Forest & Wood Products Australia

Forests, Plantations, Wood Products & Australia's Carbon Balance

Contents

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1. SCION Innovation Hub (Patrick Reynolds & Irving Smith Architects)

2. Gippsland Performing Arts Centre (MASSLAM & Jackson Architecture)

3,4. Pieman Chest of Drawers Anton Gerner - Designer

Introduction

The sustainable forest products industry in Australia can help reduce society's energy use and greenhouse gas emissions.

This Guide has been developed to indicate the extent to which plantations and other commercial forests, as well as the wood products produced from those forests, contribute to Australia's carbon balance. It also identifies opportunities to improve that contribution. While the storage of carbon in forests is well understood, the important contribution that wood (both in service and after disposal) makes to carbon storage is less well recognised.

We hope this Guide extends your knowledge of the positive role of forest and wood products in the carbon economy.

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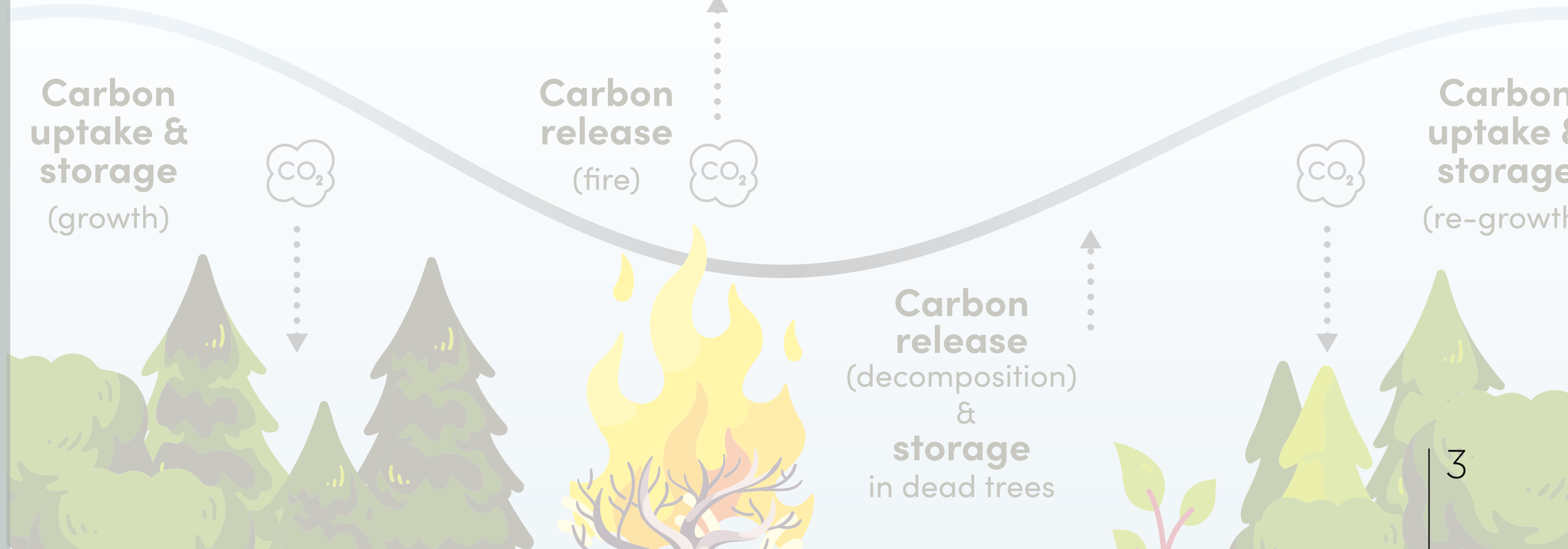
This Guide describes the key concepts associated with the life cycle of carbon in forest products and provides the latest facts and figures on the carbon balance in production forests and forest products in Australia. Existing frameworks for carbon accounting in the forestry sector, and opportunities to participate in carbon markets are described. There are various opportunities to improve the climate benefits of the industry even further.

The positive role of sustainably managed forests in the global carbon cycle is widely recognised. The forest products industry in Australia is an important potential contributor to climate change mitigation. Sustainably managed plantations and native forests sequester carbon, and carbon can be stored for many decades in wood products. These range from traditional applications such as hardwood flooring and pine wall framing to newer products such as mass timber products in mid- to high-rise buildings. Carbon continues to be stored indefinitely even when products enter landfills. There are also net climate change benefits by selecting sustainably produced wood products over alternative products with higher greenhouse gas (GHG) emission footprints.

The analysis of carbon flows between the atmosphere, forests, and wood and paper products involves estimates, assumptions and the use of models to simulate carbon fluxes over time. There are uncertainties in all these elements. Estimates presented here are the best available drawn from various sources based on realistic assumptions.



1 | Key facts and figures

Forests and Carbon

About **50%** of the dry weight of trees is made up of carbon.

Carbon is taken up by plants in the process of photosynthesis and released during respiration and when biomass dies. Most of the biomass in trees is in the woody fraction (stem and branches) and roots. Bark and leaves typically account for 10-15% of the biomass in mature trees. About 50% of the dry weight of trees is made up of carbon. On average, each cubic metre of Australian sawn softwood and hardwood timber stores 900 and 1,220 kilograms respectively, of CO_2-eq sequestered from the atmosphere

Forests in Australia contain an estimated 10.5 billion tonnes of carbon (excluding soil carbon). This forest carbon reservoir, when converted to CO_2 emissions, is equivalent to 77 times Australia's greenhouse gas (GHG) emissions in 2021. An additional 11.5 billion tonnes of carbon is estimated to be stored in forest soils.

Forests in Australia contain an estimated **10.5 billion tonnes** of carbon

Carbon sequestration in trees **typically decreases** with age

The rate of carbon sequestration in trees typically decreases with age. For example, in tall dense eucalypt forests the growth rates decrease progressively from around 6.4 tonnes carbon per hectare per year (for 1-10 year old trees) to around 0.7 tonnes carbon per hectare per year for trees over 100 years old.

Bushfires are common in Australia and result in significant GHG emissions. For example, the 2019-20 bushfires in eastern Australia resulted in the emission of approximately 830 million tonnes CO_2 equivalents (CO_2-eq). Much of this carbon is taken up in regrowing trees and shrubs after fires.

Carbon released in bushfires is **taken up in regrowing trees** and shrubs after fires.

Wood Products and Carbon

Managing a small proportion of Australian forests for multiple uses, including timber production, can provide significant climate benefits when all relevant life cycle factors are taken into account, rather than using imports from unsustainable sources or alternative high GHG-emitting products.

Only 1.4% of the carbon in wood in landfills is lost to the atmosphere

At the end of their service life, wood products can continue to provide climate benefits. If the wood product is recycled or re-used, it will continue to retain carbon. If it is used to generate renewable energy, it likely displaces the use of fossil fuels. If it goes to landfill, almost all the carbon will be locked up - only 1.4% of the carbon in wood in landfills is lost to the atmosphere.

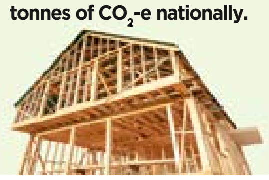
Following harvesting, some of the carbon is transferred to wood products and some is released. In a sustainably managed forest this is balanced by regrowth established after harvesting. For each cubic metre of kiln-dried sawn softwood, kiln-dried sawn hardwood and dressed white cypress pine a total of 900, 1220 and 1223 kg CO_2-eq respectively is stored in the product at least for the duration of its service life. Wood products in use in Australia contain 97 million tonnes of carbon.

Wood products in use in Australia contain 97 million tonnes of carbon.

Wood products in Australian landfills represent a growing carbon reservoir, storing approximately 51.5 million tonnes of carbon. The combined accumulated carbon stock in Australian wood products in service and in landfills is equivalent to approximately all of Australia's annual GHG emissions.

Maximising the use of wood products in typical residential houses results in a net saving of around 30 t CO_2-e per house compared to products such as concrete and bricks. A 10% increase in the market share of timber in buildings would lead to annual emission reductions of 1.9 mt CO_2-e nationally.

A 10% increase in the market share of timber in buildings would lead to annual emission reductions of 1.9 million tonnes of CO_2-e nationally.



The climate benefits of using wood products depends on them coming from sustainably managed forests. For example, hardwood flooring from sustainably managed Australian native forests results in a net climate benefit 20 times greater than the use of hardwood flooring sourced from poorly managed tropical forests.

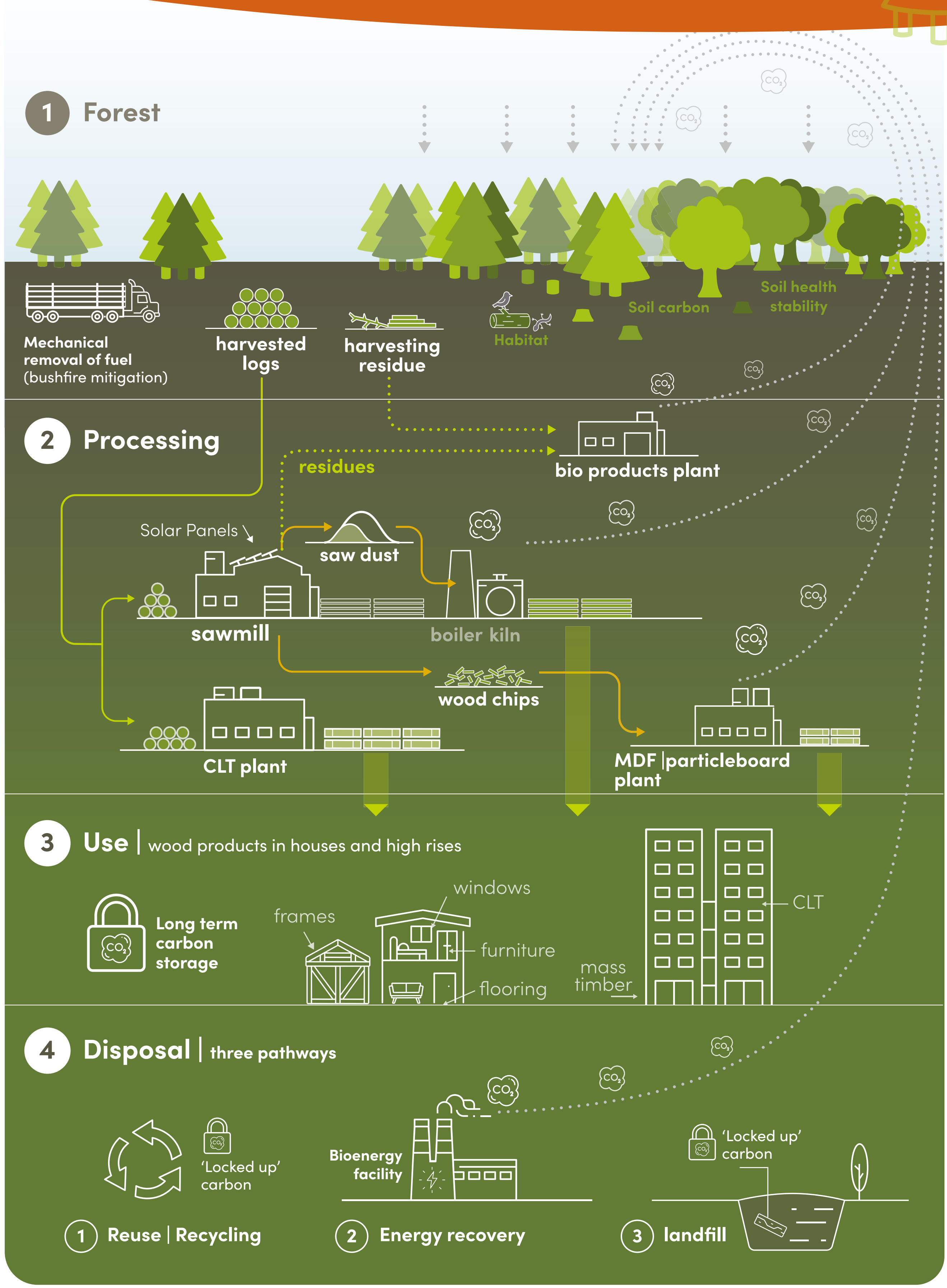
Using wood has climate advantages over non-wood products. For example, the use of native hardwood electricity poles from the North Coast of NSW results in a net climate benefit five times greater than using steel and concrete transmission poles, while use of fencing from sustainable pine plantations results in a net climate benefit five times greater than steel fencing.

Use of hardwood electricity poles instead of concrete or steel is five times better for the climate

Bioproducts such as bioplastics, biochar, biotextiles and biochemicals can replace materials made using fossil fuels, which will become increasingly limited. This represents an opportunity for the forest industry to make optimal use of harvest and manufacturing residues with significant climate change benefits.

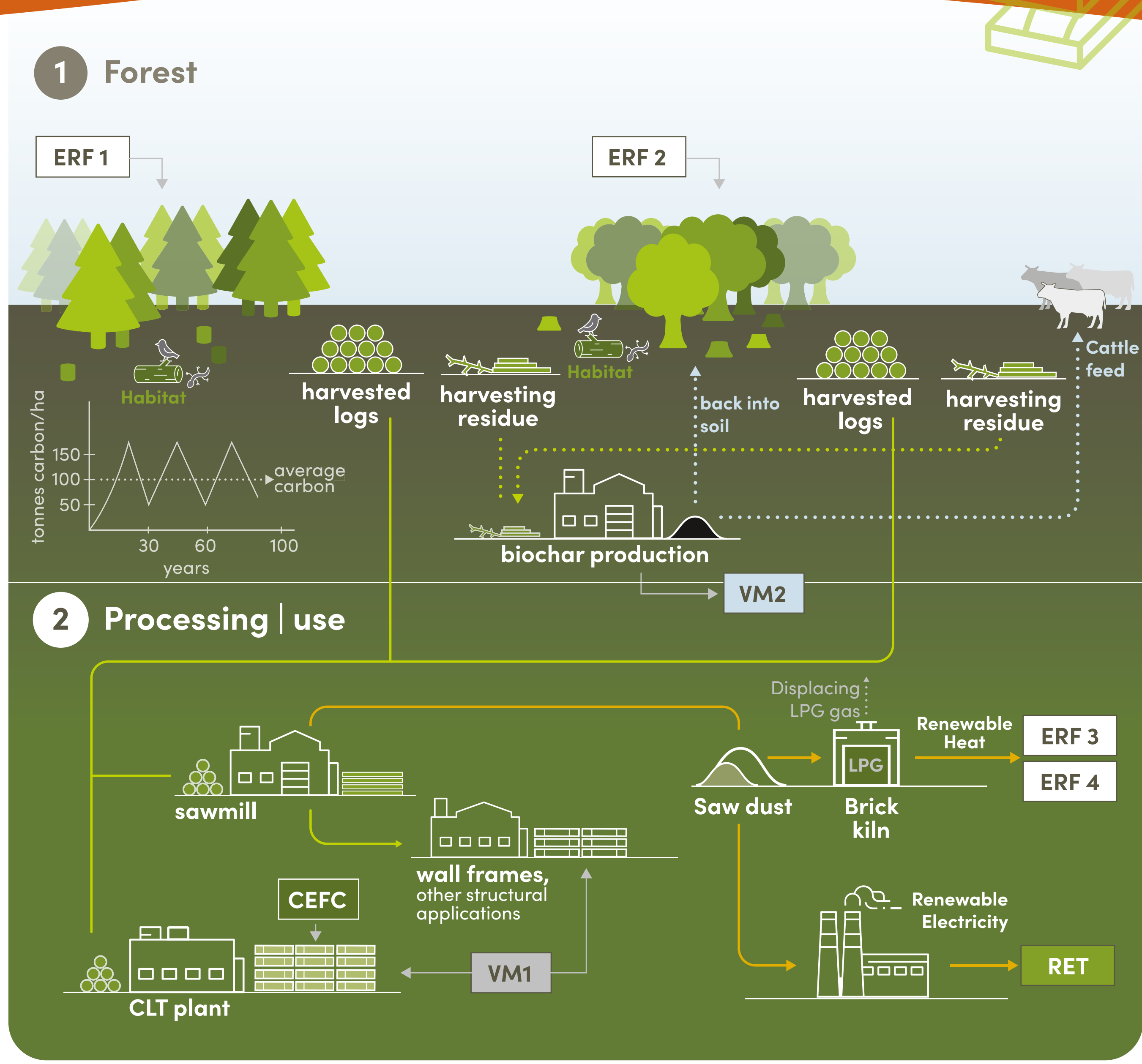
Forestry and climate mitigation

How can Australian forestry help with climate mitigation?



Forestry and carbon markets

What opportunities are there for the forest industry to participate in carbon markets?



LEGEND

ERF 1	Plantation forestry method	ERF 3	Industrial electricity and fuel efficiency method
ERF 2	Farm forestry method	ERF 4	Facilities method
VM1	Puro Earth Bio-based construction method	VM2	Puro Earth Biochar methodology
CEFC	$300m timber building program	RET	RECs (Renewable energy credits)

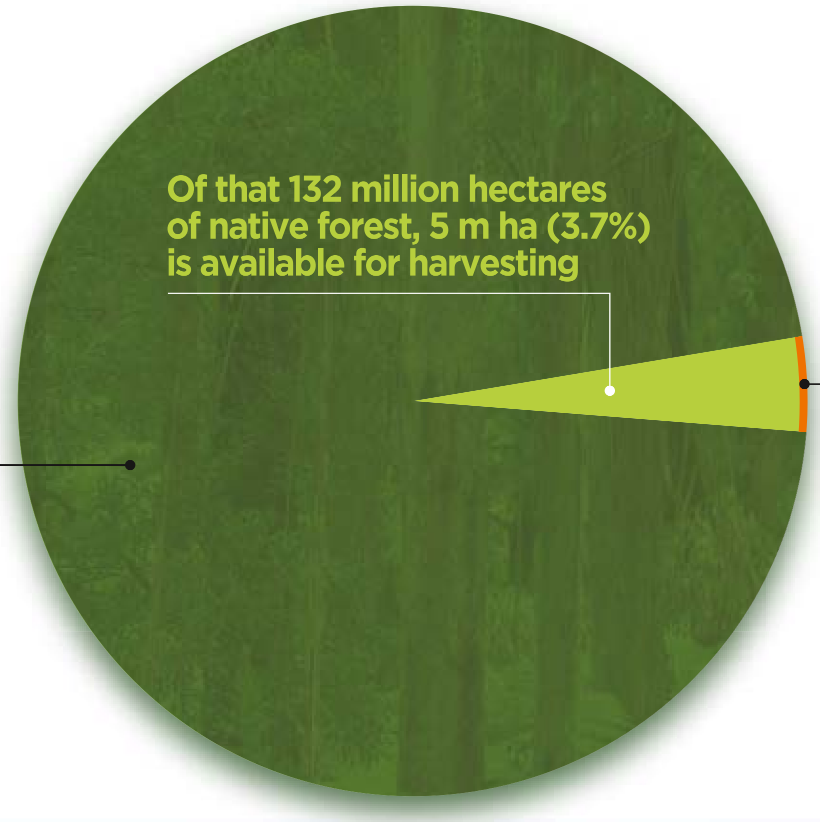
ERF = Emissions Reduction Fund
VM = Voluntary Market
CEFC = Clean Energy Finance Corporation
RET = Renewable Energy Target

2 Carbon in Australian native forests & plantations

Forests in Australia cover 134 million hectares, 17% of the country's land area. They sequester carbon as individual growing trees absorb CO_2 from the atmosphere through photosynthesis. Carbon is stored in the tree biomass in the form of carbon compounds such as carbohydrates (including cellulose and hemicellulose) and lignin. One tonne of carbon sequestered represents 3.67 tonnes of CO_2 removed from the atmosphere.

Australian forests contain an estimated 10.5 billion tonnes of carbon (excluding soil carbon)[1], captured by the removal, by forest plants, of almost 38.5 billion tonnes of CO_2 from the atmosphere. This represents around 77 times Australia's annual net GHG emissions (emissions for the year to December 2021). Approximately 11.5 billion tonnes of carbon is estimated to be contained in forest soils in Australia[2].

Most of the carbon (98.8%) in Australian forests is in native forests, with approximately 83% of the area dominated by Eucalypt and Acacia forests. They include protected areas (national parks), state forests (managed for multiple uses including wood production) and private native forest land. The balance (1.2%) is in plantations (softwoods – mostly *Pinus radiata*, and hardwoods which encompass primarily a range of native Eucalypt species). In 2016, 3 billion tonnes of carbon were stored in production native forests and 258 million tonnes of carbon were stored in plantations (57% in softwood plantations and 43% in hardwood plantations)[3].



Source of data: Australia's State of the Forests Report 2018[62]

In 2016, 3 billion tonnes of carbon were stored in production native forests and 258 million tonnes of carbon were stored in plantations.

The rate and extent to which trees sequester carbon is influenced by many factors including species, site quality, climate and management. The rate of carbon sequestration in trees typically decreases with age. For example, in tall dense eucalypt forests the growth rates decrease progressively from around 6.4 tonnes carbon per hectare per year (for 1-10 year old trees), to around 0.7 tonnes carbon per hectare per year for trees over 100 years old[4]. **Carbon stocks in mature managed native forests, including those managed for multiple uses including production and those managed for conservation, typically range between 130 to 415 tonnes of carbon per hectare[5].** This is consistent with estimates for mature temperate forest types around the world (e.g., 199–586 tonnes of carbon per hectare for temperate forests in North America, 146–439 tonnes of carbon per hectare for temperate forests in Chile). Globally, the recent Global Forest Goals report[6] has identified that on current projections, Oceania, Europe and Asia are on track to maintain forest carbon stocks, as their forest area is projected to increase by 3% between 2015 and 2030, based on the net gains in forest area that were seen in these regions during 2010 to 2020.

Much of the biomass in trees is in the woody fraction (stem and branches) and roots. Bark and leaves typically account for 10-15% of the above-ground biomass in trees. **Though the carbon content of the biomass in trees can vary with plant part and wood type, typically about 50% of the dry weight of trees is made up of carbon[7].**

Rainfall zone	Fraction of biomass allocated to:					
	Stems	Branches	Bark	Leaves	Coarse Roots	Fine Roots
≥500 mm	0.49	0.11	0.09	0.04	0.24	0.03
<500 mm	0.28	0.22	0.08	0.07	0.27	0.08

Table 1 – Partitioning of biomass between the tree components under different rainfall zones.

Species	Fraction of biomass allocated to:					
	Stems	Branches	Bark	Leaves	Coarse Roots	Fine Roots
E. globulus	0.41	0.19	0.07	0.11	0.19	0.03
P. radiata	0.47	0.14	0.06	0.09	0.21	0.03
P. pinaster	0.38	0.11	0.05	0.07	0.33	0.07
Env plantings	0.29	0.20	0.09	0.13	0.25	0.05
Mallees	0.24	0.16	0.04	0.11	0.36	0.08

Table 2 - Biomass partitioning for a range of tree species grown in Australia.

Forestry is relatively unique to the Australian economy in that it is a net carbon 'sink'.

Sustainable forest management ensures that the productive capacity of the forest is maintained over time[10]. Typically, this means biomass removals do not exceed forest growth, maintaining stable carbon stocks. When trees are harvested, some of the carbon is retained in the various wood products, and a proportion of the biomass stays in the forest. Carbon in these residues left in the forest may be emitted back into the atmosphere as a result of fire or decay, while some will be retained in the soil. Roots also die off and decompose but the rate is slower; in an Australian study the coarse roots of hardwoods remained intact for 25 years after harvest, with up to 50% of the roots still present 85 years after harvest[11] .

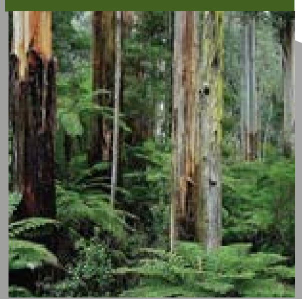
GHG emissions from the land use, land-use change, and forestry (LULUCF) sector is a balance of emissions from converting forests to other uses, converting other uses to forests, activities like harvesting and regeneration, and fire and other disturbances. Australia's net GHG emissions in the LULUCF sector in 2020 were negative, at around 26 million tonnes CO_2-eq[12] (i.e. a net carbon removal from the atmosphere), as sequestration in existing and newly planted forests exceeded losses through land clearing and other disturbances. Forestry is relatively unique to the Australian economy in that it is a net carbon 'sink'.

There is potential to significantly increase this carbon sink in Australia, including by growing new commercial plantations to meet the current shortfalls in timber supply and anticipated demand increases. The current area of commercial plantations in Australia is insufficient to meet current and future demand for wood products.

Carbon stocks in native vegetation

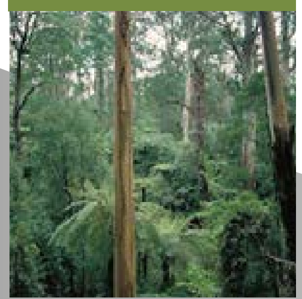
Tonnes per hectare of carbon in above-ground biomass

Tall Open Forest



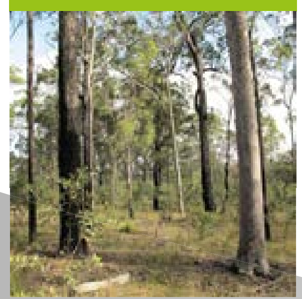
900

Open Forest



340

Woodland

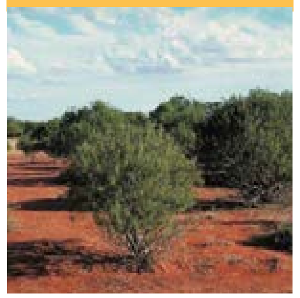


90

Open Woodland

45

Shrubland



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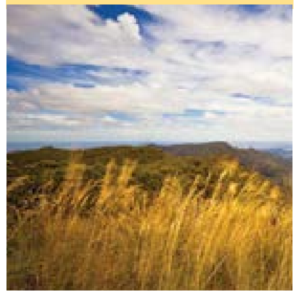
Grassland



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Distribution of native vegetation types

3 Emissions from fire

Emissions from major bushfires can be very large. The most recent large bushfires in 2019 burned 7.4 million hectares of forest, with resulting greenhouse emissions estimated at 830 million tonnes CO_2-e[15]

Most Australian forests are well adapted to, and require, fire for regeneration and health. Fires take many different forms, varying in intensity depending on the environment and weather conditions, and whether they are initiated and spread naturally or under human control. Following bushfires, many eucalypt species recover quickly through regrowth from epicormic shoots. Lower intensity fires primarily burn only litter and small deadwood . Fires therefore vary in frequency and intensity across Australia, with implications for the estimation of their impact on carbon stocks[14].

Temperate eucalypt forests are characterised by bushfire intervals on the scale of decades. Prescribed burning is practised in temperate forests to reduce fuel loads or for ecological reasons. This involves managed, low-intensity burns during the cooler and wetter months of the year, to mitigate the risk and severity of wildfires by reducing fuel loads. These managed fires typically consume only a small proportion of the dead organic matter present in the forest.

Australia's national greenhouse gas inventory includes estimates of GHG emissions for managed fires (e.g. prescribed burning) and bushfires, which are reported separately for a range of forest types. Emissions from major bushfires can be very large – for example the large bushfires in Australia from 2019 burned 7.4 million hectares of forest, with resulting greenhouse emissions estimated at 830 million tonnes CO_2-e[15]. This is equivalent to approximately 166% of Australia's annual GHG emissions.

Although these emissions are very large, for many forest systems much of the carbon emitted is expected to be re-absorbed by regrowing trees, within 10 to 15 years[16].

As stated in the CSIRO State of the Climate Report[17], there has been an increase in extreme fire weather, and in the length of the fire season, across large parts of the country since the 1950s, especially in southern Australia. Climate change affects the dryness and amount of fuel, through changes in rainfall and air temperature and atmospheric moisture content that exacerbate landscape drying. Furthermore, increased CO_2 can also alter the rate and amount of plant growth, which may also affect the fuel load. Increased frequency and intensity of extreme heat because of climate change can also worsen extreme fire weather risk. This makes it essential to continue research on a range of methods for reducing fuel loads and bushfire intensity, including mechanical fuel load reduction techniques and Indigenous cultural burning techniques. Fire management strategies can result in significant climate benefits. For example, the Emissions Reduction Fund (ERF) has two methods available that credit emissions avoidance and sequestration from improved fire management in savannas[18]. Savanna fire management projects reduce the size, intensity and frequency of savanna wildfires in northern Australia, resulting in fewer greenhouse gas emissions and, in some cases, more carbon being sequestered in dead organic matter.

Prescribed low-intensity burning is practised in temperate forests to mitigate the risk and severity of wildfires by reducing fuel loads.

The 2019 bushfires resulted in emissions more than 1.5 times greater than Australia's annual emissions

4 | Residues for bioproducts

In sustainably managed forests, when biomass is created as a by-product of tree harvesting for sawlogs or pulp, the carbon emitted in bioenergy generation is re-absorbed by growing trees as part of the natural carbon cycling.

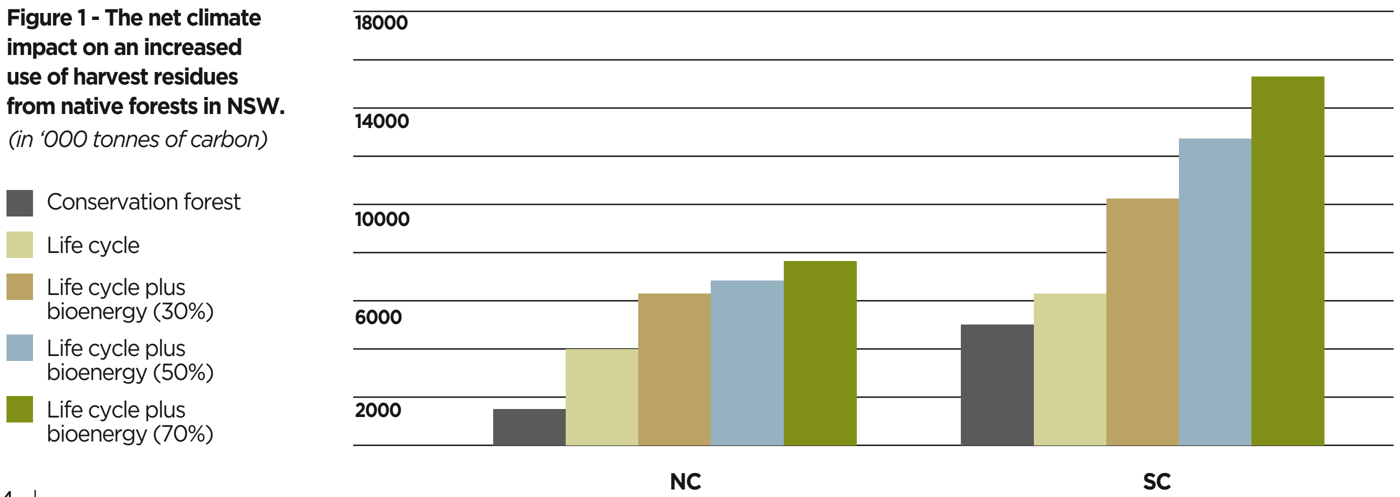
The harvest of trees and conversion of logs into finished wood products results in the generation of residues in the forest (defective tree stems, branches, bark and leaves) and from timber processing (offcuts, sawdust and shavings). The amount of forest residues varies with forest type, tree species, silviculture, and local markets. Harvest residues range from 22% to 53% of the tree biomass for native hardwoods, and 15% to 25% for plantation pines[19]. When considering use of residues, it is important to take into account nutrition needs for future trees, soil stability and habitat needs. Much of the carbon in the residues left in the forest will eventually be released back into the atmosphere due to fire or decay.

In wood processing facilities, residues are generated at various stages of production. In the manufacture of green sawn boards in a typical sawmill, just under half of the biomass in the logs is converted into residues. Further residues are associated with finishing the sawn boards. Some residues are used in paper making in Australia or overseas, or panel products such as particleboard and MDF, where the carbon may be stored for decades. Others are used in landscaping or animal bedding where the carbon is emitted back into the atmosphere relatively quickly.

The use of wood biomass for bioenergy is growing around the world[20]. Use of residues for bioenergy can reduce GHG emissions if this replaces fossil fuel energy; however, concerns are often raised about the sustainability of timber extraction and the resulting CO_2 emissions. In sustainably managed forests, when biomass is created as a by-product of tree harvesting for sawlogs or pulp, the carbon emitted in bioenergy generation is re-absorbed by growing trees as part of the natural carbon cycling. Estimates of climate impacts of using biomass for bioenergy need to consider GHG emissions due to fuel usage in the extraction and transport of biomass.

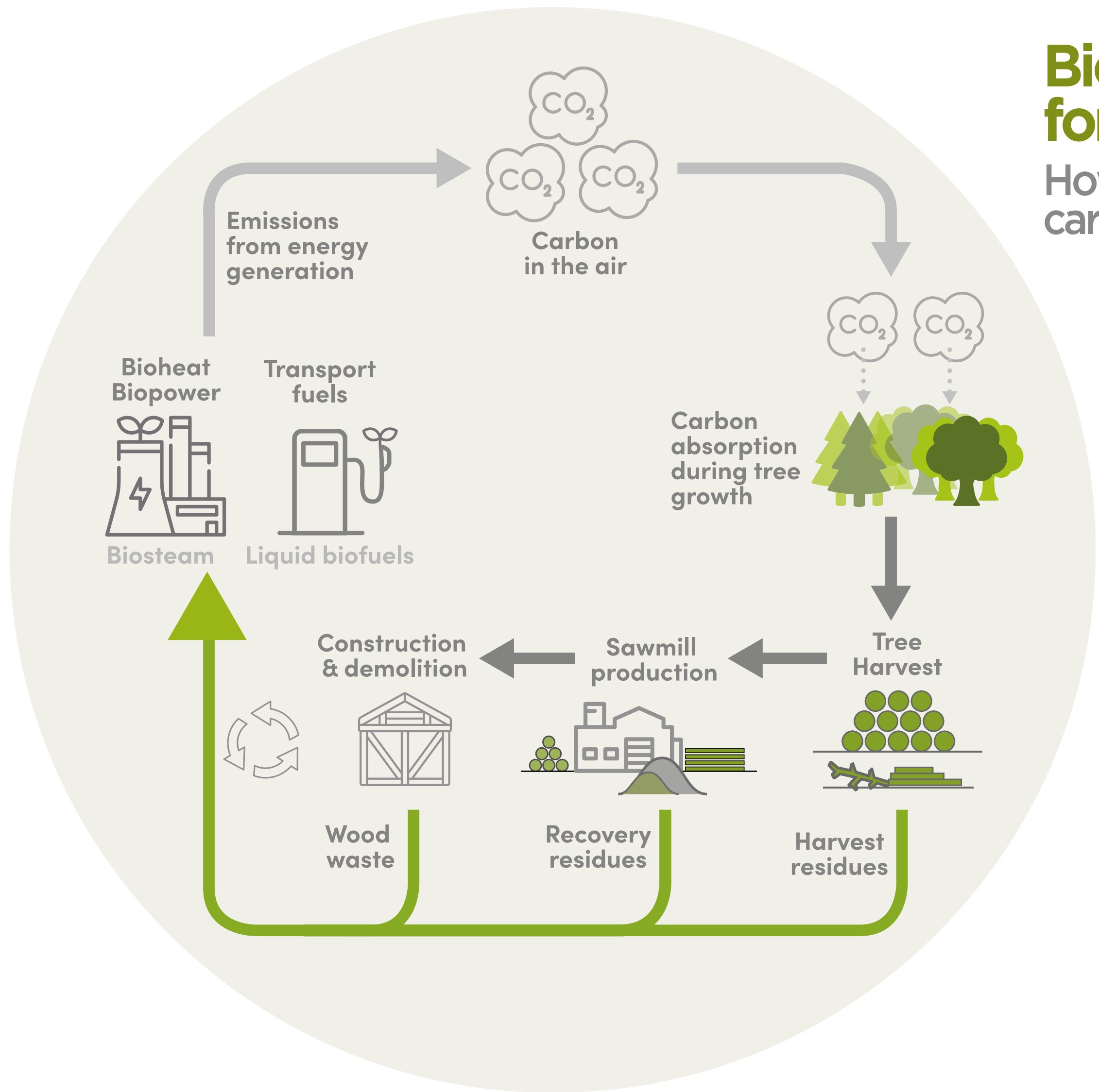
In Australia, where a large volume of harvest residue remains in the forest and is burned after harvest for fire management or decays in situ, and where coal is still the main source of energy, the GHG mitigation benefit of utilizing harvest and processing residues for bioenergy generation can be significant. This benefit has been shown in previous studies[21], where the increased use of residues for bioenergy generation significantly increased the climate benefit associated with forestry activities (Figure 1). This benefit takes into account a reduction in carbon storage in harvest slash residues due to an increased removal of residues from the forest.

Figure 1 - The net climate impact on an increased use of harvest residues from native forests in NSW.
(in '000 tonnes of carbon)



Biomass for bioenergy

How does the carbon cycle work?



The critical contribution that bioenergy is expected to play in future climate change mitigation scenarios is highlighted in the recent IPCC report on mitigation pathways for keeping global warming to 1.5°C . The share of primary energy provided by bioenergy is predicted to increase from a median value of 10.3% in 2020 to 26.4% by 2050 across the full range of these pathways[23]. Ultimately, as we move away from our dependency on fossil fuels, the best strategy for use of residues from a climate perspective may be the manufacture of long-lived products such as biochar, or bioenergy combined with carbon capture and use (BECCU). In BECCU systems the carbon dioxide that is emitted is captured and used for a given application. Global requirements for primary energy from biomass to meet Paris Agreement goals range from about 100 to 400 billion GJ per year, and BECCU is expected to play an important role in achieving net zero GHG emissions[24].

5 Biogenic and fossil emissions in wood production

In sawmills, a large proportion of the energy used to convert logs into wood products may be sourced from biogenic sources such as sawmill residues.

The management of commercial forests and processing of logs into wood products requires the use of energy. Some of that energy may be derived from fossil fuels (e.g. diesel used in machines to harvest trees and trucks to transport logs). Use of these fossil fuels results in CO_2 emissions that contribute to climate change. In sawmills, a large proportion of the energy used to convert logs into wood products may be from biogenic sources such as sawmill residues. For example, many kilns used to dry timber rely on wood biomass for energy.

The release of the biomass carbon does not result in net GHG emissions if this wood is from sustainably managed forests. The small amounts of nitrous oxide and methane released from forests, product storage and produced during combustion of residues should be included in the carbon footprint calculations. Those emissions are accounted for as 'biogenic GHG emissions other than CO_2'.

Detailed information on the emission footprint of the key types of wood products used in Australia is contained in Environmental Product Declarations (EPDs). For example (as illustrated in Figure 2) the production of 1 m³ of kiln-dried dressed softwood results in 157 kg CO_2-eq of fossil-fuel derived emissions and 25 kg CO_2-eq of biogenic GHG emissions other than CO_2. The biogenic CO_2 emissions from production do not count towards the emission footprint of the product as the CO_2 is re-absorbed by the growing trees in sustainable forest systems. At the mill gate, this results in a net carbon footprint of -718 kg CO_2/m³ of dry and dressed softwood. In other words, when both carbon stored in the timber and cradle-to-gate fossil GHG emission and biogenic GHG emissions other than CO_2 are accounted for, the net impact is the retention of 718 kg CO_2 in each cubic metre of timber produced.

Detailed information on the emission footprint of the key types of wood products used in Australia is contained in Environmental Product Declarations (EPDs)

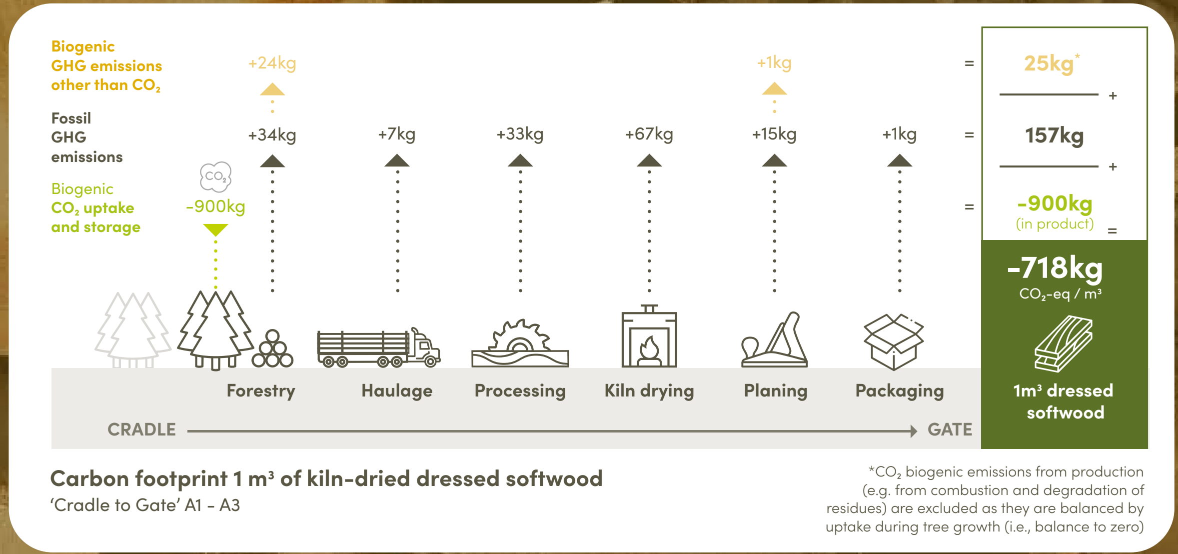


Figure 2 - Carbon footprint of 1m³ of kiln-dried dressed softwood[25]

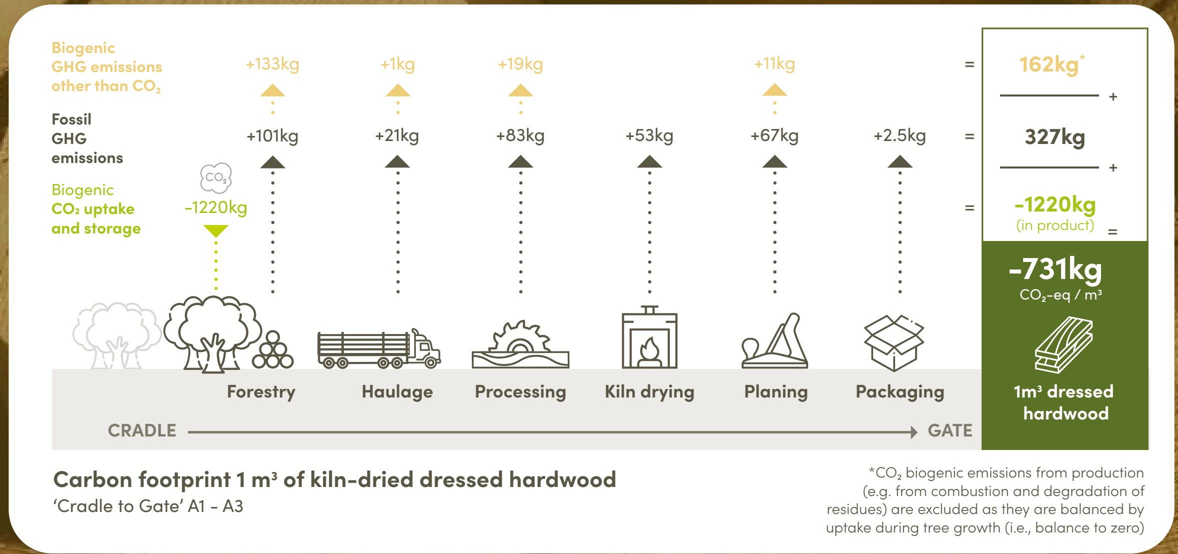


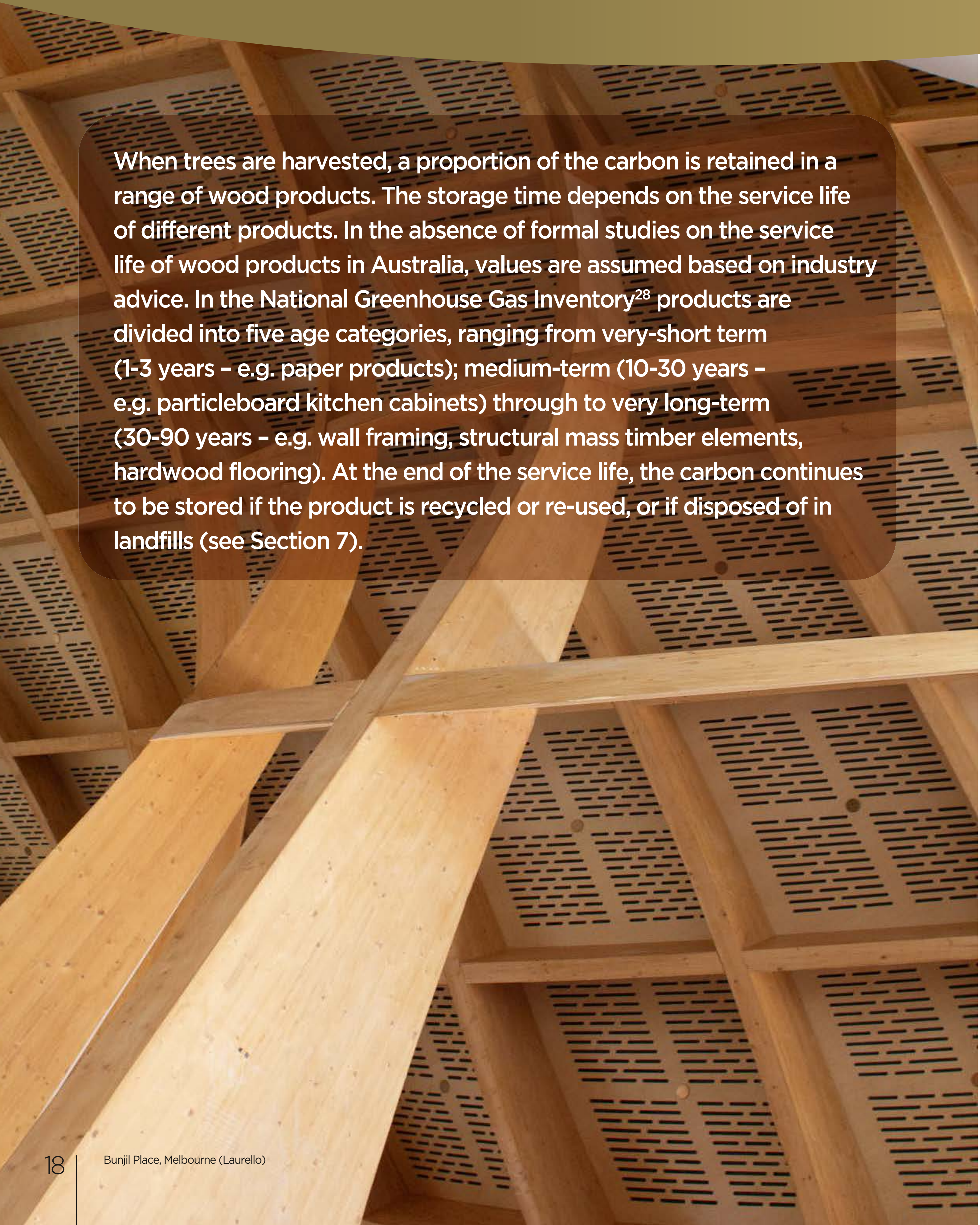
Figure 3 - Carbon footprint of 1m³ of kiln-dried dressed hardwood[26]

The production of 1m³ of kiln-dried dressed hardwood results in 327 kg CO_2-eq of fossil-fuel derived emissions and 162 kg CO_2-eq of biogenic GHG emissions; with a net carbon footprint of -731 kg CO_2/m

Figure 4 - Carbon footprint of 1m3 of kiln-dried dressed white cypress[27]

The production of 1 m³ of dressed white cypress results in 188 kg CO_2-eq of fossil-fuel derived emissions and 26 kg CO_2-eq of biogenic GHG emissions, with a net carbon footprint of -1009 kg CO_2/m³.

6 Wood products in service



When trees are harvested, a proportion of the carbon is retained in a range of wood products. The storage time depends on the service life of different products. In the absence of formal studies on the service life of wood products in Australia, values are assumed based on industry advice. In the National Greenhouse Gas Inventory[28] products are divided into five age categories, ranging from very-short term (1-3 years – e.g. paper products); medium-term (10-30 years – e.g. particleboard kitchen cabinets) through to very long-term (30-90 years – e.g. wall framing, structural mass timber elements, hardwood flooring). At the end of the service life, the carbon continues to be stored if the product is recycled or re-used, or if disposed of in landfills (see Section 7).

Bunjil Place, Melbourne (Laurello)

AU Wood Product Group	AU Selected Product	Stored carbon in final product kg CO_2/m^3
Sawn Softwood	Kiln-dried dressed softwood	900
Sawn Hardwood	Kiln-dried dressed hardwood	1220
Sawn white cypress	Dressed white cypress	1223

Table 3 - Amount of carbon stored in Australian sawn wood products (weighted average)[29]

For each cubic metre of kiln-dried sawn softwood and hardwood, and sawn white cypress, a total of 900, 1220 and 1223 kg of CO_2 is stored in the product at least for the duration of their service lives.

Carbon in imported wood products in service

Around one-third of the wood products used in Australia are imported. The net emissions or storage from those products will depend on whether they are sourced from sustainable forest operations. Wood from unsustainable operations, for example where land is converted to other forms of land cover, trees are not re-established or forest carbon stocks are not maintained, may negate any benefit associated with carbon storage in the product.

Carbon in wood products in the built environment

Environmental performance data for construction products is in demand from architects, developers, legislators and, increasingly, from consumers. There is significant potential to use more wood products in building applications. This can increase carbon in the national wood products pool and displace emissions associated with more energy-intensive building products such as steel and concrete. This benefit has been quantified in Life Cycle Assessment (LCA) studies. In LCAs the environmental impacts of a product or production system are quantified in all relevant stages of the product life cycle, from production to disposal. For example, an LCA study has demonstrated that maximising the use of wood products in typical single-storey and double-storey houses in Sydney could result in a net saving of around 30 t CO_2-e per house[31].

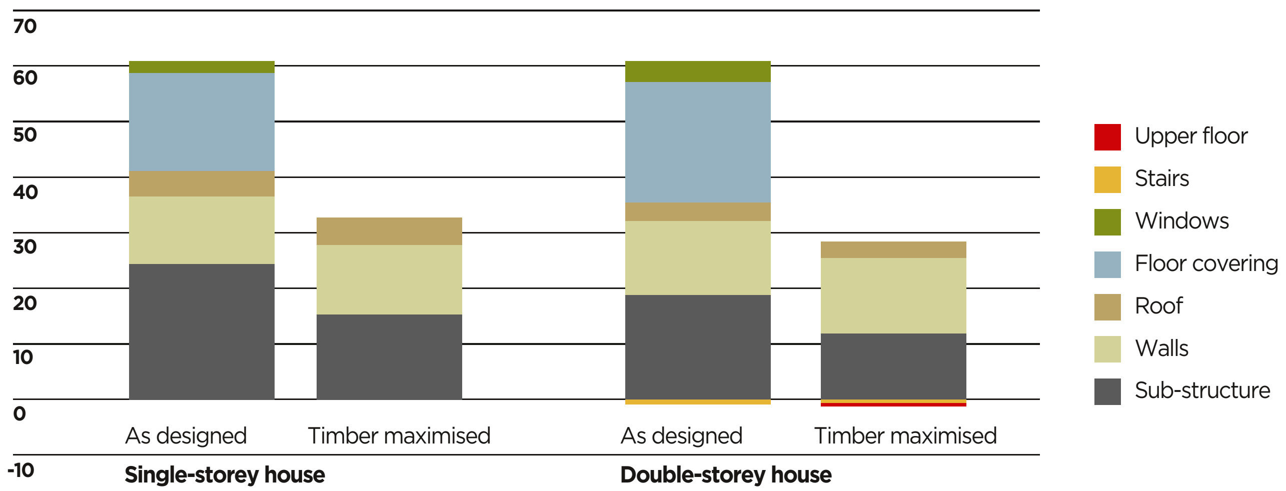


Figure 5 – Greenhouse gas emissions (in tonnes of CO_2-e) for house as originally designed and with timber maximised by component[32]

Each year the pool of carbon in wood products in service in Australia increases by approximately 3.5 million tonnes. The accumulated carbon pool in wood products in service amounts to 97 million tonnes of carbon[30].

Using mass timber construction with engineered wood products, such as cross-laminated timber and glulam, also provides opportunities to reduce emissions.

Using mass timber construction with engineered wood products, such as cross-laminated timber and glulam, also provides opportunities to reduce emissions. For example, when one hectare of plantation pine is converted into wood products suitable for mass timber application, it can be used to build up to 23 wood apartments in wood mid-rise buildings compared to concrete apartment construction, with GHG emission reductions of up to 547 t CO_2-e[33]. Alternatively, if that one hectare of pine plantations is used to produce timber wall frames, the greenhouse gas emissions through the life cycle are 55-197 t CO_2-e lower compared to building steel-framed houses[34].

In LCAs and other impact assessment methods of buildings, there are two significant metrics: emissions due to operational requirements of the building (e.g. energy requirements to heat or cool the building) and the emissions embedded in the products used in the construction of the building (embodied carbon).

Evidence of a product's embodied carbon performance is included within an independently verified EPD, which contains third-party verified LCA results for a specified standard quantity of a product or assembly. EPDs are published under FWPA's WoodSolutions brand for seven Australian wood product groups.

EPDs are the most common approach used for documenting building product emissions and are recommended for calculating embodied carbon emissions of buildings as they provide data that are more transparent, precise, and representative.

The drive to build more sustainably has strengthened the need to measure the carbon footprint of proposed developments. This has led to the development of rating tools such as the new Green Star Buildings by the Green Building Council of Australia and the Infrastructure Sustainability Council's IS Rating Scheme.

At present, building rating tools do not acknowledge the benefit of carbon storage in wood products, partly because of the lack of agreed methods for accounting for biogenic carbon in construction.

For example, the Canadian Green Building Council states that biogenic carbon should not be included in the embodied carbon values reported, but projects are encouraged to report it separately[36].

The Green Building Council of Australia has a similar stance, and the biogenic carbon is not allowed to be used to offset emissions from alternative products.

Biogenic carbon can be taken into account in the whole of life calculations for the building. By comparison, an LCA approach to assessing the climate benefits of using more wood products in buildings would consider the carbon contained in wood products, as well as the substitution effects of replacing more emissions-intensive building materials.

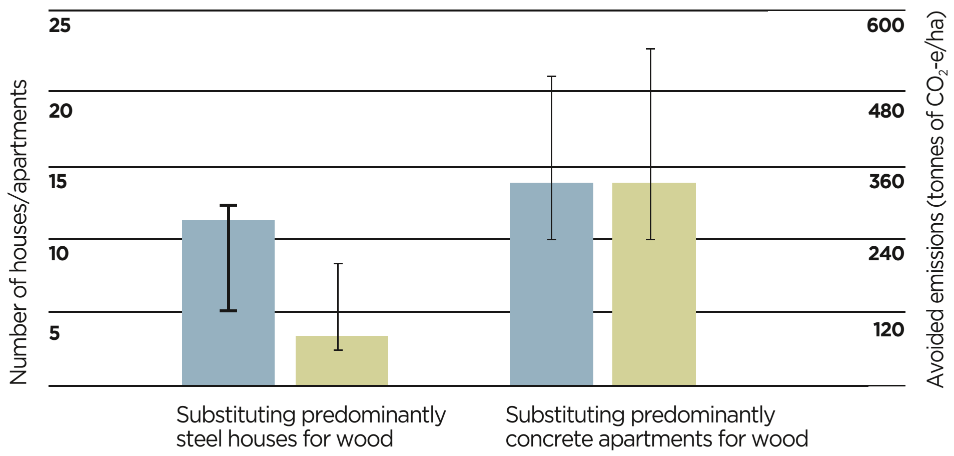
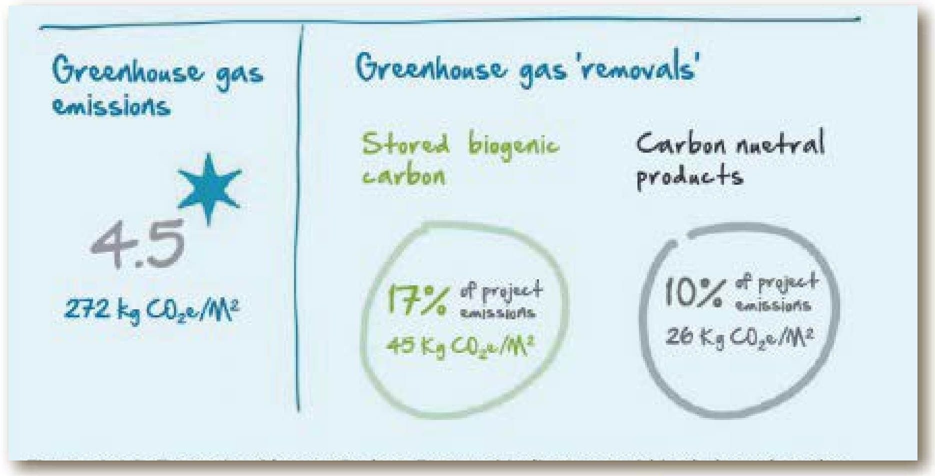


Figure 6 – Estimated reduction in embodied emissions through substitution of steel and concrete buildings for wood[35]



Example of how a Carbon Removal Indicator could look, based on the Renewable Energy Indicator

NABERS, the National Australian Built Environment Rating System, provides a simple, reliable and comparable sustainability measurement of commercial building sector projects such as apartments, hotels, offices shopping centres, etc. NABERS is currently looking to implement an Embodied Emissions Tool and their consultation paper (see Example of how a Carbon Removal Indicator could look, based on the Renewable Energy Indicator) provides a recognition of the importance of biogenic carbon stored in timber utilising a greenhouse gas Carbon Removal Indicator.

7 Carbon in wood products at end-of-life

Carbon loss from wood and wood products in Australian landfills is insignificant - a maximum of 1.4% of the carbon may be lost, with the remainder stored indefinitely.

Where a wood product is re-used or recycled, the carbon will continue to be stored for as long as the product remains in service. If, at the end of life, the wood product is burnt to generate energy and the wood came from a sustainably managed source, the energy is considered renewable and may therefore be claimed to displace fossil fuels. Alternatively, wood is deposited in landfills.

It is estimated that, over time, the annual quantities of carbon in wood products deposited in landfills in Australia have reduced from an average of 1.2 Mt to approximately 0.55 Mt in 2019[37]. Given this magnitude is significant in national GHG accounts, it is important to understand the carbon dynamics of wood products in landfills. Decay of organic materials in landfills results in the generation of both CO_2 and methane, in roughly equal proportions. Methane is a greenhouse gas 27 to 30 times as powerful as carbon dioxide over 100 years.

The scientific understanding of carbon dynamics of wood products in landfills has evolved considerably in recent years, based on excavations of old landfills and experimental bioreactor work[38] .

This work has conclusively demonstrated that carbon loss from wood and wood products in Australian landfills is insignificant - a maximum of 1.4% of the carbon may be lost, with the remainder stored indefinitely. This is primarily because anaerobic conditions prevalent in modern landfills favour the presence of anaerobic bacteria, which are poor degraders of woody material.

In the National GHG Inventory it is estimated that the disposal of wood products in Australian landfills has resulted in a carbon reservoir of approximately 51.5 mt. This estimate is conservative, as it assumes that 10% of the carbon has been lost and emitted as CO_2 and methane.

Wood can also be reused and recycled but reliable information on the proportion of wood products currently recycled in Australia is limited. Given the volumes of wood products being disposed of in landfills, much more recovery and reuse could take place. Commercial energy from waste projects involving wood products are also limited.

End-of-life wood products after 46 years in landfill

8 Product substitution

Wood products require comparatively lower energy in their extraction and manufacture compared to GHG-intensive materials such as bricks, aluminium and concrete. Therefore, use of wood products in place of alternative materials avoids GHG emissions. This substitution benefit can be quantified by calculating the difference in the GHG emissions associated with the production of the wood product and the alternative product.

The use of wood products may not always result in a climate benefit, e.g. in the case of a wood product that displaces another wood product with a lower emission footprint. However, if a wood product displaces a non-wood product, it typically results in lower net GHG emissions. The higher the emission footprint of the alternative products relative to wood products, the higher the GHG 'savings' associated with the use of wood products.

Each time there is a choice between a product with a low GHG intensity and a product with a high GHG intensity, by choosing products with lower GHG intensity the consumer has a direct impact on GHG emissions.

This substitution benefit has been quantified for Australian hardwood products from New South Wales and Victoria (Figure 7). Use of Australian hardwood decking instead of unsustainably sourced South-East Asian timber decking results in a climate benefit 20 times greater. Use of Australian hardwood electricity poles results in a climate benefit approximately five times greater than that of equivalent steel or concrete poles.

Wood products require comparatively lower energy in their extraction and manufacture compared to GHG-intensive materials such as bricks, aluminium and concrete.

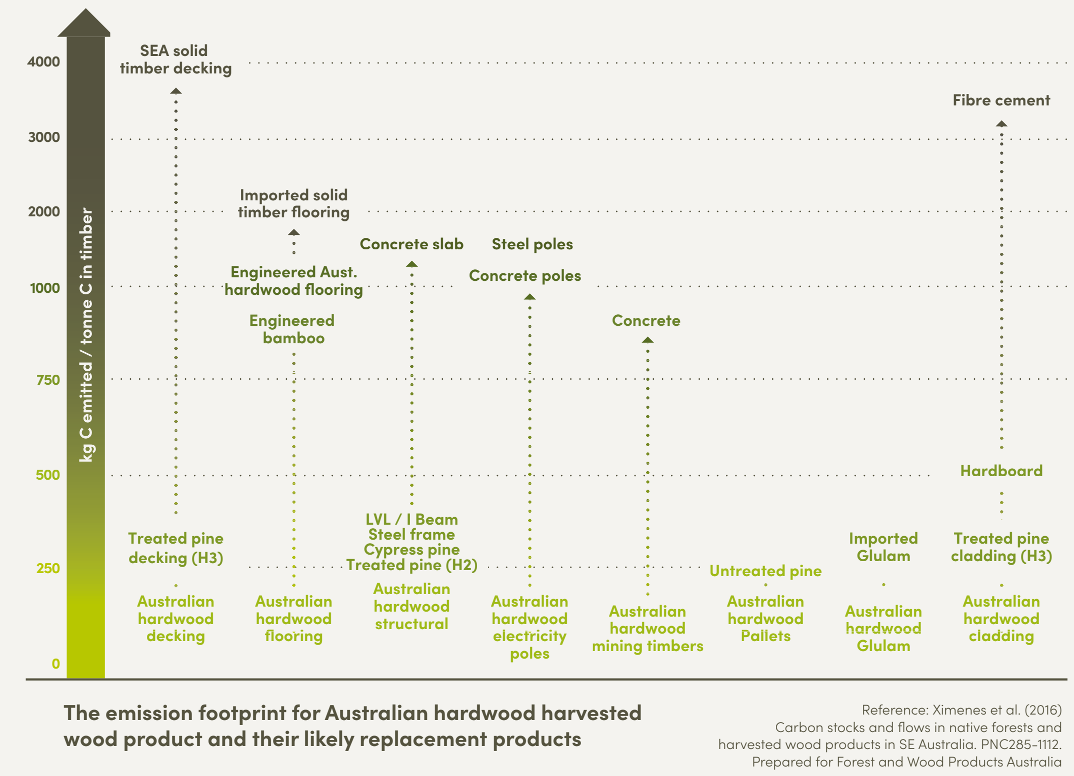


Figure 7 - Emission footprint for Australian hardwood wood products and their likely replacement products[39]

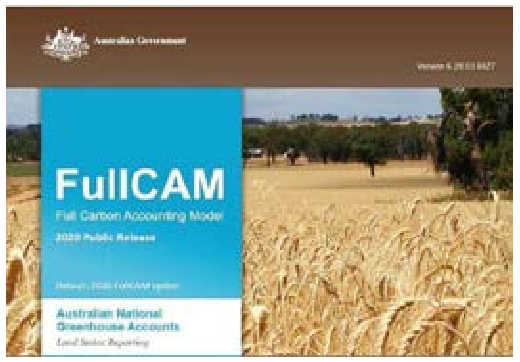
9 Carbon accounting in forests and wood products

There are two key international frameworks in which GHG emissions in forests and in wood products are reported and accounted for: the United Nations Framework Convention on Climate Change (UNFCCC), under which the national GHG inventory (National Inventory Report) is submitted, and the Kyoto Protocol that applies to signatory countries with emission reduction commitments. Each of these frameworks is guided by different principles. The 2005 Kyoto Protocol was followed in 2015 by the Paris Agreement, which aims to strengthen the global response to the threat of climate change by limiting global warming to well below 2°C and preferably to 1.5°C, compared to pre-industrial levels. Australia is party to the Kyoto Protocol and the Paris Agreement. The Kyoto Protocol resulted from negotiations between countries designed to create incentives and share the burden for emission reductions. The accounting rules were agreed by signatory countries via the Intergovernmental Panel on Climate Change (IPCC)[40]. The Protocol sets binding emission reduction targets for 37 countries (including Australia) and economies in transition and the European Union. It allowed reporting only on emissions from specific forest-related activities (afforestation, reforestation, deforestation and activities in 'managed forests') and was designed to provide incentives for behavioural change. It did not provide comprehensive accounting for all emissions and removals. For example, to avoid creating incentives for more wood products to go to landfills, the Kyoto accounting rules assume that where wood products were deposited in landfills, the carbon was completely oxidised at the time of disposal. As indicated previously, this assumption is incorrect.

National Greenhouse Gas Inventories (NGGIs) under the United Nations Framework Convention on Climate Change (UNFCCC) is the global reporting requirement for all signatory countries[41]. The UNFCCC aims to prevent "dangerous" human interference with the climate system. Accounting is done on a sectoral basis, with carbon removals and emissions due to forestry activity reported under Land use, Land-use change and Forestry (LULUCF)[42]. Its purpose is to be as accurate and comprehensive as possible in estimating emissions from different sectors. The UNFCCC accounting framework is therefore a better approximation to "what the atmosphere sees" than the Kyoto framework.

Australia's National Inventory Report fulfils Australia's reporting requirements on GHG emissions under the UNFCCC and the Kyoto Protocol. It mostly uses country-specific methodologies and emissions factors. It relies heavily on the FullCAM model (Full Carbon Accounting Methodology) to calculate emissions and removals associated with forestry activities. FullCAM estimates the carbon stock change in ecosystems including above and belowground biomass. It is a biophysical model, simulating carbon dynamics for single locations. The aboveground biomass in trees is estimated, and belowground biomass, dead organic matter, wood products, and soil carbon are also calculated, using a combination of a forest growth model (3PG) and empirical relationships. FullCAM is also used to calculate the carbon benefit of land-based projects under the Emissions Reduction Fund (ERF). This is discussed below.

The UNFCCC and Kyoto accounting frameworks do not directly reflect the product substitution benefits associated with using wood products because emissions from alternative products such as steel and concrete, and fossil fuel energy are accounted for in other industry sectors. **The LCA approach is designed to compare different products and account for GHG emissions throughout the life of the product or production system, regardless of which industry sector generates them.** Thus, LCA provides a better representation of the GHG emissions associated with a particular product.



10 Carbon market opportunities for forestry

Opportunities for the forest industry to participate in the carbon market exist domestically via the Emissions Reduction Fund (ERF) or internationally via voluntary carbon markets.

The ERF works via a reverse auction system, where project proponents submit their bids for contracts to sell Australian Carbon Credits Units (ACCUs) to the Australian Government (via the Clean Energy Regulator - CER). The Australian Government evaluates if the proposals represent value for money and the CER determines whether they comply with the requirements of the relevant method in the ERF. Methods lay out the rules for emissions reduction or carbon storage projects. For the forest industry, the main method of interest is the Plantation Forestry Method[43] which provides opportunities for the following activities related to commercial plantation forests:

- establishing a new plantation forest
- converting a short-rotation plantation to a long-rotation plantation
- continuing rotational harvest cycles in a plantation forest (to avoid conversion to non-forest land).
- Transitioning a plantation forest to a permanent (no harvest) forest, in situations where that plantation is at risk of being converted to non-forested land.

The method accounts for both carbon sequestration in forests as well as carbon storage in wood products in service. Credits are calculated based on long-term average carbon stocks modelled over a period of 100 years.

In addition to the Plantation Forestry Method, other opportunities for the forest industry to participate in the ERF include the Industrial Electricity and Fuel Efficiency method[44] and the Facilities method[45]. In both cases the opportunity relates to the use of biomass to generate bioenergy, displacing the use of fossil fuels.

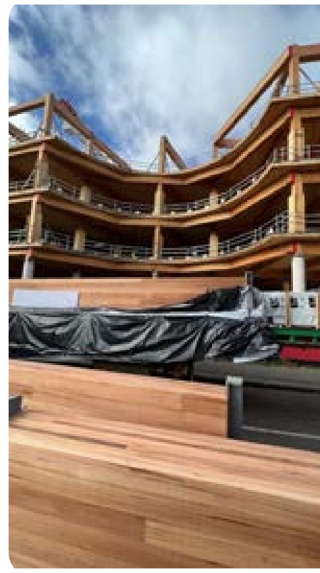
There are other activities not currently included in the ERF that would provide further incentive for forestry activities while achieving significant emission reductions. One example relates to the net climate benefits associated with the use of timber in mass timber construction (e.g. in mid to high-rise buildings).

An increase in the market share of timber in buildings has a dual benefit – the climate benefit from the displacement of greenhouse-intensive alternatives, and the additional carbon sequestration in new plantations required to meet the increased demand for wood products.

It has been estimated that a 10% increase in the market share of timber to 2050 would lead to annual emission reductions of 1.9 mt CO_2-e[46]. In the international voluntary carbon market framework, a method to reward the use of timber in buildings already exists: the Bio-based Construction Materials method under the Puro Earth standard[47]. CO_2 removal in the Bio-based Construction Materials Method results from the wooden building elements storing the carbon captured by trees. The CO_2 removal is considered long term when used in construction of buildings. However, the method does not quantify the net greenhouse benefits associated with the displacement of more greenhouse-intensive building products.

The Puro Earth framework also includes a method for rewarding long-term carbon capture in biochar[48]. CO_2 removal results from biomass being heated in an environment with no or limited supply of oxygen, through pyrolysis or gasification processes. This results in the production of a char material in which the carbon atoms have bonds stronger than those found in the parent biomass, and is therefore resistant to biotic and abiotic degradation processes when placed in the environment (e.g. biochar can be used as a soil amendment, in water filtration or road-making). This presents an opportunity for forestry, as harvest and processing residues are ideal feedstock for biochar production.

Additional opportunities exist to consider sustainable timber harvesting with silvicultural improvement in areas of native forests with sub-optimal and degraded stands (e.g. overstocked). This could be an activity for consideration as a new method development under the ERF, where the benefits from forest management including wood products could be quantified, compared to unmanaged regrowth or cleared regrowth. This would provide landholders with choice (in addition to existing human-induced regeneration methods). It could also help address land clearing, as the net returns from silviculture will be higher.



Images above: Ballarat GovHub, Ballarat (Peter Bennets)

11 Net carbon balance of forest management

In Australia, only a small proportion of the native forest estate is managed for multiple uses including wood production. This production not only helps meet Australia's demand for wood products but can also provide greater climate benefits than managing for conservation alone.

The carbon balance of forests managed for multiple uses including wood production is the result of complex dynamics along the whole supply chain. According to the IPCC's latest Assessment Report[49], sustainable forest management can help to manage vulnerabilities due to climate change (e.g. fires, droughts), while increasing and maintaining forest carbon sinks through harvest, transfer of carbon to wood products and their use to store carbon and substitute emissions-intensive construction materials.

In Australia, only a small proportion of the native forest estate is managed for multiple uses including wood production. This production not only helps meet Australia's demand for wood products but can also provide greater climate benefits than managing for conservation alone.

There are life cycle studies at a landscape level that have concluded that the climate benefits from production native forests in New South Wales and Victoria, taking into account both carbon sequestration in forests and the carbon dynamics in wood products, are superior to those from forests managed for conservation only (e.g. Figure 8).[51] Other studies have arrived at different conclusions[e.g.52]. The results of different studies depend on many different assumptions and need to be interpreted with care. Often the differences in the outcomes can be linked to a range of analytical and framework issues[50]. In such assessments, it is important to adopt an accounting framework that included all carbon emissions and removals required to more closely represent what the atmosphere 'sees'.

Internationally, some life cycle-based studies have also concluded that production forestry leads to superior climate outcomes[51]. In Canada, studies that have considered all key carbon removals and emissions pathways concluded that the most effective strategies for climate change mitigation in the medium to long term were those that involved optimum sustainable utilisation of forest resources[52].

It has been suggested by some that wood products from native forests in Australia could be replaced with products from the existing plantation estate. However, the existing plantation estate has not expanded at anywhere near the required rate to meet demand, and the species grown are usually not suitable for replacing the products such as flooring and external decking, for which native forest timbers are used. Therefore, if wood products are to replace native forest timbers, these are likely to be imported. While much of the volume of sawn timber currently imported into Australia is plantation timber for construction, replacement of native hardwood products carries a significant risk of 'leakage' through increased emissions from native forests harvested (often unsustainably) outside Australia. This risk is clearly identified by Kastner et al[53], who argue that policies aimed at increasing forest-based carbon stocks and reducing areas available for production should take into account the indirect impacts associated with the likely increase in production elsewhere.

Active forest management can play a role in reducing susceptibility to bushfires, pests, and disease, which in turn leads to climate benefits.

Active forest management can play a role in reducing susceptibility to bushfires, pests, and disease, which in turn leads to climate benefits. Active management also provides economic incentives that can deter forest conversion to agriculture, urban development and other land uses that have substantial and permanent impacts on carbon storage and emissions[55]. These other benefits from having a well-resourced forest management sector, with income from wood production to help offset forest management costs and fire-fighting capability, for example, are often overlooked in terms of their contribution to climate change mitigation opportunities.

Both new commercial plantations and not-for-harvest plantings result in net climate benefits. In the case of commercial plantings, the benefits are multiple, and include:

- the average long-term carbon stocks in the trees
- continued carbon storage in wood products
- the net substitution benefit associated with the use of wood products that are harvested and replanted on a regular basis in place of GHG-intensive alternatives.

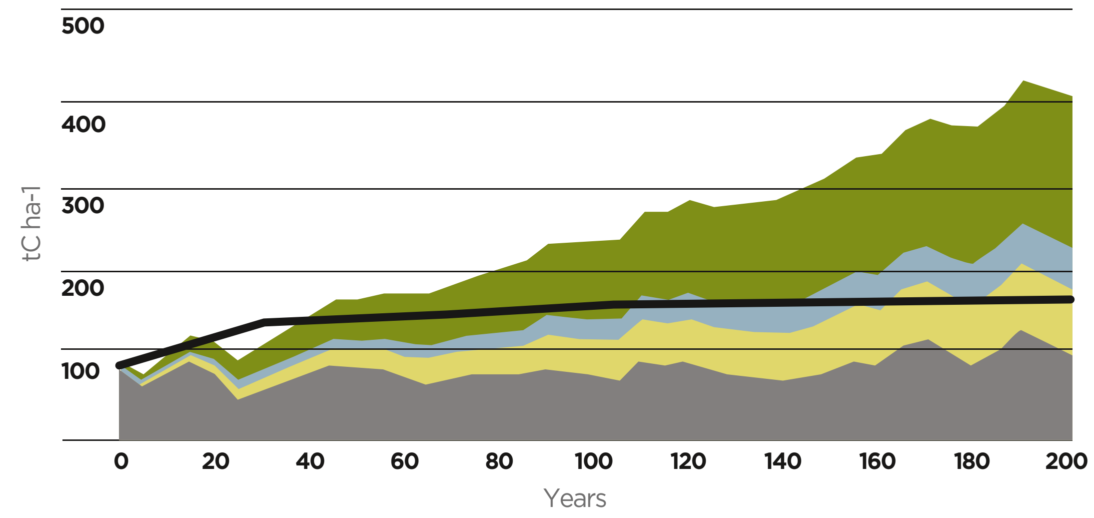


Figure 8 – GHG implications of the conservation and production scenarios for NSW North Coast native forests modelled over a 200-year period[54]

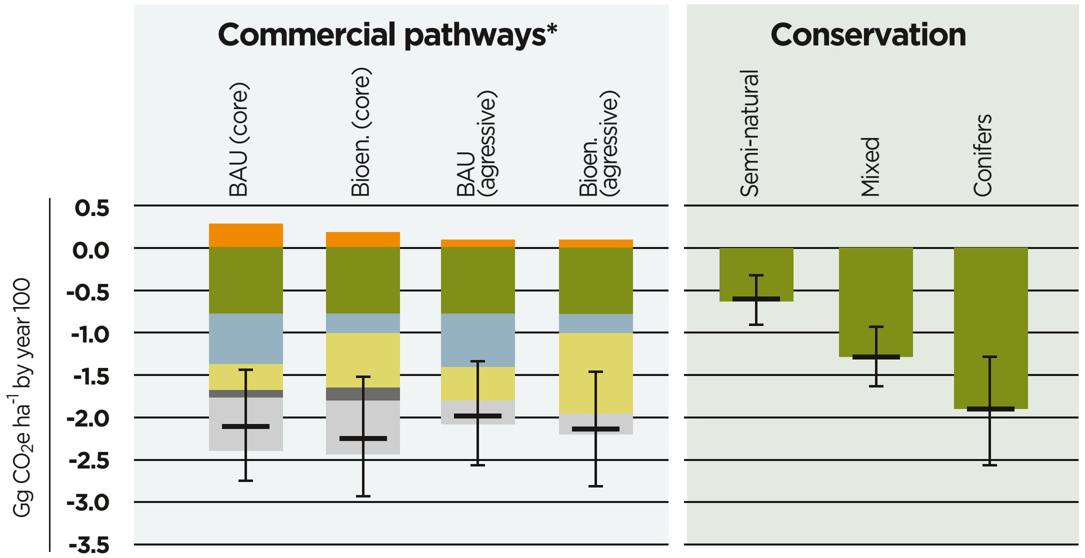


Figure 9 – Contribution of major processes to cumulative GHG fluxes from one hectare of afforested land (planted in 2020) by year 100, for commercial and conservation forests[57]

**These pathways involve differing rates of fossil fuel replacement, and differing rates of carbon capture and storage implementation across industry sectors, representing different future contexts in which forestry value chains could exist*

The relative GHG benefits of commercial plantations compared to not-for-harvest plantings has been demonstrated in a recent study. The UK has a national planting strategy of 30,000 ha per year from 2020 to 2050. Using dynamic life cycle assessment[56], it was estimated that commercial plantations could mitigate 1.64 billion tonnes CO_2-eq by 2120 (cumulative), compared with 0.54 billion tonnes CO_2-eq for a semi-natural broadleaf conservation forest, or 1.09 billion tonnes CO_2-eq for an equal planting rate of 15,000 ha per year of each forest type. Those results pertain to regions with commercial forest rotations of around 50 years. In regions with faster tree growth rates and shorter forestry cycles such as typical commercial Radiata pine stands in Australia (rotations of 30-35 years), the climate benefits of commercial plantations are expected to be even higher.

In a recent study conducted for FWPA[58], it was estimated that to offset the equivalent of 10% of the GHG emissions from the top 50 ASX companies in Australia for the next 25 years, an area of commercial radiata pine plantations equivalent to about 1.5 times the size of the current total commercial plantation area in Australia would need to be planted.

Ultimately the best climate outcome will result from the strategic use and careful balancing of commercial plantations, native forests managed for multiple uses including production and conservation forests and not for harvest plantings.

12 Wood and the bioeconomy

Biochar

Green hydrogen

Increasing the sustainable use of bio-based products to replace fossil fuel-based products will be essential if the world is to meet many of the sustainable development goals

The climate change mitigation potential of production forests can be further enhanced by the optimal use of sustainably derived harvest and processing residues and end-of-life timber in the production of bio-products. There are large volumes of this resource currently under-utilised in Australia; in NSW alone the figure is conservatively estimated at two million tonnes of forestry residues[59]. Using this resource to generate bio-products can result in substantial emission reductions by displacing fossil-fuel based products. As the Food and Agriculture Organization of the United Nations stated in a recent report[60] 'increasing the sustainable use of bio-based products to replace fossil fuel-based products will be essential if the world is to meet many of the sustainable development goals'. Demand for wood is expected to grow as the circular bioeconomy expands and new products are developed. Commercial forests could supply a large share of these future demands while delivering comparable or more long-term GHG mitigation compared with conservation forests.

In addition to renewed opportunities for traditional bioenergy markets, new potential markets include:

- engineered and modified timber construction products
- biochar
- renewable diesel, sustainable aviation fuel and green chemicals
- green hydrogen
- textiles.

Greenhouse gas abatement potential is likely to be substantial; for example every kilogram of carbon used in wood-based textiles results in a net saving of 2.8 kilograms of carbon[61]. The higher value of the products, the more financially viable removal of the residues becomes. These new products have the potential to have a significant, positive impact on the carbon balance of production forests.

CLT House
FMD Architects

13 Opportunities and conclusions

Forestry and wood products make a significant positive contribution to Australia's carbon balance. This contribution is multi-faceted, with opportunities along each stage of the supply chain. Importantly, there is significant room for the industry to increase this climate benefit, as the world moves away from fossil fuels and the bioeconomy becomes the norm.

While various policies and schemes around the world acknowledge the role trees play in sequestering carbon, they do not fully recognise the role of wood products in storing carbon for the long term, nor do they recognise climate benefits of substitution. Australia can lead the way by providing incentives for optimal use of the biomass from forestry. These measures can include:

- Promoting the optimal use of harvest and processing residues, including incentives for novel bio-products and bioenergy

- GHG accounting methods for emissions trading where the full value of carbon in forests and wood products is included

- Building rating schemes that assign value accurately to both the physical carbon storage in products and the substitution benefit

- End-of-life schemes that promote the most favourable emissions reduction outcome for the various wood products

To maximise opportunities from the environmental credentials of wood, the challenge for the industry is to:

1. Ensure that the positive contribution that forestry and wood products makes to the carbon balance in Australia is recognised widely.

and

2. Manage the carbon pool in forests and wood products so that the carbon uptake and storage and the resulting positive effects on climate change are optimised.

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