From Science to Policy 7
Substitution effects of wood-based products in climate change mitigation
Online materials

Methods of the systematic review

We identified appropriate studies based on a comprehensive literature search. We began by conducting three queries in Scopus:

1 forest AND (displace* OR substitut*) AND carbon AND product*
2 lca AND wood AND substit*
3 compar* and LCA and wood

These queries identified 488 studies, 87 and 377 studies, respectively. We screened the documents for relevance based on information provided in titles, abstracts, keywords and results, and shortened the list to 81 studies in the first query, 22 studies in the second query and 12 studies in the third query. We also reviewed the reference lists of the identified studies to identify additional relevant references and considered the studies by Rüter et al. (2016) and Valada et al. (2016). Reviewed studies were limited to those published in English, Swedish, Finnish, German or French.

The review includes only studies that provided original substitution factors and excluded studies relying fully on substitution factors from previous studies. Furthermore, we included studies which contained original data that could be used to calculate substitution factors, i.e. GHG emissions from a wood product, GHG emissions from a functionally-equivalent non-wood product, amount of wood contained in the wood product, and amount of wood contained in the non-wood product. Studies were excluded from the meta-analysis if they only provided estimates for emissions during the life cycle of a wood product but did not compare against a non-wood product. For studies that included multiple scenarios or estimates for substitution factors, we included each estimate as a separate datapoint in our meta-analysis.

In total, we identified 51 relevant studies, containing 433 separate substitution factors. We compiled the substitution factor data in a spreadsheet, together with other relevant data including the life cycle stage(s) considered in the study, the type of wood and non-wood products, and characteristics of the manufacturing process and end-of-life management of the products. We then converted the substitution factors into common units of GHG emission reduction due to using wood products (expressed in mass units of carbon) per unit of additional wood used in the wood product compared to the non-wood product (expressed in mass units of carbon). Where necessary for unit conversions, we used IPCC default values for sawn wood density (0.458 Mg oven dry mass per m^3 air dry volume) and for carbon fraction of oven dry wood (0.5) (IPCC 2013). Unless otherwise stated, we assumed an air-dry moisture content of 15% (mass of water per mass of oven dry wood). Analyses were carried out in R version 3.4.2.

List of studies that have been included in the review

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Grann, B., 2013. A Comparative Life Cycle Assessment of Two Multistory Residential Buildings. Cross-Laminated Timber vs. Concrete Slab and Column with Light Guage Steel Walls, Vancouver: FPInnovations. Project No. 301006840

Gustavsson, L., Pingoud, K., Sathre, R., 2006. Carbon dioxide balance of wood substitution: Comparing concrete- and wood-framed buildings. Mitigation and Adaptation Strategies for Global Change 11(3), 667–691.

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John, S., Nebel, B., Perez, N., Buchanan, A., 2009. Environmental Impacts of Multi-Storey Buildings Using Different Construction Materials. Research Report 2008-02, Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch, New Zealand.

Jönsson, Å., Tillman, A-M., Svensson, T., 1997. Life cycle assessment of flooring materials: Case study. Building and Environment 32(3), 245–255.

Kayo, C., Hashimoto, S., Numata, A., Hamada, M., 2011. Reductions in greenhouse gas emissions by using wood to protect against soil liquefaction. Journal of Wood Science 57, 234–240.

Kayo, C., Noda, R., 2018. Climate Change Mitigation Potential of Wood Use in Civil Engineering in Japan Based on Life-Cycle Assessment. Sustainability 10, 561.

Kayo, C., Watanabe, C., Sasaki, T., Kumagai, S., Noda, R., Hashimoto, S., 2015. Life cycle greenhouse gas emissions of woodchip-paved walkways using tsunami salt-damaged wood: examination in Otsuchi, Iwate Prefecture. Journal of Wood Science 61, 620–629.

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Lippke, B., Wilson, J., Perez-Garcia, J., Bowyer, J., Meil, J., 2004. CORRIM: Life-cycle environmental performance of renewable building materials. Forest Products Journal 54(6), 8–19.

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Noda, R., Kayo, C., Sasaki, T., Takaoku, S., 2014. Evaluation of CO2 emissions reductions by timber check dams and their economic effectiveness. Journal of Wood Science 60, 461–472.

Noda, R., Kayo, C., Yamanouchi, M., Shibata, N., 2016. Life cycle greenhouse gas emission of wooden guardrails: a study in Nagano Prefecture. Journal of Wood Science 62, 181–193.

Petersen, A.K., Solberg, B., 2002. Greenhouse gas emissions, life-cycle inventory and cost-efficiency of using laminated wood instead of steel construction. Case: beams at Gardermoen airport. Environmental Science and Policy 5(2), 169–182.

Petersen, A.K., Solberg, B., 2003. Substitution between floor constructions in wood and natural stone: Comparison of energy consumption, greenhouse gas emissions, and costs over the life cycle. Canadian Journal of Forest Research 33(6), 1061–1075.

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Review of upscaling studies

Table 1 summarizes the data types and approaches applied in upscaling calculations in eight different studies representing 7 countries. These studies used some of the same information (e.g. FAO statistics) but most used regional or national databases. In many cases modeling approaches (MO) were applied to reflect dynamic processes, and these models are a combination of empirical data (D) and process models. Scaling up to larger landscapes or country level analyses always relied on smaller scale studies (ST) and/or assumptions (AS).

Table 1: Data sources applied in upscaling studies

D Empirical data
SD Statistical Database
ST Studies
AS Assumptions
MO Model(s)
- Not Available

	Smyth et al. 2014	Chen et al. 2018	Matsumoto et al. 2016	Knauf et al. 2015	Soimakallio et al. 2016	Suter et al. 2017	Braun et al. 2016	Lundmark et al. 2014
Forest GHG emissions and removals	**D, MO**	**D, MO**	**SD, ST, MO**	**D, MO**	**AS, MO**	**SD, MO**	**SD**	**SD, ST, MO**
Primary Wood Products	**SD**	**SD, MO**	**SD, MO**	**SD, MO**	**SD, MO**	**SD, MO**	**SD, MO**	**MO**
End Use Statistics	**ST, SD**	**SD, MO**	**SD, MO**	**ST**	**SD**	**SD**	**MO**	**ST**
Emission Values	**ST**	**ST**	**ST**	**ST**	**AS, ST**	**SD**	**ST**	**SD**
Half Lives	**AS**	**ST**	**ST**	**ST**	**-**	**AS**	**AS**	**ST**
Alternative products	**ST**	**ST**	**-**	**ST**	**-**	**-**	**-**	**ST**

Braun, M., Fritz, D., Weiss, P., Braschel, N., Büchsenmeister, R., Freudenschuß, A., Gschwantner, T., Jandl, R., Ledermann, T., Neumann, M., Pölz., W., Schadauer, K., Schmid, C., Schwarzbauer, P., & Stern, T., 2016. A holistic assessment of greenhouse gas dynamics from forests to the effects of wood products use in Austria, Carbon Management, 7(5–6), pp. 271–283.

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Knauf, M., Köhl, M., Mues, V., Olschofsky, K., Frühwald, A. 2015. Modeling the CO2-effects of forest management and wood usage on a regional basis. Carbon Balance and Management, 10 (1)

Lundmark, T., Bergh, J., Hofer, P., Lundström, A., Nordin, A., Poudel, B.C., Sathre, R., Taverna, R. and Werner, F., 2014. Potential Roles of Swedish Forestry in the Context of Climate Change Mitigation, Forests 2014, 5, 557–578; doi:10.3390/f5040557

Matsumoto, M., Oka, H., Mitsuda, Y., Hashimoto, S., Kayo, C., Tsunetsugu, Y. & Tonosaki, M., 2016. Potential contributions of forestry and wood use to climate change mitigation in Japan. Journal of Forest Research, 21, 211–222.

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