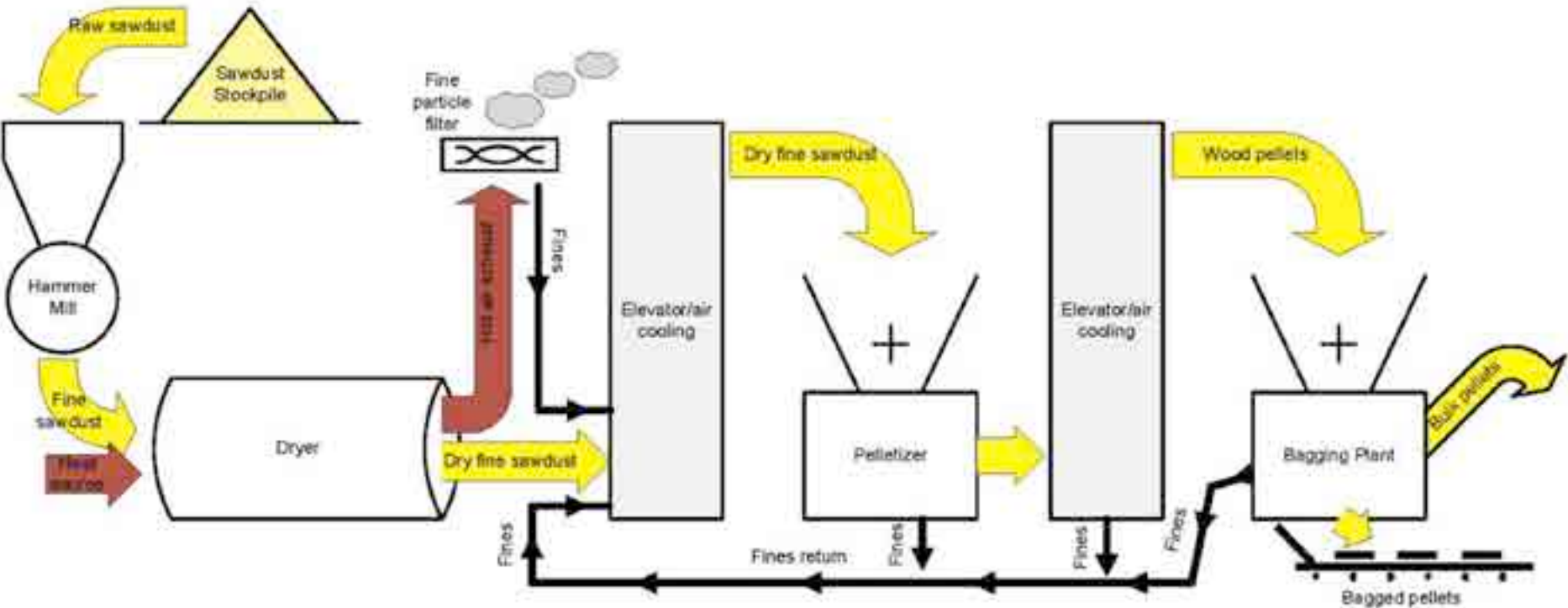
As mentioned above, wood pellets are produced when fine sawdust is dried and then compressed through a die via a pelletiser press. The high pressures involved in the press causes a large increase in the temperature of the material which in turn causes lignin in the wood to form glue which binds the material upon cooling (IEA Bioenergy, 2009). The intent of the whole process is to increase the energy density of the original material and to generate a fuel of consistent quality in terms of size, moisture, energy and ash content (see section 4.1.1). With a bulk density of 600kg/m³ plus, wood pellets are more than 2 to 3 times the densities of wood chips or sawdust.

Figure 4.3 diagrammatically represents the typical steps in wood pellet manufacture (where sawdust is the feedstock). A wood pellet production facility is likely to include:

- a store for the feedstock;
- a hammermill and screen to generate consistent particle size in the sawdust/shavings;
- a dryer which reduces moisture content below the desired level (8 – 10% by weight);
- a heat or hot air source for the dryer (usually a gas burner or wood pellet heater);
- elevators and conveyors that move the material between the different processing steps;
- a pellet press;

- a control system that governs each operation and the rate of flow of material through the plant;
and
- a bagging plant and/or bulk handling system for the final product.

Figure 4.3 Schematic diagram of a pellet plant.



Where whole logs or material other than sawdust is used as a feedstock – other pre-processing plant will be required (e.g. tub grinders, chippers, hammer mills) to reduce the material to sawdust consistency.

As with any industrial process economies of scale are apparent with the production of wood pellets. Small scale diesel or electric powered pelleting mills (at sub \$10,000 cost) are available where sawdust can be fed in by hand and pellets manufactured for use by a single household, small business or farm. Such mills, whilst inexpensive, are likely to produce pellets at high cost per labour unit and wood pellets of variable quality. Conceivably such small mills could be setup with a small scale hammermill and dryer to improve pellet quality. However once the facility is housed in a building and various conveyors are required to move material from one process to another to improve efficiency and a bagging plant is added, capital costs are likely to rise substantially. The wood pellet mill run by Pellet Heaters Australia at Woodburn currently produces 3,000 tonnes annually (Bailey, pers. comm.), is likely to represent a multi-hundred thousand dollar investment and by world standards is a small plant. 'Natures Flame' a wood pellet manufacturer in New Zealand operates a number of multi-million dollar plants each producing approximately 25,000 tonnes annually (Kernohan 2011). It's most modern plant is currently producing 40,000 tonnes per year with plans to increase output to 100,000 tonnes/annum. The expansion will require an investment of 50 to 60 million dollars (Kernohan, pers.comm.). Kernohan suggests that a plant producing 100,000 tonnes per year is a world class sized facility with best economies of scale without having to import feedstock excessive distances.

4.4.4 Briquettes

Briquettes are produced in much the same way as wood pellets except they are much larger (30 – 100mm in diameter, IEA Bioenergy, 2009). The critical difference is that briquettes are designed to be used in conventional log heaters. Their use as fuel therefore comes with most of the disadvantages of solid firewood fuel which in the case of the southern New England includes excessive wood smoke pollution and methane emissions due to incomplete combustion. They are fed manually into the firebox which also disallows all of the automated efficiency advantages of wood pellet stoves. For these reasons briquettes are not considered further in this report.

4.4.5 HotBlocks

HotBlocks are another form of combustible manufactured fuel. They are made by compressing a mixture of sawdust and cardboard waste under high pressure into moulded blocks (HotBlocks.net.au). It is claimed the manufacturing process provides a fuel of much higher density and energy content than conventional firewood (approximately 30% more). Since HotBlocks are manufactured from waste material their use as fuel also eliminates the impacts on biodiversity of firewood harvesting. However again they are designed to be used in conventional log heaters which generate all of the drawbacks with regard air pollution and methane emissions and lack the automated efficiency advantages of wood pellet stoves. HotBlocks are also substantially more expensive than wood pellets (\$576/tonne exclusive of freight from Melbourne where they are manufactured, (Jane Rudd, pers. Comm). For these reasons HotBlocks are not considered further in this report.

4.5 Biomass pellet storage, handling and distribution

Wood pellets are traded either in plastic water resistant bags (10, 15 or 20kg depending on manufacturer) or in bulk (sold by the tonne). Consumers with room-size domestic pellet heaters are likely to use bagged product since typical usage is one or two bags a week (Bailey, pers. comm.) and bags are easier to handle and require no special equipment for storage. A dry surface in a garage or garden shed is all that is required. Bags are wholesaled and transported on one-tonne pallets and a typical annual usage for a room-sized pellet heater is 1 or 2 pallets /year (Kernohan, pers. comm.).

All of the current production from the Pellet Heaters Australia Woodburn factory is sold as bagged product. It is anticipated that any initial development of pellet heating in the southern New England is likely to rely on bagged wood pellets.

Bulk pellets (where available) are less expensive on a per tonne basis since packaging and transport costs are lower. In countries where they are utilised, bulk pellets are transported either in typical bulk transport tipping trucks for very large users or in purpose built trucks usually with their own truck mounted auger for delivery to smaller domestic customers. Such vehicles are in common use in the New England region for the delivery of pelleted stock feeds. Wood pellets are hygroscopic (absorb moisture) and need to be kept dry (IEA Bioenergy, 2009) therefore, for bulk pellets, dry rain-proof storage in silos or purpose built sheds or bunkers is required. Bulk pellets are normally augured into silos or sheds or tip-dumped directly from the truck into bunkers. Pneumatic conveyors or blowers are unsuitable for the loading and unloading of wood pellets since too many fines are produced in the process.

Consumers with high usage rates (e.g. commercial wood pellet fired boilers, buildings with pellet heaters used for central heating) are more likely to invest in the special storages necessary to take advantage of bulk delivered wood pellets, although, where space permits, smaller silos mounted beside homes are possible for domestic users.

4.6 Pellet heater market penetration and growth

4.6.1 Europe

Norway

Pellet heaters came on the market in Norway around 2001^v

In 2003, very high electricity prices, due to drought and a cold winter^{vi}, made pellet stoves an attractive alternative for home heating.^{vii}

In 2004, pellet stoves were regarded as having a bright future.^{viii}

Sales in Norway peaked in 2006 at 3,000 per year, falling to 1,376 in 2007 and 1,700 in 2008. Norway's only manufacturer of pellet stoves stopped production in July 2011. State subsidies and cheaper electricity, which makes ground and air source heat pumps competitive with pellet stoves, are reasons being advanced for the downturn in the industry.^{ix}

Also pellet prices increased over the period when electricity prices were falling.^x

4.6.2 USA and Canada

In 2008, Canada had 30 pellet plants, 9 of which were in British Columbia (BC); with about 35 plants in the planning stage, 13 of them to be located in BC (Pa 2010). Overall, about 90% of the pellets produced in Canada were exported and 78% of these pellets were shipped to Europe (Pa 2010). Local use included commercial boilers, for which the emissions limit in Metro Vancouver is .0051 g/MJ or about .09 g/kg of pellets, so that advanced technology such as wood gasification or filtration are required to meet the emissions limits.

In Ontario, where the government has committed to eliminating the use of coal for electricity production by December 31, 2014, pellets are being considered as an alternative to coal-fired power generation (Zhang, 2009).

4.6.3 Australia and New Zealand

Pellet heaters are becoming increasingly popular in NZ. In May 2010, there were an estimated 10,000 pellet fires in residences, of which 8,000 were in the Canterbury (Christchurch) area, where the

average home burns 1 to 1.5 tonne of pellets per year. There is also a growing market in the North Island, where average fuel consumption is about 0.75 tonnes per year (Cox 2010).

Pellets are also used in commercial applications, including heating for 40 schools (in May 2010), as well as universities, hospitals, prisons, factories, accommodation and to provide heating for swimming pools.

Supplies of pellets are readily available with least 10 pellet-production companies situated throughout the country, with offices from Auckland to Invercargill. Natures Flame, for example, has production plants in Christchurch, Rotorua and Taupo and does bagged deliveries (15 kg or 1 tonne) to any address in NZ. Production is expanding at the Taupo plant, from 40 kilotonnes/yr in 2010 to 100 and then 180 kilotonnes/yr. Expanding the plant is expected to cost an additional \$20 million on top of the \$35 million already invested (Kernohan, 2011). The company has agents in Italy, France and throughout Europe, and has exported bulk shipments to Holland, the UK and Japan. Currently, about 25,000 tonnes of pellets are exported annually but this is likely to increase.

There is a limited market for pellets and pellet heaters in Australia. Perhaps the greatest concentration of pellet heaters is in Launceston, Tasmania, where there is a local distributor of pellet heaters and local pellet manufacture.

There is also a small pellet plant at Woodburn in northern NSW, owned by Pellet Heaters Australia (PHA). PHA manufactures and ships approximately 1,500 tons of premium quality packaged wood pellet fuel per year from its plant in Woodburn NSW to customers all over Australia.

Typical size bags are 20kg. Standard pallet configurations are 1 tonne or 1000kg containing 50 x 20kg bags. Product is shipped by truckload (22 or 34 tonnes per load). Smaller or larger shipments are available on request.

Some community groups are trying to encourage use of pellet heaters in Australia. Among them is the Ballarat Renewable Energy and Zero Emissions Group (BREAZE), which is currently developing a bulk-buy scheme.

4.7 Factors known to influence pellet heater uptake

The theory of the diffusion of technological innovations (Rogers, 1995) proposes that five attributes of a technology determine the rate at which it is adopted: relative advantage, compatibility, complexity, trialability and observability. In the context of pellet heaters, these attributes are generally determined by the manufacturers, according to their views as to the heater attributes that may be attractive to purchasers.

Theories of the determinants of pro-environmental behaviour, i.e. behaviours (including purchasing behaviours) that have improved environmental outcomes identify three types of factors that influence these behaviours: (a) rational assessment of costs and benefits (the latter being influenced by perceived behavioural control), (b) awareness of moral and social norms relevant to the behaviour and (c) affective and symbolic motivations (Steg and Vlek, 2009). The second factor, above, has been approached from a number of perspectives, including the value basis of environmental beliefs and behaviour, measures of environmental concern, and various norm-activation approaches (Steg and Vlek, 2009).

The two subsections below follow this two fold division of factors influencing pellet heater uptake.

4.7.1 Pellet heater attributes

A number of studies, mostly in Scandinavia and North America have examined the influence of pellet heater attributes on their uptake. In a review of this literature, Sopha et al. (2010) identified six main attributes that were important in choice of wood pellet heating:

- functional reliability,

- indoor air quality,
- purchase cost,
- fuel cost,
- amount of work operating the heater, and
- the security of fuel supply.

Problems with pellet stoves that have been reported include variation in the size and quality of pellets, soot and ash problems and difficulties getting the stove to light.^{xi}

Positive attributes that have been reported by pellet heater users in Norway include:^{xii}

- cleanliness,
- easy to carry fuel and fill hopper,
- maintains a constant temperature in the house,
- only have to fill hopper every few days, and
- payback period of about two years when replacing oil heating.

Negative attributes reported by the same users include:

- noise from fan,
- noise of pellets falling in combustion chamber,
- need to change flue to smaller diameter to prevent flue condensation, and
- need to build a small storage shed for the bags of pellets.

In Sweden, the different attributes of pellet heaters compared to pellet boilers resulted in rapid uptake of the latter, but much slower uptake of the former. This was because of the compatibility of pellet boilers with the existing basement hydronic heating systems, whereas there had been no tradition of free-standing stoves in living rooms (Henning, 2005).

It is important to note that the attributes of pellet heaters as predictors of uptake is entirely dependent upon the local domestic and economic context. For example, the ease of filling the hopper may be regarded as advantageous by someone used to a wood heater, but be regarded as onerous by someone accustomed to reverse cycle air conditioning. The economic attractiveness is entirely dependent on the fuel price relativities in the locality where pellet heaters are being purchased.

4.7.2 Attributes of purchasers of pellet heaters

As with other domestic technologies aimed at reducing environmental impacts, age and income have been found to influence the uptake of pellet heaters (Sopha et al., 2010), with younger people more likely to adopt new technologies such as pellet heaters and higher income households having the capacity to stay with electric heating when this is more expensive than pellet heating. However, it is important not to over-simplify these relationships as it is quite possible that in some circumstances, such as where wood heating is common, pellet heating may be preferred by older people to reduce the physical work in providing heating. Also higher income households may be able to afford to take risks if pellet heating is generally perceived as an untried and risky heating option.

4.8 Transformative technologies

There are a number of competing options for domestic space heating where technological developments have the potential to transform the mix of heating types used in houses.

4.8.1 Masonry heaters

Masonry heaters have a long tradition in northern Europe, but are becoming increasingly popular in USA and Canada. The heater is set within a large mass of masonry (chosen to suit the room décor) and there is a convoluted smoke path through the masonry to absorb as much heat as possible before it exits through a standard metal flue. The heater is operated at a high burn rate for several hours a day and radiates heat from the masonry for the remainder of the time. Because of the high burn rate and high temperatures, low emissions levels are achieved (e.g. 2.96g/kg is claimed for the Canadian-made Tempcast, tested in the USA -http://www.heavenlyheat.com.au/?page_id=13).

Masonry heaters reduce the amount of time spent tending and reloading fires so may be an attractive option for some households in Armidale. The Australian re-seller for Tempcast stoves reports that, for rural Victoria with frosty nights and 3-8degC days, the masonry heater in his house maintains 17degC in the house with one lighting per day, compared to 12degC without the heater. A drawback is the volume of masonry that has to be built around the heater, so installation takes a lot more than the several hours required for a wood heater. In houses with wooden floors on piers, considerable work may be required to provide a foundation for the heater.

Figure 4.4 Example of a masonry heater.



4.8.2 Ultra-low emissions wood stoves

Ultra low emission biomass combustion technologies include:

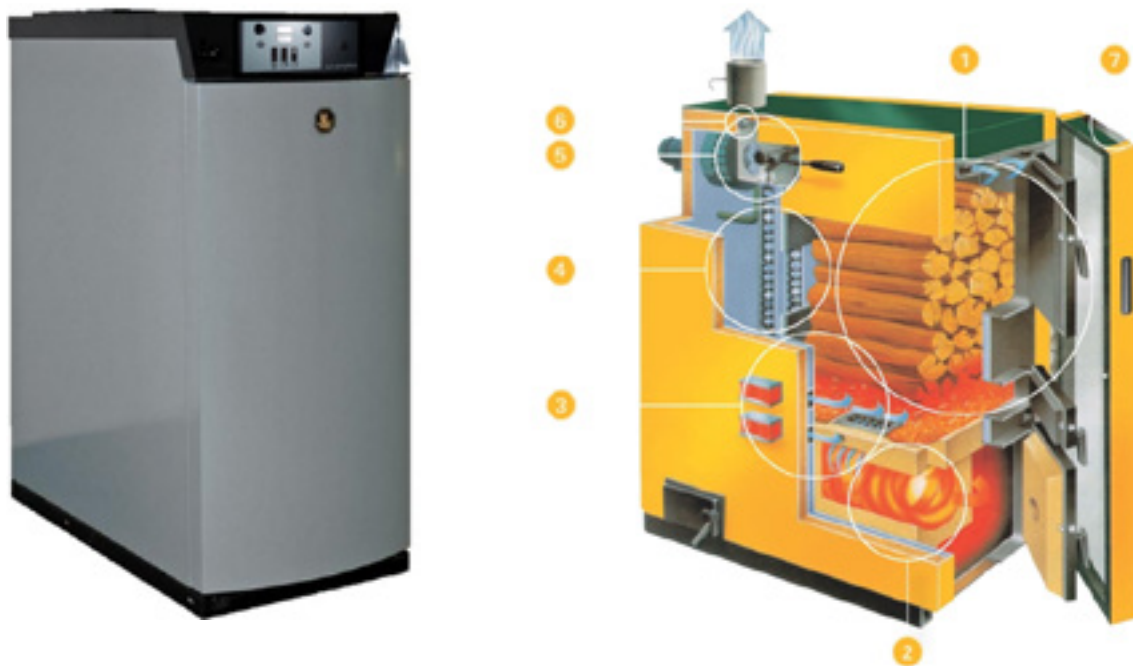
- ceramic lined, insulated combustion chambers,
- primary and secondary combustion zones with separate air supplies,
- flue gas sensors,
- heat exchangers, and

- microprocessor control.

These stoves, which are available in Europe and the USA, rely on wood gasification, whereby wood in a primary chamber is heated to drive combustible gases downwards into a ceramic lined secondary chamber where these gases are burned at 1,800 degC to 2,000 degC. Most of these stoves are able to use split logs, wood chips or furniture factory waste. There are also models specifically using wood pellets as the fuel with some European models achieving emissions levels of 0.09g/kg (Albrecht, n.d.).

Figure 4.5 Examples of ultra-low emissions wood boilers

– Tarm Solo Plus, USA (left) and KWB Classicfire, Austria (right).



A number of projects are under way in Europe to further develop these technologies, with a goal of achieving near zero emissions (see, for example, “Next generation small-scale biomass combustion technologies with ultra-low emissions”, <http://www.ultralowdust.eu/index.php?id=201>). Consistent with the European emphasis on hydronic systems for domestic space heating, these technologies are being applied to boilers.

However, some of these technologies are being adapted in New Zealand and the USA by manufacturers of free standing wood heaters. These achieve emissions levels of 0.3 - 0.4 g/kg (Environment Canterbury Regional Council, 2012). Models include Ethos Ares fireplace insert stoves, Pyroclassic IV, and Woodsman Tarras MKII. Similar heaters manufactured in the USA, such as the Quadrafire Millenium 4300 ACC are also available in New Zealand and Victoria.

If the New Zealand manufacturers continue their adoption of European technologies, and were to obtain appropriate test certification using Australian hardwoods and were to market their products aggressively in Australia, these wood heaters could become attractive alternatives to pellet heaters.

Figure 4.6 An example of a New Zealand low emissions wood heater, the Pyroclassic IV.



The extent to which these wood heaters will meet their specified emissions levels under real-life conditions will depend on how much control is in the hands of the operators. European and USA wood gasification boilers, which are completely microprocessor controlled, are likely to perform in real-life very close to the specified emissions levels. Some New Zealand low emissions wood heaters have Automatic Combustion Control, and these may also eliminate much, if not all, of the human error that leads to real-life emissions exceeding specified emissions levels. If a substantial amount of control is in the hands of human operators, then the New Zealand low emissions stoves may have higher level emissions than specified.

4.8.3 Pellet production

Torrefaction

Torrefaction is a relatively low temperature pyrolysis process that improves the energy density of biomass fuels, making it economic to transport fuels over longer distances. It can be applied to various biomass fuels, including wood pellets. Torrefied biomass is hydrophobic, and thus less demanding in its storage requirements than wood pellets. Torrefaction has the potential to alter the economics of wood pellet supply, making the exploitation of more distant biomass sources possible and lowering transport and storage costs.

Solar kilns

Solar kilns are an emerging technology in the Australian timber industry (see, for example, the Australian firm, Solarkilns, <http://www.solarkilns.com>). Solar kilns are designed to lower timber moisture contents, while minimising losses due to splitting and checking. At this stage, it does not appear that the technology has been applied to the drying of timber wastes prior to pellet production and there may be considerable technical barriers to drying a bulk material, compared to drying timber which can be stacked with adequate air spaces. If these barriers could be overcome, then given that drying costs are a significant part of the price of wood pellets, solar kiln drying of timber wastes could result in substantial price reductions.

Mobile pellet plants

There is a considerable range of small scale wood-pelleting equipment available in China and the USA. These are likely to be most attractive to people who have their own biomass sources, wish to produce pellets for their own use and have heaters that could cope with variation in pellet quality. For example, for biomass that needed no drying, cooling or bagging, a Pellet Pros PP85 (www.pelletpros.com) could produce 36 kg/hr of pellets at a cost for electricity of \$0.02 per kg. If pellet quality is to be maintained and the product sold, then dryers, coolers and baggers are required. Using Pellet Pros equipment, the total capital outlay for a dryer, pellet mill, cooler and bagger to handle 450kg/hr is around \$54,000 plus freight to Australia. Operating costs including electricity and diesel fuel are still around \$0.02 per kg. However, an operation of this size would require substantial investment in a building, storage, conveyors, loader, forklift etc. The viability or otherwise of a pelleting operation of this scale in Armidale would depend very much on the individual proprietor, whether they already owned some of the equipment or commercial space and whether they could run the operation with no hired labour.

4.9 The role of public policy

4.9.1 Health costs – a major driver for public policy

There is an ever-growing body of research linking exposure to air pollution to adverse health effects. This has been one of the main factors driving public policy formulation to reduce reliance on wood heaters and substitute other forms of domestic heating, such as pellet heaters.

PM2.5

The most health-hazardous air pollutant, responsible for about 10-20 times as many premature deaths as the next worst pollutant (ozone) are fine particles less than 2.5 microns (millionths of a metre) in diameter, known as PM2.5. PM2.5 are so small they behave like gases and enter homes in the same way as the air we need to breathe. Consequently, indoor PM2.5 measurements are closely related to outdoor concentrations.

There is no known safe level of PM2.5 pollution. Studies show substantial adverse health effects at levels well below the Australian advisory PM2.5 standard. For example, a study published in February 2012 reported median Canadian PM2.5 pollution levels of 7.4 ug/m³. An increase of 3 ug/m³ in PM2.5 pollution was associated with a 9% increase in deaths from ischemic heart disease

and 3-4.5% increases in all deaths (Crouse et al. 2012). In Quebec, 61% of PM_{2.5} emissions are woodsmoke (Lung Association of Quebec 2009).

A similar study in Christchurch, NZ, where 76% of particle pollution is woodsmoke, but only 13% from industry, 11.7% from diesel vehicles and 0.3% from petrol vehicles, compared death rates with pollution measurements in the different suburbs. After adjusting for other factors such as age, sex, ethnicity, socio-economic status and tobacco smoking habits) death rates were related to average particle pollution measurements. Estimates for each increase of 10 µg/m³ of annual PM₁₀ (fine particles less than 10 microns) exposure were:

- 34% increase in respiratory deaths
- 11% increase in circulatory deaths
- 8% increase in all deaths

With a range in annual PM₁₀ pollution from less than 1 to about 20 µg/m³, this implies that the worst polluted areas had 64% more respiratory deaths, 22% more circulatory deaths and 16% more total deaths (Fisher et al. 2007).

A previous study (HAPINZ - Health and Air Pollution in NZ) estimated the health costs using a much lower dose-response relationship of 4.3% increased mortality per 10 µg/m³ of annual PM₁₀ exposure. At the time, Christchurch had a total of 38,184 solid fuel heaters and 8570 open fires, implying an annual cost of \$2,700 per heater per year. Estimates based on the observed 8% increase in death rates would amount to more than \$5,000 per heater per year.

Woodsmoke contains the same and very similar chemicals to tobacco smoke and it is associated with the similar health problems – heart and lung diseases, reduced ability of the lungs to fight infection, cancers, middle ear infections, triggering of asthma attacks and bronchiolitis in children. According to a review of the health effects of woodsmoke by Naeher et al (., 2007): “*Organic extracts of ambient particulate matter (PM) containing substantial quantities of woodsmoke are 30- fold more potent than extracts of cigarette smoke condensate in a mouse skin tumour induction assay (Cupitt et al., 1994)*”

An Austrian study assumed emissions of 30 mg/MJ for pellets, 50 mg/MJ for log-burning heaters and 90 mg/MJ for wood chips (approx 0.48, 0.8 and 1.44 g/kg). A modelling exercise was conducted to predict the effect the 36.8% of households currently using light fuel oil switching to biomass, but no change in the 25.5% of households using natural gas. The scenario assumed that log-heaters use would increase from 13.6 to 21.5% of households, wood chip heaters from 14.4 to 31.7% and pellet heaters from 9.6 to 21.2% of households.

Table 4.4 Estimated annual health costs of air pollution in Christchurch.

This study, published in 2005 (Fisher et al 2005), assuming 4.3% increased mortality per 10 $\mu\text{g}/\text{m}^3$ of annual PM10 exposure, just over half the observed increase in mortality in a study published in 2007 (Fisher et al. 2007).

Effect	Domestic	Industrial	Vehicle	Total
Mortality	\$93.0M	\$13.5M	\$12.0M	\$118.5M
Cancer	\$0.8M	\$0.2M	\$0.2M	\$1.2M
Chronic bronchitis	\$2.7M	\$0.7M	\$0.6M	\$4.0M
Admission cardio-vascular	\$0.1M	\$0.05M	\$0.05M	\$0.2M
Admission respiratory	\$0.4M	\$0.1M	\$0.1M	\$0.6M
Restricted activity days	\$30.0M	\$7.0M	\$6.0M	\$43.0M
Minor hospital costs	\$0.15M	\$0.03M	\$0.02M	\$0.2M
Total	\$127M	\$22M	\$19M	\$168M

M = millions of NZ dollars. Source Fisher et al. 2005.

Despite the relatively low level of emissions per heater (30 to 90 mg/MJ) the result would be an increase of 174 deaths per year in a country of 1.4 million. (Haluza et al., 2012).

Hospital admissions

A comprehensive study looked at PM2.5 pollution and 1.5 million admissions to over 3,000 hospitals in the US state of New England. PM2.5 pollution, estimated from 78 monitoring stations supplemented by satellite data and modelling, was split into long-term (annual) averages and short-term (day-to-day) variation. Annual average PM2.5 pollution ranged from 3.5 to 17.8 $\mu\text{g}/\text{m}^3$. The strongest relationships were found for long-term exposure, which was estimated to increase hospital admissions for respiratory, cardiovascular, strokes and diabetes by respectively 4.2, 3.1, 3.5 and 6.3% for increased annual exposure of 10 $\mu\text{g}/\text{m}^3$. As well as these overall increase related to average pollution where people live, short-term variation in pollution also affected admissions rates by 0.7, 1.0, 0.2 and 1.0 per cent respectively for respiratory, cardiovascular, strokes and diabetes admissions.

Other toxic chemicals

Recent studies have shown other serious health effects of air pollution. A US study measured exposure to PAHs in women's home environment during the third trimester of pregnancy. Measured exposure was used to split the mothers into two groups – those with PAH over 2.26 ng/m^3 (high exposure) and those with PAH less than this (low exposure group). Children whose mothers were in the high exposure group scored about 5 points lower on IQ tests when they started school. (Perera et al. 2009).

A follow-up study examined behavioural problems. The proportions of children with behavioural problems considered borderline or clinical were:

Anxious/Depressed	6.32%	
Attention Problems	6.72%	
Anxiety Problems (DSM)	9.48%	
Attention Deficit Hyperactivity Problems (DSM)		7.91%

Genetic damage from adducts to a specific chemical – benzo[a]pyrene (BaP) was measured in umbilical cord blood. Average BaP exposure was reported to be about 0.5 ng/m^3 . The 41% of children with detectable BaP adducts in umbilical cord blood had a 4-fold increase in attention problems, and 2.6-fold increases in attention/hyperactivity problems and anxiety problems. (Perera et al. 2012).

Several other studies have linked PAH exposure to reduced IQ of school age children, as has prenatal maternal exposure to woodsmoke in Guatemala. (Dix-Cooper et al, 2011).

4.9.2 Greenhouse gas emissions – the second driver for public policy

Under the Copenhagen Accord, the major emitters of greenhouse gases agreed that the global average temperature increase should be kept below 2 °C. Current projections for the ‘business as usual’ scenario imply that this limit will be exceeded by 2050.

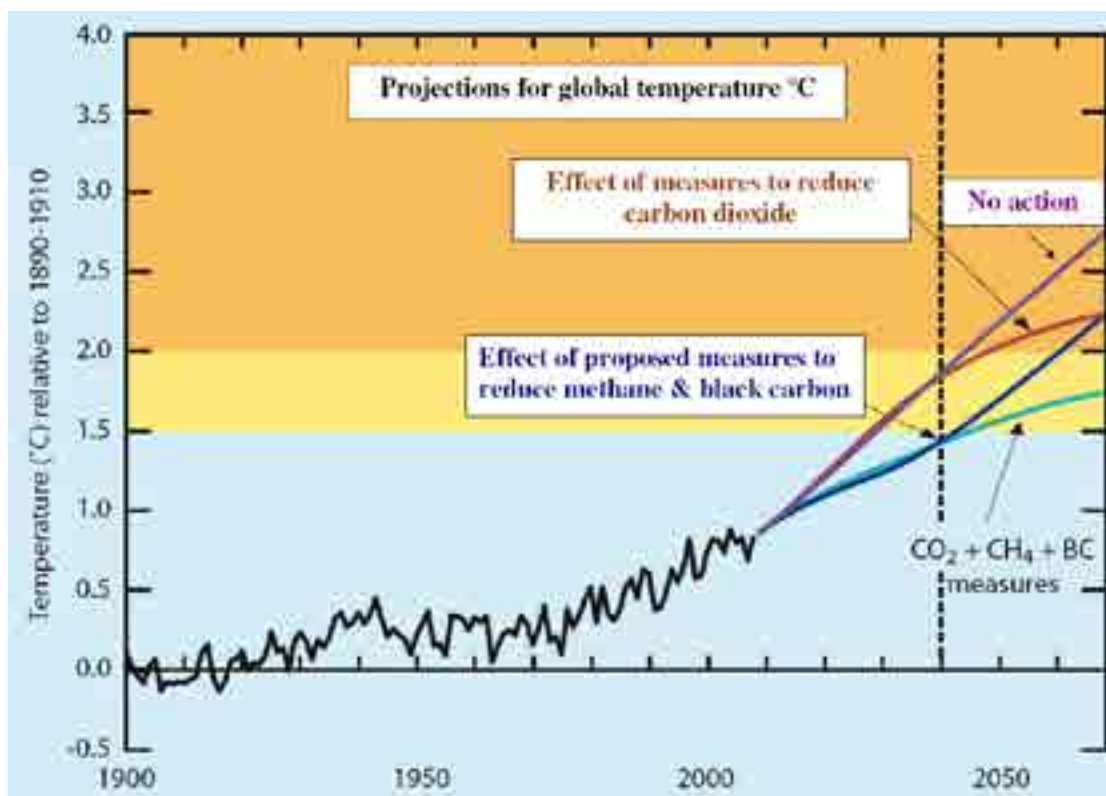
As shown in Figure 4.7 (from <http://www.unep.org/publications/ebooks/slcf/>) without the UNEP’s recommended measures to reduce methane and black carbon (purple line), world temperatures are almost certain to exceed the 2 °C target.

In the short to medium term wood heaters emit significant quantities of methane and black carbon (UNEP, 2011; Robinson, 2011). These chemicals don’t stay in the atmosphere for as long as carbon dioxide, but cause significant amounts of short-term warming, which will increase melting of polar icecaps and frozen methane undersea and in permafrost.

The net emissions of methane and carbon dioxide from burning firewood domestically are low compared to fossil fuel heaters (Paul et al, 2003) however the effect of harvesting dead timber to fuel wood heaters is to concentrate in the present, future emissions of methane that would have occurred naturally as the timber decayed. Coarse woody debris and soil organic matter can act as very long term carbon sinks. When logs are removed and used as firewood, the carbon they contain is immediately released to the atmosphere. It takes many years of growth to remove an equivalent volume of carbon from the atmosphere and store it in living plants again. Net emissions depend on the harvesting and transport regime for firewood. Regimes where silvicultural waste is used over short distances provide the lowest net emissions.

Electricity in Australia is largely derived from the combustion of fossil fuels such as coal and gas. Using this type of electricity or natural gas for home heating results in indirect greenhouse gas emissions. There is no sequestration associated with the burning of fossil fuels, unlike the net emissions of non-fossil carbon from burning wood, as long as the wood is replaced with new plants.

Figure 4.7 United Nations Environment Projections for global temperatures with and without a package of 16 measures (including phasing out log-burning heaters in developed countries in favour of pellet heaters) to reduce methane and black carbon emissions



Firewood burnt in wood heaters will therefore lead to a short term increase in emissions. Wood derived from plantation or silvicultural waste, such as that used in the manufacture of wood pellets, has a lower net emission, although greenhouse gases are still emitted earlier than they would have been through natural decay. Net GhG emissions from fossil fuels will be higher in the long term than from other sources. The lowest GhG emissions for domestic space heating will come from electricity derived from renewable sources, such as hydro, wind and solar, and from direct passive solar heating.

A team of 50 scientists from the United Nations Environment Program and the World Meteorological Association considered over 2,000 measures to reduce air pollution and help the world keep below the 2 °C. They recommended a package of the 16 best measures, one of which was to phase out log-burning heaters in developed countries. This is contrary to the CSIRO study (Paul et al, 2003) that considered the net emissions from firewood including emissions and sequestration.

4.9.3 Biodiversity policy

The Commonwealth Government (through ANZLECC) developed a national approach to firewood collection (Anon, 2001). The objectives of this policy framework are to:

1. “Protect remnant native vegetation, threatened ecosystems and habitat for threatened and declining wildlife species.
2. Encourage ecologically sustainable firewood collection from native forest, woodland and plantations.
3. Contribute to broader environmental objectives, including improved air quality, ameliorating dryland salinity, and contributing to carbon sequestration.”

The policy includes a strategy to develop a sustainable firewood industry based on the use of silvicultural residues and waste timber through the implementation of the following actions:

- Foster and support farm forestry planning, on-ground works and communication activities in targeted regions – e.g. the Murray Darling Basin.
- Target incentives for conservation and sustainable management of private native vegetation subject to firewood collection.
- Encourage use of residues of forestry operations in private and State forests as an alternative source of firewood.
- Encourage greater use of waste wood from road widening, urban subdivisions, local council activities and building operations and environmental weeds as firewood.

Some of these actions are implemented through the Commonwealth Government’s Caring For Our Country Program (previously the Natural Heritage Trust). The “*Logs Have Life Inside*” program produced educational material to encourage consumers to reduce their impacts on the environment (for example see: <http://www.environment.gov.au/land/publications/firewood-tips.html>).

The National Approach to Firewood Collection, through the NHT, supported the development of a voluntary code of practice, which firewood merchants could adopt (<http://www.firewood.asn.au/images/stories/code%20080214.pdf>). The code and certification scheme was developed and implemented through the Firewood Association of Australia (FAA). Members of FAA agree to adopt the Code of Practice when they join. Currently (June 2012) there are only 32 members in NSW. Only one firewood supplier on the Northern Tablelands is a member. While the

Code of Practice includes statements about reducing the impact of collection on biodiversity, there is no way to confirm that suppliers comply with these parts of the code. Relevant sections of the Code of Practice include:

2. Firewood will be sourced in accordance with sustainable management principles to protect biodiversity and ecosystem processes, including:

- Firewood will not be collected from areas where collection may have a significant impact on listed threatened species or listed threatened ecological communities,
- Firewood will be collected in a manner that conforms to regional vegetation and catchment management/natural resource management plans and other relevant plans.

7. Firewood will preferably be sourced from harvesting operations in plantations and sustainably managed native forests that are regenerated and regrown, or from residue from manufacturing processes or salvage operations.

In NSW ‘the removal of dead wood and dead trees’ (for firewood and other purposes) is listed as a key threatening process under the Threatened Species Conservation Act, 1995.

4.9.4 Education and regulation

Since political and popular support for regulation of wood stoves is unlikely to occur without awareness of the reasons for regulation, in most countries regulatory initiatives have been supported by education programs.

Pellet heaters are becoming more popular in Canada, following education measures and regulations to alert the public to the health effects of woodsmoke. Public policy is most advanced in Montreal, where the Quebec Lung Association focussed on relevant health messages, e.g. that using a wood heater for 9 hours produces more particle pollution than a car does in a year. (Lung Association of Quebec 2009). Despite freezing cold winters where the daily maximum temperature is below freezing, Montreal no longer permits the installation of log-burning heaters. There is, however, no restriction on the installation of pellet heaters.

In New Zealand, concerns about air quality have led to restrictions on the installation of log-burning heaters in areas where woodsmoke builds up. For example, in most of Christchurch, the installation of log-burning heaters is not permitted, except low emissions models (with emissions rating less than 1.0 g/kg) as replacements for more polluting models in houses that already have a log-burning heater.

Additional restrictions mean that most existing log-burning heaters have to be removed. In Otago, regulations required the removal of all log-burning stoves with emissions ratings greater than 1.5 g/kg by 1 January 2012 (<http://www.odt.co.nz/regions/central-otago/155796/last-winter-open-fires>). In Christchurch, starting from 1 April 2012, use of log-burning heaters more than 15 years old was banned. (see <http://ecan.govt.nz/news-and-notice/news/pages/christchurch-clean-air-plan-reaches-key-milestone.aspx>)

Christchurch’s Clean Heat Program also offers subsidies for pellet heaters and efficient reverse cycle air conditioners be installed as replacements for existing wood burners. In total, about 12,000 houses in Christchurch have replaced wood burners with reverse cycle heat pumps. Surprisingly, this had minimal effect on electricity consumption. Usage was monitored in 1,973 households that replaced wood burners with heat pumps - the average increase was 1%. The authors of the study explained:

“Additionally, in order to receive subsidies from ECan, households were retrofitted to meet NZ Building Code standards for ceiling and underfloor insulation, potentially reducing the use of other forms of electrical heating, such as the bedroom heater.” (O’Connell et al. 2010).

For families who previously had to buy firewood, the 1% increase in electricity consumption is likely to represents a substantial saving on the cost of firewood. In comparison, electricity consumption

decreased by 4% in the 662 households who replaced wood burners with pellet heaters. (O’Connell et al. 2010). Such figures are difficult to interpret, but the 5% difference for pellet vs reverse cycle, seems a relatively low proportion of household heating. It suggests that other features of heat pumps, e.g. ducting to other rooms, may have led to a greater reduction in supplementary heating in households that installed heat pumps. Nonetheless, families that opted for pellet heaters, in conjunction with upgraded insulation where necessary, also benefitted from a small reduction in electricity consumption.

By focussing on a targeted reduction in air pollution, Christchurch’s policy has increased awareness of the health effects of woodsmoke pollution and resulted in a shift to other forms of heating. A key reason for 8,000 pellet heaters being installed in the Christchurch region is almost certainly the increased public awareness of the health effects and health costs of woodsmoke pollution.

Some Sydney councils do not permit new wood heaters to be installed. These include Waverley, Camden and Holroyd, with others requiring non-polluting heating in new developments, e.g. Manooka Valley, Oran Park and Turner Road Growth Precincts.

4.9.5 Education and replacement subsidies

The only major success in terms of woodsmoke reduction in Australia is Launceston, Tasmania, where funding of \$2.05 million was provided for education and subsidies to replace heaters. Local respiratory physician, Dr Jim Markos, chairman of the Tasmanian Branch of the Australian Lung Foundation, chaired the woodsmoke reduction committee. Initiatives included TV advertising, which emphasized the health effects of breathing woodsmoke. Some adverts featured the local Asthma Foundation members.

Subsidies were provided to remove about 2,000 wood heaters with another 2,000 heaters being removed, simply as a result of the education program, without any subsidies being provided. A local retailer said that pellet heaters were quite popular because of their convenience and lack of mess.

4.9.6 Standards

AS4013 (limit 4 g of particles per kg of wood burned) applies to most installation in Australia. New Zealand has much lower limits – 0.7 g/kg to 1.0 g/kg fuel are required in areas where woodsmoke builds up, and 1.5 g/kg in all other urban areas. In addition, some areas (e.g. Christchurch) prohibit the installation of new heaters, except as replacements for more polluting models.

4.9.7 Insulation subsidies

A remarkably successful approach in NZ was to offer insulation and energy efficiency audits as part of a package promoting the replacement of wood heaters. O’Connell et al. (2010) reported the results of the Christchurch’s Clean Heat Program (CHP): *“The results suggest that the CHP has had very limited impact on electricity usage overall, despite around 8,000 of the households shifting from solid fuel heating to heat pump.”* When the data is examined further, those households that removed an open fire reported a decrease (-2 to -3%) in electricity usage after installation of a heat pump. This result reflects the inefficiency of open fires, which are often backed up by electric heaters. Removal of the need for supplementary electric heaters, following installation of efficient heat pumps, resulted in reduced electricity consumption.

“Additionally, in order to receive subsidies from ECan, households were retrofitted to meet NZ Building Code standards for ceiling and underfloor insulation, potentially reducing the use of other forms of electrical heating, such as the bedroom heater.”

4.9.8 Current policy proposals in Australia

NSW Government Woodsmoke Control Options Policy Analysis

In December 2011, the NSW Government released a study commissioned an economic analysis of policy options to control woodsmoke. Using similar methodology to that used to estimate the cost of traffic emissions, the estimated health cost of woodsmoke in NSW was -\$8,072 million. (NSW OEH 2011). With an estimated 372,203 heaters were in use in 2010, the estimated net present health cost works out at more than \$21,500 for every heater in the state.

Table 4.5 compares the cost of implementation, including costs to industry, compared with the health benefits of various options.

Table 4.5 Cost (Net Present Values, NPV) of various policy options (including costs to industry compared to the health benefits)

(Source NSW OEH 2011)

	NPV, \$million		
	Health Benefit	Cost	Net Benefit
4) Phase out at sale of house	\$4,015	-\$36	\$3,978
2) Ban on heater sales	\$2,206	-\$134	\$2,071
7) Licensing fees	\$1,267	\$11	\$1,278
6) Sales tax on new wood heaters	\$1,049	-\$1	\$1,048
9) Cash incentive phase out	\$879	-\$12	\$867
8) Levying an excise/tax on biomass fuels	\$419	\$36	\$455
5) Fuel moisture content regulations	\$399	-\$33	\$366
3) Efficiency standards (60%,3g/kg)	\$301	-\$3	\$298

The greatest benefit – reducing health costs by over \$4 billion for a cost of just \$36 million was to phase out use of wood heaters when houses were offered for sale. A ban on the sale of new heaters was the second most cost effective option, saving \$2.2 billion for an estimate cost of \$134 million.

The NSW Government plans to use the results of the economic analysis to release a consultation document to reduce the health costs of wood smoke in NSW.

ACT Consultation Paper “Addressing Wood Heater Pollution in the ACT” and Exposure Draft Legislation:

In the ACT, a consultation paper and Exposure Draft Legislation was released on 1 June 2012. Only a small number of households use wood as the main source of heating in the ACT (2.9% in 2005; 3.9% in 2008; 2.3% in 2011) but air pollution levels increase 3-fold in winter, equivalent to increased annual PM2.5 exposure of 3 ug/m³. If the health effects are similar to those observed in the recent Canadian study, a 3 ug/m³ increase in PM2.5 exposure might increase annual mortality by 3-4.5% and increase deaths from ischemic heart disease by 9%.

The draft legislation proposes a new emissions limit of 1 g/kg and efficiency of 65%.

Other recommendations in the consultation paper include:

- Introducing mobile air quality monitoring to improve the response to pollution problem;
- Improving local enforcement options to ensure people use wood heaters correctly;
- Improving the way air quality data and the health effects of wood smoke are communicated to Canberrans;

- Expanding the wood heater replacement program to include low emissions electric heating, and an increased subsidy.

This ACT consultation paper suggests several additional measures for community discussion, including:

- Ensuring all new wood heaters are sold with information about the health impacts of wood smoke;
- Phasing out non-compliant wood heaters by setting a date by which all wood heaters in the ACT must meet a standard;
- Phasing out non-compliant wood heaters by requiring their removal upon the sale of the premises;
- Allowing the installation of new wood heaters only when they are replacing existing wood heaters, until such time as a new health-based standard has been developed for real-life emissions;
- Using market mechanisms to reduce wood heater emissions, such as sales tax or licensing of wood heaters.

Currently, these proposals do not single out pellet heaters as a clean heating option. However, if subsidy programs for replacement of wood heaters, or regulations on types of heating that can be installed in new homes are introduced, then it is likely that pellet heaters could appear on the associated lists of approved heaters, as is the case in New Zealand.

4.9.9 Impact of policy

Overseas, reducing wood smoke has led to significant improvements in health. For example, in 2003, regulations were introduced in the San Joaquin Valley requiring mandatory curtailment of residential wood burning when air quality was forecast to be poor, as well as: voluntary curtailment, restrictions to the type of fuel burned, a complaint process, prohibition of new or used uncertified devices, and a limit on the density of residential burning devices.

Subsequent investigation showed that the implementation of these regulations reduced the risk of age-standardized mortality due to ischemic heart disease and cerebrovascular disease decreased 4.8% (95% CI: 1.00, 1.09) and 5.4% (95% CI: 0.97, 1.14), respectively, while there were no meaningful differences in rates detected in other non-injury deaths. Burn season average concentrations of CO, NO₂, and PM_{2.5} decreased 20%, 13%, and 25% after regulation implementation, respectively (P < 0.05). Burn season average concentrations of benzo(a)pyrene, butadiene, benzene, and toluene decreased 32%, 44%, 29%, and 34% after regulation implementation, respectively (P < 0.05, Gilbreath and Yap, 2008).

In Libby, Montana, education and the replacement of virtually all non-certified heaters in Libby, Montana with mainly certified wood heating produced a very modest reduction in emissions of 19% (Figure 4., Noonan, 2011). This reduction was insufficient to enable the town to meet air quality standards. The red line shows the number of stoves changed in Libby, Montana, USA. The black line and individual points show PM_{2.5} pollution. Libby had about 1,500 stoves, about half as many as the 3,500 in Armidale (Khan, 2002), or 11% of the 13,200 wood heaters in Launceston in the year 2000 (DEH and CSIRO, 2005).

A major success in Australia was Launceston, where PM_{2.5} levels fell as the number of wood heaters fell from 46% of its 28,621 households in the year 2000 to less than 20% in 2007.

The program was considered a remarkable success, with 70% of households switching to locally non-polluting heating, resulting in a 70% reduction in measured pollution levels. (Meyer et al. 2008).

Although considerable effort was also expended on targeted education to improve wood heater operation in Launceston households that continued to use wood heating, and although follow-up

observations often showed less visible smoke, it is difficult to quantify the effect of this measure on woodsmoke reduction. The observed reduction in PM_{2.5} measurements appeared to depend mainly on the number of wood heaters. Other factors, such as AS4013-compliance, or education on how to operate heaters, appears to have had little effect on overall pollution levels.

Figure 4.8 Daily average PM_{2.5} levels in Libby, Montana, USA, before and after virtually all old wood stoves were replaced by new ones. The red line shows the number of stoves replaced with daily average PM_{2.5} levels in black and seasonal averages in purple.

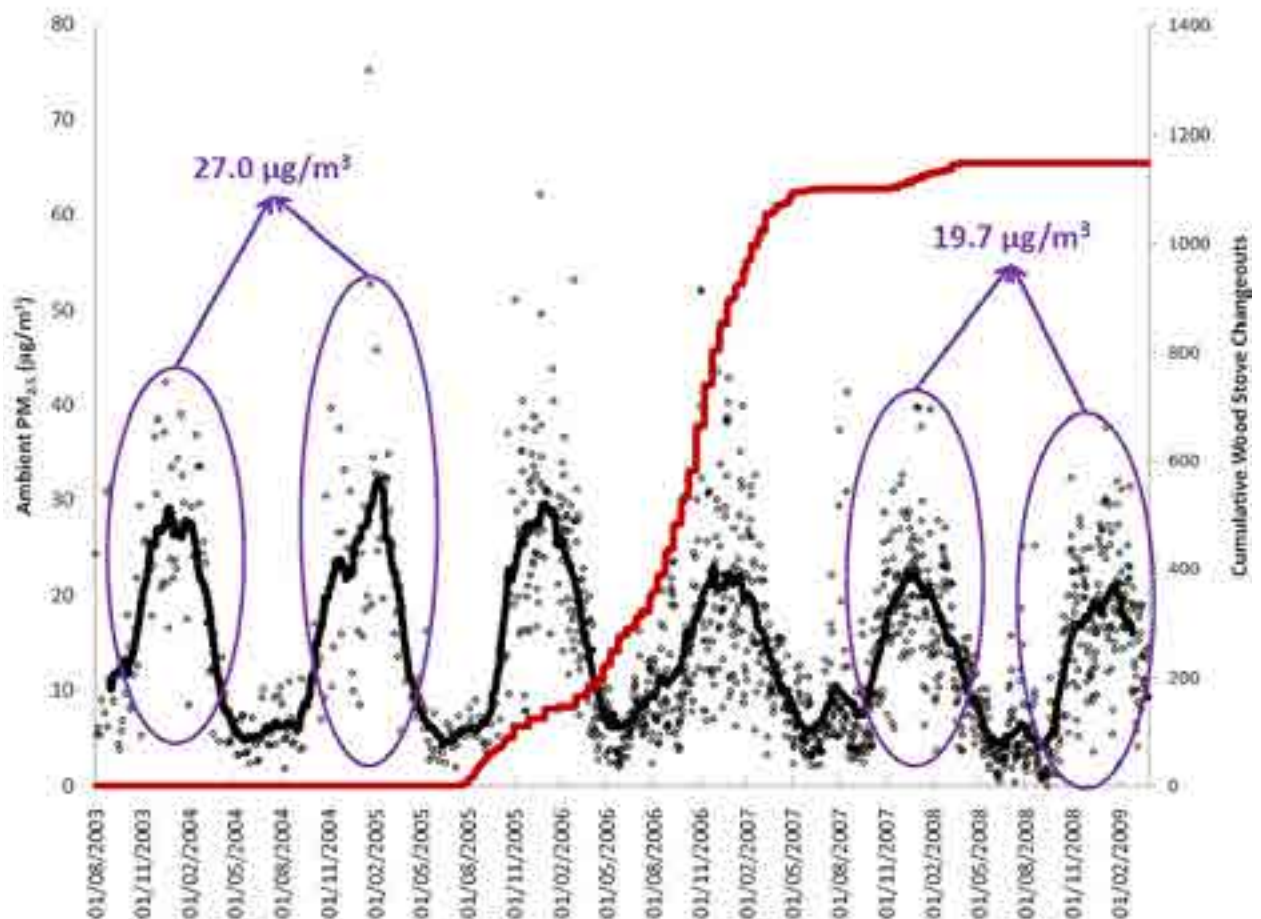
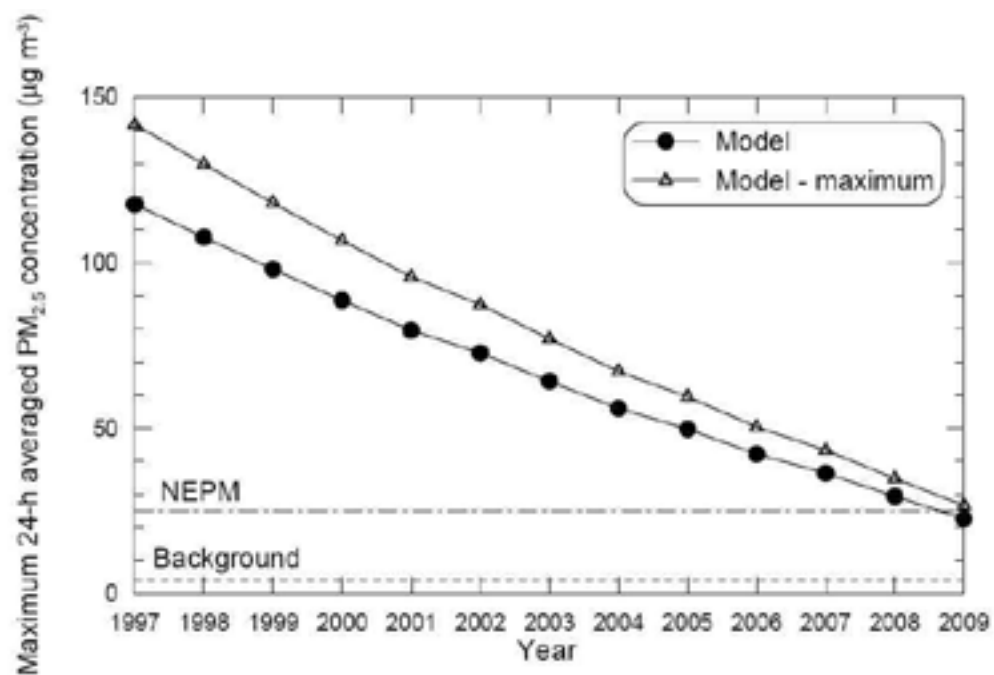


Figure 4.9 Results of CSIRO modelling of 24-average PM_{2.5} levels, which decrease steadily over time as wood heater uses declines.



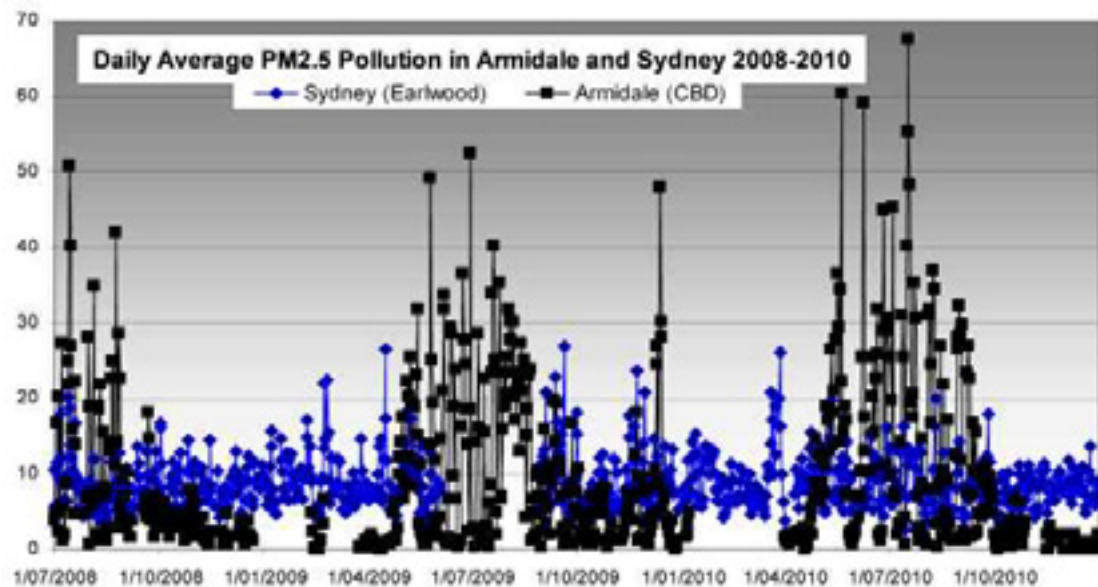
5 Current Situation in Armidale

5.1 The wood smoke problem

5.1.1 Winter air quality

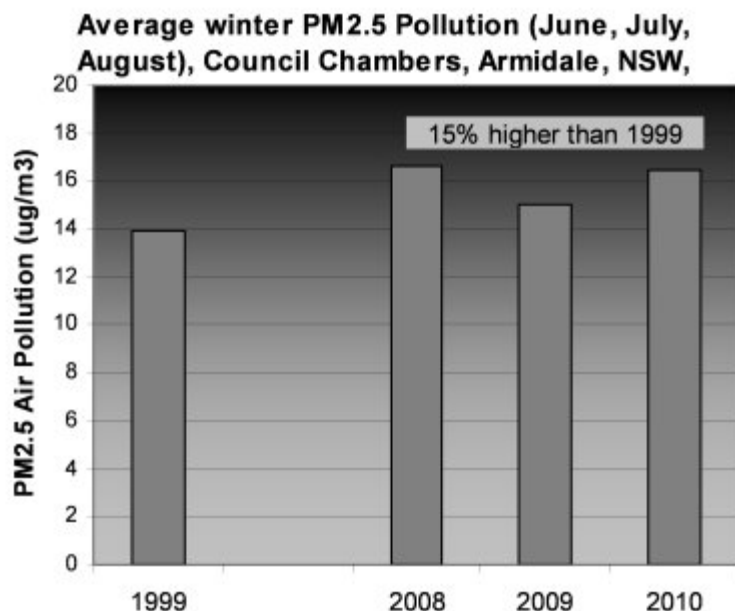
PM2.5 Fine particle pollution in Armidale is currently measured by a DustTrak monitor installed on the roof of Armidale Dumaresq Council building in Rusden Street. It has been calibrated by John Innes, EPA, Tasmania to record the concentration of particles less than 2.5 microns (PM2.5) in wood smoke aerosols.

Figure 5.1 Daily average PM2.5 Pollution in Armidale and Sydney 2008-2010, and photo of pollution in May, 2011



Measurements were also available for 1999, when a study related PM2.5 measurements in Armidale to visits to GPs for respiratory complaints (Kahn et al. 2007). The results show no improvement in average PM2.5 wintertime concentrations (June-August)

Figure 5.2 Average winter PM2.5 Pollution (June, July, August), Council Chambers, Armidale NSW

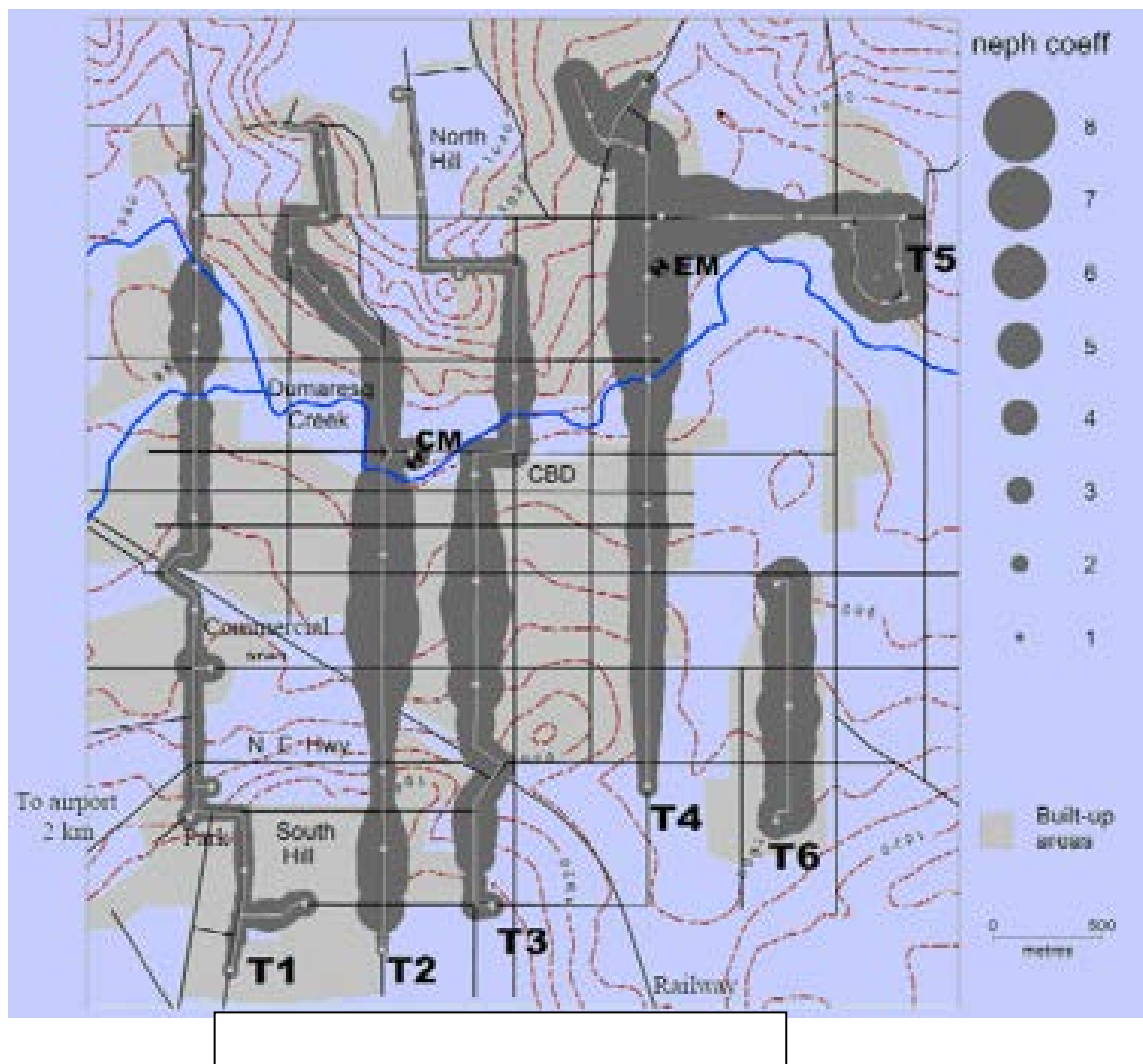


5.1.2 Health problems in Armidale due to wood smoke

The spatial distribution of particle pollution was measured in Armidale using a mobile nephelometer to measure pollution along 6 north-south transects up and down the valley – See Figure 5.3. Pollution levels are indicated by the width of the shading along each route. The residential area of East Armidale had some of the highest wood smoke measurements with high measurements also recorded in residential areas immediately south of the CBD.

Estimated annual population exposure to PM2.5 was estimated to PM2.5 from pollution measurements in each area compared to a fixed reference monitor. PM2.5 exposure from wood smoke was estimated to be 11.5 ug/m3, implying increased mortality by about 7%, with estimated cost of about \$4270 per wood heater per year. (Robinson 2011).

Figure 5.3 Air pollution in Armidale, NSW in 1996 (source Robinson et al, 2007)
Measurements were made along 5 north-south transects and one circular transect.
Pollution levels (nephelometer coefficients) are indicated by the width of the grey line along the transect.



Polycyclic Aromatic Hydrocarbons (PAH). The NSW EPA also measured toxic chemicals known as PAH at a site next to the creeklands, indicated by 'CM' on the above map.

In the US PAH study described above, exposure over 2.26 ng/m^3 was associated with an average reduction in IQ when the children started school. Measured wintertime PAH in Armidale (creeklands average 8.62 ng/m^3 , maximum 24.0) (NSW EPA 2002) were almost four times this value, suggesting that PAH exposure is likely to affect future generations of children born to mothers living in polluted areas of Armidale. Measured levels of BaP - 1.3 ng/m^3 - were also higher than the average of 0.5 ng/m^3 in the US study.

Effects of short-term variation. A small study in 1999 reported a significant correlation between wood smoke pollution and visits to Armidale GPs for respiratory complaints. The estimated increase was remarkably high - 6.9% increase in visits to GPs per increase of 10 ug/m^3 in $\text{PM}_{2.5}$ pollution measured in what (according to the spatial mapping paper) was the most polluted residential area. The average $\text{PM}_{2.5}$ pollution from 1 June to 20 August was 31.8 ug/m^3 with a range of 1.7 to 140.5 ug/m^3 . The large variation was noted to depend mainly on wind speeds. When there was no wind, there was a strong build-up of wood smoke pollution. On windier days the pollution was blown elsewhere. Pollution in this area was highly correlated with Council's pollution monitor at the Council chambers ($r = 0.86$), although with few residential chimneys in this area, average of 13.9

ug/m³ was much lower. Altogether, the observed increase of 6.9% per of 8.8 visits per day equates to about 750 additional visits per year. Note however, that this is the estimated effect of short-term variation. Other studies, e.g. the US study of 1.5 million hospital admissions in New England reported much greater effects of longer term exposure than day-to-day variation.

5.1.3 Public perceptions of the health risks of wood smoke

Several surveys have investigated the use of wood heaters in Armidale, notably surveys by Armidale Council in the mid-1990s as well as a survey by the University of New England in 1999. In the latter survey, only 24% of people with wood heaters said the statement "emissions from open fires and solid fuel heaters contain substances harmful to humans" was true. A majority (52%) said it was false; the remainder were unsure.^[23] There was also a discrepancy between the perceptions of people with wood heaters and those with other forms of heating.

In the community survey for the current study, there was wide public awareness that the winter haze in Armidale was caused by wood heaters (Figure 5.4). However, respondents with wood heaters, wood cookers or open fires attributed less importance to these as a source of the haze than did those with no wood burning appliances in their home. Those with wood burning appliances attributed more importance to natural mist as the source of the haze.

In rating a range of health risks, smoke from wood heaters was second only to passive smoking in the average level of risk assigned to it by respondents (Figure 5.5). The list of possible risks was taken from a survey carried out by the West Australian Department of Health in 2009 (Department of Health 2009). For the random sample of West Australian residents, smoke from wood heaters rated relatively lowly, between the rating for germs in drinking water and mobile phone towers. This suggests that Armidale residents rate wood smoke more highly as a health risk than do residents of some other parts of Australia. This could be attributed to the higher incidence of wood smoke, and/or greater awareness created by community education campaigns. However, Figure 5.5 shows that those in Armidale with wood burning appliances are generally less risk averse, and rate the health risks from wood smoke much lower, compared to those with no wood burning appliances. This suggests that general health consciousness and risk averseness are having some impact on choice of heating options in Armidale.

Figure 5.4 Perceptions of the importance of various contributory sources to winter haze in Armidale.

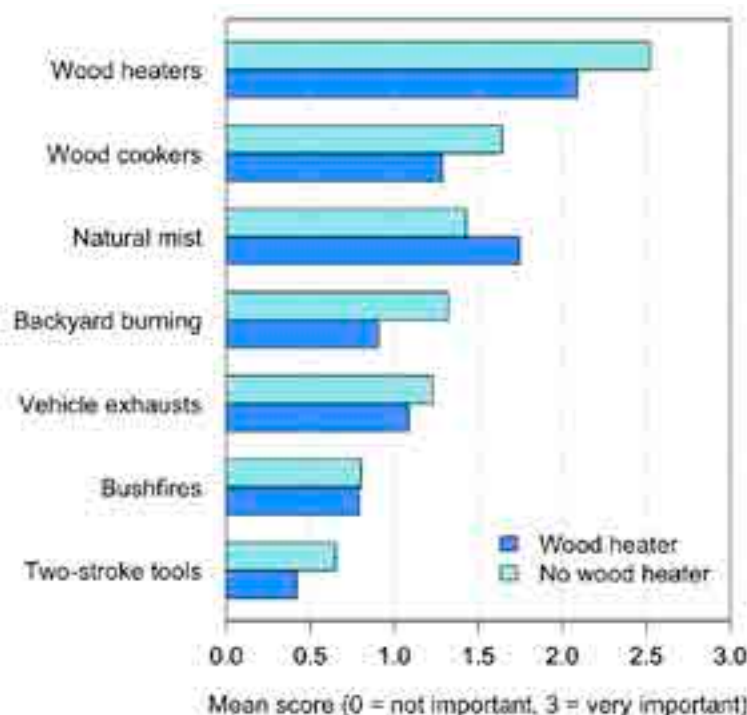
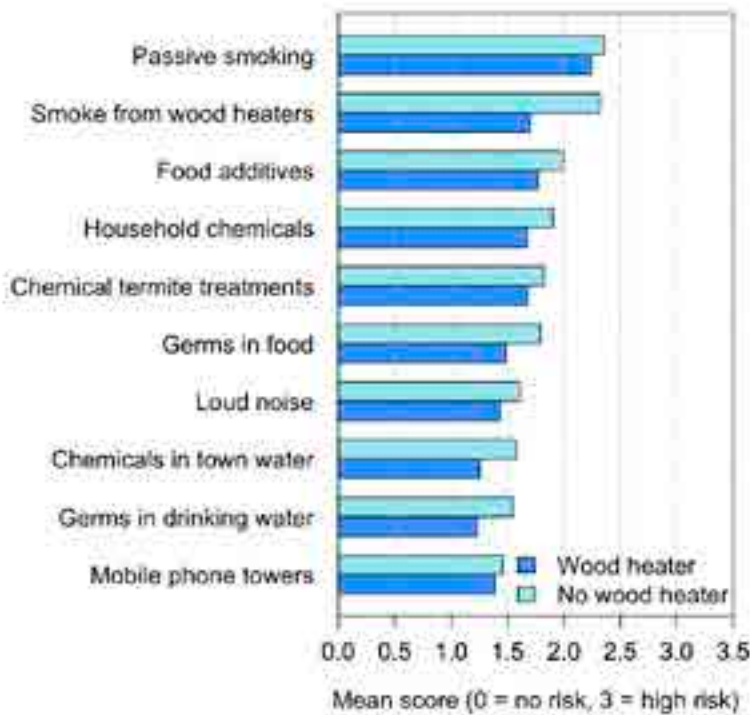


Figure 5.5 Perceptions of the level of risk to self or family of a range of possible health risks.



For two statements about the emissions of wood heaters relative to cars, and the health costs related to wood heater use, just over one half of respondents in each case said they were unsure whether the question posed was true or false (Table 5.1).

Table 5.1 Percentages giving “True”, “False”, or “Unsure” for two questions about the health impacts of wood smoke.

	True (correct)	False	Unsure
The average brand-new log-burning wood heater on the Northern Tablelands gives off more fine particles in its smoke per year than 300 passenger cars.	23.1	20.1	56.8
The average log-burning wood heater in an urban area causes additional health costs to residents of over \$3,800.	20.8	24.2	55.1

The approximately equal percentages for “True” and “False” strongly suggests that many of those who did not indicate they were unsure, were actually guessing.

Among those who did not have any form of wood heating 57 per cent reported that they had had problems or annoyance with smoke from other people’s wood heaters, whereas among those who had some form of wood heating, only 27 per cent reported they had had these problems. Since the spatial location of wood heaters in Armidale is random (i.e. each house with a wood heater is not surrounded by houses with other forms of wood heating), the difference between these two groups has to be perceptual. The lower incidence of perceived problems among the wood heater owners is consistent with their lower risk averseness described above.

5.1.4 Winter wood heating

Types of heating

As described in section 3.2.3, approximately one half of households in Armidale have a wood heater. This amounts to approximately 3,500 households. Wood heating is combined with other forms of heating in many households, although wood heating is by far the most common type of heating (Figure 5.6). Of those who have some form of wood heating (wood heater, slow combustion stove, open fire), 43 per cent have no other type of heating apart from wood heating. The most common additional non-wood heating among those with wood heating is unflued gas (48 per cent).

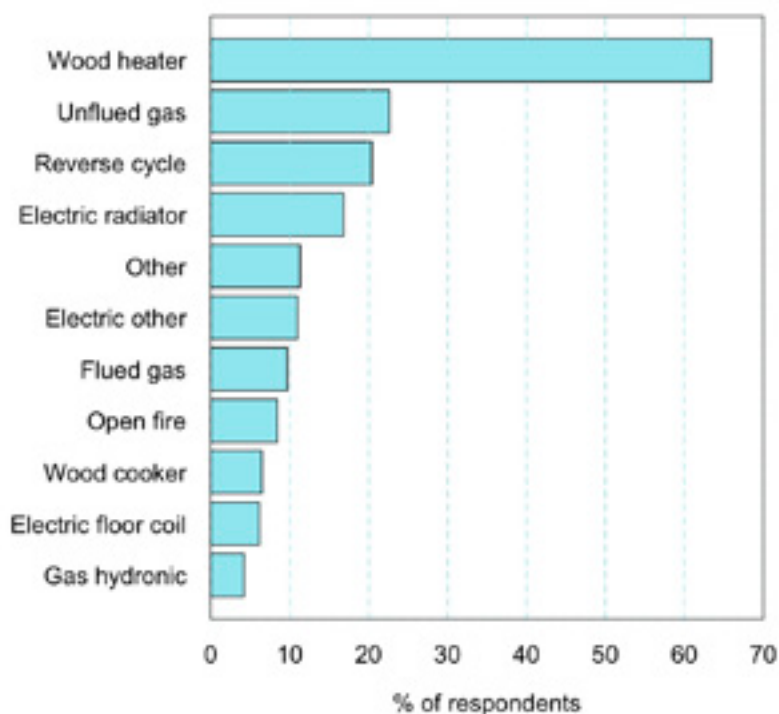
Ages of wood heaters

The average age of wood heaters owned by respondents was 13.3 years. AS 4013 of 4g/kg was introduced in 1999 and at least 43 per cent of the heaters owned by respondents were older than this. The proportion of these pre-AS4013 wood heaters in the stock of wood heaters may be higher than this, as some respondents had bought homes with wood heaters already in place, and so gave an age based on the date of house purchase. So it is possible that as much as one half of the stock of wood heaters in Armidale and Uralla is composed of the older models with higher emissions levels.

Wood heater purchase intentions

In all, 21 per cent of respondents indicated that they intended to buy a wood heater in the next few years. Among those who already owned a wood heater, 26 per cent intended to buy a wood heater in the next few years. The average age of wood heaters belonging to these respondents was 14.0 years. Given this is only slightly higher than the mean age of all wood heaters, it is likely that intended wood heater replacements will bring about only slight reduction in the aggregate emissions from wood heaters in Armidale and Uralla.

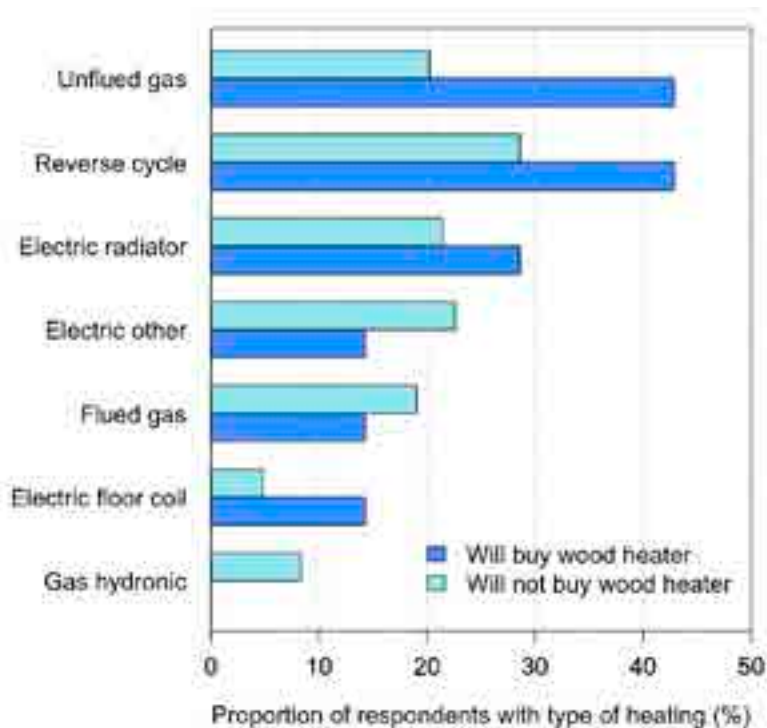
Figure 5.6 Proportions of respondents with various types of heating.



The reasons advanced by those with wood heaters who intended to buy a new wood heater in the next few years mostly referred to the age, state of repair, or excessive wood consumption of the existing heater. Substantial numbers referred to their preference for the cheapness and quality of warmth of wood heating. A number of respondents were buying a wood heater to provide additional heating in parts of the house currently not heated, or in new extensions, or to replace other forms of heating in parts of the house.

Among those respondents who did not have any form of wood heating, 14.3 per cent reported that they intend to buy a wood heater in the next few years. Comparison of the types of non-wood heating among those who intended to buy a wood heater and those who did not (Figure 5.7), shows that unflued gas, reverse cycle, and electric radiator and electric floor coil are disproportionately over-represented among those intending to buy a wood heater, whereas other electric heating (oil filled column heaters, fan heaters, wall panels), flued gas and gas hydronic are disproportionately under-represented among those intending to buy a wood heater.

Figure 5.7 Comparison of the types of heating among those with no wood heating who intended to buy a wood heater in the next few years, and those who did not.



The reasons given for buying a wood heater among respondents currently with no form of wood heating generally related to the perception that wood heaters provided secure heating of a better quality and quantity and at a cheaper price. Examples of reasons advanced include:

- Warmth and cooktop when power goes out. Ambience.
- Air conditioning not cosy.
- Friendly (radiant) heat source compared to reverse cycle ... hopefully higher efficiency.
- To heat more of the house.
- New house. Spreads heat effectively.
- Because they are warmer ...
- Other heating methods have become too expensive and do not heat adequately.

The reasons advanced by respondents with non-wood heating who intend to buy a wood heater, taken with the findings shown in Figure 5.8, suggests that there is a certain amount of dissatisfaction with unflued gas, reverse cycle, electric radiators and electric floor coils, either due to the cost of heating or the perceived quality of the heat supplied. Security of heating is also obviously important for some respondents.

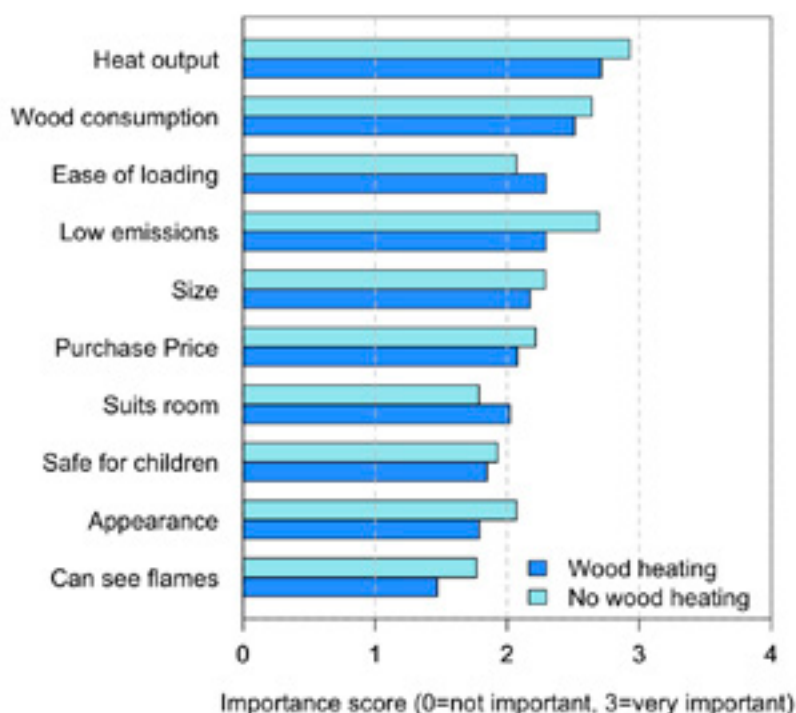
Dissatisfaction could be due to the use of these forms of heating in poorly insulated houses, however no significant difference was found between the mean house insulation score for respondents with non-wood heating who intended to buy a wood heater and those who did not. The house insulation score was calculated as the sum of the following scores for each type of insulation, weighted by the figure following each type:

- ceiling insulation – 3,
- wall insulation – 2,
- floor insulation – 1,
- double glazing – 2,
- close fitting thick curtains – 2, and
- draught sealing around doors and windows – 2.

Wood heater attributes important in purchase decision

As shown in Figure 5.8, the most importance was attached by respondents who intended to buy a wood heater to aspects relating to the physical performance of the wood heater. Price was well down in the attribute ranking. The mean of the prices respondents expected to pay for a new wood heater was \$2,134. This figure is close to the mean price of 28 wood heaters advertised on Ebay (“Buy Now” price, buyer to collect) at the time of writing of this report, viz. \$2,055. There was relatively little difference in the importance placed on the various attributes by those who currently had wood heaters, and those who did not.

Figure 5.8 Comparison of the importance of wood heater attributes in the purchase decision, between those who currently have wood heating and those who do not.



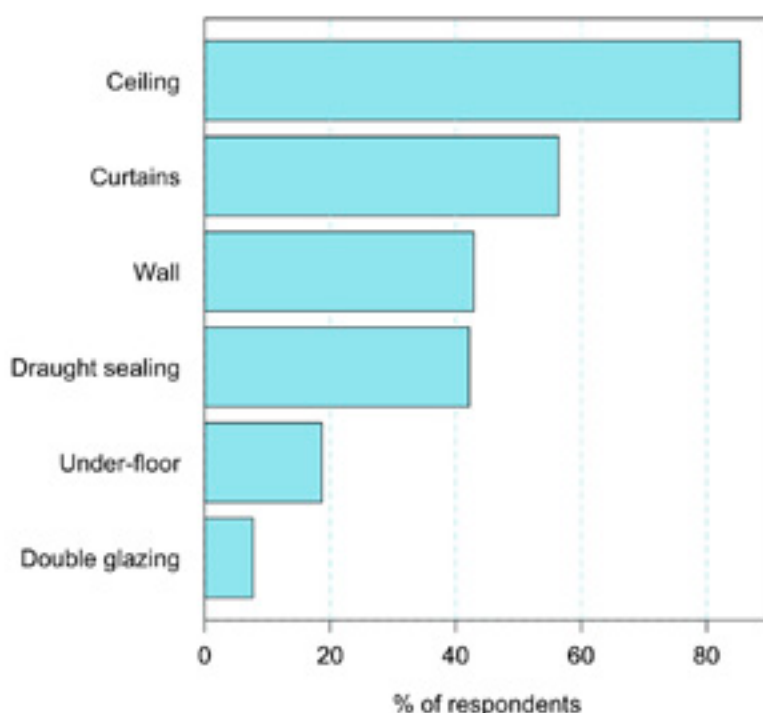
Levels of insulation

The amount of insulation in houses has a major influence on both the amount of heating required, and the perceptions of thermal comfort. The perceived thermal comfort in a room is a function of air

temperature, relative humidity, air movement, and the meant radiative temperature. The latter is the area weighted mean of the temperatures of all the surfaces in the room. The perceived temperature is generally taken to be the mean of air temperature and mean radiative temperature of a room. For example, on a winter's night with sub-zero ambient temperatures, a poorly insulated room with single glazing and no curtains could have a mean radiative temperature as low as 5degC, even though a fan heater or reverse cycle unit is supplying air at 25degC. Perceived temperature would be 15degC, and even lower than this if a person is in the draught of air from the heater. This would be well below accepted thermal comfort levels.

Respondents who were renting their homes were removed from the calculations of levels on insulation, on the grounds that these respondents were less likely to know what insulation was in their home. Despite this adjustment, it is still possible that some owner respondents did not know what insulation was in the ceilings, walls or under the floor in their home. For this reason the figures in Figure 5.9 could be underestimates of the actual incidence of insulation in Armidale and Uralla homes.

Figure 5.9 Proportion of house owner respondents with various types of insulation.



On the other hand, some respondents may have considered reflective foil sarking as insulation, which would result in an overestimate of the incidence of insulation. A survey of new houses constructed in 1992 (Gow, 1992), found that 47% had no ceiling insulation other than reflective foil, and 67% no wall insulation other than foil. Less than 10% had adequate north facing glass and thermal mass (Gow, 1992). Given the relative ease of installing ceiling insulation compared to wall insulation, and the subsidy programs for insulation between 1992 and the present day, the substantially higher figure for the incidence of ceiling insulation in 2012 compared to 1992, and the slight increase in the incidence of wall insulation would suggest that the survey figures are not too wide of the mark.

It appears from Figure 5.9 that the scope for ceiling insulation programs to improve the thermal efficiency of the housing stock is fairly limited. However, there is considerable scope to improve thermal efficiency with close-fitting curtains, drapes or blinds with good insulating properties, and to improve draught sealing. The figure for wall insulation is unexpectedly high, given the age of the housing stock, although the figure would be reasonable if reflective foil in wall cavities was being counted as insulation.

5.2 Biodiversity and firewood harvesting

Driscoll et al (2000) reported that approximately half of the firewood used in Australia was collected by the user rather than purchased from a supplier. The situation in New England is very similar (Wall, 1997). While most firewood is collected from private land, significant quantities of firewood are collected from roadsides, Travelling Stock Routes and Crown Reserves. Ecosystems in these areas often have high conservation values because of irregular grazing patterns, and support populations of threatened fauna and flora. Therefore firewood collection from roadsides and reserves has a disproportionate impact on biodiversity.

Wall (1997) also reported that most firewood users preferred high density species such as ironbark (predominantly *Eucalyptus sideroxylon* and *E. crebra*), box (*E. albens*, *E. melliodora*, *E. microcarpa*) and red gum (*E. blakelyi*, *E. camaldulensis*). Stringybark species such as *E. caliginosa*, *E. laevopinea* and *E. macrorhyncha* were less preferred but still used. Discussions with local firewood suppliers indicate that these are still the preferred species.

As living trees, ironbarks and box species are important food sources for the critically endangered Regent Honeyeater (*Anthochaera phrygia*), whose numbers are continuing to decline in NSW. Regent Honeyeaters migrate through the box-ironbark forests of the western slopes of the Great Dividing Range, where large volumes of firewood are collected for use in the New England region. As dead trees, both standing and fallen, box, ironbark and red gum species provide durable hollows and cracks which are used as habitat by many birds, reptiles, mammals (such as the Vulnerable species –Squirrel Glider) and invertebrates. Hollows suitable for use by these animals can take up to 150 years to develop in living trees (Lindenmayer et al, 2003) so are not easily replaced by regenerated or planted seedlings.

In NSW ‘the removal of dead wood and dead trees’ (for firewood and other purposes) is listed as a key threatening process under the Threatened Species Conservation Act, 1995. The Commonwealth Government (through ANZLECC) developed a national approach to firewood collection (Anon, 2001), which included the development of a voluntary code of practice, to which firewood merchants could adopt. The code and certification scheme (which primarily indicated seasoning and moisture content of wood) was developed and implemented through the Firewood Association of Australia. Only one firewood supplier on the Northern Tablelands became certified.

Given the species preferences and current sources for supply of firewood on the Northern Tablelands, there are few options for consumers wishing to minimise the impact of their firewood usage on biodiversity. However, two options could be developed in order to give consumers this choice:

- The development of a supply of firewood from sustainable sources such as plantation thinnings (both hardwood and softwood), farm timber, “green waste” or silvicultural thinnings from native forest; or
- Development of pellets manufactured from sawmill or silvicultural wastes.

The Canberra firewood market has a number of suppliers offering “eco-loads” which are a mix of firewood sourced from sawmill offcuts, pine forest thinnings and conventional firewood sources. While no such mixtures are available on the Northern Tablelands, they could be developed, because sources of wood from waste and silvicultural streams exist. However, as already noted, Australian wood heaters burning softwoods have much higher woodsmoke and methane emissions, so this practice is likely to increase the health problems from air pollution.

In 2002 State Forests of NSW conducted a plantation firewood trial (Heathcote, 2002). This trial looked at the feasibility and economics of using plantation hardwood thinnings from the Dorrigo area to supply 10% of the Armidale firewood market. The trial found that this wood could be used in conjunction with woodland species but not by itself because of its low density. The study found that there would be a positive impact on woodland birds from replacing 10% of woodland-collected wood with the plantation resource. This study also reviewed the literature on the impact of firewood harvesting on declining woodland birds and found that in the Armidale region the following species and species guilds were directly affected:

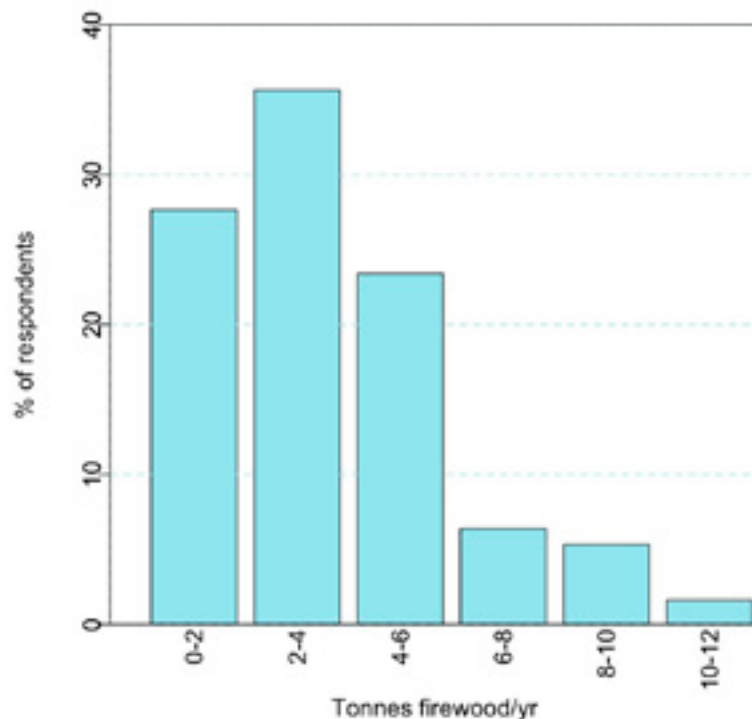
- Buff-rumped Thornbill,
- White-winged Chough,
- Hollow-nesters,
- Foliage gleaners,
- Bark-feeders,
- Honeyeaters,
- Brown-treecreepers,
- Hooded Robins,
- Eastern Yellow Robins,
- Speckled Warblers,
- Turquoise Parrots,
- Crested Shrike-tits.



5.2.1 Firewood use

The community survey asked for the quantity of firewood used in an average year, with respondents able to answer in tonnes, ute or small trailer loads, or truck loads. Ute or small trailer loads were assumed to be 0.5 tonnes and truck loads, 3.0 tonnes. The mean annual firewood use was 3.95 tonnes (median, 3.23 tonnes). There was a wide range of annual tonnages as shown in Figure 5.10.

Figure 5.10 Distribution of tonnes of firewood used per year.



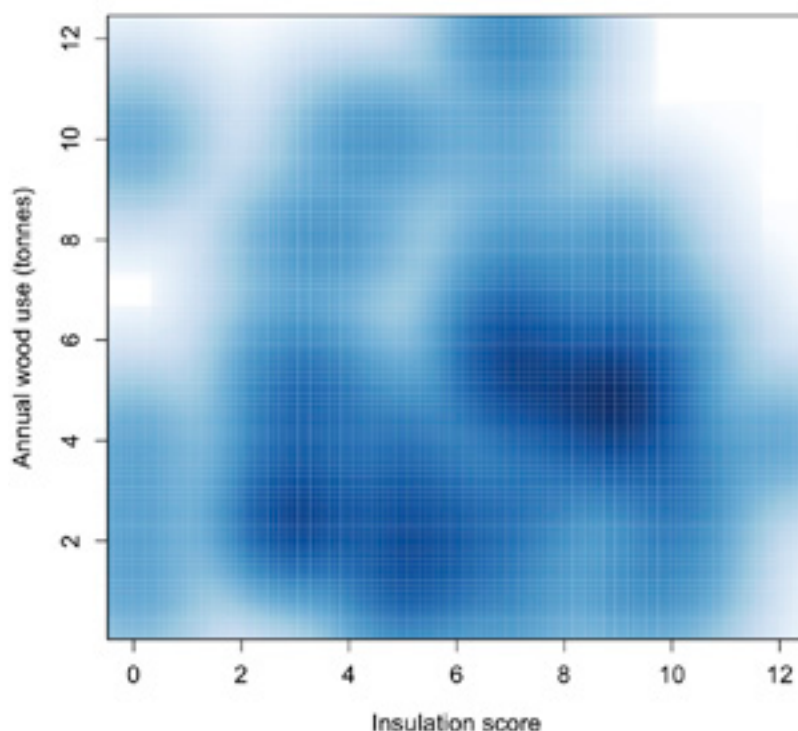
If the mean of 3.95 tonnes per year is taken to be representative of the 3,500 households with wood heating in Armidale, the annual consumption could be estimated as just under 14,000 tonnes. These figures are reasonably consistent with other estimates that have been published.

Driscoll et al (2000) found that the average annual firewood use in regional areas was 3.6 tonnes. Of the firewood collected, 76% came from fallen dead trees, 18% from standing dead trees and the remaining 6% from live trees. However, firewood is becoming increasingly scarce, suggesting that these proportions may have changed over the past 12 years. In 2010, it was estimated that 80-90% of firewood sold in Canberra was from dead, standing paddock trees trucked from up to 400 km away (McArthur 2010).

Wall (1997) found that 18,000 tonnes of firewood was used each year in Armidale and a total of 31,000 in the Southern New England region, with wood coming from the New England Tablelands, escarpment forests, woodlands of the North West Slopes and Plains and as far afield as south-east Queensland and the Pilliga Forest.

For the respondents to the community survey there was no relationship between amount of firewood consumed and the insulation score for the house (Figure 5.11).

Figure 5.11 Density plot showing the amount of firewood use per year compared to the insulation score for houses. Darker blue shading signifies a higher number of respondents with the firewood use and insulation score shown on the axes.



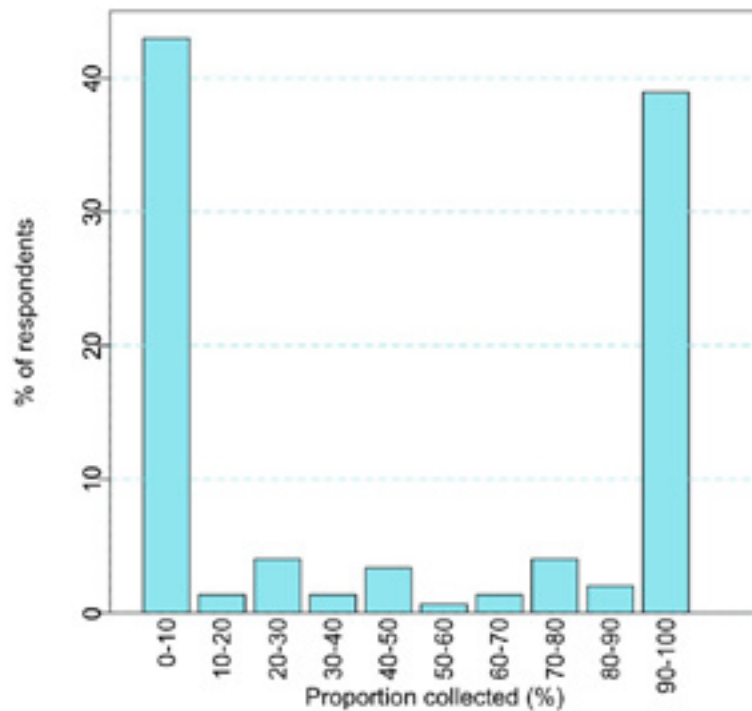
There was also no relationship between the amount of firewood consumed and whether or not wood heating was the only source of heat in the house. The absence of these expected relationships is probably due to both the unreliability of householder reporting of firewood consumption, and wide variation in how wood heaters are operated, the proportion of the house heated and the interior temperatures maintained. This is consistent with the difficulties that have been encountered in other studies in reconciling householder reporting of fuel use and the thermal characteristics of the building envelope (see, for example, Camilleri, 2008).

The idiosyncratic operation of wood heaters and living spaces, and a wide range in perceptions of thermal comfort, means that the decrease in wood consumption, and a corresponding reduction in emissions, is by no means guaranteed by programs to improve insulation standards. Thermal audits and basic thermal life skills training would be essential to ensure that insulation is being installed where most needed, and that householder behaviours did not negate the value of the insulation.

5.2.2 Firewood collection

The distribution of the proportion of firewood collected from roadsides and paddocks by those respondents who provided this figure is strongly bimodal (Figure 5.12), with around 80 per cent of respondents equally divided between those who collect little or none of their firewood from these areas, and those who collect all their firewood from these areas. The distribution is very similar if just those who returned a questionnaire from the survey of Armidale streets are included.

Figure 5.12 Distribution of the proportion of firewood collected from roadsides and paddocks.



The average annual tonnage of wood collected per respondent household in Armidale streets was 2.7 tonnes. If these households who provided information are representative of the 3,500 households with wood heaters in Armidale, then the annual tonnage collected from roadsides and paddocks could be estimated to be just under 9,500 tonnes.

5.3 Biomass resources

There are currently few alternatives to the use of dead native trees for firewood in New England. Alternative sources that have been identified include:

- Sawmill waste,
- Plantation thinnings (silvicultural waste),
- Recycled construction timber,
- Urban 'green debris',
- Wood from thinned farm woodlots or shelterbelts,
- Purpose-grown firewood,
- Silvicultural waste from native forests,
- Horticultural waste products such as olive pips and nut shells,
- 'Woody weeds' such as willow, pine, poplars, privet, box elder and honey locust.

The merits of having a wood pellet manufacturing plant local to the southern New England include: the development of a new local industry; a reduction in the transport cost component of wood pellets; and ensuring a local supply. The main pre-requisite of local pellet manufacture is a sufficient supply of suitable biomass at reasonable cost. Ideal sources of biomass for wood pellet manufacture are inexpensive, plentiful and preferably waste material and/or are by-products of other sustainable biomass-based industries. Current and potential sources of woody biomass in the southern New England region with these characteristics include:

- Low quality logs and thinnings from timber plantations (principally *Pinus radiata*);
- Low quality logs and thinnings from native timber production forests;
- Biomass from farm planted woodlots and agro forests;
- Urban waste wood and green waste;
- Sawmill waste wood and sawdust.

5.3.1 Energy and ash content of local biomass sources

Material from any of the sources listed above is potentially suitable provided it is capable of being manufactured into pellets that meet minimum standards (see section 4.1.1 and table 5.2). As part of this study a sample of each of the biomass sources listed above (except for sawmill waste which is already readily accepted as a wood pellet raw material) was analysed for energy and ash content. Appendix 3 lists the sources and characteristics of each of the samples collected and table 5.2 presents the results of the energy and ash analysis of each sample.

The tree species selected for sampling were either:

- Common timber plantation species (e.g. *Pinus radiata*);
- The most common species from native timber production forests (e.g. several stringybarks);
- Species which are frequently planted on farms (e.g. Manna Gum);
- Species that are suitable for direct seeding and have potential as a biomass crop (e.g. Wattle species); or
- Exotic species that are common weeds or have potential to be grown as a coppice biomass crop on farms (e.g. Silver Poplar).

Table 5.2 The results of ash and energy analysis for a variety of different biomass samples collected in the Southern New England region of NSW.

Species	Ash (% dry weight)	Energy (MJ/Kg)
Desirable level	<1.0	>16.5
Plantation timber species		
Radiata pine. <i>Pinus radiata</i>	0.28	20.42
Shining gum <i>Eucalyptus nitens</i>	0.86	19.12

Native forest timber species		
Messmate Stringybark. <i>E. obliqua</i>	0.59	19.22
Silvertop stringybark. <i>E. laevopinea</i>	0.25	19.15
New England stringybark <i>E. caliginosa</i>	0.15	19.15
New England blackbutt <i>E. campanulata</i>	0.21	19.11
Narrow-leaved peppermint <i>E. radiata</i>	0.20	19.08
Farm tree planting species		
River Oak <i>Casuarina cunninghamiana</i>	1.72	18.76
Manna gum <i>E. viminalis</i>	0.66	19.16
Snow gum <i>E. pauciflora</i>	0.39	19.12
New England peppermint. <i>E. nova-anglica</i>	0.66	19.17
Mountain gum <i>E.dalrympleana</i>	0.61	19.06
Yellow box. <i>E. melliodora</i>	0.65	18.78
Blakely's red gum. <i>E. blakelyi</i>	0.71	18.98
Direct seed species (whole tree samples)		
Silvery wattle. <i>Acacia dealbata</i>	1.9	18.68
Red-stemmed wattle. <i>A. rubida</i>	1.26	18.79
Fern-leaf wattle. <i>A. filicifolia</i>	3.69	18.71
Hickory wattle. <i>A. implexa</i>	2.19	19.14
Exotic species		
Silver poplar <i>Populus alba</i>	0.51	18.83
Cracked willow <i>Salix cractua</i>	2.81	18.43
Weeping willow <i>S. babylonica</i>	3.20	18.22
Urban green waste		
Armidale green waste mulch (average un-sieved)	10.90	17.12

Range of values	2.86 – 20.07	15.96 – 18.70
Armidale green waste mulch (average sieved) – sieved through a 20mm screen, fine material discarded.	3.23	18.43
Range of values	2.03 – 4.08	18.23 – 18.61

It is acknowledged that the characteristics of individual wood samples from a particular tree species can vary according to tree age and a whole variety of site and management factors and their interactions. The results from this small study are intended to be used as a guide to the likely characteristics of these biomass sources and should be considered indicative only.

Generally the results indicate that any biomass source from trees that had been de-barked would be suitable for manufacturing wood pellets for small pellet heaters. Biomass sources that contained bark and leaves or other organic material generally had too much ash content (e.g. whole-tree acacia samples). Each of the biomass sources are discussed in more detail below.

5.3.2 Timber plantations

In the region there is a large State Forest *Pinus radiata* plantation resource to the south and east of Walcha (about 9,872 ha, Brandis and Ryan, 2002); and four major privately owned pine plantations (total of approx. 1700 ha, Jay 2008). It is likely that collectively there are also several hundred hectares of smaller farm woodlots of pine (Jay 2008).

Pine plantations are typically clear-felled at economic harvest age and replanted. Depending on the site and how they have been managed, only a certain proportion of the trees at harvest produce logs suitable for high value saw logs. The remainder are low quality logs suitable for biomass or pulp markets. Potential yields of biomass/pulp quality logs suitable for wood pellet manufacture from the State Forest resource are estimated at 40,000 to 60,000m³/yr (Fussel, pers. comm. in ESD 2005, and Warren Shawner pers. comm., State Forests Operations, Walcha). These estimates have recently been verified since over the last 2 years 40,000m³ /annum of low quality and small logs (down to 8cm small end diameter) have actually been harvested from State Forest plantations to satisfy a temporary Chinese market (Shawner pers. comm.). This market has since closed. Allowing for a density of 450kg/m³, 40,000 to 60,000m³ equates to 18,000 to 27,000 dry tonnes potentially available from this source annually. Currently there are no significant markets for this resource, a small proportion is sent to out-of-region wood chip markets from time to time (Shawner, pers.com.). Usually, however, low quality logs are felled and windrowed to waste creating a nuisance for plantation re-establishment.

The forest condition and harvesting activity occurring in the private plantation estate was recently reviewed by the Northern Inland Forestry Investment group (Jay 2008). That study indicated that most of this resource is mature and has had limited silvicultural management (some thinning on better areas); consequently it too has a high proportion of low quality stems suitable for pulp and biomass markets. Jay estimates a standing total gross volume of around 590,000m³, of this he estimates around 200,000m³ would be pulpwood and tops and the remaining 390,000m³ suitable for sawlogs. Allowing for 20% of the pulpwood and tops to be uneconomic to harvest from the forest (mostly the smaller and most heavily branched tops) this represents a potential standing volume of biomass/pulp material at around 160,000m³. This suggests therefore the ratio of suitable biomass material to sawlog is about 0.25:1. Jay (2008) estimates that up to 20,000m³/yr of sawlogs could be harvested over the next 12 years from these private plantations. Using the above ratio of biomass material to sawlog, this equates to 5000m³/yr of low quality logs or 2250 dry tonnes. Actual harvest levels of sawlogs in 2008 were about 7500m³ (Jay, 2008). At 2008 harvest levels this equates to about 2,000m³ of low quality

material that could have been harvested for wood pellet manufacture or approximately 900 dry tonnes per year. Just like the State Forest plantations, there currently exists no significant market for this resource.

5.3.3 Timber production native forests

It is well accepted locally that the nature and management history of native tablelands forests produces forest stands with a high proportion of stems with low quality potential logs. The common management practice (especially in privately owned native forests) of harvesting only the highest commercial grade trees over successive harvest cycles (high grading) is a principal reason for this situation. The lack of markets for low quality logs and the marginal economics of most current harvesting operations means there remain no incentive to avoid high grading. Consequently many native forests are dominated by low quality trees which are competing for resources with the ever fewer better quality saw-log producing trees. Accordingly a biomass market for small and defective logs are likely to be attractive to native forest managers both State and private, and would allow better silvicultural management of these forests.

From table 5.2 all of the common eucalypt species of the local timber production native forests produce wood very suitable for wood pellet production.

State Forests - Approximately 100,000 ha of native forest occur in State Forests of the region (pers. comm. Warren Shawner, State Forests), principally in the Styx River forest block east of Armidale and in the forests east and south of Walcha. Shawner (pers. comm.) suggests that a conservative estimate of the sustainable yield of low quality logs (suitable for pulping or biomass but unsuitable for sawing) from these forests would be 40,000m³ annually. Allowing for a density of 600kg/m³ this equates to 24,000 dry tonnes. Currently there are no significant markets for this resource.

Private Native Forests (PNF) - In the southern New England, most commercial forest types (i.e. suitable for timber production) occurs on the eastern side of the tablelands with some occurrences also on the western fall. More fragmented occurrences of PNF are also scattered throughout the remaining tablelands which have been largely developed for agriculture. Accurate rates of harvest from this resource are difficult to ascertain.

McDonald and Brandis (2001) reviewed the private native timber resource of the wider region including most of the Armidale/Dumaresq, Uralla and Walcha shires. They estimated that there are approximately 104,000 ha of PNF of commercial forest types collectively within those 3 shires. They noted that a large proportion of the standing timber in these forests was of low quality unsuitable for sawlogs (about 80% in the commercial forests of the Armidale/Dumaresq and Uralla Shires and 70% in the commercial forest types of the Walcha Shire). They also estimated that low quality logs would also make up approximately 55% of the annual yield of these forests even with good silvicultural management. They noted that at the time of their study (late 1990s) approximately 1.6% of the commercial forest area was being harvested in any one year (i.e. approximately 1660ha). With a minimum harvest level of 5m³/ha of sawlogs necessary for an economically viable harvest operation (McDonald and Brandis, 2001) that data suggests an annual harvest of at least 8300m³ of sawlog at the time. Given the ratio of low quality (biomass) logs to sawlog on an annual yield basis of at least 1:1, a similar minimum yield of 8000m³ or so could have been achieved for low quality logs. Allowing for dry weight density of 600kg/m³ this represents 4800 dry tonnes as a minimum per year. This is likely to be a very conservative estimate when considering that 26,000 tonnes was estimated as a reasonable yield from the state forest resource of a similar size.

Currently in NSW, PNF Property Vegetation Plans (PVPs) are legally required before management of native forests for timber production. Part of the requirements of a PNF PVPs includes annual reporting of harvest activity by the forest manager. Despite this, it is difficult to ascertain with any real accuracy the current level of harvest of PNF in the region (Steve Gowlland, Office of Environment and Heritage, pers. comm.). The reasons being that annual harvest reporting is done by landholder estimate using very coarse categories (<500m³, 500 – 2000m³ and over 2000m³) for each

harvest area and logs are sold to a wide variety of markets many of which are outside the region (e.g. coastal sawmills).

5.3.4 Farm-planted woodlots and agro-forests

It has been suggested that a biomass industry based on farm grown trees would be a desirable land use for the southern New England. Material could be sourced either directly from purpose grown biomass tree crops or from thinnings and low quality logs as by-products from farm timber production. Options with low establishment costs and where the biomass enterprise provides shelter and landscape benefits to the agricultural operation of the farm are likely to be the most favoured by farmers. Currently there is very little uptake of agro-forestry for timber production as a land use by the regions landholders.

Purpose grown biomass crops with some potential include direct sown acacias where whole trees are harvested mechanically on a relative short rotation (i.e. less than 10yrs), or coppice crops where stems are harvested periodically and trees regrow from the woody base. For the New England, exotic species such as silver poplars and some willow species have apparently suitable growth rates and adaptability traits that may suit such coppicing systems. Indeed these species are common in many farmland landscapes of the region. However their suitability for efficient biomass production and the best methods of establishment and management for these species will need to be verified by local research. Poplars and willows have been grown for biomass for several decades in the northern hemisphere (IEA Bioenergy 2003).

From Table 5.2 the *Acacia* species samples analysed for ash and energy content unfortunately show high levels of ash (probably a result of high levels of bark and leaf in the samples). If these samples are representative then a biomass crop based on whole-of-tree harvesting with these species would not generate material of a suitable quality to manufacture wood pellets. A processing step that removes leaf and bark would be required. Alternatively this material would need blending with very low ash yielding biomass such as pine sawdust.

Of the exotic species that are potentially coppice candidates, only the silver poplar sample tested satisfactorily as a source of material to manufacture wood pellets, even though the sample was not debarked. The willow species again had too much ash content and if these samples are representative, could not be used as a primary biomass source.

It would appear that biomass generated as a by-product from farm grown timber has some potential. At this stage the only commercial timber species grown successfully across a wide range of southern New England farmland is *Pinus radiata*, this species is already widely used as a raw material for wood pellet manufacture. Recent trials (Carr, 2009) however have indicated that many local and non-local eucalypts also show promise, particularly on the higher rainfall parts of the tablelands and on upper slope and ridge top locations.

The climate and soil types of the southern New England are conducive to growing biomass. FullCAM (AGO, 2005), the Australian Government's carbon accounting tree growth model, estimates that a central southern New England location (eg Wollun) is capable of growing a plantation of *P. radiata* at over 6 tonnes of biomass (dry wgt)/ha/year over its first 30 years. A recent field assessment (Andrews, unpublished data, 2009) was made of existing pine windbreaks and a collection of mixed native species tree corridors on the property "Blaxland", Wollun. Collectively these farm tree plantings which varied in age from 5 to 19 years grew an average of 3.3t dry matter/ha/yr. Growth rates varied from a low of 0.8t/ha/year for a sparsely established native species planting to 6.2t/ha/yr for a 19 year old, well established radiata pine windbreak. Similarly, in a tree carbon audit of Chiswick Field Station - FD McMaster Laboratory CSIRO (Andrews, 2010), 19 year old mixed tree species corridors averaged an estimated 1.8 t dry wgt/ha/yr growth rate with a range of 0.5 to 2.9 tonnes/ha/yr. These growth rates were achieved on a low lying, frost-hollow landscape generally considered a poor tree growing site.

Currently small tonnages of low quality pine and eucalypt logs suitable for wood pellet manufacture could be expected to be generated from farm tree plantings. This industry would require further

development and some lead time until it could provide useful amounts of material. However, given the area of cleared land potentially available for this land use (even if it occupied as little as 10% of each farm) tonnages eclipsing those generated by the region's current pine plantation estate are entirely possible.

As part of this project, Southern New England Landcare and Armidale Dumaresq Council have established a small trial and demonstration plot of local firewood species adjacent to the ADC Waste Transfer Station. The site features a number of *Eucalyptus* and *Acacia* species established through seedling transplant and by direct seeding. Each of these species were selected for their suitability as firewood species and as potential species for the manufacture of pellets based on the sampled ash content.

5.3.5 Urban waste wood and green waste

The city of Armidale generates about 4,000 tonnes of wood waste (builder's timber waste) and 10,000 tonnes of green waste annually (Mike Porter pers.comm.). Guyra, Uralla and Walcha are likely to generate similar amounts of wood and green waste in proportion to their populations.

The shredded wood (builders) waste at the Armidale Dumaresq waste and recycling facility was examined as part of this study. Unfortunately it was found to have a significant plastic component (especially melamine laminate) and is likely to contain metal fragments (nails and fasteners). As such is an unsuitable material for wood pellet manufacture without further treatment. Mike Porter advises that in future this material will be sorted into solid timber waste and manufactured timber waste (i.e. laminates, plywood etc.). Potentially, at least part of this material may be clean enough to produce pellets. He estimates about 40% of the waste wood would constitute the cleaner material.

Armidale's urban green waste is generated from clippings and prunings from street trees and from private and public parks and gardens. This material is mulched using industrial scale machinery at the Armidale waste management facility and resold as garden mulch. Samples of ADC green waste mulch were analysed for ash and energy content (Table 5.2 shows the results). There was considerable variation in the results for the 5 random samples taken. Un-sieved mulch had ash content that varied from 2.8 to 20% and clearly this material is unsuitable for wood pellet manufacture. Sieving out the finer organic material (and probably soil and grit) improved the results and reduced the level of variation (ash content ranged between 2% and 4%, with an average of 3.23%). However, even after sieving, this material would need to be blended with low ash biomass before being suitable for pellet manufacture. Mike Porter (pers. comm.) indicates that all of this material currently has a local market in any case.

5.3.6 Sawmill wastes and sawdust

Five sawmills in the region were contacted by phone to determine the level of wood waste they each generate and how it is currently used or disposed of. A summary of the information collected is presented in table 5.3. Most are softwood processors, the vast majority of hardwood logs harvested from the region are processed in coastal mills. All of the coastal mills are in excess of 200km from the major southern New England centres and therefore out of economic haulage distance to consider their wastes as a local feedstock source.

Table 5.3 The type, estimated volumes and current end use of sawmill waste produced by some of the timber processors in the wider New England region of NSW.

Sawmill	Product	Estimated Volume per annum	Current method of disposal
McVickers, Quirindi	Pine sawdust & shavings	7800m ³	Sold to a contractor who on-sells to a variety of end users – animal bedding (chickens, pigs, horses),

			landscape supplies, compost makers.
	Pine wood chip	7800m ³	Sold to Visy pulp mill Tumut
Corrective Services, (CSI) Glen Innes	Pine wood chip and sawdust	7000m ³	Sold to a variety of animal industries and landscape companies
Dale and Meyers, Nundle	Pine and hardwood chip and sawdust	3000m ³	Sold to a variety of animal industries and landscape companies
Tamworth Treated Timbers, Nemingha	Pine sawdust	1000m ³	Mainly to local horse stables
	Pine offcuts and flitches	Similar volume to sawdust	Currently limited markets, owners investigating hammer milling to produce sawdust.
New England Timbers, Armidale	Hardwood sawdust	Variable – up to 1500m ³	Sold informally out of the timber yard to the public and private buyers
	Offcuts and flitches	Not known - probably over 1000m ³	Docked into short lengths and sold as firewood out of the yard
	Approximate TOTAL	30,000m ³ or approximately 10,000 dry tonnes	

Sawdust is the raw material used by the Woodburn pellet mill operated by Pellet Heaters Australia. It requires minimal additional processing to turn into pellets. The regional saw millers indicate that currently sufficient markets already exist for all sawdust at prices ranging from \$4 to \$19/m³. However Tamworth Treated Timbers and the CSI mill anticipate expansion in the near future and will be looking for additional markets. Tamworth Treated Timbers would like a better market for their flitches and offcuts which currently provide them with a disposal problem.

5.3.7 Other biomass sources in neighbouring regions

Underutilised forest resources are not unique to the southern New England. In the neighbouring Northwest Slopes and Plains there are also considerable areas of State and privately owned timber production forests where markets for small and low quality logs are virtually non-existent. The white cypress pine native forests in particular have a tendency to regenerate as very dense stands. Such stands often require substantial thinning to allow commercial trees to achieve reasonable size and growth rates. However the cost of such management is prohibitive without a market for the thinnings. Additionally at final harvest, as with any native forest, there are also substantial volumes of low quality logs suitable for biomass that could be harvested sustainably if only a market were available. Warwick Bratby (Regional Manager, Western Region, State Forests, pers. comm.) indicates that potentially the available quantity of such resources “could be in the order of tens of thousands of tonnes annually”. He also indicates that white cypress has a high energy content compared to several other common tree species and would be entirely suitable for the manufacture of wood pellets.

Summary of the regional biomass resource

Table 5.4 A summary of the current and potential sources of biomass that occurs in the southern New England of NSW that might provide raw material for a wood pellet manufacturing plant.

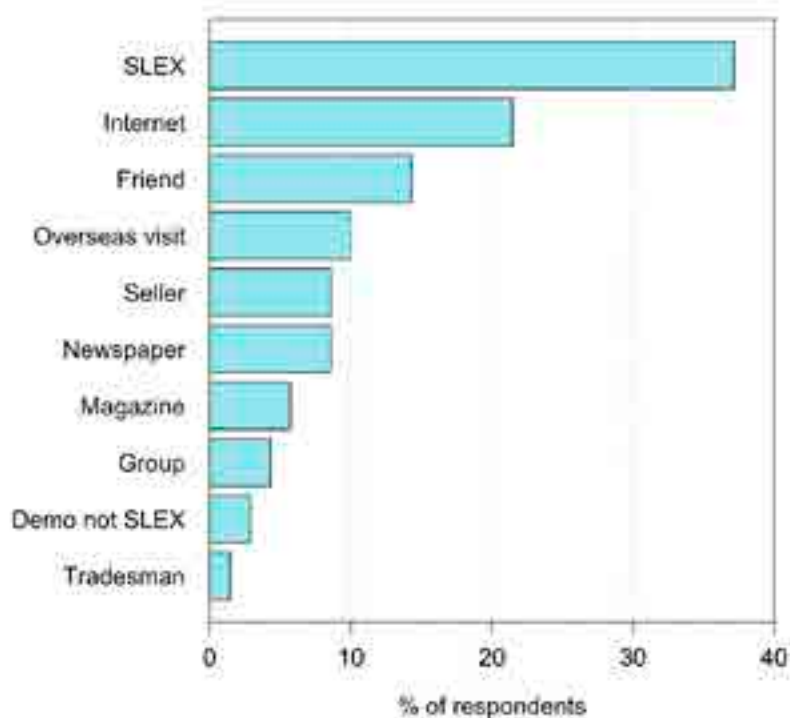
Material	Estimated annual yield (dry tonnes)	Suitability for pellets	Current use/comments
Low quality logs – State Forest native forest hardwoods	24,000	yes	Unharvested or thinned to waste
Low quality logs – PNF hardwoods	Minimum 4800	yes	Unharvested
Low quality logs – State Forest pine plantation	18000 to 27000	yes	Small proportion to out-of-region woodchip markets – remainder felled and windrowed to waste
Low quality logs – private pine plantation	900# to 2440#	yes	Felled and windrowed to waste. #for the next 12 to 30 years if forests are not replanted, in perpetuity if they are.
Farm planted trees	unknown	Yes (most species)	Almost no current industry – will require development and sufficient lead time. Whole tree acacias and willows unlikely to be suitable.
Urban waste (builders wood waste - Armidale)	4000	No – contains plastics and metals	Will be used as bio-capping of landfill. Additional sorting and processing of this waste to generate cleaner material may provide suitable feedstock for pellets.
Urban waste (green waste - Armidale)	10,000	Mostly no – ash content too high	Used in landscaping and gardens locally. Sieved material may be blended with other biomass of very low ash content.
Sawmill waste	10,000	Yes – a common raw material	A variety of markets from animal bedding to landscape uses and compost making.
Total of suitable material	Approximately 56,000 to 68,000 dry tonnes/annum		

5.4 Pellet heaters

5.4.1 Community knowledge about pellet heaters

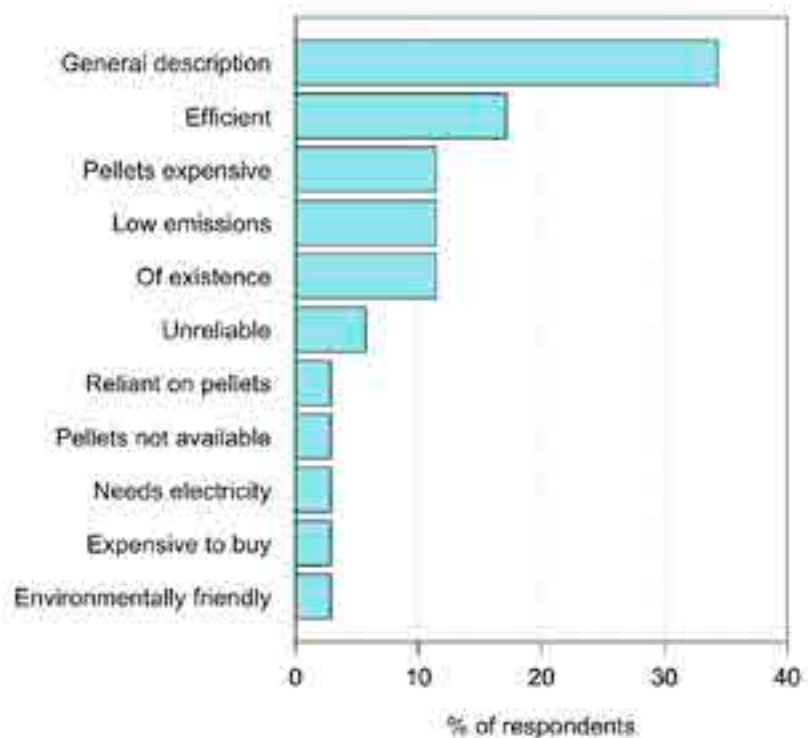
In all, 62 per cent of respondents who filled in the pellet heater survey had not heard of pellet heaters prior to the survey. The most common source of information for those who had heard of pellet heaters was the Armidale Sustainable Living Expo the previous year (Figure 5.13).

Figure 5.13 Sources from which respondents had heard about pellet heaters.



The aspects of pellet heaters, apart from their general features, that were most commonly known were their efficiency, low emissions and that pellets were expensive (Figure 5.14)

Figure 5.14 What respondents who had heard of pellet heaters knew about them.



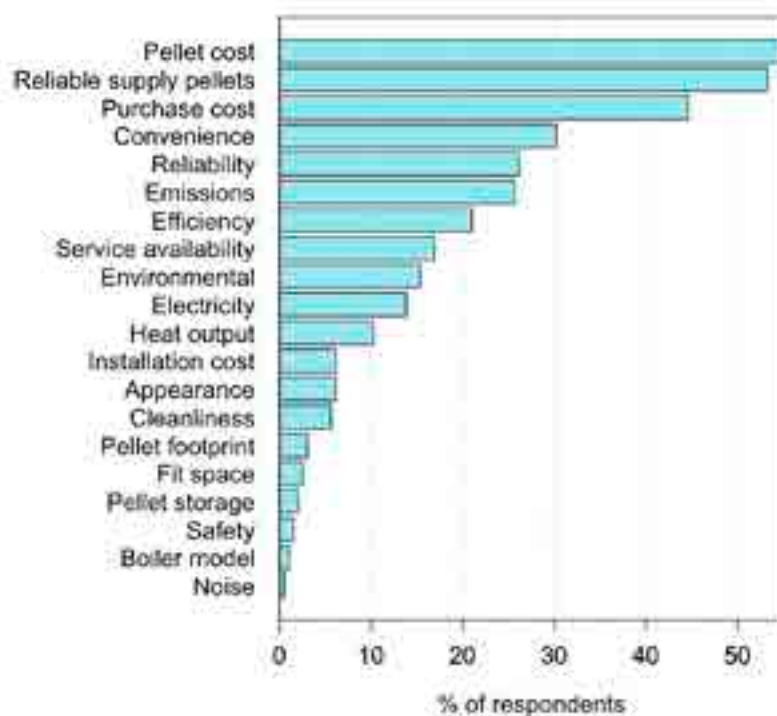
5.4.2 Interest in purchasing a pellet heater

In all, 67 per cent of respondents who answered the pellet heater survey said that they would consider a pellet heater if they were buying a stove to heat their house. Among those who were intending to buy a wood heater in the next few years, the proportion who would consider a pellet heater was 74 per cent.

Respondents were asked four open questions about the features of pellet heaters that would be important in a purchase, the features that would discourage a purchase, what additional information was needed to make a purchase decision and, if it was indicated that the respondent was not interested in considering a pellet heater, the reasons for this.

The text responses to these four questions were recoded to a small number of pellet heater attributes (Figure 5.15). Pellet cost and reliability of supply were both mentioned by more than 50 per cent of respondents. Purchase cost, reliability and service availability were aspects that might discourage purchase mentioned by a substantial proportion of respondents. Convenience, emissions and efficiency were also mentioned by considerable numbers of respondents, as attributes that would favour a purchase.

Figure 5.15 Proportion of respondents naming various pellet heater attributes as important in a purchase decision



Many respondents regarded the cost of pellets as prohibitive (in a direct comparison of price per tonne). Others were concerned that if there was only one supplier of pellets the monopoly would result in increasing prices. There were also concerns that the use of electricity by the heater would increase the heating costs.

The reliability of supply was an important issue for many respondents, who were obviously concerned about being left without heating in winter. For the same reason, the need for electricity for the heater to operate was mentioned as a disadvantage. Clearly, the popularity of wood heating rests partly on the security of heating, with wood able to be scavenged even if firewood supplies became short.

Concerns about the reliability of pellet heaters were mostly based upon the fact that they contain moving and electronic parts, as well as the spectre of being left without heating in winter if local servicing was not available. To a certain extent, the concerns about moving and electronic parts could be expected with a new consumer appliance with which people have had limited experience. The concerns would soon disappear if pellet heaters operate with the same reliability as all the other consumer durables with moving and electronic parts that are part of everyday life.

References to environmental issues occurred both as reasons favouring pellet heaters, and reasons against them. Some respondents saw the use of waste wood as an environmental benefit, while others were concerned about chemicals in the waste wood that might end up in the flue emissions. Others were concerned about forestry waste being used for pellets, when it might serve ecological functions if left on the ground after forestry operations. Some respondents raised concerns about the overall carbon footprint of pellets, when manufacturing and transport energy are taken into account.

Overall, the concerns expressed by respondents about the costs of pellet heating appeared to be based on reasonable assessments of the costs of heaters and pellets. However, in terms of frequency of mentions, the appeal of convenience, low emissions and heating efficiency are not far behind the economic concerns. This suggests there is potential for reasonable levels of uptake, if the issues of cost and reliability of pellet supply can be addressed. An extremely conservative estimate of the uptake is simply to take the number of respondents with wood heating who indicated they expected to replace their wood heater in the next few years, as well as indicating they would consider a pellet heater. These respondents number 35 in all. If the survey respondents with wood heaters are taken to

be representative of the 3,500 households with wood heaters in Armidale, then the uptake could be as much as 700 pellet heaters.

5.4.3 Price and availability in Armidale

There is currently no retail outlet selling pellet heaters in Armidale. Pellet heaters could be landed in Armidale from retailers in other parts of south eastern Australia for prices ranging between \$3,900 and \$4,300.

Ferg Lister of Parkwood Fires manufactures a range of pellet heaters in New Zealand. He recently developed a new heater (Parkwood Mia) with an improved electronic control and self-cleaning mechanism which he anticipates will retail in Armidale for \$3300 (AUD) plus the cost of a flue kit. The heater has a maximum output of 8.3 kW.

5.5 Biomass pellet availability

The consumption of firewood in the southern New England was estimated at 31,000 tonnes/year (Wall, 1997) and given the relative efficiencies of wood pellet heaters to solid fire wood heaters, the same level of home heating could be achieved with approximately one third of that tonnage of wood pellets. For example, average firewood consumption in Launceston was reported to be 4.8 tonnes per year (BDA, 2006). However, the local pellet supplier claims “One tonne of pellets equates to over 4 tonnes or 10 meters of fire wood. A typical Tasmanian pellet heater user consumes 1 tonne of pellets per winter” (Pellet Fires Tasmania, 2012). A similar figure for pellet consumption was supplied by a representative of Firemakers Ltd in Wonthaggi.

However, given the practicalities, consumer resistance to change, and the capital costs involved, 10,000 tonnes/year wood pellet consumption is unlikely without a significant lead-in time. It is likely that a critical market size will be necessary before a local wood pellet manufacturing plant would be viable. Prior to this, pellets will need to be imported from outside the region.

As mentioned previously bagged wood pellets are available from Pellet Heaters Australia based at Woodburn near Ballina NSW. They can be purchased at wholesale prices by the pallet load and transportation by road is possible, however, because of the unusual route is unlikely to be at low cost. Lowest cost road transport to and from the southern New England is made via the New England Highway either north to Brisbane or south to Newcastle/Sydney. Either direction/destination allows for back-loading opportunities for transport companies utilising largest scale trucks. To minimise transport costs, wood pellets from Woodburn will either have to travel via Brisbane or will need to be special trip loads and large enough to fill whole trucks if transported direct Woodburn-Armidale.

Bagged wood pellets are also readily available from New Zealand at similar cost. Natures Flame has successfully exported containers of palletted, bagged wood pellets to Melbourne and Tasmania in recent years (Kernohan, pers. comm.). However in the case of delivery to the southern New England, some experience with importing them (i.e. arranging handling, storage and transport from the closest sea ports - Brisbane or Newcastle) will need to be gained before New Zealand wood pellets are routinely available locally.

5.6 Heating costs in Armidale

“Average” heating costs are notoriously difficult to estimate, due to the widely variable ways in which people operate heating systems and their houses and the wide variation in perceptions of thermal comfort (see, for example, Camilleri et al., 2008; Lloyd, 2006; Cupples et al., 2006).

To estimate the heating costs for various options in Armidale, two approaches were used: obtaining estimates from the respondents to the community survey and calculating estimated heating costs from secondary data on the thermal performance of houses and fuel prices.

5.6.1 Survey estimates of annual heating costs

The estimates of the average annual heating costs reported by respondents, separated into three different types of households according to the mix of heating types, are given in Table 5.5.

Table 5.5 Survey estimates of average annual heating costs for three types of household, according to the mix of heating types

Wood heating only	Wood heating and other types of heating	Other types of heating only
\$452*	\$809	\$834
\$621**		

*Heating costs as reported

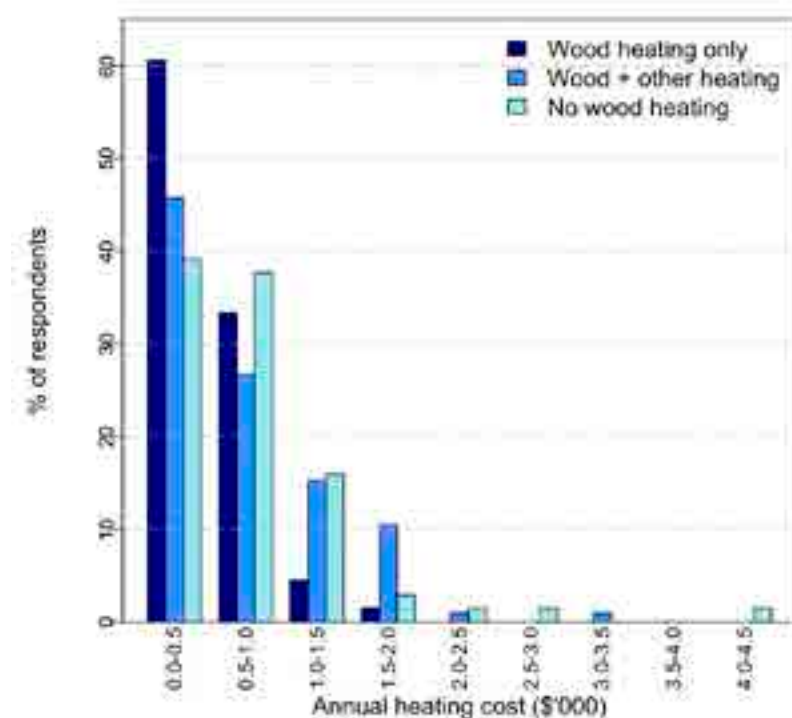
**Heating costs if wood collected from roadsides and paddocks is costed at either the price the respondent paid for bought wood, or at \$185/tonne if all the wood was collected.

The distribution of heating costs for each of the three types of household is shown in Figure 5.16. The small number of households with very high heating costs (over \$2,000/yr) tend to have wood and other types of heating, or heating types other than wood. There was no relationship between annual heating costs and the insulation score for households, reflecting the wide variation in how heating appliances are used, how much of the house is heated and perceptions of thermal comfort.

5.6.2 Estimates of heating costs from secondary data

Heating costs were estimated from secondary data in two forms: heating cost in dollars per kWh of heat supplied, and annual heating cost for an “average” Armidale house. The former estimate is only affected by the fuel price and the efficiency of the heating appliance (which may be affected by the way the appliance is operated). The latter is affected in addition by the thermal properties of the house to which heat is supplied.

Figure 5.16 Distributions of annual heating costs for households with wood heating only, wood and other heating, and no wood heating.



Dollars per kWh heat supplied

These estimates used the following assumptions:

- calorific value of dry wood of 4.68kWh/kg,
- firewood moisture content of 10 per cent,
- firewood price of \$185/tonne
- pellet heater efficiency of 79.5 per cent,
- calorific value of wood pellets of 5.10 kWh/kg,
- pellet heater uses 100kWh per month electricity
- pellet price of \$600/tonne (assumes 25 per cent retail mark-up),
- 3 star reverse cycle air conditioner with a coefficient of performance (COP) of 2.2 in heating mode,
- electricity price of \$0.30/kWh
- efficiency of 81 per cent for flued gas heating,
- gas price of \$0.0492/MJ.

The estimates obtained are shown in Table 5.6. They compare well with figures calculated by Consumer New Zealand. An important issue for the calculation of wood heating costs per kWh is the amount of overheating that might occur because of the inability of wood heaters to supply small amounts of heat when weather conditions are mild, but cool enough for householders to want to

increase interior temperatures. Overheating can also occur because householders prefer to keep the heater burning all night, rather than having to relight it in the morning.

Table 5.6 Comparative per kWh heating costs for a range of heating costs calculated for Armidale, with published figures for New Zealand for comparison.

	Wood heating	Pellet heating	Reverse cycle	Flued gas LPG
Armidale	AUD\$0.10/kWh	AUD\$0.17/kWh	AUD\$0.14/kWh	AUD\$0.22/kWh
New Zealand*	NZD\$0.10/kWh	NZD\$0.21/kWh	NZD\$0.16/kWh	NZD\$0.23/kWh

*Midpoints of ranges given by Consumer NZ for April 2012 (www.consumer.org.nz/reports/heating-options/fuel-prices-compared)

One way to estimate the overheating factor is to compare the published efficiencies of storage wood heaters and standard wood heaters. The former are designed to burn for short periods and store large quantities of heat to be released slowly when the fire is out, so are inherently more efficient. This gives an overheating factor of 1.4, i.e. 40 per cent more wood is used than is necessary to maintain thermal comfort. If the overheating factor is included in the per kWh heating cost for wood, it rises to AUD\$0.15/kWh.

Annual heating cost

Given a figure for the cost per kWh of heat supplied, annual heating cost can be estimated if certain assumptions are made about the number of degree heating days at the location and the thermal characteristics of the building being heated. As mentioned above, actual costs can vary widely due to differences in how people operate heaters and perceptions of thermal comfort. The annual heating costs below were based on the following assumptions

- 700 15degC heating days,
- a wood heater overheating factor of 1.4,
- wood heaters operated overnight,
- heaters used to heat main living areas, but not whole house,
- a 180m² house of brick veneer construction on a concrete slab,
- a ceiling height of 2.7m
- a pitched metal roof and R1.5 ceiling insulation,
- walls with reflective foil only,
- ten 1800x900mm single glazed windows, with four windows facing north,
- curtains on windows with an R value of 1,
- two wooden exterior doors with R values of 1, and
- 0.8 air exchanges per hour.

The estimated annual heating costs and fuel use are shown in Table 5.7.

Table 5.7 Estimated annual heating costs and fuel use for Armidale.

Wood heating	Pellet heating	Reverse cycle	Flued gas
\$678	\$829	\$653	\$1,092
3.7 tonnes firewood	1.2 tonnes pellets	2,178kWh electricity	21.3GJ LPG

The estimated annual wood heating cost of \$678 compares well with the reported value of \$621 by those respondents with wood heating only (Table 5.7). The wood tonnage figure also compares well with the reported annual tonnage from the community survey of 3.95 tonnes mean, and 3.23 median, for respondents with wood heating only (section 0).

The estimated annual heating costs for other heating options are difficult to compare with values reported in the community survey because, apart from a substantial group of households who have only wood heating, other households have a mix of heating options.

5.7 State and local government policy initiatives

5.7.1 Current policies

Since the mid-1990s the Armidale Dumaresq Council has undertaken a number of initiatives, including those listed below, quoted from the Council's POL134: Policy for sustainable domestic energy use and local air quality of June 2010:

- Established a community reference group (now a full advisory Committee to Council) to assist with appropriate policy direction and implementation;
- Provided significant financial incentives, such as interest free loans and subsidies for insulation and new heating systems/technologies;
- Undertaken a range of public education and related media programs on domestic energy efficiency, including the construction of a display home;
- Obtained related Government funding to supplement local program resources;
- Monitored air quality in Armidale and regularly reported the results to the community;
- Conducted smoke patrols and issued abatement notices for excessively smoking chimneys;
- Maintained a dialogue with relevant Government agencies and industry groups, including making submissions for future actions and initiatives.

POL134 strengthened the Council's approval procedures for domestic solid fuel heater installations, the approval requirement being a power conferred on local government by the Local Government Act 1993. The emissions standard for solid fuel heaters installed in new buildings in urban areas was set at 2.5g/kg, and 3.0g/kg for any other installation. The Local Government Act also gives the Council enforcement powers, e.g. to have solid fuel heaters installed without approval removed or replaced and to issue fines to owners for installation without approval.

Armidale Dumaresq Council in POL134 has stated that it does not have the power to ban wood heaters, although in a Regulatory Impact Statement in July 2010, the NSW Government noted that two local government areas, The Hills Shire and Camden, had banned wood heaters in specific new release areas (Department of Environment and Climate Change, 2010).

The Protection of the Environment Operations Act 1997 gives local government the power to issue Smoke Abatement Notices. POL134 established a sequence of actions against owners of excessively

smoking solid fuel heaters starting with warnings and education and progressing to punitive action through fines for failure to comply with a Smoke Abatement Notice.

The Protection of the Environment Operations Act defines excessive smoke as:

the emission of a visible plume of smoke from a chimney for a continuous period of not less than 10 minutes, including a period of not less than 30 seconds when the plume extends at least 10 metres from the point at which the smoke is emitted from the chimney.

There appears to have been very little, if any, use of the punitive measures available to the Council and PM2.5 levels remain unsatisfactorily high. In 2011, these levels exceeded the Australian National Environmental Protection Measure advisory level on 26 days (Armidale Dumaresq Council, 2011).

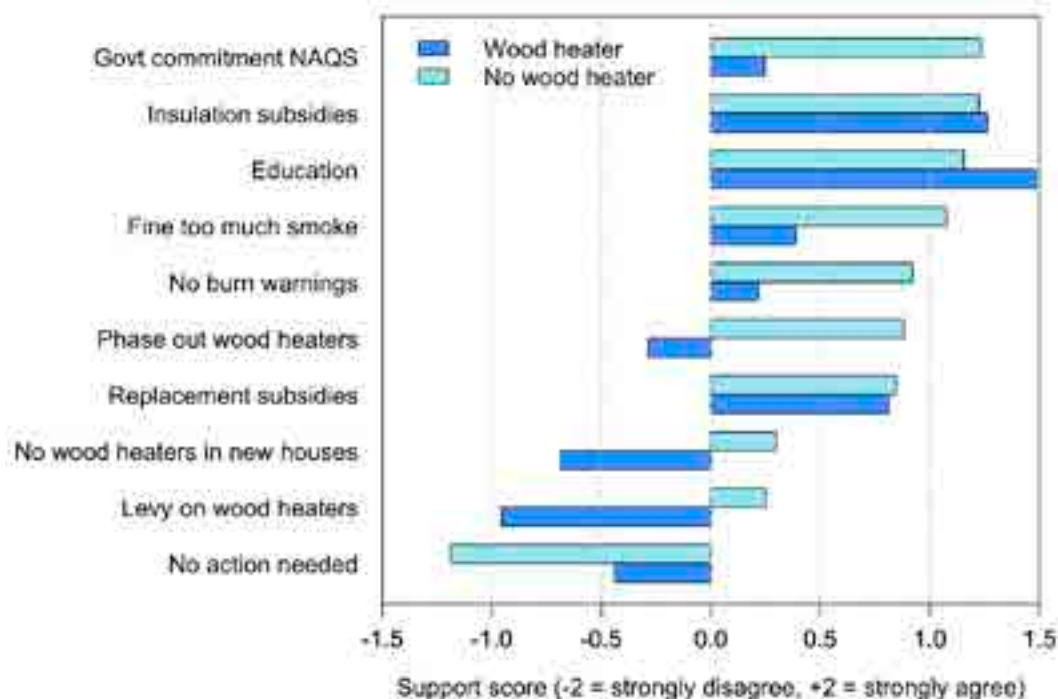
5.7.2 Community preferences for policy approaches

The community survey asked respondents for their views on a range of policy options to reduce wood smoke levels in Armidale. The options provided were as follows:

- No action is needed.
- Educate the community on how to reduce the smoke from wood heaters.
- Fines as a last resort for people who ignore recommendations on operating wood heaters properly, and make too much smoke.
- Subsidies to help people to replace their wood heater with another type of heater.
- Subsidies to help people insulate their houses so they need less heating.
- Not allowing wood heaters in new houses.
- Annual levy on houses with wood heaters to cover the cost of air quality monitoring and community education.
- Warnings on local radio before cold, still evenings when lighting wood heaters would make the air very smoky.
- Gradually phase out log-burning heaters in built up areas.
- A government commitment to ensure residential areas meet the National Air Quality Standards within 5 years.

The levels of support for these option are shown in Figure 5.17.

Figure 5.17 Levels of support for various policy approaches given by respondents with wood heating and those without.



The figure shows there are distinct differences in the level of support for various options between those with wood heating and those with other forms of heating. The greatest disparity in views is for options that involve strong restrictions or levies on wood heaters, while there is broad support for replacement and insulations subsidies and education programs.

6 Discussion of Results

6.1 The need for policy action in Armidale

As described in section 4.9 the health impacts of wood smoke inhalation are widely recognised and accepted in the international medical and toxicological literature. Recognition of these impacts in urban areas with poor air quality due to wood smoke has been a major driver for policy initiatives to improve air quality. There have been no studies that have attempted to compare wood smoke problems in Armidale with the other environmental and public health issues in the town that compete for attention and scarce public funds. However, other towns with a similar climate and housing stock, such as Launceston and Christchurch have undertaken major policy initiatives with good results, while the combination of community awareness, and a small replacement subsidy program in Armidale has brought little or no improvement in winter air quality.

Further, the community survey results suggest that the natural background replacement rate of wood heaters with newer models will have almost no impact on air quality at least for several decades (section 5.1.4); a finding that is consistent with modelling in the AECOM (2011) study. If significant numbers of households respond to rising electricity and gas prices by purchasing wood heaters for the first time, air quality in Armidale is likely to worsen further.

There is a risk of serious economic harm over the long term if continued high pollution levels discourage new residents from coming to Armidale or living in the central low-lying areas of the city. The authors are aware of a number of instances where people have moved out of Armidale because of health problems with wood smoke. Ultimately, there is a risk to property values in the low lying residential areas of Armidale if those with the financial means move to the higher areas, or out of town. In contrast, a solution to Armidale's woodsmoke problem could attract 'tree-changers' to a city that could be justifiably proud of its clean, country air.

6.2 Policy options

At the most basic level, there are four approaches that would reduce wood smoke particulate emissions:

- improve the housing stock so that existing wood heaters are used less frequently,
- replace the existing stock of wood heaters with newer models currently available that have lower particulate emissions levels,
- replace wood heaters with other forms of heating which, while they have very low particulate emissions levels, are designed in such a way that it is impossible to exceed these low levels (fool-proof low emissions heating), and
- replace wood heaters with electric heating that produces no particulate emissions at the site of use.

These options are discussed in detail in the remainder of this section, and those involving wood heater replacement are summarised in Table 6.1 at the end of the section.

6.2.1 Improve housing stock

Unfortunately, Armidale is saddled with a housing stock that, by the standards of thermal efficiency in other developed countries with similar climates, can only be regarded as seriously deficient. Investment in improved thermal efficiency has the attraction that it yields a stream of benefits indefinitely into the future. However, for the individual home owner, the benefits over the anticipated period of ownership may not cover the cost of investment, while a future owner receives the benefits.

This split incentive problem has been overcome in the USA and in Victoria by local government subsidising or paying in full for thermal efficiency improvements, with the outlay recovered by an addition to property rates. This way the repayment liability remains with the property, rather than the owner.

The results of the community survey suggest there is still considerable scope for improvement in the energy efficiency of homes in Armidale, although for wall insulation and under-slab or floor insulation, the costs of retrofit may be prohibitive. For example, there appears to be ample scope for increasing the level of use of simple draught sealing and interior window insulation. Although, the costs of retrofit may be prohibitive for wall insulation and under-slab or floor insulation, such retrofits are common in Canberra (Heat, 2012).

However, it is also necessary to consider whether an improvement in thermal efficiency would make a significant difference to wood heater use. The results of the community survey show there is no relationship between the self-reported levels of insulation in houses and wood use. While any relationship is likely to be partly obscured by the imprecision of self-reporting, it is likely that variation in how houses and their heating are managed by home owners is also obscuring the relationship.

This suggests that it is essential that any program to support the improvement of the thermal efficiency of Armidale homes be accompanied by householder training in thermal life skills, i.e the knowledge and skill needed to operate a home so that maximum thermal comfort is obtained within the limitations of thermal efficiency of the building envelope.

It is also important that any program to support the improvement of thermal efficiency of homes use professional energy audits to assess where the best gains in thermal performance can be obtained at least cost. For example, for the “average” Armidale home described in section 5.6.2, increasing the R value of ceiling insulation by one unit would lead to a 5 per cent reduction in heating requirements, whereas reducing the number of air exchanges per hour from 1.2 to 1.0 would lead to a 12 per cent reduction in heating needs.

Experience from air quality programs elsewhere suggests that improved thermal efficiency is unlikely by itself to bring about the reductions in wood use sufficient to reduce particulate emissions to acceptable levels in Armidale. However, improvements in thermal efficiency is an essential adjunct to any heater replacement programs, to keep heating costs with the replacement heaters comparable with the former costs with wood heaters.

6.2.2 Replacing wood heaters with newer models

As described in section 4.1.3 the newer models of wood heaters, compliant with AS 4013, are not immune to producing particulate emissions in quantities well above the standard, due to poor operating practices by owners. In theory, replacing the 43 per cent of wood heaters in Armidale that were manufactured prior to the introduction of AS 4013 should bring about a substantial reduction in aggregate particulate emissions. However, whether this occurred or not would depend upon the enforcement of responsible operation of wood heaters, and past experience suggests that Armidale Dumaresq Council has found this difficult to do. This option should have some impact on the biodiversity impacts of wood collection by wood heater owners, due to the increased efficiency of the newer wood heaters.

6.2.3 Fool-proof low emissions heating

From the findings of the literature review, it appears there are several forms of wood heating where cleaner burning is obtained by microprocessor control, or by physical design, thereby eliminating the possibility of poor operation by owners raising the particulate emission levels. Flued gas heating does this also.

Masonry heaters

The simplest of these are masonry heaters (section 4.8.1). While the particulate emissions reductions are relatively modest, these wood heaters address one of the main reasons for high real-life particulate emissions from current wood heaters, viz. the owners' desire to have a warm house in the morning and avoid having to relight a fire, so that wood heaters are filled late in the evening and left on low burn all night. This and the fact that masonry heaters have no special fuel requirements increases the likelihood of uptake. However, the purchase price, currently \$8,000 - \$10,000 in Victoria for imported Canadian masonry heaters, is well beyond what most owners of wood heaters would expect to pay. As the community survey shows (section 5.1.4), Armidale residents expect to pay around \$2,000 for a wood heater. Masonry heaters are not considered further.

Low particulate emissions wood heaters

The next option in increasing order of technological complexity is the low particulate emissions wood heaters (section 4.8.2). These also offer modest to significant reductions in the levels of particulate emissions compared to AS 4013 wood heaters. They have sufficiently long burn times to meet people's desire for overnight heating with a fire still burning in the morning, and are not prohibitively expensive (e.g. \$2,950 for a Quadrafire Millennium 4300, without flue kit, in Victoria).

Pellet heaters

Pellet heaters have a greater degree of technological complexity, but offer much greater reductions in particulate emissions than either of the heater types mentioned above. From the figure in Table 5., an "average" Armidale household using 1.2 tonnes of pellets per year would contribute emissions of 0.6 kg of PM_{2.5} per year. This compares with real-life emissions of about 10 g/kg (Meyer, 2008) for new log-burning heaters, and total particulate emissions of about 40 kg PM_{2.5} for a typical wood heater burning 4 tonnes of firewood per year.

Thus, measurement of real-life particulate emissions from current Australian wood stoves coupled with the NZ and European data on particulate emissions from pellet stoves suggests that a reduction in particulate emissions of 98 per cent can be achieved by substituting pellet heaters for wood heaters.

Pellet heaters with timers and thermostatic control offer users much greater control over the diurnal heating cycle and convenience in refuelling. Pellet heaters prices are similar to those for low particulate emissions wood heaters, but are completely dependent on a supply of wood pellets. The prospects for establishing such a supply in Armidale are discussed below.

A further advantage of pellet heaters is their potential to significantly reduce the collection of fallen and standing dead trees for firewood.

Wood gasifier boilers

While wood gasifier boilers (section 4.8.2) have the lowest levels of particulate emissions of all forms of domestic heating based on wood combustion, hydronic heating is used in a very small fraction of Armidale homes. The costs of boilers and retrofitting hydronic heating will be prohibitive for the foreseeable future and this heating option is not considered further.

Flued gas heaters

Flued gas space heaters include models that are convective only, convective and radiant, and radiant only. Heat delivery can be direct to a single room, or ducted throughout the house. Heaters with a decorative log effect are not considered further as these have very low efficiencies (Commonwealth of Australia, 2011).

The particulate emissions from flued gas heaters are negligible, although the CO₂ emissions are from the combustion of fossil fuels, not from a potentially renewable energy source as is the case for wood heating. The price range of flued gas heaters is comparable with that of the cheaper wood heaters.

Gas heating in Armidale will depend on LPG for the foreseeable future. The price of LPG in Armidale is 80 per cent higher than the price of natural gas in Tamworth.

6.2.4 Electric heating

Electric heating falls into two types: resistance heating and heat pumps. Resistance heating can be further divided according to whether heat is delivered mainly by radiation from the heater (bar and wall strip radiators) or by a combination of radiation and convection (oil filled column heaters, wall panel heaters and fan forced heaters). While resistance heating may be suitable for providing heating in specific locations within a house, the price of electricity in Armidale and the low efficiency of resistance heating makes it prohibitive for heating significant proportions of a house. However, the very cheap purchase price of various forms of resistance heater maintains their popularity as a heating choice.

Heat pumps, commonly referred to in Australia as reverse cycle air conditioners, are available window/wall units where the evaporator, condenser and compressor are in the one unit, and split systems where the compressor is outside the building. Multi-split systems have more than one indoor heating/cooling units and a single outdoor compressor. Ducted split systems convey conditioned air via ceiling ducts from a single heating/cooling unit connected to an exterior compressor.

The purchase price of reverse cycle air conditioners varies from as low as around \$600 for small wall mounted units, through \$1,500 - \$2,500 for one to one split systems (depending on output), to \$5,000 - \$10,000 for ducted systems (depending on size of house).

Cheaper reverse cycle air conditioners with a low star rating are likely to perform poorly at Armidale's winter evening temperatures. In contrast to most gas heating and all wood heating (apart from wood boilers), reverse cycle air conditioning produces no radiant heat. For a poorly insulated house with a cheap reverse cycle air conditioner, thermal comfort is likely to be low in Armidale's winter conditions. As the results from the community survey show, this may be a factor that is driving the uptake of wood heating in houses currently with reverse cycle air conditioning as their main form of heating.

Table 6.1 Summary of heating options

	AS 4013 wood heater	Low emissions wood heater	Pellet heater	Flued gas heater	Electric RC AC	Electric resistance
Purchase price relative to AS 4013 wood heater (similar heat output)	1.0	1.5	1.5 – 2.1	0.75 – 1.0	0.8 – 1.2	0.05 – 0.25
Running cost cents per kWh heat supplied	10 -15*	8-11	17	22	14	30
Thermal comfort	High	High	High	High	Medium	Medium
Convenience	Low	Low	Medium	High	High	High
Particulate emissions at site of use	High**	Medium	Low	Nil	Nil	Nil
Methane emissions	High**	Medium	Low	Nil	Nil	Nil

Fossil fuel derived CO₂ emissions	Low	Low	Low	High	High	High
Fuel impact on biodiversity	High***	High	Very low	Low and indirect	Low and indirect	Low and indirect

* assuming wood is purchased – running cost could be zero if all wood is collected rather than purchased.

** assumes wood heaters operated under real-life conditions – could be reduced by improved operation of wood heaters.

*** assumes a significant proportion of wood collected, as is currently the situation in Armidale – could be reduced if more waste or plantation grown wood was used.

6.3 Public and private benefits and costs of heater replacement

The public benefits and costs of replacements of the various heating options for Armidale are summarised in Table 6.2. The sums for health, biodiversity, and greenhouse gas emissions for each replacement option are shown in brackets in the left hand column of the table. This shows that the greatest public benefit would come from the replacement of AS 4013 wood heaters with pellet heaters (8), followed by flued gas heaters (4), followed by low emissions wood heaters and reverse cycle air conditioning (3), followed by electric resistance heating (2). Were there any low emissions wood heaters in Armidale, there would also be significant public benefits in replacing them with other forms of heating (apart from AS 4013 wood heaters). This analysis assumes an equal weighting for changes in health, biodiversity and greenhouse gas benefits. In reality, the value assigned to each uses non-comparable metrics, which will be different according to the context. Biodiversity benefits are hard to quantify, but can be estimated from the ‘willingness-to-pay’ method(), which are highly subjective. Greenhouse gas emissions can be quantified by the current value of the carbon tax (\$23/tonne CO₂° in 2012). Methane emissions, because of their 25-fold higher impact on atmospheric warming, will have a value of \$575/tonne. Health costs per wood heater have been estimated at about \$4,270 per year, (Robinson, 2007).

Table 6.2 Heating substitution matrix – public benefits and costs. The figures in brackets below each heating type in the left hand column are the sums of the benefits and costs for each option in the row.

Replace heaters below with heaters on the right	Low emissions wood heater	Pellet heater	Flued gas heater	Electric RC AC	Electric resistance
AS 4013 wood heater (3, 8, 4, 3, 2)	Health (+) Biodiv (+) GHG (+)	Health (+++) Biodiv (+++) GHG (++)	Health (+++) Biodiv (+++) GHG (- -)	Health (+++) Biodiv (+++) GHG (- - -)	Health (+++) Biodiv (+++) GHG (- - - -)
Low emissions wood heater (6, 4, 3, 2)		Health (++) Biodiv (+++) GHG (+)	Health (+++) Biodiv (+++) GHG (- -)	Health (+++) Biodiv (+++) GHG (- - -)	Health (+++) Biodiv (+++) GHG (- - - -)
Pellet heater (-1, -2, -3)			Health (+) Biodiv (n.c.) GHG (- -)	Health (+) Biodiv (n.c.) GHG (- - -)	Health (+) Biodiv (n.c.) GHG (- - - -)
Flued gas heater (-1, -2)				Health (n.c.) Biodiv (n.c.) GHG (-)	Health (n.c.) Biodiv (n.c.) GHG (- -)
Electric RC AC (-1)					Health (n.c.) Biodiv (n.c.) GHG (-)

n.c. = no change, biodiv = biodiversity

Table 6.3 Heating substitution matrix – private benefits and costs. The figures in brackets below each heating type in the right hand column are the sums of the benefits and costs for each option in the row.

Buy heaters on right instead of heater below	Low emissions wood heater	Pellet heater	Flued gas heater	Electric RC AC	Electric resistance
AS 4013 wood heater (wood purchased) (0, -1, 2, 2, 2)	Buy \$ (-) Run \$ (+) Comfort (n.c) Conven (n.c.)	Buy \$ (- -) Run \$ (-) Comfort (n.c) Conven (++)	Buy \$ (+) Run \$ (- -) Comfort (n.c) Conven (+++)	Buy \$ (n.c.) Run \$ (n.c) Comfort (-) Conven (+++)	Buy \$ (++++) Run \$ (- - -) Comfort (-) Conven (+++)
Low emissions wood heater (-1, 3, 2, 2)		Buy \$ (- -) Run \$ (-) Comfort (n.c) Conven (++)	Buy \$ (++) Run \$ (- -) Comfort (n.c) Conven (+++)	Buy \$ (+) Run \$ (-) Comfort (-) Conven (+++)	Buy \$ (++++) Run \$ (- - - -) Comfort (-) Conven (+++)
Pellet heater (6, 5, 3)			Buy \$ (++++) Run \$ (+) Comfort (n.c) Conven (++)	Buy \$ (++++) Run \$ (+) Comfort (-) Conven (++)	Buy \$ (++++) Run \$ (- -) Comfort (-) Conven (++)
Flued gas heater (0, 0)				Buy \$ (-) Run \$ (+) Comfort (-) Conven (n.c.)	Buy \$ (++++) Run \$ (- - -) Comfort (n.c.) Conven (n.c.)
Electric RC AC (-1)					Buy \$ (++++) Run \$ (- - - -) Comfort (n.c.) Conven (n.c.)

* n.c. = no change

Table 6.3, above, shows the private benefits that a house owner who was replacing their heating system would obtain by choosing one type of heating system compared to another. For a person comparing purchase of various types of heating versus a wood heater, they would see no net benefit in choosing either a low emissions wood heater or a pellet heater (sums of 0 and -1 in the first row of the table). If this person was collecting all or most of their own firewood, they would have no incentive to buy any other type of heating. For those buying all their own wood, gas and electric heating would be moderately attractive.

On the other hand, for a person comparing purchase of a pellet heater with other types of heating, there would be very large private benefits in not buying a pellet heater - (6, 5, 3) for flued gas, reverse cycle and radiant electric heating respectively.

The comparison of the public and private benefits of wood heater replacement show that there is a substantial public benefit if pellet heaters replaced wood heaters, but a substantial private cost were a person to choose a pellet heater rather than other alternatives.

The magnitude of this private cost, once a purchase has been made, depends critically upon the price of wood pellets. The next section discusses the potential for local production of wood pellets in southern New England.

6.4 Producing wood pellets in the New England.

The development of a local wood pellet manufacturing facility would be desirable from a regional development point of view. The establishment of a wood pellet plant would represent a new industry for the area, provide jobs and increase economic activity. It would also undoubtedly provide pellets at lower cost to local consumers compared to imported pellets and increase the security of supply. On

the other hand if wood pellets become a large proportion of the local home heating fuel market, there is a risk the wood pellet industry will displace the economic throughput of current firewood harvesters and re-sellers. Therefore it would be desirable to manufacture wood pellets locally to capture any of this displaced economic activity rather than import wood pellets and effectively export those economic benefits. It is also conceivable though that wood pellet heating could displace oil, gas and electric heating as well. In this case localising the industry should provide net economic improvements to the regional economy.

6.4.1 The viability of wood pellet manufacture in the southern New England.

There is any number of scenarios where wood pellets could be manufactured in different localities in the local region from a number of different biomass sources. The nearest existing wood pellet manufacturing plant (Pellet Heaters Australia) is at Woodburn on the NSW north coast and the largest potential market for wood pellets in the region would be the Armidale urban area. All local wood pellet manufacturing scenarios need to be cost competitive with this current source and delivery destination (i.e. bagged wood pellets delivered to Armidale).

In order to compare different wood pellet manufacturing scenarios in the southern New England a simple spread sheet model was constructed which calculates the estimated cost of production of wood pellets given different available feedstock and two regional mill locations. The model provides estimated figures in cost per bagged tonne delivered Armidale and occurs in Appendix 4.

With an indicative transport cost of \$5/km for heavy trucks (loads 20 tonnes plus, Mick McCulloch pers. comm.), and a bulk price (bagged in one tonne pellet lots) of \$395/tonne at the Woodburn plant (orders of 20tonnes or more, Rod Bailey pers. comm.), the cheapest current whole sale price of bagged pellets landed Armidale would be approximately \$484/tonne. That would be the price if a full truck load of bagged pellets on 1 tonne pallets were collected from Woodburn and delivered via the shortest highway route available to heavy trucks (Woodburn, Grafton, Glen Innes, Armidale). Note a retail margin will need to be added to cover storage and distribution to actual customers. This is the indicative price that any local mill will need to compete with.

Given the potential market size for wood pellets in the New England (up to 15,000 tonnes/year), it is reasonable to assume that any potential wood pellet mill would be of a similar size to the one located at Woodburn and have similar manufacturing costs. For the purposes of the model those manufacturing costs were assumed to be the current whole-sale price per tonne, less the feedstock price (see Appendix 4 for this calculation and all other estimated costs and assumptions).

Table 6.4 Summarises the results of the economic comparisons of various local wood pellet manufacturing scenarios for the southern New England examined via a spread sheet model (Appendix 4).

	Feedstock source			
Costs provided are bagged pellets landed Armidale in \$/tonne	Low quality logs from nearest pine plantation and/or native State Forest		Sawdust from a range of nearest sawmills	
Wood pellet plant location	Estimated average cost	Range in values	Estimated average cost	Range in values
Walcha	\$467	\$465 - 469	\$423	\$402 - \$434
Armidale	\$462	\$450 - \$473	\$396	\$365 - \$421
Imported wood pellets from Woodburn, North Coast NSW.			\$484	

Yearly production of wood pellets that could be produced from these sources in tonnes		
	Low quality logs	Sawdust
Walcha	47,400	3,650
Armidale	38,600	4,150

From Table 6.4 it has been estimated that local manufacture of wood pellets would supply the southern New England with pellets at a lower price than importing them from outside the region. It is also clear, using current sawdust prices, that wood pellets could be manufactured more cheaply in the southern New England using sawdust as the feedstock compared to using low quality logs from pine plantations or timber production native forests. This is not surprising since all of the harvesting and transport costs of sawdust are already captured in the sawlog supply chain to the sawmill, and sawdust is a by-product of the timber sawing process. Using whole-logs as a source of feedstock requires the wood pellet supply chain to bear all of the harvest, transport and additional pre-processing costs (chipping or grinding). Indeed, if these estimates are accurate, local pellet production from low quality logs does not come at much of a price advantage compared to importing pellets from Woodburn (ie approximately \$20/tonne). However these cost comparisons assumes sawdust can be purchased in the region at current prices. The development of a wood pellet market would add competitive pressures to the local sawdust price since currently all sawdust can be sold to a variety of end users. This is in contrast to any industry that can utilise low quality logs. Virtually all low quality logs from the timber production forests of the region have at present no market.

It is noteworthy that the total tonnages of low quality logs available could provide sufficient feedstock for a wood pellet mill of much larger size than the Woodburn mill. A wood pellet mill producing 30,000 to 50,000 tonnes/year is likely to have more favourable economies of scale and produce wood pellets at lower production costs. However to be viable such a mill would need to seek additional markets outside of the region for its wood pellets.

The slight wood pellet manufacture and supply cost advantage of an Armidale pellet mill location compared to Walcha (particularly with sawdust as feedstock) reflects transport cost differences. Both centres have similar transport costs for the importation of feedstock (see Appendix 4) however Armidale is the principal end market destination requiring no transport costs for the finished product.

6.4.2 The viability of wood pellet manufacture in the wider New England region.

The simplest and most inexpensive route to regionally produced wood pellets would be to establish a pellet factory alongside one of the major sawmills and value-add the sawmill wastes. Two of the regions sawmills generate enough waste to support a wood pellet factory of at least the size of the Woodburn facility. They are both just outside the southern New England study area and include the McVicker's Mill at Quirindi and the Corrective Services sawmill at Glen Innes. Pellets manufactured at these sites, at a manufacture cost similar to the Woodburn pellet mill, could be landed in Armidale for approximately \$420/tonne (i.e. some \$60/tonne cheaper than importing pellets from Woodburn). This assumes sawdust direct from the nearby sawmill at an average input price of \$40/tonne, manufacturing cost of \$340/tonne and transport of palletted bagged pellets to Armidale at around \$40/tonne (the two sawmills are both approximately 160 road km from Armidale and the above price assumes 20 tonne truck loads at \$5/km).

Assuming a 25 per cent mark up, locally produced pellets at \$525 per tonne would provide heating at \$0.15 per kWh, a figure that is closely competitive with firewood (purchased) and reverse cycle air conditioning.

6.5 Concluding remarks

From a national perspective, pellet heaters are unlikely to achieve widespread uptake in areas that need space cooling in summer as well as space heating in winter. This would apply to much of coastal southern Australia, where winters are not severe enough to significantly reduce the efficiency of reverse cycle air conditioners in heating mode. For many people, the thermal discomfort of air conditioners in heating mode for short periods is a small price to pay for the thermal comfort in cooling mode during long hot summers. For those willing to pay for both summer air conditioning and a separate heater for the winter, pellet heaters may still be an attractive option in areas where log wood supplies are expensive, or the concentration of population and adverse winter atmospheric conditions rule out wood heaters.

For areas of Australia with severe winters and cool summers, such as the Tasmanian central tablelands, and the Australian Alps and the Northern Tablelands of New South Wales, the issue of levels of insulation becomes important. For poorly insulated houses, which tend to be the norm, reverse cycle air conditioning in heating mode becomes a less attractive heating option, due to much longer periods of exposure to thermal discomfort and the expense due to the low efficiency at sub-zero temperatures. For these houses, wood heaters have been the preferred choice because the high radiant energy output raises the temperatures of interior surfaces and contributes to a sense of much higher thermal comfort.

Pellet heaters, because of their efficiency and forced air heat extraction, do not have the same radiant energy output as wood heaters and will likely to be experienced as inadequate in poorly insulated homes. However, in well insulated homes they will compete well with reverse cycle air conditioning as far as thermal comfort and running cost goes. Their requirement for more effort on the part of the user, and higher purchase price will put them at a disadvantage relative to reverse cycle air conditioning.

For Armidale, continuing with only community awareness programs about wood heater operation and limited replacement subsidy programs will not improve winter air quality. A home insulation program will have limited impact on air quality, although this could be improved by requiring participants in the program to undertake some thermal life skills training. An improvement in air quality to acceptable particulate levels can only be achieved through replacement of significant numbers of wood heaters with other types of heating.

It has been shown that substantial public benefit would come from replacing wood heaters with pellet heaters, however purchase cost, running cost and concerns about reliability and pellet supply security pose substantial private disincentives. These disincentives could be reduced if pellets were to be produced locally. While there are ample quantities of the feedstock for producing pellets available in the region, a pellet mill at a scale that would be economically viable, would have to find pellet markets outside the New England region, since its production would be greater than the local consumption for heating.

The development of a regional wood pellet industry would depend on the uptake of pellet heaters in the New England and the eventual size of the market (likely maximum is 15,000 tonnes/annum if all solid wood heaters are replaced by wood pellet heaters).

Initially, wood pellets of good quality are available from Woodburn on the North Coast of NSW or could be imported from New Zealand. Likely whole-sale prices for such pellets would be approximately \$480/tonne delivered Armidale.

In the medium to long term it would be desirable for a number of reasons to develop a local wood pellet processing facility. In this study, it was estimated that local pellets could potentially be produced using a wood pellet factory of similar scale and technology to the Woodburn plant for about \$20 to \$80/tonne cheaper than imports, depending on the feedstock used.

There are abundant biomass resources in the region (e.g. in excess of 60,000 tonnes/annum from existing waste and forest industries) that could potentially provide feedstock to such a wood pellet production facility. The two most logical sources of feedstock are: sawdust from regional sawmills;

and low quality logs from local pine plantations and native timber production forests. Other potential feedstock examined in this study included urban timber and green wastes, low quality logs from farm forestry and purpose grown biomass crops on farms. Urban timber and green waste was found to be unsuitable as feedstock due to quality issues. Farm grown timber and purpose grown biomass have some potential however there is currently very little farm forestry in the region and the whole industry would require considerable development.

The simplest pathway to regional wood pellet production would be to install a wood pellet factory in close proximity to one of the two largest sawmills and utilise sawdust as the feedstock. World-wide, sawdust is the most common feedstock source for producing wood pellets. In this study it was estimated that wood pellets could potentially be produced from sawdust using a local wood pellet factory of similar scale and technology to the Woodburn plant for approximately \$400 to \$430/tonne. This cost of production assumes sawdust can be purchased at current prices. The potential downsides of using local sawdust are: that currently all regional sawdust has an existing market and wood pellet production would represent a competitor for sawdust supply, potentially driving up the price; and, the local sawmills produce an estimated 10,000 dry tonnes of sawdust in total which is therefore an obvious limit to regional wood pellet production from this source.

Silvicultural thinnings and low quality logs from the timber production forests of the region currently have virtually no market. It was estimated that between 47,000 and 58,000 dry tonnes of this feedstock could be sustainably produced from the region's timber production forests and plantations each year. In this study, it was estimated that wood pellets could be produced from this source using a local wood pellet factory of similar scale and technology to the Woodburn plant for approximately \$450 to \$470/tonne. Unfortunately this biomass source is more expensive than sawdust due to the need for pre-processing logs (de-barking, grinding or chipping) and to cover the costs of tree harvesting. For sawdust, tree harvesting costs are absorbed by the timber production supply chain. Wood pellets could potentially be produced more cheaply from this biomass source if a wood pellet mill of much larger scale were utilised (simply due to the advantages of economies of scale). However, a mill that could utilise most of the low quality logs produced in this region would need to develop larger out-of-region markets to utilise all of its potential wood pellet production.

Any transfer of home heating fuel from firewood collected from standing and fallen dead timber to waste wood, will have a positive impact on biodiversity. Pellet heaters provide one option to achieve this, but other options should also be explored such as: using waste wood from urban tree-felling operations; using woody weeds as firewood (willows and poplars); utilisation of wood from farm plantations; and utilisation of silvicultural waste from hardwood and softwood plantations in the region.

Utilising silvicultural waste instead of dead timber from natural woodlands will result in a net decrease in greenhouse gas emissions because of the faster sequestration rates in managed plantations compared to woodlands (Paul et al, 2003). It may be possible to claim credits for this net change in greenhouse gas emissions into the price of pellet manufacture in the region, if this becomes an eligible option under emissions trading schemes such as the Carbon Tax.

7 Implications

The motivation for investigating pellet heaters for the Northern Tablelands has been to reduce wood smoke pollution and to reduce the amount of firewood collected in order to reduce the negative impacts on biodiversity. Pellet heaters are unlikely to provide a comprehensive solution to either problem in the short term and it is important to understand where they fit as part of a broad approach.

From a national perspective, pellet heaters are unlikely to achieve widespread uptake in areas that need space cooling in summer as well as space heating in winter. This would apply to much of coastal southern Australia, where winters are not severe enough to significantly reduce the efficiency of reverse cycle air conditioners in heating mode. For many people, the thermal discomfort of air conditioners in heating mode for short periods is a small price to pay for the thermal comfort in cooling mode during long hot summers. For those willing to pay for both summer air conditioning and a separate heater for the winter, pellet heaters may still be an attractive option in areas where log wood supplies are expensive, or the concentration of population and adverse winter atmospheric conditions rule out wood heaters.

For areas of Australia with severe winters and cool summers, such as the Tasmanian central tablelands, and the Australian Alps and the Northern Tablelands of New South Wales, the issue of levels of insulation becomes important. For poorly insulated houses, which tend to be the norm, reverse cycle air conditioning in heating mode becomes a less attractive heating option, due to much longer periods of exposure to thermal discomfort and the expense due to the low efficiency at sub-zero temperatures. For these houses, wood heaters have been the preferred choice because the high radiant energy output raises the temperatures of interior surfaces and contributes to a sense of much higher thermal comfort.

However, if insulation is improved, preferences could change. Despite Norway's much lower temperatures, in their insulated homes, ground and air source heat pumps are cost-competitive with pellet stoves and appear to be a more popular choice. The efficiency of reverse cycle heat pumps has improved considerably over recent years (www.energyrating.com.au) making this a more viable and cost-competitive option.

Pellet heaters, because of their efficiency and forced air heat extraction, do not have the same radiant energy output as wood heaters and will likely to be experienced as inadequate in poorly insulated homes. However, in well insulated homes they will compete well with reverse cycle air conditioning as far as thermal comfort and running cost goes. Their requirement for more effort on the part of the user, and higher purchase price will put them at a disadvantage relative to reverse cycle air conditioning.

Apart from the relativities of the physical attributes of the heating options, peoples' values may also influence purchasing decisions. While people's values and circumstances are unlikely to radically change, a sudden change in policy or regulation may have a significant impact on the relativities of purchase prices and fuel costs across heating options, and so upon people's choice of home heating. This has been the case in Christchurch and Launceston, where aggressive public awareness campaigns, subsidies for wood heater replacement and regulation of installation of wood heaters in new homes lead to the uptake of large numbers of pellet heaters.

Table 7.1 compares a number of common space heating options on a number of characteristics, including those that triggered this project. The benefits derived from switching from other heat sources to pellet heaters are both public and private. There will be different motivations to encourage a switch to pellet heaters for individual consumers than for policy makers.

We see that the greatest benefits to be gained from significant numbers of people switching from wood heaters to pellet heaters will be public, such as improvement in the amenity of the city, a reduction in health effects from wood smoke and a reduced impact on biodiversity. The benefits to individuals in switching from a wood heater to a pellet heater will be minimal (greater convenience) while the costs may be great (purchasing a pellet heater). This creates an ideal opportunity to use

public policy in order to gain public benefits by assisting individual actions. Levies or rebates may help individuals overcome the high cost of switching from wood to pellet heaters with resulting gains in public health and environmental benefits.

In other cases a switch from a reverse-cycle air conditioner to a pellet heater will result in minimal public or private benefit. Such a switch would result in a reduction in greenhouse gas emissions but a slight increase in wood smoke emissions. Therefore, there is little benefit to be gained from a change in public policy or investment of public money. Table 7.2 demonstrates the benefits or otherwise of changing to a pellet heater.

Table 7.1 Comparison of characteristics of different heat sources

	Wood heater	Pellet heater	Reverse Cycle	Flued Gas	Bar/Column heater
Wood smoke emissions	High	Low	Nil	Nil	Nil
Impact on biodiversity	High*	Low	Low and indirect	Low and indirect	Low and indirect
Greenhouse gas emissions (CO ₂ and methane)	High**	Low	High	High	Very high
Purchase cost	Medium	High	Medium	Medium	Low
Running costs	Low-medium***	High	Medium	High	Very high
Convenience	Low	Medium	High	High	High
Quality of warmth	High	High	Medium	High	Medium

*presumes common practice of using standing or fallen native trees. Can be improved by using plantation or waste wood.

** presumes common usage of wood heaters, not manufacturers specifications under ideal conditions. Can be improved through optimal burning practice.

*** running costs of wood heaters depends on whether wood is collected or bought.

Table 7.2 Benefits or otherwise of changing to pellet heaters from existing heat sources.

Change from	to	Benefit (or Disbenefit)	Who
Wood heater	Pellet heater	Smoke (+++)	Public
		Biodiversity (++)	Public
		GhG (++)	Public

		Convenience (+)	Private
		Warmth (no change)	Private
Reverse cycle or Gas	Pellet heater	Smoke (-)	Public
		Biodiversity (no change)	
		GhG (++)	Public
		Convenience (-)	Private
		Warmth (+)	Private
Bar or column heater	Pellet heater	Smoke (-)	Public
		Biodiversity (+)	Public
		GhG (+++)	Public
		Convenience (-)	Private
		Warmth (++)	Private

7.1 National and State governments

At a national level there are a number of towns and cities in a similar situation to Armidale, viz., a thermally substandard housing stock, a winter climate cold enough to make wood heaters a popular choice, growing firewood demand causing biodiversity declines across the hinterlands and winter air quality that fails to meet national health standards. Such localities lie along the highlands of NSW and Victoria and in the highlands of Tasmania. There is a massive split incentive problem in these regions, with State and Commonwealth governments standing to benefit from the reduced health costs that would follow wood smoke reduction, while local government is the best suited to implementation of policies to encourage the uptake of alternatives to wood heaters, such as pellet heaters.

The findings of this study suggest that for cities like Armidale, improvements in air quality require more than the modest programs that local government can afford. Accordingly there is an urgent need to establish funding programs at a State and/or Commonwealth level to support local government efforts to improve winter air quality.

Such programs will be more cost effective if the Commonwealth government continues to drive improvements in wood heater efficiency and emissions levels through the revision of mandatory performance standards.

State Governments to review the economic analysis in the NSW Woodsmoke Control Options report, which concluded that health costs would be reduced by over \$4 billion for a cost of just \$36 million if existing wood heaters were removed before houses are offered for sale. A ban on the sale of new heaters was the second most cost effective option, saving \$2.2 billion for an estimate cost of \$134 million. Given the large benefits for relatively small costs, these recommendations should be implemented Australia-wide unless there are compelling reasons to do otherwise.

7.2 Local government

The clear implication for local government in cities such as Armidale is that the status quo is not an option. While local government resources are limited, there is a need to ensure that the available resources and powers are used as effectively as possible. To this end a number of recommendations for local government are made in the next chapter.

Effective programs recognise the heterogeneity of the target population. In the case of home heating in Armidale, there is a wide diversity of housing standards, heating types, and a wide range of household budgets that can be spent on heating. As well as designing for this diversity, an effective program to improve winter air quality will have the flexibility to adapt to changing relative prices in firewood, wood pellets, electricity and gas. Pellet heaters are likely to be just one part of the solution to Armidale's poor winter air quality, either as solution for a particular type of household, or as a solution for a particular period of time.

Local governments frequently face strong lobbying pressure from local businesses seeking to insulate themselves from changes that are occurring in their industries or in consumer demand. Leadership is required from local government to balance public and private interest and to make a critical assessment of claims from businesses for special consideration, particularly when that consideration comes at substantial public cost. The establishment of the Armidale Mall despite strident opposition from local businesses is an example of this kind of local government leadership. Similar leadership will be required in any program to reduce the number of wood heaters used in Armidale.

Local government may also have a role to play in encouraging the establishment of a regional pellet manufacturing business through direct support to investors. This support may take the form of land provision, rate relief or incentives in return for the establishment of a new business creating jobs and revenue and contributing to improvements in air quality and local biodiversity. Regional Development Australia Northern Inland (RDANI) could also play a role in supporting the development of a pellet manufacturing industry.

7.3 Local home heating retailers, plumbers and electricians

There are a substantial number of local businesses in towns like Armidale that sell, install and service heating systems based on wood, gas and electricity. Of all the heating types in use in Armidale, it is only pellet heaters that offer the opportunity for retailers to sell both the heater and a fuel that can be conveniently stored in retail premises.

While the cost of pellet heaters is outside the range indicated in the survey that people are willing to pay, there will be a number of individuals willing to buy a pellet heater. Having a local supplier and companies who can install and maintain the heaters will ensure they become part of the heating options available to residents in the area.

The development of a regional wood pellet industry would depend on the uptake of pellet heaters in the New England and the eventual size of the market (likely maximum is 15,000 tonnes/annum if all solid wood heaters are replaced by wood pellet heaters).

Initially wood pellets of good quality are available from Woodburn on the North Coast of NSW or could be imported from New Zealand. Likely whole-sale prices for such pellets would be approximately \$480/tonne delivered Armidale.

7.4 Pellet manufacturers

As yet there are no pellet manufacturers operating on the Northern Tablelands. The implications of our research for potential manufacturers are that:

- Pellets for domestic space heating require a higher standard than can be produced on low-cost, small scale equipment,
- There are a range of sources available in the region suitable for pellet manufacture. While sawdust is the best source, most sawdust in the region is utilised for other purposes (predominantly by horse owners). Thinnings from softwood plantations near Glen Innes and Niangala would be sufficient to supply a large pellet mill, but would require additional processing compared to sawdust.
- A medium scale pellet manufacturing plant could be established using silvicultural thinnings and could expect to produce pellets at a similar cost to those available from other sources, but without the additional transport costs.
- In order to create a cost-effective pellet manufacturing operation an annual throughput of approximately 50,000 tonnes would be needed. While there is sufficient resource to supply material for such a mill, it is unlikely that regional demand could ever use this volume of pellets. A mill would need to create export markets beyond the region to warrant this level of production. Demand could also be increased if industrial boilers were adopted for users of large quantities of energy for heating, such as schools, universities, hospitals and government buildings.

8 Recommendations

Pellet heaters are a realistic alternative to wood heaters for domestic space heating which can reduce pollution from wood smoke, reduce the impact on biodiversity from firewood collection and reduce greenhouse gas emissions. Our research shows that the higher price of pellet heaters compared to wood heaters and the uncertainty about the reliability of a supply of pellets are the biggest barriers to an increased uptake of pellet heaters. Of all the alternatives to wood heating, pellet heaters offer the greatest amount of public benefit, but face the greatest level of private disincentives.

In order to overcome these barriers and obtain the extensive public benefits from replacing some wood heaters with pellet heaters, we recommend:

- Running a discount, bulk-buy scheme similar to ‘Farming the Sun’ (http://www.starfishenterprises.net/Farming_The_Sun) to get approximately 20 heaters installed and operating in Armidale. A condition of the discount might be that the householder hold one open day in winter and monitor pellet usage and amenity of these heaters (case studies) and use this information in the education campaign described below. The scheme should include a small amount of support for several local tradespersons to obtain training in pellet heater installation from the supplier. One of more of these heaters should be installed in a public space. Sustainable Living Armidale or Starfish Enterprises, both local non-government organisations could run the bulk-buy scheme.
- Sustainable Living Australia, Armidale Dumaresq Council or other suitable organisation to set up a pellet buying cooperative to bulk buy a truckload of pellets, with members drawn from heater buyers. The cooperative would be wound down as soon as any local business established a pellet supply in Armidale, but continue to hold an emergency supply sufficient for one winter for cooperative members.
- Encourage local businesses to offer pellet heaters and pellets for sale and to install and maintain them. Offer information from this report and pellet heater manufacturer’s contacts obtained through this project.
- Armidale Dumaresq Council to:
 - publicise the fact that wood heater replacement subsidy can be used for pellet heaters,
 - Provide a factsheet on how to compare the efficiency of different replacement heating systems and the benefits of insulation for residents considering replacing wood heaters
 - recipients of wood heater replacement subsidies to be strongly advised to have an accredited energy efficiency audit and if necessary, upgrade thermal efficiency of the house, and to attend accredited thermal life skills training (such as that offered by Armidale Sustainable Living),
 - decrease allowable emissions from wood-burning heaters to <1g/kg for all new installations,
 - make new subdivisions ‘smoke-free’ areas where only pellet heaters, gas or electric heating can be installed.
- Supply this report to local government, local industry and business groups to raise awareness about pellet heaters, biomass resources in the region and pellet manufacture. The establishment of a pellet manufacturing industry in the region is feasible, but will require significant private investment and due diligence by investors.
- Education campaign to be carried out by Armidale Dumaresq Council or a suitable community group to cover:
 - health effects of wood smoke;
 - comparison of running costs and emissions for pellet heaters, wood heaters, air conditioners and unflued gas heaters (the spread sheets prepared for this purpose for the current project will be made available);
 - thermal life skills with insulation and draught sealing, and
 - responsible wood heater operation.

The Commonwealth Department of Sustainability, Environment, Water, Population and Communities to assess the effectiveness of the National Wood heater Audit Program Action Plan, taking particular account of continuing studies showing that AS 4013 wood heaters under real-life conditions have emissions considerably in excess of the Standard, of the fact that there has been little or no improvement in winter air quality in rural highland towns such as Armidale and of the findings of this study that show that at natural background replacement rates of wood heaters, there will be no decrease in aggregate emissions levels for decades.

State Governments to review the economic analysis in the NSW Woodsmoke Control Options report.

9 Appendices

Appendix 1. Communications

Throughout this project we have communicated the aims and findings to the public and organisations with an interest in the research. Communication activities have included:

- Display at Sustainable Living Expo Armidale (SLEX) in October 2011. We set up a large display with posters, samples of material for manufacturing pellets, bags of pellets and brochures. Ferg Lister from Parkwood Fires NZ set up and operated a pellet heater in the display tent which attracted a lot of interest from SLEX visitors. Rod Bailey from Pellet Fires Australia also attended for one day. Both Ferg and Rod and members of the research team were on hand to answer questions from the public during the 3 days.
- We developed three large display posters on the impact of wood smoke on health and greenhouse gases and the impact of firewood collection on biodiversity. These posters have been used in many displays throughout the region.
- David Carr gave a presentation about the project findings to the 2011 Bioenergy Australia conference. The presentation was included in the conference proceedings.
- A public forum was held in Armidale on 31st May 2012 to let people know the findings from the research and to seek feedback on the results. The discussion at this forum enabled the research team to then formulate recommendations for this report. The forum was attended by wood heater suppliers, local government representatives, members of Sustainable Living Armidale and interested members of the public.



- There was considerable interest in the project from the regional media which resulted in several stories including a feature article in The Armidale Express.

Appendix 2. Survey questionnaire

Pellet heaters

A new type of wood heating for New England?



Pellet heaters are a new type of wood heater that uses small manufactured wood pellets. They have the convenience of lighting automatically, temperature control by thermostat and produce much less smoke.

Southern New England Landcare and the University of New England have been funded to research the potential for these heaters in New England.

If you can spare a few minutes of your time, we would like to invite you to give your opinions about these new heaters, and the older wood heaters.

Even if you don't have a wood heater, we would still be interested in your opinions.

There is more information on the back of this page about the survey and who to contact if you have any questions.



Australian Government
**Rural Industries Research and
Development Corporation**





Australian Government
Rural Industries Research and
Development Corporation



INSTITUTE FOR **Rural Futures**

Institute for Rural Futures
University of New England
Armidale NSW 2351

INFORMATION SHEET for PARTICIPANTS

Research Project: Realising Pellet Stoves' Potential for Pollution and Green House Gas Reduction

We wish to invite you to participate in the research on the above topic by completing some or all of the enclosed survey. This page provides more information about the research and we hope you will consider being involved.

If you wish to contact us about the research, our details are provided at the bottom of the page.

Aim of the Research

Pellet heaters have been slow to catch on in New England. We are trying to find out the reasons why, so that this clean and convenient type of wood heating can become more widely used in New England.

Time Requirements

If You Can Only Spare Five Minutes

If you've only got five minutes to spare, please fill in the five minute *Home Heating* survey on the **white page**, or on-line at: www.surveymonkey.com/s/woodheater.

Your Views about Pellet Heaters

If you have a further five minutes to spare, and would like to tell us what you think about the new pellet heaters, please read the information sheet, *More about Pellet Heaters* and fill in **both** the *Home Heating* survey on the **white page** and the *Pellet Heater* survey on the **green page**, or go on-line to the web page above.

Your Views about Air Quality in Your Town

If you are concerned about air quality in your town, you can take another five minutes to fill in the *Air Quality* survey on the pink page, that is, fill in the **white page, the green page and pink page**, or go on-line to the web page above.

About the Survey

You have received this survey because you live in one of the streets we have letterboxed. Your participation is entirely voluntary. You can send your survey back in the reply paid envelope, or do the survey on-line. Completion and submission of the survey will be taken to signify your consent for the information you have supplied to be used in the study. You are free to withdraw your consent at any time. Just contact one of the project staff below and your survey will be destroyed and the data will be deleted from the study.

The information you provide will be completely confidential, and your name and address will not be known to us. The returned questionnaires and the information is kept in secure storage at UNE. Only the research team has access, and the questionnaires and information will be destroyed after five years. The information given by any one individual will not be published.

Yours sincerely

Ian Reeve (Survey Manager)
University of New England
67735145 ireeve@une.edu.au

Dave Carr (Project Leader)
Southern New England Landcare
67729123 dave@snelcc.org.au

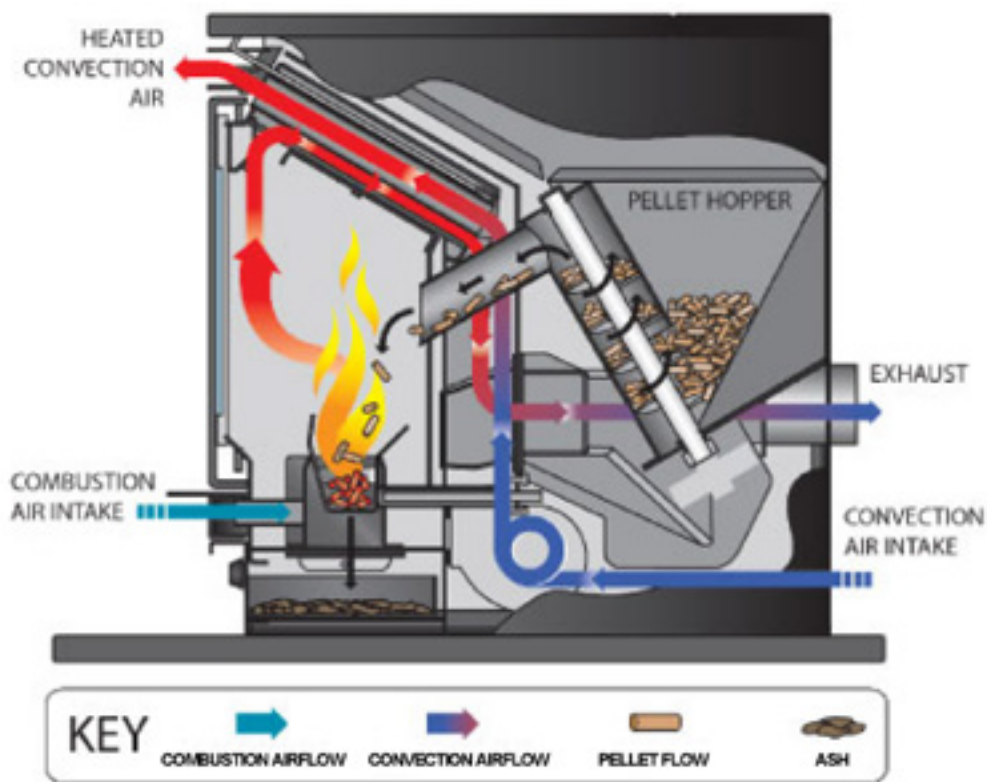
This project has been approved by the Human Research Ethics Committee of the University of New England (Approval No. HE11-217 Valid to 21/12/2012). Should you have any complaints concerning the manner in which this research is conducted, please contact the Research Ethics Officer at the following address: Research Services, University of New England, Armidale, NSW 2351. Telephone: (02) 6773 3449 Facsimile: (02) 6773 3543 Email: Ethics@une.edu.au

More about Pellet Heaters

Pellet heaters or pellet stoves are a type of wood heater that is becoming increasingly popular in New Zealand and have been used for years in North America and Europe. These heaters use less wood than an ordinary wood heater uses, and produce much less smoke.

The pellets are the thickness of a pencil and made from forestry thinnings, waste wood or plantation timber. The pellets go in a hopper, and are fed into the fire automatically, according to the temperature set on the thermostat. The heaters light themselves and the thermostat can be programmed so the heater lights up and goes out at particular times of the day. One fill of the hopper lasts up to several days, depending on the thermostat setting.

How They Work



The screw auger transfers wood pellets from the pellet hopper to the combustion pot, which sits in the base of the fire box. The combustion pot is surrounded by fine air nozzles which may be supplied by a blower, or air drawn in by the convection of flue gases up the flue. The blower, which draws its air from the room, also passes air over the top and/or around the fire box, and back into the room. Pellet ash drops through the bottom of the combustion pot into an ash tray in the base of the stove. Automatic lighting of the stove and the amount of air draft is controlled by electronics in the stove itself – all the owner has to do is set the thermostat for the temperature they want. Some models have a small back-up battery, so the stove continues to operate if there is a power outage.

Advantages of Pellet Heaters

Breathing wood smoke causes similar health problems to breathing tobacco smoke – heart and lung diseases, middle ear infections, bronchiolitis in babies, cancers and increased risk of respiratory infections. Pellet heaters produce only one tenth of the smoke that wood heaters do, so they can reduce these health problems caused by wood smoke. With a recent United Nations study recommending that log-burning wood heaters be phased out in developed countries like Australia, the pellet heater is an attractive alternative that keeps the visual appeal of the wood heater.

Pellets provide at least 50% more heat than a similar weight of firewood. Since pellet heaters can be set to switch on automatically in the early morning, there may be no need to have a fire burning all night, which further reduces the amount of pellets needed.

Wood pellets are made from a variety of woods including forestry waste, woody weeds and small-diameter plantation-grown timber. This can reduce the impact on biodiversity of firewood harvesting from dead trees and logs.

Pellet heaters are a more convenient form of heating than wood heaters. The heat output is easily controlled, there is no need for a wood heap and splitting wood, and they produce much less ash.

Disadvantages of Pellet Heaters

A well-made pellet heater should have a life similar to a well-made wood heater. However, because a pellet heater has electronics and moving parts, failures in minor components can make the heater unusable, requiring a technician to repair the heater.

If the pellet heater does not have a back-up battery, it may be difficult to operate during power outages.

If wood pellets become unavailable for any reason, the heater cannot be operated with any other fuel.

What's Available in Australia?

Pellet heaters sold in Australia range from 7kW to 14kW heat output, and have emissions less than 1 gram per kilogram of wood burnt. They are currently available from:

Firemakers Ltd, Wonthaggi, Vic 3995. 03 5672 5700;

Ipswich Skylights, North Ipswich, Qld 4305. Phone: 07 3201 5222;

Pellet Fires Australia, Dandenong, Vic 3175, Phone: 1300 735 538.

What about the Wood Pellets?

Pellets can be purchased in 20kg bags and are clean and easy to handle. A bag of pellets will run the stove for 10-28 hours, depending on the thermostat setting. Pellets cost between \$400 and \$600 tonne. Pellets are currently being manufactured on the NSW North Coast.

Five Minute Survey: Home Heating

PART A

1 What sort of heating do you have in your home, and how old are the heating appliances?
(please tick each form of heating you have – if more than one appliance of the same type, please give the age of the oldest appliance)

Wood heating stove (freestanding or fireplace insert)	☐	_____ years old
Wood cooking stove	☐	_____ years old
Open fire	☐	_____ years old
Electric bar radiators	☐	_____ years old
Electric reverse cycle air conditioning or heat pump	☐	_____ years old
Electric in-floor heating	☐	_____ years old
Gas heating, unflued	☐	_____ years old
Gas heating, flued	☐	_____ years old
Central heating, gas fired	☐	_____ years old
Other (please specify)_____	☐	_____ years old

2 Approximately how much does this heating cost you to run each year? \$_____

3 Does your home have any of the following? (please tick any that apply)

Insulation in the ceiling	☐
Insulation in the walls	☐
Insulation under the floor	☐
Double- glazed windows	☐
Close-fitting thick curtains, drapes or blinds	☐
Draught sealing around doors and windows	☐
Other (please specify)_____	☐

PART B

If you presently have one or more wood heating stoves, please answer the questions below, otherwise skip to PART C, on the back of this page.

- 1 About how much wood do you use in an average year?
 _____tonnes, or _____ute or small trailer loads, or _____truck loads
- 2 If you collected any of this wood from paddocks or road sides, about what percentage of the wood you use comes from this source? _____%

PART C

If you expect to be buying a wood heating stove in the next few years, please answer the questions below. Otherwise, skip to PART D, below.

- 1 What is the main reason you expect to be buying a wood heater?

1B. How much do you expect to pay for your new wood heater? \$_____

1C. How important will each of the following features be in choosing which wood heater you buy? (please tick a box for each feature)

	Very important	Important	Somewhat important	Not important
Purchase price	☐	☐	☐	☐
Size	☐	☐	☐	☐
Heat output	☐	☐	☐	☐
Ease of loading with wood	☐	☐	☐	☐
How much wood it uses	☐	☐	☐	☐
Overall appearance	☐	☐	☐	☐
Suits the room where it is going	☐	☐	☐	☐
Good view of the flames	☐	☐	☐	☐

Safe for small children	☐	☐	☐	☐
Low smoke emissions levels	☐	☐	☐	☐
Other <i>(please specify)</i>	☐	☐	☐	☐

PART D

1 To which age group do you belong?

Under 20 ☐ 20-29 ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60 or over ☐

2 Which of the following best describes your household?

Single person household. ☐

Family household – most members are related to each other. ☐

Group household – most members are not related to each other . ☐

3 Do you own or rent your home?

Own ☐ Rent ☐

-Thank You for Helping Us with This Important Project-

Pellet Heater Survey

If you haven't already done so, please read the information sheet "More about Pellet Heaters", then answer the questions below.

1 Before this survey, had you ever heard of pellet heaters?

NO. ☐  Please go to Question 2, below

YES. ☐  Please go to Question 1A, below

1A. If you had heard of pellet heaters, what did you know about them, and what was your source of information?

2 If you were buying a stove to heat your house with, would you consider buying a pellet heater?

NO. ☐  Please go to Question 5, on the back of this page.

YES. ☐  Please go to Question 2A, below

2A. Which features of pellet heaters would be important to you in making the purchase?

2B. Are there any aspects of pellet heaters that might discourage you from buying one?

3 If you were to seriously consider buying a pellet heater, what things would you want to know more about before making the decision?

4 Thinking about the advantages and disadvantages of pellet heaters, would you be prepared to pay more or less for a pellet heater compared to an equivalent wood heater?

- | | |
|-------------------------------------|--------------------------|
| 20% less for a pellet heater | ☐ |
| 10% less for a pellet heater | ☐ |
| Pay about the same price | ☐ |
| 10% more for a pellet heater | ☐ |
| 20% more for a pellet heater | ☐ |
| 30% more for a pellet heater | ☐ |
| 40% more for a pellet heater | ☐ |
| 50% more for a pellet heater | ☐ |

Thank you for your help. There are no more questions to answer.

5 Is there any particular reason you would not consider buying a pellet heater?

-Thank You for Helping Us with This Important Project-

Air Quality Survey

1 The air is often very hazy on winter mornings. In your opinion, how important is each of the following in causing the haze? (please tick one box for each source)

	Very important	Important	Somewhat important	Not important	Not sure
Natural mist or fog	☐	☐	☐	☐	☐
Bushfires in the region	☐	☐	☐	☐	☐
Wood heaters	☐	☐	☐	☐	☐
Slow combustion cooking stoves	☐	☐	☐	☐	☐
Car and motor bike exhausts	☐	☐	☐	☐	☐
Motor mowers, chain saws, whipper snippers	☐	☐	☐	☐	☐
Backyard burning of garden rubbish	☐	☐	☐	☐	☐
Other (please specify) _____	☐	☐	☐	☐	☐

2 How much do you consider each of the following to be a health risk to you or your family? (please tick one box for each risk)

	High risk	Moderate risk	Low risk	No risk	Not sure
Mobile phone towers	☐	☐	☐	☐	☐
Food additives	☐	☐	☐	☐	☐
Chemical termite treatments	☐	☐	☐	☐	☐
Other people's cigarette smoke	☐	☐	☐	☐	☐
Loud noise from traffic or industry	☐	☐	☐	☐	☐
Smoke from wood heaters	☐	☐	☐	☐	☐
Germs in drinking water	☐	☐	☐	☐	☐

Chemicals and poisons used in the home and garden	☐	☐	☐	☐	☐
Germs in food	☐	☐	☐	☐	☐
Chemicals in town water	☐	☐	☐	☐	☐

3 Has your household ever experienced problems or annoyance as a result of smoke from other people's wood heaters? YES. ☐ NO. ☐

4 In towns like Launceston in Tasmania and Christchurch in NZ, various actions have been taken to reduce the amount of wood smoke in the air. How much do you agree or disagree that each of the following actions should be taken in your town? (please tick one box for each risk)

	Strongly agree	Agree	Neutral or not sure	Disagree	Strongly disagree
No action is needed.	☐	☐	☐	☐	☐
Educate the community on how to reduce the smoke from wood heaters.	☐	☐	☐	☐	☐
Fines as a last resort for people who ignore recommendations on operating wood heaters properly, and make too much smoke.	☐	☐	☐	☐	☐
Subsidies to help people to replace their wood heater with another type of heater.	☐	☐	☐	☐	☐
Subsidies to help people insulate their houses so they need less heating.	☐	☐	☐	☐	☐
Not allowing wood heaters in new houses.	☐	☐	☐	☐	☐
Annual levy on houses with wood heaters to cover the cost of air quality monitoring and community education.	☐	☐	☐	☐	☐
Warnings on local radio before cold, still evenings when lighting wood heaters would make the air very smoky.	☐	☐	☐	☐	☐
Gradually phase out log-burning heaters in built up areas.	☐	☐	☐	☐	☐
A government commitment to ensure residential areas meet the National Air Quality Standards within 5 years.	☐	☐	☐	☐	☐
Other (<i>please specify</i>)	☐	☐	☐	☐	☐

5 **For each of the statements below, please indicate whether you believe they are true or false.**

	True	False	Not sure
The average brand-new log-burning wood heater on the Northern Tablelands gives off more fine particles in its smoke per year than 300 passenger cars.	☐	☐	☐
The average log-burning wood heater in an urban area causes additional health costs to residents of over \$3,800.	☐	☐	☐

-Thank You for Helping Us with This Important Project-

Appendix 3. Sources and characteristics of a variety of different biomass samples collected in the southern New England region of NSW.

Tree species samples were either whole-tree (Acacias), or from the bole or a large branch, each was between 100 and 200mm in diameter and 1500 – 2000 mm in length when collected in the field. These samples were then passed through a street tree wood chipper courtesy of Armidale Dumaresq Council and a 500g random mixed sample of the resulting wood chips were sent to the Environmental Analysis Laboratory, Lismore, for analysis. In the lab, wood chip samples were hammer milled and oven dried to constant weight, ash content was determined in a muffle oven and energy content via a bomb calorimeter.

It is acknowledged that the characteristics of individual wood samples from a particular tree species can vary according to tree age and a whole variety of site and management factors and their interactions. The results from this small study are intended to be used as a guide to the likely characteristics of these biomass sources and should be considered indicative only.

Sample	• Sample Description
• Native forest timber species	
Messmate Stringybark <i>Eucalyptus obliqua</i>	• 12 yr old tree in Greening Australia farm forestry trial Wongwibinda (Carr, 2009), sample was from the tree bole approx. 15cm diameter and was de-barked.
Silvertop stringybark <i>E. laevopinea</i>	• 12 yr old tree in Greening Australia farm forestry trial Wongwibinda, sample was from the tree bole approx. 15cm diameter and was de-barked.
New England stringybark <i>E. calignosa</i>	Small tree in a native forest 20km east of Armidale, sample was from the tree bole 20cm diameter and was de-barked, tree age est. 50yrs +
New England blackbutt <i>E. campanulata</i>	• Small regrowth tree in a native forest 20km east of Armidale, sample was from the tree bole 18cm diameter and was de-barked, tree age about 15yrs.
Narrow-leaved peppermint <i>E. radiata</i>	Small tree in a native forest 50km north east of Armidale, sample was from the tree bole 20cm diameter and was de-barked, tree age 50yrs +
• Plantation timber species	
Radiata pine <i>Pinus radiata</i>	Section of bole of a small tree in Armidale park land– removed as part of a weeding operation, 15cm diameter, was de-barked. Age unknown.
Shining gum <i>E.</i>	• 6 yr old tree in farm planting Metz 20km east of Armidale,

<i>nitens</i>	sample was from the tree bole approx.15cm diameter and was de-barked.
Farm tree planting species	
River Oak <i>Casuarina cunninghamiana</i>	10 yr old tree in farm planting Metz 20km east of Armidale, sample was from the tree bole approx.10cm diameter and was de-barked.
Manna gum <i>E. viminalis</i>	12 yr old tree in Greening Australia farm forestry trial Wongwibinda, sample was from the tree bole approx 15cm diameter and was de-barked.
Snow gum <i>E. pauciflora</i>	25 yr old tree Armidale Dumaresq Council waste water treatment plant amenity planting, sample was from a tree branch approx 15cm diameter and was de-barked.
New England peppermint <i>E. nova-anglica</i>	25 yr old tree Armidale Dumaresq Council waste water treatment plant amenity planting, sample was from a tree bole approx 18cm diameter and was de-barked.
Mountain gum <i>E.dalrympleana</i>	12 yr old tree in Greening Australia farm forestry trial Wongwibinda, sample was from the tree bole approx 15cm diameter and was de-barked.
Yellow box <i>E. melliodora</i>	12 yr old tree Armidale Dumaresq Council waste water treatment plant fire-wood trial, sample was from a tree bole approx 12cm diameter and was de-barked.
Blakely's red gum <i>E. blakelyi</i>	12 yr old tree Armidale Dumaresq Council waste water treatment plant fire-wood trial, sample was from a tree bole approx 10cm diameter and was de-barked.
Silvery wattle <i>Acacia dealbata</i>	15 yr old tree Armidale Dumaresq Council waste water treatment plant fire wood trial planting, sample was a whole tree (including all branches and leaves) 10cm diameter and was not de-barked.
Red-stemmed wattle <i>A. rubida</i>	10 yr old tree in farm planting Metz 20km east of Armidale, sample was a whole tree 10cm diameter and was not de-barked.
Fern-leaf wattle <i>A. filicifolia</i>	6 yr old tree in farm planting Metz 20km east of Armidale, sample was a whole tree 8cm diameter and was not de-barked.
Hickory wattle <i>A. implexa</i>	Small regrowth tree in a native forest 20km east of Armidale, sample was the whole tree, 8cm diameter and was not de-barked, tree age 7yrs.

• Exotic species	
Silver poplar <i>Populus alba</i>	Section of a large branch from a tree in Armidale park land/ creekside– removed as part of a weeding operation was not debarked, age unknown.
Cracked willow <i>Salix cractua</i>	Section of a large branch from a tree in a reserve 5km north of Armidale – removed as part of a weeding operation was not debarked, age unknown.
Weeping willow <i>S. babylonica</i>	Section of a large branch from a tree in Armidale park land/ creekside– removed as part of a weeding operation was not debarked, age unknown.
• Urban green waste	
Armidale green waste mulch	Armidale Dumaresq waste depot – 5 different random samples taken from mulch heaps to gauge level of variability. Each sample was also sieved through a 20mm screen to test the removal of finer organic matter on ash content. Both sieved and un-sieved samples were analysed.

Appendix 4. Wood pellet manufacturing scenarios for southern New England region – an economic comparison.

In order to compare different wood pellet manufacturing scenarios in the southern New England a simple spread sheet model was constructed which calculates the cost of production of wood pellets given different available feedstock and two regional mill locations. The model provides figures in cost per bagged tonne delivered Armidale. The type of inputs, their cost and other assumptions used in developing the spread sheet, are summarised below. See also the spread sheet in Table A4.1.

Two manufacturing scenarios considered are:

Scenario 1: Manufacture at Walcha, haul in logs or saw mill waste, transport packaged pellets to Armidale

Scenario 2: Manufacture at Armidale haul in logs or saw mill waste as feedstock.

Manufacturing price

Pellet Heaters Australia utilise sawdust from various saw mills on the north coast as feedstock. Its price was not available to this study as it was commercial in-confidence. However, assuming sawdust prices from North Coast saw mills are similar to the ones revealed by local New England saw mills (ie average \$40/dry tonne or approximately \$12/m³); and allowing for road transport costs from the main sawmills at Grafton and Casino to Woodburn (average 80km); suggests sawdust would cost Pellet Heaters Australia approximately \$55/dry tonne landed at the mill. Given the factory door price of the bagged pellets (i.e. \$395/tonne), this suggests a manufacturing and packaging cost of approximately \$340/tonne. This figure was used in the spread sheet as an indicative manufacturing cost and covers all other business and input costs, labour, interest and return on capital.

A number of feedstock sources were considered including: Low quality logs from Walcha pine plantations and State Forests native forest (Walcha area for the Walcha mill and Styx River forests for the Armidale mill); sawdust from various sawmills; green waste material from Armidale Waste Transfer Centre.

- Various costs of feedstock, harvesting and treatment, and transport included:
- Cut, snig and load on log trucks, logs from forests or plantations: Will vary considerably due to terrain and access – assumes terrain suitable for mechanical harvesting = average \$26/m³ for pine (from Jay 2008 with allowances for CPI) and \$35/m³ for hardwood (Mick O'Neill, North Coast Forestry Services pers.comm.) – converted to dry tonne basis using a density 0.45 for pine and 0.6 for hardwood.
- Log haulage rates: varies according to road class, estimated to be 15c/tonne/km for highways and regional roads, 26c/tonne/km secondary roads and 90c/tonne/km for forest tracks (adapted from Jay 2008 with additional 3%/annum to allow for CPI)
- Debark logs at pellet mill (pine only): Not known, \$2/tonne is authors estimate only.
- Grind/chip/shave/hammermill logs to sawdust consistency: Allowed \$10/tonne as an indicative estimate only as there are no reliable cost estimates available for these operations. As an indication, chipping costs for small hardwood logs harvested in plantations in Victoria were reported at \$8.90/tonne when conducted at the roadside (Ghaffariyan, 2011)
- Sawdust (local to SNE): Varied from \$4 - \$19/m³ (average approx. \$12m³) or \$19.80 to \$62.70/dry tonne (average approximately \$40/dry tonne -various saw millers pers. comm.)
- Transport of sawdust (28 tonne loads): \$5/km (highway or major regional road - Mick McCulloch pers. comm.)

Table A4.1

Table A4.1		Walcha pellet plant						Armidale pellet plant						
Inputs (costs are per dry tonne) Material cost/log royalty Harvest cost Transport to pellet mill Debarking Pre-treatment grind/ chip Pellet manufacture Transport pellets to Armidale Total cost whole-sale delivered Armidale Total possible production from this source (tonnes pellets/annum)	Woodburn pellets ¹	Pine logs Walcha	Native forest logs Walcha ²	Nundle sawdust (pine & hardwood)	Glen Innes sawdust (pine)	Nemingha sawdust (pine)	Average all sawdusts	Armidale sawdust (hardwood) ²	Glen Innes sawdust	Nundle sawdust (pine & hardwood)	Nemingha sawdust	Average all sawdusts	Pine logs Walcha	Native forest logs Styx ²
	395.00	11.10	8.30	19.80	39.60	62.70	40.70	23.10	39.60	19.80	62.70	36.30	11.10	8.30
		57.80	58.30										57.80	58.30
		33.00	33.00	26.30	39.25	15.18	27.00	2.00	27.80	29.60	18.50	19.48	51.60	33.00
		2.00											2.00	
		10.00	10.00										10.00	10.00
		340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00	340.00
	89.00	15.50	15.50	15.50	15.50	15.50	15.50							
	484.00	469.40	465.10	401.60	434.35	433.38	423.20	365.10	407.40	389.40	421.20	395.78	472.50	449.60
		30,000	17,400	1,000	2,300	350	3650	500	2,300	1,000	350	4150	30,000	8,600

Note 1 : Material cost is whole-sale cost of bagged pellets on pallets at the Woodburn (north coast NSW) mill door

Note 2 : cannot manufacture solely from this source, hardwood makes pellets that are too dense (Bailey pers. comm.) - need some softwood

Cost Assumptions

Royalties - allowed \$5/m³ stumpage cost; discrepancy hardwood -softwood due to pine density .45, euc density assumed .6

Sawdust costs quoted by sawmills at the mill (converted per m³ price to dry tonne by multiplying by 3.3, ie assumed bulk density of sawdust is .300 but is highly variable)

Harvesting cost @ \$26/m³ for pine from Jay 2008, @\$35/m³ for hardwoods (Mick O'Neill pers. comm.) - note these costs converted to dry tonne basis and again cost differences due to density differences

Log transport as indicated in report; assumed average haulage 80km (Pine plantations and native forest to Walcha and Styx State Forests to Armidale), 2km in bush, 28km secondary rd, 50km main road
- for pine logs Walcha to Armidale added 62km major rd costs

Sawdust transport based on 80m³/27 dry tonne loads walking floor bulk trucks @ \$5/km (Mick McCulloch pers. comm.)

Pine logs need debarking at pellet mill, hardwood de-barked in bush.

The breakdown of the State Forest native hardwood low quality log resource (total of 26,000 tonnes) has been estimated at 33% Styx forests 67% Walcha forests based on approximate relative area

Costs in red lettering are indicative estimates only as there are no reliable cost estimates available. These operations highly dependent on machinery layout and scale

As an indication, chipping costs for small hardwood logs gathered at the log dump using a large scale Bruks Chipper in bluegum plantations Victoria were recently reported at \$8.90/tonne (Ghaffariyan, 2011)

Appendix 5. Personal communication sources

(with much gratitude)

Contact	Organisation
James Armstrong	CSI Sawmill, Glen Innes.
Rod Bailey	(formerly) Pellet Heaters Australia, Woodburn.
Warwick Bratby	Regional Forester, State Forests, Western Region.
Boyd Chase	McVickers Softwood Sawmill, Quirindi.
Steve Gowlland	NSW Office of Environment and Heritage, Newcastle
Peter Kernohan	Natures Flame, Lake Taupo, New Zealand
Ross Lakin	Dales and Meyers Sawmill, Nundle.
Ferg Lister	Parkwood Fires, New Zealand
Mick McCulloch	McCulloch Bulk Haulage, Tamworth.
Mick O'Neill	North Coast Forestry Services, Casino.
Mike Porter	Armidale Dumaresq Council, Armidale.
Kerry Rummery	Taminda Timbers, Tamworth.
Jenny Schofield	New England Timbers, Armidale.
Warren Shawner	Forest Operations, State Forests, Walcha.
Peter Turner	Tamworth Treated Timbers, Nemingha.

10 Bibliography

- Albrecht, R.J. n.d. Ultra-low Emissions, European-style Wood Combustion Technology for a Sustainable Energy Future. Presentation under the auspices of the New York State Energy Research and Development Authority. [http://www.adksc.org/e\\$pi_dec/RAYALB~1.PDF](http://www.adksc.org/e$pi_dec/RAYALB~1.PDF). Accessed 8/12/2012.
- Andrews, S. 2009. Field assessment of biomass and carbon in farm tree plantings on the property 'Blaxland', Wollun NSW. – unpublished data.
- Andrews, S. 2010. 'Chiswick Tree Carbon Audit' – a report to the manager.
- Anon. 2001. *National Approach to Firewood Collection and Use in Australia*. Australia and New Zealand Environment and Conservation Council.
- Armidale Dumaresq Council, 2011. *Supplementary State of the Environment Report 2010-2011*. Armidale Dumaresq Council, Armidale, NSW.
- BDA 2006. Wood heater Particle Emissions and Operating Efficiency Standards: Cost Benefit Analysis: Report prepared for the Department of the Environment and Heritage (Available at: <http://www.environment.gov.au/atmosphere/airquality/publications/pubs/wood-particle-emissions.pdf>).
- Brandis, J and Ryan, M. 2002. 'Softwood Development Strategy.' A report to Walcha Council.
- Camilleri, M., French, L. and Isaacs, N 2008. *Wood and solid fuel heating in New Zealand. Conference Paper No 129. XXXVth International Association of Housing Science World Congress on Housing Science, Melbourne 4-6 Sept 2007. Building Research Association of New Zealand.*
- Carr, D. 2009. 'Farm Forestry Species Trials – North West Slopes and Plains, Dorrigo Plateau and Northern Tablelands NSW.' RIRDC Publication No. 09 – 087
- Crouse DL, Peters PA, van Donkelaar A, Goldberg MS, Villeneuve PJ, Brion O. 2012. *Risk of Non-accidental and Cardiovascular Mortality in Relation to Long-term Exposure to Low Concentrations of Fine Particulate Matter: A Canadian National-level Cohort Study*. Environ Health Perspect.
- Cupitt, L. T., Glen, W. G., and Lewtas, J. 1994. *Exposure and risk from ambient particle-bound pollution in an airshed dominated by residential wood combustion and mobile sources. Environmental Health Perspectives*, 102(S4):75–84.
- Cupples J., Guyatt V., Pearce J. 2007. "Put on a jacket, you wuss": cultural identities, home heating, and air pollution in Christchurch, New Zealand. *Environment and Planning A*, 39(12), 2883 – 2898.
- Department of Environment and Climate Change. 2010. *Regulatory Impact Statement. Proposed Protection of the Environment Operations (Clean Air) Regulation 2010*. Department of Environment and Climate Change, Sydney.
- Department of Health. 2009. *Community survey of perceived environmental health risks in Western Australia 2009*. Public Health Division, Department of Health West Australia, Perth.
- DECC. 2007. *Threatened Species Profile – Bush Stone Curlew*. NSW Department of Environment and Climate Change.
- DEH & CSIRO. 2005. *Woodheaters in Launceston – Impacts on Air Quality*. CSIRO Atmospheric Research, Aspendale Victoria 3195.

- Dix-Cooper L, Eskenazi B, Romero C, Balmes J, Smith KR. 2011. *Neurodevelopmental performance among school age children in rural Guatemala is associated with prenatal and postnatal exposure to carbon monoxide, a marker for exposure to woodsmoke*. *NeuroToxicology*;33(2):246–254.
- Driscoll, D., Milkovits, G., and Freudenberger, D. 2000. *Firewood in Australia: Impact and use of firewood in Australia*. CSIRO Sustainable Ecosystems, Canberra.
- Edwards SC, Jedrychowski W, Butscher M, Camann D, Kieltyka A, Mroz E. 2010. *Prenatal Exposure to Airborne Polycyclic Aromatic Hydrocarbons and Children's Intelligence at Age 5 in a Prospective Cohort Study in Poland*. *Environ Health Perspect*.
- Environment Canterbury Regional Council. 2012. *Authorised solid fuel burners*. <http://ecan.govt.nz/services/online-services/pages/authorised-solid-fuel-burners.aspx> Accessed 20/5/2012.
- ESD Consulting. 2005. *'Feasibility Study for Utilisation of Residual Wood in the Walcha Region.'* A report to the Northern Inland Forestry Investment Group. New England / North West Regional Development Board.
- Fisher G, Kjellstrom T, Kingham S, Hales S, Shrestha R. 2007. *Health and Air Pollution in New Zealand, Final Report*: Health Research Council of New Zealand & Ministry for the Environment & Ministry of Transport.
- Fisher G, Kjellstrom T, Woodward A, Hales S, Town I, Sturman A. 2005. *Health and Air Pollution in New Zealand: Christchurch Pilot Study*: (available at: <http://www.hapinz.org.nz/>).
- Garnett, S.T., and Crowley, G.M. 2000. *The Action Plan for Australian Birds*. Environment Australia, Canberra.
- Ghaffariyan, M.R. 2011. *'Biomass Operations Costs in Australia: From Stump to Mill.'* Conference presentation 'Towards 2020 - growing our sustainable future' Bioenergy conference QLD.
- Gilbreath S, Yap P. 2008. *The Potential Impact of Residential Wood Burning Regulations in a California Region: Concurrent Wintertime Reductions in Ambient Pollution and Cardiovascular Mortality*. *Epidemiology*;19(6)
- Gras J. 2002. *Emissions from Domestic Solid Fuel Burning Appliances.*: Environment Australia Technical Report No. 5, March 2002.
URL:<http://www.environment.gov.au/atmosphere/airquality/publications/report5/index.html>.
- Haluza, D. 2012. *Estimated health impact of a shift from light fuel to residential wood-burning in Upper Austria*. *J Expos Sci Environ Epidemiol*.
- HEAT (Home Energy Advice Team). 2012. *Cavity Wall Insulation*. http://www.heat.net.au/action-advice-page/pdfs/factsheets/old_factsheet_pdfs/cavity_wall_insulation_web.pdf
- Heathcote, R. 2002. *Armidale Plantation Firewood Trial: Maintaining Biodiversity by Substituting Native Woodland Firewood Supplies with Hardwood Plantation Thinnings – an Armidale Case Study*. State Forests of NSW and Bushcare.
- Henning, A. 2005. *Equal Couples in Equal Houses: Cultural perspectives on Swedish solar and bio-pellet heating design*. In: Guy, S. and Moore, S. (Eds), *Sustainable Architectures: Cultures and Natures in Europe and North America*. Spon Press, New York, London.
- IEA Bioenergy. 2003. *Sustainable Production of Woody Biomass for Energy – A position paper*.

- IEA Bioenergy. 2009. *Bioenergy- a Sustainable and Reliable Energy Source. MAIN REPORT*. Energy Research Centre of the Netherlands.
- Jay, A. 2008. '*Northern Inland Private Softwood - Resource and Market Opportunities*.' A report to the Northern Inland Forestry Investment Group.
- Johansson LS, Leckner B, Gustavsson L, Cooper D, Tullin C, Potter A. 2004. *Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets*. Atmospheric Environment 4;38(25):4183-4195.
- Kelly C, Mues S, Webley W 2007, *Real-life Emissions Testing of Pellet Burners in Tokoroa*. Warm Homes Technical Report. : Ministry for the Environment, Wellington, New Zealand.
- Kernohan, P. 2011. '*Wood Pellet Production and Market Development*'. Conference presentation 'Towards 2020 - growing our sustainable future' Bioenergy conference QLD.
- Khan L. 2002. '*Particulate Air Pollution in Armidale*'. PhD Thesis, Univ. New England, Armidale, NSW.
- Khan L, Parton K, Doran H. 2007. *Cost of Particulate Air Pollution in Armidale: A Clinical Event Survey*. Environmental Health;7(2):11-21.
- Lindenmayer, D.B., Claridge, A., Hazell, D., Michael, D., Crane, M., MacGregor, C. and Cunningham, R. 2003. *Wildlife on Farms: How to Conserve Native Animals*. CSIRO Publishing, Collingwood.
- Lloyd, B. 2006. *Fuel poverty in New Zealand*. Social Policy Journal of New Zealand, 27, 144-155.
- Lung Association of Quebec. 2009. *Wood heating: a public health issue for the Montréal region*. http://www.pq.lung.ca/environnement-environnement/wood_smoke-fumee_bois/enjeu-montreal/.
- MacNally, R., Parkinson, A., Horrocks, G. and Young, M. 2000. *Current Loads of Coarse Woody Debris on South-eastern Australian Floodplains: Evaluation of Change and Implications for Restoration*. Restoration Ecology, 10 (4) pp 627-635.
- McArthur, I. 2010. *Report on the sustainable re-use of timber from felled urban trees in the ACT*, Farm Forestry Consulting.
- McDonald, P. and Brandis, J. 2001. '*Southern New England Tablelands Private Forests Inventory*'. A report to the New England– Northwest Regional Development Board, Armidale.
- Meyer CP, Luhar A, Gillett R, Keywood M. 2008. *Measurement of real-world PM10 emission factors and emission profiles from woodheaters by in situ source monitoring and atmospheric verification methods*: CSIRO Marine and Atmospheric Research (CMAR), (available at: <http://www.environment.gov.au/atmosphere/airquality/publications/emission-factor.html>).
- Ministry for the Environment. 2011. *New Zealand Domestic Solid Fuel Burner Authorisation Manual. March 2011 Edition*. Ministry for the Environment, Wellington.
- Morgan TE, Davis DA, Iwata N, Tanner JA, Snyder D, Ning Z. 2011. *Glutamatergic Neurons in Rodent Models Respond to Nanoscale Particulate Urban Air Pollutants in Vivo and in Vitro*. Environ Health Perspect;119(7).
- Munro, N.T., Lindenmayer, D.B., & Fischer, J. 2007. *Faunal response to revegetation in agricultural areas of Australia: A review*. Ecological Management & Restoration, 8, 199-207.

- Munroe RL, Gauvain M. 2012. *Exposure to open-fire cooking and cognitive performance in children*. International Journal of Environmental Health Research; 22(2):156-164.
- Naeher, L.P., Brauer, M., Lipsett, M., Zelikoff, J.T., Simpson, C.C., Koenig, J.Q. and Smith, K.R. 2007. *Woodsmoke Health Effects: A Review*. Inhalation Toxicology; 19:67-106.
- Noonan, C. W. 2011. *Reducing community and household exposures to residential wood combustion*. International Symposium on Biomass Combustion, Vancouver, British Columbia.
- NSW EPA. 2002. *Dioxins, Organics, Polycyclic Aromatic Hydrocarbons and Heavy Metals*. <http://www.environment.nsw.gov.au/air/dopahhm/pahresults.htm> (accessed May 2006).
- NSW OEH. 2011. *Economic Appraisal of Wood Smoke Control Measures*: AECOM Australia Pty Ltd. Prepared for the Office of Environment and Heritage. Available at: <http://www.environment.nsw.gov.au/woodsmoke/smokecontrolopts.htm>.
- NSW Scientific Committee. 2001. *Brown treecreeper (eastern subspecies) – Vulnerable species determination final*. Department of Environment and Conservation, Sydney.
- O’Connell MJ, Gaudin MR, Kirk LE. 2010. *The Clean Heat Project: Improving air quality and energy efficiency outcomes for the Canterbury Region*. Air Quality and Climate Change; 44(2):28-34.
- Olsen, G.; Cooper, D.; Huxtable, D.; Carslake, J.; Bartle, J. R. 2004. ‘*SEARCH Project Report*.’ Perth, Australia: Western Australian Government.
- Oregon Department of Energy. n.d. *List of stoves qualifying for tax credits*. <http://oregon.gov/energy/CONS/pages/res/tax/pelletstovelist.aspx>. Accessed 8/6/2012.
- Pa AA. 2010. *Development of British Columbia wood pellet life cycle inventory and its utilization in the evaluation of domestic pellet applications*. MSc Thesis, University of British Columbia 2010.
- Paul, K., Booth, T., Elliot, A., Jovanovic, T., Polglase, P. and Kirschbaum, M. 2003. *Life Cycle Assessment of Greenhouse Gas Emissions from Domestic Woodheating: Greenhouse Gas Emissions from Firewood Production Systems*. Bush for Greenhouse/ CSIRO Forestry and Forest Products, Canberra.
- Pellet Fires Tasmania. 2012. *Your guide to Heating & Ventilation in Tasmania*. <http://www.pftas.com.au/pages/files/heating-guide.pdf> (accessed June 2012).
- Perera FP, Tang D, Tu YH, Cruz LA, Borjas M, Bernert T. 2004. *Biomarkers in maternal and newborn blood indicate heightened fetal susceptibility to procarcinogenic DNA damage*. Environ Health Perspect ;112(10):1133-6.
- Perera F, Tang W-y, Herbstman J, Tang D, Levin L, Miller R. 2009. *Relation of DNA Methylation of 5'-CpG Island of ACSL3 to Transplacental Exposure to Airborne Polycyclic Aromatic Hydrocarbons and Childhood Asthma*. PLoS ONE ;4(2):e4488.
- Perera FP, Li Z, Whyatt R, Hoepner L, Wang S, Camann D. 2009. *Prenatal Airborne Polycyclic Aromatic Hydrocarbon Exposure and Child IQ at Age 5 Years*. Pediatrics;124(2):e195-202.
- Perera FP, Tang D, Wang S, Vishnevetsky J, Zhang B, Diaz D. 2012. *Prenatal Polycyclic Aromatic Hydrocarbon (PAH) Exposure and Child Behavior at age 6-7*. Environ Health Perspect.
- Robinson DL 2011. *Australian wood heaters currently increase global warming and health costs*. Atmospheric Pollution Research;2(3):267-274.

- Robinson DL, Monro JM, Campbell EA. 2007. *Spatial variability and population exposure to PM_{2.5} pollution from woodsmoke in a New South Wales country town*. Atmospheric Environment; 41:5464–5478.
- Rogers E. 1995. *Diffusion of Innovations*, 4th ed. Free Press, New York.
- Scott AJ. 2005. *Real-life emissions from residential wood burning appliances in New Zealand*: Environment Canterbury, August.
- Siddiqui AR, Gold EB, Yang X, Lee K, Brown KH, Bhutta ZA. 2008. *Prenatal Exposure to Wood Fuel Smoke and Low Birth Weight*. Environ Health Perspect;116(4).
- Sopha, B.M., Klöckner, C.A., Skjevraak, G. and Hertwich, E.G. 2010. *Norwegian households' perception of wood pellet stove compared to air-to-air heat pump and electric heating*. Energy Policy 38:3744-3754.
- Steg, L. and Vlek, C. 2009. *Encouraging pro-environmental behaviour: An integrative review and research agenda*. Journal of Environmental Psychology 29, 209-317.
- Tidemann, C.R. and Flavel, S.C. 1987. *Factors affecting choice of diurnal roost site by tree-hole bats (Microchiroptera) in south-eastern Australia*. Australian Wildlife Research 14 (4).
- Todd JJ. 2003. *Wood-Smoke Handbook: Woodheaters, Firewood and Operator Practice: Eco-Energy Options*. (available at: <http://www.deh.gov.au/atmosphere/airquality/publications/handbook/>).
- Todd JJ. 2008. *Emission Auditing Of New Woodheaters In Australia And New Zealand*. Clean Air and Environmental Quality;42(3).
- UNEP. 2011. *Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers*: United Nations Environment Programme. <http://www.unep.org/publications/ebooks/slcf/> (accessed 18 March 2012).
- US Dept Energy. 2011. *Wood and pellet heating*. http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12570. Accessed 5/6/2012.
- US EPA. n.d. *Current list of EPA-certified wood stoves*. <http://www.epa.gov/Compliance/resources/publications/monitoring/caa/woodstoves/certifiedwood.pdf> . Accessed 6/6/2012.
- Veras MM, Damaceno-Rodrigues NR, Caldini EG, Ribeiro AACM, Mayhew TM, Saldiva PHN. 2008. *Particulate Urban Air Pollution Affects the Functional Morphology of Mouse Placenta*. Biology of Reproduction 79(3):578-584.
- Wall, J. 1997. *'Sustainability of the Armidale fuelwood industry on the Northern Tablelands of New South Wales : resource yield, supply, demand and management options'*. PhD Thesis. University of New England, Armidale.
- West, P.W., Stol, J., Cawsey, E.M. and Freudenberger, D. 2008. *Firewood harvest from forests of the Murray-Darling Basin, Australia Part 1. Long-term, sustainable supply from native forests* Biomass and Bioenergy 32: 1206-1219
- Weuve J, Puett RC, Schwartz J, Yanosky JD, Laden F, Grodstein F. 2012. *Exposure to Particulate Air Pollution and Cognitive Decline in Older Women*. Arch Intern Med;172(3):219-227.

Yang S. 2011. *Woodsmoke linked to pneumonia, cognitive impacts*. . University of California.
<http://www.universityofcalifornia.edu/news/article/26663>.

Zhang Y, McKechnie J, Cormier D, Lyng R, Mabee W, Ogino A. 2009. *Life Cycle Emissions and Cost of Producing Electricity from Coal, Natural Gas, and Wood Pellets in Ontario, Canada*.
Environmental Science & Technology;44(1):538-544.

Footnotes

ⁱ For example, Lohberger pellet cookers are priced at £6168 in the UK – see www.thewoodheatingcompany.co.uk/store/range_cookers/pellet_and_wood_fired_cookers/lohberger_lcp_80_classic. Some pellet stoves designed primarily for space heating offer a grill, which takes advantage of the stove's air blowers to draw the cooking gases into the flue – see, for example the Harman Oakwood pellet stove in the USA – www.harmanstoves.com/products/details.asp?f=OAKWDCISTV&nav=features.

ⁱⁱ Source: www.firemakers.com.au.

ⁱⁱⁱ The list of qualifying stoves and their characteristics is available from the US EPA website at:
http://www.epa.gov/Compliance/resources/publications/monitoring/caa/woodstoves/certified_wood.pdf.

^{iv} For more information on MCZ wood and pellet stoves, see the company's website at:
<http://www.mcz.it/en/>.

^v From a 2006 discussion on a handyman website at: <http://www.byggebolig.no/index.php?topic=18556.0>

^{vi} Most electricity in Norway is from hydroelectric power stations.

^{vii} Fact sheet from the Consumer Council (Forbrukerrådet), February 2009.
http://forbrukerportalen.no/Artikler/2009/hvor_ble_det_av_pelletsen

^{viii} Press release on the closure of the Bionordic pellet oven factory in Jostedal, July 2011.
<http://www.nobio.no/images/stories/PDF/jostedal.pdf>

^{ix} Newspaper article, Aftenposten, 12/7/2001.
<http://mobil.aftenposten.no/article.htm?articleId=3405345>

^x Fact sheet from the Consumer Council (Forbrukerrådet), February 2009.
http://forbrukerportalen.no/Artikler/2009/hvor_ble_det_av_pelletsen

^{xi} Fact sheet from the Consumer Council (Forbrukerrådet), February 2009.
http://forbrukerportalen.no/Artikler/2009/hvor_ble_det_av_pelletsen

^{xii} From a 2006 discussion on a handyman website at: <http://www.byggebolig.no/index.php?topic=18556.0>

Wood Pellet Stoves for Pollution and Greenhouse Gas Reduction

By David Carr, Ian Reeve, Shane Andrews and Dorothy Robinson

Pub. No. 12/O65

This research was carried out in the Northern Tablelands of NSW to determine whether pellet heaters could provide an alternative form of domestic space heating without the environmental and health costs of current space heating options. The research looked at barriers to adoption of pellet heaters and opportunities to increase their uptake. This included an examination of options for manufacturing pellets locally from a range of sustainable sources.

RIRDC is a partnership between government and industry to invest in R&D for more productive and sustainable rural industries. We invest in new and emerging rural industries, a suite of established rural industries and national rural issues.

Most of the information we produce can be downloaded for free or purchased from our website <www.rirdc.gov.au>.

RIRDC books can also be purchased by phoning 1300 634 313 for a local call fee.



RURAL INDUSTRIES

Research & Development Corporation

Phone: 02 6271 4100

Fax: 02 6271 4199

Bookshop: 1300 634 313

Email: rirdc@rirdc.gov.au

Postal Address: PO Box 4776,
Kingston ACT 2604

Street Address: Level 2, 15 National Circuit,
Barton ACT 2600

www.rirdc.gov.au

Cover image: An example of a New Zealand low emissions wood heater, the Pyroclassic IV