Discussion of requirements for obtaining Renewable Energy Certificates (RECs)

The renewable Energy (Electricity) Regulations 2001, state that in order for electricity generated from combustion of wood waste from native forests to qualify for Renewable Energy Certificates (RECs), the wood waste must:

i) not be the primary purpose of harvest

ii) meet relevant planning/approval processes during its production

iii) meet Ecologically Sustainable Forest Management (ESFM) principles.

This report is relevant to parts of (ii), and particularly point (iii) above. Ecological sustainability is defined in the Renewable Energy Act (2000) only at the level of high order principles (e.g. integrating economic, environmental and social factors; applying the precautionary principle; maintaining inter-generational equity; maintaining ecological integrity etc). No guidance is given as to how these should be implemented. The regulations suggest that ESFM could be demonstrated in relation to RFA requirements, or via approval by the Minister. Again this is unclear, and will require detailed discussion with the Office of the Renewable Energy Regulator (ORER).

This report provides an assessment of the ecological (environmental) aspects of ESFM relating to harvest of native forest residues for fuelwood. It thus is a relevant input to the broader assessment of ESFM by the ORER.

Research and Development Needs

A number of key R&D needs have been identified, and these are summarised here. Reference is made back to sections of the report where the issue has been discussed in detail.

Management of CWD

- Development of procedures for modelling the temporal dynamics of CWD across the total forest estate. This requires better understanding of the inputs and decay rates of a range of woody biomass components (see Sections 2 and 7).
- Establishing the dispersal characteristics of representative log-dependent species in a range of taxonomic classes (Section 7).
- Establishing the proportion of biota that are dependent on large logs, and that are at risk because of slow dispersal (Section 7).
- Comparison of the biota and successional change for natural CWD, classes of logging slash, and trees felled and left to provide CWD habitat (Section 7).

Protection of soils, water and nutrient cycles

- Further development of the visual assessment methods proposed by Pennington and Laffan (2001) for monitoring the effects of harvesting intensity on soil disturbance and consequences for seedling regeneration and water values (Section 3).
- Studies of temporal nutrient dynamics in accumulating duff layers and CWD in cool wet eucalypt forests of southern Tasmania (Section 5).
- The role of wattles in replacing N lost by harvesting and fire, and their effect on N dynamics over the forest rotation. New methods are required (eg. use of stable isotopes) for such studies, necessitating collaboration with an institute with advanced technology (Section 5).

Plant Biodiversity

- Measurement and understanding of patch-to-patch variation in plant species composition to enable coupe-level variation to be interpreted at the scale of the forested landscape. Such studies will incorporate responses following a range of natural and managed disturbance regimes (Section 6).

Greenhouse

- Studies to better quantify non-CO_2 greenhouse gas emissions under a range of field burning conditions (Section 8).

Appendix 1 - Details of Greenhouse Gas Calculations

The Greenhouse balance calculations were based on a simple growth model that keeps track of all the key carbon pools in a forest ecosystem. Total biomass, B, was calculated as:

$$B = B_{max} [1 - \exp(-r\ a)]^n \qquad (1)$$

with B_{max} being the maximum total biomass of a mature stand and 'a' is stand age in years and 'r' and 'n' are parameters.

Stem biomass was then calculated as:

$$S = B\ r_{max}\ (B / B_{max})^{xp} \qquad (2)$$

where r_{max} is the maximum proportion of total biomass that can be contained in the stem and xp is an empirical exponent.

Bark, Bk, coarse roots, Rc, fine roots, Rf, leaves, L, and branches, Bc are calculated as:

$$Bk = S\ [bk_{min} + (bk_{max} - bk_{min}) \exp(bk_1\ B / B_{max})] \qquad (3a)$$

$$Rc = [rc_1\ (S + Bk)] \qquad (3b)$$

$$Rf = F\ [rf_{min} + (rf_{max} - rf_{min}) \exp(rf_1\ B / B_{max})] \qquad (3c)$$

$$L = F\ [l_{min} + (l_{max} - l_{min}) \exp(l_1\ B / B_{max})] \qquad (3d)$$

$$Bc = F - Rf - L \qquad (3e)$$

where F is the total amount of fine material in fine roots, branches and leaves so that

$$F = Rf + Bc + L \qquad (4a)$$

$$F = B - S - Bk - Rc \qquad (4b)$$

Wood density is taken as a constant without inclusion of age effects on wood density.

The other parameters in eqn. 3 are empirical parameters given in Table A1.

Table A1: Parameters used in describing stand characteristics. Parameters were chosen to achieve consistency with the growth equations given by West and Mattay (1993) and unpublished information made available by Forestry Tasmania. Wood density is taken from Ilic et al. (2000)

B_{max}	700 tDW ha^{-1}	rc_1	0.25	rf_{max}	0.4
r	0.015	wood density	0.568	rf_{min}	0.25
n	1.25	bk_{max}	0.20	rf_1	-2.0
r_{max}	0.7	bk_{min}	0.050	f_{max}	0.2
x_p	0.3	bk_1	-3.0	f_{min}	0.15
				f_1	-2.0

Stand characteristics of a typical stand are further illustrated through Figures A1-A4.

Figure A1: Growth of biomass components over time without disturbance. Total tree biomass, stem mass, coarse roots and stem volume are shown in (a) and branches, fine roots, bark and foliage in (b).

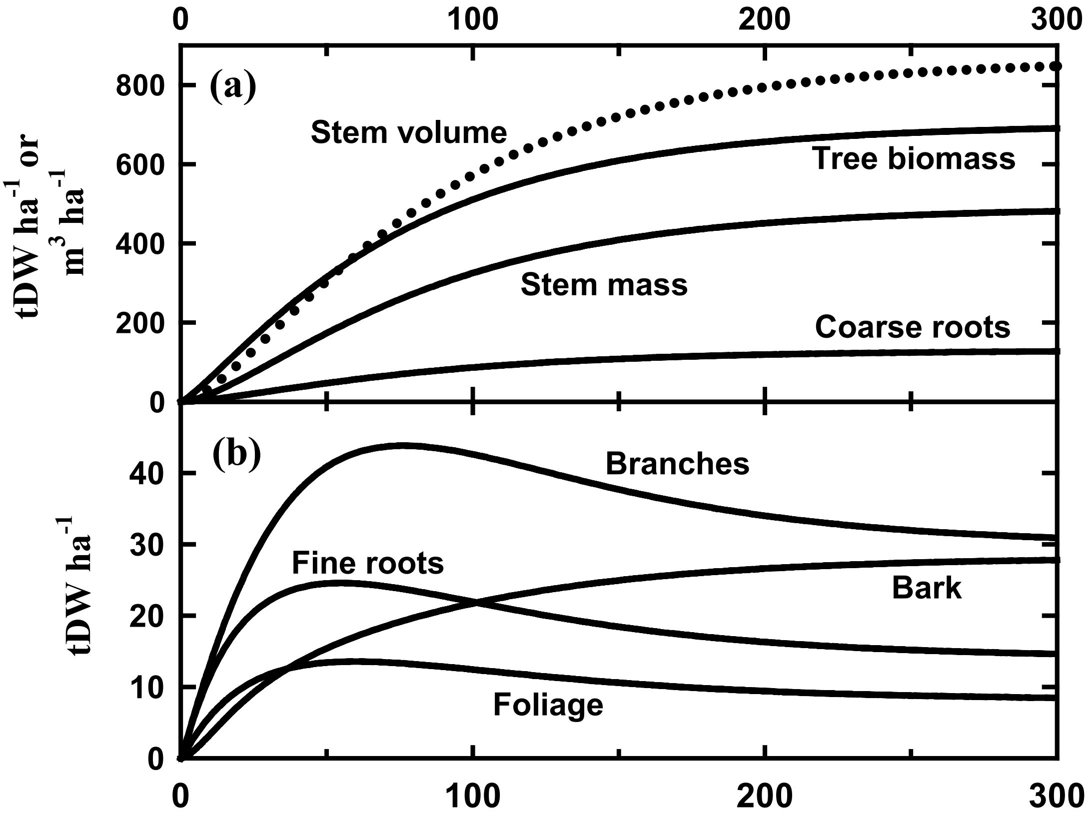
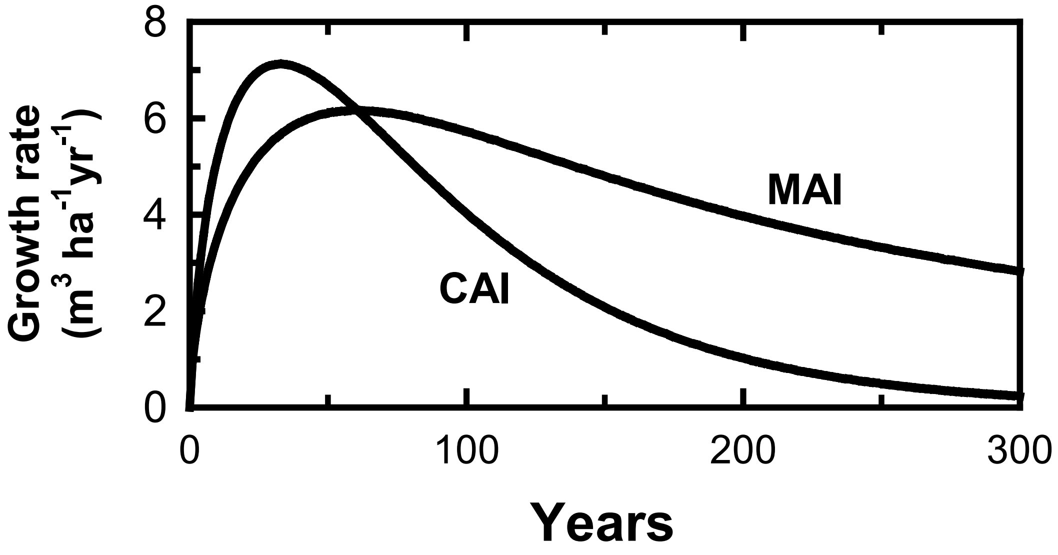
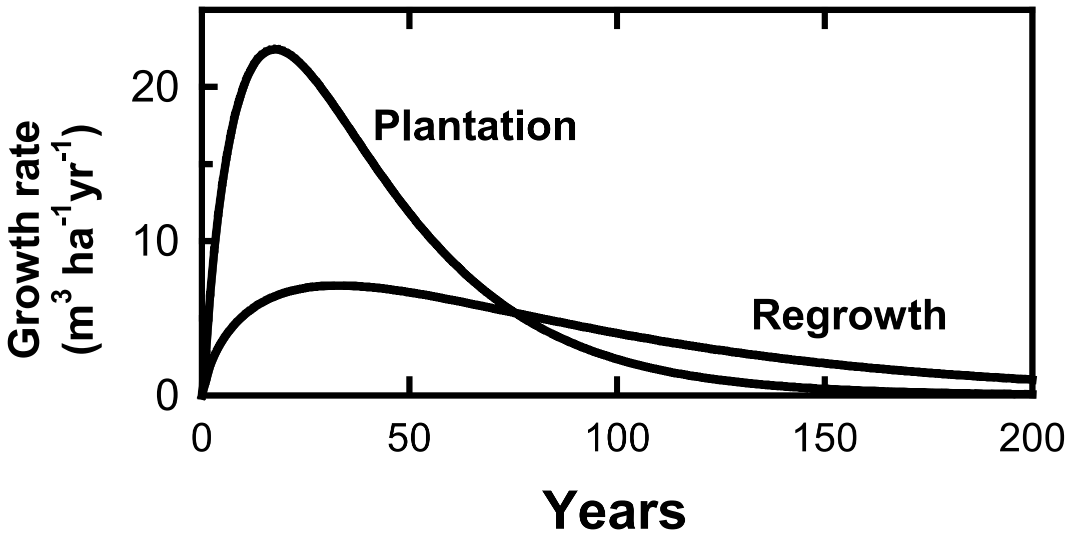


Figure A2: Wood growth rates for natural regrowth forest.



For simulating plantation growth, eq. 1 was used with the parameters given in Table A1. Figure A3 contrasts the growth rates used for natural regrowth stands and plantations. To simulate plantation growth, the following parameters were used: Bmax = 1000 tDW ha^{-1}, r = 0.035 and n = 1.4. Plantations were assumed to be managed of a shorter rotation of just 30 years.

Figure A3: Current annual increments for regrowth forests and plantations.



During stand growth, biomass can be removed either by thinning or through fire. Subsequent stem growth was calculated as though the stand had been rejuvenated by the disturbance. This was done by calculating an 'equivalent' stand age of the thinned or fire-affected stand:

Since $B = B_{max} [1 - \exp(-r\ a)]^n$ according to eq. 1, an 'equivalent age' could be calculated as:

$$a = -\ln\{1-[B\ (1-f_{loss})/B_{max}]^{(1/n)}\}\ /\ r \quad (6)$$

where f_{loss} is the proportion of stems lost in the fire or thinning operation and the other parameters are as defined previously. Subsequent growth of stems and all biomass components was then calculated like that of a younger stand.

Annual growth of each biomass component, B_x, other than the stem was calculated as:

$$B_x = [B_{x(a)} + B_{x(a-1)}] + B_{x(a)}\ t_x \quad (7)$$

where $B_{x(a)}$ is the equilibrium size of the biomass component at age 'a', $B_{x(a-1)}$ is the size of the biomass component in a stand one year younger and t_x is the turn-over rate of each biomass component. Turn-over rates of all biomass components other than the stem are given in Table A2. In addition to that physiological turn-over rate, further turn-over due to natural self-thinning had to added. It was assumed that 1% of trees died naturally every year in natural and regrowth stands but that there was no natural mortality in plantations.

Following partial defoliation through thinning or fire, biomass components other than the stem exponentially increased back to the trajectories that they would have followed without the intervening thinning, with the time course of following that exponential course dependent on the respective turn-over times of the different biomass pools. Hence, leaves retain canopy closure relatively faster (after 5 - 10 years) whereas branches require 20 to 30 years before reaching the same extent as they would have had without fire or thinning.

Table A2: Turn-over rates of different biomass components.

Branches	0.07
Bark	0.10
Leaves	0.50
Coarse roots	0.07
Fine roots	0.50

At the initial harvest, it was assumed that only 50% of stemwood was removed for products. 50% was then either left on site or half of it used for fuelwood. The material left on site was then assumed to be subject to a regeneration burn, with 80% of fine material consumed in the fire and 50% of the coarse woody material left on site.

Table A3: Fates of different biomass components during thinning. Two different options are given for the initial harvest at time 0 which represent the two central scenarios investigated here. Thinning rates apply only to the plantation scenario. No thinning was assumed for the regrowth scenario.

Age	Thinned (%)	Retained on site (%)	Removed as products (%)	Used as fuelwood (%)
0	100	50	50	0
0	100	25	50	25
10	30	0	100	0
15	30	0	100	0

Thinning was assumed to be carried out only in plantations according to the schedule given in Table A3. At each initial thinning, it was assumed that all thinned stems would be removed from the site.

Soil organic matter was simulated as two pools, an active and an 'inert' pool. Specified fractions of litter pools could form active soil organic matter. Active soil organic matter could be lost by decomposition and released to the atmosphere or 'encapsulated' to form 'inert' soil organic matter. 'Inert' soil organic matter could also be formed as charcoal formation during fires. Specifically, changes in active soil organic matter, dS_a/dt, were calculated as:

$$dS_a/dt = f(Lt) - s_1\ S_a - e\ S_a \quad (8)$$

where S_a is the pool of active soil organic matter, Lt is the total mass of litter, f is the fraction of litter that forms active soil organic matter, s_1 is the fraction of active soil organic matter that decomposes annually and e is the fraction encapsulated to form 'inert' soil organic matter. The conversion of litter to active soil organic matter is expressed here as a single pool and fraction that is converted. It is actually treated in much greater detail in the model, with specified fractions of each biomass pool first being separated into decomposable and resistant fractions, with each separate pool decomposing at their respective turn-over times and specified fractions being lost as CO_2 or converted to organic matter.

The change in 'inert' soil organic matter, dS_i/dt, is then calculated as:

$$dS_i/dt = e\,S_a - s_2\,S_i \qquad (9)$$

where S_i is the pool of 'inert' soil organic matter and s_s is the fraction of 'inert' soil organic matter that decomposes annually.

Despite its relative complexity, this model is still a vast simplification of the carbon cycle in the soil. In particular, if soil nutrient cycles had been modelled together with the corresponding carbon pools, then actual changes would have been likely to have been smaller than simulated here. Nutrient pools provide a negative feed-back effect that mitigate against rapid changes in soil organic matter. In reality soil carbon cannot build up significantly without concomitant increases in soil nutrients contained in soil organic matter and losses are reduced because nutrients mineralised during soil carbon losses allow greater subsequent plant productivity and greater carbon input into the system. These changes are explored in some greater depth in the main Section.

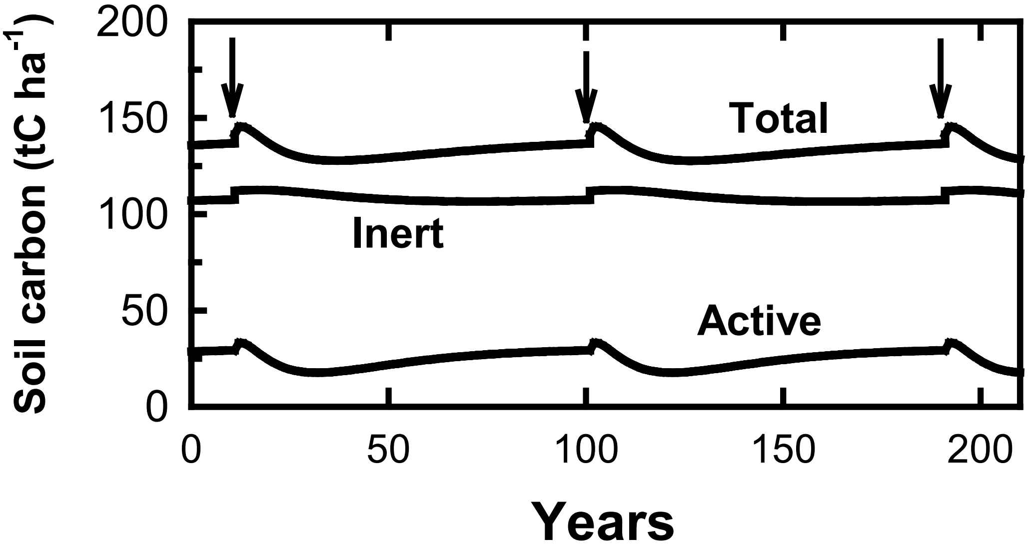
Table A4: Parameters that control the dynamics of soil organic matter and coarse woody debris.

s_1	0.08
e	0.02
s_2	0.005
f_d	0.06
f_r	0.02
p_d	0.5

With the model as described soil organic matter changes following a 200-year sequence are shown in Fig. A5. Active soil organic matter increases following the initial harvest as litter, especially from dead coarse roots, is turned into active organic matter. It then decreases as the new stands initially produces less litter through normal turn-over than did the previous mature stand. It then increases again with increasing size and turn-over of biomass pools, before the pattern is repeated after the harvest at year 100.

The 'inert' pool changes relatively much less. It shows a sudden increase in response to the fires as years 50 and 150 due to the influx of charcoal produced during the fires.

Figure A5: Response of soil organic matter during a 200-year sequence. For this simulation, it was assumed that a mature stand was originally cut at time 10, and then underwent two regrowth cycles. Logging occurred in years 100 and 190 as indicated by arrows in the Figure.



For the present analysis, the decay of coarse woody debris is the most critical individual aspect. Its decay is modelled here as a two-component system with different turn-over times so that:

$D_t = D_d + D_r$ (10)

where D_t is total woody debris and D_d and D_r are decomposable and resistant fractions, respectively and

$D_d / dt = p_d D_f - f_d D_d$ (11a)

$D_r / dt = (1 - p_d) D_f - f_r D_r$ (11a)

where p_d is the proportion of fresh dead wood classified as decomposable dead wood, D_f is the amount of fresh dead wood being produced and f_d and f_r are the annual loss fractions of decomposable and resistant dead wood, respectively. The values used for these parameters is given in Table A3.

Fires were assumed to occur at following an initial harvest in order to foster regeneration of a new forest stand. This is a regeneration burn that removes only litter. No subsequent fires were assumed to occur over the life of the rotation. Key parameters that describe the burning pattern are given in Table A5.

Table A5: Key parameters that describe burning regimes.

	Year	Fraction of stem C burnt	Fraction of stem C that becomes debris	Fraction of fine litter C burnt	Fraction of coarse woody C burnt
Natural forest	50	0.1	0.15	0.75	0.2
	300	0.25	0.75	0.8	0.2
After logging (regrowth)	0	n/a	n/a	0.8	0.5
After logging (plantation)	0	n/a	n/a	0.8	0.75

Under the natural fire regime, there are assumed to be fires every 100 years, with the two burning events alternating. After 300 years, there is assumed to be a stand-replacing fire. Different burning efficiencies were assumed for regrowth and plantations because the preparation for plantation establishment usually involves the windrowing of woody debris which then achieves a greater burning efficiency.

Calculations of non-CO_2 trace gas emissions

Trace gas emissions, $E_{x,f}$, for each type of trace gas, x, during forest fires are calculates as:

$$E_{x,f} = W\ (C/W)\ (N/C)\ e_{x,1}\ M_x\ G_x \qquad (12)$$

where W is the dry weight of biomass being burnt, (C/W), is the proportional carbon content of that biomass, (N/C) is the ratio of nitrogen to carbon in that biomass, $e_{x,1}$ is the emission factor for each trace gas, M_x is the weight of each trace gas relative to carbon and G_x is the Greenhouse warming potential of each trace gas. This calculation is relevant for N_2O and NO_x, whereas calculations for the other trace gases can omit the term (N/C). Resultant emissions are expressed in kg CO_2 equivalent.

Trace gas emissions during industrial burning, $E_{x,i}$, for each type of trace gas are calculates as:

$$E_{x,i} = W\ (E/W)\ e_{x,2}\ G_x \qquad (13)$$

where (E/W) is the energy content per unit biomass and $e_{x,2}$ is the emission rate for each trace gas. The relevant factors in Eqs. and are given in Table 6.