Carbon Benefits of Not Landfilling End-of-Life Wood Pallets & Packaging in New South Wales – Assumptions Report

2nd Edition - June 2012

Report for NSW Environment Protection Authority.

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NSW EPA

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1 INTRODUCTION

Wood pallets and packaging are ubiquitous in business-to-business trade and logistics in NSW and the rest of Australia. While thriving businesses exist in wood pallet pooling and repair and reuse large quantities end-of-life wood pallets and packaging are still generated and sent to landfill.

In 2008, the Resource Recovery Section of the then Department of Environment, Climate Change and Water (DECCW)[1] undertook a major survey of the commercial and industrial (C&I) waste disposed to landfills in the Sydney Metropolitan Area (SMA) and found that a total of 288,000 tonnes of wood were disposed to landfills in the SMA in 2007-08. 140,000 tonnes (49%) of wood in the mixed C&I waste stream was made up of mainly wood pallets and crates.

As a result of the large quantities generated and the high potential for increased recovery and utilization, the National Timber Product Stewardship Group has also identified end-of-life wood packaging as a priority waste stream in their Product Stewardship Action Plan *Timber – More Life*.

At the same time pallet repair and reuse companies have identified that many companies, are seeking to reduce the disposal of waste to landfill as well as reduce the greenhouse gas emissions of their supply chain.

This Calculator has been developed to provide organisations that dispose of end-of-life wood packaging with an estimate of the greenhouse gas (GHG) emissions of the major waste management options. This accompanying assumptions report has been prepared so that companies utilising the calculator are aware of the assumptions made, which are conservative. Particular companies circumstances may differ from those made here in which case GHG emissions may be greater or less.

The calculator utilises a life cycle assessment methodology in line with ISO 14044. It also utilises the GHG Protocol - **Corporate Value Chain (Scope 3) Accounting and Reporting Standard**. For most companies with end-of-life wood packaging these emissions are Scope 3 emissions however these emissions may be the scope 1 emissions of a waste management company.

Reuse/repair, recovery for recycling or generation of renewable energy all entail some measure of greenhouse gas emissions as well as the avoidance of greenhouse gas associated with manufacturing processes. All greenhouse gas savings are net benefits, that is, benefits after the average impacts of collection, transport and reprocessing have been accounted for.

IMPORTANT NOTE:

Wood packaging that is used to import or export goods may have been subject to immunisation with heat, sterilisation with fumigant or treatment with permanent preservatives for quarantine purposes. Immunisation with heat or sterilisation with the non-residual gas methyl bromide is very common and is not a barrier to reuse or recycling. Wood packaging treated with permanent preservatives is able to be reused

[1] In 2011 DECCW became the Office of Environment & Heritage (OEH). In 2012, the Waste and Resource Recovery section of OEH became part of the NSW Environment Protection Authority (EPA).

however shredding for use as mulch or animal bedding is not recommended and is actually not permitted in many jurisdictions, including NSW. Recovery for use in renewable energy products may also be restricted. Engineered wood products such as plywood, particleboard and MDF used for wood packaging may also not be permitted to be used in NSW for recycled products such as mulch. More information on the restrictions in NSW can be found on the website of the NSW Environment Protection Authority on the resource recovery exemptions web pages.

The incidence of treatment of wood packaging with permanent preservatives is very low. A report on the incidence of metal-based preservatives, and its likely source, in the wood packaging waste stream can be found on the website of the National Timber Product Stewardship Group at www.timberstewardship.org.au

Wood packaging may also become contaminated with chemicals spilled during use and transport. In NSW, under the Protection of the Environment Operations Act the generator of the waste is responsible for its correct waste classification and disposal. Wood packaging that is contaminated should be separated and disposed of appropriately and not sent for recycling or shredding into renewable energy products.

2 GOAL, SCOPE AND FUNCTIONAL UNIT

2.1 Goal

This Calculator has been developed to provide organisations that dispose of end-of-life wood packaging in New South Wales such as wood pallets, skids, crates and bins with an estimate of the greenhouse gas (GHG) direct and avoided emissions of the major waste management options.

2.2 Scope

The following scenarios are included for comparative assessment in the Calculator:

- Reuse and repair compared to disposal in a landfill
- Reuse and repair compared to shredding and recycling for landscape mulch, animal bedding and new particleboard
- Reuse and repair compared to shredding and industrial energy recovery in place of fossil fuel.

Note that the geographic scope is confined to New South Wales.

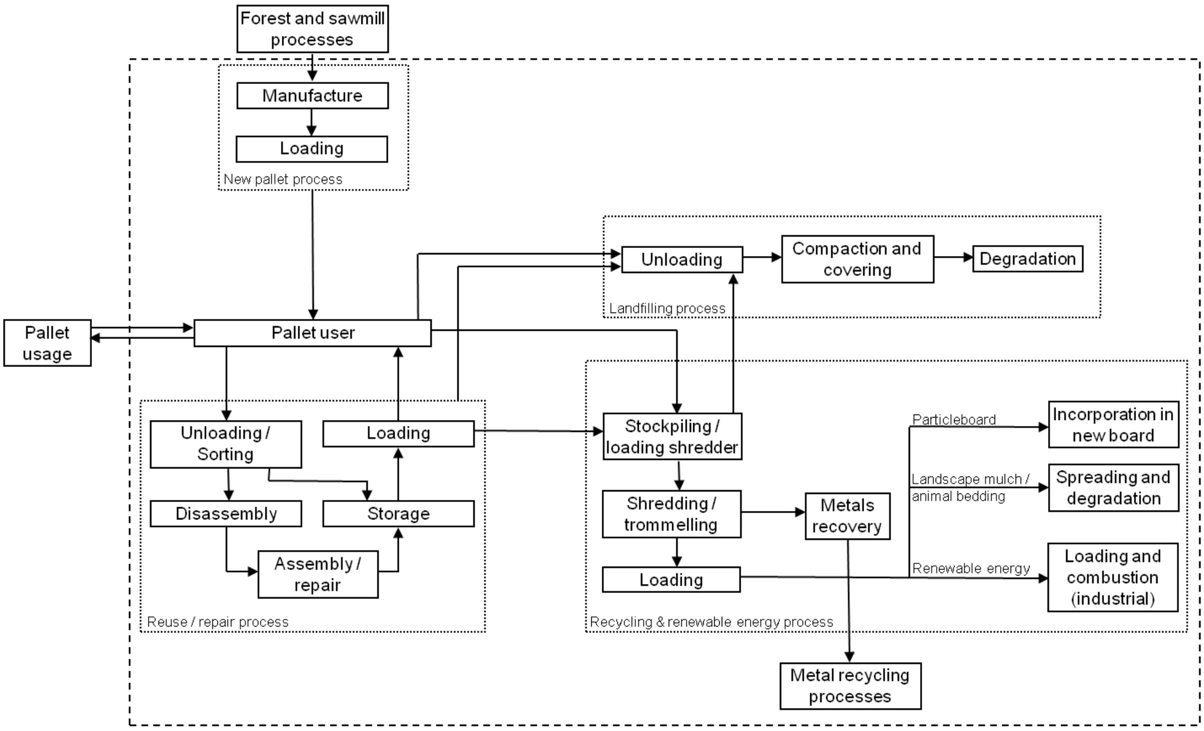
2.3 Functional Unit

The functional unit is one (1) tonne of wood packaging.

2.4 System Boundary

The system boundary describes the processes included and excluded from the study.

Figure 1: System Boundary



3 PROCESS DESCRIPTIONS, PARAMETERS AND ASSUMPTIONS

Wood packaging is used for the transport of goods around and into and out of Australia. Wood packaging such as pallets and skids are usually of standard dimension. Most of those used to transport goods around in Australia are the Australian Standard pallet (1165mm x 1165mm) and most of those are used to transport goods around in Australia. A small proportion of wood pallets used are not the Australian standard size as they are built for custom size products which are used to export goods.

Wood packaging such as crates and boxes are more often custom built to suit a particular commodity. Many have been used to import goods into Australia.

3.1 Reuse and Repair

Recovered wooden pallets, or their component parts such as bearers and decking boards, can be used as a substitute for new hardwood and softwood in the repair of or construction of new pallets.

The pallet reprocessing process picks-up or accepts end-of-life wood pallets or pallet timber that has been collected and sorts the timber according to size and type.

Pallets received that are suitable for reuse without repair/resizing are on-sold, while those requiring only simple repairs may have boards replaced with recycled or first-use boards.

Pallets that cannot be repaired may be disassembled into bearers and deck-board components by cutting, pulling apart or other processes. Deck-boards are resized according to the required size of new pallets, and pallets are rebuilt using a combination of new, recycled and first-use bearers and deck-boards.

Waste timber from off-cuts and reject bearers/deck-boards are sent to timber recyclers for shredding.

In the case of straight forward reuse, new pallets are not produced. However reuse does not have any impact on new timber production so there are no avoided processes. This is because new timber production is driven by the production of structurally graded timber and lower quality case grade timber, used to produce new pallets, is a by-product of this production process. If there is reduced demand for case-grade timber, production of structural timber (and case-grade by-products) products would carry on as production of structural grade sawn timber is the primary driver

However, reuse of pallets does affect the demand for freight transport of case-grade timber to a pallet manufacturer. Therefore the reuse of pallets offsets the transport of case grade timber from the sawmill to the new pallet manufacturer

Repair and reuse of wood pallets results in the use of recovered and new case grade timber.

The parameters and associated flows are summarised in Table 1.

Storage of carbon in wood pallets

Carbon is stored in wood whether in trees or wood products. When trees grow the remove they CO_2 from the atmosphere to form wood and release oxygen back into the atmosphere. About half the dry weight of wood is carbon in the form of various lignocellulosic compounds. This carbon remains stored in the wood until it is burnt or breaks down because of chemical action or decay into greenhouse gases.[2]

In the case of wood in pallets, the carbon stored in the wood remains in the pallet for the life of its service. The longer the service life the longer the carbon is stored and the longer greenhouse gases are kept out of the atmosphere.

Softwood wood pallets and cases have an estimated medium service life of 2 years and hardwood wood pallets have an estimated medium service life of 6 years (Richards 2007).

Repair and reuse of timber pallets extends their service life. This increased service life means that greenhouse gas emissions from recycling processes, aerobic degradation or disposal in landfill are delayed.

The storage of carbon by reuse and repair may be significant when considering the general pool of wood pallets; however it is considered outside the scope of this calculator and report.

Table 1: Parameters and flows associated with wood pallet reuse and repair

Parameter	Flow	Unit	Comments	Source
Transport load to reuse / repair facility	200	Pallets	Per load	Enviro Pallets
Pallet weight	24.3	kg	Average weight	Enviro Pallets
Freight distance	20	km		Enviro Pallets
Backhaul ratio	1:1		Trucks are usually loaded in each direction	Enviro Pallets
Fuel consumption - rigid truck post 2004	28.9	litres / 100km		CSIRO
Diesel energy content	38.6	GJ/kL		DCCEE (2011a)

3.2 Recycling

End-of-life wood packaging may be recycled and shredded for utilisation as landscape mulch, animal bedding and/or particleboard.

[2] It is assumed that for wood pallets in service no decay occurs.

This process involves collection and stockpiling of wood packaging. Unsuitable or contaminated packaging is either not accepted (and therefore landfilled) or, if it accepted, identified internally and separated and disposed of to landfill by the recycler.[3] Once a critical mass of acceptable quality material is stockpiled a loader is used to feed a wood shredder. In the shredding process wood metal connectors such as nails and nail plates are removed by magnetic devices for later transport to a metal recycler. The shredded wood is then fed through a trommel to separate oversize material and to also separate the wood into different particle sized products. Large oversize material is passed through the shredder and trommel again.

Mid-size and small-size shredded wood is suitable for landscape mulch. Very small size wood is suitable for use as animal bedding. Particle-sizing for recycling into new particleboard can be anything from small to large.

The respective recovered wood products are loaded onto large trucks fitted with walking floors for delivery to landscape sites, animal facilities (such as broiler chicken sheds) within a reasonable distance to minimise transport costs and to particleboard factories.

Any recovered metal connectors are stockpiled and sent to a recycler where they replace new steel in the production process.

The parameters and associated flows associated with production of shredded recovered wood for recycling and renewable energy are outlines in Table 2 below.

Table 2: Parameters and flows associated with production of shredded recovered wood for recycling and renewable energy

Parameter	Flow	Unit	Comments	Source
Transport load to shredding facility	20	m^3	Transported in large open bins or on contained trucks	DECCW (2010b)
Load density	156	kg/m^3		DECCW (2010b)
Waste freight distance	20	km		DECCW (2010b)
Backhaul ratio	1:2		Trucks are usually empty on return	Benedict Recycling
Fuel consumption - rigid truck	28.9	litres / 100km		CSIRO
Diesel energy content	38.6	GJ/kL		DCCEE (2011a)
Shredder fuel consumption	120	litres / hour	diesel	Benedict Recycling
Excavator feeding shredder fuel	30	litres / hour	diesel	Benedict Recycling

[3] It is assumed that the wood packaging sourced for shredding into land applications meets the Protection of the Environment Operations (Waste) Regulation 2005 and that it meets the raw mulch general exemption 2008. That is wood packaging and pallets that do not include preservative treated or coated wood residues or engineered wood products. The raw mulch general exemption 2008 can be downloaded from http://www.environment.nsw.gov.au/waste/generalRRE.htm

consumption				
Loader feeding trommel fuel consumption	12	litres / hour	diesel	Benedict Recycling
Loader and stockpiling finished screened product fuel consumption	12	litres / hour	diesel	Benedict Recycling
Loading truck fuel consumption	12	litres / hour	diesel	Benedict Recycling
Shredder throughput	90	m^3 / hour		Benedict Recycling
Trommel screening throughput	45	45m^3 / hour		Benedict Recycling
Bulk density of shredded wood packaging	250	kg/m3		Benedict Recycling
Recovery of steel from shredded packaging	0.75	kg/m3 shredded		EMRC
Recovery of steel from shredded packaging	3	kg/tonne		EMRC
Avoided primary steel production emissions	0.003	tonnes $C0_2$-e/tonne of shredded wood		DECCW (2010a)

3.2.1 Landscape mulch

Landscape mulch is spread onsite by hand or by moving equipment such as large diameter blowing devices. Wood mulch usually lasts a couple of years depending on particle-size and site conditions before aerobically degrading to carbon dioxide. As it breaks down the wood also adds nutrients and carbon to the soil.

The use of recycled end-of-life wood packaging as landscape mulch either displaces the use of garden organics sourced from municipal collections; softwood or hardwood woodchips or bark sourced as by-products from sawmills and wood product manufacturers utilising new timber.

Using landscape mulch derived from recycled wood pallets offsets the use of recovered garden organics and/or the use of pre-consumer wood products such as wood chip or bark sourced from sawmills. As both these product release CO_2 upon degradation and have similar transport and processing requirements, no offsets from the recycling of shredded wood packaging as landscape mulch is included.

As a conservative approach, increased storage of carbon in soil from the use of recovered wood as raw mulch or bedding (and applied to land) is not considered.

The parameters and associated flows for production and supply of landscape mulch are summarised in Table 3 below.

Table 3: Parameters and flows associated with supply of virgin landscape mulch

Parameter	Flow	Unit	Comments	Source
Transport load to landscape sites	90	m3		Benedict Recycling
Transport distance	20	km	Estimate based on delivery to sites within SMA	TDA
Pine bark – bulk density	350	kg/m3		Amazon soils
Freight volume of pine bark	90	m3	Estimate	TDA
Freight distance of pine bark	354	Km	Average distance from main pine sawmills in Tumut, Tumbarumba and Oberon to Sydney	TDA
Back load ratio	1:2		Trucks are usually empty on return	TDA

3.2.2 Animal bedding

Animal bedding placed in a broiler chicken shed is spread with a mechanical spreader before chicks are brought in. After approximately six-seven weeks the grown chickens are removed and the sheds cleaned out with the used bedding removed. The used bedding, now with added chicken manure, is now called litter and is utilised on surrounding farms or by soil suppliers in the manufacture of horticultural or nursery soil mixes.

The use of bedding made from end-of-life wood packaging displaces the use of hardwood and softwood sawdust and shavings sourced as by-products from sawmills and wood product manufacturers which are manufacturing new (or recovered) timber.

The used bedding degrades aerobically quite quickly to carbon dioxide.

Using chicken bedding derived from recycled wood pallets offsets the use of pre-consumer wood products such as wood chip or bark sourced from sawmills or agricultural residues from crop harvesting and processing such as rice hulls. As both these product release CO_2 upon aerobic degradation and have similar transport and processing requirements, no offsets from the recycling of shredded wood packaging as animal bedding is included.

As a conservative approach, increased storage of carbon in soil from the use of recovered wood as raw mulch or bedding (and applied to land) is not considered.

The parameters and associated flows for production and supply of animal bedding are summarised in Table 4 below.

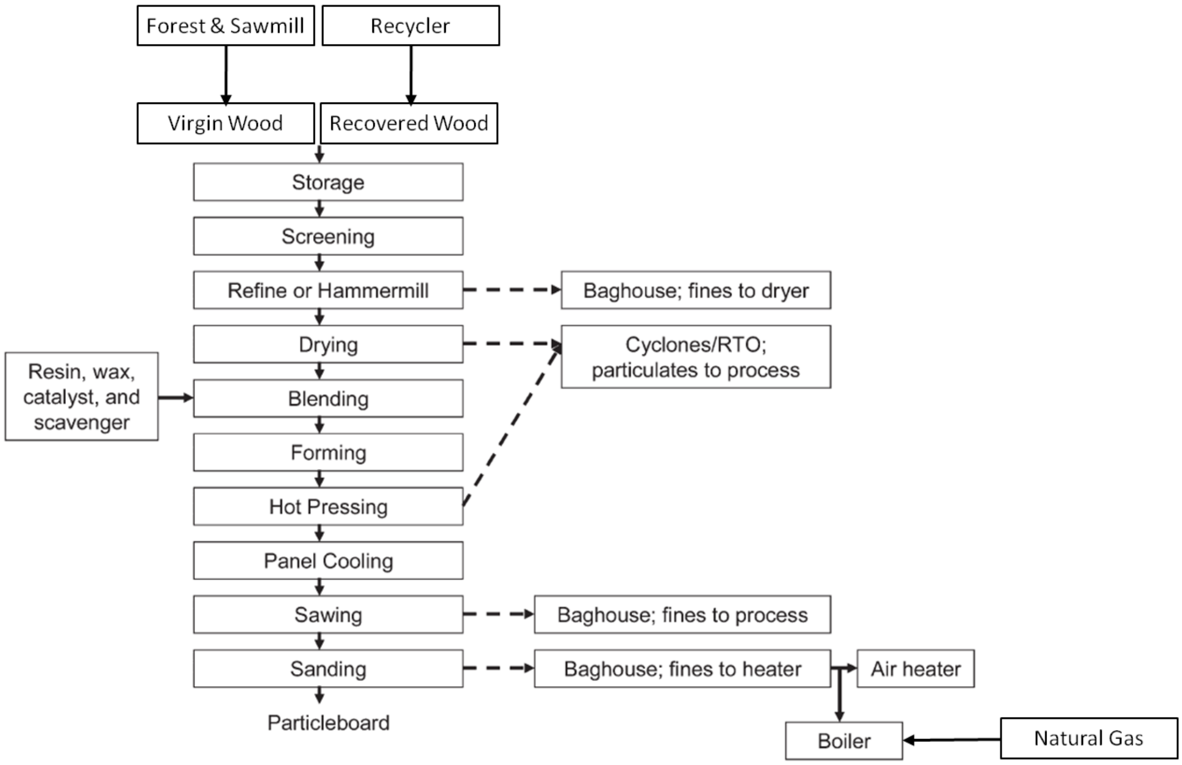
Table 4: Parameters and flows associated with virgin animal bedding

Parameter	Flow	Unit	Comments	Source
Transport load to poultry sheds	90	m3		Benedict Recycling
Transport distance	72	km	Estimate based on poultry industry in SMA, lower hunter and central coast	Contract Poultry Group
Sawdust and shavings – bulk density (average of wet and dry)	170	kg/m3	Calculated from bulk density of sawdust and shavings	Runge et. al
Freight volume of sawdust / shavings	90	m3		Contract Poultry Group
Freight distance of sawdust / shavings	178	Km		Contract Poultry Group
Back load ratio	1:2		Trucks are usually empty on return	Contract Poultry Group

3.2.3 Particleboard

Particleboard in Australia is manufactured from forest thinnings, veneer peeler cores and sawmill residues including off-cuts, planer shavings and sawdust. This is referred to as virgin wood. All wood inputs are chipped and flaked into particles, dried and then sprayed with liquid adhesive. Wax and other inputs are also added to some products such as high moisture resistant panels and particleboard flooring.

Figure 2: Particleboard manufacturing process. Source: Based on Wilson (2010)



Before drying to moisture content of between 3-5% all wood is screened and refined and/or milled by hammermills to correct shapes and sizes (Wilson 2010). All particles are sent through dryers. The amount of energy needed for drying the wood particles is highly dependent on the moisture content of the wood inputs. Virgin wood is green and has high moisture content which varies significantly between species. The moisture content of radiata pine, the most common input species for particleboard in Australia is estimated to be 50% (Ximenes et al 2008).

Wood utilised in particleboard manufacture from recovered end-of-life wood packaging takes the place of virgin wood. The moisture content of recovered wood is much lower ranging from 12-20% (Benedict Recycling 2010). A conservative estimate of 20% is used in the calculator.

After the particles have been dried, the subsequent processes in the manufacturing of particleboard are the same whether or not recovered wood is used. The use of recovered wood therefore does not have any implications for GHG emissions following the drying process so they are not described in any further detail.

Process waste (wood waste) and in some cases wood fuel sourced directly for this purpose is used to fire boilers. The heat and steam generated is used to dry particles as well as heat oil used in the pressing processes. Natural gas is used as the supplementary fuel as there is not enough biomass waste for the boiler.

Recovered wood has been estimated to replace 10% of virgin wood in new particleboard at D&R Henderson's particleboard plant[4] (Advantage Recycling 2012). As it has a lower moisture content, less recovered wood is needed (by weight and volume) to be sourced, transported, milled and dried. All other processes in the making of new particleboard are identical whether virgin or recovered wood is used.

The parameters and associated flows for production and recovered shredded wood for use in the production of new particleboard are summarised in Table 5 below.

It should be noted end-of-life particleboard and plywood, with proper controls, can also be included in the particleboard recycling route.

[4] The only facility that currently uses wood packaging recovered from the waste stream in NSW is D&R Henderson's facility in Benalla Victoria.

Table 5: Parameters and flows of associated with transport and incorporation of recovered shredded wood in place of virgin wood in production of new particleboard

Parameter	Flow	Unit	Comments	Source
Transport load to particleboard manufacturer of recovered wood	90	m3		Advantage Recycling
Transport distance of recovered wood	630	km	Distance to D&R Henderson in Benalla, Victoria	Calculated by TDA
Back load ratio of recovered wood	1:1		Trucks are loaded each way	Advantage Recycling
Bulk density of recovered wood	250	kg/m3		TDA
Moisture content of recovered wood	20	%	High-point of MC range of 12-20%	Benedict Recycling 2010
Freight distance of virgin wood	116	Km	Average distance from sawmills and plantations to Benalla	Tucker et al (2009)
Freight volume of virgin pine	90	m3	Estimate	TDA
Moisture content of virgin radiata pine	50	%		Ximenes et al (2008)
Green density of virgin wood (at 50% MC)	900	kg/m3	Unseasoned radiata pine	AS1720.2
Bulk density of virgin wood (at 50% MC)	500	kg/m3	Estimate	TDA
Quantity of virgin wood (MC 50%) needed to provide same amount of chip as 1 tonne of recovered wood (20% MC)	1.6	tonnes	Calculated	TDA
Electricity consumed to refine and mill wood	44	kwh/tonne		Wilson
Emissions of electricity consumed	1.21	kg CO_2-e/kWh	Victorian supply (Scope 2)	DCCEE (2011b)
Emissions of electricity consumed	1.35	kg CO_2-e/kWh	Victorian supply (Scope 2 and Scope 3)	DCCEE (2011b)
Diesel consumed to refine and mill wood	2	L/tonne		Wilson
Energy content of diesel fuel	38.6	GJ/kl		DCCEE (2011a)
Moisture content of dry wood used for particleboard production	5	%	High point of range of 3-5%	Wilson
Amount of heavy fuel oil needed to evaporate each kilogram of water from wood	0.12	kg		Merrid & Christensen

Energy content factor of fuel oil	39.7	GJ/kL		DCCEE (2011a)
Density of heavy fuel oil	991	tonne/kL		Shell
Energy required to evaporate each kilogram of water from wood	4.76	MJ/kg	Calculated	TDA
Proportion of boiler energy that is supplied by biomass	68	%	Australian average for particleboard manufacturing	Tucker et al
Proportion of boiler energy that is supplied by natural gas	32	%	Australian average for particleboard manufacturing	Tucker et al
Energy content of biomass MC 50%	10.2	GJ/tonne	Energy content of greenwood (>20%)	DCCEE (2011a)
CO_2 emissions of combustion of wood	0[5]	kg CO_2-e/GJ		DCCEE (2011a)
CH_4 emissions factors for of combustion of wood	0.08	kg CO_2-e/GJ		DCCEE (2011a)
NO_2 emissions factors for of combustion of wood	1.2	kg CO_2-e/GJ		DCCEE (2011a)
Total CO_2e emissions of combustion of wood	1.28	kg CO_2-e/GJ	Calculated	TDA
Energy content of natural gas distributed in a pipeline pipelines	0.393	GJ/m3		DCCEE (2011a)
CO_2 emissions of combustion of natural gas	51.2	kg CO_2-e/GJ		DCCEE (2011a)
CH_4 emissions factors for of combustion of natural gas	0.1	kg CO_2-e/GJ		DCCEE (2011a)
NO_2 emissions factors for of combustion of natural gas	0.02	kg CO_2-e/GJ		DCCEE (2011a)
Total CO_2e emissions of combustion of natural gas	51.32	kg CO_2-e/GJ	Calculated	TDA
GHG Emissions factor for biomass/natural gas mix	17.3	kgCO_2e/Gj	Calculated	TDA
Average percentage of recycled content compared to virgin wood in particleboard	10	%	Estimate	Advantage Recycling
Biogenic CO_2 emissions factor	3.67			Ximenes et al (2007)
Carbon content of wood (dry weight basis)	50	%		Ximenes et al (2007)
Biogenic CO_2 emissions from combustion of 1 tonne of recovered wood (20% MC)	1.47	tonnes CO_2	Calculated	TDA

[5] Under the 2006 IPCC Guidelines, the GHG emission factor for CO_2 released from combustion of biogenic carbon fuels is zero (DCCEE 2011b)

Storage of carbon in particleboard products

Carbon is stored in wood whether in trees or wood products. When trees grow they remove CO_2 from the atmosphere to form wood and release oxygen back into the atmosphere. About half the dry weight of wood is carbon in the form of various lignocellulosic compounds. This carbon remains stored in the wood until it is burnt or breaks down because of chemical action or decay into greenhouse gases.

In the case of wood used in the production of particleboard, most of the carbon stored in the wood remains in the particleboard for its entire service life.[6] The longer the service life the longer the carbon is stored and the longer greenhouse gases are kept out of the atmosphere.

How long greenhouse gases are kept out of the atmosphere depends on the product service life and various particleboard products have different estimated service lives. A study by Jaakko Pöyry(1999) estimates that the various particleboard products have service lives ranging between 3-90 years. The medium service life of the main particleboard products are provided in Table 6 below. Based on a TDA estimate of the proportion of production of the main particleboard products, it is estimated that the medium service life of all particleboard products is 29 years in Australia. Thus, using recovered wood in new particleboard extends the storage of carbon for an additional 29 years.

This is a significant extension of service life (and carbon storage) compared to the medium service life of softwood pallets and crates noted in Section 3.1.

Subsequent reuse, recycling or use as renewable energy will either further extend or release the carbon stored in the particleboard. Accounting for this is however beyond the scope of this calculator and report.

Table 6: Estimated service life of particleboard products

Service life of particleboard in shop-fittings and DIY	6	years	Medium life	Jaakko Pöyry (1999)
Service life of particleboard in kitchens and bathrooms	20	years	Medium life	Jaakko Pöyry (1999)
Service life of particleboard in flooring	50	years	Medium life	Jaakko Pöyry (1999)
Ratio of production into shop-fittings/ kitchens & bathrooms and flooring/lining	20/40/ 40		Estimate	TDA
Medium service life of all particleboard	29	years	Calculated	TDA

[6] It is estimated that 5% of particleboard is disposed of before end use in the form of sawdust and offcuts. This waste is usually disposed to landfill. As the recycled component is only 10% of this 5% wastage the greenhouse gas emissions from disposal and degradation of this waste is considered negligible.

3.3 Renewable Energy

End-of-life wood packaging may also be used in NSW in combustion in place of fossil fuels to generate electricity to earn renewable energy credits (RECS)[7]. The shredding process is identical to that described above in recycling. The shredded wood is transported to a power station where it is co-fired with fossil fuels, which is NSW black coal. The shredded wood is added by a dedicated loader onto a separate conveyor and 'sprinkled' on top of the coal feed (currently at maximum of 3% of the total feed). The coal/wood mix is fed into series of bunkers and then conveyed to a table mill where it is milled into a very fine mix before being fed into the boilers and combusted to produce steam for the generation of electricity.

The addition of wood displaces the need to combust black coal. Carbon dioxide emissions from combusting wood are regarded as in balance with the carbon dioxide absorbed by the growing trees during photosynthesis so do not add additional carbon dioxide to the atmosphere. A small amount of other greenhouse gases such as methane and nitrous oxide are released during combustion and must be taken into account when calculating greenhouse gas emissions and subsequent global warming potential (GWP).Combustion of wood packaging assumes standard combustion emission factors from NGER technical guidelines for black coal and wood and typical energy content and electricity generation for the wood.

Using shredded wood derived from recycled wood packaging as fuel to generate electricity offsets the mining, processing and combustion of the fossil fuel black coal in NSW.

However, to comply with the *GHG Protocol* **-** *Corporate Value Chain (Scope 3) Accounting and Reporting Standard* biogenic carbon dioxide emissions are required to be reported separately. The standard conversion factor of carbon to carbon dioxide of 44/12 or 3.67 (obtained from Ximenes *et al* 2007) is used to calculate the biogenic carbon dioxide emissions from combustion.

Particle-sizing for renewable energy products varies depending on the facility (see below).

The parameters and associated flows for transport and combustion of shredded wood pallets as well as mining and combustion of NSW/ACT black coal and are summarised in Table 7 below.

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[7] It is assumed that the end-of-life wood packaging used as renewable energy meets the Protection of the Environment Operations (Waste) Regulation 2005. It is also assumed that facilities utilising shredded wood for fuel have the appropriate development approvals, Environment Protection license, were required, and the appropriate approval to utilise a non-standard fuel such as uncontaminated end-of-life wood packaging. For further guidance refer to *Guidance Note: Assessment of Non-Standard Fuels* which can be downloaded from http://www.environment.nsw.gov.au/waste/RREapplications.htm

Table 7: Parameters and flows associated with combustion of recovered shredded wood packaging and NSW and ACT black coal

Parameter	Flow	Unit	Comments	Source
Transport load to power station	90	m3		Delta Electricity
Transport distance	130	km	Transport to central coast	Delta Electricity
Backhaul ratio	1:2		Trucks are usually empty on return	Delta Electricity
Moisture content of shredded wood	20	%		TDA
Energy content of wood at 20% MC	16.2	GJ/tonne		DCCEE (2011a)
CO_2 emissions for combustion of wood[8]	0			DCCEE (2011a)
CH_4 emissions factors for combustion of wood	0.08			DCCEE (2011a)
NO_2 emissions factors for combustion of wood	1.2			DCCEE (2011a)
Energy content of NSW black coal	27	GJ/tonne		DCCEE (2011a)
Scope 2 emissions from supply of electricity - NSW and ACT	0.89	CO_2-e/kWh		DCCEE (2011b)
Scope 2 and scope 3 emissions from supply of electricity - NSW and ACT	1.07	CO_2-e/kWh		DCCEE (2011b)
Biogenic CO_2 emissions factor	3.67			Ximenes et al (2007)
Carbon content of wood (dry weight basis)	50	%		Ximenes et al (2007)
Biogenic CO_2 emissions from combustion of 1 tonne of recovered wood (20% MC)	1.47	tonnes CO_2	Calculated	TDA

3.4 Landfilling

If landfilled, wood packaging is assumed to be transported to a landfill and tipped. A loader consolidates all waste and a compacter condenses the waste to decrease the volume and increase density. It is assumed that all waste is covered with shale that is excavated from the landfill site.

The parameters used for GHG emissions resulting from degradation of 1 kilogram of wood in landfill are set out in Tables 8, 9 and 10 below:

[8] Under the 2006 IPCC Guidelines, the GHG emission factor for CO_2 released from combustion of biogenic carbon fuels is zero (DCCEE 2011b)

In this calculator and this report, the current parameters used by the DCCEE for degradation of wood under anaerobic conditions in MSW landfills have been chosen and are highlighted in yellow in the Table below. Since the first edition of this report the DOCf value used in this report was incorporated into the NGER (Measurement) Determination for the Reporting Year 2011-2012 by June 2011 (DCCEE 2011a).

This degradation factor is a conservative assumption. A recent peer reviewed study by the same researchers in the United States who provided the evidence for the review by DCCEE has found that the DOCf values should be even lower (Wang et al 2011).

Storage of carbon in wood product in landfill

As 24% of all carbon within wood products within landfill is assumed to degrade in the landfill, the remaining 76% of carbon within the wood is assumed to remain stored in the landfill for the long term.

Table 8: Parameters and flows of transport to landfill of waste wood packaging

Parameter	Flow	Unit	Comments	Source
Transport load to landfill	20	m^3	Transported in large open bins or on contained trucks	DECCW (2010b)
Backload ratio	1:2		Trucks are empty on return	TDA
Load density	156	kg/m^3		DECCW (2010b)
Waste freight distance	20	km		DECCW (2010b)

Table 9: Parameters and flows of compaction and covering at landfill of waste wood packaging

Parameter	Flow	Unit	Comments	Source
Loader - average fuel consumption	13	litres / hour		DECCW (2010b)
Loader - average hours of operation	55	hours of operation per week		Veolia
Compactor - average fuel consumption	70	litres / hour		Veolia
Compactor - Average hours of operation	55	hours of operation per week		Veolia
Excavator - Average fuel consumption	21	litres / hour		Veolia
Excavator - Average hours of operation	22.5	hours of operation per week		Veolia
Dump truck - Average fuel consumption	11	litres / hour		Veolia
Dump truck - Average hours of operation	22.5	hours of operation per week		Veolia
Waste quantity processed	7200	tonnes per week		Veolia
Proportion of waste that is wood packaging	10	%		DECCW (2010b)

Table 10: Parameters and flows in landfill of degradation of waste wood packaging. ***Source: Based on Ximenes & Grant (unpublished)***

Parameter	Unit	Default IPCC	DCCEE	DPI NSW
Degradable organic carbon (dry mass basis)	%	49	49	49
Fraction of degradable organic carbon which degrades (DOCf value)	%	50[9]	24	10
Fraction of landfill gas which is methane	%	50	50	50
Fraction of methane recovered	%	55	55	55
Fraction of methane recovered for power generation	%	75	75	75
Efficiency of power generation	%	35	35	35
Oxidation factor	%	10	10	10
Carbon stored in landfill	kg	0.245	0.372	0.441
Final methane emission	kg	0.058	0.0318	0.0116
Methane global warming potential compared to carbon dioxide (100 years)	factor	21	21	21
Final emission (carbon dioxide equivalent)	kg	1.218	0.6678	0.2436

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3.5 Summary of GHG emissions and avoided emissions for different management options

FACTORS	GHG emissions (negative) and removals (positive)	MANAGEMENT OPTIONS for END-OF-LIFE WOODEN PACKAGING				
		REUSE	REPAIR/REUSE	RECYCLING (Mulch / Animal Bedding/ Particleboard)	RENEWABLE ENERGY	LANDFILLING
FACTORS CONSIDERED	Emissions	Emissions from: • transport to reuse facility	Emissions from: • transport to repair/reuse facility	Emissions from: • transport to shredding facility • processing energy used to operate plant and machinery to shred • transport to end-user	Emissions from: • transport to shredding facility • processing energy used to operate plant and machinery to shred • transport to electricity generator • combustion of wood (non-CO_2)	Emissions from: • transport to landfill • pushing, compaction and covering of wood at landfill • anaerobic degradation of wood in landfill
	Removals	Savings (offsets) from: • reduced transport from sawmill to new pallet manufacturer • transport to landfill • pushing, compaction and covering of wood packaging at landfill • anaerobic degradation of wood in landfill	Savings (offsets) from: • Reduced transport from sawmill to new pallet manufacturer • transport to landfill • pushing, compaction and covering of wood packaging at landfill • anaerobic degradation of wood in landfill	Savings (offsets) from: • use of metal recovered from fixings in place of virgin metal • reduced processing and transport of virgin materials • reduced emissions from refining & drying virgin wood • transport to landfill • pushing, compaction and covering of wood packaging at landfill • anaerobic degradation of wood in landfill	Savings (offsets) from: • use of metal recovered from fixings in place of virgin metal • reduced mining, processing, transport, and combustion of black coal • transport to landfill • pushing, compaction and covering of wood packaging at landfill • anaerobic degradation of wood in landfill	Savings (offsets) from: NA
FACTORS <u>NOT</u> CONSIDERED (insignificant or outside scope)	Emissions	Emissions from: • movement of reused packaging • human labour, warehouse lighting, heating, cooling etc	Emissions from: • movement and repair of packaging • human labour, warehouse lighting, heating, cooling etc	Emissions from: • spreading of mulch and bedding • human labour, lighting, heating, cooling etc	Emissions from: • loading onto coal feed • human labour, lighting, heating, cooling etc	Emissions from: • unloading wood packaging at landfill • human labour, lighting, heating, cooling etc
	Removals	Savings (offsets) from: • reduced energy usage by pallet manufacturer	Savings (offsets) from: • reduced energy usage by pallet manufacturer		None	None
Note: Positive emissions mean that there is a GHG emission from the process. Negative emissions means that the nominated recovery options option results in an avoided GHG emission. These avoided GHG emissions are subtracted from the positive GHG emissions for the chosen management option.						

4 ASSUMPTIONS REGARDING NEW TIMBER

4.1 Forests

All new timber used in the manufacture of wooden packaging is assumed to come from sustainably harvested plantations. The forest producing the timber is assumed to be in a steady state with no net increase or decrease in carbon stored in the forest over time. Timber removed from forests used and then placed in landfill, where a large fraction of the timber does not degrade, represents a net increase in carbon storage. (Refer to Ximenes *et. al* (2007) and Jaako Poyry (1999)).

4.2 New Timber

Sawn wood is assumed to be Australian sourced case-grade softwood which is kiln-dried. Case-grade softwood is produced as a by-product of the process of manufacturing structural grade softwood timber for construction so reduced consumption of case-grade softwood does not reduce new timber production. If consumption of new case-grade timber is avoided (e.g. by reuse) new case-grade timber is either used for other non-structural/utility purposes (such as fencing, landscape). Alternatively, if this market is not available or suitable, the wood is shredded for other applications (such as use in particleboard manufacture, landscape mulch or animal bedding). Either way the case-grade timber is not landfilled as waste.

It should be noted that these assumptions are different to those made in the *Environmental Benefits of Recycling* study (DECCW 2010a) which accounted for avoidance of greenhouse gas emissions from the growth and processing of structural pine.

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6 ASSUMPTIONS REVIEW AND ACTIONS

A review of the assumptions reports was carried out by Fabiano Ximenes - Acting Program Leader - New Forests, Climate in Primary Industries Industry & Investment NSW. The following comments were made and actions undertaken.

Section	FX comment	Action/changes
Title	Title is confusing	Title changed
-	Needs an introduction to give some background	Introduction added
Reuse and Repair	I think you mean “production of structural timber”	Text changed
	May be better to say instead: “as production of structural grade sawn timber is the primary driver”	Text changed
Table 5	Moisture content of wood packaging May be a bit too high [12%], doesn’t take into account green packing cases?	Moisture content adjusted up to 20%
Recycling	Better to say: “In the shredding process”	Text changed
	Not sure if you can really refer to those technically as “wood products”	Text changed to “recovered wood products”
Landfilling	What type, MSW , C&D or C&I? If C&D then the DOCf can be zero –maybe could be modelled as an alternative scenario	Text changed to Municipal Solid Waste landfill. A footnote added that explains that this is a conservative assumption and that if wood packaging is disposed in non-putrescible landfill a DOCf value of zero would be appropriate.
	The parameters apply “For degradation of wood under anaerobic conditions in landfills”	Text changed
Forests	This is not true, as each time wood is placed in landfill a high % of that C is stored for the long-term, constantly adding to the pool regardless of whether there are plantations in new areas or greater yields.	This line and previous line deleted