A preliminary re-assessment of the relative contribution of PM_{10} particle pollution from forest industry burns and domestic wood heating to the Tasmanian airshed in 2008

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The *Tasmanian Air Quality Strategy* (2006)[1] gives figures for PM_{10} particle emissions (particles up to 10 millionths of a metre in size) to the Tasmanian airshed from various sources, including domestic woodheaters and forest burning (categorised as fuel reduction burns, regeneration burns, and wildfires). The *Strategy* reported for 2003-2004 that domestic solid fuel heating contributed 41% of the total PM_{10} particle emissions in Tasmania, while forest burning (categorised above) contributed 3%. That is, domestic wood heaters were estimated to contribute to the airshed about 14 times the amount of particle pollution as forest burning. These are emissions to the Tasmanian airshed, and are not an estimate of the relative contributions to population exposure.

These data were sourced from the National Pollution Inventory (NPI)[2]. The values for particle emissions from domestic heating and forest burning have not changed in the NPI between 1999-2000 and 2007-2008. The values are 3,300 tonnes per year of particles from domestic wood heating, and 260 tonnes per year of particles for forest burns. That is, domestic heating is assessed by these figures as contributing about 13 times as much particle pollution as does *all* forest burning. The slight differences between the figures quoted in the *Strategy* (a ratio of 14 times) and in the actual tonnages from the NPI data (a ratio of 13 times) are likely due to rounding errors in the calculation of percentages.

Officers of the Environment Division supporting the Tasmania EPA have been investigating the validity of these figures for the 2008 season. This article documents the results of this investigation. The values presented here should be regarded only as *representative* of actual levels, and should not be taken as definitive. Additionally the values will vary from year to year, depending on the level of forest industry operations and meteorological conditions.

The Forest Practices Authority reported that a total of 579 forest industry burns took place between April and June 2008 (Chuter, 2008), covering an area of 31,000 ha. Of these burns, slightly less than 18,000 ha were considered to be ‘heavy-fuel’ burns, with the remainder being ‘light’ or ‘very light’ fuel burns. According to a study carried out in a ‘wet’ eucalyptus obliqua forest in southern Tasmania, ‘heavy-fuel’ burns consume around 400 tonnes per hectare of logging residue (Slijepcevic, 2001). If this is taken as being representative of heavy fuel loads throughout the state, the 18,000 ha of ‘heavy fuel’ burns conducted by the Tasmanian forest industry in 2008 can be estimated to have consumed approximately 7.2 million tonnes of wood.

For particle emission rates ranging from 12 grams per kilogram of wood burnt (from the NPI emission estimation manual) to 17 grams per kilogram of wood burnt (from a

[1] Available at http://www.environment.tas.gov.au/index.aspx?base=222. See Figure 2, page 28.
[2] National Pollution Inventory (NPI), http://www.npi.gov.au

CSIRO/Bushfire Co-operative Research Centre value, assuming 10% moisture loading in the wood fuel), the total particle emission to the Tasmanian airshed in 2008 from heavy-fuel forest industry planned burns is consequently estimated to be in the range from 86,000 to 120,000 tonnes. This is between 330 and 460 times greater than the value estimated in the NPI (260 tonnes) for particle production from *all* forest burning (including wildfires), not just from planned forest industry burns.

Figures from the Australian Bureau of Statistics[3] lead to an estimate of 42,000 combustion stoves and 4,300 open fireplaces in Tasmanian residences in 2008. Assuming particle emission rates of 10 grams per kilogram of wood burnt for combustion stoves (from a CSIRO study of 'real-world' wood heater use in Launceston) and 17 grams per kilogram of wood burnt for open fires, and assuming each domestic heater uses 10 tonnes of wood per annum, this leads to an estimate of 5,000 tonnes of emitted particles from domestic wood heating. This is about 1.5 times the value (3,300) given in the NPI. The difference may be due to differences in the assumed annual wood consumption per heater and particle emission rates.

Hence under these revised figures, in 2008 forest industry planned burns were likely to have contributed to the Tasmanian airshed between *seventeen* and *twenty four* times the particle pollution produced by domestic wood heaters (86,000 to 122,000 tonnes from planned forest burns compared to 5,000 tonnes from domestic heaters), not *one-fourteenth* as the *Tasmanian Air Quality Strategy 2006* figures would indicate. As noted, these figures refer only to total emissions to the airshed from these sources, and do not attempt to account for the relative contributions to population exposure.

An investigation of the NPI data sources has been undertaken. It appears that the NPI category of forest burning, which is stated to include 'fuel reduction burns, regeneration burns, agricultural burns and wildfires', does not in fact include regeneration burns, even though the category is explicitly noted to include them. This conclusion was determined by tracing back through the literature to check the various references used in the NPI determination. The NPI 'forest burning' category appears to relate only to low fuel-loading (in tonnes per hectare) burns, typical of 'fuel reduction' and 'environmental management' burns, and omits the much higher fuel-loading burns that are encountered in forest industry regeneration activities. The NPI database also appears to under-report the level of fuel-reduction burns, environmental burns, and wildfires in Tasmania.

The under-reporting of the amount of forest burning in Tasmania in the NPI (and hence the consequent under-estimate of particle emission levels from forest industry operations in the *Tasmanian Air Quality Strategy 2006*) thus appears to be due to an omission of the 'regeneration' burn category rather than a miscalculation or data error. Officers of the Environment Division, supporting the EPA, have derived these revised, albeit indicative, figures now that more comprehensive data have become available. As noted previously, these are emissions to the Tasmanian airshed, and are not an estimate of the relative contributions to population exposure. The earlier figures reported in the *Strategy* have been used in good faith by a number of agencies and organisations in the past, as well as being a matter of public record.

[3] ABS, ENVIRONMENTAL ISSUES: Energy use and Conservation, 4602.0.55.001, March 2008, page 60

Further work is underway on related issues. A full review of all data, with input from all relevant stakeholders, appears warranted.

The new Base-Line Air Network of EPA Tasmania (BLANkET) is designed to provide a much greater spatial coverage of planned burn smoke in Tasmania than has hitherto been obtained. The first five (of 15) stations were commissioned in the north-east of the state in May 2009, with more stations in preparation. The BLANkET network will provide real-time indicative air quality data via the Environment Division web pages. The data will be used to study the movement and dispersal of smoke in the greater Tasmanian airshed, and will contribute to the management of planned burn smoke.

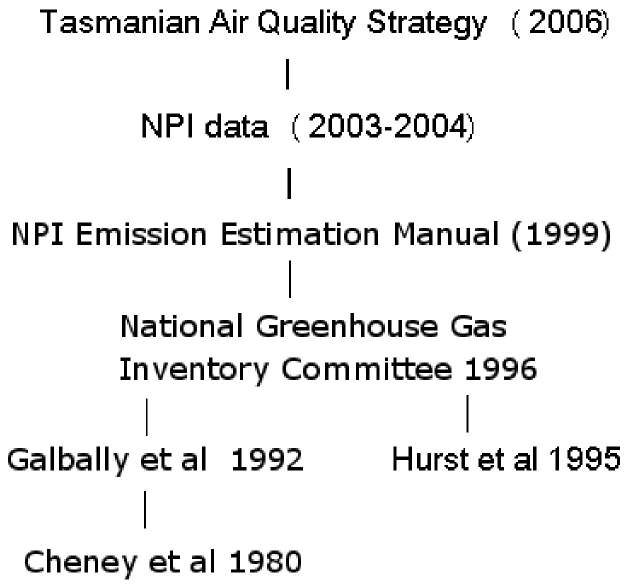
References:

Chuter, R., 2008, 'Review of the implementation and effectiveness of the 2008 interim fire management/smoke dispersal guidelines', Report to the Forest Practices Authority

Slijepcevic, A., 2001, 'Loss of carbon during controlled regeneration burns in Eucalytpus obliqua forest', Tasforests, Vol. 13, No. 2, pp 281-289

Background detail of the preliminary re-assessment:

This literature path of the data sources used by the *Tasmanian Air Quality Strategy* is shown schematically in the following figure to provide an overview prior to discussing the detail. The reference list leads from the NPI Emissions Estimation manual (1999) through the National Greenhouse Gas Inventory Committee (1996), and then splits to Galbally et al. (1992) the source at Cheney et al. (1980) on one path, and to Hurst et al. (1995) on the other.



The NPI manual 'Emissions Estimation Technique for Aggregated Emissions for Prescribed Burning and Wildfires' (September 1999) gives the methods by which emissions from forest burning were estimated. Tables 2 (page 8) and 4 (page 11) from the NPI manual list the following fuel loading and emission rate data for Tasmania. The fuel loading values (tonnes per hectare) are one key to following the evidence trail. For prescribed forest burning the fuel loading is given as 8.4 tonnes per hectare.

TASMANIA	Wildfire	Forest/Prescribed burning	Temperate Grassland
Fuel loadings	28 t/ha	8.4 t/ha	7.0 t/ha
Emission rates	7.5 g/kg	12 g/kg	10 g/kg

The NPI manual cites as its source the 'Workbook for Non-carbon dioxide gases from the biosphere' (Workbook 5.1, revision 1, 1996, National Greenhouse Gas Inventory Committee, DEST). Appendix A.9 of this workbook (given on page 34 of the workbook) lists fuel loads for prescribed burning in each jurisdiction. For Tasmania the raw fuel load is given as 20 t/ha. Appendix A.10 of this workbook notes the burning efficiency (i.e. how much of the available fuel is consumed in a burn) for Tasmanian prescribed burning is 0.42. Hence the fuel consumed will be twenty tonnes per hectare times 0.42, which is 8.4 t/ha. This matches the relevant value (prescribed burning fuel load) in the NPI table above. The DEST 'Workbook' tables for prescribed burning are reproduced in the following figure for reference.

Table A.9
Fuel loads for Prescribed Burning of Forest in Australia
(Mg/ha)

State	NSW FL_{ikl} (Mg/ha)	Tas FL_{ikl} (Mg/ha)	WA FL_{ikl} (Mg/ha)	SA FL_{ikl} (Mg/ha)	Vic FL_{ikl} (Mg/ha)	Qld FL_{ikl} (Mg/ha)	NT FL_{ikl} (Mg/ha)	ACT FL_{ikl} (Mg/ha)
Load	18.9	20.0	12.0	9.6	17.2	9.3	3.1	18.1

Table A.10
Burning efficiencies for Prescribed Burning in Australia

State	Burning efficiency z_{jk}
All	0.42

Before proceeding, it is worth noting that 20 tonnes per hectare is equivalent to 2kg per square metre. This is a very low fuel loading, much lower than for a regeneration burn as detailed below.

The DEST ‘Workbook for Non-carbon dioxide gases from the biosphere’ cites several papers as the source of the quoted figures. These include Galbally et al (1992) and Hurst et al. (1995, to be discussed below). Table 3 of Galbally et al. (1992) is reproduced below, giving estimates of biomass burning across Australia. The entry for wildfires has a fuel consumed value of 35 t/ha, which is close to the 28 t/ha quoted for Tasmania in the NPI figures above. The entry for ‘prescribed forest burning’ quotes for Australia a fuel consumed value of 10 t/ha, also in reasonable agreement with the 8.4 t/ha for Tasmania from the DEST Workbook. Note however the entry immediately below the prescribed burning entry is for ‘regeneration burns’, and gives a much larger fuel consumed value of 250 t/ha.

Table 3. Estimates of biomass burning in Australia from Cheney *et al.* 1980

Biomass type	Area burned (Mha yr^{-1})	Fuel consumed (t ha^{-1})	Fuel consumed (Mt yr^{-1})
Grasslands			
Tropical, sub-tropical	25.0	4.0	100.0
Arid, semiarid	4.1	1.5	6.2
Other	0.4	2.0	0.9
Agricultural waste			
Sugarcane	0.25	15.0	3.8
Cereal stubble	6.0	2.5	15.1
Forests			
Wildfires	0.8	35.0	28.0
> Prescribed burning	0.8	10.0 <	8.0
> Regeneration	0.02	250.0 <	5.1
Plantation establishment	0.02	150.0	3.1
Clearing for agriculture	0.04	75.0	3.1
Other	0.02	100.0	2.0
Total	37.45		175.3

The Galbally et al (1992) data are sourced from Cheney et al. (1980). The data presented by Cheney et al. are effectively identical with those presented by Galbally et al. (1992) although they are in a slightly different format.

Hence, while the ‘wildfire’ and ‘prescribed burning’ categories appear to have been transcribed from the Cheney/Galbally sources to the DEST Greenhouse Gas workbook (as evidenced by the fuel loading values), the ‘regeneration burn’ category (250 t/ha fuel loading) has not been. The NPI Estimations Manual draws on the DEST Greenhouse Gas workbook, therefore giving entries for the ‘wildfire’ and ‘prescribed burning’ categories, but, not the ‘regeneration’ category.

There is information for Tasmania of fuel loadings (in tonnes/ha) in forestry operation areas. Marsden-Smedley and Slijepcevic (2001) estimated that the ‘fine fuel’ loads (fuel diameters less than or equal to 25 mm) in unlogged wet forests varied from 13 to 20 t/ha. These pre-logging fine fuel loads are comparable to the NPI ‘prescribed burning’ fuel loadings for Tasmania. However, the fine fuel loads increased to between 40 and 80 t/ha *after* logging, due to the presence of logging debris.

Moreover, the *total* fuel loadings (not just the ‘fine fuels’) are much higher: Slijepcevic (2001) presented data that show the post-logging, pre-burning fuel loads in wet Tasmanian forests are order of 650 t/ha, with about 400 t/ha actually burnt in a post-logging (regeneration) burn - hence the burning efficiency is about 0.6. The value of 400 t/ha of fuel consumed in a Tasmanian regeneration burn is reasonably consistent with the Australia-wide ‘regeneration’ category value of 250 t/ha given by Cheney et al. (1980) noted above. Just under 70% of the 31,000 ha of forest industry burning in Tasmania in 2008 was of heavy fuel-load areas.

A possible explanation for the absence of ‘regeneration burns’ in the DEST ‘Workbook’ is that for carbon accounting, regeneration of forest areas may be considered carbon neutral, at least in a steady-state situation. This may explain why the regeneration burns were not included in the Greenhouse Gas workbook. Verification of this hypothesis was sought from one of the compilers of the 1996 Workbook, but with the passage of time it was not possible for this to be confirmed or refuted. For estimating pollution emissions levels however all sources need to be included. The NPI data appear deficient in this regard.

For completeness, it is noted that the burning efficiency of 0.42 for prescribed burning given in the NPI appears to be sourced from Hurst et al. (1995). The figure below reproduces table 74.3 of Hurst et al. (1995). The value of 0.42 appears in the ‘Prescribed’ burn row. Note too that a category exists for a ‘clearing’ (for agricultural purposes) fire type, which has a listed annual total biomass burnt nearly ten times than of ‘prescribed burns’. From the table, the biomass burned in this category of fire is about 8 times greater than the corresponding entry for prescribed burns.

Table 74.3 Estimates of biomass, carbon, and nitrogen annually burned in Australian biomass fires

Fire Type	Biomass exposed (Gg dm yr^{-1})	Burning efficiency	Biomass burned (Gg dm yr^{-1})	Fuel carbon content	Carbon burned (Gg C yr^{-1})	Fuel N:C	Nitrogen burned (Gg N yr^{-1})
Savanna	240 000	0 72	173 000	0 46	79 600	0 020[a]	1590[a]
			Forest				
> Clearing			40 100	0.46	18 500	0 011	203
> Prescribed	11 800	0 42	4960	0 46	2280	0.011	25
> Wild	21 900	0 72	15 800	0 46	7250	0 011	80
Total			60 900		28 000		308
			Crop Waste				
Wheat	5190	0 96	4980	0 4	1990	0 008	15.9
Coarse grains	2760	0 96	2650	0 4	1060	0 008	8 5
Sugar cane	845	0.96	811	0 4	324	0.025	8 1
Total	8790		8440		3380		32 5
			All Biomass Burning				
Total			242 000		111 000		1930[b]

All estimates from *NGGIC* 1994 for 1990 except where noted.
a. Hurst et al (1994b)
b Adapted from *NGGIC* [1994] using savanna estimate of Hurst et al (1994b)

Using the NPI figure of 260 tonnes of particles per annum from ‘prescribed burns’ for Tasmania, and working backwards, knowing the NPI adopted emission rate (12 g/kg of particles) and a fuel consumed value of 8.4 t/ha, one can calculate that an area of approximately 2600 ha would need to be burnt to produce this amount of particles. For comparison, in 2008 the Tasmanian Parks and Wildlife Service undertook some 4900 ha of very light fuel burns as part of their environmental management and fuel reduction work (Parks and Wildlife Service communication to the Air Section). This amount of (environmental and fuel reduction) burning, by one agency alone, would be enough to supply (at least) the 260 tonnes of particles to the Tasmanian airshed that the NPI data estimates to occur each year. This supports the view that the NPI data for ‘forest burning’ could not feasibly include a contribution from the heavy fuel-loading regeneration burns as well.

Further reading of the DEST workbook provides further evidence that the NPI data underestimates the amount of low-fuel-load burns and wildfire burns in Tasmania. Table C.15.90 (page 65) of the DEST workbook presents data indicating an annual average area near 24,000 ha of low-fuel load burns in Tasmania, based on 9 years of data, yielding a total mass burnt near 202,000 tonnes (Table C.16.90). Tables C.18.90 and C.19.90 (page 67) of the DEST workbook provide similar data for wildfires in Tasmania, giving annual totals of 17,000 ha burnt and 495,000 tonnes of wood consumed. Together such low-fuel load burns and wildfires would produce about 6,100 tonnes of particles. This is significantly higher than the 260 tonnes of particle emissions that the NPI database says is produced annually in Tasmania in the NPI 'forest burning' category, which is supposed to include prescribed burns, fuel reduction burns, wildfires, and agricultural burns.

A full review of the input data forming the NPI sources appears needed.

Report compiled by J. Innis and R. Hyde.

References:

Cheney et al, 1980, 'Release of Carbon to the atmosphere in Australian vegetation fires', in *Carbon Dioxide and Climate: Australian Research*, ed. G.I. Pearman, Aust. Acad. Sci, 1980, pp153-158

Galbally et al, 1992, 'Biosphere-Atmosphere exchange of trace gases over Australia', in *Australia's renewable Resources, Sustainability and Global Change,* eds. R.M. Gifford and M.M. Barson, Bureau of Mineral Resources, Canberra, pp117-149.

Hurst et al., 1995,'Trace gas emission from biomass burning in Australia', in *Global Biomass Burning*, ed. J. Levine, Chapman conference on Global Biomass Burning, Williamsburg, VA, March 1995

Marsden-Smedley, J.B., and Slijepcevic, A., 2001, 'Fuel Characteristics and low intensity burning in Eucalyptus obliqua wet forest at the Warra LTER site, Tasforests, Vol. 13, No. 2, pp 261-279

Slijepcevic, A., 2001, 'Loss of carbon during controlled regeneration burns in Eucalytpus obliqua forest', Tasforests, Vol. 13, No. 2, pp 281-289