

FIGURE 6: TOP DIRECT HUMAN-MADE AND NATURAL SOURCES OF PM_{2.5} EMISSIONS (TONNES/YEAR) FOR SYDNEY REGION (EPA 2012)



The most health-hazardous pollutant in our air (responsible for more premature deaths than any other pollutant) is PM_{2.5} pollution - fine particles less than 2.5 millionth of a meter that penetrate the deepest recesses of our lungs where they can enter the bloodstream and transport toxins to every organ of the body including the brain. PM_{2.5} pollution increases the risk of heart attacks, strokes, lung diseases, cancers, cot deaths, Alzheimer's and autism.

Sydney's PM_{2.5} pollution causes an estimated 520 premature deaths every year, resulting in the loss of 6,300 years of life. Although only a small proportion of Sydney households use wood heating, the Clean Air for NSW Consultation paper shows that wood smoke is the largest single source of PM_{2.5} emissions, contributing 47% of Sydney's annual PM_{2.5} particle pollution and up to 75% of particle emissions in July each year.

The consultation paper cites AECOM's economic analysis from 2011 that for current business-as-usual policies the

health costs of wood smoke in NSW are estimated at \$8.1 billion over 20 years. The analysis showed these health costs could be halved by requiring wood heaters to be removed before houses are sold. An additional \$2.2 billion could be saved by not allowing new wood heaters, which were estimated to have health costs of thousands of dollars per heater per year.

NSW Chief Medical Officer Kerry Chant said wood heaters are so detrimental to health she supports banning and phasing them out in built-up urban areas. When Launceston residents became aware of the health damage from woodsmoke, the vast majority chose to switch to non-polluting heating.

The success of Launceston's woodsmoke reduction program (which reduced wintertime deaths from respiratory disease by 28% and cardiovascular disease deaths by 20%) shows that informed communities support the recommendations of the NSW Chief Medical Officer.

The problem is that the vast majority of people in NSW have no idea about the health risks of breathing woodsmoke, or the advice of the NSW Chief Medical Officer. Although areas where woodsmoke builds up (such as Armidale) suffer the greatest health problems, anyone living near a house with wood heating has increased health risks from additional PM_{2.5} exposure. If NSW residents knew and understood the enormous health costs of wood



Emissions from new wood heaters satisfying the Australian "standard" to apply until 2019

Armidale, NSW, 9 August 2016.



smoke, a large majority would support the advice of the Chief Medical Officer of NSW.

The Federal Government's Wood Heater Consultation Regulation Impact Statement (CRIS) considered ways to reduce woodsmoke pollution. The policy options were predicted to reduce PM_{2.5} emissions by 4% to 20%. These options were considered so derisory that only 37% of submissions expressed a preference for any of them. Instead, 56% of respondents wanted an outright ban or moratorium on new installations until better regulations are implemented and 42% called for the wood heaters to be banned in urban areas. Adverse health effects on families, often requiring increasing medicinal solutions, including steroid use for asthma diagnoses in children, were reported in 39% of submissions. Similar neighbourhood examples were cited in submissions from other stakeholders, such as academic and community groups.

Policies should be based on what an informed public would want. Few would consider it acceptable to allow new heaters with estimated health costs of thousands of dollars per heater per year that emit more PM_{2.5} (the most health-hazardous air

pollutant) per year than 1,000 passenger cars. Typical emissions from brand new heaters satisfying the standard to apply until 2019 in NSW are shown in the photos (above). This represents an unsafe level of pollution.

Legislation is required urgently to prevent any more unsafe wood heaters from being installed in NSW. Although health impacts are particularly bad in areas where woodsmoke builds up (e.g. Armidale), anyone living near to a new wood heater will suffer increased health risks because of the resulting increase in PM_{2.5} exposure.

A peer-reviewed paper published in *Air Quality and Climate Change* (August/November 2016) found little or no benefits from recent woodsmoke-reduction programs that attempted to persuade people to operate heaters correctly. These programs often involve substantial costs, e.g. Armidale Dumaresq Council's submission to the wood heater CRIS in 2013 states that "Council has taken an active role for over 20 years seeking to bring about an improvement in local air quality" and "has committed more than \$300,000 (excluding wages) in the past 10 years on wood smoke abatement measures." As in Launceston, initial efforts concentrated on replacing wood heaters with non-polluting heating. However, the main focus in the past 10 years has been on persuading residents to operate heaters correctly. Measurements show that Armidale's woodsmoke pollution is now worse than in 1999. Appeals to operate heaters correctly appear to have little effect.

Research indicates that the credibility of health information messages is weakened when people sees new wood heaters emitting large plumes of smoke. Many residents seem to conclude that wood smoke could not possibly be dangerous because smoky wood heaters continue to be installed, instead of affordable, non-polluting alternatives.

Modern, efficient heat pumps have superseded wood stoves and natural gas as the most cost-effective heating. They can deliver 5 or 6 times as much heat to the home as they use in electric power and are effective at low temperatures, providing 3 to 4.5 times as much heat even when the temperature outside is -10 °C (10 degrees below freezing). They are affordable (cheaper than buying a wood heater), cause less global warming (zero in households that use green power) and have lower running costs than buying firewood.

Given the widespread availability of affordable, non-polluting alternatives, the most equitable and cost-effective policy is not to permit new wood heaters. As well as preventing additional unhealthy pollution, this policy helps wood heater users realize that the health effects of woodsmoke pollution are serious and that every effort should be made to operate heaters correctly. Residents whose health or lifestyle is affected by other people's woodsmoke also need

assistance. Funding could be raised by a small “polluter-pays” levy on wood heater use, which, according to AECOM’s economic analysis, would reduce the health costs of woodsmoke and save NSW another \$1.28 billion.

One of the most cost-effective ways to gain public support for such measures is to demonstrate that non-polluting heating is more affordable than a wood heater and has lower running costs. In Armidale, Starfish Initiatives, a registered charity that aims to promote sustainability, has a proposal for a program to use traditional and social media to encourage expressions of interest for assistance to replace wood heaters with affordable, non-polluting, climate-friendly heating, with the help of energy audits, pollution measurements and a dedicated website to provide information on the project’s progress and the health effects of woodsmoke. Armidale would be an ideal location for such a demonstration project. We hope this idea will become a reality for the benefit of the local community and the millions of NSW residents experiencing increased risk of health problems from woodsmoke.

The Clean Air for NSW Consultation paper has many useful strategies – replacing 2-stroke garden equipment, encouraging cycling and walking (and ideally encouraging lighter vehicles in preference to SUV in urban areas), tackling off-road diesel emissions, reducing the health impacts of hazard-reduction and other open burning, minimizing emissions from coal-fired power stations and strengthening the mine rehabilitation framework.

This submission concentrates on wood heating because of its massive, disproportionate contribution to PM2.5 emissions and consequent damage to public health. Wood heater regulation is the most blatant example of failed policy. Families who buy new wood stoves have no idea that the current 'standard' of 2.5 g/kg is so lax that the average new wood heater emits more pollution per year than 300 diesel SUV and has estimated health costs of \$3,700 per year in Sydney. Implementing the chief medical officer's recommendation is the quickest and most cost-effective way to clean up our air and prevent hundreds of premature deaths every year.

Air quality is a very important health and environmental issue. We would like to be kept informed via email and participate in future air quality initiatives.

What makes a Successful Woodsmoke-Reduction Program?

D L Robinson

ABSTRACT

Launceston's successful woodsmoke program reduced wintertime deaths from respiratory disease by 28% and cardiovascular disease deaths by 20%. Year round, for men, the reductions were 23% (respiratory), 18% (cardiovascular) and 11.4% (all deaths). The focus was on explaining the health effects of woodsmoke pollution and replacing wood stoves with non-polluting heating. In contrast, programs in NSW and the more recent programs in Tasmania that encouraged residents to operate heaters correctly do not appear to have been effective.

Modern, efficient heat pumps have superseded wood stoves and natural gas as the most cost-effective heating. They can deliver 5 or 6 times as much heat to the home as they use in electric power and are effective at low temperatures, providing 3 to 4.5 times as much heat even when the temperature outside is -10°C (10 degrees below freezing). They are affordable (cheaper than buying a wood heater), cause less global warming (zero in households that use green power) and have lower running costs than buying firewood. The vast majority of Australian and New Zealand households use non-polluting heating.

New woodsmoke programs should focus on explaining the health effects to the entire community to gain support for legislation to implement the recommendations of the NSW Chief Medical Officer, the UN Environment Program and World Meteorological Organization to gradually phase out log-burning heaters in areas where affordable non-polluting alternatives are available. A NSW EPA Consultancy report identified 3 extremely cost-effective measures – not permitting new log-burning heaters to be installed, requiring existing heaters to be removed when houses are sold, and requiring households a small 'polluter-pays' annual licence for wood heaters that could help fund education and home insulation programs and replacing wood heating with non-polluting alternatives. These 3 measures were estimated to reduce the \$8 billion health cost (over 20 years) of woodsmoke in NSW by at least 75%. An informed community, that fully understands the health effects of breathing woodsmoke, would most likely support these measures.

Keywords: Woodsmoke Reduction, Air Pollution, Heat Pump, Home Heating, PM2.5, Health

INTRODUCTION

Recent studies with improved estimates of air pollution (land measurements combined with satellite data or output from land-use regression models) show that fine particle pollution is much more hazardous to health than previously thought. In New Zealand (NZ), a $10\text{ }\mu\text{g}/\text{m}^3$ increase in annual PM10 exposure was found to increase adult all-cause mortality by 7% (Hales *et al.* 2012). This result was used in an updated Health and Air Pollution in New Zealand Study (HAPINZ) in which man-made particle pollution was estimated to cost NZ\$4.28 billion per year or \$1,061 per person. More than half (56%) of the cost was attributed to domestic fires and wood burners (Kuschel *et al.* 2012). Only a minority of NZ households have wood heating (census data: 39% in 2006; 34.7% in 2013) so the estimated cost amounts to thousands of dollars per wood heater per year. In New South Wales (NSW) the health costs of woodsmoke were estimated at more than \$8 billion over 20 years, *i.e.* more than \$20,000 for every wood heater in NSW. This article reviews the efficacy of woodsmoke-reduction campaigns and the attitude of wood heater users, in order to identify the best and most cost-effective options for reducing or eliminating woodsmoke pollution and the associated damage to health.

WOODSMOKE CAMPAIGNS

Success in Launceston – 40% less PM2.5 and fewer deaths

Launceston's successful woodsmoke program reduced deaths in winter from respiratory disease by 28% and cardiovascular disease by 20%. Year round, for men, the reductions were 23% (respiratory), 18% (cardiovascular) and 11.4% (all deaths, Johnston *et al.* 2013). The program focussed on the health effects of woodsmoke pollution. Wood stove users were encouraged to switch to non-polluting heating by the slogan: *"Isn't it time to you gave up smoking?"* Expenditure was modest – 2,000 households received subsidies of about \$500 to remove wood heaters. Many other households replaced wood stoves with non-polluting heating entirely at their own expense.

Tasmania's Burn Brighter Campaign and 'SmartBurn' catalysts ineffective

The improvements in Launceston were contrasted with two recent campaigns in a conference presentation by Dr Fay Johnston (Johnston 2016). A 'Burn Brighter'

campaign told residents of one town that "smoke pollution increases death rates in the community, but the good news is we can reduce the amount of smoke, save lives and also save money by following a few simple steps." In another town, 78% of wood heater users were given a 'SmartBurn' catalyst. After adjusting for temperature, humidity wind speed and air pressure, there was no difference in pollution measurements between the 'Burn Brighter' and 'SmartBurn' towns and two control towns. The overall conclusion was that improved emissions standards, education to improve wood heater use and retrofitting catalysts were ineffective in reducing pollution, but removing wood heaters was highly effective. Woodsmoke was said to be Tasmania's most important contributor to poor health. Future heating needs to be affordable, acceptable, ultra-low polluting and fool-proof (Johnston 2016).

Muswellbrook – continued high woodsmoke pollution

The Hunter valley town of Muswellbrook is close to open-cut mines and power stations that generate enough electricity for 3.25 million homes. PM2.5 monitoring began in December 2010, with an average of $6.4\text{ }\mu\text{g}/\text{m}^3$ to 30 April 2011. Values started to increase in May, which had a monthly average of $12.9\text{ }\mu\text{g}/\text{m}^3$. A press release in June 2011 by the NSW Office of Environment and Heritage stated that the *"higher concentrations of PM2.5 particles measured at the Muswellbrook and Singleton air quality monitoring sites over the weekend was likely due to woodheater use"* (NSW OEH 2011). The Upper Hunter Fine Particle Characterisation Study (UHFPS) focussed on PM2.5, because this pollutant *"is associated with greater health risks than coarser particle pollution"* (NSWEPA 2013). The final report confirmed the substantial contribution from woodsmoke (Hibberd *et al.* 2013, Figure 1).

Muswellbrook received grants of \$40,000 in 2013 and 2014 for woodsmoke reduction (UHAQAC 2015). The NSW EPA's 'Stay warm, breathe easy' leaflet, told homeowners that *"By making a few simple changes you can enjoy the warmth of your wood heater and reduce wood smoke and its impact on you and other people in your community."* The graph of PM2.5 measurements by year and month (Figure 2) shows the program had very little effect on pollution levels.

No reduction in Armidale

Woodsmoke pollution has been recognised as a problem in Armidale, NSW for many

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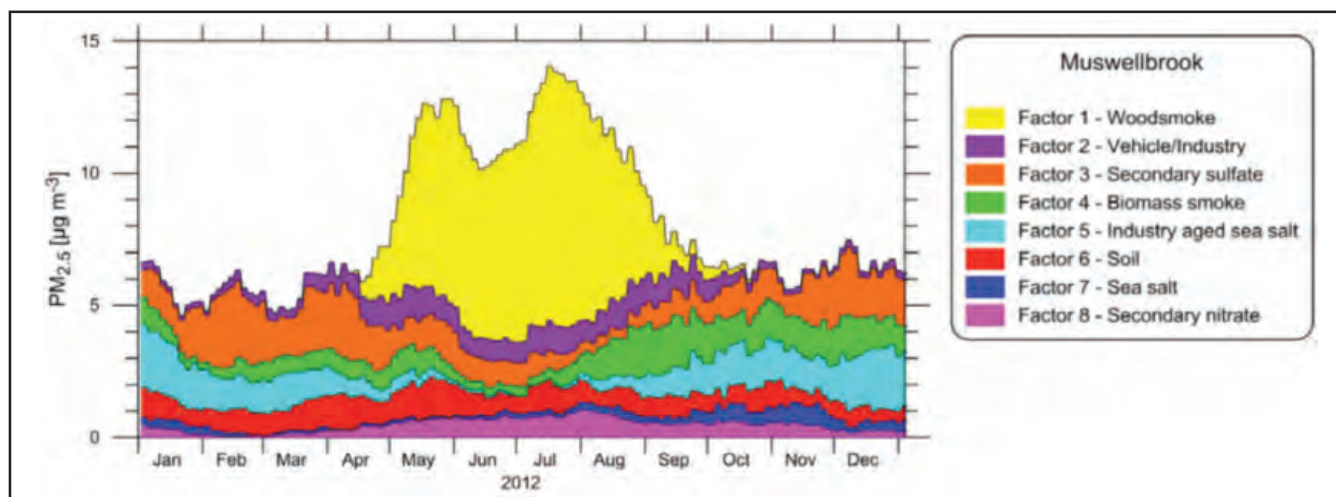


Figure 1 – Results of the Upper Hunter Fine Particle Characterisation Study (Hibberd *et al.* 2013) showing the substantial contribution (62% in winter, 30% year-round) from domestic wood heating.

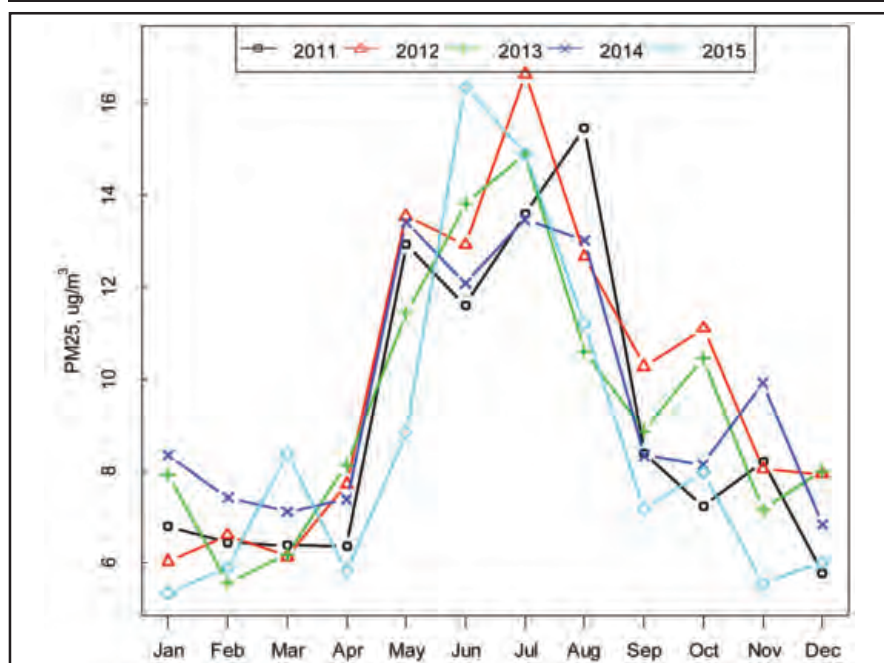


Figure 2 – Monthly average PM_{2.5} measurements in Muswellbrook (source: NSW EPA data).

years. As in Muswellbrook, the focus has been on educational programs to encourage owners to operate wood stoves correctly. For example, Armidale Regional Council's website (2016) tells residents: "When operated properly, the vast majority of wood heaters will burn without smoking excessively. Laboratory tests by experts have shown that operating a wood stove properly, burning a hot fire with dry wood, can reduce smoke levels by up to 90%."

A pollution-mapping exercise in 1996 concluded that Armidale's woodsmoke increased PM_{2.5} exposure by about 11.5 µg/m³, equivalent (according to standard exposure-response-relationships) to about 11.5 premature deaths every year, or a loss of 115 years of healthy life (Robinson *et al.* 2007). Little, if any, progress has been made in cleaning up the air, which has many more high-polluted days than Muswellbrook (Figure 3). Since 2011, new wood heaters installed in Armidale must have an emissions rating < 2.5 g/kg (the Australian standard that will apply until 2019) and residents are provided with information on how to operate them correctly. When woodsmoke was measured at the Armidale CBD from June to August 1999 (for a study that found a significant

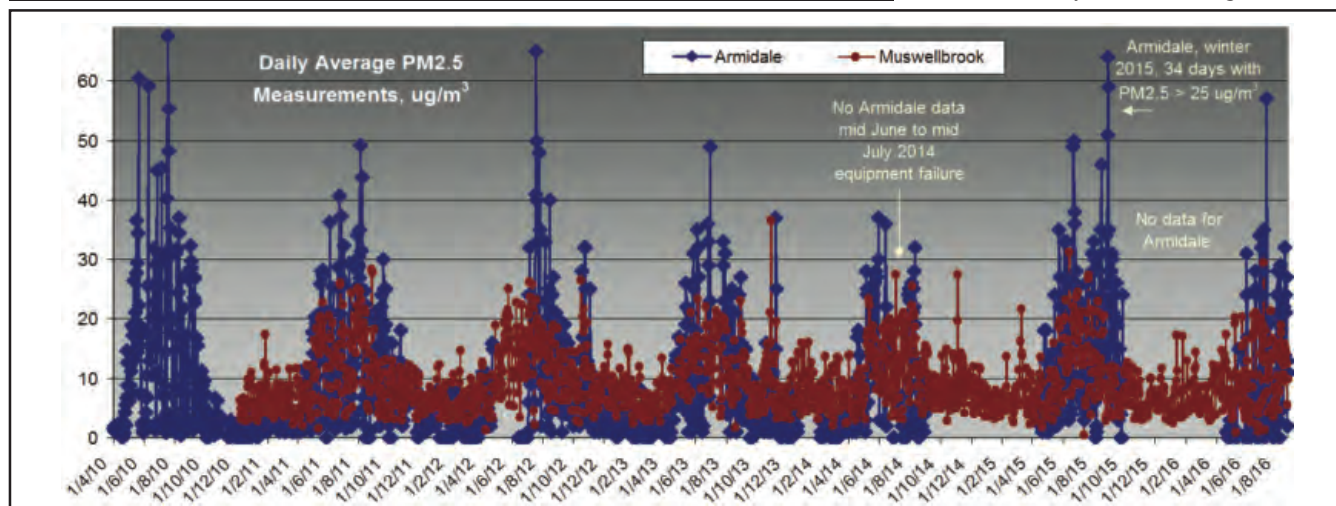


Figure 3 – Comparison of PM_{2.5} measurements in Muswellbrook (NSW EPA data) and with PM_{2.5} at the council building in Armidale (measured by a DustTrack calibrated for woodsmoke).

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relationship between woodsmoke pollution and visits to GPs for respiratory complaints, estimated to cost over \$150,000 per year, Khan *et al.* 2007), PM_{2.5} averaged 13.9 $\mu\text{g}/\text{m}^3$. The same months in 2015 averaged 14.1 $\mu\text{g}/\text{m}^3$. Life expectancy of men in the New England North West (77.9 years) is 3.7 years less than the average for greater Sydney. Central Armidale had 34 days in the 2015 wood heating season when the daily average PM_{2.5} exceeded 25 $\mu\text{g}/\text{m}^3$ (and 53 days exceeding the standard to apply in 2025). In a submission to the Federal Government in 2013 on wood-heater regulation, Armidale Dumaesq council stated: "It is estimated that Council has committed more than \$300,000 (excluding wages) in the past 10 years on wood smoke abatement measures." Figure 4 (taken 9 August 2016) shows that little has been achieved by efforts to persuade residents to operate heaters correctly.

Woodsmoke up to 40% of Newcastle & Sydney's winter PM_{2.5}

In April 2016, the final report of the Lower Hunter Particle Characterisation Study noted that a substantial proportion of Newcastle's wintertime PM_{2.5} pollution is woodsmoke: 41% (2.8 $\mu\text{g}/\text{m}^3$) at Beresfield, 31% (1.8 $\mu\text{g}/\text{m}^3$) at Newcastle and Mayfield, and 11% (1.2 $\mu\text{g}/\text{m}^3$) at Stockton (Hibberd *et al.* 2016). In Liverpool, Sydney, ion beam analyses were used to determine the source of particles collected on filters. Woodsmoke "represented around 40% of the fine fraction in winter dropping to nearly zero in the summer" (Cohen *et al.* 2011). The 2008 emissions inventory (NSWEPA 2013) lists residential wood heating as emitting 5,457 tonnes PM_{2.5} per year, 51% of all Sydney's PM_{2.5} emissions. The Sydney Particle Characterisation study (SPCS, Phase 2, from 16 April to 14 May at Westmead) also investigated woodsmoke. The build-up of levoglucosan in the second half of the observation period was found to be related to the onset of cooler ambient temperatures and therefore considered likely to have a significant wood heater component (Cope *et al.* 2014). A case study combined the SPCS measurements with the emissions inventory data to estimate that in winter residential wood heating accounts for 10 to 30% of population PM_{2.5} exposure (Cope *et al.* 2014). Monthly average PM_{2.5} measurements for 2014 and 2015 (Figure 4) are consistent with the chemical analyses. Muswellbrook (62% of wintertime PM_{2.5} from wood heating) has the highest PM_{2.5} measurements in winter, with Liverpool (40%) second. PM_{2.5} measurements in other locations show smaller wintertime peaks. The smaller peak in springtime in Figure 5 might relate to bushfires or hazard-reduction burns.

Modest success in New Zealand

The proportion of NZ households using wood as primary or secondary heating declined from 42.8% in 2001 to 39% in 2006 and 34.7% in 2013 (Statistics NZ 2015); there was an estimated 23% reduction in PM_{2.5} emissions from home heating from 2006 to 2013 (MFE & Statistics NZ 2015). Pollution, however, remains above acceptable limits.



Figure 4 – Armidale, NSW, 9 August 2016.

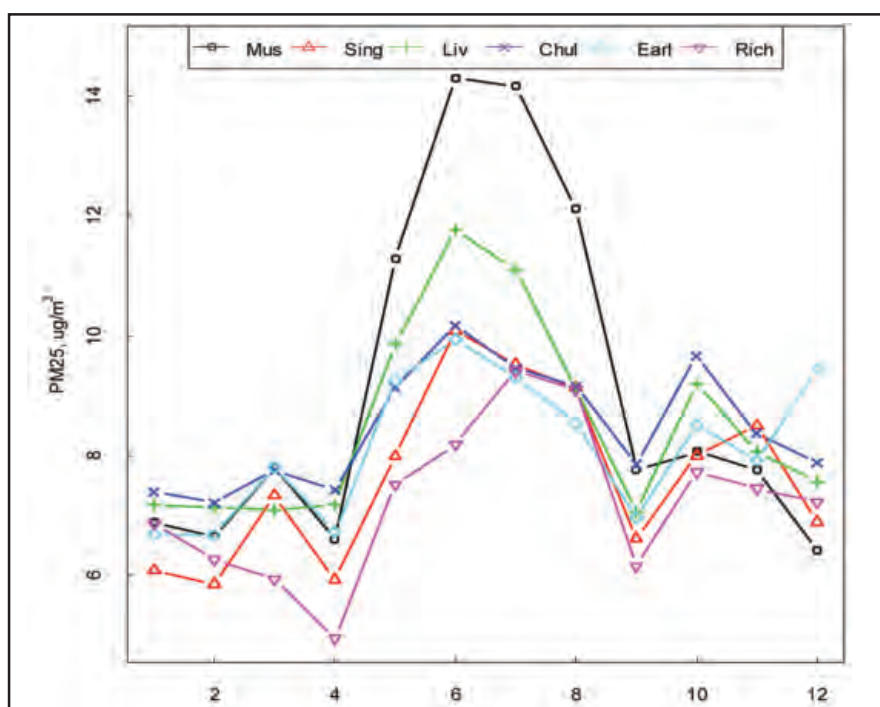


Figure 5 – Monthly average PM_{2.5} measurements (NSW EPA data) in 2014/15 in the Hunter Valley (Muswellbrook and Singleton) and Sydney (Earldown, Chullora, Richmond and Liverpool).

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In 2013, Christchurch exceeded the WHO PM_{2.5} guideline of 25 µg/m³ on 22 days; Masterton had 36 exceedances and Timaru 55. The majority (96%) of exceedances were from May to August (the colder months) and attributed to home heating emissions (MFE & Statistics NZ 2015). The WHO annual guideline of 10 µg/m³ was exceeded in the 3 cities by 9 to 40% (MFE & Statistics NZ 2015).

Progressively stricter woodsmoke policies have been introduced in Christchurch since 2000 when all new heaters were required to have emissions ratings < 1.5 g/kg. A reduced limit of 1.0 g/kg was required in Christchurch in 2002, and the entire Canterbury area from 1 January 2004. In addition, new houses and homes without wood heaters in Christchurch were not permitted to install them after 2002. An emissions inventory for 2009 reported that electricity was the most popular form of heating (81% of households) in metropolitan Christchurch. Only 18% reported using log-burning heaters (Smithson 2011). From April 2010, Christchurch also prohibited the use of wood heaters more than 15 years old. Real-life emissions, measured in 4 studies from 2003 to 2009 involving a total of 37 households, averaged 6.6 g/kg dry wood (5.0 g/kg wet), much higher than the average ANZS4013 ratings of 0.85 g/kg (Wilton 2012).

The 'Canterbury 1' test procedures were published in January 2015 to encourage the development of ultra-low emission wood burners with thermal efficiency of at least 65% that *"under strict real life operating conditions can meet an emissions and efficiency standard of 38 milligrams per megajoule or emits less than 0.5 grams of particulate per kg of fuel burned"* (ECAN 2016). Ultra-low emission wood-burners (currently 8 models are available) will be permitted in all houses. The impact of this change remains to be seen. Not all aspects of incorrect operation are easily overcome by improved technology. For example, arsenic can exceed national ambient air quality guideline of 5.5 ng/m³ by up to 2 times because of illegal burning of treated timber (Cavanagh *et al.* 2012). In Australia, 42% of the lead in Muswellbrook's air was attributed to burning painted wood in domestic wood heaters, despite advice to the contrary (Hibberd *et al.* 2013). However, real-life emissions of 0.5 g/kg offer the possibility of further improvements using filtration technology (that have enabled substantial reductions in pollution from power stations and diesel vehicles) as well as the possibility of sensors to detect lead, arsenic or other toxins. A health impact assessment noted that most wood burning households were upper or middle income earners (ECAN & CDHB 2014).

ATTITUDES OF WOOD STOVE USERS

In the hope of achieving greater reductions in woodsmoke pollution, a study was commissioned into heating methods and attitudes of wood stove users in the Hunter Valley (Databuild 2016). The study found that a considerable majority of households (73%)

in Muswellbrook and Singleton do not use wood heating. About half the households with wood heaters (14% of the total) were in town centres or other urban areas, where population exposure to PM_{2.5} pollution is of greatest concern.

Attitudes of wood heater users were determined from a sample of 203 households using wood heating; 77% were in town centres and 23% in villages out of town. Only 28.6% of respondents agreed with the statement that "particles in the smoke coming out of the chimney can be harmful to my family and my neighbours' health." A similar lack of understanding was shown in Armidale Dumaresq Council's consultation on wood heater policy in 2010; only 34% of the 84 respondents thought that woodsmoke was a serious health problem.

The general conclusion of the researchers was that there was little awareness of, and a reluctance to acknowledge, the harmful effects of woodsmoke. Wood heater users often dismissed the results of published studies showing the contribution of woodsmoke to the pollution in the Hunter Valley, e.g. when Figure 1 was shown to focus groups, wood stove users often described it as 'untruthful'.

Only 18% of wood heater users were classed as 'conditional accepters' who were prepared to listen and even change their behaviour around wood heaters if they were convinced that it would be worthwhile and any changes were not too onerous. The remainder were classed as oblivious (don't understand that wood smoke is harmful to human health), rejecters (don't accept that wood smoke is harmful to human health) and 'rationalisers' (don't consider any harm caused by wood smoke to be of concern, or as bad as that caused by mining and other sources of particle pollution).

These attitudes provide considerable insight into why the woodsmoke-reduction programs in Armidale and Muswellbrook have failed to reduce pollution. Governments are expected to regulate harmful substances. Lead in petrol and asbestos were banned. Regulations also protect people against passive smoking. The public sees a simple, consistent message about cigarettes because adverts promoting tobacco are banned. In contrast, public information about wood heaters consists mainly of glamorous adverts for new heaters. None ever give the faintest impression that woodsmoke could be harmful. Instead, prospective purchasers are told that wood heaters benefit the environment. Together with the current lack of regulation on woodsmoke, these messages negate current efforts to reduce woodsmoke and give the impression that woodsmoke cannot possibly be harmful, or anything like as bad as passive smoking.

Many people remember benzo[a]pyrene (BaP) as the known human carcinogen featured in the "every cigarette is doing you damage" TV adverts, but very few understand that burning 10 kg of wood in a correctly-operated Australian heater emits as much BaP as in the smoke from a quarter of a

million cigarettes (AAQG 2014).

Figure 6, showing emissions from brand-new heaters installed in new houses Armidale, demonstrates that reality bears little or no relationship to the adverts. All except the top left chimney are known to satisfy the current AS4013 standard that will apply until 2019. Complaints to the local council about the level of emissions appear to have no effect, even when excessive outdoor PM_{2.5} levels are shown to cause excessive indoor PM_{2.5} levels (Appendix 4) in a house with tightly closed windows and sealing tape applied around the door.

SUMMARY OF HEALTH EFFECTS

NSW Chief Medical Officer Kerry Chant said wood heaters are so detrimental to health she supports banning and phasing them out in built-up urban areas (Gilmore 2014). The NSW Asthma Foundation warned: wood smoke emissions in winter pose a bigger health danger in built up urban areas than cars or cigarettes. Australian Lung Foundation spokesman Dr James Markos said wood fire heaters should be banned from urban areas. He said *"real-life emissions from new wood-heaters have little relationship to measurements from a perfectly operated test model under laboratory conditions"* (Gilmore 2014). A source apportionment study found that: *"Across four US cities, among the primary PM_{2.5} sources assessed, biomass burning PM_{2.5} was most strongly associated with respiratory (ill) health"* (Krall *et al.* 2016).

Woodsmoke, and the PM_{2.5} pollution it contains, is linked to reduced ability of the lungs to fight infection, elevated blood pressure, increased risk of heart attacks, strokes, lung diseases, Alzheimer's, smaller brains, cancers (lung, mouth, throat, breast and cervical cancers in adults, blood and brain cancers in children), cot deaths, genetic damage in babies and reduced IQ and behavioural problems when children start school (AAQG 2015). For women over 70, increased exposure of 3.5 µg/m³ PM_{2.5} reduced the volume of white matter in the brain by 6.2 cm³ (Chen *et al.* 2015). The American Heart Association published a study in their journal, Stroke, showing that, for people over 60, increased PM_{2.5} exposure of just 2 µg/m³ was associated with a 0.32% smaller total cerebral brain volume and a 46% higher risk of covert brain infarcts, a type of silent stroke (AHA 2015). One in six Australians will be affected by stroke, the nation's leading cause of disability (Fisher 2015). Living downwind of one Australian wood heater (new or old) will often increase annual PM_{2.5} exposure by more than 2 µg/m³.

Woodsmoke was found to cause 12 to 30 times as many tumours in mice and mutations in bacteria as the same amount of cigarette smoke (Naeher *et al.* 2007). Breathing cigarette smoke transports chemicals to the bloodstream and directly to smokers' brains. Similarly, the cancer-causing chemicals in woodsmoke enter the bloodstream and are carried to every organ in the body, causing similar health problems



Figure 6 – Emissions from new wood heaters satisfying the Australian “standard” to apply until 2019.

– heart attacks and strokes as well as lung diseases, cancers and premature aging (Numan *et al.* 2015). Few people realise that PM_{2.5} causes more premature deaths than any other air pollutant (WHO 2016), that there is no safe level of PM_{2.5} pollution, or that the average new Australian wood stove emits more PM_{2.5} per year than 1,000 passenger cars (AAQG 2011).

Fierce opposition from wood heating industry

Past efforts to protect public health have been fiercely opposed by the wood heating industry. In 2007, the majority of the Standards Committee supported an interim measure (by 15 votes to 4) of halving the wood heater emissions limit while a test to measure real-life emissions was being developed. The recommendation was not implemented because of opposition from wood heating industry. Work on the

developing a new test and updating the standard was abandoned. A new committee approved a weaker “standard” in August 2014 based on the original test that bears little relationship to real-life emissions. Despite being nowhere near adequate to protect human health, the only option for the new committee would be to approve the changes as better than nothing. When legislation aiming to reduce woodsmoke was proposed in the Australian Capital Territory (ACT), the AHHA (the peak wood heating industry body) spent so much money opposing politicians at the 2012 ACT election that it was fined for breaking political funding laws (Cox *et al.* 2014). The AHHA also fiercely opposed Camden Council’s initiatives to require all new heaters to have emissions ratings of 1.0 g/kg or less. They hired billboards, paid for prominent advertising on the back of buses and in newspapers quoting AHHA General Manager Demi Brown that “the justification

for the draft planning proposal was not driven by the results of any strategic study or evidence-based report.” In fact, a study in 2006 (BDA 2006) found a net benefit of \$1.1 billion if Camden council’s proposals were adopted universally. The AHHA was also noted to have misled the Senate Inquiry into Air Pollution and Health about the failure or the Standards Australia Committee to agree on a new standard in 2007. The wood heating industry’s claims of environmental benefits are extremely dubious, in the light of recommendations by the UN Environment Program and World Meteorological Organization to phase out log-burning heaters in developed countries to reduce global warming as well as improve health (see Appendix 2 for details).

AUSTRALIAN FEDERAL GOVERNMENT: DELAYS & INEFFECTIVE POLICIES

In March 2008 the Environment Protection and Heritage Standing Committee (EPHSC) agreed that a nationally consistent approach to wood heater emissions was needed and that the EPHSC would develop a consultation regulation impact statement (CRIS) (NEPCSC 2013). The CRIS was produced 5 years later. It discussed the high cost of particle emissions, ranging from \$263 per kg in Melbourne and Sydney to \$113 in smaller capital cities and regional centres (e.g. Launceston, Armidale, Wagga). Combined with the NSW EPA’s estimate of 5,457 tonnes of PM_{2.5} emitted every year by wood heating in Sydney, this implies annual health costs of \$1.44 billion in a city where only 4.4% of households use wood as the main form of heating (ABS 2014), comparable or greater than the estimate of \$600 million to \$1.5 billion (AMA 2013) for vehicle emissions over the entire country. Even under the best practice operation achieved in Launceston, a new heater burning Sydney’s average of 2 tonnes per year will emit 18.8 kg PM_{2.5} with estimated annual cost in Sydney of \$4,944.

The CRIS options were predicted to reduce PM_{2.5} emissions by 4% to 20%; they were considered so derisory that only 22 (37%) of submissions expressed a preference for any of them. Instead, 56% of respondents wanted an outright ban or moratorium on new installations until better regulations are implemented; 42% called for the wood heaters to be banned in urban areas. Adverse health effects on families, often requiring increasing medicinal solutions, including steroid use for asthma diagnoses in children, were reported in 23 submissions (39%). Similar neighbourhood examples were cited in submissions from other stakeholders, such as academic and community groups.

A decision RIS (DRIS) was prepared by the Department of Environment (DOE 2016) and assessed by the Office of Best Practice Regulation (OBPR). Despite not being supported by the majority of submissions, the DRIS argued that not permitting new installations would imposing unnecessary restrictions on households in areas not experiencing air quality impacts from wood

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heaters. This ignores the fact that there is no 'safe' level of pollution (Barnett 2014), i.e. every wood heater adds to health costs, irrespective of whether it is in an area with recognised air quality impacts. Continuing to allow new wood heaters with estimated health costs that are considerably higher than any possible benefit imposes substantial, unnecessary costs on the rest of the community. The DRIS also argued that not allowing new heaters might result in some owners holding on to existing heaters instead of upgrading them. This problem was avoided in Christchurch by not allowing new wood burners, except models rated < 1.0 g/kg installed as replacements for more polluting heaters.

Appendix 1 lists the policies to be adopted as part of DRIS, including permitting the installation of heaters with emissions at the level shown in Figure 6 and no realistic mechanism to protect neighbours. A stated aim is to develop and adopt a common definition of excessive smoke. An obvious definition is the amount that could damage the health of neighbours. However, with recent research showing increased PM_{2.5} exposure of just 2 µg/m³ associated with a 0.32% smaller total cerebral brain volume and a 46% higher risk of covert brain infarcts (Wilker *et al.* 2015), even wood heaters with no visible smoke emissions could pose an unacceptable risk.

The argument in the DRIS that wood heaters are a cost-competitive form of heating is demonstrably false when community health costs (thousands of dollars per heater per year) are included in the equation. The same logic of ignoring health costs would lead to the conclusion that asbestos is a cost-competitive building material. Effective regulations were required because the benefits are not worth the risk.

Meeting the NEPM particle standards (max annual average PM_{2.5} of 8 µg/m³, falling to 7 µg/m³ in 2025) was described as a challenge "in Sydney and some regions in New South Wales, where relatively high use of solid fuel heaters produces elevated levels of particles in autumn and winter" (NEPC 2013). In 2013, the highest average PM_{2.5} pollution (9.5 µg/m³) was at Liverpool, Sydney, where woodsmoke was noted to represent around 40% of PM_{2.5} in winter (Cohen *et al.* 2011). With an estimated 520 premature deaths in Sydney every year (representing a loss of 6,300 life years, Morgan *et al.* 2013), tackling the disproportionate contribution from domestic wood stoves would entail much lower costs and achieve greater benefits than tackling pollution from vehicles or coal mining.

The Australian Energy Efficiency Council (AEEC) criticized current regulatory processes as not in the public interest, citing delays in introducing new and updated standards. For example, the lack of appropriate air-conditioner standards before 2009 was considered to have contributed to the rapid growth in peak electricity demand and rise in electricity prices (AEEC 2016).

POLICIES NEEDED TO PROTECT PUBLIC HEALTH

Policies should represent the wishes of an informed community

Once Launceston residents understood the health effects of breathing woodsmoke, most chose to switch to non-polluting heating. The chief medical officer of NSW advised that wood heaters are so detrimental to health she supports bans and phase-outs in built-up urban areas. It seems unlikely that an informed community would not disregard the advice of the NSW chief medical officer or support use of heaters that emit more PM_{2.5} per year than 1,000 passenger cars and with estimated health costs of thousands of dollars per year that could increase PM_{2.5} for neighbouring residents by 2 µg/m³, especially in the light of studies that even this modest increase was associated with a 0.32% smaller total cerebral brain volume and 46% higher risk of covert brain infarcts (AHA 2015).

Wood-heater standards should represent the interests of the whole community

The most important stakeholders for a standard specifying allowable air pollution limits are health professionals with skills in epidemiology, yet none appear to be represented on the current Standards Australia Committee. The tobacco industry would not be allowed to veto changes to a standard for cigarette packaging, so why should the vested interests of a profit-driven industry be allowed to affect the development of an important standard relating to pollution and environment? The current process for setting wood heater standards is so flawed that Environment Canterbury researched and published its own test procedure (ECAN 2015). Current wood stove models also cause more global warming (over the critical period until the 2 degree limit is likely to be exceeded – see Appendix 2) than heating several similar houses with non-polluting alternatives. A new standard should require heaters to have a negligible impact on the health or lifestyle of people living nearby and negligible emissions of short-lived-climate pollutants (SLCP).

Policies should protect individuals

The pollution map by the University of New England Air Quality Research Group showed that many residential areas in Armidale had much higher PM_{2.5} pollution than the central monitoring site. Car-based monitoring in Tasmania recorded PM_{2.5} measurements exceeding 100 µg/m³ from individual plumes of smoke (Innis *et al.* 2013). Measurements at a backyard in Scottsdale, Tas, revealed 17 exceedances of the PM_{2.5} standard from 12 August to 10 September 2012, but none at the official BLANKET station in a rural area approximately 1.5 km from the town (Innis *et al.* 2013). These results imply that current regulations are inadequate to prevent individuals from exposure to excessive and unhealthy levels of pollution.

The US EPA is developing an air sensor toolbox for citizen scientists because "citizens are interested in learning more about local

air quality where they live, work and play" (USEPA 2016). US\$4.5 million has also been committed in grants to six research organizations to develop and use low-cost air pollution sensor technology, while engaging communities to learn about their local air quality (Newsroom America 2016). Non-profit organizations such as Purple Air in Utah (www.purpleair.org/) are also developing low-cost particle sensors. The Tasmanian EPA has developed a low-cost highly-portable, real-time, woodsmoke-monitoring station that appears to reliably assess the impact of local pollution levels (Innis *et al.* 2015). The Toronto Environmental Alliance and Environment Hamilton received funding from the Metcalf Foundation to measure and map particle pollution in their cities (TEA 2016).

Individuals should be protected by extending the definition of 'excessive smoke' to include emissions that cause elevated PM_{2.5} pollution readings that could affect the health of nearby residents or prevent them from enjoying their properties.

Non-polluting heating cheaper than wood

Modern heat pumps have superseded piped natural gas as the most cost-effective heating in Australian cities (Forcey 2015). Efficient heat pumps can deliver 5 or 6 times as much heat to the home as they use in electric power (Wright 2011). They are also effective at low temperatures, providing 3 to 4.5 times as much heat even when the outside temperature is -10°C (10 degrees below freezing). They are affordable (cheaper than buying a wood heater), cause less global warming (zero in households that use green power) and have lower running costs than buying firewood.

Most cost-effective policy options

A suite of options to reduce woodsmoke were investigated by NSW OEH (2011). Top of the list, with estimated benefits of over \$4 billion in NSW for a modest cost of \$36 million was the requirement to remove wood heaters before houses are offered for sale. The next most cost-effective option was not allowing new wood heaters to be installed, with estimated benefits of \$2,206 million for an estimated cost of \$134 million. The third option, licensing fees, was expected to save \$1,267 million in health costs and raise \$11 million in revenue that could be used to fund education and woodsmoke-reduction programs, deal with complaints from people whose health or lifestyle is adversely affected by other people's woodsmoke and provide subsidies to upgrade home insulation and replace wood-heaters with non-polluting heating. An informed community would most likely support these measures, which are unlikely to cause any hardship or fuel poverty, and were predicted to save at least 75% of the \$8 billion health cost of wood heaters in NSW.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Ineffective and inequitable policies with much greater health and environmental costs than benefits are not in the public interest. Instead of continuing with unsuccessful approaches that have failed to reduce pollution, woodsmoke programs should adopt the successful methods that alerted Launceston residents to the health effects of woodsmoke and resulted in the majority of households switching to non-polluting alternatives. Education – that there is no safe level of PM2.5 pollution, that recent research shows PM2.5 pollution is much more harmful than previously thought, and that a modern wood stove emits more PM2.5 per year than 1,000 passenger cars – needs to be backed up by regulation. If regulators don't take the issue seriously, why would wood stove users? The three cost-effective policies described above should be implemented in all urban areas to maximize community-wide benefits for least cost. Fuel poverty and hardship could be minimized, as would the detrimental effects on the health and lifestyle of nearby residents, by using the revenue from licencing fees to assist low-income families and those affected by other people's woodsmoke. The revenue should also be used to develop and fund effective national education programs explaining the health effects of M2.5 pollution and showing how PM2.5 emissions from wood heaters compare to other sources of PM2.5.

The standard-setting process for wood heaters requires urgent reform so that people are not misled by slick advertising and misleading information from vested interests. CASANZ should consider using its membership of the Standards Australia Committee to advocate for this important issue. It is of great concern that people contemplating a new heating system are likely to be misled into thinking that new wood heaters are clean and environmentally friendly simply because they satisfy an 'Australian Standard' when the Chief Medical Officer of NSW considers them so polluting she recommends banning and phasing them out, and the current "standard" is considered so inadequate that Environment Canterbury has developed its own, much stricter test procedure and emission limits.

Effective woodsmoke programs will generate considerable benefits for the community, e.g. implementing the three measures is predicted to save at least 75% of the \$8 billion health cost of wood heaters in NSW. The lack of progress in reducing woodsmoke pollution and the current level of ignorance of most wood stove owners, shows just how much is yet to be done.

APPENDICES

1. Recommended policy option, wood heater DRIS (DOE 2016)

The wood heater Decision Regulatory Impact Statement (DRIS) opted for Option 2 (Better Practice). This option is similar to current policies and includes the implementation of

the new Standards by all states and territories and stronger compliance with the standards, through state based audits and in-service measures, such as wood heater replacement incentive programmes and education programmes to ensure the appropriate use of wood heaters.

This approach recognises that the control of wood heater emissions and air quality is a state and territory government responsibility. States and territories would lead the effort to ensure compliance with the new Standards and deliver in-service measures drawing on the better practices from across all Australian jurisdictions. The approach is intended to promote broader, more consistent policies, programmes and practices in the management of wood heater emissions and would seek to build on these experiences and work cooperatively with stakeholders. Programmes proven effective in one jurisdiction would be able to be replicated in other jurisdictions through the sharing of policy, practice and procedural documentation and experience in implementation. Elements of this approach include:

Standards. All states and territories will adopt and enforce the new Standards.

Compliance. State/territory based retail audit programmes to identify non-compliant wood heaters and take enforcement action under current powers. The option assumes regular audits following the introduction of the new Standards over the analysis period. Co-operation between jurisdictions would reduce the audit activity required in relation to retailers operating in more than one jurisdiction.

In-service programmes

- State/territory based implementation, in conjunction with stakeholders, of better practice wood heater education and awareness programmes on the appropriate use of wood heaters.
- Adopting better practice state/territory based complementary measures, including wood heater replacement programmes, managed and delivered by relevant local and state authorities and applicable to wood heaters in priority areas.
- The development and adoption of a common definition for excessive smoke to be delivered by jurisdictions in a way that would best suit their enforcement and/or abatement requirements.
- States and territories would determine and control the acceptable methods for modification and installation of new and second hand wood heaters.

The policy seeks to maximise the use of current regulatory settings, policies, programmes and practices in use across Australia with minimal change to the regulatory burden on industry or consumers.

2. Global warming and environmental issues

A team of 50 experts from the UN Environment Program and the World

Meteorological Organization (UNEP/WMO) modelled global temperature rises and recommended a package of 16 measures, without which the temperatures rise was expected to exceed 1.5 °C within 15 years and 2 °C within 35 years (UNEP 2011). The package aims to reduce short-lived climate pollutants (SLCP), also called super-pollutants. Three experts – a Nobel prizewinner, a renowned climate scientist and sustainability guru explain: *"The best and fastest way to prevent immediate climate destabilization lies in cutting back on emissions of super pollutants (black carbon, methane, ozone precursors and HCFC) that make outsized contributions"* (Molina et al. 2016).

SLCP are responsible for about half of current warming, but stay in the atmosphere for much shorter periods of time than CO₂. Tackling SLCP is the fastest way to slow the global temperature increase and give the world a fighting change of meeting the target set at Paris. Reducing SLCP slows current warming and prevents future warming by slowing the melting of glaciers (so that they continue to reflect radiation back into space) and preventing the release of the super-pollutant methane from melting permafrost and under-sea ice. The three experts warned: *"Cutting CO₂ emissions remains imperative, and cannot be delayed ...the parallel strategy of reducing super pollutants is perhaps even more important to avert disastrous consequences in the near-term."* (Molina et al. 2016).

The UNEP/WMO package includes replacing traditional brick kilns with less polluting designs, preventing methane leaks from mines, pipelines, and landfills, clean diesels, cleaner heating and cooking stoves in developing countries, banning the open burning of agricultural waste and phasing out log-burning stoves in developed countries. Implementing these measures is a win-win situation – good for the climate and good for our health (UNEP 2011).

3. Potential role for Clean Air Societies

The knowledge and expertise of CASANZ members could play a vital part in educating people about the major sources and health effects of air pollution and validating/standardizing measurements from low-cost particle sensors. After appropriate validation, measurements from portable monitors backed up by photographic evidence, might be admitted as evidence of excessive smoke emissions. In addition, the measurements from low-cost sensors will enhance our knowledge about air pollution and provide valuable data for epidemiologists to obtain more accurate estimates of the damage to health from exposure to air pollution. As in other countries, given the substantial public benefits, such projects should qualify for public funding.

CASANZ might also consider a new class of membership for lay people not employed in the clean air sector and a new special interest group to serve their needs. Membership fees and administrative overheads could be kept to a minimum by use of email for all communications and

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electronic access to the journal instead of hard copies. Lay members could make a substantial contribution towards raising the profile of clean air research and helping CASANZ become an important champion for effective policies on clean air and climate change.

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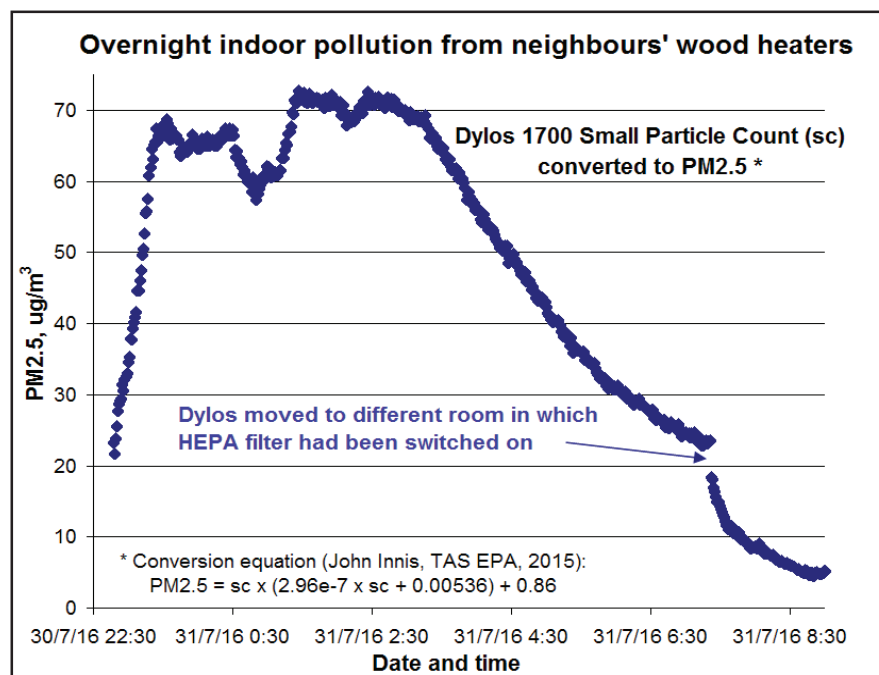


Figure 7 – Example of overnight indoor pollution from an incorrectly operated heater in Armidale, NSW. Local councils do not appear to have the resources to deal with complaints about excessive smoke, even if presented with photographs or PM2.5 measurements.

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