CHAPTER 7
BEHAVIOUR, PERCEPTIONS AND ATTITUDES TOWARDS WOOD HEATING AND AIR POLLUTION – A HOUSEHOLD SURVEY

7.1 Introduction

Understanding people's behaviour and their perceptions and attitudes towards wood heating and air quality is central to this study of particulate air pollution. This chapter presents the findings of a household survey, which investigated behaviour, perceptions and attitudes toward wood heating and air pollution in Armidale.

7.2 Methodology

Data were collected through face-to-face interviews with 300 households. Data collection took place during the period December 1998 to March 1999. Each interview lasted for 30 to 45 minutes. The trained interviewer was briefed for the administration of the questionnaire.

To select the sample household, a list of all households was obtained from Armidale Dumaresq Council. From the total of 11,956 households, 600 were selected randomly. The interviewer approached every second selected household with the intent of obtaining a sample of size 300. If a household was unable to take part, a reserve household adjacent on the list was used. This enabled spatial representation to be maintained.

The sample size of 300 was selected because it was considered that this would offer sufficient power in the subsequent statistical estimates. Also the costly nature of face-to-face interviews made a larger sample size prohibitive, for comparison, the 1996 ADC survey had a size of 224.

To avoid ethical issues or concerns, informed consent was obtained from each respondent before the survey. About two weeks before the interview, a letter was delivered to each potential respondent. The letter explained to the respondents their right to refuse to answer any question, or to discontinue the interview at any time; the purpose of the study; the types of questions to be asked in the interview; and the confidential nature of the information provided by the respondents. The respondents were assured that no personal information would be revealed or identified in the study report.

A written questionnaire was used to gather information. The questionnaire was administered using a trained interviewer visiting respondents at their home. This enabled a higher participation rate than a mail survey and ensured better quality responses.

The questionnaire had three parts. Part one had wood heater related questions. Part two contained questions focussing on attitudes towards woodsmoke and willingness to pay for clean air. The last part collected demographic data on the respondent including age, sex, education levels, income, occupation, and family size. Appendix B contains the questionnaire. The survey findings are discussed under six main headings:

i. Socio-economic characteristics of the respondents
ii. Wood heater and wood burning information
iii. Wood heater user's attitudes towards wood heating and woodsmoke
iv. Public awareness about woodsmoke and air pollution
v. Community attitudes towards various schemes to reduce air pollution
vi. Willingness to pay for clean air.

7.3 Socio-Economic Characteristics

The socio-economic characteristics of the survey population have been summarised in Tables 7.1— 7.4. Armidale census data for 1996 has been included where available. When sample data are compared with Armidale census data it is clear that the survey sample was a representative sample of the total population. The larger variation is between age distribution, but this is readily explained by the fact that the survey did not include the tertiary student population (living in University or school residence), which is a large contributor to the 18-30 years age group.

Around 48 per cent of respondents were male and 52 per cent were female. The age distribution of respondents is summarised in Table 7.1. The sample reflects the aging population of Armidale, with 21.7 per cent being 60 and over. The mean household size was 2.9 (Armidale average is 2.7), ranging from 1 to 8 members. Most respondents (90 per cent) lived in a single or detached house, with 8 per cent living in flats or units.

Table 7.1: Distribution of Respondents According to Age and Sex

Description	Frequency	Per cent	Armidale (Per cent)
Sex			
Male	143	47.7	47.6
Female	157	52.3	52.4
Total	**300**	**100**	**100**
Age	**Frequency**	**Per cent**	**Armidale (Per cent)**
18-29 years	66	22.0	33.2
30-39 years	60	20.0	20.0
40-49 years	65	21.7	18.2
50-59 years	44	14.7	11.2
60 and over	65	21.7	17.4

Concerning the respondent's educational background, 4.7 per cent had only primary education, 28 per cent were educated to secondary level, and 21.6 per cent were university graduates. Nineteen per cent of respondent possessed TAFE qualifications, 16 per cent higher school certificates, and 11 per cent postgraduate degrees (Table 7.2). The percentage of respondents with university and postgraduate qualifications was higher than the national average, probably because Armidale is a university town. The occupation of respondents (Table 7.3) has a higher than average proportion in the managerial/professional category, probably for the same reason.

Table 7.2: Distribution of Respondents According to Education

Education levels	Frequency	Per cent
Primary	14	4.7
Secondary	84	28.0
HSC	48	16.0
TAFE	57	19.0
University	65	21.6
Post graduate	32	10.7
Total	**300**	**100**

Table 7.3: Distribution of Respondents According to Occupation

Occupation	Frequency	Per cent
Farmer	2	0.7
Managerial/professional	65	21.7
Clerical/sales	19	6.4
Technical/trades	37	12.4
Labourer	13	4.3
Services	18	6.0
Student	28	9.4
Home duties	9	3.0
Self employed	19	6.4
Retired	53	17.7
Unemployed	11	3.7
Others	25	8.4
N/A*	1	0.3
Total	**300**	**100**

* One person did not respond to the occupational question

Table 7.4: Distribution of Respondents According to Income

Income level	Frequency	Per cent	Armidale (Per cent)
Less than $ 20,000	111	37.0	32
$20,000-$40,000	87	29.0	33
$40,000-$60,000	50	16.7	21
More than $60,000	36	12.0	6
N/A*	16	5.3	12
Total	**300**	**100**	**100**

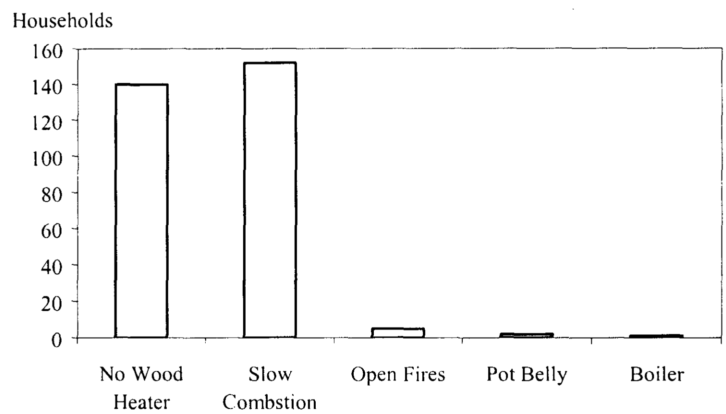
* 16 respondents did not answer the income question

7.4 Wood Heater and Wood Burning Related Results

Of the sample surveyed, 160 respondents (53.3 per cent) indicated that they had some form of wood heater and 140 (46.7 per cent) used other forms of energy for winter heating. This compares with 56 per cent ownership in a previous survey in 1996, suggesting little change in the proportion of homes having wood heaters in recent years.

Of those who had wood heaters, 95 per cent used slow combustion heaters, 3 per cent had open fires and 2 per cent had potbelly heaters. Around 44 per cent of respondents said that they installed their wood heaters themselves and 56 per cent indicated that their heater was installed by some one else.

Figure 7.1: Types of Heater Used by the Surveyed Sample



Of those with wood heaters, 85 per cent indicated that they use their heater every day in winter and a further 8 per cent use it several days a week. Around 51 per cent of wood heater users stated that they burn wood for 24 hours a day and a further 23.8 per cent burn it for more than 8 hours per day.

The household survey found that around 62 per cent of respondents regularly leave their heater burning slowly overnight by lowering the air controls, a further 4.4 per cent often does this and 8.8 per cent sometimes does. Only 25 per cent indicated that they never leave the heater to burn slowly over night.

Most of the users (92.55 per cent) indicated that they always burn aged wood. The household survey also found that while around 70 per cent of the respondents buy their firewood from dealers, 30 per cent collect firewood from their property or forests or get it from friends or relatives. Around 95 per cent indicated that they always use hard wood and only 5 per cent use soft or scrap wood.

7.5 Attitudes towards Wood Heating and Woodsmoke

A variety of strategies have been introduced to reduce woodsmoke problems around the world (for example: mandatory use of smokefree fuel in London, mandatory burn bans in New Mexico, California, Klamath Falls, Oregon, Reno; voluntary bans in Sydney; permit systems in Telluride-Colorado). Some of these options were canvassed in the household survey to examine community attitudes towards them.

In the household survey, respondents were posed a hypothetical question: *Assuming the cost of a load of normal firewood is $60.00 and that it is possible instead to buy wood that does not pollute. How much would you be willing to pay for a load of this special wood?* They were then given alternative closed responses.

Around 24 per cent of respondents indicated that they would not buy the special non-polluting wood. Thirty-eight per cent would only pay the same amount for a non-polluting substitute that they pay now for normal firewood. Only 38 per cent would pay more than what they currently pay for non-polluting wood.

The data were further analysed in conjunction with socio-economic factors. The level of education had a significant influence on responses. Around 67 per cent with primary education did not want to pay for special wood, followed by around 36 per cent with secondary education. In contrast only 11 per cent with a university degrees and 18 per cent with post-graduate degree were unwilling to pay for the special wood (Chi-square = 49.493, df = 35, P = 0.053).

Income level had some influence on willingness to pay for special non-polluting wood. Of respondents with less than $20,000 income, only 22.6 per cent were prepared to pay more for non-polluting wood than what they are paying now. Around 44 per cent of respondents with incomes between $20,000 to $60,000 and 58 per cent who earn more than $60,000 were willing to pay some extra for special wood (Chi-square= 40.961, df = 38, P = 0.054).

Sources of wood supply and willingness to pay for special non-polluting wood were highly related. Around 55 per cent indicated that they would not buy the special wood and would continue to collect wood, since this was cheaper. Only 9 per cent of respondents who collected their own wood would pay extra for special wood. Many more of the respondents

(62 per cent) who buy wood from a supplier were willing to pay some extra money for special wood (Chi-square = 50.745, df = 14, P<0.001).

To assess the acceptability of mandatory bans in Armidale, respondents were asked: *On the days when air pollution is high (about 1 day in 2 during July) would you be prepared not to light your heater if the EPA requested.* Sixty-five per cent of respondents revealed that they were not prepared to not light when requested.

Another option to reduce woodsmoke is to introduce a permit system. To assess this option, another hypothetical question was posed: *Supposing that in the future Armidale Dumaresq Council decides that the number of wood heater needs to be restricted, and that it will issue yearly permits that households that have wood heaters would need to buy. If the permit costs: $50 would you move to alternative form of heating? What if it was $100 or $150 or $200.* The responses are shown in Table 7.5.

Table 7.5: Permit Costs and Wood-Heater Usage

Permit Cost	Keep the wood-heater	Move to alternative	Compare the cost
$50	76.9%	15.0%	8.1%
$100	59.4%	20.6%	20.0%
$150	53.1%	20.7%	26.2%
$200	50.0%	21.9%	28.1%

The results show that if permits cost $50 per year, 77 per cent of respondents will pay the fees and keep their wood heater, while around 15 per cent will move to some alternative form of heating. Around 8 per cent indicate that they will compare the cost of alternative heating and the cost of wood heating with a permit and then choose the cheaper option.

If the permit costs $100, almost 60 per cent indicated that they would buy a permit, 20.6 per cent of the residents expressed their intention to move to alternative heating, while 20 per cent would compare the costs of a permit with the alternative.

When the cost of the permit is raised to $150, 53 per cent reported that they would keep the wood heater, 21 per cent would look for an alternative and 26 per cent will first compare the cost and make a choice.

At even higher permit costs ($200 per year), 50 per cent of respondents would keep their wood heater, 22 per cent felt they would switch to alternative heating and 28 per cent would compare the costs.

The data were also analysed to see the impact of the implied increased price of wood heater use (due to the permit price) on the demand of firewood.

To do the analysis it was assumed that the current price of firewood was $60 per tonne and that the frequency distribution of firewood use in Armidale population is a truncated normal distribution with a mean of 3.5 tonnes per year. Table 7.6 shows the prices of firewood under permit prices of $50 and $200 with different possible amounts of wood consumption.

Table 7.6: Cost of Firewood after Introducing Permits

Wood consumption (tonnes)	Frequency	Permit $50 per year	Permit $200 per year
1	0.083	110	260
2	0.167	85	160
3	0.250	77	127.7
4	0.250	72.5	110
5	0.167	70	100
6	0.083	68.3	93.3
Weighted average price		$80	$132.21

With a $50 permit price, the weighted price of per tonne wood becomes $80, which represent around a 33 per cent increase from the initial price of $60. A 33 per cent price increase associated with a 15 per cent reduction in use is an elasticity of about –0.45 (assuming that those moving out of wood heating are equally likely to come from each level of consumption). Adding another 8.1 per cent who wanted to compare the cost, the elasticity becomes –0.71.

For a $200 permit cost, a reduction in 21.9 per cent represents an elasticity of -0.18 and of 50 per cent (21.9 + 28.1) represents elasticity of -0.41. The results are summarised in Table 7.7

Table 7.7: Elasticity of Demand

	Permit \$50 per year	Permit \$200 per year
Move to alternative	-0.45	-0.18
Move to alternative + Compare the cost	-0.70	-0.41

It is evident from Table 7.7 that with higher prices, demand becomes more inelastic. Overall, these elasticity estimates suggest that the use of a permit will have a relatively small effect on the demand for firewood; consumption will decrease but only by a small amount.

The data were further analysed to see the impact of the permit system on total consumption of firewood in Armidale. As seen in Table 7.5, with a \$200 permit price, 50 per cent of the wood heater users would still keep their wood heater. These 50 per cent also use significant amounts of firewood. Out of these 50 per cent, around 84 per cent used wood heater every day and more than 56 per cent used 24 hours a day.

Respondents who stated they would keep the wood heater gave two different reasons:

i. Some believed that even with the additional cost of permits, it would be cheaper to have wood heating, since some collect their own wood.
ii. Some respondents have a personal attachment to wood heating and/or consider it to be more effective than other forms of heating.

7.6 Public Awareness of Woodsmoke and Air Pollution

7.6.1 Relative Importance of Air Pollution in Armidale

In general, the survey population was aware that there is particulate air pollution in Armidale, although they disagree about its relative importance. To make a comparison, air pollution was ranked against four other contemporary social problems. To estimate the overall ranking, each response were assigned a number from 1 to 5 representing importance, where the most important response was numbered 5, the second most important issue number 4 and so on. Values were multiplied by their respective frequencies to get the total values for each response and then ranked accordingly. Unemployment was the most important issue according to the survey population (Table 7.8). Air pollution was ranked fifth after unemployment, crime, drugs, and homelessness problems.

Table 7.8: Important Issues in Armidale

Issues	Most Important	2nd	3rd	4th	5th	Overall
Unemployment	131	61	83	23	2	1
Crime	111	100	61	21	6	2
Drugs	46	104	82	41	29	3
Homelessness	8	20	34	106	131	4
Air pollution	4	15	40	109	132	5

7.6.2 Health Effects of Woodsmoke

Over recent years Armidale Dumaresq Council and EPA have tried to educate the public about the adverse effects of woodsmoke on human health. The household survey found that shortcomings in the public awareness of the health effects of woodsmoke.

As shown in Table 7.9, 47 per cent of respondents claimed either that the statement *emission from open fires and solid fuel heaters contain substances harmful to humans* was false or else they were unsure. Only 53 per cent believed emissions are harmful. This may partly reflect the mistaken belief that PM2.5 particles do not penetrate indoor.

When the same data were analysed in conjunction with whether the respondent has a wood heater or not, the situation became clearer. Around 58 per cent of people without a wood heater agreed with the statement *emissions from open fires and solid fuel heater contain substances harmful to humans*. In contrast, only 48 per cent of wood heater users accept that the emissions are harmful.

Table 7.9: Emissions from Solid Fuel Heaters Harmful to Humans

Opinion	Without Wood Heater		With Wood Heater		Total	
	Frequency	*Percent*	*Frequency*	*Percent*	*Frequency*	*Percent*
True	81	58%	77	48%	158	52.7%
False	26	18%	38	24%	64	21.3%
Not sure	33	24%	45	28%	78	26.0%

The data were further analysed by sex, age, education level, occupation and whether the respondent had suffered any respiratory illness in the most recent winter.

Education level was also highly related to whether emissions were believed harmful or not. Only about 36 per cent of respondents with primary education believed emissions from woodsmoke were harmful, whereas around 62 per cent of respondents with university degrees and 81 per cent of respondents with postgraduate degrees believed them to be harmful (Chi-squire =4.078, df 10 and $P < 0.001$).

In general, younger respondents were more concerned about the health effects of wood heater emissions. Around 64 per cent of respondents aged between18-29 believed them to be harmful. Around 46 per cent and 41 per cent from the age groups 50-59 and 60 years and above believed that emissions were harmful (Chi-square = 14.853 with df = 8 and $P = 0.062$).

The data were analysed in conjunction with whether the respondent or any family member had suffered from asthma or any respiratory diseases in the previous winter. Around 59 per cent indicated no such problems, 41 per cent indicated that they had suffered from asthma or respiratory illness during the last winter. Among the sufferers, 14.7 per cent had asthma, 7.3 per cent had night-time cough, 4.7 per cent suffered from bronchitis, 3.3 had other chest complaints and 11 per cent had more than one problem.

Among the survey population with no respiratory-related illness, only 47 per cent believed emissions from wood heaters were harmful, whereas 90 per cent who had respiratory complaints the previous winter believed emissions from wood heaters were harmful.

7.6.3 Degree of Change

Comparing air pollution over the past three years (Table 7.10), 20.7 per cent of respondents believed that Armidale's air pollution has worsened, 50 per cent believed it to be about the same and 6 per cent believed that it has improved.

Table 7.10: Beliefs about Air Quality in Armidale over Recent Years

Opinion	Without Wood Heater		With Wood Heater		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Better	10	7.1	8	5.0	18	6.0
About the same	54	38.6	96	60.0	150	50.0
Worse	41	29.3	22	13.7	63	21.0
Don't know	35	25.0	34	21.3	69	23.0

The same data were analysed to see if there was a difference between the users and non-users of wood heaters. Table 7.10 shows about 30 per cent of respondents without wood heaters thought that air pollution in Armidale has worsened in the last 3 years compared to only 13 per cent with wood heaters (Chi-Square = 18.196, df = 4, P = 0.001).

The survey revealed differences between males and females. Around 8 per cent of males but only 4.5 per cent of females believed that Armidale's air quality was better. About 57 per cent of males and 44 per cent of females thought air quality has remained about the same over the past 3 years. Around 20 per cent of males and 21 per cent of females believed that air quality has worsened. A larger proportion of female respondents (31 per cent) were unsure, compared to 15 per cent of males.

7.6.4 Problems with Other People's Wood Heaters

The survey included an item to assess whether respondents had experienced any problems from wood heaters in nearby properties: *Has your household ever experienced problems or annoyance as result of other people using solid fuel home heating in your area?* They were also asked how serious they considered the woodsmoke problem to be in their neighbourhood.

A large number of respondents (69.3 per cent) claimed to be "never or hardly" affected by air pollution. About 20.3 per cent of respondents reported that they were affected sometimes and 9.7 per cent felt that they repeatedly experienced problems (Table 7.11).

Table 7.11: Problems from Other People's Wood Heaters

Opinion	Without Wood Heater		With Wood Heater		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Never or hardly ever	74	52.9	134	83.8	208	69.3
Sometimes	43	30.7	18	11.3	61	20.3
Quite often	22	15.7	7	4.2	29	9.7
Not sure	1	0.7	1	0.6	2	0.7

When the data were further analysed according to whether respondents had a wood heater, the results showed significant differences. Forty-six per cent of respondents without wood heaters experienced some sort of problems. In contrast, only 15 per cent with wood heaters experienced problems (Chi-square = 34.131, df = 3 and $P<0.001$).

Further analysis of the 30 per cent of those who had experienced problems showed that 30 per cent believed that it was a significant problem, 64 per cent believed that it was a bit of a problem, the remaining 6 per cent believed that the problem was not serious.

Interestingly, males and females expressed very similar attitudes towards experiencing problems with other people's wood heater.

7.6.5 Perceived Need To Do Something about Air Pollution

When asked if Armidale needed to address winter woodsmoke pollution, about 54 per cent believed Armidale needed to do something to reduce the winter air pollution, 27 per cent thought no action is necessary and about 18 per cent were unsure.

There was a significant difference between the opinions of wood heater users and non-wood heater users. Around 66 per cent of non-wood heater users thought Armidale needed to do something about woodsmoke, whereas only 44 per cent of the wood heater users believed so (Chi square = 14.332, df = 2 and P = 0.001).

The "need for action" was analysed in conjunction with beliefs about the harmfulness of emissions. Among the respondents who believed emissions from woodsmoke harmful, 75.3

per cent were of the opinion that Armidale needed to do something about woodsmoke. Only 12 per cent of them did not agree that Armidale needed to act (Chi-Square = 71.283, df = 4 and P<0.001).

Male and female views were not significantly different, 56.6 per cent of men believed Armidale needs to do something about air pollution compared to 52.2 per cent of women.

7.7 Attitudes to Schemes to Reduce Air Pollution

Various policy options used to reduce particulate air pollution elsewhere were canvassed during the survey. Respondents were asked if they would support any of the suggested alternative strategies for use in Armidale. The results are listed in Table 7.12.

Table 7.12: Support for Various Schemes to Reduce Air Pollution

Strategy	Approve	Disapprove	Not sure
Encourage people not to light fires or solid fuel heaters on days when high pollution is predicted	50.7%	39.7%	9.6%
Only allow people to burn wood that is purchased from an accredited supplier	27.3%	66.0%	6.7%
Impose fines on households that produce large amounts of woodsmoke	36.0%	55.7%	8.3%
Gradually phase out any burning of wood or coal in private home	33.3%	53.0%	13.7%
Impose an annual charge on households that have solid fuel heaters	19.7%	73.7%	6.7%
Prohibit people from lighting fires or solid fuel heaters on days when high pollution is predicted	8.7%	83.0%	8.3%
Prohibit new solid fuel heaters or open fires being installed in private homes	16.3%	70.7%	13.0%
Limit the number of homes in an area, which can have a solid fuel heater or open fires	18.0%	74.7%	7.3%

None of the options found strong support, although strongest support was found for options which encouraged people not to light fires when air pollution was high (50.7 per cent of approval rate), followed by imposing fines on households which produced excessive woodsmoke (36 per cent approval rate).

Strong opposition was expressed towards a strategy that prohibited the use of solid fuel when air pollution levels were high; followed by disapproval of a strategy limiting the number of homes in an area that could have a solid fuel heater or open fires (74.7 per cent); next was an annual charge imposed on households that had solid fuel heaters (73 per cent disapproval); and lastly a strategy that prohibited new solid fuel heaters or open fires being installed (70.7 per cent disapproval).

There were some differences of opinion between wood heater users and non-wood heater users. As shown in Table 7.13, encouraging people not to light fires when air pollution is high had fairly high approval from both wood heater users and non-users.

Table 7.13: Attitudes of Wood Heater Users and Non-Users Towards Various Options

Strategy	With Wood Heater			Without Wood Heater		
	Approve	Disapp	Not sure	Approve	Disapp	Not sure
Encourage people not to light fires when high pollution is predicted	75 (46.9%)	68 (42.5%)	17 (10.6%)	77 (55%)	51 (36.4%)	12 (8.6%)
Only allow people to burn wood that is purchased from an accredited supplier	33 (20.6%)	118 (73.8%)	9 (5.6%)	49 (35.0%)	80 (57.1%)	11 (7.9%)
Impose fines on households that produce large amount of woodsmoke	41 (25.6%)	100 (73.8%)	19 (11.9%)	67 (47.9)	67 (47.9%)	6 (4.3%)
Gradually phase out burning of wood in private home	38 (23.8%)	97 (60.6%)	25 (15.6%)	62 (44.3%)	62 (44.3%)	16 (11.4%)
Impose an annual charge on households with solid fuel heater	21 (13.1%)	129 (80.6%)	10 (6.3%)	38 (27.1%)	92 (65.7%)	10 (7.1%)
Prohibit people from lighting fires on days when high pollution is predicted	9 (5.6%)	139 (86.9%)	12 (7.5%)	17 (12.1%)	110 (78.6%)	13 (9.3%)
Prohibit new solid fuel heaters being installed	16 (10.0%)	127 (79.4%)	17 (10.6%)	33 (23.6%)	85 (60.7%)	22 (15.7%)
Limit the number of homes in an area which can have a solid fuel heaters	17 (10.6%)	132 (82.5%)	11 (6.9%)	37 (26.4%)	92 (65.7%)	11 (7.9%)

Imposing fines on the households that produce excessive amount of woodsmoke had a higher approval rate from respondents without wood heaters (48 per cent) compared to respondents with wood heaters (25 per cent) (Chi-square = 18.288, df = 2, $P < 0.001$).

Non-users showed strong support for gradually phasing out burning of wood or coal in private homes (44.3 per cent). Only 23.8 per cent of those with wood heaters supported this option (Chi-square = 14.170, df = 2, P = 0.001).

Differences were also evident for the option that prohibited any new solid fuel heaters or open fires being installed in private homes (23 per cent approval by non-users compared with only 10 per cent by wood heater users Chi-square = 13.587, df = 2, P = 0.001). The option which limited the number of homes in an area which could have a solid fuel heater or open fires received 26.4 per cent approval from non-users but only 10 per cent approval from wood heater users (Chi-square = 13.276, df = 2, P = 0.001).

Around 35 per cent of respondents without a wood heater approved the option that people only be allowed to burn wood purchased from an accredited supplier. Only 20.6 per cent of those with a wood heater agreed to the same (Chi-square = 9.323, df = 2, P = 0.009). A "polluters pays" policy, or imposing an annual charge on households that had solid fuel heaters, was supported by 27 per cent of respondents without a wood heater but only 13 per cent with a wood heater (Chi-square = 9.803, df = 2, P = 0.007).

7.8 Willingness to Pay for Clean Air

For the "willingness to pay for clean air" question two photographs were used. The first showed Armidale on a sunny July morning with considerable air pollution and the second showed Armidale on a similar July morning with no air pollution (Appendix C). It was explained that currently half of July mornings were like the first picture and half like the second. It was proposed that to improve the situation so that July mornings be more often like the second photograph, ADC would need to spend money on a project, and to do this would have to impose a levy on residents.

Respondents were asked to state their maximum willingness to pay per year to achieve satisfactory air quality standards. A payment schedule was used to indicate possible amounts, ranging from $0 to over $120. It was stated that every one living in Armidale would have to pay. Table 7.14 gives the results of respondents' "willingness to pay".

Table 7.14: Willingness to Pay for Clean Air

Amount	Frequency	Percentage
$0	181	60.3%
$20	72	24.0%
$40	26	8.7%
$60	9	3.0%
$80	5	1.7%
$100	4	1.3%
$120 and more	2	0.7%
N/A	1	0.3%
Total	**300**	**100**

Among the surveyed population, only 39.7 per cent were willing to pay some amount for clean air and 60.3 per cent revealed a willingness to pay (WTP) of zero. Overall, this would give an estimate of about $300,000 for aggregate WTP for Armidale population of 22,000. This is far smaller than the value of life estimate because WTP for clean air does not estimate the value of life.

The data were examined to determine whether socio-economic factors influenced the WTP responses. Factors examined included age, sex, education levels, occupation, income levels, duration of stay in Armidale, and whether any member of the household had suffered from any respiratory illness in the previous winter. The data were also analysed in conjunction with perceptions of and attitudes towards wood heating.

It was found that older people had a lower WTP compared to younger people. As shown in Table 7.15, 47 per cent of respondents from the 18-29 yr. age group were willing to pay some amount of money for cleaner air. On the other hand, only 27.9 per cent from the 50-59 years age group and 27.7 per cent from 60 years and over age group were willing to pay for clean air (Chi-square = 34.364, df = 24, P = 0.078).

Males (43 per cent) were more willing to pay for clean air than females (36 per cent).

As expected, respondents' education level played a significant role (Table 7.16). No respondents with primary level education were willing to pay for clean air; only 22.6 per cent of those with secondary education, 53 per cent with a university degree and 75 per cent with a postgraduate degree agreed to pay a levy for cleaner air (Chi-square = 82.691, df = 30, P<0.001).

Table 7.15: Willingness to Pay and Age Distribution

WTP	Age in Years				
	18-29	30-39	40-49	50-59	60 and over
$0	35 (53.0%)	36 (60.0%)	32 (49.2%)	31 (72.1%)	47 (72.3%)
$20	23 (34.8%)	14 (23.3%)	15 (23.1%)	10 (23.3%)	10 (15.4%)
$40	4 (6.1%)	4 (6.1%)	12 (18.5%)	2 (4.7%)	4 (6.2%)
$60	2 (3.0%)	1 (1.7%)	4 (6.2%)	-	2 (3.1%)
$80	1 (1.5%)	3 (5.0%)	1 (1.5%)	-	-
$100	-	2 (3.3%)	1 (1.5%)	-	1 (1.5%)
$120	1 (1.5%)	-	-	-	1 (1.5%)
Total	**66**	**60**	**65**	**43**	**65**

Table 7.16: Willingness to Pay and Education Level

WTP		Education			Levels	
	Primary	Secondary	HSC	TAFE	University	Post-Grad
$0	14 (100%)	65 (77.4%)	30 (62.5%)	34 (59.6%)	30 (46.9%)	8 (25.0%)
$20	-	14 (16.7%)	13 (27.1%)	17 (29.8%)	17 (26.6%)	11 (34.4%)
$40	-	2 (2.4%)	3 (6.3%)	1 (1.8%)	11 (17.2%)	9 (28.1%)
$60	-	2 (2.4%)	1 (2.1%)	5 (8.8%)	-	1 (3.0%)
$80	-	-	-	-	4 (6.3%)	1 (3.1%)
$100	-	-	1 (2.1%)	-	1 (1.6%)	2 (6.3%)
$120	-	1 (1.2%)	-	-	1 (1.6%)	-

Household income had a significant influence on WTP responses (Table 7.17). Fewer respondents (only 28.8 per cent) with income less than $20,000 were willing to pay some amount of money for clean air. Forty-six per cent from income groups $20,000 to $40,000 and $40,000 to $60,000 were willing to pay. More than half of the respondents (54.3 per cent) with income more than $60,000, indicated a positive WTP for better air quality (Chi-square = 50.614, df = 24, P = 0.001).

Single member households had lower WTP; only 27.5 per cent from 1-person households were willing to pay some money for clean air. Around 38 per cent from two-member households; 43.9 per cent from three-member households; 44 per cent from four-member households; 44.1 per cent from five-member households and 50 per cent from 6 and more member households were willing to pay some money for clean air (Chi square = 43.770, df = 30, P = 0.050).

Table 7.17: Willingness to Pay and Respondents' Income Level

WTP	Income			
	Less than $20,000	$20,000-$40,000	$40,000-$60,000	More than $60,000
$0	79 (71.2%)	47 (54.1%)	27 (54.0%)	16 (45.7%)
$20	25 (22.5%)	24 (27.6%)	10 (20.0%)	9 (25.7%)
$40	5 (4.5%)	11 (12.6%)	6 (12.0%)	4 (11.4%)
$60	2 (1.8%)	2 (2.3%)	4 (8.0%)	1 (2.9%)
$80	-	-	1 (2.0%)	4 (11.4%)
$100	-	1 (1.1%)	2 (4.0%)	1 (2.9%)
$120	-	2 (2.3%)	-	-

There was a tendency for a respondent who (or a member of whose family) had suffered respiratory symptoms to be more willing to pay than respondents who had not suffered from such symptoms. Among respondents who had asthma, 56.8 per cent had a positive WTP; a slightly higher percentage (59.1 per cent) of night-time cough sufferers also had keen WTP. Among the bronchitis sufferer 42.9 per cent were willing to pay for clean air. Among respondents who had more than one symptom during the previous winter, 42.4 per cent were willing to pay for clean air. Only 31.4 per cent of respondents with no respiratory complaints had a positive WTP (Chi square = 54.977,df = 30, P = 0.004).

This study found that occupation was not an important factor in WTP (Chi-square = 74.970,df = 66, P = 0.210). Further, household data did not indicate significant differences between wood heater users' and non-users' WTP responses (Chi-square = 8.020, df = 6, P = 0.237).

As it might be expected, people's perceptions of air pollution influenced their WTP response. More than half of the respondents (51.9 per cent) who believed that emissions from solid fuel heating were harmful for human health had a positive WTP. In contrast, only 21.9 per cent of respondents who believed emissions were not harmful were willing to pay some amount for cleaner air (Chi-square=30.694, df12, P=0.002).

Among the surveyed population who agreed that it was necessary to do something to reduce Armidale's winter pollution, 57.7 per cent were willing to pay for cleaner air. In contrast, among the respondents who believed it was not necessary to act to reduce air pollution in Armidale, only 11 per cent were willing to pay to reduce air pollution in Armidale (Chi-square = 57.545, df = 12, $P<0.001$).

7.9 Discussion

The main objective of the household study was to understand the community's perceptions, attitudes and WTP for wood heating and clean air in Armidale.

Public education and awareness has been found to be a vital component of woodsmoke reduction strategies (Robinson *et al.* 1998). In May 1996 Armidale Dumaresq Council launched an educational campaign aimed at raising awareness about woodsmoke problems in Armidale, and at informing users of solid fuel heaters about the best way to operate their heaters, so that harmful emissions were minimised. Armidale Dumaresq Council also conducted a small survey (ACC 1996) on solid fuel heating prior to their education campaign.

It is interesting to compare some of the present survey's findings with Armidale Dumaresq Council survey results to review the effectiveness of the campaign.

The present household study found 53.3 per cent of households had some form of solid fuel heating, slightly less than that found in Council's survey in 1996 (56 per cent).

The education campaign emphasised the importance of using dry and well-seasoned hardwood, since this gave more complete combustion and produced less woodsmoke (ADC undated). During the present household survey it was found that about 95 per cent respondents claimed to use hard wood for their wood heaters, compared to 54.8 per cent in Council's survey.

There has probably been an improvement in the quality/type of firewood used by participating households. Whilst 92.5 per cent of present respondents indicated that they always used dry wood, fewer households (59.5 per cent) indicated a similar practice in the earlier Council survey.

There also have been some changes in the way households operate their wood heaters. It was found that 51.3 per cent of the respondents burn their wood heater 24 hours a day, which is slightly more than was found in the Council survey (41.0 per cent).

One important component of the education campaign was to encourage people to keep their fire burning hot, not smouldering, and to let the fire go out at the end of the night. The present survey shows that fewer households (around 62 per cent) leave their wood heaters to burn slowly over night than at the time of Council's survey (78.8 per cent).

From the present household survey it appears that while the Council's initiatives for proper use of wood heaters may have had some positive influence on user behaviour, public perceptions about air pollution are still relatively poor. The belief that emissions from wood heaters were harmful for humans was 52.7 per cent with the earlier ACC survey and 55.3 per cent in the present survey.

To address the woodsmoke problem, some cities have introduced additional strategies along with educational campaigns. Three of these strategies, which have been enforced in other cities, were included in the present survey to assess wood heater users' attitudes towards them. The strategies included buying special non-polluting wood, not lighting the heaters when requested by the EPA, and the introduction of a permit system.

While 38 per cent of wood heater users agreed to pay some extra money for special non-polluting wood, 24 per cent were not willing to buy the special wood.

For the option *not lighting the heaters when requested by the EPA*, only 35 per cent of the respondents were prepared to not light their solid fuel heater if the EPA requested; the main reason being that most users had no alternative heating arrangement.

Interestingly, stronger support was found for a permit system. With a high permit cost ($200), 50 per cent respondents indicated they would keep their wood heater. While around 22 per cent of the households were willing to move to alternative heating arrangements, some 28 per cent preferred to wait and compare the cost between a wood heater plus a permit and alternatives.

From the above findings, however, it was not clear how successful this strategy would be in reducing woodsmoke pollution in Armidale. First, with higher permit price ($200), 50 per cent of the respondent indicated that they will still use their wood heater, and most of them used their wood heater every day and 24 hours of the day. Therefore the reduction of the other 50 per cent may not significantly decrease consumption of firewood in Armidale. Also since the demand for firewood in Armidale is price inelastic, a price increase will have a small impact on the reduction in consumption. Second, just because the respondents indicated that they would keep the wood heater did not necessarily mean that they would willingly buy permits. Some respondent's preferred not to give up the wood heater and to never pay for a permit. Third, since firewood is available in forests nearby in Armidale, some respondents would prefer to buy a permit to keep their wood heater. They seem to believe that it would still be cheaper to have a wood heater if wood is collected from the nearby forest. It would not be possible to ensure that such wood was dry and in good burning condition.

Looking at the responses to various policy options for reducing air pollution in Armidale, it emerged that the population was particularly against those options that were mandatory in nature. Respondents were more in favour of education rather than regulation.

An interesting contradiction emerged from the study. While there was strong support for the policy measure of encouraging households not to light fires when there was air pollution, 65 per cent of the users indicated that they were not prepared to do so at the EPA's request on high pollution days. This raises the question about the likely success of voluntary options to improve woodsmoke pollution in Armidale.

The present study also used the contingent valuation method (CVM) to assess the willingness to pay for better air quality in Armidale.

It was found that around 60 per cent of respondents stated zero WTP for clean air. Some of these responses could be interpreted as "protest" zero answers. While they may have a positive WTP, they understate their WTP because they protest parts of the scenario. It was possible to suggest reasons for zero WTP:

i. Zero responses were significantly more prevalent for persons who also did not report income, suggesting an unwillingness to reveal monetary values. A high proportion of respondents (75.0 per cent) who did not answer the income-related question had a WTP equal to zero.
ii. Some respondents with no wood heater felt that the payment system would be unfair, since it required payment from every resident regardless of whether they had a wood heater or not. Their rationale was that since domestic wood heaters caused almost all of Armidale's air pollution, those households with wood heaters should pay for this.
iii. Another class of possible protest answers were those who thought the scenarios do not apply to them. Perhaps the area these households belong to was less polluted than the scenario depicted in the photograph, and they believed that they would not be affected by such a situation.

As people get older, there may be a natural decline in enthusiasm for emission abatement, willingness or ability to assign monetary values to a good such as clean air. Sometimes older people, especially retired people, have less income and may become less willing to pay for environmental improvement. It was evident from the household survey that the older age group had a lower WTP for cleaner air than did the younger generation.

Household data suggested that males were more willing to pay for clean air than females. The results could be interpreted to mean that females were less concerned about air pollution problems. This was evident from the earlier discussion where 54 per cent of female respondents indicated that either they thought that *emissions from open fires or solid fuel heaters contain substance harmful to humans* was untrue or else they were not sure. Another explanation, mentioned by Belhaj (1998), could be that women were responsible for a household's economy and thus more constrained by its budget. Therefore they were less willing to pay for environmental goods.

The present survey revealed that level of education significantly influenced WTP responses. Because of their higher education level, such persons may be more aware of ambient conditions and effects of air quality on their health than the population in general. Since

WTP would depend on perceived rather than real risk, the results for this sub-population may reflect more informed WTP values than those of the general population. This notion is consistent with other WTP studies (Belhaj 1998; Farber and Rambaldi 1993).

As expected, household income was highly related to WTP responses. This also reflects the correlation between income and level of education. Household data also suggested that larger households care more about the future and were willing to pay higher amounts for cleaner air.

The study revealed that the public generally appeared concerned about air pollution. They were also aware of its harmful effects on heath. However, people were less ready to take responsibility for improving the environment. Most non-wood heater users were of the opinion that those who created pollution must pay for it.

It was encouraging to find that people would be more prepared to limit the use of their wood heaters if alternative heating at a cheaper price were available. A consistent finding was that younger and more educated respondents were more aware of air pollution as a problem. They were also found to be more concerned about it and were generally more willing to pay for clean air.

CHAPTER 8
WOODSMOKE POLLUTION CONTROL STRATEGIES

8.1 Introduction

Chapter 8 has two parts. The first contains a summary of Armidale's particulate air pollution problem, a short description of the current situation and the health effects of particulate air pollution in Armidale, associated economic costs, and community attitudes towards wood heaters and woodsmoke. This part is based on analyses carried out in Chapters 3, 4, 5, 6 and 7.

The second part examines legislative and voluntary strategies adopted to control particulate air pollution in Australia and other countries. This part also evaluates the applicability of such strategies in Australia and suggests appropriate policy options to reduce Armidale's air pollution.

8.2 Effect of Particulate Air Pollution in Armidale

Solid fuel home heating is widely used in Armidale. There are 3,500 slow combustion stoves and 600 fireplaces operating in the Armidale area (Wall 1997). An Armidale Dumaresq Council survey showed that around 55 per cent of households used wood for winter heating. Residents in Armidale consume approximately 17,000 tonnes of fuel wood each year. Around 150 tonnes of firewood are burned on a cold night, which produces up to 2 tonnes of particulate matter (Wall 1997). The particulates are concentrated because Armidale lies in a shallow valley which experiences frequent night-time inversions from April to October.

In Armidale, PM2.5 particulate air pollution is almost exclusively due to woodsmoke. The most polluted areas are East Armidale and south of the Central Business District (CBD). The highest pollution level is observed in the evening and at night when most people are at home. In an average year, more than 50 per cent of Armidale's winter days fall in the high to extreme category of the particulate pollution index.

In 1999, the mean daily average PM2.5 for the CBD was 13.9$\mu g/m^3$ and 31.8$\mu g/m^3$ for East Armidale. The maximum average (1-hour) in the CBD was 186.7$\mu g/m^3$, and 325.9$\mu g/m^3$ in East Armidale.

Armidale Air Quality Group estimated the population exposure for Armidale to be 20.4$\mu g/m^3$ from April to September, 5.6$\mu g/m^3$ in October and assumed no particulate pollution from November to March. Thus the average annual exposure could be considered as 10.67$\mu g/m^3$ PM2.5.

One important reason for controlling air pollution from particulate matter is the damaging effects it has on human health. These effects include premature death as well as an increase in daily hospital admissions for respiratory diseases, increased acute attacks of asthma and other respiratory diseases. Chapters 4, 5 and 6 estimated the heath and economic costs related to particulate air pollution in Armidale.

Calculations of the health effect in Chapter 4 used dose-response coefficients established by several studies. Using 10.67$\mu g/m^3$ for the average PM2.5 concentration, and a mortality dose-response function of between 0.2 and 1 per cent for each 1$\mu g/m^3$ change in PM2.5 (as lower and upper bounds), between 4 and 19 deaths are estimated to occur each year due to particulate air pollution in Armidale.

In terms of the money value of life, the literature suggests that the statistical value of a life is between A$1.6 million to A$6.5 million. Therefore, the economic cost of air pollution in Armidale for the lower bound of mortality estimates of 4 deaths per year would be between A$6.5 million and A$25.6 million. For the upper bound of mortality estimates of 19 deaths per year, the economic cost would be between A$30.4 million and A$121.6 million.

Theoretical estimates showed that in terms of morbidity, the existing level of particulate air pollution in Armidale causes between 774 (lower bound) and 1,730 (upper bound) restricted activities days (RAD). The annual cost of RAD for Armidale is between A$94,713 and A$211,715.

The total economic cost of the current levels of particulate air pollution in Armidale, with the very conservative estimate (lower bound) of total mortality and morbidity (only RAD) would be between A$6.5 million and A$25.7 million per year. It is acknowledged, however, that these estimates assume that Armidale's average exposure of 10.67 for PM2.5 (with extreme peaks and troughs) is equivalent to a continuing exposure at this level. It may be that the annual health effects would be worse because there is far greater morbidity and mortality during peaks, or they could be better because there is time to recover during the troughs. This is an area for future research.

Morbidity studies measuring the effect of air pollution on respiratory illness and asthma are recognised as a valid measure of the impact of air pollution in Australia. Chapters 5 and 6 provided an empirical analysis of Armidale air pollution and health effects.

The survey of clinical events presented in chapter 5 assessed the impact of particulate air pollution on the proportion of respiratory visits to GP clinics. The analysis of data from local GP clinics gathered over the period of study shows a significant association between particulate air pollution (PM2.5) and the occurrence of respiratory symptoms requiring a GP's attention within the population of Armidale. Total respiratory visits were found to be significantly correlated with 2-day lagged particulate air pollution.

The *Analysis of proportions* model demonstrated a positive statistical effect of air pollution on the incidence of respiratory symptoms. At average values of minimum temperature and air pollution, 14.8 per cent of all patients had respiratory illness. The results also indicated an increase of about 0.08 per cent in the proportion of respiratory patients in response to a $1 \mu g/m^3$ increase in PM2.5 particulate pollution.

Chapter 6 of the study assessed the economic costs associated with particulate air pollution in Armidale. Using Poisson regression, the total number of respiratory patients were decomposed into those caused by air pollution and those due to other causes. The estimated number due to air pollution was then multiplied by the estimated cost.

The findings showed that during the survey period, the average number of respiratory patients in Armidale due to particulate air pollution was 7.45 persons. Considering the costs and expenses arising from ailments, the average daily economic cost of respiratory symptoms due to particulate air pollution was estimated to be A$1,125.

The above economic cost is a conservative estimate and considers only the direct medical costs. Dollar outlays were measured in terms of doctors' usual charge to Medicare for clinic visits, cost of drugs and estimated loss of time on the basis of wage rate. The study did not take into account the cost of preventive or defensive measures and other costs, such as X-rays, hospital visits, alternative medicine, etc, associated with sickness and it also ignored the cost of "pain and suffering". However, the estimate is important because it shows the severity of the problem and provides both an incentive for environmental controls and a means for evaluating the benefits of specific pollution control policies.

As community awareness is essential to the success of any system of environmental management, Chapter 7 dealt with the household survey conducted to investigate behaviours, perceptions and attitudes of the public towards wood heater and air pollution in Armidale. It was evident that the community were not fully informed about the adverse effects of woodsmoke. Around 52 per cent of wood heater owners in Armidale did not know that emissions from solid fuel heaters were harmful. When evaluating the policy options to reduce the woodsmoke problem in Armidale, it seemed that the community had strong resistance towards mandatory policies, and preferred options which are voluntary in nature. When the survey enquired from respondents their willingness to pay, only around 38 per cent were willing to pay some amount of money for the clean air. Interestingly, a strong positive correlation was observed between willingness to pay and eduction levels of the respondents.

8.3 Strategies to Control Woodsmoke Pollution in Armidale

The second objective of Chapter 8 is to examine the strategies, both legislative and voluntary, for woodsmoke control adopted in Australia and elsewhere in the world. The chapter then reviews the existing policies in Armidale and suggests possible policy options to reduce air pollution in Armidale.

8.3.1 Regulation Versus Economic Instruments

The "command and control" system of regulation has been the most commonly used instrument for the management of pollution. Economists have long argued that economic instruments can reduce pollution more effectively than narrow regulatory prescriptions (Hall and Walton 1996). However, the application of economic instruments is limited in the area of woodsmoke pollution.

Command and control mechanisms rely on legislative and regulatory provisions and are implemented through directives from regulatory authorities. Until recently, regulations were almost the only instruments used for environmental protection (James 1997).

In contrast, economic instruments operate through market processes or other financial incentives. Although they take effect through various price and/or quantity controls, they usually allow for adoptive choice and decentralised decision-making by those whose behaviour is to be modified. In reality, the distinction between regulation and economic instrument often overlaps, as any system of economic instruments usually requires appropriate legislative or regulatory backing (James 1997).

A strong argument in support of economic instruments is that they provide incentives for on-going improved efficiency and environmental performance, for example, in relation to innovation, environmental protection technologies and environmental management practices. The same incentives may not be apparent in command and control systems.

In terms of effectiveness in achieving environmental objectives, the most successful instruments are those that specify quantity or quality constraints or standards. There is some uncertainty about the effectiveness of pricing controls based on the user-pays principle to achieve the desired level of environmental protection. Price increases may not always effectively promote conservation of resources because users may not change their behaviour to the desired amount when faced with an incremental change in their costs. That is, there is uncertainty about the effect of the instrument.

In practice, incentive effects may not be the primary objective in using economic instruments. Economic instruments can also be used to cover the administrative costs of regulatory functions, such as standard setting, monitoring and enforcement. It is possible to design economic instruments mainly aimed at revenue raising, rather than behaviour modification.

Environmental control costs may not represent a large proportion of total cost for households, so there may be little incentive to respond to price signals. In the management of some environmental problems, direct regulations have often been needed to provide the stimulus for improvement, economically as well as environmentally.

8.3.2 Policy Options

A successful community-wide woodsmoke reduction plan would probably include several control strategies. The final plan should focus on strategies deemed appropriate and workable for the particular community. The strategies are discussed in relation to experience in other cities and their applicability in Armidale.

8.3.2.1 Performance of wood heaters

There are ways to minimise smoke emissions from households that use wood as a domestic heating fuel. These techniques could improve the performance of the heater, cut down on maintenance and reduce air pollution. Four methods for reducing smoke are discussed below.

Type of Wood Heater

It is important to choose an efficient wood heater, which has low smoke emission. In the US, wood heaters have been regulated for some time by the USEPA. Heaters must be tested and their emissions monitored to determine the level of particulates they produce. Heaters cannot be sold to the public unless their particulate levels meet the USEPA emission standard. The sale and installation of used uncertified stoves was banned in Oregon, US from 1991 (Appel 1992).

In 1994, British Columbia, Canada introduced regulations requiring all new wood heaters to meet low emission standards and restricted the use of wood heaters in some areas based on weather conditions, including no burn periods (Ministry of Environment Lands and Parks, BC 2000).

NSW, Tasmania and the ACT made it a legal requirement for all heater models to be independently tested. Most heaters sold in recent years in Australia have undergone such testing. The regulations require wood heaters on sale to comply with AS-4013, which specifies particle emissions (EPA NSW 1998).

Installation

The installation of wood heaters is currently regulated under the Building Code of Australia (BCA). The BCA requires the wood heaters to be installed in compliance with AS-2918 (EPA Victoria 2000). While this standard focuses more on safety than environmental concerns, it sets requirements relating to flue exits and adherence to manufacturers' specifications - including non-interference with the heater's emissions controls.

The fitting of flues is also important in terms of the impact on air quality in the vicinity of the flue. Although the height and location of a flue do not influence the level of emissions, appropriate design can reduce nuisance smoke significantly. It would be appropriate to take into account the height of surrounding residences when installing a wood heater flue. EPA NSW (1998) recommend that a flue outlet is at least one metre above any structure within a 15 meter horizontal radius.

Operating a Wood Heater

Tests have shown that the same heater with the same firewood will produce up to four times as much smoke if poorly operated (Todd 1998). The recommended integral measures should include methods to reduce woodsmoke emissions from a wood heater by improving wood burning operation and maintenance practices, and by modifying wood burning conditions. These include:

i. Measures to reduce the moisture content of firewood by regulating the amount of moisture in firewood sold, and banning the use of wet firewood. The program should require wood dealers to have their wood "certified" for moisture content prior to sale. Fines should be imposed on wood dealers who sell wood that is not certified.
ii. The household survey of residents in Armidale (Chapter 7) showed that while around 70 per cent of the respondents buy their firewood from dealers, 30 per cent collect their

firewood. The proposed restrictions on the sale of wet firewood would regulate the former; the ban on the use of wet firewood would regulate the latter.

iii. It is also important to adopt appropriate wood burning habits, which may include:
   - The fire should be started with timber kindling and once well-established, further fuel should be loaded gradually.
   - The existing load should be well alight before re-loading.
   - More complete combustion is achieved by keeping the fuel size small and loosely packing it so that good contact occurs between oxygen and the fuel.

In King County, Washington State, all non-certified wood heaters must be removed before a house can be sold. Regulation also governs how users store their firewood; only seasoned firewood may be burned. Firewood dealers must be licensed and they must alert buyers if the moisture content is greater than 20 per cent (Appel 1992). The regulation also authorises the Department of Public Health to institute a proficiency test for wood stove operators.

Regulation governing the quality of fuel wood for sale is in place in Western Australia. This requires that the maximum moisture content of firewood for sale is 20 per cent. The regulation also prohibits the sale of firewood that is painted, chemically treated or coated in plastic.

Home Insulation

The purpose of the insulation program is to improve the energy efficiency of homes burning wood heaters so that less wood is burned and hence, particulate pollution reduced. To improve energy efficiency, in addition to installing insulation materials, fitting weather seals around doors and windows and lining to curtains will help reduce heating needs. Low-income homes possibly have the greater need for insulation and hence should be the focus of any financial incentive program. Financial incentives could include low-interest loans, cash grants, and tax credits.

In Butte, Montana, homes with wood heaters are subjected to stringent insulation requirements. In Medford, Oregon, residents installing new wood heaters must meet minimum insulation requirements and all wood-heater homes must meet the same insulation requirements prior to sale or rental. In Klamath County, the project *PURE* included a home insulation program that achieved a 48 per cent reduction in first year energy use for treated homes with an energy savings of US$81.50 per home (Oregon DEQ 2001b).

Despite the obvious benefits from insulation in Armidale, 47 per cent of houses built in 1992 had no ceiling insulation other than reflective foil, and 67 per cent had no wall insulation (Robinson *et al.* 1998). ADC has since introduced a mandatory insulation policy and council will refund building application fees if the plans meet 5-star solar and insulation ratings.

8.3.2.2 Change-out programs

Regulating the sale of wood heaters will have limited impact on air quality in the short term, as it will not affect the use of open fires and wood heaters currently installed. Wood heaters typically have a life of 20 years before needing replacement (EPA Victoria 2000). Open fires effectively last as long as the building. The change-out program aims to replace old wood heaters with new less polluting wood heaters or with an alternative energy source such as electicity, gas or oil.

In principle an incentive payment can be directed either at the capital cost of the conversion or at the ongoing costs, or both. As the Tamar Valley study (Atech Group 2001) found, effective options include:

i. A capital grant funded directly from the scheme.
ii. An interest free loan, with the full interest cost charged to the scheme.
iii. A reduced interest loan, with the cost of the subsidy charged to the scheme.

Old heaters can emit up to 10 times the amount of particulates of newer wood heaters (Todd 1998). The advantage in new heaters results from new technology and design improvements that, among other things, increase the air tightness of the stove. Emissions rates for new wood heaters are determined by EPA-certified testing and are reported by the manufacturer. It is important to note that the manufacturer's instructions for operation must be followed to realise the reported emission rate.

Change-out programs have been introduced in some countries such as the UK, USA, Canada and Norway. The aim of these programs is to increase the rate of turnover of older wood heaters and the replacement of open fires. The policy instruments applied in different places vary and include a combination of financial incentives and/or regulations, coupled with community education programs. Some examples are given below:

United Kingdom Experience

The London smog of December 1952 led to the creation of the Committee on Air Pollution, which resulted in the 1956 Clean Air Act. The Act prohibits the burning of high volatile bituminous coal on traditional grates in designated smoke control areas, which until recently, covered over one-third of UK dwellings (Quraishi 1987).

The difficulty in regulating the already installed coal-burning appliances was recognised in the Clean Air Act which included a provision authorising a direct subsidy of 70 per cent of the cost of a clean-burning replacement coal heater. The contribution of the central government was 40 per cent with the local government making up the remaining 30 per cent. In the case of hardship, the grant may cover the full cost of replacement, the discretion being with the local government.

Norway Example

In Oslo, subsidies of around A$700 are offered for wood heater 'Changeovers' (EPA Victoria, 2000).

USA Experience

In the winter of 1994, Lakeview, Oregon, received a grant of US$200,000 to replace wood stoves. The Program called *CLEAR* offered zero-interest deferred loans of up to US$3,500 for removing and destroying non-certified wood heaters (Oregon DEQ 2001a). It also allowed for the installation of alternative heat sources.

In Crested Butte (Colorado, USA), residents were required to replace their heaters within three years or face a financial penalty - this resulted in only 1 per cent of residents replacing their heaters. Consequently, further action was introduced in the form of public education and provision of subsidies (up to $US800) for heater changeover, co-funded by the industry and USEPA. The end result was a significant reduction in old heaters and emissions and a noticeable improvement in air quality (EPA Victoria 2000).

In Mammoth Lake (California, USA), a program was introduced under which uncertified wood heaters and open fires were required to be replaced or rendered inoperable when a house was sold. It is expected that in 15 years time this will result in 90 per cent of such heaters being out of action.

In the Klamath Falls area, the Health Services Department runs a home insulation and uncertified woodstove replacement program called the Particulate Urban Resource, or *PURE* (Oregon DEQ 2001b). Wood stoves are replaced by natural gas appliances, electrical, propane oil and geothermal heating systems and in some cases EPA phase-II certified wood heaters. This change-out program has prevented approximately 98 tonnes of pollutants from getting to air annually (Oregon DEQ 2001b).

Australian Example

The Launceston, Tasmania scheme subsidises half of the capital cost for replacing old heater with a new wood heater, and places an emission limit of 2g/kg compared with the AS-4013 standard of 3.5g/kg (Environment Australia 2001).

Review of Change-Out Programs

The success of these types of program depends on several factors. If most change-out occurs between old and new wood heaters, then the outcome is uncertain. According to Todd, cited in Atech Group Report 2001) new wood heaters produce about half the pollution of older wood heaters (non-certified heater emissions are 7g/kg and AS-4013 heaters 3.5g/kg) but success depends on their correct operation. A single incorrectly operated AS-4013 wood heater can produce as much particulate pollution as heating the entire town of Armidale with natural gas (AAQG 1999).

ADC operated a change-out program in 1998. ADC offered a total of 81 loans to replace 57 wood, 19 gas and 5 electric heaters. The average wood heater loan was A$1,818. According to the AAQG, the change-out program was unsuccessful (AAQG 2000). The Armidale experience showed little benefit in replacing an old wood heater with a new one, especially if there were no resources to ensure that heaters were operated correctly. Similar experiences in other cities suggested that it is more effective to decrease the woodsmoke problem by eliminating or decreasing dependency on wood by using an alternative fuel such as gas, electricity or oil.

Christchurch, New Zealand, which had a scheme for replacing old wood heaters by new heaters, has since decided to phase out all solid fuel heating. This includes even new heaters installed in very recent years and emitting less than 1.5g/kg of smoke, a much stricter standard than AS-4013.

Effective from 2000, the cities of Palo Alto, Los Gatos, Petaluma, San Jose and Morgan Hill in California have adopted an ordinance prohibiting the construction of new wood burning fireplaces in residential and commercial buildings (Fernandez 2001). New structures may only install gas burning fireplace.

In Klamath Fall, Oregon, 90 per cent of old wood heaters were replaced by alternative heating (Appel 1992).

In San Francisco, the "great stove change-out" ran from January 15 until February 28, 1998. The program offered residents of Northern California the chance to turn in their old stove and receive a rebate on a new cleaner burning appliance. During the first two weeks of the program, 117 old pre-USEPA certified wood stoves and fireplace inserts were turned in and scrapped. In the Bay area, the vast majority of the wood stoves were replaced with natural gas models (BAAQMD 1998).

The US change-out programs are considered more successful than that in Armidale, because the programs managed to change old heaters to alternative heating rather than to new wood burning heaters. All US change-out programs employed smoke patrol officers to monitor the smoke condition and instituted an education campaign.

Armidale Development Corporation proposed a A$20 million proposal to get the natural gas pipeline extended to Armidale. This might help increase gas heating in Armidale and reduce the number of wood heaters and hence, woodsmoke pollution.

Recently, the NSW government announced a three year, A$6 million Clean Air Fund to tackle sources of domestic pollution. The Fund allows Councils to develop and implement programs that target local air pollution. The Fund also provides cash subsidies of up to A$700 to families. The pilot program involves five NSW towns: Armidale, Albury, Cooma, Lithgow and Orange.

8.3.2.3 Smoke Patrols

One of the main causes of woodsmoke pollution is the incorrect use of wood heaters. As long as wood heaters, new or old, are operating, it is important to monitor the woodsmoke emission from these heaters. To monitor and control the situation, many US cities have introduced smoke patrol officers ("smoke cowboys") who act somewhat like a parking enforcement officer. The approach is based on the key assumption that a small proportion of wood heater users accounts for a large proportion of the woodsmoke problem.

The main duties of a smoke patrol officer could include (as mentioned in the Tamar Valley study):

i. Identification of smoky heaters, including in the late evenings and early morning;
ii. Entry and inspection to determine the cause, which could be wet wood, poor operation, faulty installation, or a choked flue;
iii. Face-to-face instruction for sourcing and storage of firewood, the correct operation of a wood heater to ensure it is both functional and environmentally safe, and on the impact of woodsmoke on air pollution and public health;
iv. Follow-up to ensure compliance, including collection of evidence and issue of warning and fine as appropriate;
v. Follow-up with firewood and equipment suppliers, including warnings and fines as appropriate; and
vi. Development of a database to facilitate further analysis and understanding of woodsmoke causes and the effectiveness of management actions.

The success of the program relies on the ability of officers to change the operating practices of offending households. Clearly they need appropriate training to understand the relationships between wood heater operation, visible smoke, particulate pollution and health effects. The officers need to motivate people by identifying discrepancies between attitude and action, that is, where a household expresses an attitude of concern about particulate pollution and its health impacts, but acts in a manner contrary to those attitudes.

In contrast to such a more-or-less advisory approach, Washington State law prohibits chimney smoke in excess of 20 per cent opacity at any time. A citation is issued whenever inspectors observe smoke exceeding the State standard. Fines range from US$100 for the first offence to US$250 for a second or subsequent offence (Makut and Fry 1992).

8.3.2.4 Curtailment programs

Woodsmoke curtailment programs aim to restrict wood burning during periods when atmospheric conditions and the level of wood burning activity result in predicted ambient concentrations of woodsmoke in excess of an accepted level. The program should include the following components: (i) public awareness, (ii) forecasting and prediction, (iii) public notification, (iv) exemptions, (v) enforcement and (vi) tracking.

Curtailment programs have been in operation for many years in the US. They involve forecasting air stagnation conditions each day in staged green, yellow and red day formats.

Green advisories are issued when violation of the National Ambient Air Quality Standard (NAAQS) is unlikely. Wood burning is unrestricted, but households are asked to use good wood burning practices.

Yellow advisories are issued for periods when air pollution is approaching accepted level as set by NAAQS. The public is asked not to burn in uncertified wood stoves except where such wood stoves are the sole source of heat.

Red advisories are issued for periods where an exceedence of the NAAQS is anticipated. The public is asked not to burn wood in their wood heaters.

A curtailment program could be either voluntary or mandatory. The town council in Lakeview and the Lakeview County Board of Commissioners formally adopted a voluntary wood burning curtailment program in 1995 (Oregon DEQ 2001a). Likewise, a voluntary curtailment program was established in Klamath Falls in 1989. In 1991, it was necessary to alter that effort to a mandatory program, coordinated through the Department of Health Services in Klamath Falls County (Oregon DEQ 2001b). Wood heater owners were required to register their stoves with the county. Curtailment exemptions are offered for low income and sole source wood burners. Similar mandatory wood burning curtailment ordinances have been passed in Juneau, Alaska; Medford, Oregon; and in Reno, Nevada (Hough *et al.*, 1992; Kay 2001).

In communities where smoke is a problem, British Columbia (Canada) has prohibited wood burning on days when atmospheric dispersion is poor.

Sydney, NSW, has voluntary curtailment of woodsmoke emissions on high pollution days. In Sydney anyone installing a new AS-4013 heater is reminded that they should obey the EPA's 'Don't Light Tonight' requests, not to use wood heaters when high pollution is forecasted (EPA NSW 2000).

The households survey in Armidale showed that 65 per cent of the respondent were not prepared 'not to light' their solid fuel heater if EPA requested, which questions the likely success of voluntary curtailment. The main reason was that the users had no alternative heating arrangement.

8.3.2.5 "Polluter pays"

Wood Heater Permit

One market approach to solving the environmental problems is based on a pollution permit system. This idea was first published by Dales (1968a, 1968b) although theoretical and practical issues were more extensively addressed by Tietenberg (1980).

The "polluter pays" principle could work in two ways. Firstly, all wood heaters would be registered with council and users would pay an annual "polluter fee". This will increase the cost of using the wood heater, and this increased cost might lead to a reduction in wood heater usage. However, there may be some uncertainty about the effectiveness of pricing controls based on the polluter pays principle in achieving the desired level of environmental protection. A price increase may not always effectively promote conservation of resources because users may not change their behaviour when faced with an incremental change in their cost. For example, the household survey in Armidale suggested that the use of a permit price would have a relatively small effect on the demand for firewood. The inelastic nature of demand means that with a higher effective price, consumption will decrease, but only by a small amount.

Secondly, the payment system may not be designed to achieve air pollution goals directly. Instead, it is possible to design the system to raise funds which could be used to support education programs, smoke patrols and other measures to reduce pollution.

Using Wall's (1997) estimate there are approximately 3,500 wood heaters in Armidale, if it was possible to introduce an entitlement permit of $60 per wood heater annually, the collection would be around $210,000 annually. The amount could be spent to fund the cost of woodsmoke patrol and community educations. Another option could be a one-off entitlement fee of $200 per woodheater, which would create a pool of money ($700,000) for carrying out woodsmoke patrol and educational campaign on particulate air pollution and its adverse health effects in Armidale.

Crested Butte, Colorado, imposed a US$30 month "polluter-pays" tax on owners of non-certified wood heaters. There were 349 conventional and 85 USEPA certified wood heaters. The policy reduced pollution by 50 per cent. Half of this was attributed to outright removal of 90 heaters and half to the replacement of 191 heaters with new USEPA certified heaters (ABC 1998).

Telluride, Colorado, has strict control over wood heater use. To install a new wood heater, households must purchase two permits, costing approximately US$2,000 (ABC 1998).

Fines

The threat of fines for operating heaters in an environmentally unsatisfactory manner has resulted in a significant reduction in smoke levels in many areas. In Albuquerque, New

Mexico, the first offence for woodsmoke violation is punished by a fine of US$300 or 90 days in jail, or both (Stapp and Harley 1992)

In July 2001, Armidale Dumaresq Council decided to crack down on air pollution through fines – initially A$320, followed by A$750 for non-compliance under the *Protection of the Environment Administration Act*. Armidale is the first city in Australia to introduce new laws to reduce the output of smoke emissions from wood heaters. However, it is too early to evaluate the effectiveness of this policy on reduction of woodsmoke pollution in Armidale.

8.3.2.6 Education programs

Public awareness and eduction is critical for the success of any woodsmoke emission control program. The local or lead planning agency should provide sufficient resources and staff to develop programs that educate the public about:

i. Health risk of woodsmoke;
ii. Proper wood burning operation and maintenance;
iii. Relevant state, local, and EPA Regulations;
iv. Heating fuels and practices; and
v. Available stove types, including their emissions and relative efficiencies.

Council could organize meetings, workshops and seminars on woodsmoke reduction issues. The events may take place in homes, schools, health facilities, and community centres.

Public awareness programs could include radio announcements, posters, bulk mailing, newspaper articles, distribution of information on the health effects of woodsmoke, public speaking engagements and forums on PM2.5 (woodsmoke) and its health effects, proper woodburning methods and local ordinance requirements, and coordination with wood heaters and home heating device dealers, government agencies and public service organisations.

Campaigns in Australia have focused on educating people on how to operate their heater correctly rather than why woodsmoke is a problem. The harmful impact of woodsmoke on human health has received little attention. Eduction programs in Australia have had considerable difficulty getting over the message that woodsmoke is harmful. For example, ADC and the EPA conducted eduction campaigns on woodsmoke from 1996 onward. However, the household survey shows that 52 per cent of wood heater owners were still unaware that woodsmoke is harmful.

One important component of the eduction campaign is to encourage people to keep their fire burning hot, not smouldering, and to let the fire go out at the end of the night. However, the Armidale household survey found that around 62 per cent of respondents left their heater burning slowly overnight by lowering the air controls, a further 4.4 per cent often did this and around 9 per cent sometimes did.

Education programs in Australia have generally failed to persuade people to operate heaters correctly.

US woodsmoke reduction strategies appear to have been more successful. Based on years of experience of woodsmoke reduction programs, Stoneman and Pace, USEPA (1992), emphasised that measures critical to the success of any residential woodsmoke control program were education on the health effects of woodsmoke, mandatory curtailment when smoke was likely to build up and restrictions on the performance of woodstoves installed. Also recommended were taxes and incentives to discourage use of wood burning devices in new houses and to encourage a reduction in the total number of wood burning devices.

Unless owners understand why they should take the time and trouble to operate heaters correctly, they will not be motivated to do so. Recognising that regulation and enforcement alone cannot solve the problem of wood burning, the Paget Sound Air Pollution Control Agency, Washington State, employs a public educator to explain the programs. The single most important eduction message that the Agency has emphasised is 'Woodsmoke is more than a nuisance, it is a health hazard' (ABC 1998).

8.4 Policy Options to Reduce Air Pollution in Armidale

The process of developing wood burning strategies must be both effective and politically palatable, and it is an evolutionary process. Based on the household survey and research of existing programs, some policy options for reducing woodsmoke in Armidale are presented in the discussion below.

Until recently, Armidale's control strategy was toward public eduction, mandatory home insulation and a change-over program. However, the results indicated that these efforts alone were inadequate to achieve the expected outcomes, although they were a necessary part of the woodsmoke solution.

The control measures have to be predominantly more *preventive* in nature and more *permanent* in scope. After understanding the severeness of problems, health effects and associated costs, it is important to take an integrated and comprehensive approach to improve the situation. The long-run objective of Armidale air pollution control strategies should be a "smoke free" Armidale, and the short-run objective to markedly reduce the smoke pollution.

The following policy options are recommended to achieve the long-term objective of a smoke free Armidale.

i. Possibly, the safest course of action to achieve the long-run objective of a smoke free Armidale is to discourage new wood heaters in Armidale. It is important to have regulations to ban the installation of solid fuel heaters in new houses.
ii. Replacement of wood heaters through various incentives and requirements.

In many cases, implementation of these two policies could be expensive to both public and government and difficult to enforce. Such measures demand a strong partnership between state and local government agencies and the public. To achieve public support, ADC should develop a comprehensive public awareness campaign to educate the public about the extent of the problem, especially the harmful health effects of woodsmoke.

The second set of strategies are related to the short-run objective, to reduce woodsmoke from existing wood heaters:

i. A vigorous campaign, mainly targeting wood-heating households, about the importance of the correct operation of wood heaters. Council must provide material on correct operation of wood heaters, health effects of woodsmoke, and a penalty for incorrect operation.
ii. Employing a smoke patrol officer to monitor the situation. The officer must be equipped with a mobile phone to respond to complaints, witness emissions and take action to remedy the situation.
iii. Mandatory curtailment, "Don't Light Tonight" requests, issued when high pollution is forecast.
iv. Continue existing polices such as mandatory home insulation and Council's new laws providing for fines of more than A$300 for a first offence and A$750 for repeats offenders.
v. A "polluter pay" permit system (say A$200) should be introduced. This will discourage wood heaters, and the revenue used to support an education campaign and smoke patrol costs.
vi. Financial assistance programs for lower income groups for replacement of existing wood heaters with cleaner alternatives.
vii. Encouragement by ADC to improve the energy efficiency of dwelling and provision for further research on solar heating in Armidale.

In the light of the household survey in Armidale, it is important to note that public education and awareness will have a crucial role in achieving the goal of smoke free Armidale. As evident from the survey, the community in Armidale generally was suspicious of economic instruments and resistant towards mandatory policies. Overseas experiences suggest that public support for economic instruments and financial mechanisms will be most favourable where it can be shown that funds are being allocated to environment programs and projects.

To be effective, the program should be tailored to the prevailing attitudes towards wood heaters and wood burning habits of the community in Armidale. The scope and nature of the air pollution control program in Armidale may need to be adjusted as the characteristics of pollution and the population changes over time.

CHAPTER 9
SUMMARY, CONCLUSION AND RECOMMENDATIONS

9.1 Summary and Conclusion

The harmful effects of air pollution have long been known. Epidemiological studies have consistently shown an association between particulate air pollution, especially with fine particles, and mortality and morbidity. Until about 1980, it was considered that mortality and morbidity did not increase unless the levels of particulate and other pollution passed a threshold level. Recent epidemiological studies have established mortality and morbidity responses at low levels of particulate pollution. The results of these studies have been both coherent and consistent.

The convergence of epidemiological results suggests a clear role of particulates, especially fine particulates, in triggering a number of adverse health effects including increased rate of lower respiratory symptoms, upper respiratory symptoms, increased hospital admissions, increased emergency room visits, asthma attacks, a decrease in lung function and increased mortality.

Particulate pollution health effects have been associated with different particulate size fractions. Small particles, such as those from fossil fuel combustion, are likely to be the most dangerous, because they can be inhaled deeply into the lungs, settling in areas where the body's natural clearance mechanisms are unable to remove them. There is no threshold concentration of either PM10 or PM2.5 below which adverse health effects have not been observed.

Woodsmoke consists almost entirely of fine particles. Emissions from domestic wood heaters are an increasing and potential harmful source of air pollution in Australia. The adverse health effects of woodsmoke pollution have been studied in the US and other countries, but despite substantial quantities of pollution generated by wood burning, little research has been carried out in Australia. Armidale, a small town in the NSW, provided an ideal testing ground for investigating the adverse effects of woodsmoke because the air pollution in the locality is almost totally due to wood burning.

The main objective of the study was to estimate the effects of particulate air pollution in Armidale in terms of health status and economic cost. A three-stage approach was taken to identify and quantify the association between particulate air pollution and health related effects in Armidale.

The first stage involved a theoretical estimation of the economic cost of particulate air pollution in Armidale. The computations of health effect in Chapter 4 are based on dose-response coefficients established in recent studies. The calculation was carried out using 10.67$\mu g/m^3$ for the average PM2.5 concentration and a mortality dose-response function of 0.2 and 1 per cent for each 1$\mu g/m^3$ change in PM2.5 as lower and upper bounds. It was estimated that between 4 and 19 deaths occur per year due to particulate air pollution in Armidale.

From the literature, the worth of a human life is statistically between A$1.6 million and A$6.5 million. The economic cost of air pollution in Armidale for the lower bound mortality estimate of 4 deaths per year, is thus the range between A$6.4 million to A$25.6 million. For the upper bound mortality estimate of 19 deaths per year, the range becomes A$30.4 million to A$121.6 million. In terms of morbidity, the existing levels of particulate air pollution causes between 773.8 (lower bound) and 1,729 (upper bound) restricted activities days (RAD). The annual cost of RAD for Armidale is in the range of A$94,713 to A$211,715.

The total economic cost of the current levels of particulate air pollution in Armidale, using conservative estimates of total mortality (lower bound) and morbidity (only RAD) are in the range of A$6.5 million to A$25.7 million per year. These estimates are based on the assumption that Armidale's average exposure of 10.67$\mu g/m^3$ for PM2.5 (with extreme peaks and troughts) is equivalent to a continuing exposure of this level.

The second stage of the study involved a survey of clinical events. This part of the study empirically estimated the statistical relationship between respiratory morbidity and particulate air pollution in Armidale.

The survey of clinical events presented in Chapter 5 examined the impact of particulate air pollution on the proportion of respiratory visits to GP clinics. The analysis of data from local

GP clinics gathered over the period of study showed a significant association between particulate air pollution (PM2.5) and the occurrence of respiratory symptoms requiring a GP's attention within the population of Armidale. Total respiratory visits were significantly correlated with 2-day lagged particulate air pollution. The model *Analysis of proportion* statistically demonstrated a positive effect of air pollution on incidences of respiratory symptoms. At average winter values of minimum temperature and air pollution, about 14.8 per cent of all patients had respiratory illness associated with air pollution.

Chapter 6 assessed the economic costs associated with particulate air pollution in Armidale. Using Poisson regression, the analysis decomposed the total number of respiratory patients into those caused by air pollution and those due to other causes. The estimated number due to air pollution was then multiplied by the estimated cost. The findings showed that during the period of survey, on average 7.45 respiratory patients were due to particulate air pollution in Armidale. The average daily cost of pollution induced respiratory illness was $1,125 during the survey period.

The economic estimates in this study consider only direct medical costs and represent a conservative projection. The dollar outlays were measured in terms of doctors' usual charge to Medicare for clinic visits, cost of drugs and estimated loss of time on the basis of wage rate. The study did not take in to account the preventive or defensive measures, and made no attempt to value other costs, such as X-rays, hospital visits, alternative medicine etc, associated with sickness, and ignored the costs of "pain and suffering". However, the estimates are important because they show the severity of the problem and provide both an impetus for environmental controls and a means for evaluating the benefits of specific pollution control policies.

Community acceptance is essential for the success of any system of environmental management or protection. The third stage of the study (Chapter 7) involved a household survey that investigated respondent's behaviour, perceptions and attitudes towards wood heaters and air pollution in Armidale. Around 53 per cent of the respondent had wood heaters, around 80 per cent of them used their wood heater every day and another 8 per cent used it several days in a week. It was apparent that the community was not fully informed about the adverse effects of smoke from wood heaters. Some 52 per cent of wood heater owners in Armidale did not know that emissions from solid fuel heaters were harmful.

The household survey proposed several pollution reduction policies to gauge community attitudes toward them. The community showed strong resistance toward mandatory policies and a preference towards policies that were voluntary in nature. The contingent valuation method was used to assess the willingness to pay (WTP) for better air quality. Only 40 per cent of respondents were WTP some amount for clean air. There was strong correlation between willingness to pay and respondents' eduction levels. Some of the "zero" WTP responses could be interpreted as "protests".

9.2 Policy Recommendations

The study examined strategies, both legislative and voluntary, for woodsmoke control that have been adopted overseas. It also explored possible policy options to reduce particulate air pollution in Armidale. The long-run objective of Armidale air pollution control strategies should be a *smoke free* Armidale. The short-run objective should be to considerably reduce smoke pollution. To achieve the long-run objective, it will be necessary to regulate to ban installation of solid fuel heaters in new houses and to replace existing wood heaters through various incentives and requirements.

Policies to achieve the short-run objective include: conduct an educational campaign, mainly targeting households using wood heaters; employ a smoke patrol officer to monitor the situation; enforce mandatory curtailment of "Don't Light Tonight" when high pollution is forecasted; introduce a "polluter pays" permit system to discourage wood heaters and use this revenue to support the cost of the eduction campaign and smoke patrol; and offer a financial assistance program for the replacement of existing wood heaters with cleaner alternatives for the lower income group.

Usually, public awareness and participation are the keys to successful policy change. Widespread environmental education promotes understanding of the relationship between pollution and health, and encourages public involvement. It is important to use street campaigns, and to encourage air quality monitoring displays. The media can also participate in raising awareness by disseminating air-pollution related data.

9.3 Significance of the Study

This study is significant because:

i. Despite substantial amounts of pollution generated by wood heaters in Australia, this study is the first to examine in a rigorous manner the health effects of particulate air pollution produced by woodsmoke.

ii. The study results show an association between particulate air pollution and respiratory morbidity in Armidale. In addition, the estimated relationships are consistent with statistical findings of other studies reviewed in Chapter 2, confirming a relationship between air pollution and human health.

iii. The study makes an important contribution in terms of methodology. As far as it is known, this is the first use of GP data to investigate the relationship between air pollution and health effects in terms of respiratory symptoms and economic cost, using Analysis of Proportion and Poisson regression.

iv. The study, investigating Armidale's air pollution problem, has considered both the health effect and the economic cost, and has combined community perceptions and attitudes towards wood heaters and air pollution, which are critical to assessing policy options.

v. The study provides important propositions for public health campaigns for controlling air pollution in Australian communities, and for future legislative regulation of domestic wood burners. Knowledge gained from the study will be useful in formulation of public health policy to control air pollution in Australia, particularly in areas using wood heaters.

9.4 Limitation of the Study and Further Study

When interpreting the study results, one must consider that the results are *merely indications* of the extent of effects and economic costs as opposed to accurate measurement. The dose-response relationship, quantity of exposure, frequency of effects, and economic values are simply estimates of quantification. Nevertheless, the approach of this study has been to produce the best *conservative* estimates.

The empirical analysis was based on GP data only. To have more complete estimates, the study could include hospital visits, visits to alternative medicine provider and so on. The cost estimates used would be improved by including cost of X-rays, tests, hospital uses, preventive medication, and by including a contingent valuation survey to estimate the value of "pain and suffering".

Large uncertainties about the existence and magnitude of the health effects of air pollution still exist. The reported epidemiological studies focused on short-term dose-response relationships. That is, the health impacts were detected a short period after the observed increase in concentration of PM, usually within few days. Long-term exposure to PM may have additional adverse health impacts. The assessment will probably change over time as new clinical, epidemiological and economic research is carried out.

The study estimates of the effects of particulate air pollution in Armidale are based on averages and simple assumptions. The economic costs considered in the study are conservative and can be understood as providing the lower bounds for the estimates. Nevertheless, they provide valuable information about the adverse health effects and the economic cost of particulate air pollution in Armidale and could, in turn, be used to provide a range of economic values for controlling pollution.

APPENDIX A

Estimation of Model 1
(Average Daily Air Pollution from AAQG)

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.10717E-01	0.1536E01	0.6977	0.486
Temp1	-0.77936E-02	0.1477E-01	-0.5275	0.598
Temp2	-0.13465E-01	0.1510E-01	-0.8918	0.373
Temp3	0.27302E-01	0.1277E-01	2.137	0.033
Temp4	-0.83203E-02	0.1250E-01	-0.6659	0.506
AP	-0.30322E-03	0.1567E-02	-0.1935	0.847
AP1	-0.45951E-03	0.1773E-02	-0.2591	0.796
AP2	0.47905E-02	0.1835E-02	2.611	0.010
AP3	0.72095E-03	0.1873E-02	0.3849	0.701
AP4	0.17881E-02	0.1729E-02	1.035	0.302
C1	-0.39659	0.1156	-3.431	0.001
C2	-0.84009	0.1361	-6.174	0.000
C3	-0.12551	0.1199	-1.047	0.296
C4	-0.23916E-01	0.1539	-0.1554	0.877
C5	-0.22459	0.1743	-1.288	0.199
Constant	-1.7434	0.1512	-11.53	0.000

Estimation of Model 2

(Average Daily Air Pollution, ACC/EPA)

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.11153E-01	0.1588E-01	0.7025	0.483
Temp1	-0.17872E-01	0.1512E-01	-1.182	0.238
Temp2	-0.19166E-01	0.1526E-01	-1.256	0.210
Temp3	0.25043E-01	0.1282E-01	1.954	0.052
Temp4	-0.13777E-01	0.1176E-01	-1.171	0.242
AP	-0.32517E-02	0.3792E-02	-0.8576	0.392
AP1	-0.22686E-03	0.4829E-02	-0.4698E-01	0.963
AP2	0.58811E-02	0.4948E-02	1.189	0.236
AP3	0.36941E-02	0.5371E-02	0.6878	0.492
AP4	0.66467E-02	0.5030E-02	1.321	0.187
C1	-0.38917	0.1171	-3.325	0.001
C2	-0.81790	0.1379	-5.931	0.000
C3	-0.11845	0.1214	-0.9755	0.330
C4	0.28937E-02	0.1554	0.1862E-01	0.985
C5	-0.18941	0.1761	-1.076	0.283
Constant	-1.6908	0.1569	-10.78	0.000

Estimation of Model 3

(Mean Average Daily Air Pollution, AAQG+ACC/EPA)

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.89236E-02	0.1586E-01	0.5626	0.574
Temp1	-0.77054E-02	0.1513E-01	-0.5091	0.611
Temp2	-0.12994E-01	0.1545E-01	-0.8408	0.401
Temp3	0.26901E-01	0.1280E-01	2.101	0.037
Temp4	-0.98493E-02	0.1230E-01	-0.8007	0.424
AP	-0.10145E-02	0.2283E-02	-0.4444	0.657
AP1	-0.56048E-03	0.2678E-02	-0.2093	0.834
AP2	0.66414E-02	0.2757E-02	2.409	0.017
AP3	0.17781E-02	0.2922E-02	0.6085	0.543
AP4	0.28869E-02	0.2653E-02	1.088	0.277
C1	-0.39537	0.1159	-3.410	0.001
C2	-0.83328	0.1365	-6.105	0.000
C3	-0.12127	0.1203	-1.008	0.314
C4	-0.18553E-01	0.1542	-0.1203	0.904
C5	-0.21845	0.1747	-1.250	0.212
Constant	-1.7558	0.1602	-10.96	0.000

Estimation of Model 4

Maximum Daily Air Pollution, AAQG

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.37855E-02	0.1560E-01	0.2427	0.808
Temp1	-0.10147E-01	0.1446E-01	-0.7016	0.484
Temp2	-0.10675E-01	0.1510E-01	-0.7070	0.480
Temp3	0.32807E-01	0.1291E-01	2.542	0.012
Temp4	-0.44412E-02	0.1271E-01	-0.3493	0.727
AP	-.56955E-03	0.5953E-03	-0.9567	0.340
AP1	-0.36327E-03	0.6879E-03	-0.5281	0.598
AP2	0.16953E-02	0.7345E-03	2.308	0.022
AP3	0.16837E-03	0.8168E-03	0.2061	0.837
AP4	0.11892E-02	0.7038E-03	1.690	0.092
C1	-0.39839	0.1151	-3.460	0.001
C2	-0.83561	0.1357	-6.159	0.000
C3	-0.11894	0.1195	-0.9952	0.320
C4	-0.16174E-01	0.1532	-0.1056	0.916
C5	-0.24299	0.1736	-1.400	0.163
Constant	-1.7387	0.1630	-10.67	0.000

Estimation of Model 5

Max Daily Air Pollution, ACC/EPA

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.15548E-01	0.1386E-01	1.122	0.263
Temp1	-0.21004E-01	0.1437E-01	-1.462	0.145
Temp2	-0.23284E-01	0.1432E-01	-1.626	0.105
Temp3	0.20674E-01	0.1205E-01	1.716	0.087
Temp4	-0.15029E-01	0.1205E-01	-1.247	0.214
AP	-0.58548E-03	0.1035E-02	-0.5655	0.572
AP1	-0.11971E-03	0.1222E-02	-0.9797E-01	0.922
AP2	0.16770E-02	0.1417E-02	1.184	0.238
AP3	0.86483E-03	0.1334E-02	0.6482	0.517
AP4	0.98218E-03	0.1099E-02	0.8941	0.327
C1	-0.38160	0.1173	-3.254	0.001
C2	-0.80132	0.1382	-5.798	0.000
C3	-0.11775	0.1218	-0.9672	0.334
C4	0.50946E-02	0.1560	0.3299E-01	0.974
C5	-0.19564	0.1765	1.109	0.269
Constant	-1.6481	0.1385	-11.90	0.000

Estimation of Model 6

Mean Max Daily Air Pollution, AAQG+ACC/EPA

Variables	Estimated Coefficient	Standard Error	T-Ratio	P-Value
Temp	0.64111E-02	0.1541E-01	0.4159	0.678
Temp1	-0.10008E-01	0.1473E-01	-0.6794	0.497
Temp2	-0.12730E-01	0.1520E-01	-0.8376	0.403
Temp3	0.30316E-01	0.1268E-01	2.391	0.017
Temp4	-0.75259E-02	0.1259E-01	-0.5978	0.550
AP	-0.67478E-03	0.7992E-03	-0.8444	0.399
AP1	-0.36625E-03	0.9529E-3	-0.3843	0.701
AP2	0.21982E-02	0.1019E-02	2.157	0.032
AP3	0.52226E-03	0.1102E-02	0.4740	0.636
AP4	0.15773E-02	0.9574E-03	1.648	0.101
C1	-0.39429	0.1156	-3.411	0.001
C2	-0.82772	0.1362	-6.077	0.000
C3	-0.11930	0.1200	-0.9939	0.321
C4	-0.11820E-01	0.1538	-0.7685E-01	0.939
C5	-0.23401	0.1743	-1.343	0.180
Constant	-1.7661	0.1646	-10.73	0.000

APPENDIX B
HOUSEHOLD SURVEY QUESTIONNAIRE

CENTRE FOR HEALTH RESEARCH AND DEVELOPMENT,
UNIVERSITY OF NEW ENGLAND
Solid Fuel Heating Survey Questionnaire

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1 Do you use an open fire or a solid fuel heater for home heating at this address? (Solid fuel includes a fuel such as wood, coal or coke.) If YES, what sort of heater(s) does the household use? *(Circle all that apply. Please clarify if necessary.)*

No, no solid fuel heating 1
Yes, open fire(s) 2
Yes, pot belly stove(s) 3
Yes, slow combustion heater(s) 4
Yes, other solid fuel heating (specify: ______________) 5

IF YOU ANSWERED 'NO SOLID FUEL HEATING' IN QUESTION 1 PLEASE GO TO QUESTION 11.

2 Did you or your family choose to buy or install (any of) the fire place(s)/solid fuel heater(s) in this home, or was it bought or installed by someone else?

Bought/installed self 1
By someone else 2
Not sure 3

3a During winter, about how often does your household use the solid fuel heater or light a fire? Would that be — *(circle one)*

Less than once a week 1
Once or twice a week 2
Several times a week 3
Every day or almost every day 4
Not sure 5

3b On days when you do use the heater or fire(s), about how many hours, on average, would it burn?

4 hours or less 1
5 – 6 hours 2
7 – 8 hours 3
Over 8 hours – but not all the time 4
24 hours a day 5
Not sure 6

4 What sort of fuel does your household *mostly* burn in its fire/heater(s) — apart from kindling etc that you may use to *start* the fire? *(Circle one only. If "Any particular sort of wood", please clarify if known.)*

Hardwood (includes fence palings) 1
Softwood 2
Scrap wood, whatever timber is available 3
Wood, specified 4
Coal 5
Coke 6
Paper/cardboard 7
Rubbish 8
Other (specify: ______________) 9
Not sure 10

5 How or from whom do you *mostly* get your fuel? *(Circle one only.)*

Buy from a dealer/retailer 1

Given by friends/neighbours/relatives etc 2

Find/get it ourselves (eg on the property, in the bush, reuse waste timber, etc) 3

Other (specify: ______________________) 4

Not sure 5

6 Some people prefer to burn old wood, or wood that has been left for six months or more of age. As far as your household heating is concerned, do you: *(Circle only one)*

Always burn old or aged wood 1

Mostly burn old or aged wood 2

Sometimes burn old or aged wood 3

Don't mind whether the wood that you use is aged or not 4

Not sure 5

Not applicable — don't burn wood 6

7 Does your household leave the heater to burn slowly overnight by lowering the air controls?

Always 1

Often 2

Sometimes 3

Never 4

8 Assuming that the cost of a load of normal firewood is $60.00 and that it is possible instead to buy wood that does not pollute. How much would you be willing to pay for a load of this special wood?

$60	______	$100	______
$70	______	$120	______
$80	______	$150 or more	______
$90	______		

9 On days when the air pollution rating is high or above (about 1 day in 2 during July) would you be prepared not to light your wood heater if the EPA requested it?

YES	
NO	

10 Supposing that in the future Armidale City Council decides that the number of wood heaters needs to be restricted, and that it will issue yearly permits that households that have wood heaters would need to buy. If the permit costs:

	No	Yes
$50 would you move to an alternative form of heating?	☐	☐
what if it was $100	☐	☐
or $150	☐	☐
$200	☐	☐

↓ ↓

GO TO NEXT QUESTION

11 Please read the following four statements. In each case can you indicate whether you think the statement is true or false, or you are not sure. *(Circle one response on each line.)*

	True	False	Not sure
(a) Airtight slow combustion heaters use fuel much more efficiently than open fires.	1	2	3
(b) Emissions from open fires and solid fuel heaters contain substances that are harmful to humans.	1	2	3
(c) In terms of environment protection, it makes no difference whether the wood that people burn for heating is aged or not.	1	2	3
(d) Armidale will have to do something about woodsmoke.		2	3

12 Has your household ever experienced problems or annoyance as a result of other people using solid fuel home heating in your area? Would that be *(circle only one)*

Never or hardly ever .... 1 Go to Q14

Sometimes, from time to time 2

Quite often, regularly 3

Not sure .... 4 Go to Q14

13 In winter, in your neighbourhood, would you say that smoke or emissions from home fires or solid fuel heaters is — *(Circle only one)*

Not a problem 1

A bit of a problem 2

A significant problem 3

Not sure 4

14 Armidale City Council and the Environment Protection Authority are carrying out a community education campaign on the environmental aspects of using solid fuel heating (including open fires) in the home.

Some people have suggested that other steps should be taken to regulate or control the use of open fires or solid fuel heaters in the home. Can you tell me whether you would generally *approve* or *disapprove* of the following possibilities? *(Circle one on each line.)*

	Approve	Disapprove	Not sure
(a) Encourage people not to light fires or solid fuel heaters on days when high pollution is predicted.	1	2	3
(b) Prohibit people from lighting fires or solid fuel heaters on days when high pollution is predicted.	1	2	3
(c) Prohibit any new solid fuel heaters or open fires being installed in private homes.	1	2	3
(d) Limit the number of homes in an area which can have a solid fuel heater or open fire.	1	2	3
(e) Gradually phase out any burning of wood or coal in private homes.	1	2	3
(f) Impose an annual charge of say $40.00 on households that have solid fuel heaters.	1	2	3
(g) Only allow people to burn wood that is purchased from an accredited supplier.	1	2	3
(h) Impose fines on households that produce large amounts of woodsmoke.	1	2	3

15 In Armidale, how important do you think the following issues are?
(Please rank, 1 = most important)

Issues	
Unemployment	....
Crime	....
Homelessness	....
Air Pollution	....
Drugs	....

16 Compared with 3 years ago, do you think Armidale's air pollution today is:

- Better ☐
- About the same ☐
- Worse ☐
- Don't know ☐

17a Do you own or rent this property?

- own ☐
- rent ☐

17b Please look at these photographs. The first shows Armidale on a sunny July morning with considerable air pollution. The second shows Armidale on a similar July morning with no air pollution. Currently half of July mornings are like the first picture and half are like the second. Suppose that to improve things so that every July morning gets to be like the second picture, Armidale City Council needs to spend some money on a project and this will need an increase in the rates. Remembering that everyone in Armidale will be paying for this, how much of a rate/rent increase would you be willing to accept?

- $0 ☐
- $20 per year ☐
- $40 per year ☐
- $60 per year ☐
- $100 per year ☐
- $120 or more per year? ☐

18 Which of the following best describes this dwelling? *(Circle one)*

Single/detached house	1
Townhouse/villa/terrace	2
Flat or home unit	3
Other (specify: ________________________)	4

19 Which of these age groups are you in?

18 – 29	1
30 – 39	2
40 – 49	3
50 – 59	4
60 or over	5

20 Male? .... 1 Female? 2

21 What level of education have you completed?

- Primary completed/not completed .... ☐
- Secondary completed/not completed .... ☐
- H.S.C. completed/not completed .... ☐
- Technical College (TAFE) completed/not completed .... ☐
- University completed/not completed .... ☐
- Post Graduate completed/not completed .... ☐

22 Occupation of main income earner in this household

- Farmer .... ☐
- Managerial/Professional .... ☐
- Clerical/Sales .... ☐
- Technical/Trades .... ☐
- Labourer .... ☐
- Services .... ☐
- Student .... ☐
- Home duties .... ☐
- Self employed .... ☐
- Retired .... ☐
- Unemployed .... ☐
- Others (please specify) .... ☐

23 Household size:

- 1 person ☐
- 2 people ☐
- 3 people ☐
- 4 people ☐
- 5 people ☐
- 6 people ☐
- 7 people ☐
- 8 and more ☐

24 Did you or any member of your family suffer from one or more of the following diseases during the 1998 winter?

Asthma	☐	Bronchitis	☐
Night time cough	☐	Other chest complaint	☐

25 How long have you lived in Armidale? ....

26 Approximate household income per year:

- Less then $20,000 ☐
- $20,000–$40,000 ☐
- $40,000–$60,000 ☐
- More then $60,000 ☐

Thank You

APPENDIX C
PHOTOGRAPHS OF ARMIDALE WINTER WITH AND WITHOUT SMOKE POLLUTION

REFERENCES

Abbey DE, Hwang B, Burchette R, Vancuren T and Mills P. 1995. Estimated long-term ambient concentrations of PM10 and development of respiratory symptoms in a nonsmoking population. *Archives of Environmental Health 50:139-151.*

Abramson M and Beer T. 1998. Something particular in the air we breathe? Editorials, *Medical J. Australia 169:452-453.*

Ainsworth P and Gow S. 1998. Woodsmoke monitoring and community eduction: A local government perspective, **in** KA Parton (Ed.), *Particulate Pollution in Australian Rural Towns*. Centre for Health Research and Development, University of New England, Armidale.

Ainsworth P. 1996. A role for local government - air particulate monitoring. *Environmental Health Review 25:21-7.*

Alberini A, Cropper M, Tsu-Tan Fu, Krupnick A, Jin-Tan Liu, Shaw D and Harrington W. 1996. What is the value of reduced morbidity in Taiwan? **in** R Medelsohn and D Show (Eds.) *The Economics of Pollution Control in the Asia Pacific*, Edward Elgar, Aldershot.

Appel JR. 1992. Current limitations and future prospects of residential wood combustion controls in the Pacific Northwest **in** JC Chow and DM Ono (Eds.). *PM10 Standards and Nontraditional Particulate Source Controls*, Air & Waste Management Association, Pittsburg.

Armidale Air Quality Group (AAQG). 1999. *What can we do?* http://www.ozemail.com.au/~airquality.

Armidale Air Quality Group (AAQG). 2000. Air Pollution modelling results for Armidale, 1995-1999 and the effects of the wood heater change-out program held in Feb/March 1998. http://www.ozemail.com.au/~airquality .

Armidale City Council. 1995. *State of The Environment Report.* Armidale City Council Planning and Environmental Services Division. Armidale.

Armidale City Council. 1996. *Air Quality Awareness: Solid Fuel Heating Survey, 1996 Community Survey*. Armidale.

Armidale City Council. undated. *Home Heating-Loans for Replacement of Insufficient Wood Heaters.* Armidale City Council, Armidale.

Armidale City Council. undated. *Woodsmoke in Armidale City: A Burning Issue.* Armidale City Council, Armidale.

Atech Group. 2001. *Woodheater Emissions*. Management for Tamar Valley Scoping Study, Environment Australia.

Atkinson SE and Crocker TD. 1982. *A Baysean Approach to Assessing the Robustness of Hedonic Property Value Studies.* Manuscript. Department of Economics, University of Wyoming.

Atkinson SE and Halvorsen. 1990. The valuation of risks to life: Evidence from the market for automobiles, *The Review of Economics and Statistics 133-136.*

Ausrtalian Broadcasting Corporation (ABC). 1998. Great Moments in Science: Wood Smoke Part 2, www.abc.net.au/science/k2/moments/gmis9841.htm

Australian Bureau of Statistics (ABS). 1997. *1996 Census of Population and Housing- Basic Community Profiles, Northern Tablelands*, Commonwealth of Australia.

Australian Bureau of Statistics (ABS). 2000. *Average Weekly Earning, States and Australia*, ABS Cat no.6301.0. Commonwealth of Australia.

Ayers G, Keywood M, Gras J, Cohen D and Baily G. 1999. *Chemical and Physical Properties of Australian Fine Particles: A Pilot Study*, Final Report to Environment Australia from the CSIRO Division of Atmospheric Research and Australian Nuclear Science and Technology Origination.

Barnes PJ, Honsson B and Klim JB. 1996. The cost of asthma, *European Respiratory Journal 9:636-642.*

Baruch R. 1998. The health effects from air pollution: Results of Sydney studies, **in** KA Parton (Ed.), *Particulate Pollution in Australian Rural Towns*. Centre for Health Research and Development, University of New England, Armidale.

Bay Area Air Quality Management Division (BAAQMD). 1998. *Woodsmoke Reduction Program Yielding Results*, Press release BAAQMD. San Francisco, CA, www.Baaqmd.gov\pie\press\pr980211.htm

Belhaj M. 1998. *Estimating the Benefits of Clean Air: Contingent Valuation and Hedonic Price Methods.* Department of Economics. Goteborgs University, Sweden.

Bender B, Gronbeng TJ and Hwang HS. 1980. Choice of functional form and the demand for air quality, *Review of Economics and Statistics 62(4):638-643.*

Berger M, Blomqueist G, Kenkel D and Tolley G. 1987. Valuing changes in health risks: a comparison of alternative measures. *Southern Economic Journal 53:967-984.*

Brauer M, Koutrakis P, Keeler GJ and Spengler JD. 1989. Indoor and outdoor concentrations of inorganic acidic aerosols and gases. *J. Waste Management Association 41:171-181*

Broome J. 1978. Trying to value a life. *J. Public Economics 9:91-100.*

Brunekreef B, Dockery D and Krzyanowski M. 1995. Epidemiologic Studies on short-term effects of low levels of major ambient air pollution components. *Environmental Health Perspectives, 103(9)(suppl 2):3-1.*

Burr P. 1994. *Climatic Averages and Extremes, Armidale, NSW*, Agronomy and Soil Science Department, University of New England, Armidale.

Carlsson F and Johanesson-Stenman O. 2000. Willingness to pay for improved air quality in Sweden, *Applied Economics 32:661.*

Chattopadhyay and Braden JB. 1998. *Measuring the Benefits of Clean Air: A Two Stage Hedonic Study Based on the Chicago Housing Market.* Department of Economics, Binghamton University, Binghamton, NY. 13902.

Chestnut L, Colome L, Keller L, Lambert W, Ostro B, Rowe R and Wojciechowski S. 1988. *Heart Disease Patients' Averting Behaviour, Costs of Illness, and Willingness-To-Pay to Avoid Angina Episodes.* Report to the Office of Policy Analysis. U.S. Environmental Protection Agency, Washington, DC, USA.

Chestnut L, Schwartz J, Savitz DA and Burchfiet CM. 1991. Pulmonary Function and Ambient Particulate Matter: Epidemiological Evidence from NHANESI, *Archive of Environmental Health 46:135-144.*

Chestnut L, Ostro B and Vichit-Vadakan. 1997. Transferability of air pollution control benefits estimates from the United States to developing Countries: Evidence from the Bangkok study, *American J. Agricultural Economics 79:1630-1635.*

Chestnut L. 1995. *Human Health Benefits from Sulfate Reduction under Tittle IV of the 1990 Clean Air act Amendments,* Final Report. US Environmental Protection Agency, Washington, D.C, USA.

Choudhury AH, Gordian ME and Morris SS. 1997. Associations between respiratory illness and PM10 air pollution, *Archive of Environmental Health, 52(2):113-117.*

Christainsen GB and Degen CG. 1980. Air pollution and mortality rate: A note on Lave and Seskin's pooling of cross-section and time-series data, *J. Environmental Economics and Management 7:149-155.*

Cifuentes L and Lave LB. 1997. Association of daily mortality and air pollution in Philadelphia, 1983-1988, *J. Air and Waste Management.*

Cooper B and Rice D. 1976. The economic cost of illness revisited, *Social Security Bulletin 39:21-36.*

Cooper JA, Currie LA and Klouda GA. 1981. Assessment of contemporary carbon combustion source contributions to urban air particulate level using Carbon-14 measurements, *Environ Science Technology 15:1045-1050.*

Corbett S, Morrell S, Morgan G, Waters J and Baker D. 1996. 1994 Bushfire/1993 asthma episode study, **in** *Proceedings of Health and Urban Air Quality in NSW Conference,* Sydney, June 3-4.

Coursey D, Hovis J and Schulze W. 1987. The disparity between willingness to accept and willingness to pay measures of value, *Quarterly J. Economics 679-689.*

Crocker T *et al.* 1979. *Methods Development for Assessing Air Pollution Control Benefits,* vol 1, USEPA 600/5-70-00/a February.

Cropper ML and Freeman III. 1991. Environmental health effects, **in** J Braden and C Kolstad (Eds.) *Measuring the Demand for Environmental Quality,* Elsevier Science Publishers.

Cropper ML, Simon N, Alberini A, Arora S and Sharma PK. 1997. The health benefits of air pollution control in Delhi. *American J. Agricultural Economics 79:1625-1629.*

Cropper ML. 1981. Measuring the benefits from reduced morbidity. *American Economic Review 71(2):235-245.*

Cummings RG, Brookshire DS and Schulze WD. 1986. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* Rowman and Allenheld, Publishers, Totowa, New Jersey, USA.

Dales JH, 1968a, Land, water and ownership, *Canadian J. Economics 1:797-804.*

Dales JH, 1968b, *Pollution, Property and Prices*, Toronto University Press. Toronto.

Delfino JR, Murphy-Moulton AM, Burnett RT, Brook JR and Becklake MR. 1997. Effects of air pollution on emergency room visits for respiratory illness in Montreal, Quebec. *American J. Respiratory and Critical Care Medicine 155:568-576.*

Department of Health, NSW. 1996. New England Area Health Profile, NSW.

Desvousges W *et al.* 1993. *Review of Health Effects Resulting from Exposure to Air pollution.* Working Paper, Taskforce on Externality Costing, Research Triangle Institute, US.

Dickens WT. 1984. Differences between risk premium in union and non-union wages and the case for occupational safety regulation, *American Economic Review 74:320-323.*

Dickey J. 1997. *World Wide Web Report on Proposed USEPA National Ambient Air Quality Standards*, Harvard University, www.med.harvard.edu\chge\news2\html

Dickie M and Gerking S. 1989. Benefits of reduced morbidity from air pollution control: A survey, **in** H Folmer and E Ireland (Eds.), *Valuation Methods and Policy Making in Environmental Economics.* Studies in Environmental Science 36, Elsevier.

Dickie M and Gerking S. 1991. Willingness to pay for Ozone control: inferences from the demand for medical care. *J. Environmental Economics & Management 21(1):1-16.*

Dickie M, Gerking S, Brookshire D, Coursey D, Schulze W, Coulson A and Tashkin D. 1987. Reconciling averting behaviour and contingent valuation benefit estimates of reducing symptoms of ozone exposure draft. **in** *Improving Accuracy and Reducing Costs of Environmental Benefit Assessments.* USEPA Washington.

Dickie M, Gerking S, Schulze W, Coulson A and Tashkin D. 1986. Values of symptoms of ozone exposure: an application of the averting behaviour method. **in** *Improving Accuracy and Reducing Costs of Environmental Benefit Assessments,* USEPA Washington.

Dockery DW and Pope CA. 1996. Epidemiology of acute health effects: Summary of time-series studies, **in** R Wilson and J Spengler (Eds.), *Particles in Our Air: Concentrations and Health Effects*, Harvard University Press.

Dockery DW and Schwartz J. 1995. Particulate air pollution and mortality more than the Pheladelphia story. *Epidemiology 6:629-632.*

Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay MA, Ferris BG and Speizer FE. 1993. An association between air pollution and mortality in six US cities. *New England J. Medicine 329(24):1753-1759.*

Dockery DW, Ware JH, Ferris BG, Spizer FE, and Cook NR. 1982. Changes in pulmonary function in children associated with air pollution episodes. *J. Air Pollution Control Association 32:937-942.*

Dockery DW and Pope CA. 1994. Acute respiratory effects of particulate air pollution. *Annual Review of Public Health 15:107-32.*

Dockery DW. 1996. Review of NSW Health Department Health and Air Research Program, **in** *Proceedings of Health and Urban Air Quality in NSW Conference*, Sydney, June 3-4.

Environment Australia. 2000. *Breathe the Benefits.* http://www.environment.gov.au/woodsmoke.html.

Environment Protection Authority (EPA) New South Wales. 1998. *Draft Environmental Guidelines for Selecting, Installing and Operating Domestic Solid Fuel Heaters*, Environment Protection Authority, New South Wales, April.

Environment Protection Authority (EPA) New South Wales. 2000. *Wood Smoke: Listen out for Don't Light Tonight alerts,* Environment Protection Authority, New South Wales.

Environment Protection Authority (EPA) Victoria. 2000. *Draft Air Quality Improvement Plan*, Publication 707, Environment Protection Authority, Victoria.

Environment Protection Authority (EPA), Victoria. 1998. *State of Knowledge Report on Airborne Particles in Australia and NewZealand.* Draft Report to ANZECC.

Eskeland GS. 1997. Air pollution requires multi-pollutant analysis: the case of Santiago, Chile. *American J. Agricultural Economics 79:1636-1642.*

Evans JS, Kinney PL, Koehler JL and Cooper DW. 1984. Relationship between cross-sectional and time series studies. *J. Air Pollution Control Association 34:551-553.*

Fairly D. 1990. The relationship of daily mortality to suspended particulates in Santa Clara County 1980-1986. *Environmental Health Perspectives 89:159-168.*

Farber S and Rambaldi A. 1993. Willingness to pay to avoid acute ambient air quality conditions: The case of outdoor excercisers, *Contemporary Policy Issues 11:19-30.*

Fernandez, L. 2001. Palo Alto sued over fireplace limits, *Mercury News*, www.Californiaheartsandhomes.org\news.html

Fisher A, Violette and Chestnut L. 1989. The value of reducing risks of death: a note on new evidence. *J. Policy Analysis and Management 8:88-100.*

Folinsbee LJ. 1992. Human health effects of air pollution. *Environmental Health Perspectives 100:45-56.*

Forsberg B, Stjembeng N, Falk M, Lundback B and Wall SA. 1993. Pollution levels, meteorological conditions and asthma symptoms. *European Respiratory Journal 6:1109-1115.*

Freeman AM. 1979. Hedonic price, property values and measuring environmental benefits: A survey of issues. *Scand. J. Econ. 81:154-173*

Freeman AM. 1982. *Air and Water Pollution Control: A Benefit-Cost Assessment*, John Wiley and Sons, New York.

Gegax D, Gerking S and Schulze W. 1985. *Perceived Risk and the Marginal Value of Safety*. Working paper. US Environmental Protection Agency, Washington DC.

Gegax D, Gerking S and Schulze W. 1991. Perceived risk and the marginal value of safety. *Review of Economics and Statistics 73:589-596.*

Gerking S and Stanley LR. 1986. An economic analysis of air pollution and health: the case of St. Louis. *The Review of Economics and Statistics LXVIII(1):115-121.*

Greene WH. 1997. *Econometric Analysis*. Prentice Hall, New Jersey.

Grossman M. 1972. On the concept of health capital and the demand for health, *J. Political Economy 80:223-255.*

Hall J and Walton A. 1996. A case study in pollution markets: dismal science vs dismal reality. *Contemporary Economic Policy 14:67-79.*

Hall JV, Brajer V, Kleinman MT and Fairley D. 1994. *The Economic Value of Quantifiable Ozone and PM10 Related Health Effects in the San Francisco Bay Area*. Final report to the Bay Area Air Quality Management District.

Hall JV, Winer AM, Kleinman MT, Lurmann FW, Brajer V and Colome SD. 1989. *Economic Assessment of the Health Benefits from Improvements in Air Quality in the South Coast Air Basin*, Final Report, South Coast Air Quality Management District, California State University, Fullerton Foundation, Fullerton. CA, June.

Hall JV, Winer AM, Kleinman MT, Lurmann FW, Brajer V and Colome SD. 1992. Valuing the health benefits of clean air. *Science 255:812-817.*

Hanemann WM. 1991. Willingness to pay and willingness to accept: how much can they differ. *American Economic Review 81:635-647.*

Hoek G, Schwartz J, Groot B and Eilers P. 1997. Effects of ambient particulate matter and ozone on daily mortality in Rotterdam, the Netherlands. *Archives of Environmental Health 52(6):455-463.*

Hough M, Stenens G and Aalbers S. 1992. Progress to achieve residential wood combustion PM10 emission reductions in Medford, Oregon as determined by compliance surveys and ambient monitoring, **in** JC Chow and DM Ono (Eds.), *PM10 Standards and Nontraditional Particulate Source Controls*, Air & Waste Management Association, Pittsburg.

Huang Wen-Chi and Lin JS. 1998. *Valuing the Economic Benefits of Air Quality Improvement- A Case Study of the Kaohsiang and Pingtung Areas.* Department of Agribusiness Management, National University of Science and Technology, Taiwan.

Ilabaca M, Olaeta I, Campos E, Villaine J, Tellez-Rojo MM and Romieu I. 1999. Associations between levels of fine particles and emergency visits for pneumonia and other respiratory illness among children in Santiago, Chile. *J. Air and Waste Management Association 49(9):154-63.*

Jalaludin B. 1996. Air pollution and asthma in Western Sydney, **in** *Proceedings of the Health and Urban Air Quality in NSW Conference*, Sydney June 3-4.

James D. 1997. *Environmental Incentives: Australian Experience with Economic instruments for Environmental Management*, report prepared for Environment Australia.

Jones-Lee MW, Hammerton M and Philips PR. 1985. The value of safety: results from a national sample survey. *Economics Journal 95:49-72.*

Jones-Lee MW. 1976. *The Value of Life: An Economic Analysis*, University of Chicago Press.

Kay J. 2001. Sharp rise in wood burning fireplaces in use to ease utility bills. *San Francisco Chronicle*, www.sfgate.com

Kelsall JE, Samet JM, Zeger SL and Xu J. 1997. Air pollution and mortality in Philadelphia, 1974-1988. *American J. Epidemiology 146(9):750-762.*

Keywood M, Ayers G, Gras J and Cohen D. 2000. Size-revalued: chemistry of Australian urban Aerosols. *Proc. Clean Air and Environment Conference, Sydney.*

Khalil MA, Edger SA and Rasmussen RA. 1983. A gaseous tracer model for air pollution from residential wood burning. *Environmental Science and Technology, 17:555-559.*

Kinney PL and Ozkaynak H. 1991. Associations of Daily Mortality and Air Pollution in Los Angeles County. *Environmental Research 54:99-120.*

Klemm RJ, Mason RM, Heiling CM, Neas LM and Dockery DW. 2000. Is daily mortality associated specifically with fine particles? Data reconstruction and replication of analyses. *J. Air Waste Management Assoc. 50(7):1215-22.*

Knetsch JL and Sinden JA. 1984. Willingness to pay and compensation demand: experimental evidence of an unexpected disparity in measures of value. *Quarterly J. Economics 507-521.*

Koenig JQ, Larson TV, Harley QS, Rebolledo V, Dumber K, Checkoway H, Wang SZ, Lin D and Pierson WE. 1993. Pulmonary function changes in children associated with fine particulate matters. *Environmental Research 63(1):26-38.*

Krewski D, Burnett RT, Goldben MS, Hoover K, Siemiatgcki J, Jerret M, Abranhamowicz M and White WH. 2000, Reanalysis of the Harvard six cities study and the American Cancer Society study of particulate air pollution and mortality. *Special Report of the Institutes' Particulate Epidemiology Reanalysis Project.* Cambridge, MA, Health Effects Institute.

Krupnick AJ and Portney PR. 1991. Controlling urban air pollution: A benefit cost assessment. *Science 252:522-527.*

Krupnick AJ, Harrington W & Ostro B. 1990. Ambient ozone and acute health effects: evidence from daily data. *J. Environmental Econ. & Management 18:1-18.*

Landefeld J and Seskin E. 1982. The economic value of life: linking theory to practice. *American J. Public Health 72:555-566.*

Larson TV and Koenig JQ. 1994. Wood smoke: emissions and noncancer respiratory effects. *Annual Review of Public Health 15:133-56.*

Lave LB and Seskin EP. 1970. Air pollution and human health. *Science 169:723-733.*

Lave LB and Seskin EP. 1973. An analysis of the association between US mortality and air pollution. *J. the American Statistical Association 68:284-290.*

Lave LB and Seskin EP. 1977. *Air Pollution and Human Health.* John Hopkins University Press, Baltimore, MD.

Lewis PR, Hensley M, Wlodarczyk J, Toneguzzi R, Westley-Wise V, Dunn T and Calvert D. 1998. Outdoor air pollution and children's respiratory symptoms in the steel cities of New South Wales. *Medical J. Australia 169:459-463.*

Lewis PR. 1996. The Hunter- Illawarra study of airways and air pollution (HISAPP), **in** *Proc. Health and Urban Air Quality in NSW Conference, Sydney June 3-4.*

Lewis PR. 1998. Health effects of particulate pollution, **in** KA Parton (Ed.), *Particulate Pollution in Australian Rural Towns.* Centre for Health Research and Development, University of New England, Armidale.

Li Y and Roth HD. 1995. Daily mortality analysis by using different regression models in Philadelphia County, 1993-1900. *Inhal Toxicology 7:45-58.*

Linacre E and Hobbs J. 1977. *The Australian Climate Environment.* John Wiley and Sons, Brisbane.

Lind R. 1982. A primer on the major issues relating to the discount rate for evaluating national energy options, **in** R Lind (Ed.), *Discounting for Time and Risk in Energy Policy,* John Hopkins University Press for Resources for the Future, Baltimore.

Lipfert FW. 1978. Statistical Studies of Mortality and Air Pollution. PhD Dissertation, Union Graduate School, Cincinnati, Ohio.

Lipfert FW. 1984. Air pollution and mortality: Specification searches using SMSA-based data. *J. Environmental Management 11:208-243.*

Lippmann M and Lioy PJ. 1985. Critical issues in air pollution epidemiology. *Environmental Health Prospective 62:243-258.*

Lipsett M, Hurley S and Ostro B. 1997. Air pollution and Emergency room visits for Asthma in Santa Clara county, California. *Environmental Health Perspectives, 105(20):216-222.*

Liu BC and Yu ESH. 1977. Mortality and air pollution revisited. *J. Air Pollution Control Association 26:968-971.*

Loehman ET, Park S and Boldt D. 1994. Willingness to pay for gains and losses in visibility and health. *Land Economics 70(4):478-98.*

Loehman, ET, Berg S, Arroyo A, Hedinger R, Schwartz J, Shaw M, Fahien R, De V, Fishe R, Rio D, Rossley W and Green A. 1979. Distribution analysis of regional benifits and cost of air quality control. *J. Environmental Economics and Management 6:222-243.*

Logan WPD. 1953. Mortality in the London fog incident 1952. *Lancet February 14 336-338.*

Lynn DA. 1976. *Air Pollution: Threat and Response.* Addison-Wesley Pub. Co.

Makut N and Fry S. 1992. Woodsmoke control in the Puget Sound Region, **in** JC Chow and DM Ono (Eds.), *PM10 Standards and Nontraditional Particulate Source Controls*, Air and Waste Management Association, Pittsburg.

Mark GB. 1994. A critical appraisal of the evidence for the adverse respiratory effects due to exposure to environmental ozone and particulate pollution: relevance to air quality guidelines. *Australian New Zealand J. Medicine 24:202-23.*

Marrack D. 1995. All PM10 are not biologically equal. *International Conference on Particulate Matter, Health and Regulatory Issues, Pittsburgh*, PA.

Martin AE and Bradley WH. 1960. Mortality, fog and atmospheric pollution, An investigation during the winter of 1958-1959. *Monthly Bull. Ministry of Health Lab Service, 19:56-73.*

Martin AE. 1964. Mortality and morbidity statistics and air pollution. *Proc. Roy. Soc. Med. 57:969-975.*

Mazumder S, Schimmel H and Higgings ITT. 1982. Relationship of daily mortality to air pollution: An analysis of 14 London winters. 1958/59-1971/72. *Archive of Environmental Health 38:213-220*

Miller FJ, Gardner DE, Graham JA, Lee RE, Wilson WE and Bachmann JD. 1979. Size considerations for establishing a standard for inhaleable particles. *J. Air Pollution Control Association 29:610-615.*

Miller TR, Lawrence BA, Jensen AM, Waehner GM, Spicer RS, Cohen MA. 1997. *The Consumer Product safety Commission's Revised Injury Cost Model.* Peer review Draft Prepared for the US Consumer Product Safety Commission, July.

Miller TR. 1989. Willingness to pay comes of age: Will the system survive? *Northwestern University Law Review 83:876-907.*

Ministry of Environment, Lands and Parks. 1995. *Fine Particulates, What they are and How they Affect Us*. Ministry of Environment, Lands and Parks British Columbia (BC), June

Ministry of Environment, Lands and Parks. 2001. *Woodsmoke.* Ministry of Environment, Lands and Parks, British Columbia (BC). www.epa.bc

Mishan EJ. 1971. Evaluation of life and limb: A theoretical approach. *J. Political Economy 79:687-705.*

Moolgavkar SH and Luebeck EG. 1996. A critical review of the evidence on particles air pollution and mortality. *Epidemiology 7:420-428.*

Moolgavkar SH, Luebeck EG, Hall TA and Anderson EL. 1985. Particulate air pollution, sulfur dioxide, and daily mortality: A reanalysis of the Steubenville data. *Inhalation Toxicology 7:35-44.*

Moolgavkar SH, Luebeck EG, Hall TA and Anderson EL. 1995. Air pollution, and daily mortality in Philadelphia. *Epidemiology 6: 476-484.*

Moore M, and Viscussi. 1988. Doubling the estimated value of life: results using new occupational fatality data. *J. Policy Analysis and Management 7:476-490.*

Morawska L, Thomas S, Bofinger N, Wainwright D and Nale D. 1998. Comprehensive Characterisation of Aerosols in a Subtropical Urban Atmosphere: Particles size distribution and correlation with gaseous pollutants. *Atmospheric Environment 32:2467-2478.*

Morgan G, Corbett S, Wlodarczyk J and Lewis, P. 1998a. Air pollution and daily mortality in Sydney, Australia. 1989-1993. *American J. Public Health 88(5):759-64.*

Morgan G, Corbett S and Wlodarczyk J. 1998b. Air pollution and hospital admissions in Sydney, Australia. 1990-1994. *American J. Public Health 88(12):1761-1766.*

Morgan G. 1996. Daily mortality and air pollution in Sydney, **in** *Proceedings of the Health and Urban Air Quality in NSW Conference, Sydney* June 3-4.

National Environment Protection Council (NEPC). 1997. *Towards a National Environment protection Measure for Ambient Air Quality*. Discussion Paper, August. NEPC, Adelaide.

National Environment Protection Council (NEPC). 2001. *The Need for a PM2.5 Standard in Australia*. Issues Paper. NEPC, Adelaide.

Navrud S. 1989. Estimating social benefits of environmental improvements from reduced acid depositions: a contingent valuation survey, **in** H Folmer and E Ireland (Eds.), *Valuation Methods and Policy Making in Environmental Economics.* Studies in Environmental Science 36, Elsevier.

Navrud S. 1998. Valuing health impact from air pollution in Europe: new empirical evidence on morbidity, Paper presented in the *World Congress of Environmental and Resource Economists*, June 25-27, Venice, Italy.

Neas LM, Dockery DW, Koutrakis P and Speizer FE. 1999. Fine particles and peak flow in children: acidity versus mass. *Epidemiology 10(5):550-3.*

Nichols A and Harrison D. 1990. *Benefits of the 1989 Air Quality Management Plan for the South Coast Air Basin: A Reassessment.* National Economic Research Associates Inc, Cambridge.

O'Donnell C. 2002. Personal Communication.

Oregon Department of Environmental Quality (DEQ). 2001a. *Preventing PM10 Particulate Pollution in Lakeview.* Oregon Department of Environmental Quality.

Oregon Department of Environmental Quality (DEQ). 2001b. *Preventing PM10 Particulate Pollution in Klamath Falls.* Oregon Department of Environmental Quality.

Ostro BD and Rothschild S. 1989. Air pollution and acute respiratory morbidity: An observation study of multiple pollutants. *Environmental Research 50:238-247.*

Ostro BD, Lipsett ML, Wiener MB and Selner JC. 1991. Asthmatic response to airbone acid aerosols. *American J. Public Health 81:694-702.*

Ostro BD, Lipsett M, Mann JK, Krupnick A, and Harrington W. 1993. Air pollution and respiratory morbidity among adults in Southern California. *American Journal of Epidemiology 137: 691-700.*

Ostro BD, Sanchez JM, Aranda C and Eskeland GS. 1996. Air pollution and mortality: results from a study of Santiago, Chile. *J. Exposure Analysis and Environmental Epidemiology 6:97-114.*

Ostro BD. 1983. The effect of air pollution on work loss and morbidity. *J. Environmental Economics and Management 10:371-382.*

Ostro BD. 1984. A search for a threshold in the relationship of air pollution to mortality: A reanalysis of data on London winters. *Environmental Health Prospect 58:397-399.*

Ostro BD. 1987. Air pollution and morbidity revisited: A specification test. *J. Environmental Economics and Management 14:87-98.*

Ostro BD. 1990. Associations between morbidity and alternative measures of particulate matter. *Risk Analysis 10:421-427.*

Ostro BD. 1993. The association of air pollution mortality: examining the case for inference. *Archive of Environmental Health 48:336-342.*

Ostro BD. 1994. *The Health Effects of Air Pollution: A Methodology with Applications to Jakarta.* World Bank Working Paper Series No.1301 Washington DC.

Ostro BD. 1998. *Air Pollution and Health Effects: A Study of Respiratory Illness Among Children in Santiago Chile.* World Bank Grant No. RPO 678-48.

Ozkaynak H and Thurston GD. 1987. Associations between 1980 US mortality rates and alternative measures of airborne particle concentration. *Risk Analysis 7:449-461*

Pearce D and Crowards T. 1996. Particulate matter and human health in the United Kingdom, *Energy Policy 24(7):609-619.*

Peat J, Toelle B, Gray EJ, Haby MH, Belouova E, Milles CM, and Woolcock AJ. 1996. Prevalence and severity of childhood asthma and allergic sensitisation in seven climatic regions of New South Wales. *Medical J. Australia 163: 22-26.*

Perry GB, Chai H and Dockery DW. 1983. Effects of particulate air pollution on asthmatics. *American J. Public Health 73:50-56*

Petroeschevsky A, Simpson RW, Thalib L and Rutherford S. 2001. Associations between outdoor air pollution and hospital admission in Brisbane, Australia. *Archives of Environmental Health 56:37-52*

Plagiannakos T and Parker J. 1988. *An assessment of Air Pollution Effects on Human Health in Ontario.* Energy Economics Section, Ontario.

Ponka A, Savela M and Virtanen M. 1998. Mortality and air pollution in Helsinki. *Archive of Environmental Health, 53(4):281-286.*

Ponka A. 1991. Asthma and low level air pollution in Helsinki. *Archives of Environmental Health 46(5):262-269.*

Pope CA and Dockery D. 1992. Acute health effect of PM10 pollution on symptomatic and asymptomatic children. *American Review of Respiratory Disease 145:1123-1128.*

Pope CA and Dockery D. 1996. Epidemiology of chronic health effects: Cross-sectional studies, **in** R Wilson and J Spengler (Eds.), *Particles in Our Air: Concentrations and Health Effects*, Harvard University Press.

Pope CA, Schwartz J and Ronsom M. 1992. Daily mortality and PM10 pollution in Utah Valley. *Archives of Environmental Health 42:211-217.*

Pope CA, Dockery D and Schwartz J. 1995. Review of epidemological evidence of health effects of particulate air pollution. *Inhalation Toxicology 7:1-8.*

Pope CA, Dockery D, Spengler JD and Raizenne ME. 1991. Respiratory health and PM10 pollution: a daily time series analysis. *American Review of Respiratory Disease 144:668-674.*

Pope CA, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE and Heath CW. 1995. Particulate air pollution as a predictor of mortality in a prospective study of US adult. *American J. Respiratory & Critical Care Medicine 151:669-674.*

Pope CA. 1989. Respiratory disease associated with community air pollution and a steel mill, Utah Valley. *American J. Public Health 79(5):623-628.*

Pope CA. 1991. Respiratory hospital admissions associated with PM10 pollution in Utah, Salt Lake, and Cache Valleys. *Archives of Environmental Health 46(2):90-97.*

Quraishi TA. 1987. *Emission from Residential Wood-Burning Heater: A Study of the Problem, its Measurements and Control and the Determination of some Emission Factors.* PhD Thesis, University of Tasmania.

Ramdahl T, Schjoldager J, Currie LA, Hanssen JE and Moller M. 1984. Ambient impact of residential wood combustion in Elverum, Norway. *The Science of the Total Environment. Vol. 26:81-90.* Elsevier Science Publishers, Amsterdam.

Ransom MR and Pope CA, 1992, Elementary school absences and PM10 pollution in Utah Valley. *Environmental Research 58:204-219.*

Ransom MR and Pope CA. 1995. External costs of a steel mill. *Contemporary Economic Policy B:86-97.*

Rau JA. 1989. Composition and size distribution of residential wood smoke particles. *Aerosol Sci. Technol. 10:181-192.*

Raufer RK. 1997. Particulate and lead air pollution control in Cairo: benefits valuation and cost-effective control strategies. *Natural Resources Forum 21(3):209-219.*

Rennick GJ. and Jarman FC. 1992. Are children with asthma affected by smog? *Medical J. Australia 156:837-41.*

Repace JL, Ott WR and Wallace LA. 1980. Total human exposure to air pollution, Paper No. 80-61-6 Presented at the *73rd Annual Meeting of Air Pollution Control Association,* June, Montreal, Canada.

Rice D. 1966. *Estimating the Cost of Illness.* Health Economics Series No. 6, US Department of Health Education and Welfare. US Government Printing Office, Washington DC.

Roberts G and Lin J. 1998. Armidale woodsmoke issue: NSW EPA Approach, **in**: KA Parton (Ed.), *Particulate Pollution in Australian Rural Towns.* Centre for Health Research and Development, University of New England, Armidale.

Roberts G. 1995. Armidale air quality monitoring: a joint initiative of Armidale City Council and Environment Protection Authority. Armidale Air Quality Workshop, Armidale, NSW.

Robinson DL, Monro J, Campbell EA and Gras JL. 1998. Air pollution from domestic heating and health, **in**: KA Parton (Ed.), *Particulate Pollution in Australian Rural Towns.* Centre for Health Research and Development, University of New England, Armidale.

Robinson DL. 1997. *Estimating Population Exposure to Woodsmoke Pollution in a Country Town in New South Wales.* Armidale Air Quality Group, Armidale NSW.

Robinson DL. 1999. Personal communication. Armidale NSW.

Robinson DL. 2001. Health cost of pollution and solutions, paper presented in *Firewood – a Burning Issue for 21st Century.* Armidale NSW, 25-26 May.

Roemer W, Hoek G and Brunekeef B. 1993. Effect of ambient winter air pollution on respiratory health of children with chronic respiratory symptoms. *American Review of Respiratory Diseases 147:118-124.*

Rosen S. 1974. Hedonic price and implicit markets: Product differentiation in perfect competition. *J. Political Economy 82(1):24-55.*

Rowe RD and Chestnut L. 1985. *Oxidants and Asthmatics in Los Angeles: A Benefit Analysis*. Energy and Research Consultants, Inc EPA, EPA-230-07-85-010. National Technical Information Service, Virginia, USA.

Rowe RD, Chestnut L, Peherson DC and Miller C. 1986. *The Benefits of Air Pollution Control in California*, Report prepared for California Air Research Board, Contract A2-118-32, Energy and Resources Consultants, Boulder, CO.

Rutherford S, Clark E, McTainsh G, Simpson RW and Mitchell C. 1999. Characteristics of rural dust events shown to impact on asthma severity in Brisbane. *International J. Biometeoral 42:217-24.*

Samet J, Zeger SL and Berhane K. 1995. The association of mortality and particulate air pollution, **in** *Particulate Air Pollution and Daily Mortality: Reproduction and Validation of Selected Studies*, Prepared by the Health Effects Institute, Cambridge, Massachusetts, USA.

Samet JM, Bishop Y, Speizer FE, Spengler JD and Ferris BG. 1981. The relationship between air pollution and emergency room visits in an industrial community. *J. Air Pollution Control Association 31:236-40.*

Schenker M. 1993. Air pollution and mortality. *New England J. Medicine 9(24):1807-08.*

Schulze WD, Cummings RG, Brookshire DS, Thayer MA, Whitworth R and Rathmatian M. 1984. Experimental approaches for valuing environmental commodities. **in** *Methods Development in Measuring Benefits of Environmental Improvements*, Vol. II. US Environmental Protection Agency, Washington DC.

Schwartz J and Dockery DW. 1992a. Increase mortality in Philadelphia associated with daily air pollution concentrations. *American Review of Respiratory Diseases 145:600-604.*

Schwartz J and Dockery DW. 1992b. Particulate air pollution and daily mortality in Steubenville Ohio. *American J. Epidemiology 135:12-20*

Schwartz J and Marcus A. 1990. Mortality and air pollution in London: A time series analysis. *American J. Epidemiology 131:185-194.*

Schwartz J and Neas LM. 2000. Fine particles are more strongly associated than coarse particles with acute respiratory health effects in school children. *Epidemiology 11(1):6-10.*

Schwartz J, Dockery DW and Neas LM. 1996. Is daily mortality associated specifically with fine particles? *J. Air & Waste Management Association 46:927-939.*

Schwartz J, Slater D, Larson TV, Pierson WE and Koeing JQ. 1993. Particulate air pollution and hospital emergency room visits for asthma in Seattle. *American Review of Respiratory Diseases 147:826-831.*

Schwartz J, Dockery DW and Neas LM, Wypij D, Wane JH, Spengler JD, Koutrakis P, Spiezer FE, and Ferris BG. 1994. Acute effects of summer air pollution on respiratory symptoms reported in children. *American Journal of Respiratory ans Critical Care Medicine 150: 1234-1242.*

Schwartz J. 1989. Lang function and chronic exposure to air pollution: A cross-section analysis of NHANESII. *Environmental Research 50:309-321.*

Schwartz J. 1991. Particulate air pollution and daily mortality in Detroit. *Environmental Research 56:204-213.*

Schwartz J. 1994a. Air pollution and hospital admissions for the elderly in Birmingham AL. *American J. Epidemiology 139:589-590.*

Schwartz J. 1994b. Air pollution and hospital admissions for the elderly in Detroit. *American J. Resper Crit. Care Med. 150:648-655.*

Schwartz J. 1994c. PM10, ozone, and hospital admission for the elderly in Minneapolis- St. Paul. *Archive of Environmental Health 49:366-374.*

Schwartz J. 1994d. Air pollution and daily mortality: a review and meta analysis. *Environmental Research 64:36-52.*

Seaton A, MacNee W, Donaldson K and Godden D. 1995. Particulate air pollution and acute health effects. *Lancet 345:176-178.*

Sexton K and Spengler J. 1984. Winter air quality in a wood-burning community: a case study in Waterbury, Vermont. *Atmos. Environ. 18:1357-1370.*

Simpson RW and London L. 1995. *An Economic Evaluation of the Health Impacts of Air Pollution in Australia.* Report to the Brisbane City Council.

Simpson RW, Williams G, Petroeschevsky A, Morgan G, and Rutherford S. 1997. Associations between outdoor air pollution and daily mortality in Brisbane, Australia. *Archive of Environmental Health 52(60):442-454.*

Smith VK and Desvousges W. 1986. Averting behaviour: Does it exist? *Economics Letters 20:291-296.*

Smith VK and Huang Ju-Chin. 1995. Can markets value air quality? A meta-analysis of hedonic property value models. *J. Political Economy 103:209-227.*

Smith VK. 1978. Measuring the value of urban amenities. *J. Urban Economics 5(4):370-387.*

Spengler J and Wilson R. 1996. Emissions, dispersion, and concentration of particles, **in** R Wilson and J Spengler (Eds.), *Particles in Our Air: Concentrations and Health Effects*, Harvard University Press.

Spix C, Anderson H, Schwartz J, Vigotti M, Letertre A, Vonk J, Touloumi G, Balducci F, Piekarski T, Bacharova L, Ponka A and Katsouyanni K. 1998. Short term effects of air pollution on hospital admissions of respiratory diseases in Europe: a quantitative summary of APHEA study results. *Archives of Environmental Health 53(1):54-64.*

Stapp AH and Harley RA. 1992. An effective wood burning control program: Albuquerque / Bernalillo County, New Mexico, USA, **in** JC Chow and DM Ono (Eds.), *PM10 Standards and Nontraditional Particulate Source Controls.* Air and Waste Management Association, Pittsburg.

Stoneman CS and Pace T. 1992. Technical guidance for residential wood combustions: reasonably and best available control measures, **in** JC Chow and DM Ono (Eds.), *PM10 Standards and Nontraditional Particulate Source Controls.* Air and Waste Management Association, Pittsburg.

Sunyer J, Saez M, Murillo C, Castellsague J, Martinez F, and Anto J. 1993. Air pollution and emergency room admission for chronic obstructive pulmonary disease: A 5-year study. *American J. Epidemiology 137:701-705.*

Thurston GD, Ito K, and Lippmann M. 1993. The role of particulate mass versus acidity in the sulfate-respiratory hospital admissions association, paper presented on *86th Annual Meeting of the Air and Waste Management Association*, June 13-18, Denver, CO.

Thurston GD, Ito K, Kinney PL and Lippmann M. 1992. A multi-year study of air pollution and respiratory hospital admission in three New York state metropolitan areas: Results from 1988 and 1989 summer. *J. Exposure Anal. Environ. Epidemiology 2:429-459.*

Tietenberg T. 1980. Transferable discharge permits and the control of source air pollution: A survey and synthesis. *Land Economics 56:391-416.*

Todd JJ. 1992. Where there's smoke: community education in Launceston, Tasmania. *Assoc. Environ. Educ. Biannual Conf, Perth* WA, 28 Sept- Oct.

Todd JJ. 1996. Addressing the urban wood-smoke in Australia, *13th International Clean Air and Environmental Conference, Adelaide.*

Todd JJ. 1998. *Air Quality implications of Increased Softwood Burning in the Australian Capital Territory*, Report to ACT Solid Fuel Working Party, October.

Tolley G and Babcock L. 1986. *Valuation of Reduction in Human Health Symptoms and Risk.* University of Chicago, Final Report to the Office of Policy Analysis, US Environmental Protection Agency.

Tucker CD. 1991. *An Investigation of Water Quality in Dumaresq Creek, Armidale*, Unpubl. BNatRes Thesis, University of New England, Armidale, NSW.

US Environmental Protection Agency. 1996. *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and technical Information*, Office of Air Quality Planning and Standards Staff Paper, Research Triangle Park, NC. Environmental Criteria and Assessment Office, EPA-452/R-96-013.

Utell MJ and Samet JM. 1993. Particulate air pollution and health: New evidence on an old problem, *American Review of Respiratory Disease 147:1334-1335.*

Viscusi WK, Magat WA and Huber J. 1991. Pricing environmental health risks: Survey assessments of risk-risk and risk-dollar trade-offs for chronic bronchitis. *J. Environmental Economics Management 21:32-51.*

Viscusi WK. 1986. The valuation of risks to life and health: guidelines for policy analysis. **in** Bentkover *et al.* (Eds.) *Benefits Assessment: State of the Art.* pp193-210. Reidel Publishing Co, Dordrecht.

Viscusi WK. 1992. *Fatal Tradeoffs: Public and Private Responsibilities for Risk,* Oxford University Press, New York.

Viscusi WK. 1993. The value of risks and life and health. *J. Economic Literature XXXI:1912-1946.*

Voigt T, Baily M and Abramson M. 1998. Air pollution in the Latrobe Valley and its impact upon respiratory morbidity. *Australian and New Zealand J. Public Health 22(5):556-561.*

Wall J. 1995. Note compiled for Armidale City Council/Environment Protection Authority Air Quality Workshop. 26 July, Armidale, NSW.

Wall J. 1997. *Sustainability of the Armidale Fuel Wood Industry on the Northern Tablelands of New South Wales: Resource Yield, Supply and Demand and Management Options.* Unpubl. PhD Thesis, University of New England, Armidale.

Wilson R. 1996. Introduction **in** R Wilson and J Spengler (Eds.), *Particles in Our Air: Concentrations and Health Effects.* Harvard University Press.

Whittemore A and Korn E. 1980. Asthma and air pollution in the Los Angeles Area, *American J. Public Health 70:687-696.*

World Health Organisation (WHO). 1982. *Estimating Human Exposure to Air Pollutants.* WHO Publication No. 69.

World Health Organisation (WHO). 1995. *Update and Revision of the Air Quality Guidelines for Europe "Classical" Air Pollutant.* WHO Regional Office, Copenhagen.

Wyzga RE, Lipfert FW. 1995. Temperature-pollution interactions with daily mortality in Philadelphia. Paper presented at the *AWMA Symposium on Particulate Matter: Health and Regulatory Issues*, Pittsburgh, PA.

Xu X, Dockery D and Wong L. 1991. Effects of air pollution on adult pulmonary function. *Archive of Environmental Health 46:198-206.*

Zaim KK. 1997. Estimation of health and economic benefits of air pollution abatement for Turkey in 1990 and 1993. *Energy Policy 25(13):1093-1097.*

Zib P. 1984. Modelling air quality for fugitive dust from open sources in Australia. *Proc. Eighth Int. Clean Air Conf. Melbourne.* 7-11 May.