Technical Note

Carbon Analysis of Wood Composite Panels

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Abstract

Wood composite panels (WCP) are well known for their environmentally friendly attributes of being sustainable, renewable, biodegradable, and predominantly made from wood residues generated during lumber and plywood production. This paper focuses on the ability of WCPs to store carbon for long periods of time in nonstructural applications such as cabinets, furniture, and flooring. WCPs, include particleboard, medium density fiberboard (MDF), and hardboard–engineered wood siding and trim (EWST). These panels are anticipated to have an average service life of 25–30 years. In 2019, there was an estimated 291 million cubic meters (m^3) of WCPs in use in North America that corresponds to a carbon pool of 354 million metric tons of carbon dioxide equivalents. This WCP carbon pool is enough to offset 24 years of cradle-to-gate cumulative carbon emissions (fossil and biogenic sources) emitted during production of these panels. In other words, producing and using WCPs stores carbon for long periods because the amount of carbon emitted during the production of the panels is far less than what the panels themselves are capable of storing over their lifetime of product use.

Demand for sustainable ''green'' products, desired for their favorable environmental performance, is increasing in the marketplace. Recent life cycle assessment (LCA) studies document the environmental performance of composite panels (Puettmann and Salazar 2018, 2019; Puettmann et al. 2016). Wood products (in use and landfills) store 9,786 million metric tons (mt) of carbon dioxide (as CO_{2e}; Desai. and Camobreco 2020) representing two (2) times the amount of carbon stored in forests in United States (US) National Parks (Smith et al. 2019).

When round-shaped logs are processed into rectangular boards at sawmills, coproducts in the form of bark, hogged fuel, sawdust, shavings, and chips are generated. These coproducts may be used for heat energy onsite at the facilities, used in pulp and paper production, or in the manufacturing of wood composite panels (WCPs). WCPs represent 3.2 percent of the total harvested wood volume in the United States (Oswalt et al. 2019). In 2016, wood processing facilities in the United States generated 58 million mt (dry) of residues (Oswalt et al. 2019). These residues were primarily used for fuel (46%) and fiber products (38%) including WCPs.

The US softwood lumber industry produces an estimated 19 million mt per year of residue coproduct, which represents over half of the log mass entering sawmills (Milota and Puettmann 2017). Recent surveys indicate that softwood lumber producers use about 3.8 million dry mt per year of coproduct for onsite energy consumption (Milota and Puettmann 2017). This self-generated biofuel not only comes at a low environmental and economic cost to wood producers but is a direct substitution of fossil fuels with a direct reduction in carbon emissions. Increasing pressure to reduce greenhouse gas emissions, including the reduction of fossil fuel use, such as coal, have boosted interest in using wood residues from wood producing facilities to produce energy and transportation fuels (Kelley et al. 2019). The use of wood-based fuels reduces fossil-based carbon emissions, but the substitution may come with unintended consequences—such as higher carbon emission than would occur if the wood residues were used in long-term products such as wood composite panels.

The Composite Panel Association (CPA) represents North American (NA) manufacturers of composite wood and fiber panels. The NA composite panel industry stores more than 14.8 million metric tons of carbon (CO_2e) through the manufacture of panels each year. This is equivalent to carbon emissions for over 3.2 million cars (US Environmental Protection Agency [EPA] 2021).

The purpose of this study, commissioned by CPA, was to determine the net carbon impact of WCPs by measuring the total carbon storage (embedded carbon) and embodied carbon for the WCP products produced over an estimated service life of 25–30 years (the anticipated service life of panel products). The results present carbon pools and flows for particleboard, medium density fiberboard (MDF), and hardboard–engineered wood siding and trim (EWST)

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manufacturing facilities located in North America (Mexico not included) for the production years 1996–2019.

Methods and Materials

The principal raw material used in manufacturing WCPs is residual fiber sourced from forests, sawmills, and other wood processing and agricultural operations that would otherwise be discarded or used for energy. Over 90 percent of all WCP feedstocks are sourced from sustainably managed forest where carbon removals do not exceed carbon stored in the wood. We used carbon flows that are based on WCP production shipment volumes and carbon pools based on the cumulative carbon stored during the life span of the WCP containing-product. With an estimated life span of 25–30 years, we used a conservative 24-year life span for this study.

Carbon flows

Data used for calculation of carbon flows and carbon pools was obtained from CPA WCP shipments for years 1996–2019 (CPA 2017, 2019). Carbon flows are based on the mass of panel shipments (Eq. 1).

$$\text{Carbon flow}\,(\text{mt } CO_2) = \text{panel production}\,(\text{mt}) \times \frac{50}{100} \times \frac{44}{12} \tag{1}$$

where

Panel production = oven dry mass (wood component only),
mt = metric tons,
Estimated wood carbon content of panel = 50 percent,
Molecular weight of $CO_2 = 44/12$.

Carbon pools are the cumulative carbon from current and previous year shipments (Eqs. 2 and 3). Carbon pools begin with production year 1 and are calculated based on Equation 2. The assumptions are that there are no removals from the pool and pools are based on actual shipments of composite panels.

$$\text{Year } t \text{ carbon pool: } X_t = X_{t-1} + \text{carbon flow}_t \tag{2}$$

where

X = carbon pool (CO_2),
t = year,

Carbon flow = Equation 1 (carbon as CO_2 in current year production).

$$\text{Cumulative carbon pool } (\text{mt } CO_2) = \text{carbon flow}_{\text{yr1}} + \text{carbon flow}_{\text{yr2}} \ldots + \text{carbon flow}_{\text{yr}x} \tag{3}$$

Carbon emissions

The Underwriters Laboratories (UL) Product Category Rule (PCR) for North American Wood Products (UL 2018, 2019) specifies the Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI) as the default life cycle impact assessment (LCIA) method for quantifying the global warming potential (GWP; Bare 2012). The TRACI method does not account for removals or emissions of biogenic CO_2. The reporting for GWP and biogenic carbon ($CO_{2\ BIO}$) are as follows:

- $CO_{2e\ TRACI}$ includes greenhouse gases (GHG) emissions from the combustion of fossil resources, and GHG emissions other than CO_2 from the combustion of biogenic resources.
- $CO_{2\ BIO}$ includes only carbon dioxide emissions emitted from the combustion of biomass (wood).

Biogenic carbon

Biogenic carbon is the carbon derived from biomass. Trees absorb CO_2 through the process of photosynthesis, incorporating it into plant tissue as carbon. This biogenic carbon is emitted as $CO_{2\ BIO}$ and biogenic methane when trees or biomass are combusted or decay. During the production of wood products, biogenic carbon is emitted if wood biomass is combusted for energy during manufacturing or if forest residues are burned after a harvest. Biogenic carbon is stored in WCP as a negative emission when it enters the product life cycle. At the end of the wood product's life, biogenic carbon emissions can be released partially or all back into the atmosphere depending upon the end of life of treatment. Biogenic carbon emissions results were generated in SimaPro v. 9.1. (Pré Consultants 2020) and obtained from the life cycle inventory output.

Embodied carbon

Embodied carbon is the sum of the cradle-to-gate upfront carbon emissions, which includes resource extraction, material transportation, and product manufacturing and does not include the carbon stored in WCPs or changes in soil carbon pools. Embodied carbon is reported as GWP measured in carbon dioxide equivalents (CO_{2e}). We present carbon emissions from both biogenic sources ($CO_{2\ BIO}$) and fossil sources ($CO_{2e\ TRACI}$).

Both biogenic and fossil-based carbon emissions are released as a result of combustion of biomass or fossil-based fuels used during the cradle-to-gate production of WCPs. Wood composite panels producers use wood residue or waste for heat energy to operate onsite dryers and boilers. The onsite use of biomass for energy represents 23, 29, and 56 percent of the total energy consumed for particleboard, MDF, and hardboard–EWST manufacturing, respectively (Puettmann and Salazar 2018, 2019; Puettmann et al. 2016; Table 1). Natural gas is the most commonly used fossil fuel for heat energy (drying and pressing) at WCP facilities in NA.

For this paper, previous particleboard and MDF life cycle inventory (LCI) models were updated with new consumption data of fuels, electricity, and ancillary materials. For hardboard–EWST no new data were collected, and only new electricity and fuel processes were updated. Production volumes of WCP were obtained using 24 years of shipment volumes from production years 1996–2019 (CPA 2017,

Table 1.—Biomass fuel use reported for composite wood panels.[a]

	Particleboard (%)	MDF (%)	Hardboard–EWST (%)
Cradle-to-gate	23	29	56
Facility use (gate-to-gate, onsite)	20	30	56

[a] MDF = medium density fiberboard; EWST = engineered wood siding and trim.

2019). All LCA modeling was constructed in SimaPro. New GWP values and biogenic carbon emissions were calculated and applied to annual WCP production flows to obtain a carbon flow profile over 24 years. Excluded from the study were the fluxes in carbon pools from removals and decay.

Results

For particleboard, the updated NA GWP per cubic meter (m^3) value is 0.351 metric ton (mt) $CO_{2e\ TRACI}$ and 0.639 mt $CO_{2e\ TRACI}$ for MDF. For hardboard–EWST the $CO_{2e\ TRACI}$ is 0.680 mt CO_2e/m^3. In 2019, there was an estimated cumulative 291 million m^3 of WCP (particleboard, MDF, and hardboard–EWST) in use in NA that represents a cumulative carbon pool (24 yr) of 354 million mt of CO_2 where the total carbon emissions from manufacturing (cradle-to-gate) is 224 million mt CO_{2e} (Table 2). The panel cumulative carbon pool is enough to more than offset 24 years of all the CO_2 emissions ($CO_{2\ BIO}$ and $CO_{2e\ TRACI}$) from producing particleboard, MDF, and hardboard–EWST cradle-to-gate (Table 2). More carbon is stored in WCP than is released from cradle-to-gate.

Figure 1 shows carbon emissions as $CO_{2e\ TRACI}$ (orange bars) and biogenic $CO_{2\ BIO}$ (blue bars), embedded carbon (stored) as CO_2 based on total shipments for a given year (light green bars), and net GWP (embedded carbon minus emissions [$CO_{2e\ TRACI}$ and $CO_{2\ BIO}$] shown in dark green bars). For particleboard and MDF, more carbon is stored in the product than is released from all cradle-to-gate emissions, while for hardboard–EWST the carbon storage is not enough to offset the carbon emissions from cradle-to-gate. As a collective, the carbon pools of all WCPs are enough to offset the carbon emissions for all three panel types. Following the reporting requirements of the PCR, all panel products would store more carbon then was released during production (Table 3). This assumes that biogenic CO_2 emissions from combustion do not exceed the CO_2 uptake during tree growth (assuming no land-use change), leaving the balance of the biogenic carbon as carbon stored in the wood product for its lifetime.

Production of WCPs from cradle-to-gate releases more fossil carbon ($CO_{2e\ TRACI}$) than biogenic carbon ($CO_{2\ BIO}$). This is driven by regional electricity grids, resins, transportation fuels, and heat energy from natural gas. Particleboard and MDF facilities use more fossil-based fuels for heat energy generation onsite because the majority of the wood fiber at WCP facilities is incorporated into panels.

Table 2.—Cumulative carbon pools and carbon emissions from production of composite wood panels (particleboard, MDF, and hardboard—EWST) produced in North American between 1996 and 2019.[a]

	Unit	Total amount	Particleboard	MDF	EWST[b]
Cumulative panels in use past 24 yr	m^3	291,175,329	187,823,560	91,762,900	11,588,869
Carbon pool in cumulative panels	CO_2 1,000 metric tons	353,866	220,163	118,235	15,469
Carbon emission (GWP) from producing cumulative panels ($CO_{2\ BIO}$ + $CO_{2e\ TRACI}$)	CO_2 1,000 metric tons	224,526	106,695	91,261	24,569

[a] MDF = medium density fiberboard; EWST = engineered wood siding and trim; GWP = global warming potential.
[b] Hardboard–EWST production 2005–2019.

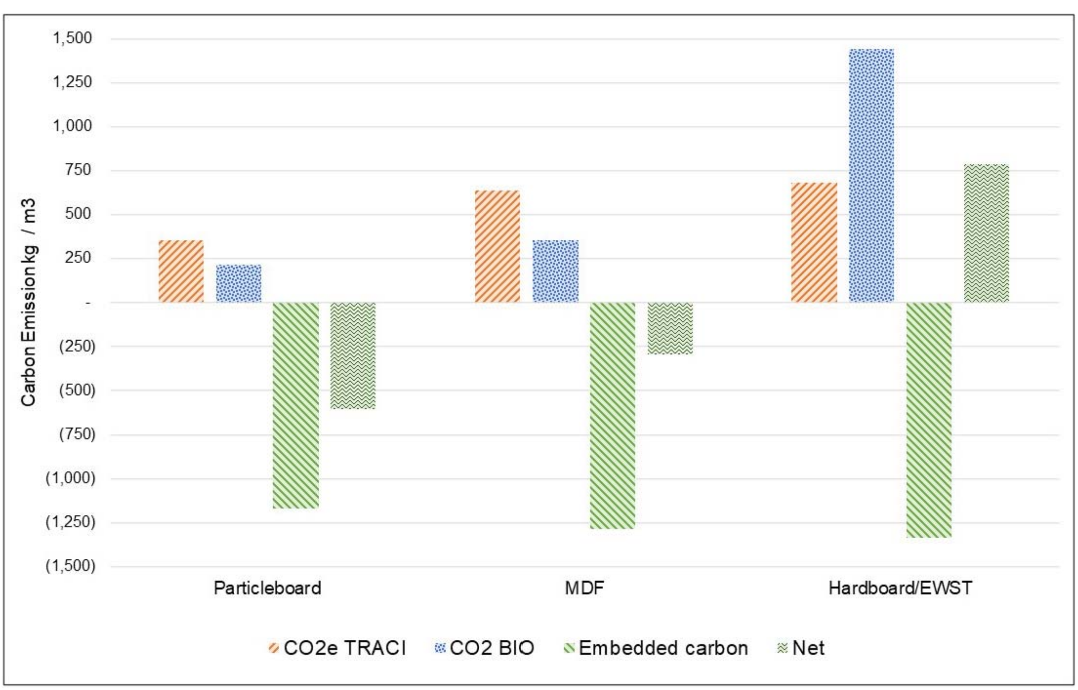

Figure 1.—Carbon emissions for $CO_{2e\ TRACI}$ and $CO_{2\ BIO}$, embedded carbon (flow), and net CO_2 expressed in kg of CO_2 for particleboard, medium density fiberboard (MDF), and hardboard–engineered siding and trim (EWST) based on 2019 North American shipments only.

Table 3.—Biogenic carbon inventory parameters for 1 m^3 of particleboard, medium density fiberboard (MDF), and hardboard–engineered wood siding and trim (EWST).

Unit	Particleboard	MDF	Hardboard–EWST
kg $CO_{2e\ TOTAL}$	351	639	680
kg $CO_{2e\ BIO}$	−1,172	−1,289	−1,335
kg $CO_{2e\ TRACI}$	351	639	680
Biogenic carbon reporting[a]			
kg $CO_{2\ BIO}$ removal	−1,203	−1,499	−2,449
kg $CO_{2\ BIO}$ in product	1,172	1,229	1,335
kg $CO_{2\ BIO}$ from combustion	31	211	1,115

[a] Reporting of biogenic removal, storage in product, and emissions from combustion as per mandatory biogenic carbon reporting per ISO 21930 (2017) and the Product Category Rule (PCR; UL 2018, 2019).

WCP facilities would need to purchase additional wood fuel and transport it to completely substitute biomass fuels for fossil-based fuels. For example, using biomass instead of natural gas as the primary heat source can avoid over 211,000 metric tons of fossil-based carbon emission ($CO_{2e\ TRACI}$) from the cradle-to-gate (based on 2019 production data only), but only if the biogenic emissions are considered carbon neutral. In actuality, more carbon emissions are released when using biogenic fuels, owing to their lower carbon density and associated heating value. In a recent white paper by Puettmann (2021), biogenic carbon emissions for particleboard increased by 154 percent and $CO_{2e\ TRACI}$ decreased by 12 percent. For MDF, biogenic carbon emissions increased by 56 percent while fossil-based carbon emissions ($CO_{2e\ TRACI}$) decreased by 24 percent.

Summary

Wood is a biobased material and thus contains biogenic carbon. Carbon is stored in WCP as a negative emission when it enters the product life cycle referred to as $CO_{2\ BIO}$. During the production of WCPs, biogenic carbon is emitted if wood biomass is combusted for energy use during manufacturing or if forest residues are burned after a harvest. Carbon flows are based on shipment volumes, while carbon pools are the cumulative carbon stored during the life span of the WCP containing-product. Assuming a life span of 25–30 years, the system boundary for this study did not consider fluxes in carbon pools (removal and decay changes). By the year 2019 there was an estimated 291 m^3 of WCP in use in North America that corresponds to a cumulative carbon pool of 354 million mt of CO_2. This cumulative WCP carbon pool is enough to offset 24 years of cumulative cradle-to-gate greenhouse gas emission (as CO_{2e}) emissions from both fossil and biogenic sources. In summary, North American WCP store much more carbon than they release as a consequence of their production. In summary, WCP are the key to maximizing tree use by providing society a useful long-lived product made from wood waste (i.e., wood fiber, chips, sawdust, plywood trim) from the production of primary wood products, while storing carbon for many years.

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