CORRIM FACT SHEET **6**

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Product and Process Environmental Improvement Analysis for Buildings
(Carbon Life Cycle Assessment)

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Life cycle analysis of house designs has shown that wood framing generally produces lower burdens than concrete or steel alternatives. How to select specific products or process changes (such as biofuel drying) to reduce environmental burdens is less obvious. Understanding the burdens imposed by specific products and processes can provide more direction.

Life cycle inventory data available from the National Renewable Energy Lab (NREL 2009) provides measures of inputs and outputs for every stage of the production of construction components. This fact sheet focuses on carbon emissions and the other green house gas outputs contributing to Global Warming Potential (GWP).

Using wood products provides a unique opportunity to store carbon from sustainably managed forests (Perez-Garcia et al 2005a). The carbon stored in the products offsets the emissions from processing the wood and potentially the emissions from other products used in construction assemblies. Using wood also substitutes for fossil-intensive non-wood materials, offsetting their emissions (Perez-Garcia et al 2005b).

Using the Athena Environmental Impact Estimator (ATHENA 2004) and data from the NREL USLCI database, we can analyze carbon impacts at the level of individual components and for construction assemblies. Figure 1 (bottom tier), starts with the carbon emissions from wood floor-joist components, dimension wood joist {Dim-Joist} and Engineered Wood Product I-Joists {EWP I-Joist}. Both products store carbon (negative emissions) because emissions from processing are more than offset by the carbon in the products themselves. In contrast, Concrete Slab and Steel Joists result in substantial carbon emissions (2-4 kgCO2/sq ft of floor).

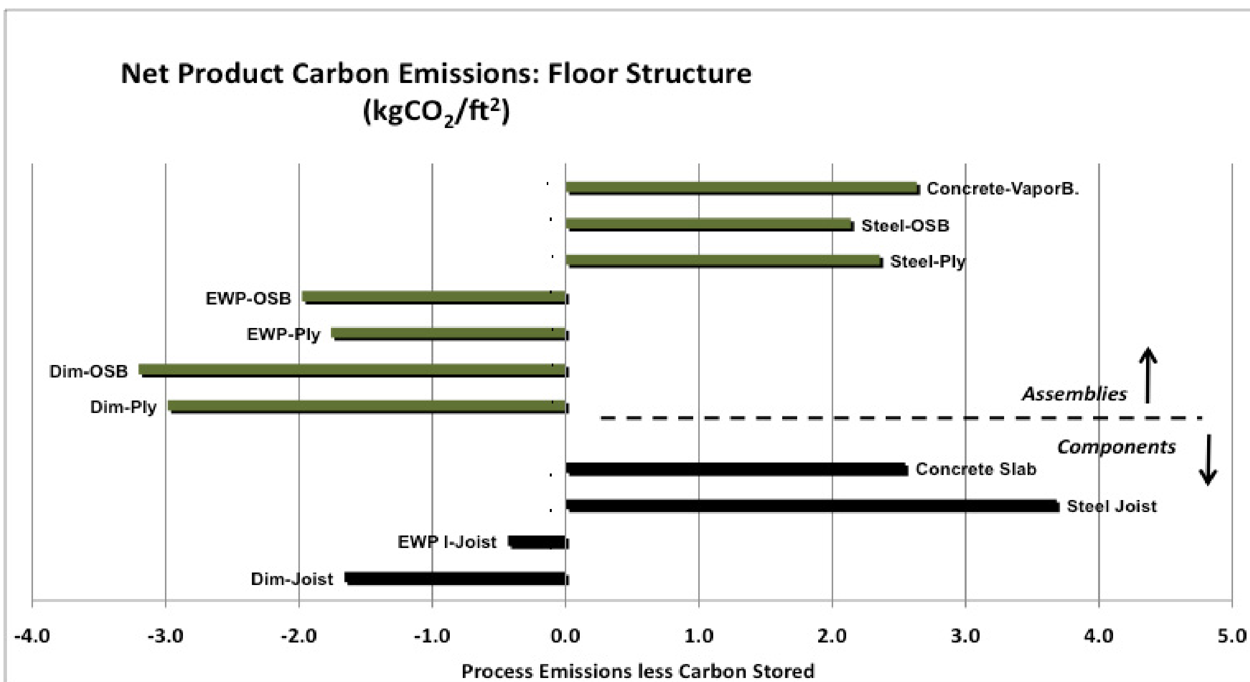

Figure 1: Process Emissions less Carbon Stored in Floor Structure Components and Assemblies from Lippke & Edmonds 2009.

Adding a wood covering, such as plywood {Ply} or oriented strandboard {OSB}) over steel joists (top tiers) does not completely offset the emissions from the heavy gauge steel that is used in flooring. Adding a vapor barrier (VaporB) to a concrete slab floor without a wood cover provides no offset. EWP I-joists with wood covering store less carbon than dimension joists because they use less fiber. However, all combinations of wood joist with wood covering store substantial amounts of carbon.

The reduction in GWP (carbon-equivalent global warming potential) for competing ***floor-assemblies*** is shown in figure 2. The EWP I-joist with an OSB cover displaces more GWP emissions than a Plywood cover alternative (top bars) because OSB is more dense, i.e. contains a little more carbon. The EWP I-joist with an OSB cover is better than concrete reducing GWP emissions by 3 kg*ft^{-2} of floor (middle bars). Another measure of interest is the emission reduction relative to the fiber used. The EWP I-joist reduces CO_2 emissions by 4.6 kg per kg (dry weight) of wood used. The comparisons with steel (bottom bar) show the wood joist and cover reducing emissions by 9.8 kg*ft^{-2}. This is more than twice as effective as the substitution for a concrete floor because steel joists must be heavy gauge to minimize floor bounce. Because the steel floor also uses wood in the floor cover, it is slightly less fiber efficient, reducing emissions by 4.2 kg per kg of wood used. If there is an adequate supply of wood, greater use of wood will improve a construction-footprint the most. If not, maximizing the efficient use of wood fiber becomes a priority.

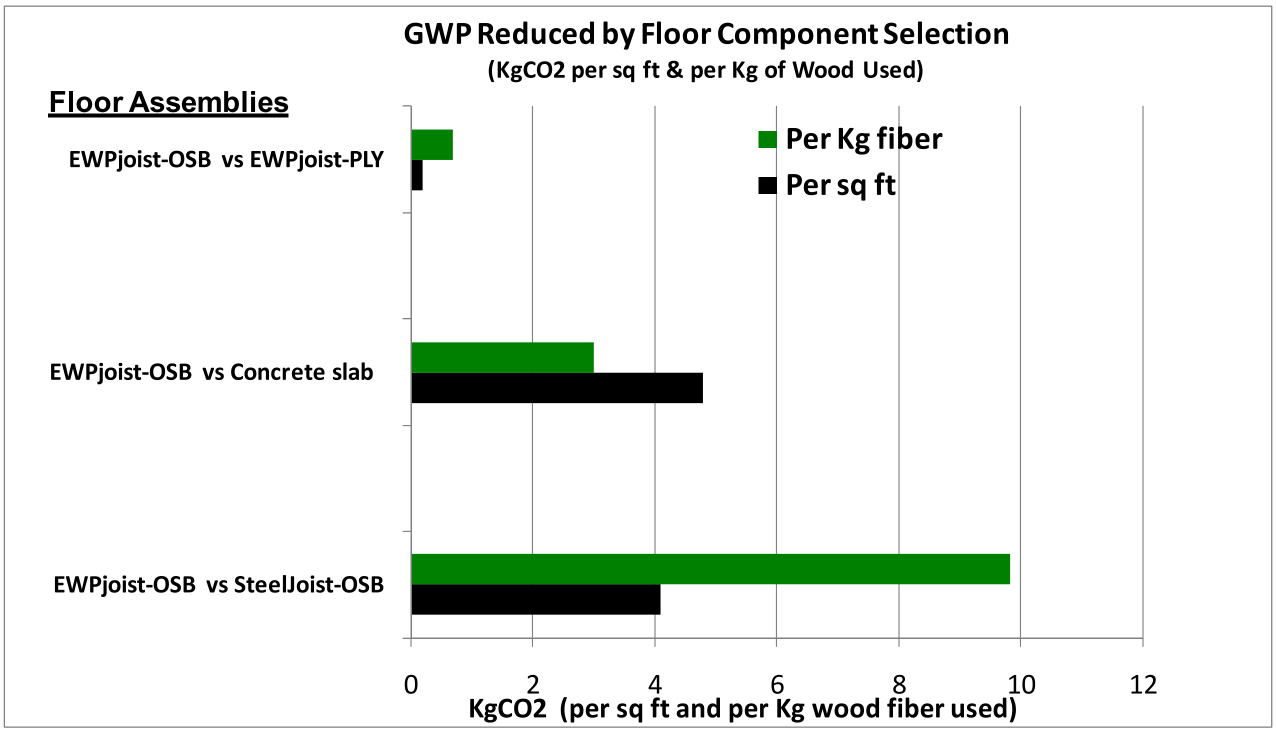

Figure 2: Reducing Global Warming Potential by Selecting Components in Floor Assemblies (per square foot and per kg of fiber) from Lippke & Edmonds 2009.

While displacing steel in floors is more 'carbon-effective' than displacing concrete, these findings cannot be generalized to wall assemblies. As noted in figure 3, the wood-wall ***components*** (kiln dried stud {KDStud}, Green Stud, Plywood, OSB, biofuel dried plywood {BioDryPly}) each store an amount of carbon that more than offsets their processing emissions. Some ***wall assemblies*** use sufficient amounts of wood to more than compensate for the carbon emissions of some non-wood components such as vinyl cladding. As a component in walls, concrete block substitutes not only for wood studs, but also for the wood sheathing and, with the addition of stucco, for any wood or vinyl cladding used with wood-framed walls. In terms of carbon emissions, the worst assembly is Concrete Block and Stucco, while the best configurations use biofuel-dried wood products (top three bars).

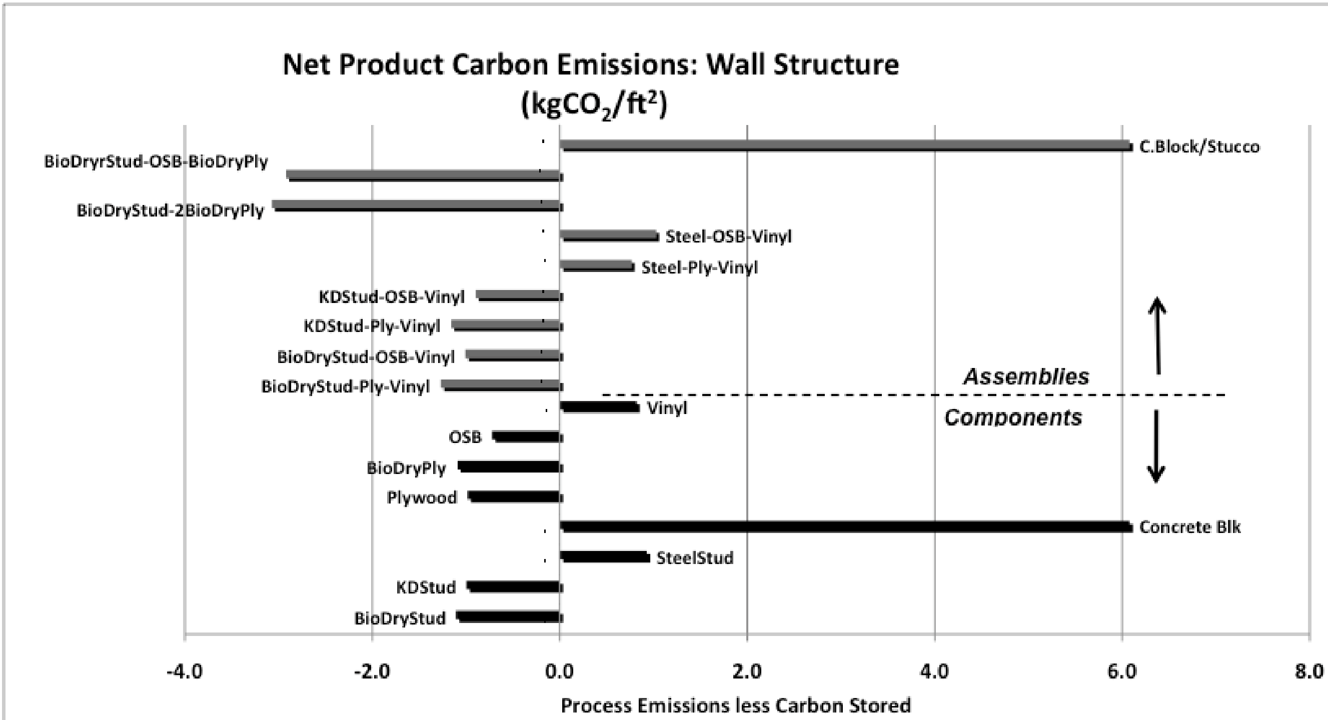

Figure 3: Process Emissions less Carbon Stored for Wall Components and Assemblies from Lippke & Edmonds 2009.

The carbon stored in an un-dried green stud is the same as for a biofuel dried stud but the latter uses more fiber as fuel. The benefit of using more biofuel is within easy reach for both wood studs and plywood (BioDryPly) but is not shown for OSB because it already uses more biofuel for drying. The assembly made of biofuel-dried-studs, biofuel-dried-plywood sheathing and cladding stores the most net carbon. There are many opportunities for product development to improve products and construction assemblies beyond these basic design options. There will also be some regional differences driven by regional energy sources and different wood species.

The reductions in GWP resulting from substituting competing wall designs are shown in figure 4. The biofuel dried stud with biofuel dried plywood in both sheathing and cladding substituting for the (more common) kiln dried stud, OSB sheathing and vinyl siding reduces GWP by 2.2 $kgCO_2*ft^{-2}$ of wall, with a fiber efficiency of 2.1 kg CO_2 reduction per 1kg of fiber used (top bars). The benefit of this substitution is almost the same as replacing a conventional steel wall assembly with a conventional wood assembly (bottom bars). If a biofuel dried stud wood wall replaces a steel framed wall assembly, the combined substitution effect is a GWP emissions reduction of 4.1 $kgCO_2$ per sq. ft. of wall, with a fiber substitution efficiency of 2.7 $kgCO_2$ per kg of wood fiber used. Using the wood designs in place of concrete and stucco walls results in GWP reductions of 7-9 $kgCO_2$ per sq. ft. of wall or and 3.5 $kgCO_2$ per 1 kg of wood fiber.

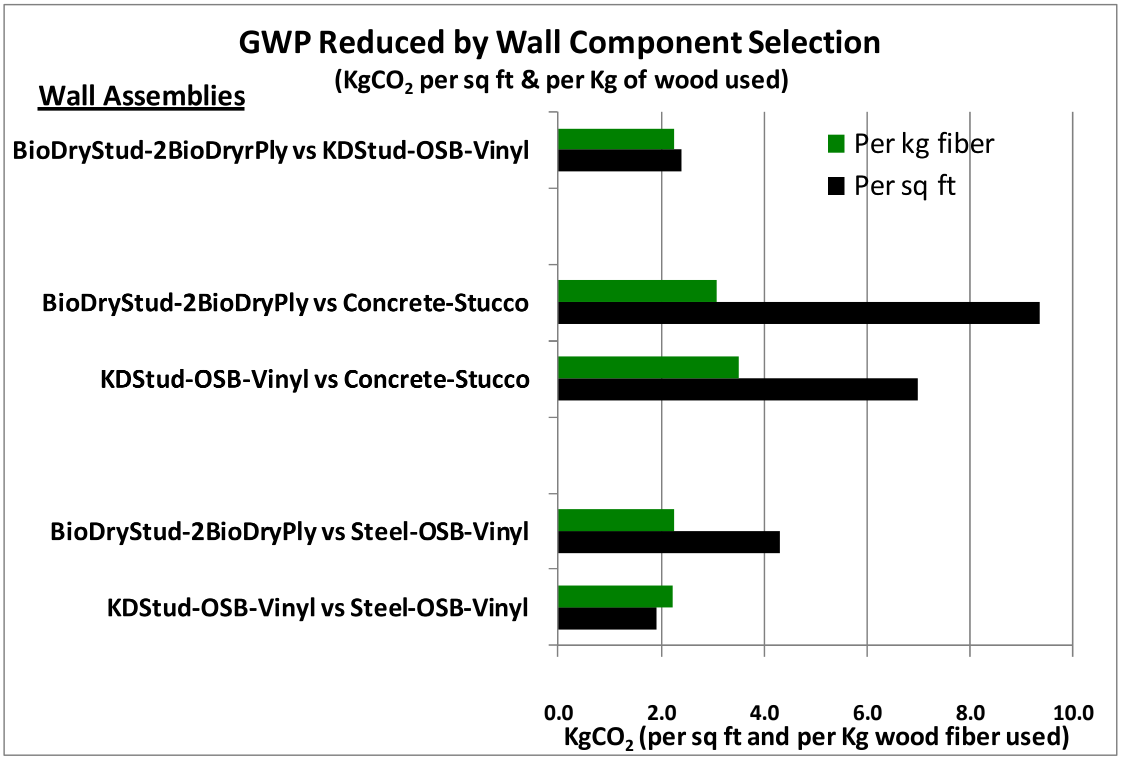

Figure 4: Reducing Global Warming Potential by Selecting Components in Wall Assemblies (per square ft of wall and per unit of fiber used) **from Lippke & Edmonds 2009.**

For wall and floor assemblies, the displacement of emissions per unit of wood fiber used is similar; however, wood-based options are more effective at displacing the carbon emissions from steel in floors and concrete in walls. Unfortunately, these differences generally are not identified or valued in market exchanges given the low value currently placed on carbon emissions from fossil fuels.

Environmental Improvement Opportunities

These results suggest there are product selection and product processing alternatives that can substantially reduce environmental burdens, as demonstrated here by GWP reductions. Use of wood in more building applications offers opportunities to avoid and offset fossil emissions from non-wood products. An understanding of net emissions from product alternatives based upon life cycle assessment is important for effective green building standards.

References

ATHENA Institute EIE. 2004. Environmental Impact Estimator (EIE – software v3.0.1). www.athenaSMI.ca Athena Sustainable Materials Institute, Ottawa, Canada

Lippke, Bruce, and James Bowyer. 2007. Environmental Life Cycle Analysis of Alternative Building Materials, Chapter 7, Handbook of Environmentally Conscious Materials and Chemicals Processing by *John Wiley & Son*

Lippke, Bruce and Lucy Edmonds. 2006. Environmental Performance Improvement in Residential Construction: the impact of products, biofuels and processes. *Forest Products Journal* 56(10):58-63.

Lippke, Bruce and Lucy Edmonds. 2009. Environmental Improvement Opportunities for Alternative Wall and Floor Designs, Module I: CORRIM Phase II Research Report. www.corrim.org.

Perez-Garcia, J., B. Lippke, D. Briggs, J. Wilson, J. Bowyer, and J. Meil. 2005a. The Environmental Performance of Renewable Building Materials in the Context of Residential Construction. *Wood Fiber Sci*. 37(5): 3-17.

Perez-Garcia, J., B. Lippke, J. Comnick, and C. Manriquez. 2005b. An Assessment of Carbon Pools, Storage, and Wood Products Market Substitution Using Life-Cycle Analysis Results. *Wood Fiber Sci*. 37(5):140-148.

NREL. 2009. U.S. Life-Cycle Inventory Database. http://www.nrel.gov/lci/

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