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UPDATING OF U.S. WOOD PRODUCT LIFE-CYCLE ASSESSMENT DATA FOR ENVIRONMENTAL PRODUCT DECLARATIONS

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ABSTRACT: The marketplace has an increasing desire for credible and transparent product eco-labels based on life-cycle assessment (LCA) data, especially involving international trade. Over the past several years, stakeholders in the U.S. wood products industry have developed many such "eco-labels" under the ISO standard of LCA-based environmental product declarations (EPDs). The standard requires data to be less than 10 years of age, a current issue that needs to be addressed for many structural wood products' life-cycle inventories (LCIs). Under the umbrella of the Consortium for Research on Renewable Industrial Materials (CORRIM), this data updating effort has begun. Some of these LCIs on wood products were originally evaluated as part of a CORRIM Phase I project and include softwood lumber, oriented strandboard, plywood, laminated veneer lumber, I-joists, and glulam. This paper provides the current process and status on updating wood products LCI data for LCA reports and EPDs.

KEYWORDS: CORRIM, life-cycle inventory, environmental product declarations, EPD, LCI, LCA

1 INTRODUCTION

1.1 BACKGROUND

Life-cycle assessment (LCA) is the internationally accepted and standardized method for evaluating the environmental impacts of products. LCA is a scientific approach to assessing the holistic environmental impacts of a product, including resources consumed and emissions released. It can cover the life of a product from extraction of raw materials to product production point (i.e., "cradle-to-gate") or through distribution, use, and to its final disposal point (i.e., from "cradle-to-grave") (Figure 1) [1-3].

LCAs are composed of four stages (phases) as defined by the International Organization of Standardization (ISO):

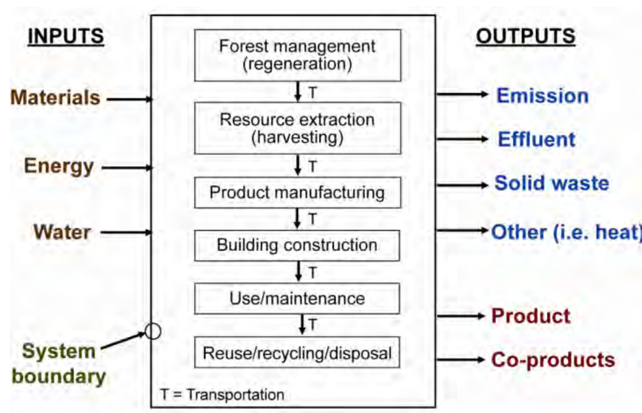

Figure 1: Complete life cycle from regeneration of trees to disposal of wood materials

(1) goal and scope definition, (2) life-cycle inventory (LCI) analysis, (3) life-cycle impact assessment (LCIA), and (4) interpretation (Figure 2). An LCA study includes all stages, but an LCI study does not include stage 3. The goal and scope set out the framework of the study and explain how and to whom results are to be communicated. An LCI measures all raw material and energy inputs and environmental outputs to manufacture a particular product, process, or service on a per unit basis within carefully

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defined system boundaries. Many earlier life-cycle analyses were simply LCI studies, not LCA studies, and therefore did not include the LCIA phase. LCIAs as part of an LCA study use LCI flows to explore impacts for four areas: human health, social health, resource depletion, and ecosystem function. In the interpretation stage, alternatives for action to reduce impacts are systematically evaluated [1-3].

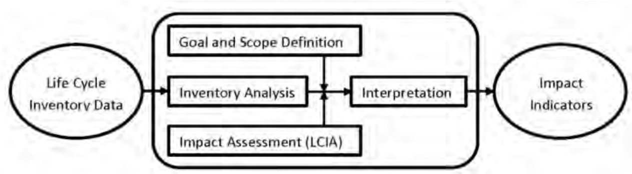

Figure 2: ***Life-cycle assessment stages***

1.2 HISTORY

In 1976, the National Academy of Sciences formed the Committee on Renewable Resources for Industrial Materials (CORRIM) to examine energy impacts of using renewable materials. CORRIM focused on energy issues for building materials. This original CORRIM study became one of the most widely recognized works regarding energy used to manufacture building materials. This study included the flow of forest-based materials into structural and architectural commodities. CORRIM examined total energy, manpower, and capital requirements in the manufacturing of 12 primary wood products, including hardwood and softwood lumber and plywood, and several "state of the art" wood composite products [4].

In 1996, under a new name (Consortium for Research on Renewable Industrial Materials), CORRIM (sometimes referred to as CORRIM II) was re-formed to update the 1976 study using international methods for conducting LCA [5-9]. In addition to energy consumption, CORRIM II reports detailed impacts in the form of emissions and wastes to the environment. Composed of 18 wood-related research institutions, including the U.S Department of Agriculture Forest Service's Forest Products Laboratory, CORRIM conducted LCIs of forest growth, harvesting, product manufacturing, distribution and transportation, product use and maintenance, and disposal and/or recycling and reuse. CORRIM is currently helping to develop an LCI database of peer-reviewed information quantifying both economic and environmental impacts of wood and nonwood building materials [10]. Using ISO standards (2000), CORRIM developed rigorous guidelines for researchers involved in conducting LCI studies on forestry and wood products [11].

1.2.1 CORRIM Phase 1

CORRIM II projects commonly referred to as Phase 1 began in the Pacific Northwest (PNW) and the Southeast (SE) United States, focusing on glued-laminated beams (glulam), plywood, oriented strandboard, softwood lumber, laminated veneer lumber, and engineered I-joists (Figure 3). The PNW and the SE are the largest structural wood products producing regions in the United States. These LCI studies are referred to as Phase I projects [12-19].

Figure 3: ***Survey region for Phase 1 [12]***

In addition to individual LCIs, LCIAs were also released comparing energy use and environmental impact of construction and operation of a wood-framed house to a steel-framed house in Minneapolis, Minnesota (Figure 4), and a wood-framed to a concrete-block house in Atlanta, Georgia (Figure 5). Lower impacts were found for the wood-framed houses in both locations when evaluated on five energy and environmental impact categories [20].

Figure 4: Typical house in Minneapolis, Minnesota (Source: Danielle F. De Tennis)

Figure 5: Typical house in Atlanta, Georgia (Source: Danielle F. De Tennis)

Environmental performance indices (Figures 6 and 7) indicate that wood-framed structures generally have less impact than steel- (Minneapolis) or concrete- (Atlanta) framed structures. For global warming potential, carbon stored in wood products used to develop the wood-framed structures was not considered in the provided figures. However, in the CORRIM-related studies, carbon storage was found to exceed any fossil CO_2 emissions from their production.

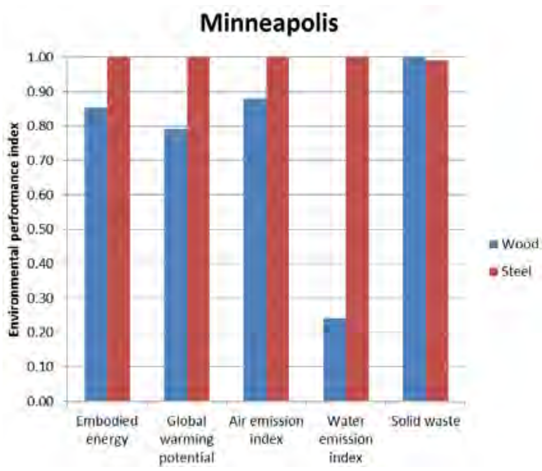

Figure 6: Environmental performance indices for a typical house built in Minneapolis, Minnesota [20]

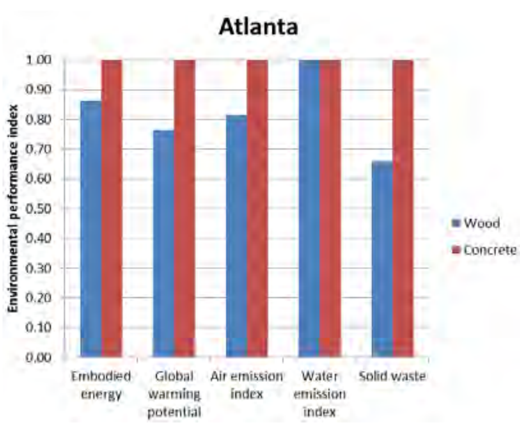

Figure 7: Environmental performance indices for a typical house built in Atlanta, Georgia [20]

These results indicate that the environmental performance of housing as measured by these indices could be improved by building more wood-framed structures and redesigning houses to incorporate more wood building materials. These houses had many common elements (concrete foundations, sheathing, and siding). When the below-ground elements are stripped away, then most of the environmental improvements indicated become larger. For example, differences in percent changes for four of the five environmental performance indices for concrete- versus wood-framed structures double or more (percent change for water emission index stays the same). The differences in percent change for the steel- versus wood-framed structures are not as significant except for the water emission index which does double.

1.2.2 CORRIM Phase 2

Phase 2 LCI projects focus mostly on the Inland West and the Northeast United States, thus extending the geographic coverage examined in Phase I projects (Figure 8). Many earlier LCIs and LCAs did not consider geographical regions and their associated differences, if any. Phase 2 focused on avoiding this shortcoming for U.S. wood products. The extension of wood products LCI research into other regions is vital because of the sensitivity that LCI studies have regarding regional (spatial) factors such as electrical grid composition, tree species, and harvesting practices. At the time of these CORRIM Phase II projects, coal generated most of the electrical power in the eastern United States, unlike in the PNW where power is derived mostly from hydropower [21, 25]. This difference has a significant environmental impact on manufacturing processes that consume large amounts of electricity. Phase 2 projects examined hardwood lumber and flooring, softwood lumber, and other forest resources [21-28].

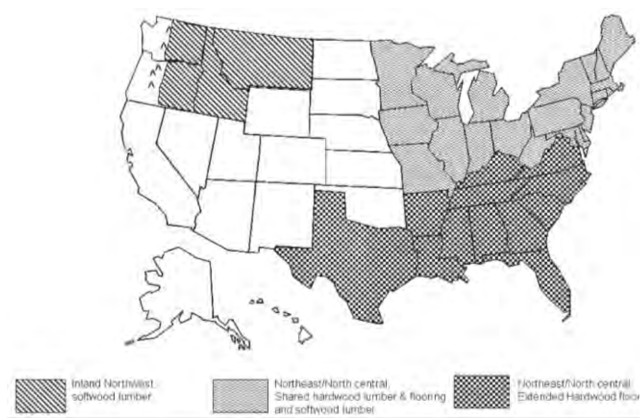

Figure 8: ***Survey region for Phase 2 [22]***

1.2.3 Stakeholder Interest in Development

Several major stakeholders have an interest in the application of LCA data, including government agencies, building industries, environmental nongovernment organizations, environmental consultants, and academia. Different stakeholders view and value LCA work differently, but all have the following concerns when conducting LCA studies: confidentiality, improper assumptions and system boundaries, misuse or misunderstanding by others (i.e., green-washing), and poor data quality.

Green-washing is wrongly stating environmental impact attributes when selling a product or service [29] (for example, stating that a new product has less environmental impacts than the alternative just because the new product is made from renewable sources). Although renewable materials do offer environmental advantages, knowing only that a product is made from renewable sources is an insufficient basis for claiming environmental superiority.

For instance, a renewable product may consume huge quantities of fertilizer that have water and air impacts that outweigh the renewable attribute.

Confidentiality of data provided by industry participants is necessary. Other barriers to effective LCA studies include lack of expertise, methodology development (search for common basis), and project cost and time [30]. Regardless of drawbacks, most stakeholders see opportunities. Industry and their corresponding associations value LCA studies because of the scientific basis used in examining environmental impacts of products and the potential for process improvement and green marketing. Government and academia, in contrast, tend to view LCA as a decision-making tool and as a basis for policy-making [29, 30]. For example, the U.S. Environmental Protection Agency utilizes LCA to categorize biofuels for their greenhouse gas (GHG) reduction potential [31].

2 PUBLIC REPORTS AND DATABASE

Since its reformation in 1996, CORRIM has identified research needs and data limitations specific to wood utilization and developed protocols to conduct the research necessary to meet those needs and limitations using LCA techniques. Eleven different wood products and four U.S. supply regions have been analyzed, culminating in a total of 20 different completed LCIs across the dominant wood products. In addition, CORRIM's research and data are publicly available through the U.S. LCI Database managed by the National Renewable Energy Laboratory (NREL) in Boulder, Colorado, and housed at the U.S. Department of Agriculture (USDA) (www.lcacommons.gov/nrel).

3 ENVIRONMENTAL PRODUCT DECLARATION

3.1 DEVELOPMENT

An environmental product declaration (EPD) is a summary of environmental impacts connected with producing and using a product or service. EPDs, often referred to as LCA-based eco-labels, are based on LCI data and the environmental impact factors generated using LCA techniques on that data [32]. It can be used to compare products on an equal basis. EPDs are designed to provide standardized LCA data in a way that is understandable to people who may not be familiar with the concepts of LCA [29]. An EPD for products is similar to a nutritional label for food. Currently, EPDs can be used in gathering points toward green building certification in LEED V4 and other green building rating systems.

EPD are being developed internationally, which will likely make products without EPDs noncompetitive over time. Therefore, products with EPDs will have market advantages over those without. For the wood products industry, EPDs provide an easy method to demonstrate the environmental performance of products relative to comparable substitutes. However, for now at least, EPDs are not intended to allow comparisons of different kinds of products. Comparisons of EPDs for steel studs (EU) and for wood framing, for example, show different functional units, some variation in impact measures, and even differences in units used in reporting impacts.

CORRIM's 15 years of ground-breaking research efforts in developing peer-reviewed LCA data on major U.S. wood products set the stage for early development of EPDs for wood products. LCA data for wood products demonstrate fairly consistently superior performance compared with nonwood materials, yet many biases continue to exist against the use of wood products. Continuing LCA data development for development and maintenance of EPDs for wood products is a natural next step for this group of research institutions. This effort will ensure the latest updates in processes are incorporated into the final product. This rigor would benefit the sector and provide information necessary for policy-related efforts to reduce the environmental impact of buildings and their development.

For consistency, building product EPDs are developed according to ISO standards and where applicable to specified Product Category Rules (PCRs) [32, 33]. PCRs are common and harmonized calculation rules used to ensure that similar procedures are consistently applied when creating/comparing EPDs. PCRs cover general ISO requirements but provide greater detail that accounts for specific variation in processes inherent in product manufacturing. A program operator ensures that the EPD was developed according to the PCR. A program operator is an individual or organization that develops the procedures that oversee development of an EPD [32]. An example of an ISO-compliant program operator in the wood products industry is FPInnovations (a CORRIM member and Canadian wood research institute).

3.2 TYPES

An EPD can be either "business-to-business" (BtoB) or "business-to-consumer" (BtoC), depending on the use. An EPD must be independently verified when it is used for BtoC communication, and a verifier must therefore be identified and retained. In general, the verifier confirms that the LCA has been done in accordance with the PCR, that all required documentation is in place to make the EPD transparent, and that the underlying PCR meets international standards.

Groups of products usually differ in their inherent environmental performance and therefore require their own PCR. Recent efforts in this arena have produced a Product Category Rule for North America Wood Products (hereafter NA PCR) that has recently been opened up for a third round of internal and external reviews. The NA PCR identifies the data and approach that must be taken when developing EPDs for North American wood products [34]. It includes specifications on impact metrics that must be reported, age of the data, system boundaries, functional units, unit processes to include in the assessment, and a host of other requirements.

3.3 UPDATE

The current PCR indicates that background data must be less than 10 years old. The LCI data produced by CORRIM research was published in peer-reviewed journals in 2005 and 2010 and uploaded to the U.S. LCI Database with updates in the ensuing years. The data were collected over a longer period, with specific age-related metrics such as electricity grids, heat sources, and resins. Eleven of 19 products have LCIs based on primary mill survey data that are 10 years old or older. CORRIM updated each report in 2012 as a first step toward meeting PCR requirements for EPD development. In the end, 15 LCA reports were produced, which include both LCI and LCIA from cradle-to-gate based on requirements for the NA PCR as it currently exists, plus the inclusion of expected expansion of boundary condition to include reforestation and management (http://www.corrim.org/pubs/reports/2013/phase1_updates/index.asp). From these, eight BtoC EPDs were published through the American Wood Council (www.awc.org/greenbuilding/epd.php) representing North American production of softwood lumber, softwood plywood, oriented strandboard, glue laminated beams, laminated veneer lumber, I-joists, particleboard, and medium density fiberboard. The EPDs listed in Table 1 are good for five years. UL Environment was the program operator that managed the development of these EPDs using the NA PCR.

One other North American wood product, cellulosic fiberboard, will be eventually developed into a BtoB EPD. Original LCI product data are being currently developed for cellulosic fiberboard with the EPD expected to be developed and published by the end of 2015.

Table 1: List of North American business-to-business environmental product declarations developed by UL Environment

Wood Product	Valid until date
Softwood lumber	April 2018
Softwood plywood	April 2018
Oriented strandboard	April 2018
Glue laminated beams	April 2018
Laminated veneer lumber	April 2018
I-Joists	July 2018.
Particleboard	November 2018
Medium density fiberboard	November 2018

Table 2 shows partial life-cycle information provided by a wood product EPD. This information was pulled from table 3 of the North American softwood lumber BtoB EPD [35]. The data provided are from cradle-to-gate, which corresponds to the BtoB PCR format. Other results as required by the PCR but not included in Table 2 include total primary energy consumption, material resources consumption, and solid waste, which are also reported along with any individual components in the EPD.

Table 2: Partial information from an environmental product declaration for North American softwood lumber, per m^3 [35]

Impact category indicator	Unit	Total	Forestry operations	Lumber production
GWP[a]	kg CO_2 eq.	72.64	10.56	62.09
AP[b]	H+ moles eq.	42.25	5.43	36.82
EP[c]	kg N eq.	0.0326	0.0123	0.0203
ODP[d]	kg CFC-11 eq.	0.000	0.0000	0.0000
SP[e]	kg O_3 eq.	14.51	2.84	11.67

[a] Global warming potential
[b] Acidification potential
[c] Eutrophication potential
[d] Ozone depletion potential
[e] Smog potential

As mentioned above, different EPDs can be developed depending on the life cycle of the product evaluated. For example, a full cradle-to-grave LCA was constructed for redwood decking [36]. As a result of this work, the first U.S. wood product BtoC EPD was produced [37]. The redwood decking EPD will be valid until September 2018. The difference between the LCI data provided for redwood decking and the eight wood product LCIs is the addition of life-cycle impacts of product delivery to customer, use phase, and disposal (i.e., landfill) in the latter study.

3.4 FOREST SUSTAINABILITY

Sustainability of timber management is the key to forest carbon (GHG) analysis. The validity of an EPD impact on carbon relies on the carbon-neutral forest assumption resulting from sustainable management. This makes forest certification a very important step in the EPD process and provides support for the product LCI findings. One significant environmental aspect included in the NA PCR involving forest management states that "Categorization of sources of wood fiber according to their forest management or certification systems" should be taken into consideration according to ASTM D 7612-10 [38].

3.5 OTHER EPDS

FPInnovations has been active in the field of EPDs for several years. As mentioned previously, they are an ISO-compliant program operator. As part of their research effort, they have developed the NA PCR and used the framework to produce the first North American wood product EPDs. This initial work generated two BtoC EPDs, western redcedar (*Thuja plicata*) siding and decking. Since the initial work, FPInnovations has developed and published individual companies' BtoB EPDs for cross-laminated timber and glulam.

4 SURVEYS

4.1 BACKGROUND

Data collection from the wood products industry to develop LCI data was primarily conducted by use of questionnaires and site visits. As one could expect, data collection was time-extensive and was usually where individual life-cycle projects would be delayed. One reason is that the questionnaires were typically long and detailed so that the needed mill data could be collected. Questionnaires were typically from five to ten pages long for individual life-cycle stages of forest resources and wood product production.

In addition, depending on the specific industry, the availability of such data was variable. The smaller size wood product production facilities commonly have fewer staff available to handle questions, and thus many times it was necessary to develop follow-up questions to gather additional information or clarification on what was already available. As part of the transparency in developing LCI data, CORRIM provided the questionnaires used to survey the individual wood product industry at the end of each of the CORRIM Reports for Phases I and II.

Figure 9 shows page three of the questionnaire to initially survey softwood lumber mills in the northeastern/north central United States as part of CORRIM Phase II projects [39]. This questionnaire was seven pages long and can be found at the back of the associated CORRIM Report.

A fundamental part of science is reproducibility. LCA is science. To allow for reproducibility of the study, questionnaires are provided to show what mill data were collected to develop the results. In addition, log volumes are of particular concern for US mills. US mills collect production data in different units so that the particular data point often has to be converted to a common data unit (i.e. metric). For example, logs are commonly scaled in thousand board feet (Mbf) using different log scale rules although some mills are now using weight scale. Anyway, the various log scale rules each have their own conversion system into a more common volumetric of cubic meter based on a few parameters including log diameter and length [40]. These conversions are shown in the CORRIM reports as well to ensure study reproducibility.

4.2 ON-LINE SURVEY MECHANISM

To help provide for a more long-term approach to the collection of wood product industry data, an on-line survey mechanism will be developed. This approach will be expected to help the wood product industry reduce the time and energy to collect and provide primary data. Consequentially, CORRIM has been evaluating several on-line tools used to collect data.

TOTAL LOG/LUMBER INPUTS (Annual Production)

- Logs: ***What type of log scaling is used?*** ____________

1. Volume of incoming logs ____________ thousand BF
2. Volume sorted & sold to outside firms ____________ thousand BF
3. Volume of logs to sawmill (on-site) ____________ thousand BF

- Rough Green Lumber

4. Volume from on-site sawmill ____________ thousand BF
5. Volume purchased from outside firms ____________ thousand BF
6. Volume sorted & sold to outside firms ____________ thousand BF
7. Volume from predryers ____________ thousand BF
8. Volume from airyard ____________ thousand BF
9. Volume to dry kilns ____________ thousand BF

- Rough Dry Lumber

10. Volume kiln-dried on-site ____________ thousand BF
11. Volume purchased from outside firms ____________ thousand BF
12. Volume sorted & sold to outside firms ____________ thousand BF
13. Volume to planer ____________ thousand BF

- Planed Dry Lumber

14. Volume from planer ____________ thousand BF
15. Volume purchased from outside firms ____________ thousand BF
16. Volume sorted and sold to outside firms ____________ thousand BF
17. Volume used internally (on-site) ____________ thousand BF

Please complete the following table showing the breakdown of the individual tree species and approximate sizes processed by your mill by species or the average log diameter. If less than 2% of total, use category labeled "Other".

Species	Total log input into sawmill (%)	Log Diameter* (in)
Total	100%	

*Please provide individual log diameters if known otherwise please state the average or range of logs processed at your facility in bottom row under Log Diameter

Figure 9: A page of a softwood lumber questionnaire [39]

Of the on-line tools evaluated, Survey Monkey was selected to be used to gather the needed primary mill data on an on-going basis. One major benefit to using Survey Monkey will be that the inputted data will be directly linked to a spreadsheet algorithm (i.e., Microsoft Excel) operating in the background.

5 CONCLUSION

CORRIM wood product LCA studies on wood products have been instrumental in informing stakeholders about the environmental benefits of using wood materials for building. Ongoing LCA research will enable the wood products industry to better understand environmental impacts associated with manufacturing their products and to plan for product and process improvements. LCA-based information should also be helpful in gaining entry into markets. Environmental concerns continue to increase, especially for the building industry, and wood products are in a good position because of positive environmental benefits demonstrated by EPDs and other marketing efforts. A great deal of ongoing work is needed to assess emerging building technologies and assemblies and to get this information into peer-reviewed literature. CORRIM is the logical entity to do this.

Green building certification systems have become progressively prominent in the building industry. Continuing LCA and EPD development will help wood products manufacturers to make product improvements and to create new products with lower environmental impacts. Such work will also help wood to compete well with other building products. Ensuring consistent funding for CORRIM will allow this organization to continue its important work in both of these areas.

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