CRADLE-TO-GATE LIFE-CYCLE ASSESSMENT OF LAMINATED VENEER LUMBER (LVL) PRODUCED IN THE SOUTHEAST REGION OF THE UNITED STATES

CORRIM FINAL REPORT

Module H2

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(values for water were revised in Tables 15, 25, 30, and 35)

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Information contained in this report is based on new survey data (2012) and supersedes information in the original Phase I report (Wilson and Dancer 2004). This report is a cradle to gate LCA and includes all forestry related upstream processes and packaging of final product. CORRIM REPORT - Life Cycle Assessment of Laminated Veneer Lumber (LVL) Production has not been certified but is written in compliance to the Product Category Rules North American Structural and Architectural Wood Products (June 2015) and can serve as a LCA for an Environmental Product Declaration.

1 EXECUTIVE SUMMARY

1.1 Study Goals

The goal of the present study was to develop life-cycle impact assessment (LCIA) data associated with gate-to-gate laminated veneer lumber (LVL) production in the southeast (SE) region of the U.S. with the ultimate aim of constructing an updated cradle-to-gate mill output life-cycle assessment (LCA). The authors collected primary (survey) mill data from LVL production facilities per Consortium on Research for Renewable Industrial Materials (CORRIM) Research Guidelines. Comparative assertions were not a goal of the present study.

1.2 Method

The authors collected primary mill data through a survey questionnaire mailed to LVL plants. This survey tracked raw material inputs (including energy), product and coproduct outputs, and pertinent emissions to water and air as well as solid waste generation. The study incorporated and translated an industry-standard production unit to a metric production unit (one cubic meter was the declared unit). Secondary data, such as premill gate processes (e.g. forestry operations, dry veneer production, electricity production), were from peer-reviewed literature per CORRIM guidelines, public databases, or other life-cycle inventory (LCI) studies completed concurrently. Primary and secondary data were used to calculate material and energy balances. With these material and energy data, the LCA was constructed to conform to internationally accepted standards. The LCI flows and LCIA results were generated using LCA modeling software populated by the U.S. LCI Database. The study based allocations on the mass and economic value of the products and coproducts produced from cradle to gate. The LCIA was performed using the Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI 2) method. Five impact categories were examined, including global warming potential (GWP (kg CO_2-eq)), acidification (kg SO_2-eq), eutrophication (kg N-eq), ozone depletion (kg chlorofluorocarbons (CFC)-11-eq), and photochemical smog (kg NOx-eq).

1.3 Life-Cycle Inventory

Cradle-to-gate LCI flows for LVL manufacturing were presented by three life stages, 1) forestry operations, 2) dry veneer production, and 3) LVL production. The majority of the raw material energy consumption occurred during dry veneer production, followed by LVL production, with a small portion arising from forestry operations. Emission data produced through modeling found that estimated biomass and fossil carbon dioxide (CO_2) emissions were 282 and 310 kg/m^3 for the SE, respectively. Veneer production occurs at veneer mills spread across the U.S., and the wood is dried prior to arrival at LVL plant facilities. The production of LVL was modeled as a single unit process (i.e. black box). The final product, LVL, by mass made up about 90% of products, and the remainder was coproducts.

The amount and type of energy used during production of building materials such as LVL are important to the holistic environmental impact of the product. Total cumulative primary energy consumption (CPEC) for the cradle-to-gate production of SE LVL was 9.98 GJ/m^3. Use of renewable energy in manufacturing LVL was substantial. Renewable biomass represented 36.2% of the total CPEC for all stages of production with veneer production consuming the most energy albeit woody biomass. Energy consumed during phenol-formaldehyde (PF) resin production along with the additives of the resin system was included in the fossil fuel use for LVL as an upstream process. Veneer production required roughly the same amount of nonrenewable fuel as the production of LVL itself. Forestry operations consumed relatively little energy (2.6%), which was exclusively fossil fuels (i.e. diesel fuel). In summary, to produce 1 m^3 of SE LVL from cradle-to-gate, 36.2% of the cumulative energy was from biomass (wood fuel) and 56.2% from fossil fuels, leaving a small portion of energy needs coming from nuclear (as electricity; 7.4%) and the remaining 0.2% from hydro, wind, solar, and geothermal.

1.4 Life-Cycle Impact Assessment

Environmental performance results for GWP, acidification, eutrophication, ozone depletion, and smog (the five impact areas) are provided. Also provided are environmental performance results for energy consumption from nonrenewable fossil and nuclear fuels and renewable sources (wind, hydro, solar, geothermal, and biomass), material resource consumption from renewable and nonrenewable sources, and solid waste. Environmental impacts associated with LVL production for the five impact categories investigated were small compared with the impacts associated with dry veneer production.

1.5 Interpretation

Emissions from forest resources LCI are small relative to manufacturing emissions (dry veneer and LVL). At the LVL production facility, emissions originate at the boiler, during hot pressing, and during sawing. Boiler emissions released are a function of the fuel burned, whereas other emissions are functions of unit processes and associated emission control devices.

Cradle-to-gate LCI results showed that 310 kg fossil CO_2 were released in the production of 1 m^3 of SE LVL. It is primarily made of wood and therefore stores carbon. Carbon content for wood products is assumed to be 50% by mass of oven-dried (OD) wood. Excluding the resin system, the amount of carbon stored in the wood portion of 1 m^3 of LVL on a production weighted average is equivalent to 995 kg CO_2 emissions if left to decay.

A mass balance was performed to verify data quality and showed that quality was high. Inputs and outputs were consistent for the four surveyed mills on a cubic meter basis. In addition, total wood mass in and total wood mass out were calculated. Difference for overall wood mass was less than 2%. A difference less than 10% is considered good for wood product manufacturing.

Energy inputs from the 2012 study were compared with earlier CORRIM reporting on LVL production. As expected from the higher CPEC, the on-site energy inputs from the updated data were substantially higher than from earlier reported PNW LVL production. In particular, electricity and natural gas consumption is driving the energy increase with differences of 41 and 76%, respectively. However, with that being said, no statistical analysis was conducted on the earlier data and different companies provided the primary 2000 only speculation can be made on the apparent differences. In this study, the weighted coefficient of variation representing the variability in the collected process data was calculated and is presented. In addition, a sensitivity analysis was performed investigating the impact to the overall output from the variation of energy inputs into LVL production.

1.6 Sensitivity Analysis

A sensitivity analysis was completed per International Organization for Standardization (ISO) 14040 standards to model the effects of on-site natural gas and electricity consumption for LVL production. For the sensitivity analysis, neither on-site natural gas nor electrical consumption during LVL production showed a substantial contribution to the overall impact as dry veneer production stage had a relatively large effect on the environmental indicators associated with energy consumption.

1.7 Key Findings

In this study, cradle-to-gate CPEC of LVL production for the U.S. was substantially higher compared with earlier CORRIM studies as well as a more recent Canadian study. A corresponding LCA update for Pacific Northwest cradle-to-gate LVL showed a similar conclusion. Yet, the authors can only speculate regarding the apparent differences because of the lack of statistical analysis of the data from other earlier studies. Two scenario analyses indicated that LVL production itself was a minor contributor to the overall process because energy inputs for veneer production were much greater than those for LVL production. As for energy inputs for LVL production itself, one possible explanation is the greater use of emission control devices including baghouses and regenerative catalytic oxidizers because of increased regulatory controls in the U.S. since the 2000s when Phase I survey data were collected.

2 ACKNOWLEDGMENTS

Primary funding for this project was through a cooperative agreement between the USDA Forest Service Forest Products Laboratory and the Consortium for Research on Renewable Industrial Materials (13-CO-11111137-014). We especially thank those companies and their employees that participated in the surveys to obtain production data. In addition, this research was supported in part by an appointment to the USDA Forest Service Research Participation Program administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and the U.S. Department of Agriculture, Forest Service. ORISE is managed by Oak Ridge Associated Universities (ORAU) under DOE contract number DE-AC05-06OR23100. All opinions expressed in this paper are those of the authors and do not necessarily reflect the policies and views of USDA, DOE, or ORAU/ORISE.

TABLE OF CONTENTS

FIGURES

TABLES

3 BACKGROUND

CORRIM, the Consortium for Research on Renewable Industrial Materials, has documented life cycle inventory (LCI) data for major wood products from various wood production regions in the U.S. Existing LCI data covered forest regeneration through to the final product at the mill gate. Specifically, research has covered nine forest products including structural and nonstructural items from four regions. This report focuses on industry-average data for LVL production in the SE region of the U.S. LCI data are then used to estimate LCIA. This study collected primary data and developed new gate-to-gate LVL production data to construct an updated cradle-to-gate manufacturing LCIA for LVL for the SE (Wilson and Dancer 2004). Treatment of biogenic carbon was taken from the Norwegian Solid Wood Product product category rules (PCR) (Aasestad 2008) and the PCR for North American Structural and Architectural Wood Products (FPInnovations 2015) to ensure comparability and consistency. Using the LCIA outcomes, stakeholders such as APA – The Engineered Wood Association and its members can explore potential process improvements and new conversion technologies along with the identification of environmental 'hotspots' internally. Intended audiences include LCA practitioners along with building specifiers looking for green building products with documentation. This LCA is in conformance with the PCR for North American Structural and Architectural Wood Products (FPInnovations 2015) and ISO 14040 and14044 standards (ISO 2006a, 2006b). This report follows data and reporting requirements as outlined in the PCR and contains the LCA components for producing a North American environmental product declaration (EPD) (ISO 2006c).

4 INTRODUCTION

Documenting the environmental performance of building products is becoming widespread because of many green marketing claims made without scientific merit (i.e. green washing). Developing EPDs for building products is one way to accomplish this objective for scientific documentation and to counter green washing (ISO 2006c; Bergman and Taylor 2011). In addition, developing wood product LCI data helps construct product LCAs that are then incorporated into developing whole building LCAs in environmental footprint software such as the Athena Impact Estimator for Buildings (ASMI 2016). Conducting whole building LCAs provides points that go toward green building certification in rating systems such as LEED v4, Green Globes, and the ICC-700 National Green Building Standard (Ritter et al 2011).

4.1 Life-Cycle Assessment

LCA is an internationally accepted method to analyze complex environmental impacts of a product or process. It is intended to be an objective and holistic examination of a product that identifies and quantifies energy and materials used and emissions and wastes released to the environment. It also assesses the impact of this energy and material use and emissions. LCA studies can evaluate full product life cycles, often referred to as "cradle-to-grave", or incorporate only a portion of the products life cycle, referred to as "cradle-to-gate" or "gate-to-gate". This study is a cradle-to-gate LCA and includes forestry operations, dry veneer production, and manufacture of LVL that is ready to be shipped at the mill gate.

As defined by ISO (2006a), LCA is a multiphase process consisting of a 1) goal and scope definition, 2) LCI, 3) LCIA, and 4) interpretation (Figure 1). These steps are interconnected, and their outcomes are based on goals of the study.

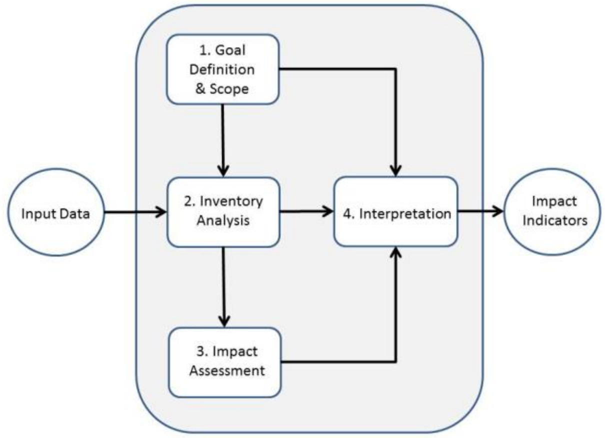

Figure 1. Steps involved in a life-cycle assessment (ISO 2006a).

The key component for conducting an LCA is the LCI step, which is the process of quantifying energy and raw material requirements, air emissions, waterborne effluents, solid waste, and other environmental releases occurring within the system boundaries.

The LCIA process uses models to characterize and assess the effects of environmental releases identified in the LCI in impact categories such as global warming, acidification, carcinogenics, respiratory effects, eutrophication, ozone depletion, ecotoxicity, and smog. For assessing the environmental impacts of LVL production, the Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) 2.0 impact method was used. TRACI is a midpoint-oriented LCIA method developed by the U.S. Environmental Protection Agency specifically for North America using input parameters consistent with U.S. locations (Bare 2011). TRACI is available through the LCA software used for modeling the LVL process (PRé Consultants 2016).

Life-cycle interpretation is the phase in which the findings of the LCI and/or the LCIA are evaluated in relation to the goal of the study to reach conclusions and recommendations. This final step in an LCA involves an investigation of significant environmental aspects (e.g. energy use and greenhouse gases), their contributions to the indicators under consideration, and determination of which unit processes in the system they come from. For example, if the outcome of an LCIA indicates a particularly high value for global warming potential, the analyst could refer to the inventory to determine which environmental flows are contributing to the high value and which unit processes those outputs are coming from.

4.2 Description of the Product

Many engineered structural wood products have been developed in the last several decades, including LVL in the early 1970s (Figure 2). Laminated veneer lumber falls into the North American Industry Classification System (NAICS) Code 321215—engineered wood member (except truss) manufacturing, which includes other structural wood engineered products such as finger joint lumber, I-joists, parallel strand lumber, and glued laminated timbers (USCB 2012; ASTM 2014). Laminated veneer lumber comprises many dry wood veneers glued together with their grain orientation in the same direction (Wilson and Dancer 2004; USEPA 2002; Stark et al 2010). It is designed to be used in the same manner as solid wood products such as sawn lumber. The veneers are made from rotary peeling of veneer logs. Laminated veneer lumber can be used in conjunction with softwood plywood or oriented strandboard (OSB) to make composite I-joists but could also be used as a standalone for headers, beams, and joists (Wilson and Dancer 2005; Puettmann et al 2013). It can be made from any wood species provided the mechanical and physical properties are suitable and it can be properly glued. In the SE region, LVL is primarily made with southern pine species including a mix of longleaf pine (*P. palustris*), shortleaf pine (*P. echinat*a), slash pine (*P. elliotti*), and loblolly pine (*P. taeda* L.) along with some hardwood mostly from yellow poplar (*Liriodendron tulipfera*) and a little from red maple (*Acer rubrum*).

Figure 2. Laminated veneer lumber.

5 METHOD

5.1 Goal

The goal of this study was to update the cradle-to-gate LCIA of LVL manufacturing for the SE U.S. The current study updated the gate-to-gate LVL manufacturing LCI data developed by Wilson and Dancer (2005) and linked it to available forest resource LCI data (Johnson et al 2005; Puettmann et al 2013) and dry veneer production LCI data (Kaestner 2015; Puettmann et al 2015) to construct a cradle-to-gate LVL LCA. The LVL LCA data will be used to help construct the cradle-to-gate LCA for I-joist production (Bergman and Alanya-Rosenbaum 2016).

5.2 Scope

In accordance with international standards (ISO 2006a, 2006b; ILCD 2010), the scope of this LCA study was to cover the life-cycle stages of LVL from forest resource activities through veneer production to the final LVL product leaving the plant. Impacts from dry veneer production were included in the analysis using LCI data developed from updating softwood plywood for the SE (Kaestner 2015; Puettmann et al 2015). The present LCA provided a cradle-to-gate analysis of cumulative energy of manufacturing and transportation of raw materials to the veneer and LVL production facilities. Analyses included CPEC of LVL production and environmental impacts like GWP.

5.2.1 Allocation procedure

Selecting an allocation approach is an important part of an LCA study. In this study, all primary energy and environmental outputs were assigned to various coproducts by mass allocation. The decision was based on the fact that LVL as the final product contained more than 90% of the mass leaving the system and because specific gravity of both LVL and associated coproducts were similar. In this study, economic allocation was performed in addition to mass allocation, because product category rules suggest using economic allocation for a multi output process when the difference in revenues is more than 10% (FPInnovations 2015). The results of analysis using economic allocation are provided in Appendix C.

5.2.2 Functional and declared unit

In accordance with the product category rule (FPInnovations 2015), the declared unit for LVL is one cubic meter (1.0 m^3). A declared unit is used in instances in which the function and the reference scenario for the whole life cycle of a wood building product cannot be stated (FPInnovations 2015). For conversion of units from the U.S. LVL industry measure, 1.0 cubic foot equals 0.02832 m^3 with an oven-dried moisture content of 6%. All input and output data were allocated to the declared unit of product based on the mass of products and coproducts

in accordance with ISO 14044 (ISO 2006b). Because the analysis did not take the declared unit to the stage of being an installed building product, no service life was assigned.

5.2.3 System boundaries

The system boundary begins with regeneration in the forest and ends with LVL at the mill gate (Figure 3). The system boundary included forest resources (A1) (site preparation and planting seedlings, forest management including fertilization and thinning, and final harvest), transportation of roundwood to the primary breakdown facility (A2), dry veneer production (A3), dry veneer transportation to the LVL facility if needed (A2), and LVL production including packaging (A3). The production of LVL was modeled as a single process representing all the steps necessary to make LVL. Three production steps exist in manufacturing LVL: (1) lay-up, (2) hot pressing, and (3) sawing and trimming, with energy generation as an auxiliary process. All emissions (i.e. outputs to the environment) and energy consumed were assigned to the LVL and the coproducts (i.e. sawdust) either by mass or economic value depending on the mass and economic allocations, respectively. A single unit (i.e. black box) approach was used to model the LVL process because little wood left the system except as the final product and because of the relative simplicity of the LVL manufacturing process. This simply means all process inputs and outputs are grouped into one LVL process.

Fuel resources used for the cradle-to-gate production of energy and electricity were included within the cumulative system boundary. Off-site emissions include those from grid electricity production, transportation of feedstock and the resin system to the plant, and fuels produced off site but consumed on site. Ancillary material consumption data such as motor oil, paint, and hydraulic fluid were included in the analysis.

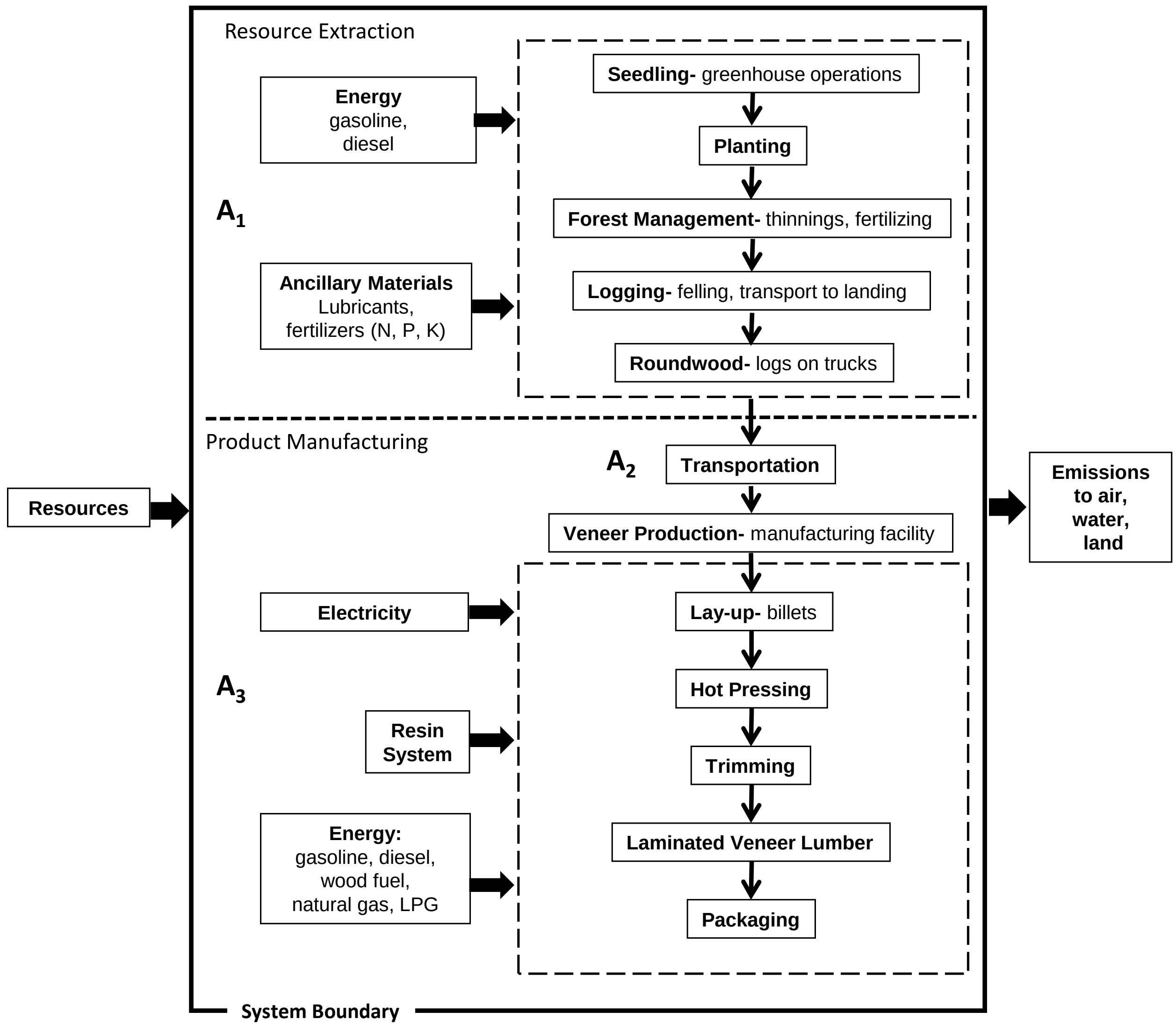

Figure 3. Cradle-to-gate system boundary and process flow for production of SE laminated veneer lumber.

5.2.4 Cut-off rules

According to the PCR, if the mass/energy of a flow is less than 1% of the cumulative mass/energy of the model flow, it may be excluded, provided its environmental relevance is minor. This analysis included all energy and mass flows for primary data.

In the primary surveys, manufacturers were asked to report total hazardous air pollutants (HAP) specific to their wood products manufacturing process, regardless of whether they were less than the 1% cutoff. These included formaldehyde, methanol, acrolein, acetaldehyde, phenol, and propionaldehyde (propanal). If applicable to the wood product, HAPs are reported later in the LCI data section.

In the primary surveys, manufacturers were asked to report total HAPs specific to their wood products manufacturing process. Under Title III of the Clean Air Act Amendments of 1990, the EPA designated HAPs that wood products facilities are required to report as surrogates for all HAPs. These are methanol, acetaldehyde, formaldehyde, propionaldehyde (propanal), acrolein, and phenol. All HAPs are included in the LCI, and no cut-off rules apply. If applicable to the wood product, HAPs are reported in Table 12 and are included in the impact assessment. Table 12 shows all air emission to the 10^{-4} to simplify and report on the dominant releases by mass. There were no cut-offs used in the impact assessment. Therefore, a complete list of all air emissions (smaller than 10^{-4}) is located in Appendix B of this report.

5.2.5 Data quality requirements

This study collected data from representative LVL manufacturers in the SE that use average technology for their regions. The dry veneer produced at the product manufacturing facilities in the SE region of the U.S. is the raw wood input to LVL production.

Total U.S. LVL production for 2012 was 1.31 million m^3. Four U.S. LVL plants representing 26.4% of 2012 U.S. production (0.344 million m^3) participated in the study by providing primary data for the SE regions (APA 2014). The SE is one of the primary regions for producing structural wood products such as LVL (Smith et al 2004). The surveyed plants provided detailed annual production data about their facilities, including on-site energy consumption, electrical usage, veneer volumes, and LVL production for 2012. Wilson and Dancer (2005) performed a 2000 U.S. LVL LCI study that covered 52% (0.221 million m^3) of production in the SE. The production of surveyed facilities for 2012 was an increase of 56% from 2000. However, unlike the earlier 2000 study, 2012 LVL production data were not available by region. Therefore, LVL production by region cannot be quantified for 2012.

5.2.6 Critical review

An internal critical review of the survey procedures, data, analysis, and report was completed by Dr. Maureen Puettmann, WoodLife Environmental Consultants, Corvallis, Oregon, to assess conformance with CORRIM and ISO 14040 standards.

The review provided assurances that the study methodology, data collection, and analyses were scientifically sound, and in conformance with internationally accepted standards and CORRIM research protocol (ISO 2006b; ILCD 2010; CORRIM 2014; FPInnovations 2015).

5.2.7 Assumptions and limitations

All flow analyses of wood and bark in the process were determined on an oven-dry weight basis with a weighted-production density of 563 kg/m^3.

Water consumption for two SE LVL plants was combined with dry veneer production for a total of 287 L/m^3 with almost all water consumed during veneer production. The veneer production stage consumed water at a rate of 285 L/m^3 LVL while the rest, 2 L/m^3, was consumed at LVL production stage (Kaestner et al 2015).

Although small in quantity relative to the wood mass, impacts from production of the resin system were included in the analysis.

5.2.8 Data collection

Primary data for the LCI were collected through surveys in accordance with CORRIM and ISO 14040 standards (Appendix F). This study relied almost exclusively on production and emissions data provided by LVL producers in the U.S., with secondary data on electrical grid inputs, fuels, and forest resource activities obtained from the U.S. LCI database (Goemans 2010; NREL 2012). The survey data represent LVL production in terms of input materials, electricity and fuel use, and emissions for the 2012 production year. Four production facilities surveyed were selected to be representative of U.S.

production practices. The primary data obtained from the surveys were weight-averaged using the following formula (Milota 2004).

5.2.9 Calculation rules

For U.S. production, LVL is commonly reported in cubic feet. The survey results were converted to a unit production basis (1 m^3) and a weighted average of input data was calculated based on production. One cubic foot of LVL equals 0.02832 m^3 with an oven-dried moisture content of 6-10%. This approach resulted in a LVL complex that represents a composite of the North American mills surveyed but may not represent any mill in particular. The U.S. LCI database was used to assess off-site impacts associated with the materials and energy used. SimaPro version 8+ (Pré Consultants 2016) was used as the accounting program to track all of the materials.

$$\bar{P}_{weighted} = \frac{\sum_{i=1}^{n} P_i x_i}{\sum_{i=1}^{n} x_i}$$

Where $\bar{P}_{weighted}$ is the weighted average of the values and is reported by 'n' mills, P_i is the reported mill value, and x_i is the fraction of the mill's value to total production of the surveyed mills for that specific value. Because the surveyed mill data varied between facilities, a statistical analysis was conducted. In this study, the weighted coefficient of variation was calculated (NIST ITL 1996). The weighted coefficient of variation (CoV_w) is the weighted standard deviation (sd_w) divided by the weighted mean ($\bar{P}_{weighted}$):

$$sd_w = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x}_w)^2}{\frac{(N' - 1)\sum_{i=1}^{N} w_i}{N'}}}$$

$$CoV_W = \frac{sd_w}{\bar{P}_{weighted}}$$

Where w_i is the weight of the i^{th} observation, 'N' is the number of nonzero weights, and $\bar{x}_w$ is the weighted mean of the observations.

Missing data were defined as data not reported in surveys of the LVL facilities. Missing data for survey items were checked with plant personnel to determine whether it was an unknown value or zero. Missing data were carefully noted so they were not averaged as zeros. Any outliers were resolved by contacting mill personnel.

5.2.10 Life-cycle impact assessment method

The LCIA was performed using the TRACI 2 method (Bare 2011). Five impact categories were examined, including GWP (kg CO_2-eq), acidification (kg SO_2-eq), eutrophication (kg N-eq), ozone depletion (kg CFC-11-eq), and photochemical smog (kg NOx-eq).

The LCIA phase establishes links between the LCI results and potential environmental impacts. The LCIA calculates impact indicators, such as GWP and smog. These impact indicators provide general, but quantifiable, indications of potential environmental impacts. The target impact indicator, the impact category, and means of characterizing the impacts are summarized in Table 1. Environmental impacts were determined using the TRACI method (Bare 2011). These five impact categories are reported, which is consistent with the requirements of the wood products PCR (FPInnovations 2015).

Table 1. Selected impact indicators, characterization models, and impact categories.

Impact indicator	Characterization model	Impact category
Greenhouse gas (GHG) emissions	Calculate total emissions in the reference unit of CO_2 equivalents for CO_2, methane, and nitrous oxide.	Global warming
Releases to air decreasing or thinning of ozone layer	Calculate the total ozone forming chemicals in the stratosphere including CFCs hydroCFCs (HCFC), chlorine, and bromine. Ozone depletion values are measured in the reference units of CFC equivalents.	Ozone depletion
Releases to air potentially resulting in acid rain (acidification)	Calculate total hydrogen ion (SO_2) equivalent for released sulfur oxides, nitrogen oxides, hydrochloric acid, and ammonia. Acidification value of SO_2 mole-eq. is used as a reference unit.	Acidification
Releases to air potentially resulting in smog	Calculate total substances that can be photochemically oxidized. Smog forming potential of O_3 is used as a reference unit.	Photochemical smog
Releases to air potentially resulting in eutrophication of water bodies	Calculate total substances that contain available nitrogen or phosphorus. Eutrophication potential of N-eq. is used as a reference unit.	Eutrophication

Each impact indicator is a measure of an aspect of a potential impact. This LCIA does not make value judgments about the impact indicators, meaning that no single indicator is given more or less value than any of the others. Additionally, each impact indicator value is stated in units that are not comparable with others. For the same reasons, indicators should not be combined or added.

6 DETAILED DESCRIPTION OF DATA AND PROCESSES

6.1 Forestry Operations

Logs used in the production of LVL in the SE include in their life cycle the upstream activities associated with establishment, growth, and harvest of trees. This group of activities is collectively referred to as forest resource management. Forest operations modeled as inputs to dry veneer and LVL production were based on forest resource LCI data inputs from the SE softwood forests (Johnson et al 2005; Puettmann et al 2013). Forestry operations vary regionally (Johnson et al 2005) but typically include some combination of growing seedlings, regeneration, site preparation, planting (where applicable), thinning, fertilization (where applicable), and final harvest. Harvesting included felling, skidding, processing, and loading for both commercial thinning and final harvest operations. For SE forests, reforestation occurs primarily by planting that requires inputs from human-related activities (i.e., the technosphere) for seedlings, site preparation, planting, and precommercial thinning (Table 2). Weighted-average allocation to different processes takes into account inherent differences in site productivity and energy usage by different kinds of logging equipment. Inputs to the forest resources management LCI include seed, electricity used during greenhouse operations, fertilizer used during seedling production and stand growth, fuel and lubricants needed to power and maintain equipment for thinning, and harvest operations. The primary output product is a log destined for softwood veneer. The coproduct nonmerchantable (logging) slash is generally left at a landing. Slash disposal was not modeled because it was assumed to decay in-situ.

Table 2. Inputs to the regeneration phase and midrotation fertilization per hectare (ha) of SE U.S. forest (Puettmann et al 2013).

Inputs	**Unit**	**Low intensity**	**Medium intensity**	**High intensity**	**Weighted average**
		Reforesting 1 ha			
Diesel and gasoline	L	38.55	132.27	272.21	104.59
Seedlings at greenhouse	p[a]	1,794	1,794	1,794	1,794
Nitrogen in fertilizer					
In seedlings	kg	0.14	0.14	0.14	0.14
On site	kg	-	264.52	712.86	189.06
Phosphorous in fertilizer					
In seedlings	kg	0.01	0.01	0.01	0.01
On site	kg	-	72.86	128.90	48.70
Potassium in fertilizer					
In seedlings	kg	0.08	0.08	0.08	0.08
On site	kg	-	-	-	-

[a]p = individual seedling.

In the SE region, most harvested lands are reforested for the next crop cycle, with the sequence of treatments from planting to harvest averaging 27 years (Johnson et al 2005; Puettmann et al 2013). Forestry operations and their associated impacts are not stationary and will change based on both past and prospective technologies, evolving forest management procedures, and market demands. Given that the nature of productivity gains is not confirmed or well developed, this assessment was based on data representing the current state of the art in forest operations. It does not discount future operations or estimate potential productivity gains from future technologies. Outputs representing quantities of product, measures of consumed resources, and emissions associated with those consumed resources were developed as a weighted average across the hectares managed for timber production. These quantities of product are used as inputs to the LVL manufacturing LCI, and the consumed resources and emissions are tracked for inclusion in the cradle-to-gate LCI.

6.2 Product Manufacturing

6.2.1 Resource transport

Wood raw materials were delivered to the LVL plants by truck and rail; the wood raw material consists primarily of dry veneer purchased off site or produced on site. However, transportation for dry veneer was only required for LVL plants purchasing dry veneer, not for LVL plants producing their own dry veneer. The final dry veneer transportation data modeled was production-weighted between purchased and produced dry veneer.

6.2.2 Veneer manufacturing

Before producing LVL, production of dry softwood veneer plies occurs. Veneers can be made during softwood plywood production or as a precursor to LVL at the same production facility. This study used veneer data provided by Puettmann et al (2015) from softwood plywood production. Dry veneer ranges in moisture content from 3-6% (oven-dry basis). The dry veneer made into LVL comes from logs of many softwood species representing a mix of longleaf pine (*Pinus palustris*), shortleaf pine (*P. echina*ta), slash pine (*P. elliotti*), and loblolly pine (*P. taeda* L.) in the SE along with some hardwood mostly from yellow poplar (*Liriodendron tulipfera*) and a little from red maple (*Acer rubrum*).

6.2.3 Phenol-formaldehyde resin

The LCI for the production of PF resin covers its cycle from in-ground resources through the production and delivery of input chemicals and fuels, through to the manufacturing of a resin as shipped to the customer (Wilson 2009). The PF resin survey data were from 13 plants in the U.S. that represented 62% of total production for the year 2005 (Wilson 2009). The inputs to produce 1.0 kg of neat PF resin consist of the two primary chemicals: 0.244 kg of phenol and 0.209 kg of methanol, a lesser amount of sodium hydroxide (0.061 kg), and 0.349 kg of water. Electricity is used for running fans and pumps and for operating emissions control equipment. Natural gas is used for boiler fuel and emission control equipment, and propane fuel is used in forklifts.

6.2.4 Energy generation

Energy for the manufacturing of LVL comes from electricity, natural gas, diesel, and liquid petroleum gas (LPG). Electricity is used to operate the lay-up and hot-pressing equipment, as well as pneumatic and mechanical conveying equipment, fans, and other equipment in the plant. Natural gas is used for generating heat for the presses. The diesel is used for equipment, which transports materials outside of the plant, and the LPG is used in forklift trucks, which are operated inside the plant. Other types of fuels including wood fuels are used to generate energy in the plywood plants to produce dry veneer. These energy sources are not analyzed in this report, but the burdens that are created are carried over into the LVL final product. For information on energy consumption for producing dry veneer, see Kaestner (2015).

6.2.5 LVL manufacturing

6.2.5.1 Lay-up

The lay-up lines are used to arrange pieces of the proper grades of dry veneer into the assembly process, apply resin to the veneer, and assemble the veneers into a mat before pressing (Baldwin 1995; Wilson and Dancer 2005). At the start of the line, a veneer feeder assembly places pieces of veneer into the lay-up sequence according to the type of LVL being produced. The product can vary in thickness and width but is most commonly produced in the dimensions of 4.45 cm (1 3/4 in) thick and 121.9 cm (4 ft) wide, into lengths from 2.44 to 18.29 m (8 to 60 ft). After pieces of veneer are arranged onto the lay-up conveyor, resin is applied to each piece of veneer, except for the top veneer layer in the LVL billet. After resin has been applied, the LVL mat is assembled layer by layer. Inputs include dry veneer and resins and outputs include LVL billet, lay-up scrap, and small amounts of volatile organic compounds (VOC) and HAPs. Although small amounts of fugitive VOCs and HAPs are emitted, they are accounted for within the hot-pressing unit process.

6.2.5.2 Hot pressing

From the lay-up line, the uncured LVL billet is sent for hot pressing. The heat and pressure applied during hydraulically pressing cures the resin thus binding the veneer layers together. Inputs include uncured LVL billets. Outputs include cured LVL billets along with emissions of particulate matter (PM), $PM_{2.5}$, VOCs, and HAPs released from heating of the wood and curing of the resins. Cold pressing can also occur at some production facilities when wider LVL billet beams are produced.

6.2.5.3 Trimming–sawing

After pressing, the LVL billet is sawn to the desired dimensions. The LVL can now be manufactured into flanges for I-joists. The wood residue generated during trimming–sawing is collected pneumatically into a wood waste collection system (i.e. baghouses). Once sawn, a protective and cosmetic sealant is sometimes applied to the LVL. Inputs include LVL billets and sealant, and outputs include finished LVL, (used) tested LVL, and wood residues along with emissions of PM, $PM_{2.5}$, and PM_{10} from collecting wood residues and VOCs and HAPs from application and curing of sealant.

6.2.5.4 Packaging

Finished LVL is packaged for transport using wooden runners and other material. Inputs include final product (LVL) and packaging material such as plastic wrapping, and outputs include packaged LVL. Packing materials represent about 1.0% of the cumulative mass of the model flow. The wooden spacers make up the bulk of this mass, representing 86.3% of the total packaging material (Table 3). The wrapping material, cardboard strap protectors, and plastic strapping make up 8.5, 3.7, and 1.5% of the packaging by mass, respectively.

Table 3. Materials used in packaging and shipping per cubic meter LVL (Puettmann et al 2013).

Material	Value	Percentage
Wrapping material – HDPE[a]- and LDPE[b]-laminated paper, kg	0.4601	8.5
PET[c] strapping, kg	0.0834	1.5
Cardboard strap protectors, kg	0.2002	3.7
Wooden spacers, kg	4.6721	86.3
Total, kg	5.4158	100

[a]High-density polyethylene (HDPE)
[b]Low-density polyethylene (LDPE)
[c]Polyethylene terephthalate (PET)

6.3 Air Emissions

The main on-site emission sources were from burning natural gas for thermal energy and from hot presses. Natural gas boilers do not typically use emission control devices. Emission control devices (ECD) such as baghouses are the primary collectors of PM. To decrease VOC emissions from dryers, mills use regenerative catalytic oxidizers (RCO), which are sometimes referred to as regenerative thermal oxidizers (RTO) and wet scrubbers. RCOs are designed to destroy VOCs and other emissions including PM and soot (USEPA 2003a).

7 INPUTS AND OUTPUTS

7.1 Material Transportation

The average haul distance for feedstock along with the components of the resin system is shown in Table 4. Based on CORRIM Phase I (Puettmann et al 2013), dry veneer distance for the SE region increased substantially to 392 km by truck compared with 84 km from the earlier data (roughly a 370% increase). However, transportation for dry veneer is only required for LVL plants purchasing dry veneer, not for LVL plants producing dry veneer. Two of the four SE LVL plants produce their veneer with one of these LVL plants both producing and purchasing dry veneer. The final dry veneer transportation data model was production-weighted between purchased and dry veneer.

Table 4. Weighted-average delivery distance (one way) by mode for materials to LVL plant.

Material delivered to mill and mode	Delivery distance (km)
Purchased dry veneer, by truck	392
Purchased dry veneer, by rail	216
Phenol-formaldehyde resin, by truck	271
Wood fuel, by truck	0.1
Log with bark to veneer production, by truck	100

7.2 Wood Boiler

Table 5 lists the wood boiler process inputs and outputs for product manufacturing in the SE. The wood boiler profile is a composite process developed in 2014 from data collected from U.S. softwood lumber and plywood industries (Puettmann and Milota 2015). No wood boiler fuel was consumed on site at the LVL plants. The wood boiler was only included to provide data for potential scenario analysis and to show what upstream emissions occurred when wood fuel was burned.

Table 5. CORRIM wood boiler process for manufacturing wood products.[a]

Products	**Unit**	**Value**	**Percentage**
Wood combusted, at boiler, at mill, RNA[b]	kg	1.0000	98.13
Wood ash, at boiler, at mill, RNA	kg	0.0191	1.87
Resources			
Water, process, surface	kg	0.31	
Water, process, well	kg	0.24	
Water, municipal, process, surface	kg	0.79	
Water, municipal, process, well	kg	0.24	
Materials–fuels			
Wood fuel	kg	1.0000	
Transport, combination truck, diesel powered/U.S., Athena	tkm	1.38E-03	
Diesel, combusted in industrial equipment/U.S.	l	8.05E-04	
Gasoline, combusted in equipment/U.S.	l	3.96E-05	
Liquefied petroleum gas, combusted in industrial boiler/U.S.	l	1.21E-05	
Lubricants	l	1.91E-05	
Engine oil	l	2.22E-05	
Hydraulic oil	l	0.00E+00	
Antifreeze	l	4.81E-07	
Ethylene glycol, at plant/RNA	kg	1.07E-06	
Solvents	kg	7.17E-07	
Water treatment	kg	1.23E-04	
Boiler streamline treatment	kg	3.67E-06	
Urea, as N, at regional storehouse/RER[c] U AWC[d]	kg	3.15E-03	
Disposal, ash, to unspecified landfill/RNA	kg	7.59E-03	
Disposal, solid waste, unspecified, to unspecified landfill/RNA	kg	7.26E-06	
Disposal, metal, to recycling/RNA	kg	3.96E-08	
Electricity–heat			
Electrical grid, SERC[e]	kWh	8.20E-02	
Natural gas, combusted in industrial boiler/U.S.	m^3	1.38E-03	
Emissions to air			
Acetaldehyde	kg	1.05E-06	
Acrolein	kg	8.07E-07	
Benzene	kg	1.69E-07	
Carbon monoxide, biogenic	kg	3.23E-03	
Carbon dioxide, biogenic	kg	1.76E+00	
Wood (dust)	kg	5.62E-04	
Formaldehyde	kg	1.26E-05	
Emissions to air	**Unit**	**Value**	
HAPs, unspecified	kg	6.27E-06	
Hydrogen chloride	kg	1.17E-06	
Lead	kg	1.75E-07	
Mercury	kg	1.83E-09	
Methane, biogenic	kg	2.23E-05	

Methanol	kg	7.95E-06	
Nitrogen oxides	kg	1.10E-03	
Particulates, <10 um	kg	4.71E-04	
Particulates, <2.5 um	kg	1.39E-04	
Phenol	kg	6.21E-07	
Propanal	kg	5.14E-08	
Sulfur dioxide	kg	7.71E-05	
VOCs	kg	8.76E-04	
Dinitrogen monoxide	kg	2.93E-06	
Naphthalene	kg	5.77E-08	
Other organic	kg	2.11E-07	
Emissions to water			
Suspended solids, unspecified	kg	8.35E-07	
Biological oxygen demand (BOD_5)	kg	2.10E-06	

[a]Boiler data from Puettmann and Milota (2015)
[b]RNA = North America
[c]RER = Europe, U = Unit
[d]AWC = American Wood Council
[e]SERC stands for Southeastern Electric Reliability Council

7.3 Energy Sources

Energy consumed on site was derived from on-site and off-site sources. On-site sources included process (thermal) energy provided by burning natural gas. Thermal energy was commonly produced in the form of steam and then used in the hot-pressing unit process. Outputs from generating thermal energy included steam from the boilers and combustion gases like fossil CO_2. The main off-site source was (grid) electricity, which released its emissions off site. Table 6 shows the electrical grid composition for LVL production in the SE region of the U.S. Coal (56.4%) and nuclear (25.2%) make up most of the SE (SERC) grid. Outputs included electricity and emissions primarily of fossil CO_2.

Table 6. Percentage of energy source for SERC electricity for producing SE LVL (NREL 2012).[a]

Energy source	Percentage of electricity produced
Natural gas	13.4
Coal	56.4
Oil	0.7
Nuclear	25.2
Hydro	2.0
Wind	0.0
Biomass	1.5
Geothermal	0.0
Miscellaneous	0.8
Total	100.0

[a]Representative of year 2008 mix of fuels used for utility electricity generation in the Southeastern U.S. SERC is comprised of Alabama, Georgia, Mississippi, North Carolina, South Carolina, and parts of Arkansas, Florida, Illinois, Iowa, Kentucky, Louisiana, Missouri, Tennessee, Texas, and Virginia.

7.4 Gate-to-Gate LVL Production

Table 7 shows the detailed description of the material and energy inputs and outputs crossing the system boundary of LVL. Under materials, wood feedstocks include purchased and produced dry veneer. Electricity consumed on site for SE was calculated to be 98.2 kWh/m^3. Natural gas was the primary fossil fuel used on site. Air emissions were derived from the surveyed mills along with pertinent emissions data categorized by the U.S. Environmental Protection Agency (USEPA 2002, 2003a, 2003b, 2003c). When available, surveyed air emission data as primary data were selected rather than secondary data. Boiler emissions are tracked separately and are not included in Table 7.

Table 7. Unit process inputs and outputs to produce one cubic meter of SE LVL.

Products	**Unit**	**Value**	**Allocation[a]**
LVL	m^3	1	88.7%
Sawdust, sold	kg	4.40E+01	6.9%
Sawdust, wood fuel	kg	6.31E+00	1.0%
Panel trim, sold	kg	5.56E+00	0.9%
Other, not specified	kg	1.60E+00	2.5%
Resources	**Unit**	**Value**	
Water, well, in ground	L	2.43E+00	
Materials–fuels	**Unit**	**Value**	
Wood feedstock, produced dry veneer, oven-dried	kg	2.54E+02	
Wood feedstock, purchased dry veneer, oven-dried	kg	3.58E+02	
PF resin	kg	2.27E+01	
Materials/fuels	**Unit**	**Value**	
Electricity, at grid	kWh	9.82E+01	
Diesel, combusted in industrial equipment	L	7.40E-01	
Gasoline, combusted in equipment	L	5.87E-02	
Propane, combusted in industrial equipment	L	7.85E-01	
Natural gas, combusted in industrial boiler, direct-fired	m3	1.93E+01	
Transport, combination truck, diesel power, wood feedstock	tkm	1.41E+02	6% water
Transport, rail, diesel power, wood feedstock	tkm	4.10E+00	6% water
Transport, combination truck, diesel powered, PF resin	tkm	9.85E+00	60% water
Transport, combination truck, diesel powered, landfill waste	tkm	5.40E+00	As is
Hydraulic fluid	kg	1.38E-02	
Greases	kg	1.72E-03	
Motor oil	kg	3.40E-02	
Waxes (sealant)	kg	6.20E-01	
Paint	kg	1.79E-01	
Wrapping material - packaging	kg	4.60E-01	
Strap protectors - packaging	L	8.34E-02	
Strapping - packaging	L	2.00E-01	
Spacers - packaging	kg	4.67E+00	
Emissions to air	**Unit**	**Value**	**Data**
Acetaldehyde	kg	2.85E-03	Primary
Carbon monoxide	kg	4.60E-02	Primary
Formaldehyde	kg	2.87E-03	Primary
Methanol	kg	6.20E-02	Primary
Nitrogen oxides	kg	1.20E-03	
PM2.5	kg	8.90E-02	
PM10	kg	8.90E-02	

Particulates, unspecified	kg	8.60E-02	
Phenol	kg	4.42E-05	Primary
Propionaldehyde	kg	3.84E-03	Primary
Sulfur dioxide	kg	3.36E-04	Primary
VOC	kg	3.34E-01	Primary
Waste to treatment	**Unit**	**Value**	
Waste to inert landfill	kg	4.66E+00	Primary
Waste to recycling	kg	3.08E+00	Primary

[a]Mass allocation approach.

7.5 Material Flows

To evaluate data quality, a weighted-average mass balance of the LVL plants was performed (Table 8). In performing the mass balance for LVL, all unit processes located within the site system boundary were considered. Veneer usage was 612 OD kg for SE mills, and 23 OD kg of binding agents from the resin system produced 1.0 m^3 (563 OD kg on average) of LVL along with some coproducts (~72 OD kg on average). PF resin made up most of the resin system. Based on the low and similar values calculated for production-weighted coefficient of variation (CoVw) for the final product, LVL shows a good consistency between facilities provided by LVL industry at 4.0% for the SE. In addition, the CoVw for total feedstock is 6.5% for the SE.

Table 8. Mass balance of SE LVL manufacturing per cubic meter.

	Southeast		
	Inputs		
	(OD kg)	**Mass (%)**	**CoVw[a] (%)**
Feedstocks			
Produced veneer	254	32.1	155
Purchased veneer	358	64.4	73.0
Total, feedstock	612	96.4	6.5
Resin system			
PF resin	22.7	3.6	30.2
Total, resin system	22.7	3.6	30.2
Total, in	635	100.0	
	Outputs		
	(OD kg)	**Mass (%)**	**CoVw[a] (%)**
Products			
LVL	563	88.7	4.0
Coproducts			
Sawdust, sold	44.0	6.9	46
Sawdust, wood fuel	6.31	1.0	221
Panel trim, sold	5.56	0.9	101
Other, not specified	16.0	2.5	-
Total, coproducts	71.9	11.3	46
Total, outputs	635	100	

[a]CoV_w, production-weighted coefficient of variation.

7.6 On-Site Energy Inputs

Weighted-average energy inputs consumed at the LVL manufacturing site were developed from survey data (Table 9). For the SE, electricity and natural gas were the primary energy inputs at 98.2 kWh and 19.3 m^3 per m^3 of LVL. The production-weighted coefficient of variation showed large variation for electricity and natural gas consumption for the SE at 67 and 53%, respectively.

Table 9. Weighted-average on-site energy inputs for SE LVL manufacturing.

Energy inputs	Quantity	Unit	CoVw[a] (%)
Electricity	98.2	kWh	67
Natural gas	19.3	m^3	53
Diesel	0.74	L	69
Propane	0.78	L	10
Gasoline	0.06	L	244

[a]CoV_w, production-weighted coefficient of variation.

8 LIFE-CYCLE INVENTORY DATA

Cradle-to-gate LCI results for LVL are presented by three life stages, (1) forestry operations (Johnson et al 2005; Puettmann et al 2013), (2) veneer production (Kaestner 2015; Puettmann et al 2015), and (3) LVL production (survey data). The majority of the raw material energy consumption occurs during veneer production, followed by the production of LVL with only a very small portion arising from forestry operations (Table 10). Wood fuel was burned primarily on site at veneer production facilities to generate thermal energy for log conditioning and drying and pressing veneers (Wilson and Dancer 2005; Bergman and Bowe 2011; Kaestner 2015). Natural gas for veneer and LVL at 38 and 34.6 m^3/m^3 was used primarily to generate thermal energy. Natural gas was consumed primarily for thermal energy generation for hot pressing the LVL billets to set and cure the resin.

Table 10. Raw material energy consumption per one cubic meter of cradle-to-gate LVL, SE (mass allocation).

Fuel	Unit	Total	Forestry operations	Dry veneer production	LVL production
Wood fuel	OD kg	1.73E+02	0.00E+00	1.71E+02	1.51E+00
Gas, natural, in ground	kg	5.21E+01	1.00E+00	2.67E+01	2.44E+01
Coal, in ground	kg	6.93E+01	2.77E-01	4.04E+01	2.86E+01
Uranium oxide, in ore	kg	1.95E-03	6.34E-06	1.14E-03	8.04E-04
Oil, crude, in ground	kg	2.10E+01	4.19E+00	6.41E+00	1.04E+01

Table 11 shows the CPEC for the cradle-to-gate production of SE LVL. The veneer life-cycle stage consumed the most primary energy at 6.83 GJ/m^3 (68.5%). Most of the primary energy was derived from wood fuel at 3.61 GJ/m^3 and natural gas at 2.83 GJ/m^3 with CPEC for all three life-cycle stages at 9.98 GJ/m^3. Coal consumption was third at 1.81 GJ/m^3 (18.2%) and came from generating electricity. Other renewable energy sources of hydro and wind along with wood fuel comprise 36.2% of CPEC. This study allocates primary energy to LVL and coproducts on mass. Primary energy is energy embodied in the original resources such as crude oil and coal before conversion.

Table 11. Cumulative primary energy consumption per one cubic meter of cradle-to-gate LVL, SE (mass allocation).

Fuel	Percentage	Total	Forestry operations	Veneer production	LVL production
		MJ/m^3			
Wood fuel	36.2	3.61E+03	0.00E+00	3.58E+03	3.15E+01
Gas, natural, in ground	28.4	2.83E+03	5.45E+01	1.45E+03	1.32E+03
Coal, in ground	18.2	1.81E+03	7.25E+00	1.06E+03	7.49E+02
Oil, crude, in ground	9.6	9.56E+02	1.91E+02	2.92E+02	4.74E+02
Uranium oxide, in ore	7.4	7.43E+02	2.41E+00	4.34E+02	3.06E+02
Hydro	0.2	1.68E+01	4.23E-03	9.09E+00	7.68E+00
Wind	0.0	1.89E-01	0.00E+00	1.10E-01	7.98E-02
Solar	0.0	1.32E-03	0.00E+00	7.63E-04	5.55E-04
Geothermal	0.0	1.12E-06	0.00E+00	1.10E-06	2.40E-08
Total	100	9.98E+03	2.55E+02	6.83E+03	2.89E+03
Total (%)		100	2.6	68.5	29.0

Wood products typically consume more energy during the manufacturing stage than any other stage (Puettmann and Wilson 2005; Winistorfer et al 2005; Puettmann et al 2010). One issue found conducting the cradle-to-gate LCA of LVL was the cumulative cradle-to-gate CPEC found for SE LVL. It was substantially higher than the CPEC of LVL production for the U.S. from earlier CORRIM studies (Puettmann and Wilson 2005; Wilson and Dancer 2005) as well as the more recent Canadian LVL LCA (ASMI 2013). To compare with an earlier CORRIM study on making 1 m^3 of LVL in the SE, cumulative allocated energy consumptions was 7.36 GJ/m^3 with a biomass energy of 47.5%, whereas CPEC for all three life-cycle stages was 9.98 GJ/m^3 according to this study (Puettmann and Wilson 2005; Wilson and Dancer 2005; Puettmann et al 2013). As in this study, Wilson and Dancer (2005) used mass allocation. A similar study in Canada reported cumulative energy consumption for LVL of 4.11 GJ/m^3 with biomass energy of 15.8% (ASMI 2013). For the Canadian LVL LCA, veneer production was embedded into the LVL production as a whole. Therefore, there was no discernable way to determine which process, veneer or LVL production, consumed the woody biomass. Additionally, GWP of 147 kg CO_2-eq/m^3 was estimated (ASMI 2013). Electricity consumed for the Canadian production of LVL was dominated by hydropower. Biomass energy percentage for this study at 36.2% is more consistent with CORRIM Phase I than is the later Canadian LCA study.

Two scenario analyses conducted indicated that LVL production itself was a minor contributor to the overall process because veneer production largely outweighs LVL production in terms of energy inputs. As for energy inputs for LVL production itself, one possible explanation is the greater use of ECDs outside of baghouses because of increased regulatory controls in the U.S. since the 2000s when Phase I survey data were collected. Kaestner (2015) explored the changes in emission regulations for boilers and heaters (USEPA 2014) and showed tightened emission regulations paralleled greater consumption of energy sources such as electricity and natural gas. In addition, tightened emission regulation affected upstream processes such as veneer drying, which had ECDs such as RCOs attached to decrease drying emissions.

Air emission data were collected from surveyed mill data that was augmented by secondary resources (Baldwin 1995; USEPA 2002). As mentioned previously, baghouses are the primary collectors of particulate matter with all four surveyed plants using this ECD. Manufacturers reported on-site air emissions (Table 7) including particulate $PM_{2.5}$ (less than 10 µm in size) and particulate PM_{10} (less than 10 µm in size), which were emitted during pressing, sawing, and trimming. Other air emissions include VOCs from pressing. Table 12 lists the emissions greater than 10^{-4} and HAPs generated from LVL production along with the ones reported by the mills themselves. Fossil and biogenic CO_2 released in the production of 1 m^3 of LVL were 310 and 282 kg, respectively. A complete list of all air emissions for the cradle-to-gate production of LVL can be found in Appendix B.

Table 12. Air emissions released per one cubic meter of LVL, cradle-to-gate, SE (mass allocation).[a]

Air emissions	Total	Forestry operations	Veneer production	LVL production
	kg/m³			
Acetaldehyde	1.47E-02	5.57E-05	1.21E-02	2.58E-03
Acrolein	1.48E-03	6.75E-06	1.46E-03	1.52E-05
Aldehydes, unspecified	8.92E-04	1.70E-04	2.85E-04	4.36E-04
Ammonia	3.31E-03	5.47E-04	2.50E-03	2.70E-04
Ammonium chloride	1.04E-04	3.36E-07	6.05E-05	4.27E-05
Benzene	9.73E-03	6.83E-05	6.18E-04	9.04E-03
Biphenyl	5.09E-08	2.06E-10	2.97E-08	2.10E-08
BTEX[b]	1.82E-02	3.50E-04	9.35E-03	8.51E-03
Carbon dioxide	1.18E+00	6.04E-01	6.69E-02	5.06E-01
Carbon dioxide, biogenic	2.82E+02	1.17E-02	2.80E+02	2.46E+00
Carbon dioxide, fossil	3.09E+02	1.36E+01	1.69E+02	1.26E+02
Carbon monoxide	4.70E-02	4.25E-05	3.76E-03	4.32E-02
Carbon monoxide, biogenic	6.98E-01	0.00E+00	6.95E-01	3.16E-03
Carbon monoxide, fossil	5.23E-01	1.22E-01	1.87E-01	2.13E-01
Cumene	1.39E-02	2.47E-11	7.87E-04	1.32E-02
Dimethyl ether	1.01E-04	0.00E+00	5.69E-06	9.52E-05
Dinitrogen monoxide	6.83E-03	3.55E-03	1.14E-03	2.14E-03
Formaldehyde	1.79E-02	8.65E-05	1.50E-02	2.80E-03
HAPs	9.86E-04	0.00E+00	9.80E-04	5.23E-06
Heat, waste	1.52E+01	0.00E+00	1.39E+00	1.38E+01
Hydrocarbons, unspecified	5.98E-04	1.94E-06	3.49E-04	2.47E-04
Hydrogen chloride	3.63E-02	1.52E-04	2.12E-02	1.49E-02
Hydrogen fluoride	4.49E-03	1.80E-05	2.62E-03	1.85E-03
Isoprene	2.93E-02	2.94E-04	1.72E-02	1.18E-02
Magnesium	3.29E-04	1.33E-06	1.92E-04	1.36E-04
Methane	9.62E-01	2.84E-02	4.95E-01	4.39E-01
Methane, biogenic	3.50E-03	0.00E+00	3.48E-03	1.86E-05
Methane, fossil	1.08E-01	2.89E-03	5.57E-02	4.95E-02
Methanol	8.73E-02	0.00E+00	3.19E-02	5.54E-02
N-Nitrodimethylamine	2.66E-04	0.00E+00	0.00E+00	2.66E-04
Nitrogen oxides	1.30E+00	2.44E-01	7.14E-01	3.43E-01
Nitrogen, total	1.37E-04	1.37E-04	0.00E+00	8.70E-07
NMVOC[c]	7.01E-02	8.27E-03	1.74E-02	4.44E-02
Organic substances, unspecified	8.05E-04	7.52E-07	7.12E-04	9.19E-05
Particulates, < 10 um	2.33E-01	0.00E+00	1.54E-01	7.93E-02
Particulates, < 2.5 um	1.63E-01	0.00E+00	8.36E-02	7.94E-02
Particulates, > 10 um	9.98E-04	0.00E+00	3.98E-04	6.00E-04

Particulates, > 2.5 um, and < 10um	2.92E-02	7.48E-03	1.27E-02	9.00E-03
Particulates, unspecified	1.83E-01	1.70E-03	6.02E-02	1.21E-01
Phenol	2.07E-03	7.47E-11	1.98E-03	9.04E-05
Propanal	3.41E-03	1.77E-09	8.04E-06	3.41E-03
Propene	5.40E-03	1.87E-04	3.64E-04	4.85E-03
Radionuclides (including radon)	2.77E-03	9.01E-06	1.62E-03	1.14E-03
Sulfur dioxide	2.23E+00	3.13E-02	1.21E+00	9.87E-01
Sulfur monoxide	4.20E-02	1.35E-02	2.37E-02	4.75E-03
Sulfur oxides	3.50E-02	1.54E-04	2.06E-03	3.28E-02
VOCs	6.96E-01	7.17E-03	3.59E-01	3.31E-01
Wood (dust)	2.21E-01	0.00E+00	2.20E-01	7.45E-04

[a] Because of large amount of air emissions, emissions greater than of 10^{-4} and HAPs generated from LVL production are shown. A complete list of all air emissions can be found in Appendix B.
[b] Benzene, toluene, ethylbenzene, and xylene, unspecified ratio.
[c] Nonmethane volatile organic compounds, unspecified origin.

All waterborne emissions occurred off site (Table 13). LVL plants are zero-discharge facilities. For unspecified suspended solids, most of the emissions came from natural gas extraction and crude oil production followed by sodium hydroxide production in third, which is used in resin production. Most chloride emissions were from the same sources except uranium fuel storage (off site; for electricity generation), which replaced production of sodium hydroxide at third.

Table 13. Emissions to water released per one cubic meter of LVL, cradle-to-gate, SE, (mass allocation).[a]

Water emissions	**Total**	**Forestry operations**	**Dry veneer production**	**LVL production**
	kg/m³			
Aluminum	1.19E-02	1.42E-03	4.80E-03	5.69E-03
Ammonia	4.40E-03	3.39E-04	1.98E-03	2.07E-03
Ammonium, ion	2.02E-04	7.19E-08	1.92E-04	1.01E-05
Barium	1.59E-01	1.96E-02	6.31E-02	7.66E-02
Benzene	2.34E-02	3.25E-05	1.53E-03	2.18E-02
Benzoic acid	3.14E-04	1.97E-05	1.46E-04	1.49E-04
BOD5	2.70E-01	3.51E-03	3.77E-02	2.29E-01
Boron	9.72E-04	6.09E-05	4.51E-04	4.60E-04
Bromide	6.64E-02	4.16E-03	3.08E-02	3.14E-02
Calcium	9.93E-01	6.23E-02	4.60E-01	4.71E-01
Calcium, ion	2.28E-03	0.00E+00	2.28E-03	1.31E-07
Chloride	1.12E+01	7.00E-01	5.19E+00	5.29E+00
Chromium	2.48E-04	4.44E-05	6.74E-05	1.36E-04
COD (chemical oxygen demand)	3.12E-01	6.51E-03	5.51E-02	2.51E-01
Cumene	3.35E-02	0.00E+00	1.89E-03	3.16E-02
Detergent, oil	2.96E-04	1.69E-05	1.39E-04	1.40E-04
DOC (dissolved organic carbon)	6.18E-02	5.78E-13	3.49E-03	5.83E-02
Fluoride	1.78E-02	1.73E-02	2.10E-04	2.59E-04
Iron	2.88E-02	2.91E-03	1.22E-02	1.37E-02
Lead	1.25E-04	1.31E-05	5.37E-05	5.77E-05
Lithium	2.52E-01	4.85E-03	1.29E-01	1.18E-01

Magnesium	1.95E-01	1.22E-02	9.03E-02	9.20E-02
Manganese	9.02E-04	2.16E-05	4.89E-04	3.91E-04
Phosphate	1.32E-02	1.30E-02	0.00E+00	1.03E-04
Propene	1.23E-02	0.00E+00	6.97E-04	1.16E-02
Radioactive species, nuclides, unspecified	3.21E+03	1.04E+01	1.88E+03	1.33E+03
Silver	6.49E-04	4.07E-05	3.01E-04	3.07E-04
Sodium	3.15E+00	1.98E-01	1.46E+00	1.49E+00
Sodium, ion	7.24E-03	0.00E+00	7.24E-03	4.14E-07
Solved solids	3.21E-02	0.00E+00	3.17E-02	3.64E-04
Strontium	1.69E-02	1.06E-03	7.84E-03	7.99E-03
Sulfate	6.76E-02	1.56E-03	3.68E-02	2.92E-02
Sulfur	8.20E-04	5.14E-05	3.81E-04	3.88E-04
Suspended solids, unspecified	1.42E+01	9.08E-01	6.52E+00	6.75E+00
Titanium	1.05E-04	1.36E-05	4.04E-05	5.08E-05
TOC (total organic carbon)	6.18E-02	0.00E+00	3.49E-03	5.83E-02
Toluene	4.91E-04	3.07E-05	2.28E-04	2.32E-04
Wastewater/m^3	6.81E-04	0.00E+00	0.00E+00	6.81E-04
Xylene	2.57E-04	1.64E-05	1.19E-04	1.22E-04
Zinc	3.06E-04	3.31E-05	1.28E-04	1.45E-04

[a] Because of the large amount of water emissions, emissions greater than of 10^{-4} and HAPs generated from LVL production are shown. A complete list of all water emissions can be found in Appendix B.

Solid emissions include ash generated at the wood boiler during veneer production and in the upstream processes, primarily fuels and resins, used in LVL production (Table 14). A total of 21.7 kg/m^3 solid waste was generated of which 2.73 kg/m^3 was recycled (Table 15). Overall, 87% of solid waste generated was landfilled.

Table 14. Waste to treatment (kg) per one cubic meter of LVL, cradle-to-gate, SE (mass allocation).

Waste to treatment	**Total**	**Forestry operations**	**Veneer production**	**LVL production**
	kg/m^3			
Waste in inert landfill	1.89E+01	0.00E+00	1.48E+01	4.14E+00
Waste to recycling	2.73E+00	0.00E+00	0.00E+00	2.73E+00
Total waste	2.17E+01	0.00E+00	1.48E+01	6.86E+00

9 LIFE-CYCLE IMPACT ASSESSMENT

Environmental performance results for GWP, acidification, eutrophication, ozone depletion, smog, energy consumption from nonrenewables (fossil and nuclear) and renewables (wind, hydro, solar, and geothermal), renewable and nonrenewable resource consumption, and solid waste are shown in Table 15. Values in Table 15 are the cumulative impact of all upstream processes required for LVL production including those from forestry, veneer, resin, packaging production, and transportation energy required to move these materials to the LVL facility. For example, differences between LVL production data in Table 7 and results in Table 15 are a result of the resources and fuels used in the upstream processes, e.g. fresh water use. In addition, the contribution of major substances to the overall impact from eutrophication, acidification, smog, and GWP categories are provided in Appendix D.

Table 15. Environmental performance of one cubic meter LVL, cradle-to-gate, SE.

Impact category	Unit	Total	Forestry operations	Veneer production	LVL production
Global warming	kg CO_2 eq	3.39E+02	1.61E+01	1.84E+02	1.40E+02
Acidification	Kg SO_2 eq	3.26E+00	2.17E-01	1.76E+00	1.28E+00
Eutrophication	kg N eq	1.22E-01	4.27E-02	3.83E-02	4.11E-02
Ozone depletion	kg CFC-11 eq	1.69E-07	1.46E-09	1.14E-08	1.56E-07
Smog	kg O_3 eq	3.56E+01	6.07E+00	1.94E+01	1.00E+01
Total primary energy consumption	**MJ**	9.98E+03	2.55E+02	6.83E+03	2.89E+03
Nonrenewable fossil	MJ	5.60E+03	2.52E+02	2.80E+03	2.55E+03
Nonrenewable nuclear	MJ	7.43E+02	2.41E+00	4.34E+02	3.06E+02
Renewable (solar, wind, hydroelectric, and geothermal)	MJ	1.70E+01	4.23E-03	9.20E+00	7.76E+00
Renewable, biomass	MJ	3.61E+03	0.00E+00	3.58E+03	3.15E+01
Material resources consumption (nonfuel resources)	**Unit**	**Total**	**Forestry operations**	**Veneer production**	**LVL production**
Nonrenewable materials	kg	1.75E+00	0.00E+00	1.72E+00	2.66E-02
Renewable materials	kg	8.84E+02	0.00E+00	8.79E+02	4.87E+00
Fresh water	L	1.33E+03	5.94E-02	9.01E+02	4.26E+02
Waste generated	**Unit**	**Total**	**Forestry operations**	**Veneer production**	**LVL production**
Solid waste	kg	2.17E+01	0.00E+00	1.48E+01	6.86E+00

10 COMPARISON OF UPDATED LCI WITH A PREVIOUS STUDY

The on-site, industry-average energy inputs reported in 2012 were substantially higher than for Phase I (Wilson and Dancer 2005; Puettmann et al 2013). In particular, electricity and natural gas consumption is driving the total impact from energy with changes of 41% and 76%, respectively (Table 16). Therefore, a sensitivity analysis investigating the energy inputs into LVL production was completed in Section 14 to determine their overall impact. However, the apparent statistical differences between the older and current studies could not be adequately addressed because no statistical description of the data from the earlier study was available. However, there was sufficient reason to attempt to quantify the energy impacts associated with LVL production.

Table 16. Production-weighted average SE on-site energy inputs for manufacturing one cubic meter LVL.

Source	Energy input			Change (%)
	SE Phase I	SE 2012	Unit	
Electricity	69.6	98.2	kWh	41
Natural gas	10.9	19.3	m^3	76
Diesel	0.37	0.74	L	100
Propane	0.48	0.78	L	63

11 TREATMENT OF BIOGENIC CARBON

Treatment of biogenic carbon is consistent with the Intergovernmental Panel for Climate Change (IPCC 2006) inventory reporting framework. There is no assumption that biomass combustion is carbon neutral but net carbon emissions from biomass combustion are assumed to be accounted for under the Land-Use Change and Forestry (LUCF) Sector and are therefore ignored in energy emissions reporting for the product LCA. This prevents double counting. Standards such as ASTM D 7612 (2010), which are used in North America to define legal, responsible, and/or certified sources of wood materials, are in place to provide assurances regarding forest regeneration and sustainable harvest rates, which serve as proxies to ensure stable carbon balances in the forest sector. They are outside the accounting framework for this LCA. This approach to the treatment of biogenic carbon was taken for the Norwegian Solid Wood Product PCR (Aasestad 2008), and the North American PCR (FPInnovations 2015) has adopted an identical approach to ensure comparability and consistency. The North American PCR approach is followed here for GWP impact reporting. Therefore, the default TRACI impact assessment method was used. This default method does not count the CO_2 emissions released during the combustion of woody biomass during production. Other emissions associated with wood combustion, e.g., methane or nitrogen oxides, do contribute to and are included in the GWP impact category. Bare (2011) gives a complete list of emission factors for the GWP impact method used. Using this method, 323 kg CO_2eq. were released in the cradle-to-gate production of 1 m^3 of LVL for the SE (Table 17). That same 1 m^3 of LVL stores 995[1] kg CO_2eq.

Table 17. Carbon balance per one cubic meter LVL, SE.

Source	kg CO_2 equivalent
Released forestry operations	16.1
Released manufacturing	323
CO_2 eq. stored in product	995

12 LIFE-CYCLE INTERPRETATION

As defined by ISO (2006a), LCI is the phase of the LCA in which the findings of either the LCI or the LCIA, or both, are combined consistent with the defined goal and scope in order to reach conclusions and recommendations. This phase in the LCA reports the significant issues based on the results presented in the LCI and LCIA of this report. Additional components report on an evaluation that considered completeness, sensitivity, and consistency checks of the LCI and LCIA results, conclusions, limitations, and recommendations.

12.1 Identification of Significant Issues

The objective of this element is to structure the results from the LCI or the LCIA phases to help determine the significant issues found in the results and presented in previous sections of this report. A contribution analysis was applied for the interpretation phase of this LCA study. A contribution analysis examines the contribution of life cycles stages, unit process contributions in a multi-unit manufacturing process, and specific substances that contribute particular impact categories.

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[1] 563 OD kg of wood in LVL x 0.964 × (0.5 kg carbon/1.0 OD kg wood) × (44 kg CO2/kmole/12 kg carbon/kmole) = 995 kg CO2 eq.

12.2 Life-Cycle Phase Contribution Analysis

Allocation was performed using both mass and economic methodologies to investigate the influence of the allocation method on the results. The contribution of five life-cycle stages to the LCA results for mass and economic allocation are provided in Table 18. Overall, the cradle-to-gate environmental impacts from LVL production for the five impact categories taken into consideration were similar for both economic and mass allocation.

Table 18. Life-cycle stages contribution analysis of one cubic meter LVL, cradle-to-gate.

Mass allocation				
Impact category	**Unit**	**Forestry operations**	**Veneer production**	**LVL production**
Global warming	kg CO_2 eq	4.7%	54.1%	41.2%
Acidification	kg SO_2 eq	6.6%	54.1%	39.3%
Eutrophication	kg N eq	35.0%	31.3%	33.7%
Ozone depletion	kg CFC-11 eq	0.9%	6.7%	92.4%
Smog	kg O_3 eq	17.1%	54.7%	28.2%
Economic allocation				
Total primary energy Consumption	**Unit**	**Forestry operations**	**Veneer production**	**LVL production**
Global warming	kg CO_2 eq	4.6%	50.0%	45.4%
Acidification	kg SO_2 eq	6.5%	49.9%	43.5%
Eutrophication	kg N eq	34.5%	28.1%	37.4%
Ozone depletion	kg CFC-11 eq	0.8%	1.6%	97.6%
Smog	kg O_3 eq	17.1%	51.2%	31.8%

12.3 Substance Contribution Analysis

The contribution of substances released to GWP is presented in Table 19. The major substances that contribute to GWP for the five life-cycle stages of LVL manufacturing include fossil CO_2 and CH_3. The results are presented for both mass and economic allocation, and CO_2 emissions provided the greatest contribution for both.

Table 19. Substance contribution analysis to global warming (kg CO_2 eq.) by life-cycle stage (total percentage basis and values are displayed).

		Mass allocation				**Economic allocation**			
Substance	**Compart-ment type**	**Total (%)**	**Forestry operations**	**Veneer production**	**LVL production**	**Total (%)**	**Forestry operations**	**Veneer production**	**LVL production**
Total of all compartments		**100.00**	1.61E+01	1.84E+02	1.40E+02	**100.00**	1.61E+01	1.73E+02	1.57E+02
Carbon dioxide	Air	91.15	1.42E+01	1.69E+02	1.27E+02	91.12	1.42E+01	1.60E+02	1.43E+02
Methane	Air	7.09	7.83E-01	1.38E+01	1.22E+01	7.10	7.83E-01	1.29E+01	1.37E+01
Other	Air	< 1	1.06E+00	3.41E-01	6.33E-01	< 1	1.06E+00	3.20E-01	7.21E-01

12.4 Completeness, Sensitivity, and Consistency Checks

Evaluating the completeness, sensitivity, and consistency of the LCA offers confidence in and reliability of the LCA results. The completeness check process verifies if information from the life-cycle phases of an LCA is sufficient for reaching the goals and scope and conclusions of the study and making sound interpretations of the results. Three life-cycle stages (forestry operations, wood material production, and LVL production) were checked for data completeness including all input elements such as raw and ancillary materials, energy, transportation scenarios, and water consumption and outputs such as products and coproducts, emissions to air, water, and land, and final waste disposals. All input and output data were found to be complete and no data gaps were identified.

The consistency check process verifies that the assumptions, methods, and data are consistently applied throughout the study and are in accordance with the goal and scope of the LCA. A comprehensive review process was completed for this LCA to make certain consistency was applied to the assumptions, methods, models, data quality including sources and accuracy, age, time-related coverage, technology, and geographical coverage.

A sensitivity analysis can be applied to the LCA to determine changes in results caused by variations in assumptions, methods, and data. Sensitivity analysis is a systematic approach for estimating the effects of the choices made concerning methods and data on the outcome of a study. Sensitivity analysis is a key component of data quality analysis and can be applied to quantify the impact of changes in assumptions or input data on study results. A sensitivity analysis was completed per ISO 14040 standards (ISO 2006a, 2006b) to model the effects of natural consumption and electricity consumption for LVL production. Sensitivity analysis can be useful to understand how various process parameters contribute to environmental output factors.

12.5 Cumulative Primary Energy Consumption

During LVL manufacturing, natural gas is used for curing resin. Changing the consumption of natural gas may have a significant effect on CPEC and GHG emissions. Lower (-20%) and higher (+20%) natural gas consumptions were selected to compare with the baseline fuel mix developed from the mill survey data (Table 20). Although natural gas usage changed by 20%, the outcomes changed less than 3% for both GHG emissions and CPEC.

Table 20. Key parameters on changing natural gas consumption during LVL production.

Parameter	Unit	Natural gas consumption		
		Low (-20%)	Surveyed (0%)	High (+20%)
GHG emissions	kg CO_2 eq.	331	339	348
CPEC	GJ	9.83	9.98	10.11

12.6 Electricity Consumption

During LVL manufacturing, electricity is used for motors including sawing and trimming. However, changing the electricity consumption by 20% changed the outcome by less than 4% for both GHG emissions and CPEC (Table 21).

Table 21. Key parameters on changing electricity consumption during LVL production.

Parameter	Unit	Electricity consumption		
		Low (-20%)	Surveyed (0%)	High (+20%)
GHG emissions	kg CO_2 eq.	327	339	352
CPEC	GJ	9.75	9.98	10.2

Although energy inputs reported for 2012 appear to be higher than those for CORRIM Phase I, the impacts of this difference in the LVL production process were small compared with the energy impacts associated with dry veneer production (Table 11). Neither natural gas nor electrical consumption on site had a substantial impact on the overall process because dry veneer production CPEC contributed roughly two-thirds of the energy impacts of LVL production.

13 CONCLUSIONS, LIMITATIONS, AND RECOMMENDATIONS

The cradle-to-gate LCA for LVL includes 1) the LCI of forest resources, which relies on secondary data, 2) the LCI of dry veneer production, which is used as an input into LVL and relies on primary survey data and secondary data for process inputs such as natural gas, diesel, and electricity, and 3) the LVL manufacturing LCI, which relies on primary survey data and secondary data for process inputs such as natural gas, residual fuel oil, diesel, and electricity. The survey results for LVL were representative of the SE regions of North America. The survey data were representative of the LVL sizes and production volumes consistent with trade association production data.

The amount and type of energy used has a substantial impact on the holistic environmental impacts of the production of building materials. For LVL from the SE region, from cradle-to-gate, 36.2% of the cumulative energy was from biomass (wood fuel) and 56.2% was from nonrenewable fossil fuels, leaving a small portion of energy needs coming from nuclear sources (7.4%) and the remaining 0.2% coming from hydro, wind, solar, and geothermal sources.

Emissions from the forest resources LCI were small relative to manufacturing emissions (veneer and LVL). At the LVL production facility, emissions originate at the boiler and during hot pressing and sawing. Boiler emissions released are a function of the fuel burned whereas other emissions are a function of the unit process and associated emission control device. Cradle-to-gate LCI results showed 310 kg fossil CO_2 were released in the production of 1 m^3 of SE LVL. Carbon content for wood products is assumed to be 50% by mass of OD wood. Excluding the resin system, the carbon stored in the wood portion of 1.0 m^3 of LVL on a production-weighted average is equivalent to 995 kg CO_2 emissions if left to decay.

Data quality was high. A wood mass balance was performed to verify data quality. Inputs and outputs were consistent for the four surveyed mills on a cubic meter basis. Percentage difference for overall wood mass was less than 2% for both regions. A percentage difference less than 10% would be good. Therefore, tracking of wood mass is excellent for this study.

Specific wood production LCA data such as LVL can be used for several purposes. One purpose is to construct cradle-to-gate LCAs for other products. For example, LVL production LCA data developed in this study can be linked as an input to develop an LCA for I-joist production. Secondly, product production companies can explore potential process improvements in conjunction with new conversion technologies to identify potential environmental ‘hotspots’. Thirdly, LCA practitioners can use the data for their studies and product customers can use the data (perhaps in the eventual form of an EPD) to assist in product selection along with building specifiers looking for green building products with documentation. Fourthly, developed wood product LCI data can contribute to product LCAs that are then incorporated into whole building LCAs in environmental footprint software. Lastly, the gate-to-gate LVL production data can be included with or used to update current LCI data found in LCI databases.

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15 APPENDIX A: CONVERSION FACTORS

Table 22. Common conversions from English to SI units.[a]

To convert from	to	multiply by
Cubic feet (ft^3)	Cubic meters (m^3)	0.02831685
Pounds (avdp) (lb)	Kilograms (kg)	0.4535924
Cubic inches (in^3)	Cubic centimeters (cm^3)	16.393
Btus	Joules (J)	1054
Cubic yards (yd^3)	Cubic meters (m^3)	0.7645549
Feet (ft)	Meters (m)	0.305
Gallons (US) (gal)	Liters (L)	3.785
Kilowatt-hours (kWh)	Mega joules (MJ)	3.6
Miles (mi)	Kilometers (km)	1.609
Ounces (avdp) (oz)	Kilograms (kg)	0.028
Square feet (ft^2)	Square meters (m^2)	0.093
Tons (short)	Kilograms (kg)	907.185
Tons (short)	Metric tons (t)	0.9071847
Pounds (lb)	Metric tons (t)	0.0004
Watts (W)	Joules/second (J/s)	1
Yards (yd)	Meters (m)	0.914
Acres (a)	Hectares (ha)	0.405

[a]**Source:** Starr (1971).

Table 23. Electricity grids and dataset name by source.

Region	North American grid	Source
Southeast	Electricity, at grid, SERC, 2008/RNA U	US LCI Database

Table 24. Energy contents and densities of various fuels.

Fuel	HHV[a] MJ/kg	Density	Density units
Coal	26.19		
Distillate fuel oil[b]	45.54	0.85	kg/L
Liquid propane gas	54.05	0.49	kg/L
Natural gas	54.45	0.70	kg/m^3
Residual fuel oil	43.45	0.96	kg/L
Wood	20.93		
Uranium	381,000.00		
Gasoline	48.36	0.72	kg/L
Diesel	44.00	0.88	kg/L

[a]HHV: High heating value. Hodgman (1955);Salazar and Meil (2009); Todreas and Kazimi (1990); Used in this study.
[b]Same as for crude oil.

16 APPENDIX B: SOUTHEAST LVL LIFE-CYCLE INVENTORY FLOWS — MASS ALLOCATION

Table 25. Mass allocation inventory.

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
1	Carbon dioxide, in air	Raw	kg	1.54E+03	2.80E+01	1.06E+01
2	Carbon, organic, in soil or biomass stock	Raw	kg	0.00E+00	0.00E+00	9.14E+02
3	Coal, 26.4 MJ per kg	Raw	kg	2.77E-01	4.04E+01	2.86E+01
4	Coal, 26.4 MJ per kg, in ground	Raw	kg	0.00E+00	1.02E-02	7.22E-05
5	Coal, bituminous, 24.8 MJ per kg	Raw	kg	0.00E+00	2.38E-05	5.18E-07
6	Coal, brown	Raw	kg	0.00E+00	2.14E-06	4.66E-08
7	Energy, from biomass	Raw	MJ	0.00E+00	3.95E-06	8.60E-08
8	Energy, from gas, natural	Raw	MJ	0.00E+00	0.00E+00	1.84E+00
9	Energy, from hydro power	Raw	MJ	4.23E-03	9.09E+00	7.68E+00
10	Energy, from oil	Raw	MJ	0.00E+00	0.00E+00	7.25E-01
11	Energy, geothermal	Raw	MJ	0.00E+00	1.10E-06	2.40E-08
12	Energy, kinetic (in wind), converted	Raw	MJ	0.00E+00	1.10E-01	7.98E-02
13	Energy, recovered	Raw	MJ	0.00E+00	3.03E-06	6.60E-08
14	Energy, solar, converted	Raw	MJ	0.00E+00	7.63E-04	5.55E-04
15	Gas, natural, 36.6 MJ per m^3	Raw	m^3	0.00E+00	9.08E-05	1.98E-06
16	Gas, natural, 46.8 MJ per kg	Raw	kg	0.00E+00	4.71E-02	1.97E-06
17	Gas, natural, 46.8 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	1.54E-04
18	Gas, natural, in ground	Raw	m^3	0.00E+00	1.05E-02	5.44E-04
19	Gas, natural/m^3	Raw	m^3	1.42E+00	3.80E+01	3.46E+01
20	Iron ore	Raw	kg	0.00E+00	0.00E+00	5.99E-08
21	Limestone	Raw	kg	0.00E+00	1.72E+00	4.59E-05
22	Limestone, in ground	Raw	kg	0.00E+00	0.00E+00	2.66E-02
23	Occupation, arable, conservation tillage	Raw	m^{2a}	0.00E+00	0.00E+00	3.43E-04
24	Occupation, arable, conventional tillage	Raw	m^{2a}	0.00E+00	0.00E+00	3.76E-04
25	Occupation, arable, reduced tillage	Raw	m^{2a}	0.00E+00	0.00E+00	2.30E-04
26	Oil, crude	Raw	kg	4.19E+00	6.41E+00	1.04E+01
27	Oil, crude, 41 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	5.60E-01
28	Oil, crude, 42 MJ per kg	Raw	kg	0.00E+00	2.12E-01	3.12E-09
29	Oil, crude, 42 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	6.19E-04
30	Oil, crude, 42.7 MJ per kg	Raw	kg	0.00E+00	4.74E-05	1.03E-06
31	Oil, crude, in ground	Raw	kg	0.00E+00	1.91E-01	2.47E-03
32	Oxygen	Raw	kg	0.00E+00	1.16E-04	2.54E-06
33	Oxygen, in air	Raw	kg	0.00E+00	1.05E-01	1.76E+00
34	Pesticides	Raw	kg	0.00E+00	0.00E+00	2.27E-07
35	Phosphate ore, in ground	Raw	kg	0.00E+00	0.00E+00	2.15E-05
36	Roundwood at forest road	Raw	m^3	1.65E+00	0.00E+00	1.05E-02
37	Sand, quartz, in ground	Raw	kg	0.00E+00	0.00E+00	2.51E-06
38	Scrap, external	Raw	kg	0.00E+00	0.00E+00	8.80E-02
39	Seed corn	Raw	kg	0.00E+00	0.00E+00	1.21E-06
40	Sodium carbonate, in ground	Raw	kg	0.00E+00	0.00E+00	2.93E-04
41	Sodium chloride	Raw	kg	0.00E+00	6.56E-02	1.10E+00
42	Sodium chloride, in ground	Raw	kg	0.00E+00	0.00E+00	2.87E-04
43	Sodium sulfate	Raw	kg	0.00E+00	0.00E+00	6.86E-04
44	Sodium sulphate, various forms, in ground	Raw	kg	0.00E+00	0.00E+00	9.06E-04
45	Sulfur, in ground	Raw	kg	0.00E+00	0.00E+00	8.57E-05
46	Sylvinite, in ground	Raw	kg	0.00E+00	0.00E+00	1.06E-05
47	Uranium oxide, 332 GJ per kg, in ore	Raw	kg	6.34E-06	1.14E-03	8.04E-04
48	Uranium, 2291 GJ per kg	Raw	kg	0.00E+00	7.14E-07	2.30E-14
49	Uranium, 2291 GJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	2.07E-09
50	Uranium, in ground	Raw	kg	0.00E+00	0.00E+00	8.26E-09
51	Water, cooling, unspecified natural origin/kg	Raw	kg	0.00E+00	1.93E-02	3.22E-01
52	Water, cooling, unspecified natural origin/m^3	Raw	m^3	0.00E+00	1.57E-01	2.76E-01
53	Water, process, surface	Raw	kg	0.00E+00	1.72E+02	3.55E+00
54	Water, process, unspecified natural origin/kg	Raw	kg	0.00E+00	3.58E-01	5.97E+00

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
55	Water, process, unspecified natural origin/m^3	Raw	m^3	0.00E+00	3.81E-05	8.31E-07
56	Water, process, well	Raw	kg	0.00E+00	7.50E+01	9.69E-01
57	Water, process, well, in ground	Raw	kg	0.00E+00	4.45E-02	7.44E-01
58	Water, river	Raw	m^3	0.00E+00	0.00E+00	3.85E-06
59	Water, unspecified natural origin, RoW	Raw	m^3	0.00E+00	2.46E-04	1.31E-06
60	Water, unspecified natural origin, US	Raw	m^3	0.00E+00	4.11E-01	0.00E+00
61	Water, unspecified natural origin/m^3	Raw	m^3	5.94E-05	8.25E-03	1.38E-01
62	Water, well, in ground	Raw	m^3	0.00E+00	0.00E+00	2.23E-05
63	Water, well, in ground, US	Raw	m^3	0.00E+00	7.70E-02	0.00E+00
64	Wood and wood waste, 20.9 MJ per kg, ovendry basis	Raw	kg	0.00E+00	1.71E+02	1.51E+00
65	Wood and wood waste, 9.5 MJ per kg	Raw	kg	0.00E+00	0.00E+00	8.66E-02
66	Wood for fiber, feedstock	Raw	kg	0.00E+00	0.00E+00	1.86E-01
67	Wood, feedstock	Raw	kg	0.00E+00	0.00E+00	1.97E-01
68	Wood, soft, standing	Raw	m^3	0.00E+00	1.50E+00	1.05E-02
69	2-chloroacetophenone	Air	kg	3.27E-11	6.98E-11	4.02E-10
70	2-methyl-4-chlorophenoxyacetic acid	Air	kg	0.00E+00	0.00E+00	2.26E-11
71	2,4-D	Air	kg	0.00E+00	0.00E+00	1.21E-09
72	5-methyl chrysene	Air	kg	2.67E-12	3.84E-10	2.72E-10
73	Acenaphthene	Air	kg	6.18E-11	8.90E-09	6.30E-09
74	Acenaphthylene	Air	kg	3.03E-11	4.37E-09	3.09E-09
75	Acetaldehyde	Air	kg	5.57E-05	1.21E-02	2.58E-03
76	Acetochlor	Air	kg	0.00E+00	0.00E+00	1.68E-08
77	Acetophenone	Air	kg	7.00E-11	1.50E-10	8.61E-10
78	Acrolein	Air	kg	6.75E-06	1.46E-03	1.52E-05
79	Alachlor	Air	kg	0.00E+00	0.00E+00	1.66E-09
80	Aldehydes, unspecified	Air	kg	1.70E-04	2.85E-04	4.36E-04
81	Ammonia	Air	kg	5.47E-04	2.50E-03	2.70E-04
82	Ammonium chloride	Air	kg	3.36E-07	6.05E-05	4.27E-05
83	Anthracene	Air	kg	2.55E-11	3.67E-09	2.60E-09
84	Antimony	Air	kg	2.18E-09	3.14E-07	2.29E-07
85	Arsenic	Air	kg	6.71E-08	7.34E-06	5.33E-06
86	Ash	Air	kg	0.00E+00	0.00E+00	5.08E-06
87	Atrazine	Air	kg	0.00E+00	0.00E+00	3.28E-08
88	Barium	Air	kg	0.00E+00	0.00E+00	1.90E-07
89	Bentazone	Air	kg	0.00E+00	0.00E+00	1.34E-10
90	Benzene	Air	kg	6.83E-05	6.18E-04	9.04E-03
91	Benzene, chloro-	Air	kg	1.03E-10	2.20E-10	1.26E-09
92	Benzene, ethyl-	Air	kg	4.39E-10	3.06E-06	1.53E-07
93	Benzo(a)anthracene	Air	kg	9.70E-12	1.40E-09	9.89E-10
94	Benzo(a)pyrene	Air	kg	4.61E-12	6.63E-10	4.70E-10
95	Benzo(b,j,k)fluoranthene	Air	kg	1.33E-11	1.92E-09	1.36E-09
96	Benzo(g,h,i)perylene	Air	kg	3.27E-12	4.71E-10	3.34E-10
97	Benzo(ghi)perylene	Air	kg	0.00E+00	1.20E-13	6.87E-18
98	Benzyl chloride	Air	kg	3.27E-09	6.98E-09	4.02E-08
99	Beryllium	Air	kg	3.37E-09	3.92E-07	3.14E-07
100	Biphenyl	Air	kg	2.06E-10	2.97E-08	2.10E-08
101	Bromoform	Air	kg	1.82E-10	3.89E-10	2.24E-09
102	Bromoxynil	Air	kg	0.00E+00	0.00E+00	2.93E-10
103	BTEX (benzene, toluene, ethylbenzene, and xylene), unspecified ratio	Air	kg	3.50E-04	9.35E-03	8.51E-03
104	Butadiene	Air	kg	2.84E-06	1.16E-06	8.27E-08
105	Cadmium	Air	kg	1.71E-08	1.46E-06	1.16E-06
106	Carbofuran	Air	kg	0.00E+00	0.00E+00	2.51E-10
107	Carbon dioxide	Air	kg	6.04E-01	6.69E-02	5.06E-01
108	Carbon dioxide, biogenic	Air	kg	1.17E-02	2.80E+02	2.46E+00
109	Carbon dioxide, fossil	Air	kg	1.36E+01	1.69E+02	1.26E+02
110	Carbon disulfide	Air	kg	6.07E-10	1.30E-09	6.65E-08
111	Carbon monoxide	Air	kg	4.25E-05	3.76E-03	4.32E-02
112	Carbon monoxide, biogenic	Air	kg	0.00E+00	6.95E-01	3.16E-03
113	Carbon monoxide, fossil	Air	kg	1.22E-01	1.87E-01	2.13E-01
114	Chloride	Air	kg	8.96E-12	5.25E-10	3.59E-10

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
115	Chlorinated fluorocarbons and hydrochlorinated fluorocarbons, unspecified	Air	kg	0.00E+00	1.12E-08	2.11E-07
116	Chlorine	Air	kg	0.00E+00	1.34E-07	3.20E-06
117	Chloroform	Air	kg	2.75E-10	5.89E-10	3.39E-09
118	Chlorpyrifos	Air	kg	0.00E+00	0.00E+00	1.93E-09
119	Chromium	Air	kg	4.90E-08	5.28E-06	3.90E-06
120	Chromium VI	Air	kg	9.58E-09	1.38E-06	9.77E-07
121	Chrysene	Air	kg	1.21E-11	1.75E-09	1.24E-09
122	Cobalt	Air	kg	8.67E-08	2.06E-06	1.67E-06
123	Copper	Air	kg	8.89E-10	3.59E-08	9.48E-08
124	Cumene	Air	kg	2.47E-11	7.87E-04	1.32E-02
125	Cyanazine	Air	kg	0.00E+00	0.00E+00	2.89E-10
126	Cyanide	Air	kg	1.17E-08	2.49E-08	1.44E-07
127	Dicamba	Air	kg	0.00E+00	0.00E+00	1.70E-09
128	Dimethenamid	Air	kg	0.00E+00	0.00E+00	4.02E-09
129	Dimethyl ether	Air	kg	0.00E+00	5.69E-06	9.52E-05
130	Dinitrogen monoxide	Air	kg	3.55E-03	1.14E-03	2.14E-03
131	Dioxin, 2,3,7,8 tetrachlorodibenzo-p-	Air	kg	2.83E-13	1.48E-11	1.31E-09
132	Dioxins (unspec.)	Air	kg	0.00E+00	0.00E+00	3.27E-15
133	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	kg	0.00E+00	0.00E+00	3.16E-19
134	Dipropylthiocarbamic acid S-ethyl ester	Air	kg	0.00E+00	0.00E+00	2.75E-09
135	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	4.86E-10	8.19E-10	2.13E-09
136	Ethane, 1,2-dibromo-	Air	kg	5.60E-12	1.22E-11	6.89E-11
137	Ethane, 1,2-dichloro-	Air	kg	1.87E-10	3.99E-10	2.30E-09
138	Ethane, chloro-	Air	kg	1.96E-10	4.19E-10	2.41E-09
139	Ethene, tetrachloro-	Air	kg	6.17E-09	7.57E-07	5.45E-07
140	Ethene, trichloro-	Air	kg	0.00E+00	0.00E+00	5.47E-14
141	Ethylene oxide	Air	kg	0.00E+00	1.25E-08	2.74E-10
142	Fluoranthene	Air	kg	8.61E-11	1.24E-08	8.78E-09
143	Fluorene	Air	kg	1.10E-10	1.59E-08	1.12E-08
144	Fluoride	Air	kg	7.03E-06	1.81E-06	3.56E-06
145	Formaldehyde	Air	kg	8.65E-05	1.50E-02	2.80E-03
146	Furan	Air	kg	5.31E-13	8.56E-11	6.04E-11
147	Glyphosate	Air	kg	0.00E+00	0.00E+00	3.62E-09
148	HAPs	Air	kg	0.00E+00	9.80E-04	5.23E-06
149	Heat, waste	Air	MJ	0.00E+00	1.39E+00	1.38E+01
150	Hexane	Air	kg	3.13E-10	6.68E-10	1.40E-07
151	Hydrazine, methyl-	Air	kg	7.93E-10	1.70E-09	9.76E-09
152	Hydrocarbons, unspecified	Air	kg	1.94E-06	3.49E-04	2.47E-04
153	Hydrogen	Air	kg	0.00E+00	4.10E-07	6.95E-06
154	Hydrogen chloride	Air	kg	1.52E-04	2.12E-02	1.49E-02
155	Hydrogen fluoride	Air	kg	1.80E-05	2.62E-03	1.85E-03
156	Hydrogen sulfide	Air	kg	2.89E-13	1.70E-11	1.16E-11
157	Indeno(1,2,3-cd)pyrene	Air	kg	7.40E-12	1.07E-09	7.54E-10
158	Iron	Air	kg	0.00E+00	0.00E+00	1.89E-07
159	Isophorone	Air	kg	2.71E-09	5.79E-09	3.33E-08
160	Isoprene	Air	kg	2.94E-04	1.72E-02	1.18E-02
161	Kerosene	Air	kg	1.61E-07	2.90E-05	2.04E-05
162	Lead	Air	kg	8.85E-08	3.50E-05	6.14E-06
163	Magnesium	Air	kg	1.33E-06	1.92E-04	1.36E-04
164	Manganese	Air	kg	9.85E-08	8.91E-06	8.88E-06
165	Mercaptans, unspecified	Air	kg	1.01E-06	2.14E-06	1.24E-05
166	Mercury	Air	kg	1.89E-08	1.92E-06	1.62E-06
167	Metals, unspecified	Air	kg	3.32E-14	1.95E-12	3.31E-05
168	Methane	Air	kg	2.84E-02	4.95E-01	4.39E-01
169	Methane, biogenic	Air	kg	0.00E+00	3.48E-03	1.86E-05
170	Methane, bromo-, Halon 1001	Air	kg	7.47E-10	1.60E-09	9.19E-09
171	Methane, chlorodifluoro-, HCFC-22	Air	kg	0.00E+00	1.04E-13	2.27E-15
172	Methane, chlorotrifluoro-, CFC-13	Air	kg	0.00E+00	9.90E-13	2.16E-14
173	Methane, dichloro-, HCC-30	Air	kg	9.93E-08	5.47E-06	4.63E-06
174	Methane, dichlorodifluoro-, CFC-12	Air	kg	4.86E-10	7.67E-10	1.21E-09
175	Methane, fossil	Air	kg	2.89E-03	5.57E-02	4.95E-02

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
176	Methane, monochloro-, R-40	Air	kg	2.47E-09	5.29E-09	3.04E-08
177	Methane, tetrachloro-, CFC-10	Air	kg	4.86E-11	1.18E-08	1.97E-07
178	Methanol	Air	kg	0.00E+00	3.19E-02	5.54E-02
179	Methyl ethyl ketone	Air	kg	1.82E-09	3.89E-09	2.24E-08
180	Methyl methacrylate	Air	kg	9.34E-11	2.00E-10	1.15E-09
181	Metolachlor	Air	kg	0.00E+00	0.00E+00	1.33E-08
182	Metribuzin	Air	kg	0.00E+00	0.00E+00	6.16E-11
183	N-Nitrodimethylamine	Air	kg	0.00E+00	0.00E+00	2.66E-04
184	Naphthalene	Air	kg	1.85E-08	9.72E-06	7.17E-07
185	Nickel	Air	kg	1.09E-06	9.70E-06	9.98E-06
186	Nitrogen oxides	Air	kg	2.44E-01	7.14E-01	3.43E-01
187	Nitrogen, total	Air	kg	1.37E-04	0.00E+00	8.70E-07
188	NMVOC, nonmethane volatile organic compounds, unspecified origin	Air	kg	8.27E-03	1.74E-02	4.44E-02
189	Organic acids	Air	kg	1.24E-09	2.22E-07	1.57E-07
190	Organic substances, unspecified	Air	kg	7.52E-07	7.12E-04	9.19E-05
191	Other organic	Air	kg	0.00E+00	3.30E-05	1.76E-07
192	PAH, polycyclic aromatic hydrocarbons	Air	kg	1.22E-05	4.81E-06	2.93E-07
193	Paraquat	Air	kg	0.00E+00	0.00E+00	2.69E-10
194	Parathion, methyl	Air	kg	0.00E+00	0.00E+00	2.03E-10
195	Particulates	Air	kg	0.00E+00	2.78E-06	4.65E-05
196	Particulates, < 10 um	Air	kg	0.00E+00	1.54E-01	7.93E-02
197	Particulates, < 2.5 um	Air	kg	0.00E+00	8.36E-02	7.94E-02
198	Particulates, > 10 um	Air	kg	0.00E+00	3.98E-04	6.00E-04
199	Particulates, > 2.5 um, and < 10 um	Air	kg	7.48E-03	1.27E-02	9.00E-03
200	Particulates, unspecified	Air	kg	1.70E-03	6.02E-02	1.21E-01
201	Pendimethalin	Air	kg	0.00E+00	0.00E+00	1.38E-09
202	Permethrin	Air	kg	0.00E+00	0.00E+00	1.24E-10
203	Phenanthrene	Air	kg	3.27E-10	4.71E-08	3.34E-08
204	Phenol	Air	kg	7.47E-11	1.98E-03	9.04E-05
205	Phenols, unspecified	Air	kg	5.03E-08	5.85E-07	8.59E-07
206	Phorate	Air	kg	0.00E+00	0.00E+00	6.37E-11
207	Phosphate	Air	kg	3.12E-06	0.00E+00	1.98E-08
208	Phthalate, dioctyl-	Air	kg	3.41E-10	7.28E-10	4.19E-09
209	Polycyclic organic matter, unspecified	Air	kg	0.00E+00	2.52E-12	5.50E-14
210	Potassium	Air	kg	0.00E+00	0.00E+00	3.36E-05
211	Propanal	Air	kg	1.77E-09	8.04E-06	3.41E-03
212	Propene	Air	kg	1.87E-04	3.64E-04	4.85E-03
213	Propylene oxide	Air	kg	0.00E+00	2.77E-06	1.34E-07
214	Pyrene	Air	kg	4.00E-11	5.76E-09	4.08E-09
215	Radioactive species, unspecified	Air	Bq	6.61E+03	9.88E+05	6.96E+05
216	Radionuclides (including radon)	Air	kg	9.01E-06	1.62E-03	1.14E-03
217	Selenium	Air	kg	1.68E-07	2.28E-05	1.64E-05
218	Simazine	Air	kg	0.00E+00	0.00E+00	8.73E-10
219	Sodium	Air	kg	0.00E+00	0.00E+00	7.75E-07
220	Styrene	Air	kg	1.17E-10	2.49E-10	1.44E-09
221	Sulfur	Air	kg	0.00E+00	0.00E+00	4.08E-06
222	Sulfur dioxide	Air	kg	3.13E-02	1.21E+00	9.87E-01
223	Sulfur monoxide	Air	kg	1.35E-02	2.37E-02	4.75E-03
224	Sulfur oxides	Air	kg	1.54E-04	2.06E-03	3.28E-02
225	Sulfur, total reduced	Air	kg	0.00E+00	0.00E+00	2.40E-06
226	Sulfuric acid, dimethyl ester	Air	kg	2.24E-10	4.79E-10	2.76E-09
227	t-Butyl methyl ether	Air	kg	1.63E-10	3.49E-10	2.01E-09
228	Tar	Air	kg	1.01E-11	5.90E-10	4.04E-10
229	Terbufos	Air	kg	0.00E+00	0.00E+00	2.17E-09
230	TOC, total organic carbon	Air	kg	0.00E+00	0.00E+00	3.17E-06
231	Toluene	Air	kg	2.97E-05	2.42E-05	1.46E-06
232	Toluene, 2,4-dinitro-	Air	kg	1.31E-12	2.79E-12	1.61E-11
233	Trichloroethane	Air	kg	0.00E+00	0.00E+00	1.86E-08
234	Vinyl acetate	Air	kg	3.55E-11	7.58E-11	4.36E-10
235	VOC, volatile organic compounds	Air	kg	7.17E-03	3.59E-01	3.31E-01
236	Wood (dust)	Air	kg	0.00E+00	2.20E-01	7.45E-04
237	Xylene	Air	kg	2.07E-05	1.43E-05	8.86E-07

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
238	Zinc	Air	kg	2.52E-06	2.40E-08	3.09E-07
239	2-hexanone	Water	kg	1.27E-07	9.39E-07	9.56E-07
240	2-methyl-4-chlorophenoxyacetic acid	Water	kg	0.00E+00	0.00E+00	9.70E-13
241	2-propanol	Water	kg	0.00E+00	0.00E+00	2.25E-09
242	2,4-D	Water	kg	0.00E+00	0.00E+00	5.20E-11
243	4-methyl-2-pentanone	Water	kg	8.15E-08	6.04E-07	6.16E-07
244	Acetaldehyde	Water	kg	0.00E+00	1.32E-08	2.88E-10
245	Acetochlor	Water	kg	0.00E+00	0.00E+00	7.21E-10
246	Acetone	Water	kg	1.94E-07	1.44E-06	1.46E-06
247	Acid as H+	Water	kg	0.00E+00	0.00E+00	1.37E-05
248	Acidity, unspecified	Water	kg	0.00E+00	0.00E+00	5.03E-15
249	Acids, unspecified	Water	kg	1.88E-10	1.10E-08	3.20E-06
250	Alachlor	Water	kg	0.00E+00	0.00E+00	7.10E-11
251	Aluminium	Water	kg	1.42E-03	4.80E-03	5.69E-03
252	Aluminum	Water	kg	0.00E+00	0.00E+00	9.09E-06
253	Ammonia	Water	kg	3.39E-04	1.98E-03	2.07E-03
254	Ammonia, as N	Water	kg	9.45E-11	5.54E-09	3.79E-09
255	Ammonium, ion	Water	kg	7.19E-08	1.92E-04	1.01E-05
256	Antimony	Water	kg	8.85E-07	2.67E-06	3.30E-06
257	Arsenic	Water	kg	1.10E-05	3.33E-05	3.48E-05
258	Arsenic, ion	Water	kg	0.00E+00	1.95E-07	1.11E-11
259	Atrazine	Water	kg	0.00E+00	0.00E+00	1.41E-09
260	Barium	Water	kg	1.96E-02	6.31E-02	7.66E-02
261	Bentazone	Water	kg	0.00E+00	0.00E+00	5.73E-12
262	Benzene	Water	kg	3.25E-05	1.53E-03	2.18E-02
263	Benzene, 1-methyl-4-(1-methylethyl)-	Water	kg	1.94E-09	1.44E-08	1.46E-08
264	Benzene, ethyl-	Water	kg	1.83E-06	1.36E-05	1.38E-05
265	Benzene, pentamethyl-	Water	kg	1.45E-09	1.08E-08	1.10E-08
266	Benzenes, alkylated, unspecified	Water	kg	7.76E-07	2.34E-06	2.90E-06
267	Benzo(a)pyrene	Water	kg	0.00E+00	0.00E+00	2.62E-13
268	Benzoic acid	Water	kg	1.97E-05	1.46E-04	1.49E-04
269	Beryllium	Water	kg	2.76E-07	1.57E-06	1.67E-06
270	Biphenyl	Water	kg	5.03E-08	1.51E-07	1.87E-07
271	BOD5	Water	kg	3.51E-03	3.77E-02	2.29E-01
272	Boron	Water	kg	6.09E-05	4.51E-04	4.60E-04
273	Bromide	Water	kg	4.16E-03	3.08E-02	3.14E-02
274	Bromoxynil	Water	kg	0.00E+00	0.00E+00	7.58E-12
275	Cadmium	Water	kg	2.70E-06	5.00E-06	5.19E-06
276	Cadmium, ion	Water	kg	0.00E+00	2.88E-08	2.70E-11
277	Calcium	Water	kg	6.23E-02	4.60E-01	4.71E-01
278	Calcium, ion	Water	kg	0.00E+00	2.28E-03	1.31E-07
279	Carbofuran	Water	kg	0.00E+00	0.00E+00	1.07E-11
280	CFCs, unspecified	Water	kg	0.00E+00	0.00E+00	2.25E-09
281	Chloride	Water	kg	7.00E-01	5.19E+00	5.29E+00
282	Chlorpyrifos	Water	kg	0.00E+00	0.00E+00	8.27E-11
283	Chromate	Water	kg	0.00E+00	0.00E+00	3.00E-13
284	Chromium	Water	kg	4.44E-05	6.74E-05	1.36E-04
285	Chromium III	Water	kg	4.55E-06	5.32E-05	1.41E-05
286	Chromium VI	Water	kg	1.50E-07	2.36E-07	3.72E-07
287	Chromium, ion	Water	kg	0.00E+00	1.22E-07	6.97E-12
288	Cobalt	Water	kg	4.30E-07	3.18E-06	3.25E-06
289	COD	Water	kg	6.51E-03	5.51E-02	2.51E-01
290	Copper	Water	kg	9.08E-06	3.55E-05	3.46E-05
291	Copper, ion	Water	kg	0.00E+00	2.02E-07	1.16E-11
292	Cumene	Water	kg	0.00E+00	1.89E-03	3.16E-02
293	Cyanazine	Water	kg	0.00E+00	0.00E+00	1.24E-11
294	Cyanide	Water	kg	1.40E-09	1.04E-08	1.06E-08
295	Decane	Water	kg	5.65E-07	4.19E-06	4.27E-06
296	Detergent, oil	Water	kg	1.69E-05	1.39E-04	1.40E-04
297	Dibenzofuran	Water	kg	3.69E-09	2.73E-08	2.79E-08
298	Dibenzothiophene	Water	kg	3.14E-09	2.26E-08	2.31E-08
299	Dicamba	Water	kg	0.00E+00	0.00E+00	7.30E-11
300	Dimethenamid	Water	kg	0.00E+00	0.00E+00	1.72E-10

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
301	Dipropylthiocarbamic acid S-ethyl ester	Water	kg	0.00E+00	0.00E+00	7.12E-11
302	Dissolved organics	Water	kg	0.00E+00	0.00E+00	8.79E-06
303	Disulfoton	Water	kg	0.00E+00	0.00E+00	4.25E-12
304	Diuron	Water	kg	0.00E+00	0.00E+00	1.19E-12
305	DOC	Water	kg	5.78E-13	3.49E-03	5.83E-02
306	Docosane	Water	kg	2.08E-08	1.54E-07	1.57E-07
307	Dodecane	Water	kg	1.07E-06	7.95E-06	8.10E-06
308	Eicosane	Water	kg	2.95E-07	2.19E-06	2.23E-06
309	Fluorene	Water	kg	0.00E+00	2.47E-13	5.38E-15
310	Fluorene, 1-methyl-	Water	kg	2.21E-09	1.64E-08	1.67E-08
311	Fluorenes, alkylated, unspecified	Water	kg	4.50E-08	1.35E-07	1.68E-07
312	Fluoride	Water	kg	1.73E-02	2.10E-04	2.59E-04
313	Fluorine	Water	kg	2.25E-08	7.49E-08	9.01E-08
314	Furan	Water	kg	0.00E+00	0.00E+00	8.26E-11
315	Glyphosate	Water	kg	0.00E+00	0.00E+00	1.55E-10
316	Hexadecane	Water	kg	1.17E-06	8.68E-06	8.84E-06
317	Hexanoic acid	Water	kg	4.07E-06	3.02E-05	3.08E-05
318	Hydrocarbons, unspecified	Water	kg	7.23E-13	4.24E-11	8.27E-08
319	Iron	Water	kg	2.91E-03	1.22E-02	1.37E-02
320	Lead	Water	kg	1.31E-05	5.37E-05	5.77E-05
321	Lead-210/kg	Water	kg	2.02E-15	1.49E-14	1.52E-14
322	Lithium	Water	kg	4.85E-03	1.29E-01	1.18E-01
323	Lithium, ion	Water	kg	0.00E+00	3.64E-05	2.08E-09
324	m-xylene	Water	kg	5.88E-07	4.36E-06	4.44E-06
325	Magnesium	Water	kg	1.22E-02	9.03E-02	9.20E-02
326	Manganese	Water	kg	2.16E-05	4.89E-04	3.91E-04
327	Mercury	Water	kg	1.03E-07	6.35E-08	7.12E-08
328	Metallic ions, unspecified	Water	kg	8.82E-12	5.17E-10	2.17E-09
329	Methane, monochloro-, R-40	Water	kg	7.81E-10	5.79E-09	5.90E-09
330	Methyl ethyl ketone	Water	kg	1.56E-09	1.16E-08	1.18E-08
331	Metolachlor	Water	kg	0.00E+00	0.00E+00	5.70E-10
332	Metribuzin	Water	kg	0.00E+00	0.00E+00	2.64E-12
333	Molybdenum	Water	kg	4.46E-07	3.30E-06	3.37E-06
334	n-hexacosane	Water	kg	1.29E-08	9.60E-08	9.78E-08
335	Naphthalene	Water	kg	3.53E-07	2.61E-06	2.66E-06
336	Naphthalene, 2-methyl-	Water	kg	3.07E-07	2.28E-06	2.32E-06
337	Naphthalenes, alkylated, unspecified	Water	kg	1.27E-08	3.83E-08	4.74E-08
338	Nickel	Water	kg	7.80E-06	2.75E-05	2.94E-05
339	Nickel, ion	Water	kg	0.00E+00	0.00E+00	2.61E-13
340	Nitrate	Water	kg	6.33E-14	3.71E-12	2.68E-07
341	Nitrate compounds	Water	kg	2.55E-12	1.49E-10	1.02E-10
342	Nitric acid	Water	kg	5.72E-09	3.35E-07	2.29E-07
343	Nitrogen, total	Water	kg	1.79E-07	3.22E-05	3.20E-05
344	o-cresol	Water	kg	5.58E-07	4.14E-06	4.21E-06
345	o-xylene	Water	kg	0.00E+00	5.25E-13	1.14E-14
346	Octadecane	Water	kg	2.89E-07	2.14E-06	2.18E-06
347	Oils, unspecified	Water	kg	4.33E-04	2.96E-03	3.09E-03
348	Organic substances, unspecified	Water	kg	0.00E+00	0.00E+00	1.65E-09
349	p-cresol	Water	kg	6.02E-07	4.46E-06	4.55E-06
350	p-xylene	Water	kg	0.00E+00	5.25E-13	1.14E-14
351	Paraquat	Water	kg	0.00E+00	0.00E+00	1.15E-11
352	Parathion, methyl	Water	kg	0.00E+00	0.00E+00	8.71E-12
353	Pendimethalin	Water	kg	0.00E+00	0.00E+00	5.93E-11
354	Permethrin	Water	kg	0.00E+00	0.00E+00	5.33E-12
355	Phenanthrene	Water	kg	4.82E-09	2.21E-08	2.46E-08
356	Phenanthrenes, alkylated, unspecified	Water	kg	5.27E-09	1.59E-08	1.97E-08
357	Phenol	Water	kg	6.63E-06	1.05E-05	1.68E-05
358	Phenol, 2,4-dimethyl-	Water	kg	5.43E-07	4.03E-06	4.10E-06
359	Phenols, unspecified	Water	kg	2.95E-06	5.53E-05	5.17E-05
360	Phorate	Water	kg	0.00E+00	0.00E+00	1.65E-12
361	Phosphate	Water	kg	1.30E-02	0.00E+00	1.03E-04
362	Phosphorus	Water	kg	0.00E+00	0.00E+00	4.62E-06
363	Phosphorus compounds, unspecified	Water	kg	0.00E+00	0.00E+00	3.05E-08

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
364	Phosphorus, total	Water	kg	0.00E+00	0.00E+00	2.73E-06
365	Process solvents, unspecified	Water	kg	0.00E+00	0.00E+00	8.26E-09
366	Propene	Water	kg	0.00E+00	6.97E-04	1.16E-02
367	Radioactive species, nuclides, unspecified	Water	Bq	1.04E+01	1.88E+03	1.33E+03
368	Radium-226/kg	Water	kg	7.01E-13	5.20E-12	5.29E-12
369	Radium-228/kg	Water	kg	3.59E-15	2.66E-14	2.71E-14
370	Selenium	Water	kg	1.97E-07	5.05E-06	3.84E-06
371	Silver	Water	kg	4.07E-05	3.01E-04	3.07E-04
372	Simazine	Water	kg	0.00E+00	0.00E+00	3.74E-11
373	Sodium	Water	kg	1.98E-01	1.46E+00	1.49E+00
374	Sodium, ion	Water	kg	0.00E+00	7.24E-03	4.14E-07
375	Solids, inorganic	Water	kg	1.45E-11	8.52E-10	5.83E-10
376	Solved solids	Water	kg	0.00E+00	3.17E-02	3.64E-04
377	Strontium	Water	kg	1.06E-03	7.84E-03	7.99E-03
378	Styrene	Water	kg	0.00E+00	2.36E-11	4.04E-10
379	Sulfate	Water	kg	1.56E-03	3.68E-02	2.92E-02
380	Sulfide	Water	kg	7.70E-07	1.49E-06	3.24E-05
381	Sulfur	Water	kg	5.14E-05	3.81E-04	3.88E-04
382	Sulfuric acid	Water	kg	0.00E+00	0.00E+00	7.25E-11
383	Surfactants	Water	kg	0.00E+00	2.43E-11	5.30E-13
384	Suspended solids, unspecified	Water	kg	9.08E-01	6.52E+00	6.75E+00
385	Tar	Water	kg	1.44E-13	8.45E-12	5.77E-12
386	Terbufos	Water	kg	0.00E+00	0.00E+00	5.62E-11
387	Tetradecane	Water	kg	4.70E-07	3.48E-06	3.55E-06
388	Thallium	Water	kg	1.86E-07	5.63E-07	6.97E-07
389	Tin	Water	kg	3.84E-06	1.85E-05	2.04E-05
390	Titanium	Water	kg	1.36E-05	4.04E-05	5.08E-05
391	Titanium, ion	Water	kg	0.00E+00	5.89E-07	3.37E-11
392	TOC	Water	kg	0.00E+00	3.49E-03	5.83E-02
393	Toluene	Water	kg	3.07E-05	2.28E-04	2.32E-04
394	Vanadium	Water	kg	5.27E-07	3.90E-06	3.98E-06
395	Waste water/m^3	Water	m^3	0.00E+00	0.00E+00	6.81E-04
396	Xylene	Water	kg	1.64E-05	1.19E-04	1.22E-04
397	Yttrium	Water	kg	1.31E-07	9.69E-07	9.87E-07
398	Zinc	Water	kg	3.31E-05	1.28E-04	1.45E-04
399	Zinc, ion	Water	kg	0.00E+00	0.00E+00	3.64E-07
400	Waste in inert landfill	Waste	kg	0.00E+00	0.00E+00	4.14E+00
401	Waste to recycling	Waste	kg	0.00E+00	0.00E+00	2.73E+00
402	Waste, solid	Waste	kg	0.00E+00	0.00E+00	9.73E-03

17 APPENDIX C: SOUTHEAST LVL LIFE-CYCLE IMPACT ASSESSMENT — ECONOMIC ALLOCATION

Cradle-to-gate LCI and impact assessment results of economic allocation are presented in this section. The results for SE LVL analyses are presented for three life-cycle stages, 1) forestry operations, 2) veneer production, and 3) LVL production. The overall cumulative energy consumption obtained from impact assessment using economic allocation is similar to the mass allocation method with a 1% difference. The difference between mass and economic allocation results for the raw material energy consumption of three life-cycle stages is not significant and ranges between 2% and 6%. The low economic value of the LVL coproducts resulted in a slightly greater environmental impact at LVL production, which also led to a greater contribution of the LVL stage to the overall life-cycle impact. The impact assessment results of selected impact categories provided only a slight difference (1%-2%) except for the ozone depletion impact category (6%). The difference in CPEC of veneer production between mass and economic allocation was less than 1%. The impact assessment results for the categories taken into consideration were similar for both allocation methods. The majority of the ozone depletion impact at the veneer production stage is assigned to the wood boiler used in veneer drying. The fuel used in wood boilers is a mixture of the coproducts coming from a downstream process at plywood production. The lower ozone depletion at veneer production stage for economic allocation is a result of lower emissions allocated to coproducts because of their low economic value.

Table 26. Raw material energy consumption per one cubic meter of cradle-to-gate LVL, SE, economic allocation.

Fuel	Unit	Total	Forestry operations	Dry veneer production	LVL production
Wood fuel	OD kg	1.62E+02	0.00E+00	1.60E+02	1.63E+00
Gas, natural, in ground	kg	5.32E+01	1.00E+00	2.48E+01	2.74E+01
Coal, in ground	kg	7.07E+01	2.77E-01	3.82E+01	3.22E+01
Uranium oxide, in ore	kg	1.99E-03	6.34E-06	1.08E-03	9.05E-04
Oil, crude, in ground	kg	2.17E+01	4.19E+00	5.83E+00	1.17E+01

Table 27. Cumulative primary energy consumption per one cubic meter of cradle-to-gate LVL, SE (economic allocation).

Fuel	Percentage	Total	Forestry operations	Veneer production	LVL production
		MJ/m^3			
Wood fuel	34.2	3.38E+03	0.00E+00	3.34E+03	3.42E+01
Gas, natural, in ground	29.3	2.90E+03	5.45E+01	1.35E+03	1.49E+03
Coal, in ground	18.7	1.85E+03	7.25E+00	1.00E+03	8.42E+02
Oil, crude, in ground	10.0	9.89E+02	1.91E+02	2.65E+02	5.33E+02
Uranium oxide, in ore	7.7	7.58E+02	2.41E+00	4.11E+02	3.45E+02
Hydro	0.2	1.74E+01	4.23E-03	8.79E+00	8.64E+00
Wind	0.0	1.96E-01	0.00E+00	1.06E-01	8.97E-02
Solar	0.0	1.37E-03	0.00E+00	7.40E-04	6.25E-04
Geothermal	0.0	1.05E-06	0.00E+00	1.03E-06	2.84E-08
Total	100	9.89E+03	2.55E+02	6.38E+03	3.25E+03
Total (%)		100	2.6	64.5	32.9

Table 28. Air emissions released per one cubic meter of LVL, cradle-to-gate, SE (economic allocation)[a].

Air emissions	Total	Forestry operations	Veneer production	LVL production
	kg/m³			
Acetaldehyde	1.36E-02	5.57E-05	1.06E-02	2.90E-03
Acrolein	1.26E-03	6.75E-06	1.23E-03	1.68E-05
Aldehydes, unspecified	9.22E-04	1.70E-04	2.60E-04	4.91E-04
Ammonia	3.18E-03	5.47E-04	2.33E-03	3.04E-04
Ammonium chloride	1.06E-04	3.36E-07	5.72E-05	4.80E-05
Benzene	1.03E-02	6.83E-05	1.02E-04	1.02E-02
BTEX[b]	1.86E-02	3.50E-04	8.69E-03	9.58E-03
Carbon dioxide	1.23E+00	6.04E-01	5.52E-02	5.70E-01
Carbon dioxide, biogenic	2.64E+02	1.17E-02	2.61E+02	2.68E+00
Carbon dioxide, fossil	3.16E+02	1.36E+01	1.60E+02	1.42E+02
Carbon disulfide	7.37E-08	6.07E-10	1.08E-09	7.21E-08
Carbon monoxide	5.21E-02	4.25E-05	3.51E-03	4.86E-02
Carbon monoxide, biogenic	6.51E-01	0.00E+00	6.47E-01	3.41E-03
Carbon monoxide, fossil	5.37E-01	1.22E-01	1.74E-01	2.40E-01
Cumene	1.48E-02	2.47E-11	3.92E-05	1.48E-02
Dimethyl ether	1.07E-04	0.00E+00	2.84E-07	1.07E-04
Dinitrogen monoxide	7.04E-03	3.55E-03	1.07E-03	2.42E-03
Formaldehyde	1.66E-02	8.65E-05	1.33E-02	3.15E-03
HAPs	9.21E-04	0.00E+00	9.16E-04	5.64E-06
Heat, waste	1.61E+01	0.00E+00	5.69E-01	1.55E+01
Hydrocarbons, unspecified	6.10E-04	1.94E-06	3.30E-04	2.77E-04
Hydrogen chloride	3.70E-02	1.52E-04	2.00E-02	1.68E-02
Hydrogen fluoride	4.58E-03	1.80E-05	2.48E-03	2.08E-03
Isoprene	2.98E-02	2.94E-04	1.63E-02	1.32E-02
Magnesium	3.36E-04	1.33E-06	1.82E-04	1.53E-04
Methane	9.84E-01	2.84E-02	4.62E-01	4.93E-01
Methane, biogenic	3.27E-03	0.00E+00	3.25E-03	2.00E-05
Methane, fossil	1.10E-01	2.89E-03	5.18E-02	5.57E-02
Methanol	8.93E-02	0.00E+00	2.69E-02	6.23E-02
N-nitrodimethylamine	2.99E-04	0.00E+00	0.00E+00	2.99E-04
Nitrogen oxides	1.30E+00	2.44E-01	6.73E-01	3.87E-01
Nitrogen, total	1.38E-04	1.37E-04	0.00E+00	1.20E-06
NMVOC[c]	7.31E-02	8.27E-03	1.48E-02	5.00E-02
Organic substances, unspecified	7.70E-04	7.52E-07	6.66E-04	1.03E-04
Particulates, < 10 um	2.22E-01	0.00E+00	1.33E-01	8.92E-02
Particulates, < 2.5 um	1.58E-01	0.00E+00	6.92E-02	8.93E-02
Particulates, > 10 um	1.07E-03	0.00E+00	3.72E-04	6.99E-04
Particulates, > 2.5 um and < 10 um	2.96E-02	7.48E-03	1.20E-02	1.01E-02
Particulates, unspecified	1.95E-01	1.70E-03	5.69E-02	1.36E-01
Phenol	1.82E-03	7.47E-11	1.72E-03	1.01E-04
Propanal	3.84E-03	1.77E-09	7.51E-06	3.83E-03
Propene	5.73E-03	1.87E-04	8.55E-05	5.46E-03
Radionuclides (including radon)	2.83E-03	9.01E-06	1.53E-03	1.29E-03
Sulfur dioxide	2.28E+00	3.13E-02	1.13E+00	1.11E+00

Sulfur monoxide	4.14E-02	1.35E-02	2.25E-02	5.36E-03
Sulfur oxides	3.81E-02	1.54E-04	1.06E-03	3.69E-02
VOCs	6.96E-01	7.17E-03	3.17E-01	3.72E-01
Wood (dust)	1.81E-01	0.00E+00	1.80E-01	8.38E-04

[a]Because of large amounts of air emissions, emissions greater than 10^{-4} and HAPs generated from LVL production are shown. A complete list of all air emissions can be found in Appendix E.
[b]BTEX (benzene, toluene, ethylbenzene, and xylene), unspecified ratio.
[c]Nonmethane VOCs, unspecified origin.

Table 29. Emissions to water released per one cubic meter of LVL, cradle-to-gate, SE (economic allocation)[a].

Water emissions	**Total**	**Forestry operations**	**Dry veneer production**	**LVL production**
	kg/m³			
Aluminium	1.22E-02	1.42E-03	4.42E-03	6.40E-03
Ammonia	4.51E-03	3.39E-04	1.83E-03	2.33E-03
Ammonium, ion	1.91E-04	7.19E-08	1.79E-04	1.13E-05
Barium	1.64E-01	1.96E-02	5.80E-02	8.62E-02
Benzene	2.49E-02	3.25E-05	2.88E-04	2.45E-02
Benzoic acid	3.22E-04	1.97E-05	1.35E-04	1.67E-04
BOD5	2.85E-01	3.51E-03	2.43E-02	2.57E-01
Boron	9.96E-04	6.09E-05	4.18E-04	5.17E-04
Bromide	6.80E-02	4.16E-03	2.85E-02	3.53E-02
Calcium	1.02E+00	6.23E-02	4.26E-01	5.30E-01
Calcium, ion	2.14E-03	0.00E+00	2.14E-03	1.47E-07
Chloride	1.15E+01	7.00E-01	4.81E+00	5.95E+00
Chromium	2.59E-04	4.44E-05	6.13E-05	1.53E-04
COD	3.29E-01	6.51E-03	4.04E-02	2.82E-01
Cumene	3.57E-02	0.00E+00	9.43E-05	3.56E-02
Detergent, oil	3.04E-04	1.69E-05	1.29E-04	1.57E-04
DOC	6.57E-02	5.78E-13	1.74E-04	6.56E-02
Fluoride	1.79E-02	1.73E-02	1.99E-04	3.19E-04
Iron	2.96E-02	2.91E-03	1.13E-02	1.54E-02
Lead	1.28E-04	1.31E-05	4.96E-05	6.50E-05
Lithium	2.57E-01	4.85E-03	1.20E-01	1.32E-01
Magnesium	1.99E-01	1.22E-02	8.36E-02	1.04E-01
Manganese	9.22E-04	2.16E-05	4.60E-04	4.40E-04
Oils, unspecified	6.65E-03	4.33E-04	2.74E-03	3.48E-03

[a]Because of large amounts of air emissions, emissions greater than of 10^{-4} and HAPs generated from LVL production are shown. A complete list of all air emissions can be found in Appendix E.

Table 30. Waste to treatment (kg) per one cubic meter of LVL, cradle-to-gate, SE (economic allocation).

Waste to treatment	Total	Forestry operations	Veneer production	LVL production
	kg/m^3			
Waste in inert landfill	1.95E+01	0.00E+00	1.48E+01	4.65E+00
Waste to recycling	3.07E+00	0.00E+00	0.00E+00	3.07E+00
Total waste	2.25E+01	0.00E+00	1.48E+01	7.72E+00

Table 31. Environmental performance of one cubic meter LVL, cradle-to-gate, SE (economic allocation).

Impact category	Unit	Total	Forestry operations	Veneer production	LVL production
Global warming	kg CO_2 equiv	3.46E+02	1.61E+01	1.73E+02	1.57E+02
Acidification	Kg SO_2 equiv	3.31E+00	2.17E-01	1.65E+00	1.44E+00
Eutrophication	kg N equiv	1.24E-01	4.27E-02	3.49E-02	4.63E-02
Ozone depletion	kg CFC-11 equiv	1.80E-07	1.46E-09	2.82E-09	1.75E-07
Smog	kg O_3 equiv	3.56E+01	6.07E+00	1.82E+01	1.13E+01
Total primary energy consumption	**MJ**	9.89E+03	2.55E+02	6.38E+03	3.25E+03
Nonrenewable fossil	MJ	5.74E+03	2.52E+02	2.62E+03	2.87E+03
Nonrenewable nuclear	MJ	7.58E+02	2.41E+00	4.11E+02	3.45E+02
Renewable (solar, wind, hydroelectric, and geothermal)	MJ	1.76E+01	4.23E-03	8.90E+00	8.73E+00
Renewable, biomass	MJ	3.38E+03	0.00E+00	3.34E+03	3.42E+01
Material resources consumption (nonfuel resources)	**Unit**	**Total**	**Forestry operations**	**Veneer production**	**LVL production**
Nonrenewable materials	kg	1.64E+00	0.00E+00	1.61E+00	2.99E-02
Renewable materials	kg	8.84E+02	0.00E+00	8.79E+02	4.87E+00
Fresh water	L	1.33E+03	5.94E-02	8.54E+02	4.79E+02
Waste generated	**Unit**	**Total**	**Forestry operations**	**Veneer production**	**LVL production**
Solid waste	kg	2.25E+01	0.00E+00	1.48E+01	7.72E+00

18 APPENDIX D: SUBSTANCE CONTRIBUTION ANALYSIS

Table 32. Substance contribution analysis to acidification (kg SO_2 eq.) by life-cycle stage (total percentage basis and values are displayed).

Substances	Compartment type	Mass allocation				Economic allocation			
		Total (%)	Forestry operations	Veneer production	LVL production	Total (%)	Forestry operations	Veneer production	LVL production
Total of all compartments		**100**	2.17E-01	1.76E+00	1.28E+00	**100**	2.17E-01	1.65E+00	1.44E+00
Sulfur dioxide	Air	68.33	3.13E-02	1.21E+00	9.88E-01	68.69	3.13E-02	1.13E+00	1.11E+00
Nitrogen oxides	Air	27.92	1.71E-01	5.00E-01	2.40E-01	27.53	1.71E-01	4.71E-01	2.71E-01
Sulfur monoxide	Air	1.29	1.35E-02	2.37E-02	4.70E-03	1.25	1.35E-02	2.25E-02	5.40E-03
Sulfur oxides	Air	1.07	2.00E-04	2.10E-03	3.28E-02	1.15	2.00E-04	1.10E-03	3.69E-02
Other substances	Air	< 1	1.19E-03	2.75E-02	1.66E-02	< 1	1.19E-03	2.60E-02	1.87E-02

Table 33. Substance contribution analysis to eutrophication (kg N eq.) by life-cycle stage (total percentage basis and values are displayed).

Substances	Compartment type	Mass allocation				Economic allocation			
		Total (%)	Forestry operations	Veneer production	LVL production	Total (%)	Forestry operations	Veneer production	LVL production
Total of all compartments		**100**	4.27E-02	3.83E-02	4.08E-02	**100**	4.27E-02	3.49E-02	4.63E-02
Nitrogen oxides	Air	47.21	1.08E-02	3.16E-02	1.52E-02	46.59	3.11E-02	0.00E+00	3.00E-04
Phosphate	Water	25.65	3.11E-02	0.00E+00	2.00E-04	25.33	3.00E-04	2.00E-03	1.41E-02
COD	Water	12.79	3.00E-04	2.80E-03	1.25E-02	13.27	2.00E-04	1.20E-03	1.29E-02
BOD_5	Water	11.06	2.00E-04	1.90E-03	1.14E-02	11.51	3.00E-04	1.40E-03	1.80E-03
Ammonia	Water	2.81	1.08E-02	3.16E-02	1.52E-02	2.83	1.08E-02	2.98E-02	1.71E-02
Other substances	Air	< 1	2.42E-04	2.33E-03	1.15E-02	< 1	6.60E-05	4.16E-04	9.26E-05

Table 34. Substance contribution analysis to smog potential (kg O_3 eq.) by life-cycle stage (total percentage basis and values are displayed).

Substances	Compartment type	Mass allocation				Economic allocation			
		Total (%)	Forestry operations	Veneer production	LVL production	Total (%)	Forestry operations	Veneer production	LVL production
Total of all compartments		**100**	6.07E+00	1.94E+01	1.00E+01	**100**	6.07E+00	1.82E+01	1.13E+01
Nitrogen oxides	Air	90.72	6.04E+00	1.77E+01	8.51E+00	90.75	6.04E+00	1.67E+01	9.59E+00
VOC	Air	7.04	2.58E-02	1.29E+00	1.19E+00	7.02	2.58E-02	1.14E+00	1.34E+00
Other substances	Air	< 1	7.31E-03	4.55E-01	3.35E-01	< 1	7.31E-03	4.09E-01	3.77E-01

19 APPENDIX E: SOUTHEAST LVL LIFE-CYCLE INVENTORY FLOWS — ECONOMIC ALLOCATION

Table 35. Economic allocation inventory.

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
1	Carbon dioxide, in air	Raw	kg	1.54E+03	2.62E+01	1.43E+01
2	Carbon, organic, in soil or biomass stock	Raw	kg	0.00E+00	0.00E+00	1.03E+03
3	Coal, 26.4 MJ per kg	Raw	kg	2.77E-01	3.82E+01	3.22E+01
4	Coal, 26.4 MJ per kg, in ground	Raw	kg	0.00E+00	9.50E-03	8.12E-05
5	Coal, bituminous, 24.8 MJ per kg	Raw	kg	0.00E+00	2.22E-05	6.13E-07
6	Coal, brown	Raw	kg	0.00E+00	2.00E-06	5.51E-08
7	Energy, from biomass	Raw	MJ	0.00E+00	3.68E-06	1.02E-07
8	Energy, from gas, natural	Raw	MJ	0.00E+00	0.00E+00	2.06E+00
9	Energy, from hydro power	Raw	MJ	4.23E-03	8.79E+00	8.64E+00
10	Energy, from oil	Raw	MJ	0.00E+00	0.00E+00	8.16E-01
11	Energy, geothermal	Raw	MJ	0.00E+00	1.03E-06	2.84E-08
12	Energy, kinetic (in wind), converted	Raw	MJ	0.00E+00	1.06E-01	8.97E-02
13	Energy, recovered	Raw	MJ	0.00E+00	2.83E-06	7.81E-08
14	Energy, solar, converted	Raw	MJ	0.00E+00	7.40E-04	6.25E-04
15	Gas, natural, 36.6 MJ per m^3	Raw	m^3	0.00E+00	8.48E-05	2.34E-06
16	Gas, natural, 46.8 MJ per kg	Raw	kg	0.00E+00	4.40E-02	2.33E-06
17	Gas, natural, 46.8 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	1.73E-04
18	Gas, natural, in ground	Raw	m^3	0.00E+00	9.80E-03	6.12E-04
19	Gas, natural/m^3	Raw	m^3	1.42E+00	3.53E+01	3.89E+01
20	Iron ore	Raw	kg	0.00E+00	0.00E+00	6.93E-09
21	Limestone	Raw	kg	0.00E+00	1.61E+00	5.16E-05
22	Limestone, in ground	Raw	kg	0.00E+00	0.00E+00	2.99E-02
23	Occupation, arable, conservation tillage	Raw	m^{2a}	0.00E+00	0.00E+00	3.86E-04
24	Occupation, arable, conventional tillage	Raw	m^{2a}	0.00E+00	0.00E+00	4.23E-04
25	Occupation, arable, reduced tillage	Raw	m^{2a}	0.00E+00	0.00E+00	2.59E-04
26	Oil, crude	Raw	kg	4.19E+00	5.83E+00	1.17E+01
27	Oil, crude, 41 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	6.31E-01
28	Oil, crude, 42 MJ per kg	Raw	kg	0.00E+00	1.98E-01	3.60E-10
29	Oil, crude, 42 MJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	6.96E-04
30	Oil, crude, 42.7 MJ per kg	Raw	kg	0.00E+00	4.43E-05	1.22E-06
31	Oil, crude, in ground	Raw	kg	0.00E+00	1.78E-01	2.77E-03
32	Oxygen	Raw	kg	0.00E+00	1.09E-04	3.00E-06
33	Oxygen, in air	Raw	kg	0.00E+00	5.24E-03	1.98E+00
34	Pesticides	Raw	kg	0.00E+00	0.00E+00	2.55E-07
35	Phosphate ore, in ground	Raw	kg	0.00E+00	0.00E+00	2.42E-05
36	Roundwood at forest road	Raw	m^3	1.65E+00	0.00E+00	1.44E-02
37	Sand, quartz, in ground	Raw	kg	0.00E+00	0.00E+00	2.82E-06
38	Scrap, external	Raw	kg	0.00E+00	0.00E+00	9.90E-02
39	Seed corn	Raw	kg	0.00E+00	0.00E+00	1.37E-06
40	Sodium carbonate, in ground	Raw	kg	0.00E+00	0.00E+00	3.30E-04
41	Sodium chloride	Raw	kg	0.00E+00	3.27E-03	1.23E+00
42	Sodium chloride, in ground	Raw	kg	0.00E+00	0.00E+00	3.23E-04
43	Sodium sulfate	Raw	kg	0.00E+00	0.00E+00	7.71E-04
44	Sodium sulphate, various forms, in ground	Raw	kg	0.00E+00	0.00E+00	1.02E-03
45	Sulfur, in ground	Raw	kg	0.00E+00	0.00E+00	9.64E-05
46	Sylvinite, in ground	Raw	kg	0.00E+00	0.00E+00	1.19E-05
47	Uranium oxide, 332 GJ per kg, in ore	Raw	kg	6.34E-06	1.08E-03	9.05E-04
48	Uranium, 2291 GJ per kg	Raw	kg	0.00E+00	6.66E-07	2.66E-15
49	Uranium, 2291 GJ per kg, in ground	Raw	kg	0.00E+00	0.00E+00	2.33E-09
50	Uranium, in ground	Raw	kg	0.00E+00	0.00E+00	9.29E-09
51	Water, cooling, unspecified natural origin/kg	Raw	kg	0.00E+00	9.60E-04	3.62E-01
52	Water, cooling, unspecified natural origin/m^3	Raw	m^3	0.00E+00	1.32E-01	3.11E-01
53	Water, process, surface	Raw	kg	0.00E+00	1.61E+02	4.01E+00
54	Water, process, unspecified natural origin/kg	Raw	kg	0.00E+00	1.78E-02	6.72E+00
55	Water, process, unspecified natural origin/m^3	Raw	m^3	0.00E+00	3.56E-05	9.83E-07
56	Water, process, well	Raw	kg	0.00E+00	7.00E+01	1.16E+00

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
57	Water, process, well, in ground	Raw	kg	0.00E+00	2.22E-03	8.37E-01
58	Water, river	Raw	m^3	0.00E+00	0.00E+00	4.33E-06
59	Water, unspecified natural origin, RoW	Raw	m^3	0.00E+00	2.30E-04	1.41E-06
60	Water, unspecified natural origin, US	Raw	m^3	0.00E+00	4.14E-01	0.00E+00
61	Water, unspecified natural origin/m^3	Raw	m^3	5.94E-05	4.11E-04	1.55E-01
62	Water, well, in ground	Raw	m^3	0.00E+00	0.00E+00	2.51E-05
63	Water, well, in ground, US	Raw	m^3	0.00E+00	7.75E-02	0.00E+00
64	Wood and wood waste, 20.9 MJ per kg, ovendry basis	Raw	kg	0.00E+00	1.60E+02	1.63E+00
65	Wood and wood waste, 9.5 MJ per kg	Raw	kg	0.00E+00	0.00E+00	9.75E-02
66	Wood for fiber, feedstock	Raw	kg	0.00E+00	0.00E+00	2.09E-01
67	Wood, feedstock	Raw	kg	0.00E+00	0.00E+00	2.22E-01
68	Wood, soft, standing	Raw	m^3	0.00E+00	1.44E+00	1.44E-02
69	2-Chloroacetophenone	Air	kg	3.27E-11	5.80E-11	4.52E-10
70	2-Methyl-4-chlorophenoxyacetic acid	Air	kg	0.00E+00	0.00E+00	2.55E-11
71	2,4-D	Air	kg	0.00E+00	0.00E+00	1.37E-09
72	5-methyl Chrysene	Air	kg	2.67E-12	3.63E-10	3.06E-10
73	Acenaphthene	Air	kg	6.18E-11	8.42E-09	7.10E-09
74	Acenaphthylene	Air	kg	3.03E-11	4.13E-09	3.48E-09
75	Acetaldehyde	Air	kg	5.57E-05	1.06E-02	2.90E-03
76	Acetochlor	Air	kg	0.00E+00	0.00E+00	1.89E-08
77	Acetophenone	Air	kg	7.00E-11	1.24E-10	9.69E-10
78	Acrolein	Air	kg	6.75E-06	1.23E-03	1.68E-05
79	Alachlor	Air	kg	0.00E+00	0.00E+00	1.86E-09
80	Aldehydes, unspecified	Air	kg	1.70E-04	2.60E-04	4.91E-04
81	Ammonia	Air	kg	5.47E-04	2.33E-03	3.04E-04
82	Ammonium chloride	Air	kg	3.36E-07	5.72E-05	4.80E-05
83	Anthracene	Air	kg	2.55E-11	3.47E-09	2.92E-09
84	Antimony	Air	kg	2.18E-09	2.97E-07	2.57E-07
85	Arsenic	Air	kg	6.71E-08	6.94E-06	5.99E-06
86	Ash	Air	kg	0.00E+00	0.00E+00	5.71E-06
87	Atrazine	Air	kg	0.00E+00	0.00E+00	3.69E-08
88	Barium	Air	kg	0.00E+00	0.00E+00	2.13E-07
89	Bentazone	Air	kg	0.00E+00	0.00E+00	1.50E-10
90	Benzene	Air	kg	6.83E-05	1.02E-04	1.02E-02
91	Benzene, chloro-	Air	kg	1.03E-10	1.82E-10	1.42E-09
92	Benzene, ethyl-	Air	kg	4.39E-10	2.99E-06	1.72E-07
93	Benzo(a)anthracene	Air	kg	9.70E-12	1.32E-09	1.11E-09
94	Benzo(a)pyrene	Air	kg	4.61E-12	6.28E-10	5.29E-10
95	Benzo(b,j,k)fluoranthene	Air	kg	1.33E-11	1.82E-09	1.53E-09
96	Benzo(g,h,i)perylene	Air	kg	3.27E-12	4.46E-10	3.76E-10
97	Benzo(ghi)perylene	Air	kg	0.00E+00	1.12E-13	7.73E-18
98	Benzyl chloride	Air	kg	3.27E-09	5.80E-09	4.52E-08
99	Beryllium	Air	kg	3.37E-09	3.70E-07	3.54E-07
100	Biphenyl	Air	kg	2.06E-10	2.81E-08	2.37E-08
101	Bromoform	Air	kg	1.82E-10	3.23E-10	2.52E-09
102	Bromoxynil	Air	kg	0.00E+00	0.00E+00	3.30E-10
103	BTEX (benzene, toluene, ethylbenzene, and xylene), unspecified ratio	Air	kg	3.50E-04	8.69E-03	9.58E-03
104	Butadiene	Air	kg	2.84E-06	1.12E-06	9.78E-08
105	Cadmium	Air	kg	1.71E-08	1.38E-06	1.31E-06
106	Carbofuran	Air	kg	0.00E+00	0.00E+00	2.82E-10
107	Carbon dioxide	Air	kg	6.04E-01	5.52E-02	5.70E-01
108	Carbon dioxide, biogenic	Air	kg	1.17E-02	2.61E+02	2.68E+00
109	Carbon dioxide, fossil	Air	kg	1.36E+01	1.60E+02	1.42E+02
110	Carbon disulfide	Air	kg	6.07E-10	1.08E-09	7.21E-08
111	Carbon monoxide	Air	kg	4.25E-05	3.51E-03	4.86E-02
112	Carbon monoxide, biogenic	Air	kg	0.00E+00	6.47E-01	3.41E-03
113	Carbon monoxide, fossil	Air	kg	1.22E-01	1.74E-01	2.40E-01
114	Chloride	Air	kg	8.96E-12	4.96E-10	4.04E-10
115	Chlorinated fluorocarbons and hydrochlorinated fluorocarbons, unspecified	Air	kg	0.00E+00	5.61E-10	2.37E-07
116	Chlorine	Air	kg	0.00E+00	6.69E-09	3.60E-06
117	Chloroform	Air	kg	2.75E-10	4.89E-10	3.81E-09

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
118	Chlorpyrifos	Air	kg	0.00E+00	0.00E+00	2.17E-09
119	Chromium	Air	kg	4.90E-08	4.98E-06	4.39E-06
120	Chromium VI	Air	kg	9.58E-09	1.30E-06	1.10E-06
121	Chrysene	Air	kg	1.21E-11	1.65E-09	1.39E-09
122	Cobalt	Air	kg	8.67E-08	1.93E-06	1.88E-06
123	Copper	Air	kg	8.89E-10	3.37E-08	1.07E-07
124	Cumene	Air	kg	2.47E-11	3.92E-05	1.48E-02
125	Cyanazine	Air	kg	0.00E+00	0.00E+00	3.25E-10
126	Cyanide	Air	kg	1.17E-08	2.07E-08	1.62E-07
127	Dicamba	Air	kg	0.00E+00	0.00E+00	1.92E-09
128	Dimethenamid	Air	kg	0.00E+00	0.00E+00	4.53E-09
129	Dimethyl ether	Air	kg	0.00E+00	2.84E-07	1.07E-04
130	Dinitrogen monoxide	Air	kg	3.55E-03	1.07E-03	2.42E-03
131	Dioxin, 2,3,7,8 tetrachlorodibenzo-p-	Air	kg	2.83E-13	1.39E-11	1.47E-09
132	Dioxins (unspec.)	Air	kg	0.00E+00	0.00E+00	3.53E-15
133	Dioxins, measured as 2,3,7,8-tetrachlorodibenzo-p-dioxin	Air	kg	0.00E+00	0.00E+00	3.55E-19
134	Dipropylthiocarbamic acid S-ethyl ester	Air	kg	0.00E+00	0.00E+00	3.10E-09
135	Ethane, 1,1,1-trichloro-, HCFC-140	Air	kg	4.86E-10	7.30E-10	2.39E-09
136	Ethane, 1,2-dibromo-	Air	kg	5.60E-12	1.01E-11	7.75E-11
137	Ethane, 1,2-dichloro-	Air	kg	1.87E-10	3.32E-10	2.58E-09
138	Ethane, chloro-	Air	kg	1.96E-10	3.48E-10	2.71E-09
139	Ethene, tetrachloro-	Air	kg	6.17E-09	7.16E-07	6.13E-07
140	Ethene, trichloro-	Air	kg	0.00E+00	0.00E+00	6.13E-14
141	Ethylene oxide	Air	kg	0.00E+00	1.17E-08	3.24E-10
142	Fluoranthene	Air	kg	8.61E-11	1.17E-08	9.88E-09
143	Fluorene	Air	kg	1.10E-10	1.50E-08	1.27E-08
144	Fluoride	Air	kg	7.03E-06	1.66E-06	4.02E-06
145	Formaldehyde	Air	kg	8.65E-05	1.33E-02	3.15E-03
146	Furan	Air	kg	5.31E-13	8.09E-11	6.79E-11
147	Glyphosate	Air	kg	0.00E+00	0.00E+00	4.07E-09
148	HAPs	Air	kg	0.00E+00	9.16E-04	5.64E-06
149	Heat, waste	Air	MJ	0.00E+00	5.69E-01	1.55E+01
150	Hexane	Air	kg	3.13E-10	5.55E-10	1.51E-07
151	Hydrazine, methyl-	Air	kg	7.93E-10	1.41E-09	1.10E-08
152	Hydrocarbons, unspecified	Air	kg	1.94E-06	3.30E-04	2.77E-04
153	Hydrogen	Air	kg	0.00E+00	2.08E-08	7.82E-06
154	Hydrogen chloride	Air	kg	1.52E-04	2.00E-02	1.68E-02
155	Hydrogen fluoride	Air	kg	1.80E-05	2.48E-03	2.08E-03
156	Hydrogen sulfide	Air	kg	2.89E-13	1.60E-11	1.31E-11
157	Indeno(1,2,3-cd)pyrene	Air	kg	7.40E-12	1.01E-09	8.49E-10
158	Iron	Air	kg	0.00E+00	0.00E+00	2.13E-07
159	Isophorone	Air	kg	2.71E-09	4.81E-09	3.75E-08
160	Isoprene	Air	kg	2.94E-04	1.63E-02	1.32E-02
161	Kerosene	Air	kg	1.61E-07	2.74E-05	2.30E-05
162	Lead	Air	kg	8.85E-08	3.28E-05	6.91E-06
163	Magnesium	Air	kg	1.33E-06	1.82E-04	1.53E-04
164	Manganese	Air	kg	9.85E-08	8.42E-06	9.96E-06
165	Mercaptans, unspecified	Air	kg	1.01E-06	1.78E-06	1.40E-05
166	Mercury	Air	kg	1.89E-08	1.79E-06	1.82E-06
167	Metals, unspecified	Air	kg	3.32E-14	1.84E-12	3.73E-05
168	Methane	Air	kg	2.84E-02	4.62E-01	4.93E-01
169	Methane, biogenic	Air	kg	0.00E+00	3.25E-03	2.00E-05
170	Methane, bromo-, Halon 1001	Air	kg	7.47E-10	1.33E-09	1.03E-08
171	Methane, chlorodifluoro-, HCFC-22	Air	kg	0.00E+00	9.74E-14	2.69E-15
172	Methane, chlorotrifluoro-, CFC-13	Air	kg	0.00E+00	9.25E-13	2.56E-14
173	Methane, dichloro-, HCC-30	Air	kg	9.93E-08	5.16E-06	5.22E-06
174	Methane, dichlorodifluoro-, CFC-12	Air	kg	4.86E-10	6.97E-10	1.36E-09
175	Methane, fossil	Air	kg	2.89E-03	5.18E-02	5.57E-02
176	Methane, monochloro-, R-40	Air	kg	2.47E-09	4.39E-09	3.42E-08
177	Methane, tetrachloro-, CFC-10	Air	kg	4.86E-11	6.55E-10	2.21E-07
178	Methanol	Air	kg	0.00E+00	2.69E-02	6.23E-02
179	Methyl ethyl ketone	Air	kg	1.82E-09	3.23E-09	2.52E-08

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
180	Methyl methacrylate	Air	kg	9.34E-11	1.66E-10	1.29E-09
181	Metolachlor	Air	kg	0.00E+00	0.00E+00	1.50E-08
182	Metribuzin	Air	kg	0.00E+00	0.00E+00	6.93E-11
183	N-Nitrodimethylamine	Air	kg	0.00E+00	0.00E+00	2.99E-04
184	Naphthalene	Air	kg	1.85E-08	9.08E-06	8.05E-07
185	Nickel	Air	kg	1.09E-06	9.00E-06	1.12E-05
186	Nitrogen oxides	Air	kg	2.44E-01	6.73E-01	3.87E-01
187	Nitrogen, total	Air	kg	1.37E-04	0.00E+00	1.20E-06
188	NMVOC, nonmethane volatile organic compounds, unspecified origin	Air	kg	8.27E-03	1.48E-02	5.00E-02
189	Organic acids	Air	kg	1.24E-09	2.10E-07	1.77E-07
190	Organic substances, unspecified	Air	kg	7.52E-07	6.66E-04	1.03E-04
191	Other organic	Air	kg	0.00E+00	3.08E-05	1.90E-07
192	PAH, polycyclic aromatic hydrocarbons	Air	kg	1.22E-05	4.61E-06	3.50E-07
193	Paraquat	Air	kg	0.00E+00	0.00E+00	3.03E-10
194	Parathion, methyl	Air	kg	0.00E+00	0.00E+00	2.29E-10
195	Particulates	Air	kg	0.00E+00	1.39E-07	5.23E-05
196	Particulates, < 10 um	Air	kg	0.00E+00	1.33E-01	8.92E-02
197	Particulates, < 2.5 um	Air	kg	0.00E+00	6.92E-02	8.93E-02
198	Particulates, > 10 um	Air	kg	0.00E+00	3.72E-04	6.99E-04
199	Particulates, > 2.5 um and < 10 um	Air	kg	7.48E-03	1.20E-02	1.01E-02
200	Particulates, unspecified	Air	kg	1.70E-03	5.69E-02	1.36E-01
201	Pendimethalin	Air	kg	0.00E+00	0.00E+00	1.56E-09
202	Permethrin	Air	kg	0.00E+00	0.00E+00	1.40E-10
203	Phenanthrene	Air	kg	3.27E-10	4.46E-08	3.76E-08
204	Phenol	Air	kg	7.47E-11	1.72E-03	1.01E-04
205	Phenols, unspecified	Air	kg	5.03E-08	5.46E-07	9.67E-07
206	Phorate	Air	kg	0.00E+00	0.00E+00	7.17E-11
207	Phosphate	Air	kg	3.12E-06	0.00E+00	2.72E-08
208	Phthalate, dioctyl-	Air	kg	3.41E-10	6.05E-10	4.72E-09
209	Polycyclic organic matter, unspecified	Air	kg	0.00E+00	2.35E-12	6.50E-14
210	Potassium	Air	kg	0.00E+00	0.00E+00	3.78E-05
211	Propanal	Air	kg	1.77E-09	7.51E-06	3.83E-03
212	Propene	Air	kg	1.87E-04	8.55E-05	5.46E-03
213	Propylene oxide	Air	kg	0.00E+00	2.71E-06	1.50E-07
214	Pyrene	Air	kg	4.00E-11	5.45E-09	4.59E-09
215	Radioactive species, unspecified	Air	Bq	6.61E+03	9.34E+05	7.84E+05
216	Radionuclides (including radon)	Air	kg	9.01E-06	1.53E-03	1.29E-03
217	Selenium	Air	kg	1.68E-07	2.16E-05	1.84E-05
218	Simazine	Air	kg	0.00E+00	0.00E+00	9.82E-10
219	Sodium	Air	kg	0.00E+00	0.00E+00	8.72E-07
220	Styrene	Air	kg	1.17E-10	2.07E-10	1.62E-09
221	Sulfur	Air	kg	0.00E+00	0.00E+00	4.60E-06
222	Sulfur dioxide	Air	kg	3.13E-02	1.13E+00	1.11E+00
223	Sulfur monoxide	Air	kg	1.35E-02	2.25E-02	5.36E-03
224	Sulfur oxides	Air	kg	1.54E-04	1.06E-03	3.69E-02
225	Sulfur, total reduced	Air	kg	0.00E+00	0.00E+00	2.70E-06
226	Sulfuric acid, dimethyl ester	Air	kg	2.24E-10	3.98E-10	3.10E-09
227	t-butyl methyl ether	Air	kg	1.63E-10	2.90E-10	2.26E-09
228	Tar	Air	kg	1.01E-11	5.58E-10	4.54E-10
229	Terbufos	Air	kg	0.00E+00	0.00E+00	2.45E-09
230	TOC	Air	kg	0.00E+00	0.00E+00	3.56E-06
231	Toluene	Air	kg	2.97E-05	2.34E-05	1.69E-06
232	Toluene, 2,4-dinitro-	Air	kg	1.31E-12	2.32E-12	1.81E-11
233	Trichloroethane	Air	kg	0.00E+00	0.00E+00	2.00E-08
234	Vinyl acetate	Air	kg	3.55E-11	6.30E-11	4.91E-10
235	VOC	Air	kg	7.17E-03	3.17E-01	3.72E-01
236	Wood (dust)	Air	kg	0.00E+00	1.80E-01	8.38E-04
237	Xylene	Air	kg	2.07E-05	1.38E-05	1.03E-06
238	Zinc	Air	kg	2.52E-06	2.25E-08	3.52E-07
239	2-hexanone	Water	kg	1.27E-07	8.69E-07	1.08E-06
240	2-methyl-4-chlorophenoxyacetic acid	Water	kg	0.00E+00	0.00E+00	1.09E-12
241	2-propanol	Water	kg	0.00E+00	0.00E+00	2.53E-09

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
242	2,4-D	Water	kg	0.00E+00	0.00E+00	5.85E-11
243	4-methyl-2-pentanone	Water	kg	8.15E-08	5.59E-07	6.93E-07
244	Acetaldehyde	Water	kg	0.00E+00	1.23E-08	3.41E-10
245	Acetochlor	Water	kg	0.00E+00	0.00E+00	8.11E-10
246	Acetone	Water	kg	1.94E-07	1.33E-06	1.65E-06
247	Acid as H+	Water	kg	0.00E+00	0.00E+00	1.55E-05
248	Acidity, unspecified	Water	kg	0.00E+00	0.00E+00	5.65E-15
249	Acids, unspecified	Water	kg	1.88E-10	1.04E-08	3.61E-06
250	Alachlor	Water	kg	0.00E+00	0.00E+00	7.98E-11
251	Aluminium	Water	kg	1.42E-03	4.42E-03	6.40E-03
252	Aluminum	Water	kg	0.00E+00	0.00E+00	1.02E-05
253	Ammonia	Water	kg	3.39E-04	1.83E-03	2.33E-03
254	Ammonia, as N	Water	kg	9.45E-11	5.23E-09	4.26E-09
255	Ammonium, ion	Water	kg	7.19E-08	1.79E-04	1.13E-05
256	Antimony	Water	kg	8.85E-07	2.45E-06	3.72E-06
257	Arsenic	Water	kg	1.10E-05	3.08E-05	3.91E-05
258	Arsenic, ion	Water	kg	0.00E+00	1.82E-07	1.25E-11
259	Atrazine	Water	kg	0.00E+00	0.00E+00	1.58E-09
260	Barium	Water	kg	1.96E-02	5.80E-02	8.62E-02
261	Bentazone	Water	kg	0.00E+00	0.00E+00	6.45E-12
262	Benzene	Water	kg	3.25E-05	2.88E-04	2.45E-02
263	Benzene, 1-methyl-4-(1-methylethyl)-	Water	kg	1.94E-09	1.33E-08	1.65E-08
264	Benzene, ethyl-	Water	kg	1.83E-06	1.26E-05	1.56E-05
265	Benzene, pentamethyl-	Water	kg	1.45E-09	9.98E-09	1.24E-08
266	Benzenes, alkylated, unspecified	Water	kg	7.76E-07	2.15E-06	3.26E-06
267	Benzo(a)pyrene	Water	kg	0.00E+00	0.00E+00	3.03E-14
268	Benzoic acid	Water	kg	1.97E-05	1.35E-04	1.67E-04
269	Beryllium	Water	kg	2.76E-07	1.45E-06	1.88E-06
270	Biphenyl	Water	kg	5.03E-08	1.39E-07	2.11E-07
271	BOD5	Water	kg	3.51E-03	2.43E-02	2.57E-01
272	Boron	Water	kg	6.09E-05	4.18E-04	5.17E-04
273	Bromide	Water	kg	4.16E-03	2.85E-02	3.53E-02
274	Bromoxynil	Water	kg	0.00E+00	0.00E+00	8.53E-12
275	Cadmium	Water	kg	2.70E-06	4.63E-06	5.84E-06
276	Cadmium, ion	Water	kg	0.00E+00	2.69E-08	3.04E-11
277	Calcium	Water	kg	6.23E-02	4.26E-01	5.30E-01
278	Calcium, ion	Water	kg	0.00E+00	2.14E-03	1.47E-07
279	Carbofuran	Water	kg	0.00E+00	0.00E+00	1.21E-11
280	CFCs, unspecified	Water	kg	0.00E+00	0.00E+00	2.53E-09
281	Chloride	Water	kg	7.00E-01	4.81E+00	5.95E+00
282	Chlorpyrifos	Water	kg	0.00E+00	0.00E+00	9.30E-11
283	Chromate	Water	kg	0.00E+00	0.00E+00	3.38E-13
284	Chromium	Water	kg	4.44E-05	6.13E-05	1.53E-04
285	Chromium III	Water	kg	4.55E-06	4.96E-05	1.59E-05
286	Chromium VI	Water	kg	1.50E-07	2.15E-07	4.20E-07
287	Chromium, ion	Water	kg	0.00E+00	1.14E-07	7.84E-12
288	Cobalt	Water	kg	4.30E-07	2.95E-06	3.65E-06
289	COD	Water	kg	6.51E-03	4.04E-02	2.82E-01
290	Copper	Water	kg	9.08E-06	3.30E-05	3.90E-05
291	Copper, ion	Water	kg	0.00E+00	1.89E-07	1.30E-11
292	Cumene	Water	kg	0.00E+00	9.43E-05	3.56E-02
293	Cyanazine	Water	kg	0.00E+00	0.00E+00	1.39E-11
294	Cyanide	Water	kg	1.40E-09	9.64E-09	1.20E-08
295	Decane	Water	kg	5.65E-07	3.88E-06	4.81E-06
296	Detergent, oil	Water	kg	1.69E-05	1.29E-04	1.57E-04
297	Dibenzofuran	Water	kg	3.69E-09	2.53E-08	3.13E-08
298	Dibenzothiophene	Water	kg	3.14E-09	2.09E-08	2.60E-08
299	Dicamba	Water	kg	0.00E+00	0.00E+00	8.21E-11
300	Dimethenamid	Water	kg	0.00E+00	0.00E+00	1.94E-10
301	Dipropylthiocarbamic acid S-ethyl ester	Water	kg	0.00E+00	0.00E+00	8.01E-11
302	Dissolved organics	Water	kg	0.00E+00	0.00E+00	9.89E-06
303	Disulfoton	Water	kg	0.00E+00	0.00E+00	4.79E-12
304	Diuron	Water	kg	0.00E+00	0.00E+00	1.34E-12

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
305	DOC	Water	kg	5.78E-13	1.74E-04	6.56E-02
306	Docosane	Water	kg	2.08E-08	1.42E-07	1.76E-07
307	Dodecane	Water	kg	1.07E-06	7.36E-06	9.12E-06
308	Eicosane	Water	kg	2.95E-07	2.03E-06	2.51E-06
309	Fluorene	Water	kg	0.00E+00	2.31E-13	6.37E-15
310	Fluorene, 1-methyl-	Water	kg	2.21E-09	1.51E-08	1.88E-08
311	Fluorenes, alkylated, unspecified	Water	kg	4.50E-08	1.25E-07	1.89E-07
312	Fluoride	Water	kg	1.73E-02	1.99E-04	3.19E-04
313	Fluorine	Water	kg	2.25E-08	6.90E-08	1.01E-07
314	Furan	Water	kg	0.00E+00	0.00E+00	9.29E-11
315	Glyphosate	Water	kg	0.00E+00	0.00E+00	1.74E-10
316	Hexadecane	Water	kg	1.17E-06	8.03E-06	9.95E-06
317	Hexanoic acid	Water	kg	4.07E-06	2.80E-05	3.46E-05
318	Hydrocarbons, unspecified	Water	kg	7.23E-13	4.00E-11	9.30E-08
319	Iron	Water	kg	2.91E-03	1.13E-02	1.54E-02
320	Lead	Water	kg	1.31E-05	4.96E-05	6.50E-05
321	Lead-210/kg	Water	kg	2.02E-15	1.38E-14	1.71E-14
322	Lithium	Water	kg	4.85E-03	1.20E-01	1.32E-01
323	Lithium, ion	Water	kg	0.00E+00	3.40E-05	2.34E-09
324	m-xylene	Water	kg	5.88E-07	4.03E-06	4.99E-06
325	Magnesium	Water	kg	1.22E-02	8.36E-02	1.04E-01
326	Manganese	Water	kg	2.16E-05	4.60E-04	4.40E-04
327	Mercury	Water	kg	1.03E-07	5.88E-08	8.03E-08
328	Metallic ions, unspecified	Water	kg	8.82E-12	4.89E-10	2.44E-09
329	Methane, monochloro-, R-40	Water	kg	7.81E-10	5.36E-09	6.64E-09
330	Methyl ethyl ketone	Water	kg	1.56E-09	1.07E-08	1.33E-08
331	Metolachlor	Water	kg	0.00E+00	0.00E+00	6.41E-10
332	Metribuzin	Water	kg	0.00E+00	0.00E+00	2.97E-12
333	Molybdenum	Water	kg	4.46E-07	3.06E-06	3.79E-06
334	n-hexacosane	Water	kg	1.29E-08	8.89E-08	1.10E-07
335	Naphthalene	Water	kg	3.53E-07	2.42E-06	3.00E-06
336	Naphthalene, 2-methyl-	Water	kg	3.07E-07	2.11E-06	2.61E-06
337	Naphthalenes, alkylated, unspecified	Water	kg	1.27E-08	3.52E-08	5.34E-08
338	Nickel	Water	kg	7.80E-06	2.54E-05	3.30E-05
339	Nickel, ion	Water	kg	0.00E+00	0.00E+00	2.94E-13
340	Nitrate	Water	kg	6.33E-14	3.51E-12	3.01E-07
341	Nitrate compounds	Water	kg	2.55E-12	1.41E-10	1.15E-10
342	Nitric acid	Water	kg	5.72E-09	3.17E-07	2.58E-07
343	Nitrogen, total	Water	kg	1.79E-07	3.05E-05	3.60E-05
344	o-cresol	Water	kg	5.58E-07	3.83E-06	4.74E-06
345	o-xylene	Water	kg	0.00E+00	4.90E-13	1.35E-14
346	Octadecane	Water	kg	2.89E-07	1.99E-06	2.46E-06
347	Oils, unspecified	Water	kg	4.33E-04	2.74E-03	3.48E-03
348	Organic substances, unspecified	Water	kg	0.00E+00	0.00E+00	1.85E-09
349	p-cresol	Water	kg	6.02E-07	4.13E-06	5.12E-06
350	p-xylene	Water	kg	0.00E+00	4.90E-13	1.35E-14
351	Paraquat	Water	kg	0.00E+00	0.00E+00	1.30E-11
352	Parathion, methyl	Water	kg	0.00E+00	0.00E+00	9.80E-12
353	Pendimethalin	Water	kg	0.00E+00	0.00E+00	6.67E-11
354	Permethrin	Water	kg	0.00E+00	0.00E+00	5.99E-12
355	Phenanthrene	Water	kg	4.82E-09	2.04E-08	2.77E-08
356	Phenanthrenes, alkylated, unspecified	Water	kg	5.27E-09	1.46E-08	2.21E-08
357	Phenol	Water	kg	6.63E-06	9.52E-06	1.89E-05
358	Phenol, 2,4-dimethyl-	Water	kg	5.43E-07	3.73E-06	4.62E-06
359	Phenols, unspecified	Water	kg	2.95E-06	5.13E-05	5.82E-05
360	Phorate	Water	kg	0.00E+00	0.00E+00	1.85E-12
361	Phosphate	Water	kg	1.30E-02	0.00E+00	1.37E-04
362	Phosphorus	Water	kg	0.00E+00	0.00E+00	5.19E-06
363	Phosphorus compounds, unspecified	Water	kg	0.00E+00	0.00E+00	3.43E-08
364	Phosphorus, total	Water	kg	0.00E+00	0.00E+00	3.07E-06
365	Process solvents, unspecified	Water	kg	0.00E+00	0.00E+00	9.29E-09
366	Propene	Water	kg	0.00E+00	3.47E-05	1.31E-02
367	Radioactive species, nuclides, unspecified	Water	Bq	1.04E+01	1.78E+03	1.49E+03

No	Substance	Compart-ment	Unit	Forest operations, US SE	Dry veneer, at LVL, US SE	LVL, at LVL plant, SE
368	Radium-226/kg	Water	kg	7.01E-13	4.81E-12	5.96E-12
369	Radium-228/kg	Water	kg	3.59E-15	2.46E-14	3.05E-14
370	Selenium	Water	kg	1.97E-07	4.76E-06	4.32E-06
371	Silver	Water	kg	4.07E-05	2.79E-04	3.46E-04
372	Simazine	Water	kg	0.00E+00	0.00E+00	4.21E-11
373	Sodium	Water	kg	1.98E-01	1.35E+00	1.68E+00
374	Sodium, ion	Water	kg	0.00E+00	6.77E-03	4.66E-07
375	Solids, inorganic	Water	kg	1.45E-11	8.06E-10	6.56E-10
376	Solved solids	Water	kg	0.00E+00	2.96E-02	4.10E-04
377	Strontium	Water	kg	1.06E-03	7.26E-03	8.99E-03
378	Styrene	Water	kg	0.00E+00	1.27E-12	4.54E-10
379	Sulfate	Water	kg	1.56E-03	3.46E-02	3.29E-02
380	Sulfide	Water	kg	7.70E-07	1.12E-06	3.64E-05
381	Sulfur	Water	kg	5.14E-05	3.53E-04	4.37E-04
382	Sulfuric acid	Water	kg	0.00E+00	0.00E+00	8.14E-11
383	Surfactants	Water	kg	0.00E+00	2.27E-11	6.27E-13
384	Suspended solids, unspecified	Water	kg	9.08E-01	6.04E+00	7.60E+00
385	Tar	Water	kg	1.44E-13	7.98E-12	6.50E-12
386	Terbufos	Water	kg	0.00E+00	0.00E+00	6.32E-11
387	Tetradecane	Water	kg	4.70E-07	3.23E-06	4.00E-06
388	Thallium	Water	kg	1.86E-07	5.18E-07	7.85E-07
389	Tin	Water	kg	3.84E-06	1.71E-05	2.29E-05
390	Titanium	Water	kg	1.36E-05	3.71E-05	5.71E-05
391	Titanium, ion	Water	kg	0.00E+00	5.51E-07	3.79E-11
392	TOC	Water	kg	0.00E+00	1.74E-04	6.56E-02
393	Toluene	Water	kg	3.07E-05	2.11E-04	2.62E-04
394	Vanadium	Water	kg	5.27E-07	3.61E-06	4.48E-06
395	Waste water/m^3	Water	m^3	0.00E+00	0.00E+00	7.66E-04
396	Xylene	Water	kg	1.64E-05	1.10E-04	1.37E-04
397	Yttrium	Water	kg	1.31E-07	8.97E-07	1.11E-06
398	Zinc	Water	kg	3.31E-05	1.18E-04	1.63E-04
399	Zinc, ion	Water	kg	0.00E+00	0.00E+00	4.10E-07
400	Waste in inert landfill	Waste	kg	0.00E+00	0.00E+00	4.65E+00
401	Waste to recycling	Waste	kg	0.00E+00	0.00E+00	3.07E+00
402	Waste, solid	Waste	kg	0.00E+00	0.00E+00	1.09E-02

20 APPENDIX F: PRODUCTION FACILITY SURVEY QUESTIONNAIRES

CORRIM SURVEY

The Consortium for Research on Renewable Industrial Materials (CORRIM)

Laminated Veneer Lumber (LVL) and Composite I-Joist Plants
2014

The information from this survey will be used in a project by CORRIM, a consortium of universities, industry, and government groups. In collaboration with the USDA Forest Service Forest Products Laboratory, APA-The Engineered Wood Association, and the American Wood Council, CORRIM is updating life-cycle assessment data that describes environmental impacts of building materials. This CORRIM survey is designed specifically for LVL and composite I-joist plants. There are three sections for this survey. The three sections are the LVL plant (pg. 3-11), the veneer mill (pg. 12-19), and the I-joist plant (pg. 20-29). Please complete the section(s) that apply to your facilities. Emission data are requested for each section.

Questions will be concentrated on **annual production**, electricity production and usage, fuel consumption, material flows, and environmental emissions. We realize that you may not have all the information requested, especially when it comes to specific equipment/processing groups or what we call 'machine centers'. The data you are able to provide will be appreciated.

Your data will be confidential; only weight-averaged values based on production for the industry will be reported.

Company: ______________________________

Facility Site (city, state): ______________________________

Should we have a follow-up question about the data, please provide the name and the following information for the contact in your company.

Name: ____________________ Title: ____________________

Telephone: ____________________ Email: ____________________

Please send the complete survey to the following email or address by March 3rd. If you have questions about the survey, contact:

Rick Bergman
Research Forest Products Technologist,
USDA Forest Service Forest Products Laboratory
One Gifford Pinchot Dr,
Madison, WI 53726-2398
(608) 231-9477 (ph) / (608) 231-9508 (fax)
rbergman@fs.fed.us

General Plant Information

Yes	No	Equipment in mill
O	O	Veneer dryer (for redry)
O	O	conventional steam, #: _________
O	O	high temp (>212F) steam # _____
O	O	direct fire, # ___________
O	O	continuous, # ___________
O	O	other:____________________
O	O	Hot pressing
O	O	Hot press(es), #_____________
		year built or updated:_______
O	O	heating system
O	O	hot oil (fired by nat. gas)
O	O	microwave
O	O	radio-frequency
		pressure (psig) ________
		temperature (°F) ________
		press time (min:sec) ________
O	O	Precipitator
O	O	Bag house
O	O	Other pollution controls?
O	O	Layup of LVL billets
O	O	Resin
O	O	phenol-formaldehyde
O	O	other ___________
O	O	other ___________
		Inputs
O	O	PLV
O	O	veneer
O	O	Sawing/trimming of LVL
O	O	Resaw
O	O	Rip saw
O	O	In-line moisture meter
O	O	Automatic grading (visual grades)
O	O	Manual grading (visual grades)
O	O	Machine grading (MSR grades)
O	O	End Trim
O	O	Wrap LVL, material ____________
O	O	Steel strapping
O	O	Plastic strapping
O	O	Cardboard corners
O	O	other:___________________
O	O	other:___________________
O	O	other:___________________
O	O	Bag house
O	O	Other pollution control

Yes	No	Equipment in mill (continued)
O	O	Boiler / cogen
O	O	wood boiler(s), #_______
O	O	gas boiler(s), #_________
O	O	oil boiler(s), #_________
O	O	propane boiler(s), #_________
O	O	Cogeneration unit
O	O	Bag house
O	O	Other pollution control?
O	O	Precipitator
O	O	other:_____________
O	O	other:___________________
O	O	other:___________________
O	O	Buy steam
O	O	Sell electricity
O	O	Routing/shaping of web and flanges
O	O	Router(s), # ___________
		Flanges
O	O	LSL
O	O	LVL
O	O	Lumber
O	O	Lumber (finger-jointed)
O	O	Assembly of I-joist
O	O	Resin
O	O	phenol-resorcinol-formaldehyde
O	O	emulsified polyurethane
O	O	other ______________________
		% MC (dry basis) ___________
O	O	Sawing/curing of I-joists
O	O	Ripsaw
O	O	Oven(s), # ___________
		Fuel source_______________
O	O	Wrap LVL, material ____________
O	O	Steel strapping
O	O	Plastic strapping
O	O	Cardboard corners
O	O	other:___________________
O	O	Bag house
O	O	Other pollution control

LVL Plant Annual Wood Production Data

Reporting year __________ **Starting month** ___________ **Ending month** ______________

LVL Annual Production			
(Please provide units of measurement if different than stated)			Total Production
1.	Annual LVL production, 2012	ft^3	
	Annual LVL production, 2012	MSF 3/8 in. basis	
	Annual LVL production, 2012	Tons (%MC)	
2.	Veneer		
	a. Produced Veneer:		
	i. Used in Mill	MSF 3/8 in. basis	
	ii. Sold	MSF 3/8 in. basis	
	b. Purchased Veneer:		
	i. Dry	MSF 3/8 in. basis	
	ii. Green	MSF 3/8 in. basis	
	c. Sold Veneer		
	i. Dry	MSF 3/8 in. basis	
	ii. Green	MSF 3/8 in. basis	
	d. Purchased Parallel Laminated Veneer (PLV)	MSF 3/8 in. basis	

Transportation method(s) and average delivery distance for purchased veneer				
	Truck (% of total)		Average delivery miles	
	Rail (% of total)		Average delivery miles	
	Other (% of total)		Average delivery miles	
	Total (%)	100%		
Transportation method(s) and average delivery distance for purchased PLV				
	Truck (% of total)		Average delivery miles	
	Rail (% of total)		Average delivery miles	
	Other (% of total)		Average delivery miles	
	Total (%)	100%		

3. If you either peel/dry or dry veneer on-site, please be sure to complete the next section on veneer mills.

LVL Plant Annual Power and Fuel Consumption

If you have completed a 2012 Annual Fuel and Energy Survey for AF&PA, you may want to attach the survey and skip to the next section entitled “Other Annual Production.” The first section refers to energy generation (non-transport fuel). (Please provide units of measurement if different)

Fuel	Unit	Quantity
Purchased electricity	kWh	
Purchased steam	lbs (°F)	
Wood Fuel *Self-generated*	Tons / (%MC)	/
Wood Fuel *Purchased*	Tons / (%MC)	/
Natural Gas	1000 ft^3	
Kerosene (fuel oil #1)	Gallons	
Fuel oil #2	Gallons	
Residual fuel oil #6 (Bunker C)	Gallons	
Diesel	Gallons	
Gasoline	Gallons	
Liquid Propane Gas	Gallons	
Total electricity for LVL plant	kWh	

If your facility produces any of the following for use on-site or for sale, please fill out the table. Enter N/A if not applicable.

Energy	Unit	Quantity (used on-site)	Quantity (sold off-site)
Electricity	kWh		
Steam	lbs (°F)		

If your facility has a boiler, please provide the following. Otherwise, enter N/A as applicable.

Boiler	Boiler size (million BTU/hr)	Boiler fuel	Boiler fuel unit	Quantity	Electricity to operate boiler (kWh)
#1					
#2					
#3					
#4					

LVL Plant Annual Transportation Fuel Use On-site

(includes all fuels for yard equipment, forklifts, and carriers)

Type	Total Quantity	Percent of total by unit process (percentage or volume)						Units
		Veneer / PLV prep	Layup	Boiler	Hot press	Saw/ trimmer	Support vehicles	
Off-road diesel								Gallons
On-road diesel								Gallons
Propane								Gallons
Gasoline								Gallons
Electricity								kWh
Other								

Other LVL Plant Annual Use Data

Formulation and usage of resin, fillers, and other components		
Component Type	Percent of Solid by Weight (range is ok)	Total annual use (lbs.)
Phenol formaldehyde		
Extender and filler		
Catalyst (NaOH)		
Water		
Other (please specify)		
Other (please specify)		

Transportation method and distance for resin			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Transportation method and distance for extender and filler			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Transportation method and distance for catalysts			
Truck (% of total)		Average delivery miles	

Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Source of Heat for Press: direct or in-direct (circle one)			
Thermal Fluid (Hot Oil) heated by	Units		
Natural Gas	1000 ft^3		
Electricity	kWh		
Steam	lbs		
Radio Frequency	kWh		
Microwave Frequency	kWh		
Other	?		

LVL Plant Annual Wood Residue Production

Wood residues are any wood material produced in conjunction with making LVL and are called co-products in this survey. For each of the co-products produced at your plant, please indicate the weight (tons) of **annual** wood residue production for the reporting period that are shipped to other users, used internally as fuel or for the production of another co-product at your facility, stockpiled for future use or land filled (estimates are acceptable). If zero, enter a dash (-). Please state units if other than tons like cubic yards. The final column (Total Quantity) should equal the sum of the individual rows.

Estimate amount of wood residue produced per Msf of LVL ___________tons/Msf LVL

Wood residue	Moisture Content (wet basis) (%)	Sold (Shipped) tons	Used Internally (as fuel) tons	Used Internally (other uses) tons	Landfill tons	Inventory tons	Total Quantity Tons
Veneer loss							
PLV loss							
Lay-up scrap							
Panel trim							
Sawdust (sawing and trimming)							
Sawdust (rip saw)							
Tested LVL, used							
Other							

LVL Plant Ancillary Material Inputs

Ancillary Material	Used		Amount	How amount was found? Mark one[1]		Where the ancillary material is emitted as a percent (estimation is ok)					
	Yes	No		M	E	Veneer / PLV prep	Layup	Boiler	Hot press	Saw/ trimmer	Comments
Hydraulic fluids	O	O	lb/yr	O	O	%	%	%	%	%	
Greases	O	O	lb/yr	O	O	%	%	%	%	%	
Motor Oil	O	O	lb/yr	O	O	%	%	%	%	%	
Plastic wrapping	O	O	lb/yr	O	O	%	%	%	%	%	
Cardboard packaging	O	O	lb/yr	O	O	%	%	%	%	%	
Steel strapping	O	O	lb/yr	O	O	%	%	%	%	%	
Plastic strapping	O	O	lb/yr	O	O	%	%	%	%	%	
Potable water	O	O	gal/yr	O	O	%	%	%	%	%	
Paints	O	O	lb/yr	O	O	%	%	%	%	%	
Waxes	O	O	lb/yr	O	O	%	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	%	

[1] Estimated (E) / Measured (M)

LVL Plant Air Emissions

If air emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached □

Substance	Emit		Amount	How amount was found?[1]			Sampling method or source[2]	Where the substance is emitted as a percent (estimation is ok)				
	Yes	No		M	E	PV		Veneer / PLV prep	Layup	Boiler	Hot press	Saw/ trimmer
Dust	O	O	lb/yr	O	O	O		%	%	%	%	%
Particulate	O	O	lb/yr	O	O	O		%	%	%	%	%
Particulate, PM10[3]	O	O	lb/yr	O	O	O		%	%	%	%	%
Particulate, PM2.5[4]	O	O	lb/yr	O	O	O		%	%	%	%	%
VOC	O	O	lb/yr	O	O	O		%	%	%	%	%
Sulfur dioxide	O	O	lb/yr	O	O	O		%	%	%	%	%
Carbon monoxide	O	O	lb/yr	O	O	O		%	%	%	%	%
Nitrous oxide	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Total	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Methanol	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Formaldehyde	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Acetaldehyde	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Propionaldehyde	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Acrolein	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Phenol	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: Acetone	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: ____________	O	O	lb/yr	O	O	O		%	%	%	%	%
HAP: ____________	O	O	lb/yr	O	O	O		%	%	%	%	%
Other organic[5]: _______	O	O	lb/yr	O	O	O		%	%	%	%	%
Other inorganic[6]: _____	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: _______________	O	O	lb/yr	O	O	O		%	%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement

[2] Sampling methods might be Method 25A, Method 5, NCASI 105. Estimates might be based on AP42, Standard Air Contaminate Discharge Permit or other source.

[3] PM10 is particulate matter up to 10 micrometers in size

[4] PM2.5 is particulate matter up to 2.5 micrometers in size

[5] Non-HAP organics that are not included in VOC value.

[6] Inorganics such as chlorine, mercury sulfur.

LVL Plant Water Emissions

If water emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached □

Substance	Emit		Amount[2]	How amount was found Mark one[3]			Sampling method or source[1]	Where the substance is emitted as a percent (estimation is ok)				
	Yes	No		M	E	PV		Veneer / PLV prep	Layup	Boiler	Hot press	Saw/ trimmer
Suspended solids	O	O	lb/yr	O	O	O		%	%	%	%	%
BOD	O	O	lb/yr	O	O	O		%	%	%	%	%
COD	O	O	lb/yr	O	O	O		%	%	%	%	%
Oil and grease	O	O	lb/yr	O	O	O		%	%	%	%	%
HAPs	O	O	lb/yr	O	O	O		%	%	%	%	%
Chemicals in boiler blowdown (if not included above)	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%	%

[1] Sampling methods is type of water test or how estimate was obtained.

[2] Report the mass of material, not the mass of material and water.

[3] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.

LVL Plant Solid Waste Production

If annual solid waste summary is available, please provide as an alternative to the following table. Check here if summary is attached ☐

Material	Amount[2] (lb/yr)	Where material is going? Landfill (L) or recycled (R) Mark one	How amount was found? Mark one[1]			Where the solid waste is emitted as a percent (estimation is ok)				
			M	E	PV	Veneer / LVL prep	Layup	Boiler	Hot press	Saw/ trimmer
Discarded Wood		L / R	O	O	O	%	%	%	%	%
Discarded Bark		L / R	O	O	O	%	%	%	%	%
Dirt and rocks		L / R	O	O	O	%	%	%	%	%
Ash		L / R	O	O	O	%	%	%	%	%
Plastic wrap		L / R	O	O	O	%	%	%	%	%
Metal strapping		L / R	O	O	O	%	%	%	%	%
Plastic strapping		L / R	O	O	O	%	%	%	%	%
Other metals		L / R	O	O	O	%	%	%	%	%
Other organics		L / R	O	O	O	%	%	%	%	%
Other non-organics		L / R	O	O	O	%	%	%	%	%
Other: ____________		L / R	O	O	O	%	%	%	%	%
Other: ____________		L / R	O	O	O	%	%	%	%	%
Other: ____________		L / R	O	O	O	%	%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.

[2] Report the mass of material, for example, report wood separately from dirt and rocks.

LVL Plant Annual Water Use

Type	Total Quantity	Percent of total by unit process (percentage or volume; estimation is ok)					Units
		Veneer / LVL prep	Layup	Boiler	Hot press	Saw/ trimmer	
Input							
Surface water							Gallons
Groundwater							Gallons
Municipal water							Gallons
Output							
Water discharged							Gallons
Water recycled							Gallons

Recycling rate of water helps reduce the water footprint.

What percent of water is recycled?		%
Was water measured or estimated?		

LVL Plant Emission Control Device (ECD)

The following is a chart of emission control devices. Please fill in all information related to the control devices.

Emission Control Device (ECD)- Type, Electricity, Fuel Usage					
	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment controlled (i.e., boiler, press, dryer, etc.)					
Type					
Model					
Year Installed					
Electricity used to operate ECD; either kWh or % of total plant use					
Natural Gas used to operate ECD; either $ft.^3$ or % of total plant use					

Machine Center Breakdown for Electricity and Fuel Use

Fill in all that apply and for which you have data. If you **do not** have given machines center such as the co-generator, either draw **a line** through that row and **write N/A**.

Machine Center	**Model/Type** **Year Installed**	**Annual electricity** **kWh or % of the total use for mill**	**Fuel Usage** **% of total use for mill**
Co-generator			
Lay-up			
Press(es)			
#1			
#2			
#3			
#4			
Billet Cuts			
Rip Saw			

If you do not peel or dry veneer or produce I-joists, congratulations you have completed the survey! However, if you do, please complete the following pages.

Veneer Mill Annual Wood Production Data

Please fill in all the information that pertains just to your plant.

Type of veneer dryer: Longitudinal, Cross flow, Jet, Rotary (circle one)

Log scale: Dolye, International, Scribner, Weight base (circle one)

Total volume of incoming softwood logs	____________	thousand BF/year
Total volume of incoming green veneer	____________	thousand ft^2 3/8" basis/year
Total volume of veneer produced on-site	____________	thousand ft^2 3/8" basis/year
Total volume of veneer produced on-site used on-site	____________	thousand ft^2 3/8" basis/year

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

Species	% of total log input into veneer mill	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

Wood species processed into veneer and approximate percentage of total:			
Species	Volume (Msf 3/8")	%MC (wet basis)	Percent
Total			100%

MILEAGE: Over the Road _______% By Rail_______%

Total number of log deliveries made to this facility annually	____________	# per year
Average one-way mileage travel to this facility to deliver logs	____________	miles

Veneer Mill Annual Transportation Fuel Use On-site

(includes all fuels for yard equipment, forklifts, and carriers)

Type	Total Quantity	Percent of total by unit process (percentage or volume)					Units
		Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying	Support Vehicle	
Off-road diesel							Gallons
On-road diesel							Gallons
Propane							Gallons
Gasoline							Gallons
Electricity							kWh
Other							

Veneer Mill Annual (Non-Transportation) Fuel Use

(boilers, cogeneration units, etc.)

Fuel	Unit	Quantity
Total electricity for veneer mill	kWh	
Purchased steam	lbs (°F)	
Wood Fuel *Self-generated*	Tons / (%MC)	/
Wood Fuel *Purchased*	Tons / (%MC)	/
Natural Gas	1000 ft^3	
Kerosene (fuel oil #1)	Gallons	
Fuel oil #2	Gallons	
Residual fuel oil #6 (Bunker C)	Gallons	
Diesel	Gallons	
Gasoline	Gallons	
Liquid Propane Gas	Gallons	

If your facility has a boiler, please provide the following. Otherwise, enter N/A as applicable.

Boiler	Boiler size (million BTU/hr)	Boiler Fuel	Boiler Fuel Unit	Quantity	Electricity to operate boiler (kWh)
#1					
#2					
#3					
#4					

Veneer Mill Machine Center Breakdown

Fill in all that apply and for which you have data. If you do not have a given machine center, draw a line through that row and write None. Please provide units.

Machine Center	Model/Type Year Installed	Annual Electricity Usage kWh or % of total electricity use for mill **(Estimation is ok)**	Fuel Usage % of total use for mill **(Estimation is ok)**
Bucking & Debarking			
Log Conditioning			
Peeling & Clipping			
Drying			
Energy Generation			
Emissions control			
Total veneer mill			

Veneer Mill Annual Wood Residue Production

This is a general material flow survey for veneer mills. Wood residues are any wood material produced in conjunction with making LVL and are called co-products in this survey. This survey is designed to trace all wood components generated during production.

Estimate amount of wood residue produced per Msf of veneer ___________tons/Msf veneer

Wood residue	Moisture Content (wet basis) (%)	Sold (Shipped) tons	Used Internally (as fuel) tons	Used Internally (other uses) tons	Landfill tons	Total Quantity Tons
Bark, green						
Roundup wood, green						
Peeler core, green						
Clippings, green						
Veneer downfall						
Trim , green						
Chips, green						
Hogged material						
Waste gate material						
Clippings, green						
Other						

For dryer(s), check heat source and give the annual fuel consumption: **indirect or direct (circle one)**		
Heat source		
☐ Steam	lbs	
☐ Natural gas direct-fired	ft^3	
☐ Wood fuel	Tons (%MC)	/
☐ Other		

Veneer moisture content information		
Average moisture content into dryer	% ovendry basis	
Average moisture content out of dryer	% ovendry basis	
Redry rate	%	

Transportation method and distance for veneer logs			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Veneer Mill Ancillary Material Inputs

Ancillary Material	Used		Amount	How amount was found? Mark one[1]		Where the ancillary material is emitted as a percent (estimation is ok)				
	Yes	No		M	E	Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying	Comments
Hydraulic fluids	O	O	lb/yr	O	O	%	%	%	%	
Greases	O	O	lb/yr	O	O	%	%	%	%	
Motor Oil	O	O	lb/yr	O	O	%	%	%	%	
Plastic wrapping	O	O	lb/yr	O	O	%	%	%	%	
Cardboard packaging	O	O	lb/yr	O	O	%	%	%	%	
Steel strapping	O	O	lb/yr	O	O	%	%	%	%	
Plastic strapping	O	O	lb/yr	O	O	%	%	%	%	
Potable water	O	O	gal/yr	O	O	%	%	%	%	
Paints	O	O	lb/yr	O	O	%	%	%	%	
Waxes	O	O	lb/yr	O	O	%	%	%	%	
Runners	O	O	lb/yr	O	O	%	%	%	%	
Boiler chemicals	O	O	lb/yr	O	O	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	
Other: ____________	O	O	lb/yr	O	O	%	%	%	%	

[1] Estimated (E) / Measured (M)

Veneer Mill Air Emissions

If air emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached ☐

Substance	Emit		Amount	How amount was found? Mark one[1]			Sampling method or source[2]	Where the substance is emitted as a percent (estimation is ok)			
	Yes	No		M	E	PV		Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying
Dust	O	O	lb/yr	O	O	O		%	%	%	%
Particulate	O	O	lb/yr	O	O	O		%	%	%	%
Particulate, PM10[3]	O	O	lb/yr	O	O	O		%	%	%	%
Particulate, PM2.5[4]	O	O	lb/yr	O	O	O		%	%	%	%
VOC	O	O	lb/yr	O	O	O		%	%	%	%
Sulfur dioxide	O	O	lb/yr	O	O	O		%	%	%	%
Carbon monoxide	O	O	lb/yr	O	O	O		%	%	%	%
Nitrous oxide	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Total	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Methanol	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Formaldehyde	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Acetaldehyde	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Propionaldehyde	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Acrolein	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Phenol	O	O	lb/yr	O	O	O		%	%	%	%
HAP: Acetone	O	O	lb/yr	O	O	O		%	%	%	%
HAP: ____________	O	O	lb/yr	O	O	O		%	%	%	%
Other organic[5]: _______	O	O	lb/yr	O	O	O		%	%	%	%
Other inorganic[6]: _____	O	O	lb/yr	O	O	O		%	%	%	%
Other: __________	O	O	lb/yr	O	O	O		%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement

[2] Sampling methods might be Method 25A, Method 5, NCASI 105. Estimates might be based on AP42, Standard Air Contaminate Discharge Permit or other source.

[3] PM10 is particulate matter up to 10 micrometers in size

[4] PM2.5 is particulate matter up to 2.5 micrometers in size

[5] Non-HAP organics that are not included in VOC value.

[6] Inorganics such as chlorine, mercury sulfur.

Veneer Mill Water Emissions

If water emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached ☐

Substance	Emit		Amount[2]	How amount was found? Mark one[3]			Sampling method or source[1]	Where the substance is emitted as a percent (Estimation is ok)			
	Yes	No		M	E	PV		Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying
Suspended solids	O	O	lb/yr	O	O	O		%	%	%	%
BOD	O	O	lb/yr	O	O	O		%	%	%	%
COD	O	O	lb/yr	O	O	O		%	%	%	%
Oil and grease	O	O	lb/yr	O	O	O		%	%	%	%
HAPs	O	O	lb/yr	O	O	O		%	%	%	%
Chemicals in boiler blowdown (if not included above)	O	O	lb/yr	O	O	O		%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%
Other: ______________	O	O	lb/yr	O	O	O		%	%	%	%

[1] Sampling methods is type of water test or how estimate was obtained.

[2] Report the mass of material, not the mass of material and water.

[3] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.

Veneer Mill Solid waste

If annual solid waste summary is available, please provide as an alternative to the following table.
Check here if summary is attached ☐

Material	Amount[2] (lb/yr)	Where material is going? Landfill (L) or recycled (R)	How amount was found? Mark one[1]	Where the solid waste is emitted as a percent (estimation is ok)			
				Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying
Discarded Wood		L / R	M / E / PV	%	%	%	%
Discarded Bark		L / R	M / E / PV	%	%	%	%
Dirt and rocks		L / R	M / E / PV	%	%	%	%
Ash		L / R	M / E / PV	%	%	%	%
Plastic wrap		L / R	M / E / PV	%	%	%	%
Plastic strapping		L / R	M / E / PV	%	%	%	%
Metal strapping		L / R	M / E / PV	%	%	%	%
Plastic bags		L / R	M / E / PV	%	%	%	%
Other metals		L / R	M / E / PV	%	%	%	%
Other organics		L / R	M / E / PV	%	%	%	%
Other non organics		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.
[2] Report the mass of material, for example, report wood separately from dirt and rocks.

Veneer Mill Annual Water Use

Type	Total Quantity	Percent of total by unit process (percentage or volume)				Units
		Bucking & Debarking	Block Conditioning	Peeling & Clipping	Drying	
Input						
Surface water						Gallons
Groundwater						Gallons
Municipal water						Gallons
Output						
Water discharged						Gallons
Water recycled						Gallons

Recycling rate of water helps reduce the water footprint.

What percent of water is recycled?		%
Was water measured or estimated?		

2012 Composite I-joists Annual Production Plant Data

Please fill in all information relevant to producing I-joists. Please provide the data on an annual basis for the year which the data is reported.

Annual I-Joists Production for 2012			
Product (Series)	Amount (lin.ft.)	Joist Depth (in.)	Flange dim. (in. x in.)

I-joists Construction-Web		
Material	Percent of total	Annual consumption (MSF 3/8")
OSB		
Plywood		
Total	100%	

Transportation Method and Delivery Distance for OSB			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Transportation Method and Delivery Distance for plywood			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Estimate amount of wood residue produced per Msf of I-joist ___________tons/Msf I-joist

Wood residue	**Moisture Content (wet basis)**	**Sold (Shipped)**	**Used Internally (as fuel)**	**Used Internally (other uses)**	**Landfill**	**Inventory**	**Total Quantity**
	(%)	tons	tons	tons	tons	tons	Tons
Sawdust, dry							
Other							
Other							

I-joists Construction-Flange		
Material	Percent of total	Annual consumption (MSF 3/8”)
LVL		
LSL		
Lumber (finger-jointed)		
Total	100%	

Transportation Method and Delivery Distance for LVL			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Transportation Method and Delivery Distance for LSL			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Transportation Method and Delivery Distance for lumber (finger-jointed)			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Annual Resin Consumption Data

Resin consumption is comprised of three different scenarios: 1) web-joint, 2) flange finger-joint, and 3) I-joist (web to flange)

1. Web-joint resin consumption	
Resin type	
Percent water	

Transportation Method and Delivery Distance for web-joint resin			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

- Please include the amount of resin used in the web-joints of the I-joist in this section. Please state whether weight is given as wet or dry weight.

- If you use the same resin for the web-joint, finger-joint, and web to flange-joint, complete the following table with total resin use and check this box ☐ ☐

- Otherwise, fill in resin use for web-joint only and then proceed to fill out resin data for flange finger-joints and I-joist (web to flange).

Formulation and usage of web-joint resin, fillers, and other components			
Component Type	Range % of Solid by Weight	Total Annual Use (lbs.)	Circle one
Resin			Wet or dry
Extender and filler			Wet or dry
Catalyst (NaOH)			Wet or dry
Water			
Other (please specify)			Wet or dry
Resin loss (lbs)			Wet or dry

2. Flange finger-joint resin consumption	
Resin type	
Percent water	

Transportation Method and Delivery Distance for flange finger-joint resin			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Formulation and usage of flange finger-joint resin, fillers, and other components			
Component Type	Range % of Solid by Weight	Total Annual Use (lbs.)	Circle one
Resin			Wet or dry
Extender and filler			Wet or dry
Catalyst (NaOH)			Wet or dry
Water			
Other (please specify)			Wet or dry
Resin loss (lbs)			Wet or dry

3. I-joist (web-to-flange) resin consumption	
Resin type	
Percent water	

Transportation Method and Delivery Distance for I-joist (web-to-flange) resin			
Truck (% of total)		Average delivery miles	
Rail (% of total)		Average delivery miles	
Other (% of total)		Average delivery miles	
Total (%)	100%		

Formulation and usage of I-joist (web-to-flange) resin, fillers, and other components

Component Type	Range % of Solid by Weight	Total Annual Use (lbs.)	Circle one
Resin			Wet or dry
Extender and filler			Wet or dry
Catalyst (NaOH)			Wet or dry
Water			
Other (please specify)			Wet or dry
Resin loss (lbs)			Wet or dry

I-joist Plant Annual (Non-Transportation) Fuel Use

(boilers, cogeneration units, etc.)

Fuel	Unit	Quantity
Total electricity for I-joist plant	kWh	
Purchased steam	lbs (°F)	
Wood Fuel *Self-generated*	Tons / (%MC)	/
Wood Fuel *Purchased*	Tons / (%MC)	/
Natural Gas	1000 ft^3	
Kerosene (fuel oil #1)	Gallons	
Fuel oil #2	Gallons	
Residual fuel oil #6 (Bunker C)	Gallons	
Diesel	Gallons	
Gasoline	Gallons	
Liquid Propane Gas	Gallons	

If your facility has a boiler, please provide the following. Otherwise, enter N/A as applicable.

Boiler	Boiler size (million BTU/hr)	Boiler Fuel	Boiler Fuel Unit	Quantity	Electricity to operate boiler (kWh)
#1					
#2					
#3					

For oven(s), check heat source and give the annual fuel consumption: indirect or direct (circle one)		
Heat source		
☐ Steam	lbs	
☐ Natural gas direct-fired	ft^3	
☐ Wood fuel	Tons (%MC)	/
☐ Other		

I-Joist Plant Annual Transportation Fuel Use On-site

(includes all fuels for yard equipment, forklifts, and carriers)

Type	Total Quantity	Percent of total by unit process (percentage or volume)					Units
		Routing / shaping	Assembly	Sawing	Curing	Support vehicles	
Off-road diesel							Gallons
On-road diesel							Gallons
Propane							Gallons
Gasoline							Gallons
Electricity							kWh
Other							

Machine Center Breakdown for Electricity and Fuel Use

Fill in all that apply and for which you have data. If you **do not** have a given machine center that is listed here, either **draw a line** through that row and **write N/A**.

Machine Center	Model/Type Year Installed	Annual Electricity kWh or % of the Total Use for Mill	Fuel Usage % of Total Use for Mill
OSB/Plywood saws			
LVL/FJ lumber saws			
Web joint shaper/router			
I-joist assembler			
I-joist saw			
Other (please specify)			
Curing Oven			
Steam			
Electricity			
Natural Gas			

I-joist Plant Ancillary Material Inputs

Ancillary Material	Used		Amount	How amount was found? Circle one[1]	Where the ancillary material is emitted as a percent (estimation is ok)				
	Yes	No			Routing / shaping	Assembly	Sawing	Curing	Comments
Hydraulic fluids	O	O	lb/yr	M / E	%	%	%	%	
Greases	O	O	lb/yr	M / E	%	%	%	%	
Motor Oil	O	O	lb/yr	M / E	%	%	%	%	
Plastic wrapping	O	O	lb/yr	M / E	%	%	%	%	
Cardboard packaging	O	O	lb/yr	M / E	%	%	%	%	
Steel strapping	O	O	lb/yr	M / E	%	%	%	%	
Plastic strapping	O	O	lb/yr	M / E	%	%	%	%	
Potable water	O	O	gal/yr	M / E	%	%	%	%	
Paints	O	O	lb/yr	M / E	%	%	%	%	
Waxes	O	O	lb/yr	M / E	%	%	%	%	
Plastic strapping	O	O	lb/yr	M / E	%	%	%	%	
Runners	O	O	lb/yr	M / E	%	%	%	%	
Boiler chemicals	O	O	lb/yr	M / E	%	%	%	%	
Other: _____________	O	O	lb/yr	M / E	%	%	%	%	
Other: _____________	O	O	lb/yr	M / E	%	%	%	%	
Other: _____________	O	O	lb/yr	M / E	%	%	%	%	

[1] Estimated (E) / Measured (M)

I-joist Plant Air Emissions

If air emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached □

Substance	Emit		Amount	How amount was found? Circle one[1]	Sampling method or source[2]	Where the substance is emitted as a percent (estimation is ok)			
	Yes	No				Routing / shaping	Assembly	Sawing	Curing
Dust	O	O	lb/yr	M / E / PV		%	%	%	%
Particulate	O	O	lb/yr	M / E / PV		%	%	%	%
Particulate, PM10[3]	O	O	lb/yr	M / E / PV		%	%	%	%
Particulate, PM2.5[4]	O	O	lb/yr	M / E / PV		%	%	%	%
VOC	O	O	lb/yr	M / E / PV		%	%	%	%
Sulfur dioxide	O	O	lb/yr	M / E / PV		%	%	%	%
Carbon monoxide	O	O	lb/yr	M / E / PV		%	%	%	%
Nitrous oxide	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Total	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Methanol	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Formaldehyde	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Acetaldehyde	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Propionaldehyde	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Acrolein	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Phenol	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: Acetone	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: ____________	O	O	lb/yr	M / E / PV		%	%	%	%
HAP: ____________	O	O	lb/yr	M / E / PV		%	%	%	%
Other organic[5]: _______	O	O	lb/yr	M / E / PV		%	%	%	%
Other inorganic[6]: _____	O	O	lb/yr	M / E / PV		%	%	%	%
Other: ______________	O	O	lb/yr	M / E / PV		%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement

[2] Sampling methods might be Method 25A, Method 5, NCASI 105. Estimates might be based on AP42, Standard Air Contaminate Discharge Permit or other source.

[3] PM10 is particulate matter up to 10 micrometers in size

[4] PM2.5 is particulate matter up to 2.5 micrometers in size

[5] Non-HAP organics that are not included in VOC value.

[6] Inorganics such as chlorine, mercury sulfur.

I-joist Plant Water Emissions

If water emission inventories are available, please provide as an alternative to the following table. Check here if inventory is attached □

Substance	Emit		Amount[2]	How amount was found? Circle one[3]	Sampling method or source[1]	Where the substance is emitted as a percent (estimation is ok)			
	Yes	No				Routing / shaping	Assembly	Sawing	Curing
Suspended solids	O	O	lb/yr	M / E / PV		%	%	%	%
BOD	O	O	lb/yr	M / E / PV		%	%	%	%
COD	O	O	lb/yr	M / E / PV		%	%	%	%
Oil and grease	O	O	lb/yr	M / E / PV		%	%	%	%
HAPs	O	O	lb/yr	M / E / PV		%	%	%	%
Chemicals in boiler blowdown (if not included above)	O	O	lb/yr	M / E / PV		%	%	%	%
Other: _______________	O	O	lb/yr	M / E / PV		%	%	%	%
Other: _______________	O	O	lb/yr	M / E / PV		%	%	%	%
Other: _______________	O	O	lb/yr	M / E / PV		%	%	%	%
Other: _______________	O	O	lb/yr	M / E / PV		%	%	%	%
Other: _______________	O	O	lb/yr	M / E / PV		%	%	%	%

[1] Sampling methods is type of water test or how estimate was obtained.

[2] Report the mass of material, not the mass of material and water.

[3] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.

I-joist Plant Solid waste

If annual solid waste summary is available, please provide as an alternative to the following table. Check here if summary is attached □

Material	Amount[2] (lb/yr)	Where material is going? Landfill (L) or recycled (R)	How amount was found? Circle one[1]	Where the solid waste is emitted as a percent (estimation is ok)			
				Routing / shaping	Assembly	Sawing	Curing
Discarded Wood		L / R	M / E / PV	%	%	%	%
Discarded Bark		L / R	M / E / PV	%	%	%	%
Dirt and rocks		L / R	M / E / PV	%	%	%	%
Ash		L / R	M / E / PV	%	%	%	%
Plastic wrap		L / R	M / E / PV	%	%	%	%
Metal strapping		L / R	M / E / PV	%	%	%	%
Cardboard packaging		L / R	M / E / PV	%	%	%	%
Plastic bags		L / R	M / E / PV	%	%	%	%
Other metals		L / R	M / E / PV	%	%	%	%
Other organics		L / R	M / E / PV	%	%	%	%
Other non organics		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%
Other: ___________		L / R	M / E / PV	%	%	%	%

[1] Estimated (E) / Measured (M)/ Permit value (PV): For example, from landfill fees, a permit, or measurement.

[2] Report the mass of material, for example, report wood separately from dirt and rocks.

I-joist Plant Annual Water Use

Type	Total Quantity	Percent of total by unit process (percentage or volume)				Units
		Routing / shaping	Assembly	Sawing	Curing	
Input						
Surface water						Gallons
Groundwater						Gallons
Municipal water						Gallons
Output						
Water discharged						Gallons
Water recycled						Gallons

Recycling rate of water helps reduce the water footprint.

What percent of water is recycled?		%
Was water measured or estimated? M/E		

Annual Emission Control Device and Environmental Emission

The following is a chart of emission control devices and a listing of chemical compounds that are observed and/or permitted. Please fill in all information related to the control devices. Then list all compounds that are collected and known for the mill for all control device sources. If you recently applied for air permit, use those numbers. Fill in all that apply and for which you have data.

Annual Emission Control Device (ECD)- Electricity and Fuel Usage					
	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment controlled (i.e., boiler, press, dryer, etc.)					
Type					
Model					
Year Installed					
Electricity used to operate ECD; either kWh or % of total plant use					
Natural gas used to operate ECD; either ft^3 or % of total plant use					