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Australian wood heaters currently increase global warming and health costs

Dorothy L. Robinson

National Centre for Rural Greenhouse Gas Research, NSW Department of Industry and Investment, Univ. of New England, Armidale, NSW 2351, Australia

ABSTRACT

Firewood production is often considered to be CO_2–neutral, if the carbon dioxide emitted by burning the wood is absorbed by replacement trees. However, burning firewood in the domestic heaters that are currently available in Australia produces methane and black carbon particles that increase global warming. The aim of this study was to estimate the amount of global warming from wood heating in Australia and evaluate ways in which this might be reduced. Methane from the average wood heater in Brisbane, Perth or Sydney is estimated to cause at least as much global warming as gas central heating an entire house with floor area of 160 m^2. In the colder climates of Canberra and Melbourne, a wood heater in the living area plus supplementary heating in other rooms is also estimated to cause more global warming than gas, or reverse cycle air–conditioning.

Australia's annual contribution to global warming would be reduced by at least 8.7 million tonnes of CO_2–equivalent (the same as removing about 21% of Australian passenger cars from the roads, or generating electricity from 5.8 million household 1 kW rooftop photovoltaic systems) if the 4.5 to 5 million tonnes of firewood currently burned in domestic wood heaters were instead used to replace coal in power stations and domestic wood heaters replaced by gas or reverse cycle air–conditioning. Replacement with pellet heaters would also reduce global warming and the health cost of $PM_{2.5}$ emissions, estimated to exceed $3 800 per wood heater per year. However, even greater reductions could be achieved if domestic wood heaters were replaced by innovative developments such as solar air heaters or local combined heat and power units that burn cleanly with minimal methane emissions, providing electricity and hot water as well as domestic heating.

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Corresponding Author:
Dorothy L. Robinson
Tel: +61-267-701837
Fax: +61-267-701830
E–mail: drd.robinson@gmail.com

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1. Introduction

Currently, the Australian wood heating industry promotes wood heaters by claiming they cause less global warming than other forms of heating (AHHA, 2010). However, although firewood harvested from a continually renewed supply is considered to be CO_2–neutral (Paul et al., 2006), a Swedish study (Johansson et al., 2004) found that methane emissions from older–style wood–fuelled burners could cause up to twice as much global warming (over the standard 100–year time horizon) as using oil–fuelled heating, whereas modern Swedish designs had much lower methane and particle emissions.

New wood heaters installed in Australian homes have similar emissions to the older–style Swedish models (Meyer et al., 2008), suggesting that, like the older–style Swedish models, they could increase global warming. The aim of this study was to estimate the amount of global warming from wood heating in Australia and evaluate ways in which this might be reduced. Data on methane emissions and firewood use were combined to estimate the total effect on global warming of wood heaters in Australia and facilitate comparison with other forms of heating, including more efficient wood heaters (e.g. pellet heaters), and other uses of biomass.

2. Methods

Published literature was reviewed to obtain estimates by location of Australian firewood consumption, wood heater emissions, as well as comparable data on energy use and greenhouse gas emissions for flued gas heaters and reverse cycle air–conditioning (rcAC).

2.1. Laboratory tests of wood heater emissions

A comprehensive laboratory study (Gras, 2002) measured emissions, for a range of fuels and burn rates, of 4 Australian wood heaters – two freestanding models satisfying the Australian Standard AS4013 (CS/62, 1999), a fireplace insert satisfying AS4013 and a popular well–used heater made in 1985. Tests (mostly of correctly–operated heaters) burning eucalypt hardwoods had average particle emissions of 4.5 g/kg fuel (range 0.2 to 21 g/kg, the latter for the larger freestanding AS4013 heater on low–burn using redgum). The larger AS4013 heater (which had the highest emissions burning eucalypts), was also tested on softwood, for which particle emissions ranged from 7 to 29.4 (mean 15.8) g/kg.

Combustion efficiency (carbon emitted as CO_2, as percentage of total carbon emissions) ranged from about 68% (for the redgum low–burn test emitting 21 g/kg) to 98%. Many different carbon compounds were found in the smoke, including CO_2 (average 2 kg per kg of eucalypt burned, 1.9 for softwood), carbon monoxide (CO, average 120 g/kg for eucalypt, 220 for softwood), methane, acetic acid, formaldehyde, benzene and unspecified Volatile Organic Compounds (VOCs). There was a consistent (negative) relationship between particle emissions and combustion efficiency (Gras, 2002).

Data from the above study (shown in Figure 1) was used to derive the equation used by the Australian Department of Climate

Change (Todd, personal communication) to calculate methane emissions from wood heaters burning eucalypts (DCC, 2009):

CH_4 (g/kg) = 1.495 x particle emissions (g/kg) (1)

A different equation is needed for softwoods, with CH_4 (g/kg) equal to about 2.15 times particle emissions (g/kg, Figure 1).

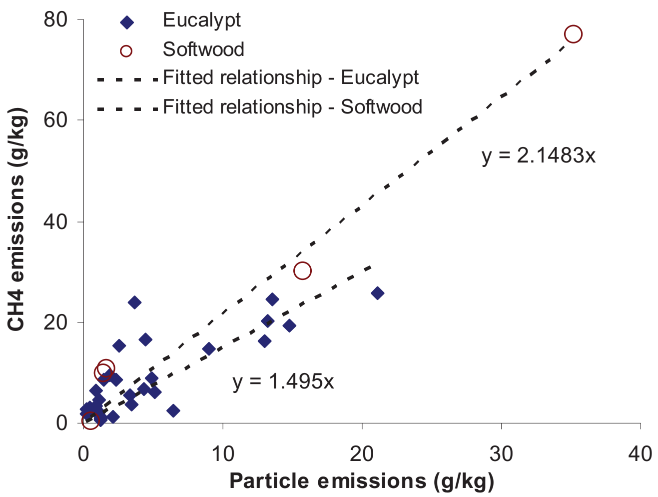

Figure 1. *Relationship between particle and methane emissions for eucalypts (r=0.78; Gras, 2002) and softwoods (r=0.98 for an Australian heater (Gras, 2002) plus the average modern and three old Swedish burners (Johansson et al., 2004).*

2.2. Household emissions

Australian heaters are designed to pass the AS4013 laboratory test, which unfortunately does not reflect the way heaters are operated in the home environment (Todd, 2008). Consequently, residential emissions are much higher (Meyer et al., 2008). Similar problems were noted in New Zealand (NZ) by Scott (2005) – emissions from 5 heaters installed in people's homes averaged 15.5 g/kg, more than 15 times their AS4013 average of 1.0 g/kg.

Emissions were also measured from 18 AS4013 heaters operated by householders in Launceston, Tasmania (Meyer et al., 2008), where education programs, including a $2 million federally–funded wood–smoke reduction program, had alerted the public to the serious health problems caused by breathing wood–smoke, with 70% of wood–heated households switching to non–polluting heating (DEH & CSIRO, 2005; Meyer et al., 2008). Knowing the health effects of wood–smoke and that their emissions were being measured, the volunteers for this study would have been motivated to take the time and trouble to operate their heaters correctly. Indeed, there was no evidence that heaters were "allowed to smolder overnight; in contrast they appeared to be re–fuelled periodically throughout". Nonetheless, about 15% of fuel carbon was emitted as CO, indicating that the dampers were usually partly or fully closed.

Particle emissions averaged 9.4 g/kg, more than twice the limit specified for the AS4013 laboratory test, twice the average in the comprehensive laboratory study (Gras, 2002), and almost twice the emissions factor (5.5 g/kg) in the National Pollutant Inventory (Meyer et al., 2008). The researchers concluded that the NPI emissions factor should be increased to 10 g/kg. Australian wood heater expert, John Todd, recommended an even higher average of 10–15 g/kg, noting that residents of other Australian cities know little about the health problems of breathing wood–smoke, so in–service emissions would be substantially higher than in Launceston (Todd and Solomon, 2009).

A value of 12.5 g/kg was therefore used as the most plausible average for Australian wood heaters burning eucalypts, leading to the estimate, from Equation (1), of 1.495 x 12.5 = 18.7 grams of methane per kg firewood. This value is in the range (14 to 25 g/kg) reported by Larson and Koenig (1994), and lower than emissions of a carefully–operated new Australian heater burning softwood (30 g/kg; Gras, 2002) or the similar value (32 g/kg; Houck et al., 2008) for older–style US heaters. It is less than a quarter of measured CH_4 emissions (77 g/kg) for an older style Swedish batch–fuelled boiler with particle emissions of 35 g/kg (Johansson et al., 2004), but higher than the estimate of 5.8 g/kg used by Solli et al. (2009) for both old stoves (emitting 40 g $PM_{2.5}$ per kg firewood) and new stoves (6.3 g $PM_{2.5}$ per kg firewood). Solli et al. (2009) sourced their emission factors from Haakonsen and Kvingedal (2001) who cited IPCC (1997). Later guidelines (IPCC, 2006) report higher CH_4 emission factors, ranging from 258 – 2 190 kg/TJ (about 4 – 35 g/kg).

Real–life emissions studies showed that domestic wood heater emissions were grossly under–estimated in Australia (Meyer et al., 2008) and NZ (Scott, 2005). A similar problem was noted in Denmark where Illerup and Nielsen (2004) concluded that $PM_{2.5}$ emissions from residential wood heating were nearly 5 times greater than the latest officially reported estimates. Because residential emissions can differ considerably from laboratory tests, realistic estimates need to be based on measurements of in–service emissions. The estimate of 18.7 g CH_4 per kg firewood, derived from estimated in–service emissions, is both realistic and consistent with published literature estimates.

With an estimated 4.5 to 5 million tonnes of firewood burned in Australia (Paul et al., 2006), estimated CH_4 emissions are 88 800 tonnes, twice the 42 710 tonnes reported in the 2008 Australian National Greenhouse Inventory for CH_4 from residential biomass burning (DCC, 2010), consistent with the new information (Meyer et al., 2008) that measured in–service emissions are much higher than NPI estimates.

2.3. GWP of non–CO_2 greenhouse gases

Table 1 summarizes estimates of global warming potentials (GWP) for methane and CO from the IPCC Fourth Assessment Report (AR4), and also by researchers at NASA (Shindell et al., 2009), who modeled interactions of gases and aerosols and concluded that the effect of methane on global warming has been under–estimated. With current levels of radiative forcing (RF) approaching levels historically correlated with an ice–free planet, Jackson (2009) discussed the likelihood of reaching irreversible points of no return (tipping points), noting that time spans of the order of decades were increasingly relevant. Consequently, 20–year GWP may be more useful indicators of the true effect than 100–year GWP.

Thus the estimate used in this study – 468 g CO_2–eq per kg firewood, calculated by multiplying CH_4 emissions (18.7 g/kg) by the AR4 estimate of methane's GWP (25) – should be considered as conservative. If NASA's estimates of GWP are closer to the correct values, or if a tipping point could be reached in less than 100 years, or if the effect of CO (noted by Meyer et al. (2008) to account for about 15% of fuel carbon i.e. about 200 g CO per kg fuel) is included, the true effect on the climate could be up to 12 times greater.

3. Results and discussion

3.1. CO_2 emissions – central heating

Estimates of the energy required per year to heat a typical Australian house (floor area 160 m^2, insulated ceiling, but not walls) in Australian Capital cities are shown in Table 2. The values (produced by the Australian Consumers Association (ACS, 1999),