CORRIM: Phase I Final Report

Module H

LAMINATED VENEER LUMBER – PACIFIC NORTHWEST AND SOUTHEAST

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EXECUTIVE SUMMARY

The objective of this study is to develop a life cycle inventory (LCI) for the production of laminated veneer lumber (LVL), based on current manufacturing practices in the Pacific Northwest (Oregon, Washington) and the Southeast (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, and Texas). Included in the study was a survey of manufacturing operations in the two regions to collect input data in terms of materials and their transportation, resin, fuel, electricity, and energy use, and output data such as products, co-products, and emissions. Also studied, included development of a LCI model, a sensitive analysis of the model, a cost analysis of the manufacturing operation, and a biogenic carbon flow analysis. This report was externally reviewed to assure that the study methodology, data collection and analyses were scientifically sound, and are in compliance with ISO 14040 and CORRIM protocol.

Laminated veneer lumber is a structural building product that is used as an alternative to structural lumber for headers, beams, joists, and as flange component in wood composite I-joists in residential and commercial construction. LVL is made in large billets with typical dimensions on the order of 1-¾ inches in thickness and four feet in width, and lengths generally of 60 feet. The product is made by applying a phenol-formaldehyde adhesive to wood veneer that are aligned in their grain orientation, and then the layered veneer is hot pressed to form large billets. For all plants surveyed except one, dry veneer was the input wood material to the process; the one exception used panels of parallel laminated veneer (PLV) as an input to make LVL. To provide a single model for various manufacturing operations, dry veneer and PLV were considered within the system boundary, meaning their environmental burden was associated with the plant site burden. Some of the plants also produced composite I-joists, however, only those resources and impacts attributed to the LVL production, were considered.

A black box approach was used to model the LCI of LVL manufacturing. This was done because of the relative simplicity of the LVL process given the small number of unit processes—lay-up of billets which included adhesive application, hot pressing to cure adhesive, and sawing the billet to size. The model could be used to look at the total number of emissions and determine on an overall production basis which inputs into the process are creating the largest amounts of emissions, as such the model can be used to assess possible process improvements. This is important considering the recent attention given to the conservation of raw materials as well as increases in the costs of electricity and fuel. This LCI data will serve as a useful benchmark to assess the environmental performance and economic feasibility of process improvements. A survey was conducted of two LVL plants in the PNW and two in the SE. Only resources and production data for making LVL were considered. The quality of the survey data is considered very good. Based on the amount of data for the two plants from each region, a comparison of values between plants established the validity of the data. Additional data analysis (i.e., mass and energy balances), as well as regional comparisons, further supported the integrity of our findings. The surveyed plants represented approximately 33% of total production for the PNW and 45% for the SE. The base unit of production for the analysis was one thousand cubic feet (MCF) of LVL. For the PNW a MCF of LVL weighed 33,000 lbs and for the SE a MCF weighed 37,800 lbs oven dry. For a mass balance slightly more wood material was input than output, therefore, to determine efficiency, the LVL produced was compared to the total amount of wood in the LVL and other co-products and waste generated by the process. For the PNW the recovery of wood material into LVL was 95.6%, while for the SE the recovery was 91.3%. The allocated mass-based burdens are 95.6% and 91.3% for LVL produced in the PNW and SE respectively. The remaining mass-based allocated burdens were assigned to the co-products sawdust, veneer and lay-up scrap, tested LVL and panel trim. A co-product is any material that is created during the manufacturing process that is sold outside of the LVL system. In the PNW the inputs to make 1.0 MCF of LVL were 6,950 lbs of dry veneer and 24,400 lbs of parallel laminated veneer, 504 lbs of phenol-formaldehyde resin and 36 lbs of phenol-resorcinol-formaldehyde resin, 401 lbs of extenders and fillers, and a small amount of catalyst. In the SE the inputs to make 1.0 MCF of LVL were 38,400 lbs of dry veneer, 656 lbs of phenol-formaldehyde resin and 588 lbs of extenders and fillers, and a small amount of catalyst. The amount of natural gas and electricity for producing a MCF of LVL in each region were for the PNW 1,660 kWh of electricity and 3,830,000 Btu of natural gas, 239,000 Btu of liquid propane gas, and 180,000 Btu of diesel. In the SE the electricity use was higher at 1,920 kWh, with natural gas use considerably higher at 10,900,000 Btu, liquid propane at 322,00 Btu, and diesel at 386,000 Btu.

Emissions to the land, air, and water are becoming increasingly important in terms of plant operations and manufacturing costs. In this study there are two different cases for emissions: 1) total emissions for the entire LVL manufacturing process, which included the site-generated emissions associated with the production of LVL, plus the off-site production emissions for resins, fuel, energy, and electricity; not included were those burdens for production of logs and transportation of materials, and 2) site-generated emissions associated with the LVL manufacturing process only, which include those associated with the production of dry veneer and parallel laminated veneer. The emissions for the two cases are referred to as total and site generated emissions respectively. Emissions for LVL in the PNW had a allocated burden of 95.7% and the SE had a burden of 91.3%. The production of LVL contributes relatively small amounts of emissions when compared to the production of input products such as resin, dry veneer, fuel, and electricity. Given this scenario, it would make sense to look at these areas (resin, veneer, PLV) as possible factors in reducing total emissions for the process. The LCI data could be used as a benchmark to assess environmental improvements.

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1.0 LIFE CYCLE INVENTORY

1.1 INTRODUCTION

Laminated veneer lumber (LVL) is a composite wood material made from sheets of veneer (generally 1/8- or 1/10-inch thick) that are laminated together with their grain orientation in the same direction and then hot pressed. LVL was first used in WWII to make airplane propellers and since the 1970's it has been used as a construction product (Neuvonen et al.1998). LVL can vary in thickness and width but is most commonly produced in the dimensions of 1 3/4-inch thick and four-feet wide, with lengths generally of 60 feet. After being ripped into narrower dimensions it is used as an alternative to structural lumber for headers and beams and also as the flange component in wood composite I-joists. According to the APA (APA—The Engineered Wood Association), in the year 2000 the US produced 44.4 million cubic feet of LVL of which 61% was used in the manufacture of I-joists and another 31% was used as headers or beams (APA 2001). Production outlooks for LVL show a steady increase for the next several years. As LVL becomes a more prevalent wood product, it becomes necessary to understand the environmental burdens associated with its manufacturing.

This project relied almost exclusively on production and emissions data provided by the wood products industry. This data was gathered through primary surveys that were sent out to LVL production facilities in the Pacific Northwest (PNW) and Southeast (SE) regions of the US. The surveys were extensive and included questions about annual production, energy and fuel uses as well as emissions, and co-product volumes. According to representatives from the APA, in the Pacific Northwest the annual production of LVL for 2001 was 20,200,000 cubic feet (20.2 MMCF), which represents approximately 45% of the LVL production for the US. This study collected data from plants in the region that would be considered large-scale operations. The survey data collected for the PNW region totaled 6,600,000 cubic feet (6.6 MMCF) of LVL representing roughly 33% of the production for the region. In the SE region the annual production of LVL in 2001 was lower than in the PNW at an estimated 15,000,000 cubic feet (15 MMCF). This represents the equivalent of roughly 34% of the total LVL produced in the US in the year 2000. Data gathered from the industry survey accounted for 7.8 MMCF of production, which is slightly over 52% of the total volume produced in the region. The quality of the survey data is considered very good. Based on the amount of data for the two plants from each region, a comparison of values between plants established the validity of the data. Additional data analysis (i.e., mass and energy balances), as well as regional comparisons, further supported the integrity of our findings.

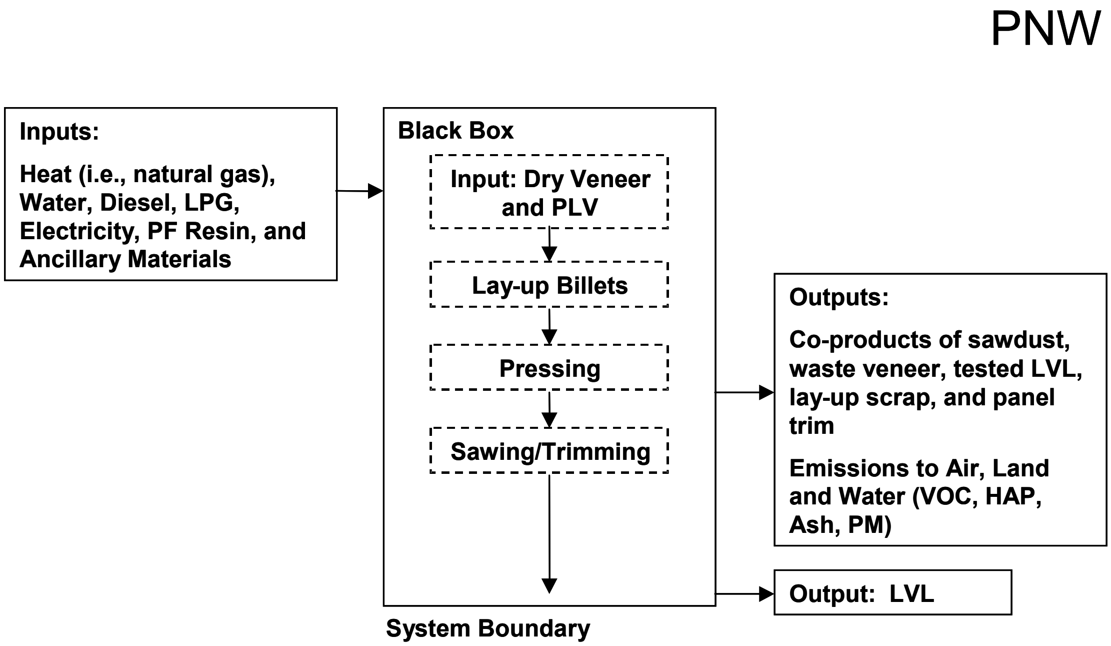
This report documents the life cycle inventory (LCI) of LVL production in the PNW and SE regions of the US. Also included in the report are a cost analysis, sensitivity analyses, and a carbon balance for each region. The LCI data will be used as input material in the CORRIM cradle-to-grave analysis of wood building materials. For a cradle-to-grave analysis, the LVL LCI data would need to be cumulated with the log resource and the transportation of materials data. This report deals only with the manufacturing of LVL and includes the relevant input and outputs as well as their environmental impacts. The primary data collection was done with the surveys while supporting secondary data was also used. This secondary data was necessary to assess the impacts of fuel, electricity, and resin manufacture and use as well as associated impacts of using these materials in the LVL process. Electricity and fuel data was gathered from Franklin Associates (1998a-1998j), Pré Consultants (2001) and the US Dept. of Energy (USDOE 2002), while information related to the production of phenol-formaldehyde resin came from ATHENA (ATHENA 1993).

The scope of this report covers a gate-to-gate LCI analysis of LVL for the PNW and SE US. Included in the PNW region are Oregon and Washington. The states that make up the SE region are Alabama, Georgia, Louisiana, Mississippi, Florida, Arkansas, and Texas. Included in the report are the product LCIs, and the transportation mileage for delivery of wood and resin based raw materials. Since this is a gate-to-gate LCI analysis, this report is limited to the production of LVL, and the transportation of wood input and resin materials to the manufacturing site, production of phenol-formaldehyde resin, electricity, natural gas, LVL and its co-products. The surveyed plants varied in the starting input material, i.e., some input dry veneer while one plant input parallel laminated veneer (PLV), while others not part of this survey, input green veneer. To provide a single model for all plants, they were treated as having dry veneer and PLV inputs, with the burdens for these materials taken from the same unit process as developed in Module D for plywood. Some of the plants also produced composite I-joists, a structural product comprised of LVL flanges and OSB webs. The plants were requested to provide the data for those resources that were directly attributed to the LVL production process.

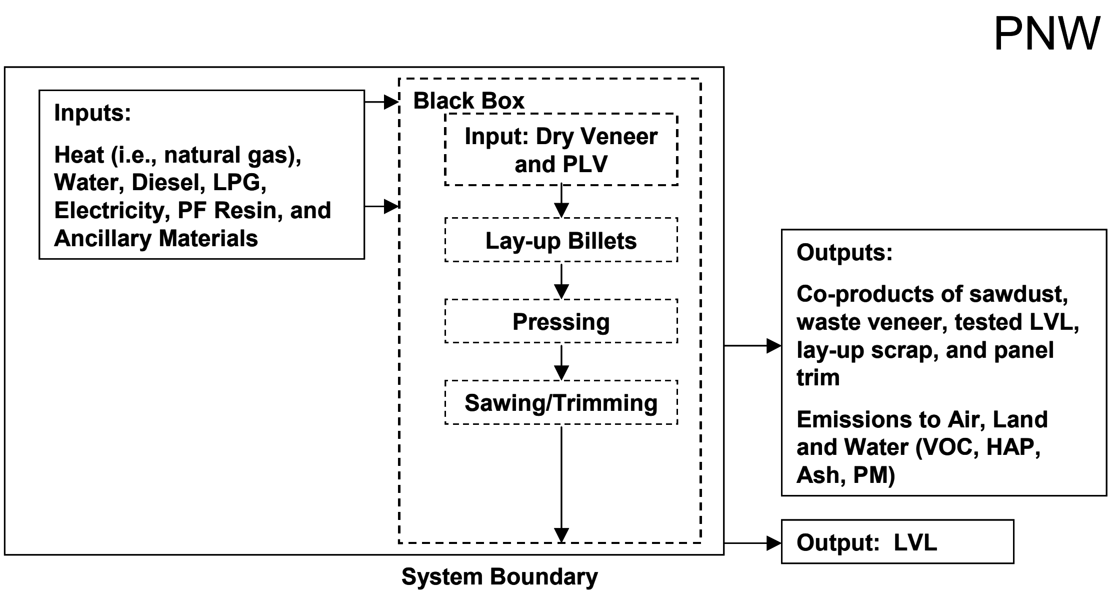
This report was externally reviewed to assure that the study methodology, data collection and analyses are scientifically sound, and are in compliance with ISO 14040 and CORRIM protocol.

1.1.1 Black Box Approach

Two models were created for LVL manufacturing, one for the PNW region and another for the SE region. These models were based on production data and used as a guideline for the LCI. The models were created with the purpose of illustrating what items belonged in the system itself and what items were peripheral to the production process. A black box approach simply means that all process inputs and outputs are lumped together into one LVL process; see Figures 1.1 and 1.2. No individual unit processes were created, thus limiting analysis of these processes. The black box approach is used because of its relative simplicity and the low number of unit processes. The results of the LVL's LCI will be used as an input into the composite I-joist LCI (see Module F) but could also be used as a stand alone for LVL headers, beams and joists. The input materials of parallel laminated veneer (PLV) and dry veneer are included as a part of the process even though these materials are generated at other manufacturing facilities. The manufacturing of PLV is the same as that for plywood except the veneers are all oriented in the same direction. The PLV is neither as thick nor as long as LVL, therefore it must be face and finger-jointed glued and pressed to make large LVL billets. Some LVL uses PLV as an input to produce product, however most use dry or green veneer to directly produce the product. The burdens associated with the PLV and the veneer will show up in the LVL process since it is a major contributor of emissions. A comparison is included in this report to show the impacts that PLV and dry veneer have on the system. The dry veneer input for each region is imported from the dry-veneer SimaPro model (see Module D) developed for the plywood LCI for each region (Wilson and Sakimoto 2004). PLV is a product that is very similar to plywood varying only in the orientation of the veneers, and would have the same process and burdens. Since it is so similar to plywood, the plywood SimaPro model (see Module D) was used to simulate this input into the system (Wilson and Sakimoto 2004).

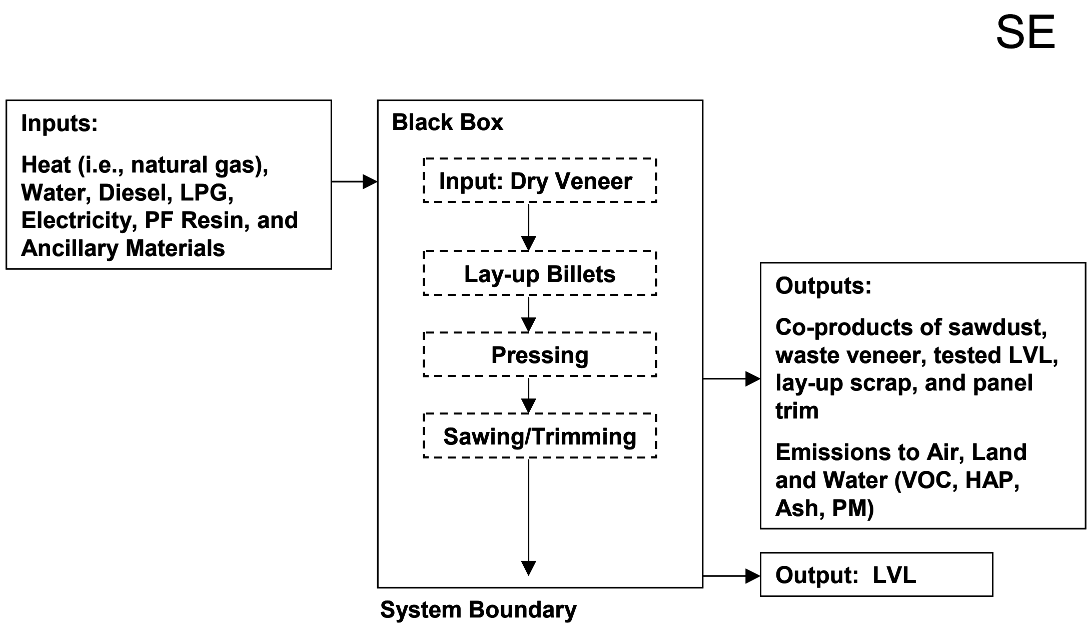


A) Site-generated emissions only

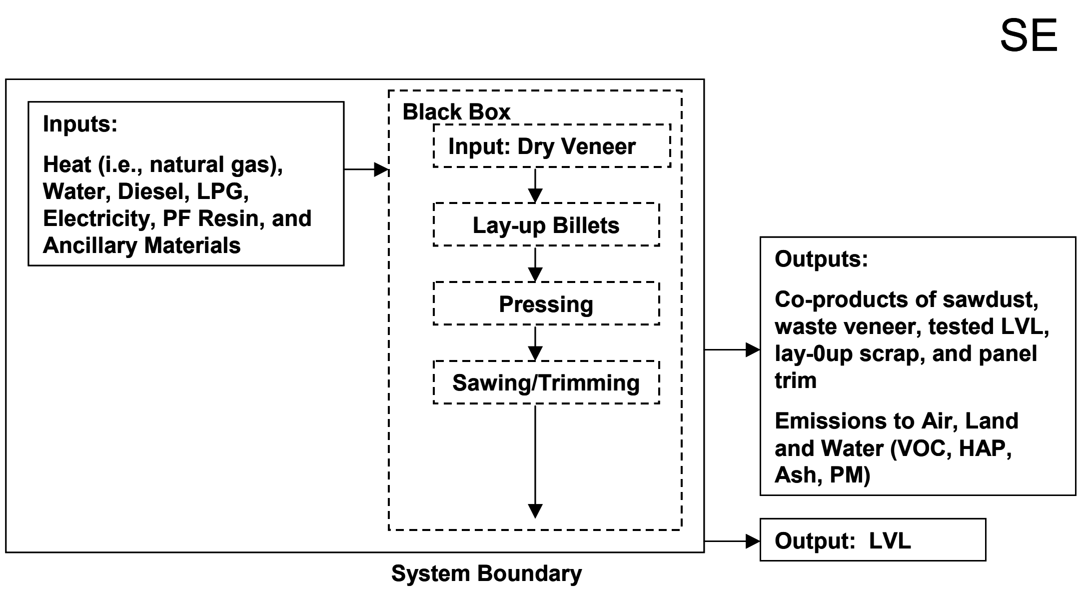


B) Total emissions which include site-generated emissions plus those for dry veneer, PLV, fuels, electricity, and resin; no burden for logs or transportation.

Figure 1.1. **System boundaries for a black box approach to the modeling of the LVL manufacturing process in the Pacific Northwest.**



A) Site-generated emissions only



B) Total emissions which include site-generated emissions plus those for dry veneer, PLV, fuels, electricity, and resin; no burden for logs or transportation.

Figure 1.2. **System boundaries for a black box approach to the modeling of the LVL manufacturing process in the Southeast.**

Description of unit processes within the black box for producing LVL:

1. Lay-up of billets: Dried veneers are aligned in their grain direction, coated with resin and composed into billets for pressing – co-products include waste veneer. For PLV, a similar process is followed except that the veneers are pressed into panels, and are then finger-jointed and laminated to make billets.

2. Pressing: Heat and pressure (320-350^{o}F and about 250 lb/in^{2}) are applied to the LVL billets, which cure the resin thereby bonding the veneers into LVL. Some plants use radio-frequency or microwave heaters to assist the curing process.

3. Sawing/Trimming: After exiting the press, the billets are sawn to the proper width and length – co-products include panel trim and sawdust and tested LVL.

Different plants use different types of lay-up lines and press systems to manufacture LVL. Some plants use automated lay-up lines where resin is applied and the veneers are laid up automatically before entering the press. Other systems require hand feeding of veneer into the spreaders where resin is applied. The main systems for pressing the billets are hot presses, which impart heat and pressure to the un-pressed LVL billets. Some presses are heated by hot-oil which natural gas heaters generally heat. Another heating system for presses is a microwave or radio-frequency system used in conjunction with oil-heated platens; this provides fast internal heating for these thick products.

Co-products are wood-based products that are generated during different phases of the LVL manufacturing process. They are called co-products because they are sold outside of the LVL boundary and their burdens are not attached to LVL. Rather, these co-products carry a weight-percentage of the total associated burdens.

1.1.2 Material Flows

The materials that are included in the PNW LCI analysis include those listed in the Table 1.1. Input materials for the LVL process are dry veneer, PLV, phenol-formaldehyde (PF) resin, and phenol-resorcinol-formaldehyde (PRF) resin. Outputs for the LVL process are LVL, sawdust, waste veneer, lay-up scrap, panel trim, and tested LVL. All of the materials in this process were considered to be on an oven-dry weight basis. Phenol-resorcinol-formaldehyde resin is used in cold-press situations for bonding panels of PLV into LVL, because the resin can cure without high temperature conditions. Table 1.2 contains the materials included in the SE LCI, which are very similar to the PNW with the notable exceptions of PLV and PRF resin.

Table 1.1. Listing of Input Materials, Co-products, and Products for Producing LVL in the PNW Region.

Input Materials	Co-products	Products
Dry Veneer	Sawdust	LVL
Parallel laminated veneer (PLV)	Waste veneer	
Phenol-formaldehyde resin	Lay-up scrap	
Phenol-resorcinol-formaldehyde	Panel trim	
	Tested LVL	

Table 1.2. Listing of Input Materials, Co-products, and Products for Producing LVL in the SE Region.

Input Materials	Co-products	Products
Dry Veneer	Sawdust	LVL
Phenol-formaldehyde resin	Waste veneer	
	Lay-up scrap	
	Panel trim	
	Tested LVL	

1.1.3 Transportation

Delivery of the input materials was by truck for all materials in the PNW and SE. The one-way delivery distances for dry veneer, PLV, and resin are listed in Table 1.3. This transportation data would be needed to determine any cradle-to-gate LCIs or for determining life cycle assessments (LCAs) since they are not include in the product gate-to-gate LCI. See Module D, the plywood LCI module, for other related transportation data.

Table 1.3. Delivery Distances (one-way) for Plywood and LVL Inputs for each Region.

Materials	PNW Delivery Distance mile	SE Delivery Distance mile
Logs for plywood	60	97
Veneer for plywood	75	153
Resin for plywood	122	98
Dry veneer for LVL	75	52
PLV for LVL	4	0
Resin for LVL	104	49

The weight of the input wood for the PNW was determined to be the value for oven-dry Douglas fir for the veneer and the value for PNW plywood (without resin) for PLV. The value for PNW plywood was obtained from the SimaPro model (see Module D) created by Wilson and Sakimoto for veneer and plywood production (Wilson and Sakimoto 2004). The amounts of veneer and PLV were given in thousand square feet 3/8-inch thick volume form, MSF 3/8-inch basis (the common industry measurement) and were converted to a cubic volume using the appropriate conversions as given by Briggs (1994). With the wood in a cubic volume it can be readily converted to a mass basis using the Wood Handbook (FPL 1987) values for the Douglas fir and southern pine and the established values for plywood as determined in the CORRIM report (Wilson et al. 2002). The density value for oven-dry Douglas fir is 30.00 lb/ft^3 and for plywood the density without resin is equal to 30.34 lb/ft^3 (Table 1.4). The density of the LVL for the PNW is 33.0 lb/ft^3 and for the SE is 37.8 lb/ft^3, when including both wood and resin in the density value.

Table 1.4. Wood Density Averages for PNW LVL Input Materials.

Product/Wood Species	Use in Survey %	Density lb/ft^3
Parallel Laminated Veneer	77.27	30.34
Douglas-fir	22.73	30.00
Total	100	30.26

[1] Wood Handbook values for wood density (FPL 1987); PNW Plywood report for PLV density

In the Southeast (SE) region it was assumed that LVL was made from the same veneer that is used to make plywood in that region. These two species are found in the Plywood report (see Module D) for the SE region (Wilson and Sakimoto 2004). The two main wood species that are used are slash pine and loblolly pine, which collectively make up southern pine. Based on a 50-50 split for each species, the average oven-dry density for southern pine in this study is 34.38 lb/ft^3 (Table 1.5).

Table 1.5. Wood Density Averages for Veneer Inputs in the SE Region.

Wood Species	Use in Survey %	Density[1] lb/ft^3
Loblolly Pine	50	31.88
Slash Pine	50	36.88
Total	100	34.38

[1]Wood Handbook values for southern pine wood species (FPL 1987); oven-dry densities

1.1.4 Assumptions

The data collection, analysis, and assumptions were based on the "Consortium for Research on Renewable Industrial Materials (CORRIM) protocol and research guidelines for life-cycle inventories" (Bowyer et al. 2002). Other considerations include:

1. An external critical review was conducted of the methodology and data analyses to ensure compliance with CORRIM and ISO 14040 protocol.
2. Data quality was found to be high based upon comparisons between plants and regions, and on mass and heat balances.
3. LCI data for site-generated emissions considered only those emissions at the manufacturing process, thus giving a gate-to-gate LCI; to provide a cradle-to-gate LCI the reader would need to include the environmental impact of the growing and harvesting of the trees for logs, the transportation of logs, resin, purchased veneer and hogged fuel to the plants. LCI date for site and off-site emissions are also considered but exclude burdens for logs and transportation of logs, resin, and purchased veneer and hogged fuel to the plant.
4. All data from the mill survey taken in 2000 was weight averaged for the four pants based on individual production of each plant in comparison to the total product for the year. Whenever missing data occurred it would be first checked with the plant, and if still not available, it was not included in the weighted average calculations.
5. The purchased veneer and PLV come with the same allocated burdens as if produced in the plywood plant for the region modeled. The SimaPro models for veneer and plywood were developed in Module D.

6. A mass-based allocation was used for assigning burdens.

7. Co-products were defined as any material that were sold outside the system boundary.

8. Liquid propane gas (LPG) and diesel fuel were for material transport at the plants. LPG is used in equipment to transport materials inside the plant and diesel fuel is used to transport materials outside the plant. The fuels were split evenly between LVL and I-joist operations, when they took place at the same plant.

9. Density values for the wood species, relating to veneer, were obtained from the Wood Handbook–Wood as an Engineering Material (FPL 1987), and based on their estimated weighted percentage. The PLV input value was derived from the wood only weight of plywood as determined in the CORRIM report (Wilson et al. 2002).

10. Veneer and PLV inputs were given in M 3/8-inch (1,000 ft^2 3/8-inch basis) volumes and converted to cubic feet.

11. At the time of the study a suitable LCI database was not available for phenol-resorcinol-formaldehyde resin, as such LCI data for phenol-formaldehyde was used.

12. All conversions for forest products are taken from Forest Products Measurements and Conversion Factors, with special emphasis on the US Pacific Northwest (Briggs 1994).

13. SimaPro v 5.0.009, a software package designed to analyze products through their entire life-cycle, was used to complete the LCI. The software is designed by Pre' Consultants B.V. and contains a database for US materials. The US database is provided by Franklin Associates.

1.2 PRODUCT YIELDS

To produce one thousand cubic feet (MCF) of LVL in the PNW, the required inputs were 6,947 lbs of dry veneer and 24,379 lbs of PLV (based on survey volumes and wood densities, Table1.5). The output yield from the survey data was 32,496 lbs of oven-dry LVL without resin and 1,487 lbs of oven-dry wood co-products. In the SE region of the US, the inputs required to produce 1.0 MCF of LVL include 37,825 lbs of southern pine veneer (based on wood volumes and densities listed in Table 1.6). Output yield for the SE includes 36,989 lbs of LVL and 3,515 lbs of wood-based co-products. A full listing of inputs and outputs is given in Table 1.6. The table includes English and SI units. The SI units are kilograms per thousand cubic meters ($kg/10^3m^3$)

Table 1.6. Inputs to Produce 1.0 MCF of LVL in each Region.

INPUTS	PNW Inputs		SE Inputs	
Materials[1]	**lb/MCF**	**kg/10^3m^3**	**lb/MCF**	**kg/10^3m^3**
Dry Veneer	6.95E+03	1.11E+05	3.84E+04	6.06E+05
Parallel laminated veneer (PLV)	2.44E+04	3.91E+05	0.00E+00	0.00E+00
Phenol-formaldehyde resin	5.04E+02	8.07E+03	6.56E+02	1.05E+04
Phenol-resorcinol-formaldehyde resin	3.60E+01	5.77E+02	0.00E+00	0.00E+00
Extenders and fillers[2]	4.01E+02	6.42E+03	5.88E+02	9.42E+03
Catalyst[2]	7.60E+00	1.22E+02	3.36E+01	5.38E+02
Electrical Use	**kWh/MCF**	**MJ/10^3m^3**	**kWh/MCF**	**MJ/10^3m^3**
Electricity	1.66E+03	2.11E+05	1.92E+03	2.45E+05
Fuel Use	**Btu/MCF**	**MJ/10^3m^3**	**Btu/MCF**	**MJ/10^3m^3**
Natural Gas	3.83E+06	1.43E+05	1.09E+07	4.06E+05
Liquid Propane Gas	2.39E+05	8.91E+03	3.22E+05	1.20E+04
Diesel	1.80E+05	6.70E+03	3.86E+05	1.44E+04

[1] All materials are on an oven-dry basis
[2] Materials not included in the SimaPro LCI; excluded based on the 2% rule in CORRIM protocol
[3] MJ= 1.0 megajoules; 10^3m^3=1.0 thousand cubic meters

A wood mass balance for each region was completed and is shown in Table 1.7. The wood was considered to be oven-dry and all resin and resin component weights were subtracted from the total weight. A slight discrepancy appeared between input and output wood values for each region. In the PNW the amount of output material was larger than the input material by 7.6%, while in the SE this difference was slightly smaller at 5.3% more output wood than input wood material. This difference can probably be attributed to the difficult nature of precisely tracking materials in a large scale manufacturing facility. Another contributing factor to the discrepancy is the wide variety of measurement units used in the manufacturing facilities. This can lead to conversion errors, which will result in a balance that is not exact.

Table 1.7. Wood mass balance for LVL Production from the PNW and SE Regions per 1.0 MCF.

INPUTS	PNW lb/MCF	PNW kg/10^3m^3	SE lb/MCF	SE kg/10^3m^3
Dry veneer	6.95E+03	1.11E+05	3.84E+04	6.14E+05
Parallel laminated veneer (PLV)	2.45E+04	3.92E+05	0.00E+00	0.00E+00
Total	3.14E+04	5.03E+05	3.84E+04	6.14E+05
OUTPUTS	**lb/MCF**	**kg/10^3m^3**	**lb/MCF**	**kg/10^3m^3**
LVL (wood only)	3.25E+04	5.21E+05	3.70E+04	5.93E+05
Veneer waste	4.71E+02	7.54E+03	6.83E+02	1.09E+04
Lay-up scrap	3.76E+02	6.02E+03	1.40E+03	2.25E+04
Tested LVL	8.46E+01	1.36E+03	1.09E+02	1.74E+03
Panel trim	4.20E+01	6.73E+02	1.04E+03	1.66E+04
Sawdust	5.14E+02	8.23E+03	2.82E+02	4.52E+03
Total	3.40E+04	5.44E+05	4.05E+04	6.49E+05

Notes: All weights are on an oven-dry basis.

1.3 MANUFACTURING ENERGY SUMMARY

1.3.1 Sources of Energy

Energy production for the manufacturing of LVL comes from electricity, natural gas, diesel and liquid propane gas (LPG). Electricity is used to operate the lay-up and pressing machine centers as well as pneumatic and mechanical conveying equipment, fans, and other equipment in the plant. Natural gas is used for the purpose of generating heat for the presses in the LVL plants. 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. Since this is a black box process, it was not necessary to break down the fuel and energy uses into sub-categories. Other types of fuels are used to generate energy in the plywood plants that produce dry veneer and PLV. These energy sources are not analyzed in this report, but the burdens that are created are carried over into this data through the SimaPro models. For an analysis of hogged fuel and other energy sources for dry veneer and PLV (plywood) production see Module D for both the PNW and SE plywood LCI data (Wilson and Sakimoto 2004).

1.3.2 Electricity Use Summary

In order to make an accurate and complete LCI for LVL production, it is necessary to know what fuel sources contribute to electricity production in each region. The breakdown for each region is given in Table 1.8 and Table 1.9. The different energy sources used to generate electricity will have very different emissions which factor into the LCI model. The source of this data was the US Department of Energy (USDOE 2001). In 2000, the dominant form of fuel source in the PNW region was hydroelectric, which made up 74.3% of the total, followed by natural gas at 12.3%. There is no burden for hydro generated electricity in the Franklin database used to determine impacts. In the SE, there are dramatic differences in the way that electricity is generated. For example in the SE, the leading fuel source in 2000 was coal at 45.6% followed by nuclear at 20.8%. In the SimaPro impact analysis there are no burdens assigned for hydro-generated electricity, but there can be significant impacts from other fuel sources (Wilson et al. 2002). As with other resources, the electricity burdens are assigned to the LVL product in the SimaPro model on a mass-based allocation. The electricity values given as inputs to the LCI model are for total electricity use — allocation occurs in the model analysis.

Table 1.8. Electric Power Industry Generation of Electricity by Primary Energy Sources and State for the Pacific Northwest Region as Defined by the US Department of Energy.

Percentage Share, 2000			
Fuel Source	**OR**	**WA**	**Average**
Coal	7.4	8.8	8.1
Petroleum	0.1	0.4	0.25
Natural Gas	17.1	7.5	12.3
Nuclear	0	7.9	3.95
Hydro	74.3	74.3	74.3
Other	1.1	1.1	1.1

Source: www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html

Table 1.9. Electric Power Industry Generation of Electricity by Primary Energy Sources and State for the Southeast Region as Defined by the US Department of Energy.

Percentage Share, 2000								
Fuel Source	**AL**	**AR**	**FL**	**GA**	**LA**	**MS**	**TX**	**Average**
Coal	61.90	64.80	25.60	37.00	37.90	54.70	37.00	45.56
Petroleum	0.20	1.30	2.30	7.90	18.50	0.50	0.70	4.49
Gas	4.30	2.70	49.60	22.50	22.70	7.80	51.60	23.03
Nuclear	25.20	26.40	17.60	28.50	16.90	26.50	9.90	21.57
Hydroelectric	4.70	1.90	0.60	0.00	0.00	5.40	0.20	1.83
Other	3.70	2.90	4.30	4.10	4.00	5.10	0.60	3.53

Source: www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html

1.4 ADHESIVE USAGE AND ENERGY / ELECTRICITY FOR PRODUCTION

Phenol-formaldehyde (PF) resin is the primary resin used in the production of LVL in both the PNW and SE regions of the US. An average of 540 lbs of PF resin is used to produce 1.0 MCF of LVL in the PNW. This number is derived both from survey data and from estimates on the amount of phenol formaldehyde used to create the PLV used in LVL manufacturing. Since the plywood resin is included in the plywood LCI, it is not included in the LVL LCI as well. This eliminates the problem of double accounting of the resin. For purposes of studying the emissions related to the production of resin used in the PNW all 540 lbs were used in the SimaPro analysis. Phenol-formaldehyde resin is comprised of 65% formaldehyde and 35% phenol on a weight basis. The total inputs into the production of 540 lbs of PF (which includes the 36 lbs of PRF) resin are included in Table 1.10 and the associated air emissions are shown in Table 1.11. In the SE US, PLV was not used as an input at any of the surveyed plants therefore the resin input is more straightforward. The amount of PF resin required to produce 1.0 MCF of LVL in the SE is 656 lbs. The total inputs (fuel, material, electricity) are shown in Table 1.10 and the associated air emissions are shown in Table 1.12. Emissions to water and land for the production of PF resin can be found in ATHENA™ 1993 and scaled to their use of resin for PNW and SE. Tables 11 and 12 also show the contribution to the total emissions for the production of LVL (note: this data excludes burden do to the production of logs and transportation of materials). The extenders, fillers and catalyst used in the resin systems to bond the veneer together were excluded from the impact analysis based on the 2% exclusion rule in the CORRIM protocol. The emissions given in the following table are the actual emissions to produce the resin and not allocated emissions.

Table 1.10. Production Requirements[1] for 540 lb of Phenol-formaldehyde Resin Needed to Manufacture 1.0 MCF of LVL in the Pacific Northwest and the 656 lb of Phenol-formaldehyde Resin Needed to Manufacture 1.0 MCF in the Southeast.

INPUTS	PNW		SE	
Materials	**lb/MCF**	**kg/10^{3}m^3**	**lb/MCF**	**kg/10^{3}m^3**
Formaldehyde	3.51E+02	5.62E+03	4.26E+02	6.83E+03
Phenol	1.89E+02	3.03E+03	2.30E+02	3.68E+03
Fuel Use	**Btu**	**MJ**	**Btu**	**MJ**
Heavy oil	3.37E+05	2.58E+03	4.09E+05	3.13E+03
Gasoline	2.32E+03	1.73E+01	2.82E+03	2.10E+01
Natural gas	6.26E+06	4.79E+04	7.60E+06	5.82E+04
Electricity Use	**kWh**	**MJ**	**kWh**	**MJ**
Electricity	3.47E+02	9.00E+03	4.21E+02	1.09E+04

[1] Data obtained from Raw Material Balances, Energy Profiles and Environmental Unit Factor Estimates: Structural Wood Products, ATHENA™ 1993

Table 1.11. **Air Emissions for the Production of the 540 lb of Phenol-formaldehyde Resin Needed to Produce 1.0 MCF of LVL in the Pacific Northwest.**

	Emissions per 1.0 MCF		
Air Emission	**PF Resin Production lb/MCF**	**Total for LVL lb/MCF**	**PF Resin Contribution to Total for LVL Production %**
Acetaldehyde	0.00E+00	3.90E-01	0.0
Acetone	0.00E+00	3.61E-01	0.0
Acrolein	1.59E-06	3.27E-05	4.9
Aldehydes	2.85E-02	3.41E-02	83.6
Alpha-pinene	0.00E+00	1.92E+00	0.0
Ammonia	3.64E-03	2.17E-02	16.8
As	9.02E-06	4.04E-04	2.2
Ba	0.00E+00	1.79E-02	0.0
Be	7.45E-07	4.65E-06	16.0
Benzene	3.81E-04	1.50E-02	2.5
Beta-pinene	0.00E+00	7.44E-01	0.0
Cd	1.01E-05	2.54E-05	40.0
Cl_2	8.22E-05	3.18E-02	0.3
CO	4.94E+00	6.81E+01	7.3
CO_2 (biomass)	0.00E+00	8.18E+03	0.0
CO_2 (fossil)	1.27E+03	3.71E+03	34.2
CO_2 (non-fossil)	6.63E-01	6.02E+02	0.1
Cobalt	1.01E-05	3.36E-05	30.1
Cr	1.11E-05	2.49E-04	4.5
Cumene	3.21E-03	3.21E-03	100.0
Dichloromethane	6.55E-06	6.29E-05	10.4
Dioxin (TEQ)	8.56E-12	8.39E-11	10.2
Fe	0.00E+00	1.79E-02	0.0
Formaldehyde	7.29E-01	1.26E+00	57.7
HCl	8.05E-03	7.94E-02	10.1
HF	1.10E-03	1.10E-02	10.0
Hg	4.38E-06	3.26E-05	13.4
K	0.00E+00	3.17E+00	0.0
Kerosene	4.70E-05	5.01E-04	9.4
Limonene	0.00E+00	2.15E-01	0.0
Metals	2.65E-04	5.48E-04	48.3
Methane	4.64E+00	1.10E+01	42.0
Methanol	0.00E+00	4.12E+00	0.0
Methyl ethyl ketone	0.00E+00	1.70E-02	0.0
Methyl i-butyl ketone	0.00E+00	1.39E-02	0.0
Mn	1.76E-05	3.68E-02	0.0
N-nitrodimethylamine	3.37E-07	3.35E-06	10.1
N_2O	9.21E-04	9.00E-03	10.2

Table 1.11 (cont.) Air Emissions for the Production of the 540 lb of Phenol-formaldehyde Resin Needed to Produce 1.0 MCF of LVL in the Pacific Northwest.

Air Emission	PF Resin Production lb/MCF	Total for LVL lb/MCF	PF Resin Contribution to Total for LVL Production %
Na	0.00E+00	7.33E-02	0.0
Naphthalene	9.87E-07	9.73E-03	0.0
Ni	1.43E-04	2.64E-03	5.4
Non methane VOC	1.30E+01	1.96E+01	66.5
NO_x	1.49E+01	3.30E+01	45.2
Organic substances	2.59E-02	7.15E-01	3.6
Particulates	1.24E-01	1.22E+01	1.0
Particulates (PM10)	1.73E-02	7.56E+00	0.2
Particulates (unspecified)	2.08E-01	1.17E+00	17.8
Pb	1.41E-05	4.95E-03	0.3
Phenol	9.40E-01	1.03E+00	91.3
Propionaldehyde	0.00E+00	1.42E-02	0.0
Sb	3.66E-06	1.35E-05	27.2
Se	1.49E-05	1.24E-04	11.9
SO_2	0.00E+00	3.65E-02	0.0
SO_x	2.40E+01	5.43E+01	44.3
Tetrachloroethene	1.55E-06	1.52E-05	10.2
Tetrachloromethane	3.96E-06	2.69E-05	14.7
THC as Carbon	0.00E+00	4.11E+00	0.0
Trichloroethene	1.50E-06	1.50E-05	10.0
VOC	0.00E+00	1.99E+01	0.0
Zn	0.00E+00	1.79E-02	0.0

Notes: Results from SimaPro LCI.

Table 1.12. Air Emissions for the Production of the 656 lb of Phenol-formaldehyde Resin Needed to Produce 1.0 MCF of LVL in the Southeast.

	Emissions per 1.0 MCF		
	PF Resin Production	Total for LVL	PF Resin Contribution to Total for LVL Production
Air Emission	lb/MCF	lb/MCF	%
Acetaldehyde	0.00E+00	2.77E-02	0.00
Acetone	0.00E+00	8.21E-01	0.00
Acrolein	8.31E-06	2.83E-04	2.94
Aldehydes	3.64E-02	6.18E-02	59.01
Ammonia	6.06E-03	3.72E-02	16.29
As	3.33E-05	7.82E-04	4.26
Ba	0.00E+00	2.56E-02	0.00
Be	3.03E-06	2.59E-05	11.68
Benzene	4.69E-04	2.14E-02	2.18
Cd	2.94E-05	2.02E-04	14.57
Cl_2	1.03E-04	4.55E-02	0.23
CO	6.25E+00	1.00E+02	6.24
CO_2 (biomass)	0.00E+00	1.06E+04	0.00
CO_2 (fossil)	2.05E+03	9.68E+03	21.12
CO_2 (non-fossil)	9.95E-01	1.57E+03	0.06
Cobalt	3.16E-05	2.29E-04	13.78
Cr	4.11E-05	6.06E-04	6.78
Cumene	3.90E-03	3.90E-03	100.00
Dichloromethane	3.37E-05	3.17E-04	10.60
Dioxin (TEQ)	4.41E-11	4.16E-10	10.59
Fe	0.00E+00	2.56E-02	0.00
Formaldehyde	8.85E-01	9.88E-01	89.53
HCl	4.16E-02	3.95E-01	10.56
HF	5.76E-03	5.47E-02	10.54
Hg	1.95E-05	1.73E-04	11.31
K	0.00E+00	4.54E+00	0.00
Kerosene	2.53E-04	2.44E-03	10.34
Metals	3.98E-04	1.48E-03	26.89
Methane	6.66E+00	2.59E+01	25.65
Methanol	0.00E+00	3.11E+00	0.00
Mn	7.03E-05	5.30E-02	0.13
N-nitrodimethylamine	1.75E-06	1.66E-05	10.55
N_2O	4.87E-03	4.60E-02	10.59
Na	0.00E+00	1.05E-01	0.00
Naphthalene	1.66E-06	1.39E-02	0.01
Ni	4.09E-04	6.05E-03	6.76
Non methane VOC	1.62E+01	3.18E+01	50.80

Table 1.12 (cont.) Air Emissions for the Production of the 656 lb of Phenol-formaldehyde Resin Needed to Produce 1.0 MCF of LVL in the Southeast.

Air Emission	PF Resin Production lb/MCF	Total for LVL lb/MCF	PF Resin Contribution to Total for LVL Production %
NO_x	1.99E+01	6.31E+01	31.50
Organic substances	3.35E-02	1.04E+00	3.22
Particulates	1.50E-01	3.72E+00	4.04
Particulates (PM10)	1.18E-01	3.21E+01	0.37
Particulates (unspecified)	7.03E-01	5.71E+00	12.30
Pb	4.31E-05	7.30E-03	0.59
Phenol	1.14E+00	1.29E+00	88.73
Sb	1.20E-05	8.97E-05	13.34
Se	6.84E-05	6.23E-04	10.98
SO_2	0.00E+00	2.12E-02	0.00
SO_x	3.31E+01	1.18E+02	28.06
Tetrachloroethene	8.05E-06	7.62E-05	10.56
Tetrachloromethane	2.29E-05	2.07E-04	11.05
Trichloroethene	7.85E-06	7.44E-05	10.54
VOC	0.00E+00	2.47E+00	0.00
Water vapor	0.00E+00	1.64E+04	0.00
Zn	0.00E+00	2.56E-02	0.00

Notes: Results from SimaPro LCI.

1.5 PROCESS RELATED EMISSIONS

The next section displays the process related emissions, as given by SimaPro, for the PNW and SE regions. The emissions that are generated by producing LVL at the plant are shown as well as those emissions that are generated at other plants but are assigned to the veneer or PLV product that is being purchased. The total emissions are for the system boundaries shown in Figures 1.1B and 1.2B. The emissions are those assigned to LVL on their mass-based allocation. The emissions are also shown with a percentage of the emissions that are generated at other facilities, i.e., for the production of dry veneer and PLV. The mass-based allocation of emissions to LVL in the PNW is 95.7% thus the other 4.3% were allocated to co-products. In the SE, the mass-based allocation percentage to LVL is lower at 91.3% with the remaining 8.7% allocated to co-products. The process air emissions for each region are listed in Tables 1.13 and 1.14 and include those to produce LVL using material resources such as dry veneer and PLV, resin, electricity, and fuels, but exclude those for harvesting logs and transportation of materials.

Table 1.13. Process Air Emissions for LVL Production from the Pacific Northwest Region—total emissions[1].

Air Emission	From Dry Veneer and PLV Inputs lb/MCF	From LVL Process lb/MCF	Total Emissions lb/MCF	From Dry Veneer and PLV %
Acetaldehyde	3.58E-01	3.19E-02	3.90E-01	91.82
Acetone	1.27E-01	2.34E-01	3.61E-01	35.23
Acrolein	2.71E-05	5.67E-06	3.27E-05	82.69
Aldehydes	2.37E-02	1.04E-02	3.41E-02	69.48
Alpha-pinene	1.92E+00	0.00E+00	1.92E+00	100.00
Ammonia	1.41E-02	7.64E-03	2.17E-02	64.78
As	3.88E-04	1.63E-05	4.04E-04	95.97
Ba	1.79E-02	0.00E+00	1.79E-02	100.00
Be	3.00E-06	1.65E-06	4.65E-06	64.51
Benzene	1.49E-02	9.36E-05	1.50E-02	99.38
Beta-pinene	7.44E-01	0.00E+00	7.44E-01	100.00
Cd	1.66E-05	8.72E-06	2.54E-05	65.61
Cl_2	3.18E-02	9.36E-06	3.18E-02	99.97
CO	6.49E+01	3.18E+00	6.81E+01	95.33
CO_2 (biomass)	8.18E+03	0.00E+00	8.18E+03	100.00
CO_2 (fossil)	2.26E+03	1.46E+03	3.71E+03	60.81
CO_2 (non-fossil)[2]	6.02E+02	0.00E+00	6.02E+02	100.00
Cobalt	2.19E-05	1.17E-05	3.36E-05	65.18
Cr	2.28E-04	2.12E-05	2.49E-04	91.47
Cumene	1.85E-03	1.36E-03	3.21E-03	57.63
Dichloromethane	4.04E-05	2.25E-05	6.29E-05	64.24
Dioxin (TEQ)	5.39E-11	3.00E-11	8.39E-11	64.28
Fe	1.79E-02	0.00E+00	1.79E-02	100.00
Formaldehyde	1.07E+00	1.96E-01	1.26E+00	84.44
HCl	5.11E-02	2.84E-02	7.94E-02	64.30
HF	7.07E-03	3.97E-03	1.10E-02	64.07
Hg	2.10E-05	1.15E-05	3.26E-05	64.57
K	3.18E+00	0.00E+00	3.18E+00	100.00
Kerosene	3.22E-04	1.80E-04	5.01E-04	64.20
Limonene	2.15E-01	0.00E+00	2.15E-01	100.00
Metals	3.57E-04	1.91E-04	5.48E-04	65.20
Methane	6.95E+00	4.09E+00	1.10E+01	62.98
Methanol	3.56E+00	5.57E-01	4.12E+00	86.48
Methyl ethyl ketone	1.70E-02	0.00E+00	1.70E-02	100.00
Methyl i-butyl ketone	1.39E-02	0.00E+00	1.39E-02	100.00
Mn	3.67E-02	9.36E-05	3.68E-02	99.75
N-nitrodimethylamine	2.15E-06	1.20E-06	3.35E-06	64.13
N_2O	5.79E-03	3.21E-03	9.00E-03	64.32
Na	7.33E-02	0.00E+00	7.33E-02	100.00

Table 1.13 (cont.) Process Air Emissions for LVL Production from the Pacific Northwest Region—total emissions[1].

Air Emission	From Dry Veneer and PLV Inputs lb/MCF	From LVL Process lb/MCF	Total Emissions lb/MCF	From Dry Veneer and PLV %
Naphthalene	9.78E-03	6.36E-02	7.33E-02	13.33
Ni	2.52E-03	1.18E-04	2.64E-03	95.53
Non methane VOC	1.28E+01	6.72E+00	1.96E+01	65.65
NO_x	2.52E+01	7.85E+00	3.30E+01	76.23
Organic substances	7.02E-01	1.31E-02	7.15E-01	98.17
Particulates	1.14E+01	8.05E-01	1.22E+01	93.38
Particulates (PM10)	7.19E+00	3.65E-01	7.56E+00	95.17
Particulates (unspecified)	7.49E-01	4.20E-01	1.17E+00	64.08
Pb	4.92E-03	2.81E-05	4.95E-03	99.43
Phenol	7.97E-01	2.32E-01	1.03E+00	77.45
Propionaldehyde	0.00E+00	1.42E-02	1.42E-02	0.00
Sb	8.74E-06	4.73E-06	1.35E-05	64.86
Se	7.99E-05	4.45E-05	1.24E-04	64.21
SO_2	2.64E-02	1.00E-02	3.65E-02	72.46
SO_x	3.42E+01	2.00E+01	5.43E+01	63.10
Tetrachloroethene	9.73E-06	5.43E-06	1.52E-05	64.20
Tetrachloromethane	1.73E-05	9.66E-06	2.69E-05	64.13
THC as Carbon	4.11E+00	0.00E+00	4.11E+00	100.00
Trichloroethene	9.63E-06	5.34E-06	1.50E-05	64.31
VOC	1.99E+01	3.74E-02	1.99E+01	99.81
Zn	1.79E-02	0.00E+00	1.79E-02	100.00

1 Includes LVL site-generated and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.

2 Non-fossil fuels appear from the SimaPro databases and are most likely biomass fuels and could be added to this category.

Table 1.14. Process Air Emissions for LVL Production from the Southeast Region—total emissions[1].

Air Emission	From Dry Veneer and PLV Inputs lb/MCF	From LVL Process lb/MCF	Total Emissions lb/MCF	From Dry Veneer and PLV %
Acetaldehyde	2.77E-02	0.00E+00	2.77E-02	100.0
Acetone	0.00E+00	8.21E-01	8.21E-01	0.0
Acrolein	2.43E-04	3.97E-05	2.83E-04	86.0
Aldehydes	1.52E-02	4.65E-02	6.18E-02	24.7
Ammonia	1.73E-02	1.99E-02	3.72E-02	46.4
As	6.42E-04	1.39E-04	7.82E-04	82.2
Ba	2.56E-02	0.00E+00	2.56E-02	100.0
Be	1.27E-05	1.33E-05	2.59E-05	48.8
Benzene	2.10E-02	4.29E-04	2.14E-02	98.0
Cd	9.47E-05	1.07E-04	2.02E-04	47.0
Cl_2	4.54E-02	1.07E-04	4.55E-02	99.8
CO	8.74E+01	1.27E+01	1.00E+02	87.4
CO_2 (biomass)	1.06E+04	0.00E+00	1.06E+04	100.0
CO_2 (fossil)	3.75E+03	5.93E+03	9.68E+03	38.8
CO_2 (non-fossil)[2]	1.57E+03	0.00E+00	1.57E+03	100.0
Cobalt	1.09E-04	1.20E-04	2.29E-04	47.7
Cr	4.31E-04	1.75E-04	6.06E-04	71.2
Cumene	0.00E+00	3.90E-03	3.90E-03	0.0
Dichloromethane	1.57E-04	1.61E-04	3.17E-04	49.3
Dioxin (TEQ)	2.05E-10	2.11E-10	4.16E-10	49.2
Fe	2.56E-02	0.00E+00	2.56E-02	100.0
Formaldehyde	7.82E-02	9.10E-01	9.88E-01	7.9
HCl	1.94E-01	2.00E-01	3.95E-01	49.2
HF	2.69E-02	2.78E-02	5.47E-02	49.2
Hg	8.46E-05	8.80E-05	1.73E-04	49.0
K	4.54E+00	0.00E+00	4.54E+00	100.0
Kerosene	1.20E-03	1.24E-03	2.44E-03	49.1
Metals	5.88E-04	8.92E-04	1.48E-03	39.7
Methane	1.01E+01	1.58E+01	2.59E+01	39.0
Methanol	2.18E-02	3.09E+00	3.11E+00	0.7
Mn	5.26E-02	3.22E-04	5.30E-02	99.4
N-nitrodimethylamine	8.19E-06	8.43E-06	1.66E-05	49.3
N_2O	2.26E-02	2.34E-02	4.60E-02	49.2
Na	1.05E-01	0.00E+00	1.05E-01	100.0
Naphthalene	1.39E-02	0.00E+00	1.39E-02	100.0
Ni	4.57E-03	1.48E-03	6.05E-03	75.5
Non methane VOC	8.38E+00	2.35E+01	3.18E+01	26.3
NO_x	2.67E+01	3.65E+01	6.31E+01	42.3
Organic substances	9.87E-01	5.25E-02	1.04E+00	94.9
Particulates	3.37E+00	3.54E-01	3.72E+00	90.5

Table 1.14 (cont.) Total Process Air Emissions for LVL Production from the Southeast Region—total emissions[1].

Air Emission	From Dry Veneer and PLV Inputs lb/MCF	From LVL Process lb/MCF	Total Emissions lb/MCF	From Dry Veneer and PLV %
Particulates (PM10)	1.22E+00	3.08E+01	3.21E+01	3.8
Particulates (unspecified)	2.77E+00	2.95E+00	5.71E+00	48.4
Pb	7.13E-03	1.72E-04	7.30E-03	97.7
Phenol	2.42E-01	1.04E+00	1.29E+00	18.8
Sb	4.29E-05	4.69E-05	8.97E-05	47.8
Se	3.06E-04	3.17E-04	6.23E-04	49.1
SO_2	2.48E-03	1.88E-02	2.12E-02	11.7
SO_x	4.41E+01	7.39E+01	1.18E+02	37.4
Tetrachloroethene	3.75E-05	3.87E-05	7.62E-05	49.2
Tetrachloromethane	1.01E-04	1.05E-04	2.07E-04	49.0
Trichloroethene	3.67E-05	3.77E-05	7.44E-05	49.3
VOC	2.29E+00	1.72E-01	2.47E+00	93.0
Water vapor	1.64E+04	0.00E+00	1.64E+04	100.0
Zn	2.56E-02	0.00E+00	2.56E-02	100.0

1. Includes LVL site-generated and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.
2. Non-fossil fuels appear from the SimaPro databases and are most likely biomass fuels and could be added to this category.

1.6 LIFE-CYCLE INVENTORY RESULTS FOR LAMINATED VENEER LUMBER PRODUCTION

Total life-cycle inventory input results that exclude logs and transportation for the production of 1.0 MCF of LVL in the PNW and SE are shown in Table 1.15 and Table 1.16. Output results for the same LCI are shown in Table 1.17 and Table 1.18. Results include processes within system boundaries as shown in Figures 1.1 B and 1.2 B, which include impacts for materials, energy, fuels, and electricity, but exclude the log resource impacts and transportation. It is important to note that the manufacturing of dry veneer and PLV are included in the system boundary. For some of the plants, the system boundary represented the plant boundary, but in other cases this was not the case. The delivery and log production burdens for the input products are not included in this analysis. The results were generated using SimaPro LCI software with the Franklin database (1998) for fuel use and electricity production burdens for their production. Emissions related to the production of PF resin were obtained from ATHENA™ (1993). All other data is based on survey data obtained from manufacturing facilities in each region.

Table 1.15. Life-cycle Inventory Inputs for Producing 1.0 MCF of LVL in the Pacific Northwest—total emissions[1].

PNW LVL-INPUTS				
Material	**Units**	**Unit/MCF**	**SI Units**	**SI Unit/$10^3 m^3$**
Phenol formaldehyde[2]	lb	5.40E+02	kg	8.65E+03
Extenders and fillers[3]	lb	4.01E+02	kg	6.42E+03
Catalyst[3]	lb	7.80E+00	kg	1.25E+02
Purchased				
Dry veneer	lb	6.95E+03	kg	1.11E+05
PLV	lb	2.44E+04	kg	3.91E+05
Electrical Use	**LVL Production, PNW**			
Electricity	kWh	1.66E+03	MJ	2.11E+05
Fuel Use				
Natural gas	Btu	3.83E+06	MJ	1.43E+05
Liquid propane gas	Btu	2.39E+05	MJ	8.90E+03
Diesel	Btu	1.80E+05	MJ	6.71E+03
Water Usage				
Municipal water source	lb	2.33E+03	kg	3.74E+04
Electrical Use	**Phenol Formaldehyde Production**			
Electricity	kWh	3.47E+02	MJ	4.41E+04
Fuel Use				
Heavy oil	Btu	3.37E+05	MJ	1.26E+04
Natural gas	Btu	2.32E+03	MJ	8.65E+01
Diesel	Btu	6.26E+06	MJ	2.33E+05

1 Includes LVL site and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.
2 Phenol-formaldehyde resin weight includes weight for phenol-resorcinol-formaldehyde resin.
3 Excluded based upon the 2% rule in the CORRIM protocol.
4 All weights are on an oven-dry basis.

Table 1.16. Life-cycle Inventory Inputs for Producing 1.0 MCF of LVL in the Southeast—total emissions[1].

SE LVL- Inputs				
Material	**Units**	**Unit/MCF**	**SI Units**	**SI Unit/$10^3 m^3$**
Phenol formaldehyde	lb	6.56E+02	kg	1.05E+04
Extenders and fillers[2]	lb	5.88E+02	kg	9.43E+03
Catalyst[2]	lb	3.36E+01	kg	5.38E+02
Purchased				
Dry veneer	lb	3.84E+04	kg	6.14E+05
Electrical Use	**LVL Production, PNW**			
Electricity	kWh	1.92E+03	MJ	2.45E+05
Fuel Use				
Natural gas	Btu	1.09E+07	MJ	4.06E+05
Liquid propane gas	Btu	3.22E+05	MJ	1.20E+04
Diesel	Btu	3.86E+05	MJ	1.44E+04
Water Usage				
Municipal water source	lb	6.08E+03	kg	9.73E+04
Well water	lb	1.95E+02	kg	3.13E+03
Recycled water	lb	1.32E+04	kg	2.11E+05
Electrical Use	**Phenol Formaldehyde Production**			
Electricity	kWh	4.21E+02	MJ	5.35E+04
Fuel Use				
Heavy oil	Btu	4.09E+05	MJ	1.52E+04
Natural gas	Btu	2.82E+03	MJ	1.05E+02
Diesel	Btu	7.60E+06	MJ	2.83E+05

1 Includes LVL site and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.
2 Excluded based on the 2% rule in the CORRIM protocol.
3 All weights are on an oven-dry basis.

Table 1.17. Life-cycle Inventory Outputs for 1.0 MCF LVL Production from the Pacific Northwest Region—total emissions[1].

Product	lb/MCF	kg/10^{3}m^3
Laminated Veneer Lumber	3.30E+04	5.29E+05

Co-products	lb/MCF	kg/10^{3}m^3
Sawdust	5.14E+02	8.23E+03
Veneer loss	4.71E+02	7.54E+03
Lay-up scrap	3.76E+02	6.02E+03
Tested LVL	8.45E+01	1.35E+03
Panel trim	4.20E+01	6.73E+02

Raw Materials	lb/MCF	kg/10^{3}m^3
PNW bark on logs	3.00E+03	4.80E+04
PNW logs	2.98E+04	4.77E+05
Coal FAL	4.41E+02	7.06E+03
Crude oil FAL	4.19E+02	6.71E+03
Limestone	5.86E+01	9.38E+02
Natural gas FAL	1.38E+03	2.22E+04
Uranium FAL	2.29E-03	3.67E-02
Wood/wood wastes FAL	5.76E+02	9.23E+03

Other Raw Materials	Btu/MCF	MJ/10^{3}m^3
Hogged Fuel-Direct Fired	2.28E+06	8.48E+04

Electricity	Btu/MCF	MJ/10^{3}m^3
Electricity from other sources	1.75E+05	6.52E+03
Energy from hydro power	1.18E+07	4.40E+05

Water Usage	lb/MCF	kg/10^{3}m^3
Municipal Water Source	1.37E+04	2.19E+05
Recycled Water	4.60E+01	7.37E+02
Well Water Source	4.10E+03	6.57E+04

Table 1.17 (cont.) Life-cycle Inventory Outputs for 1.0 MCF LVL Production from the Pacific Northwest Region—total emissions[1].

Air Emissions	lb/MCF	$kg/10^3m^3$	Air Emissions	lb/MCF	$kg/10^3m^3$
Acetaldehyde	3.90E-01	6.25E+00	Hg	3.26E-05	5.22E-04
Acetone	3.61E-01	5.79E+00	K	3.17E+00	5.08E+01
Acrolein	3.27E-05	5.25E-04	Kerosene	5.01E-04	8.03E-03
Aldehydes	3.41E-02	5.46E-01	Limonene	2.15E-01	3.45E+00
Alpha-pinene	1.92E+00	3.07E+01	Metals	5.48E-04	8.78E-03
Ammonia	2.17E-02	3.48E-01	Methane	1.10E+01	1.77E+02
As	4.04E-04	6.47E-03	Methanol	4.12E+00	6.59E+01
Ba	1.79E-02	2.86E-01	Methyl ethyl ketone	1.70E-02	2.73E-01
Be	4.65E-06	7.45E-05	Methyl i-butyl ketone	1.39E-02	2.23E-01
Benzene	1.50E-02	2.40E-01	Mn	3.68E-02	5.89E-01
Beta-pinene	7.44E-01	1.19E+01	N-nitrodimethylamine	3.35E-06	5.37E-05
Cd	2.54E-05	4.06E-04	N_2O	9.00E-03	1.44E-01
Cumene	2.64E-03	4.23E-02	Na	7.33E-02	1.17E+00
Cl_2	3.18E-02	5.10E-01	Naphthalene	9.73E-03	1.56E-01
CO	6.81E+01	1.09E+03	Ni	2.64E-03	4.23E-02
CO_2 (biomass)	8.18E+03	1.31E+05	Non methane VOC	1.96E+01	3.13E+02
CO_2 (fossil)	3.71E+03	5.95E+04	NO_x	3.30E+01	5.29E+02
CO_2 (non-fossil)	6.02E+02	9.64E+03	Organic substances	7.15E-01	1.15E+01
Cobalt	3.36E-05	5.38E-04	Particulates	1.22E+01	1.95E+02
Cr	2.49E-04	3.99E-03	Particulates (PM10)	7.56E+00	1.21E+02
Dichloromethane	6.29E-05	1.01E-03	Particulates (unspecified)	1.17E+00	1.87E+01
Dioxin (TEQ)	8.39E-11	1.34E-09	Pb	4.95E-03	7.93E-02
Fe	1.79E-02	2.86E-01	Phenol	1.03E+00	1.65E+01
Formaldehyde	1.26E+00	2.02E+01	Propionaldehyde	1.42E-02	2.28E-01
HCl	7.94E-02	1.27E+00	Sb	1.35E-05	2.16E-04
HF	1.10E-02	1.77E-01	Se	1.24E-04	1.99E-03

Table 1.17 (cont.) Life-cycle Inventory Outputs for 1.0 MCF LVL Production from the Pacific Northwest Region—total emissions[1].

Air Emissions	lb/MCF	$kg/10^3m^3$
SO_x	5.43E+01	8.69E+02
SO_2	3.65E-02	5.85E-01
Tetrachloroethene	1.52E-05	2.43E-04
Tetrachloromethane	2.69E-05	4.32E-04
THC as Carbon	4.11E+00	6.58E+01
Trichloroethene	1.50E-05	2.40E-04
VOC	1.99E+01	3.19E+02
Zn	1.79E-02	2.86E-01

Water Emissions	lb/MCF	$kg/10^3m^3$
Acid as H+	4.48E-07	7.18E-06
B	4.21E-02	6.74E-01
BOD	7.18E-02	1.15E+00
Ca	3.64E-06	5.83E-05
Calcium ions	4.28E-04	6.86E-03
Cd	3.34E-03	5.35E-02
Chromate	1.97E-05	3.16E-04
Cl-	3.34E+00	5.35E+01
COD	6.57E-01	1.05E+01
Cr	3.34E-03	5.35E-02
Cyanide	5.01E-06	8.02E-05
Dissolved solids	7.32E+01	1.17E+03
Fe	6.19E-02	9.92E-01
Fluoride ions	2.00E-03	3.21E-02
H_2SO_4	1.05E-02	1.68E-01
Hg	2.62E-07	4.20E-06

Water Emissions	lb/MCF	$kg/10^3m^3$
Metallic ions	9.54E-03	1.53E-01
Mn	3.45E-02	5.53E-01
Na	7.94E-04	1.27E-02
NH_3	1.95E-03	3.12E-02
Nitrate	1.89E-04	3.03E-03
Oil	1.30E+00	2.08E+01
Other organics	2.17E-01	3.48E+00
Pb	8.15E-07	1.31E-05
Phenol	3.10E-05	4.96E-04
Phosphate	5.27E-03	8.44E-02
Sulphate	2.86E+00	4.59E+01
Suspended solids	1.16E+00	1.86E+01
Zn	1.15E-03	1.84E-02

Solid Waste Emission	lb/MCF	$kg/10^3m^3$
Solid waste	7.00E+02	1.12E+04

Nonmaterial Emission	lb/MCF	$kg/10^3m^3$
Radioactive sub. to air	2.07E+07	3.31E+08

1 Includes LVL site and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.

2 All weights are on an oven-dry basis.

Table 1.18. Life-cycle Inventory Inputs and Outputs for 1.0 MCF LVL Production from the Southeast Region—total emissions[1].

Product	lb/MCF	kg/10^{3}m^3
Laminated Veneer Lumber	3.78E+04	6.06E+05

Co-products	lb/MCF	kg/10^{3}m^3
Sawdust	2.72E+02	4.35E+03
Veneer loss	6.94E+02	1.11E+04
Lay-up scrap	1.42E+03	2.28E+04
Tested LVL	1.20E+02	1.92E+03
Panel trim	9.99E+02	1.60E+04

Raw Materials	lb/MCF	kg/10^{3}m^3
SE Bark on Logs	3.40E+03	5.44E+04
SE Logs	3.40E+04	5.44E+05
Coal FAL	2.19E+03	3.50E+04
Crude oil FAL	6.93E+02	1.11E+04
Limestone	2.12E+02	3.40E+03
Natural gas FAL	2.42E+03	3.88E+04
Uranium FAL	1.12E-02	1.79E-01
Wood/wood wastes FAL	1.50E+03	2.40E+04

Electricity	Btu/MCF	MJ/10^{3}m^3
Electricity from other sources	5.11E+05	1.90E+04
Energy from hydro power	2.66E+05	9.90E+03

Water Usage	lb/MCF	kg/10^{3}m^3
Municipal Water Source	6.08E+03	9.73E+04
Recycled Water	1.95E+02	3.13E+03
Well Water Source	1.32E+04	2.11E+05

Table 1.18 (cont.) Life-cycle Inventory Inputs and Outputs for 1.0 MCF LVL Production from the Southeast Region—total emissions[1].

Air Emissions	lb/MCF	$kg/10^3m^3$	Air Emissions	lb/MCF	$kg/10^3m^3$
Acetaldehyde	2.77E-02	4.43E-01	Metals	1.48E-03	2.37E-02
Acetone	8.21E-01	1.32E+01	Methane	2.59E+01	4.16E+02
Acrolein	2.83E-04	4.53E-03	Methanol	3.11E+00	4.98E+01
Aldehydes	6.18E-02	9.89E-01	Mn	5.30E-02	8.48E-01
Ammonia	3.72E-02	5.96E-01	N-nitrodimethylamine	1.66E-05	2.66E-04
As	7.82E-04	1.25E-02	N_2O	4.60E-02	7.37E-01
Ba	2.56E-02	4.10E-01	Na	1.05E-01	1.68E+00
Be	2.59E-05	4.16E-04	Naphthalene	1.39E-02	2.23E-01
Benzene	2.14E-02	3.44E-01	Ni	6.05E-03	9.69E-02
Cd	2.02E-04	3.23E-03	Non methane VOC	3.18E+01	5.10E+02
Cl_2	4.55E-02	7.28E-01	NO_x	6.31E+01	1.01E+03
CO	1.00E+02	1.60E+03	Organic substances	1.04E+00	1.67E+01
CO_2 (biomass)	1.06E+04	1.71E+05	Particulates	3.72E+00	5.96E+01
CO_2 (fossil)	9.68E+03	1.55E+05	Particulates (PM10)	3.21E+01	5.14E+02
CO_2 (non-fossil)	1.57E+03	2.51E+04	Particulates (unspecified)	5.71E+00	9.15E+01
Cobalt	2.29E-04	3.68E-03	Pb	7.30E-03	1.17E-01
Cr	6.06E-04	9.70E-03	Phenol	1.29E+00	2.06E+01
Cumene	3.90E-03	6.25E-02	Sb	8.97E-05	1.44E-03
Dichloromethane	3.17E-04	5.08E-03	Se	6.23E-04	9.98E-03
Dioxin (TEQ)	4.16E-10	6.66E-09	SO_2	2.12E-02	3.40E-01
Fe	2.56E-02	4.10E-01	SO_x	1.18E+02	1.89E+03
Formaldehyde	9.88E-01	1.58E+01	Tetrachloroethene	7.62E-05	1.22E-03
HCl	3.95E-01	6.32E+00	Tetrachloromethane	2.07E-04	3.31E-03
HF	5.47E-02	8.76E-01	Trichloroethene	7.44E-05	1.19E-03
Hg	1.73E-04	2.77E-03	VOC	2.47E+00	3.95E+01
K	4.54E+00	7.27E+01	Water vapor	1.64E+04	2.63E+05
Kerosene	2.44E-03	3.92E-02	Zn	2.56E-02	4.10E-01

Table 1.18 (cont.) Life-cycle Inventory Inputs and Outputs for 1.0 MCF LVL Production from the Southeast Region—total emissions[1].

Water Emissions	lb/MCF	$kg/10^3m^3$	Water Emissions	lb/MCF	$kg/10^3m^3$
Acid as H+	7.31E-07	1.17E-05	Sulphate	5.79E+00	9.27E+01

B	2.20E-01	3.52E+00
BOD	1.24E-01	1.99E+00
Ca	4.58E-09	7.34E-08
Calcium ions	1.96E-06	3.14E-05
Cd	5.84E-03	9.36E-02
Chromate	1.59E-04	2.54E-03
Cl-	5.86E+00	9.39E+01
COD	1.12E+00	1.79E+01
Cr	5.84E-03	9.36E-02
Cyanide	8.75E-06	1.40E-04
Dissolved solids	1.28E+02	2.04E+03
Fe	3.07E-01	4.91E+00
Fluoride ions	9.72E-03	1.56E-01
H_2SO_4	5.48E-02	8.78E-01
Hg	4.59E-07	7.35E-06
Metallic ions	1.55E-02	2.49E-01
Mn	1.72E-01	2.75E+00
Na	3.86E-03	6.18E-02
NH_3	5.60E-03	8.97E-02
Nitrate	9.17E-04	1.47E-02
Oil	2.28E+00	3.66E+01
Other organics	4.08E-01	6.54E+00
Pb	1.33E-06	2.13E-05
Phenol	5.05E-05	8.09E-04
Phosphate	2.74E-02	4.40E-01
Suspended solids	4.18E+00	6.70E+01
Zn	2.02E-03	3.23E-02

Solid Waste Emission	**lb/MCF**	**kg/10^3m^3**
Solid waste	1.75E+03	2.80E+04

Nonmaterial Emission	**bq/MCF**	**bq/10^3m^3**
Radioactive sub. to air	5.40E+07	8.66E+08

1 Includes LVL site and off-site generated emissions for the production of dry veneer, PLV, and adhesive, and the production and delivery of electricity and fuel, but excludes the production of logs and other deliveries.

2 All weights are on an oven-dry basis.

It is also helpful to examine those emissions, which can be attributed to manufacturing LVL that are also known as site-generated emissions, see the system boundaries for these in Figures 1.1 A and 1.2 A. It is important to note that the dry veneer and PLV production are considered within the system boundary whether or not this actually occurred in the plant. The inputs into the system will appear exactly the same as the original LCI but the outputs will show dramatic differences because only the site emissions are considered. These site-generated emissions exclude those emissions related to producing dry veneer, PLV, resin, fuel and electricity, and as with the total emissions, they exclude the production of logs and transportation. Tables 1.19 and 1.20 show the inputs for each region. Tables 1.21 and 1.22 show the output values for the LCI without fuel, electricity, and resin for each region.

Table 1.19. Life-cycle Inventory Inputs for the Production of 1.0 MCF of LVL in the Pacific Northwest—site generated only[1].

PNW LVL-INPUTS				
Material	**Units**	**Unit/MCF**	**SI Units**	**SI Unit/10^3m^3**
Phenol formaldehyde[2]	lb	5.40E+02	kg	8.65E+03
Extenders and fillers[3]	lb	4.01E+02	kg	6.42E+03
Catalyst[3]	lb	7.80E+00	kg	1.25E+02
Purchased				
Dry Veneer	lb	6.95E+03	kg	1.11E+05
PLV	lb	2.44E+04	kg	3.91E+05
Electrical Use				
Electricity	kWh	1.66E+03	MJ	2.11E+05
Fuel Use				
Natural gas	Btu	3.83E+06	MJ	1.43E+05
Liquid propane gas	Btu	2.39E+05	MJ	8.90E+03
Diesel	Btu	1.80E+05	MJ	6.71E+03
Water Usage				
Municipal water source	lb	2.33E+03	kg	3.74E+04
Electrical Use	**Phenol Formaldehyde Production**			
Electricity	kWh	3.47E+02	MJ	4.41E+04
Fuel Use				
Heavy oil	Btu	3.37E+05	MJ	1.26E+04
Natural gas	Btu	2.32E+03	MJ	8.65E+01
Diesel	Btu	6.26E+06	MJ	2.33E+05

1. Includes LVL site generated emissions plus those for the production of dry veneer and PLV, it excludes the production of logs, resin, fuels, electricity, and their delivery.
2. Phenol-formaldehyde resin weight includes weight for phenol-resorcinol-formaldehyde resin.
3. Excluded based upon the 2% rule in the CORRIM protocol.
4. All weights are on an oven-dry basis.

Table 1.20. Life-cycle Inventory Inputs for the Production of 1.0 MCF of LVL in the Southeast—site-generated emissions[1].

SE LVL- Inputs				
Material	**Unit**	**Unit/MCF**	**SI Units**	**SI Unit/10^3m^3**
Phenol formaldehyde	lb	6.56E+02	kg	1.05E+04
Extenders and fillers[2]	lb	5.88E+02	kg	9.43E+03
Catalyst[2]	lb	3.36E+01	kg	5.38E+02
Purchased				
Dry veneer	lb	3.84E+04	kg	6.14E+05
Electrical Use				
Electricity	kWh	1.92E+03	MJ	2.45E+05
Fuel Use				
Natural gas	Btu	1.09E+07	MJ	4.06E+05
Liquid propane gas	Btu	3.22E+05	MJ	1.20E+04
Diesel	Btu	3.86E+05	MJ	1.44E+05
Water Usage				
Municipal water source	lb	6.08E+03	kg	9.73E+04
Well water	lb	1.95E+02	kg	3.13E+03
Recycled water	lb	1.32E+04	kg	2.11E+05
Electrical Use	**Phenol Formaldehyde Production**			
Electricity	kWh	4.21E+02	MJ	5.35E+04
Fuel Use				
Heavy oil	Btu	4.09E+05	MJ	1.52E+04
Natural gas	Btu	2.82E+03	MJ	1.05E+02
Diesel	Btu	7.60E+06	MJ	2.83E+05

1. Includes LVL site generated emissions plus those for the production of dry veneer, it excludes the production of logs, resin, fuels, electricity, and their delivery.
2. Excluded based upon the 2% rule in the CORRIM protocol.
3. All weights are on an oven-dry basis.

Table 1.21. Life-cycle Inventory Outputs for 1.0 MCF of LVL Production from the Pacific Northwest Region—site generated emissions[1].

Product	**lb/MCF**	**kg/10^{3}m^3**	**Water Usage**	**lb/MCF**	**kg/10^{3}m^3**
Laminated Veneer Lumber	3.30E+04	5.29E+05	Municipal Water Source	2.13E+03	3.42E+04
Co-products	**lb/MCF**	**kg/10^{3}m^3**	**Air Emissions**	**lb/MCF**	**kg/10^{3}m^3**
Sawdust	5.14E+02	8.23E+03	Acetaldehyde	3.19E-02	5.11E-01
Veneer loss	4.71E+02	7.54E+03	Acetone	2.34E-01	3.75E+00
Lay-up scrap	3.76E+02	6.02E+03	CO	5.08E-01	8.14E+00
Tested LVL	8.45E+01	1.35E+03	CO_2 (fossil)	4.57E+02	7.32E+03
Panel trim	4.20E+01	6.73E+02	Formaldehyde	9.82E-01	1.57E+01
			Methane	2.10E-02	3.36E-01
Raw Materials	**lb/MCF**	**kg/10^{3}m^3**	Methanol	5.52E-01	8.84E+00
PLV	2.33E+04	3.73E+05	Non methane VOC	2.02E-01	3.24E+00
Dry veneer	6.65E+03	1.07E+05	NO_x	1.38E+00	2.20E+01
Phenol-formaldehyde resin	5.16E+02	8.27E+03	Particulates	7.49E-01	1.20E+01
	ft^3/MCF	**m^3/10^{3}m^3**	Particulates (PM10)	2.85E-01	4.57E+00
Distillate Fuel Oil (DFO)	1.61E-01	1.61E-01	Propionaldehyde	1.42E-02	2.28E-01
Natural gas	3.84E+03	3.84E+03	SO_2	1.00E-02	1.60E-01
			SO_x	3.78E-02	6.05E-01
Electricity	**Btu/MCF**	**MJ/10^{3}m^3**	VOC	2.11E-02	3.39E-01
Electricity from ATHENA	5.40E+06	2.01E+05			

1. Includes LVL site generated emissions plus those for the production of dry veneer, it excludes the production of logs, resin, fuels, electricity, and their delivery.
2. All weights are on an oven-dry basis.

Table 1.22. Life-cycle Inventory Outputs for 1.0 MCF of LVL Production in the Southeast Region—site-generated emissions[1].

Product	lb/MCF	$kg/10^3m^3$	Water Usage	lb/MCF	$kg/10^3m^3$
Laminated Veneer Lumber	3.78E+04	6.06E+05	Municipal Water Source	3.61E+03	5.79E+04
			Recycled Water	1.69E+02	2.71E+03
Co-products	**lb/MCF**	**$kg/10^3m^3$**	Well Water Source	2.43E+02	3.89E+03
Sawdust	2.72E+02	4.35E+03			
Veneer loss	6.94E+02	1.11E+04	**Air Emissions**	**lb/MCF**	**$kg/10^3m^3$**
Lay-up scrap	1.42E+03	2.28E+04	Acetone	8.21E-01	1.32E+01
Tested LVL	1.20E+02	1.92E+03	CO	2.86E+00	4.59E+01
Panel trim	9.99E+02	1.60E+04	CO_2 (fossil)	1.14E+03	1.83E+04
			Formaldehyde	1.03E-01	1.64E+00
Raw Materials	**lb/MCF**	**$kg/10^3m^3$**	Methanol	3.09E+00	4.95E+01
Dry veneer	2.18E+03	3.49E+04	Non methane VOC	2.95E-01	4.72E+00
Phenol Formaldehyde Resin	5.98E+02	9.58E+03	NO_x	6.92E+00	1.11E+02
	ft^3/MCF	**$m^3/10^3m^3$**	Particulates	2.23E-01	3.57E+00
Distillate Fuel Oil (DFO)	3.30E-01	3.30E-01	Particulates (PM10)	3.02E+01	4.84E+02
Natural Gas Volume	1.01E+04	1.01E+04	SO_2	1.88E-02	3.01E-01
			SO_x	7.71E-02	1.23E+00
Electricity	**Btu/MCF**	**$MJ/10^3m^3$**	VOC	1.66E-01	2.66E+00
Electricity from ATHENA	5.99E+06	2.23E+05			

1. Includes LVL site generated emissions plus those for the production of dry veneer, it excludes the production of logs, resin, fuels, electricity, and their delivery.
2. All weights are on an oven-dry basis.

2.0 BIOGENIC CARBON FLOW FOR PRODUCTION OF LAMINATED VENEER LUMBER

Another element of this study was to track the biogenic carbon flow through the LVL production process. Wood is commonly considered a storage place for carbon yet the amount of carbon in wood products has yet to be completely documented. In order to perform the carbon balance it was necessary to quantify the amount of carbon in the wood inputs and the carbon in the wood related outputs. The outputs in this case include waste and emissions as well as the finished product. As a result of tracking the biogenic carbon through the system it can be determined if any carbon is missing after production. The percentage of carbon in wood was taken from a study done by Birdsey (1992). The amount of carbon in wood is specific to each species of wood. In the PNW the only veneer species considered was Douglas fir. However, there was the PLV input that had to be addressed as well. For the sake of simplicity and consistency, the PLV input was treated as being Douglas-fir material with the same carbon percentage as the veneer. The data was used from the PNW plywood report (Module D) and combined with the veneer input to create the carbon balance for the Pacific Northwest. The inputs were allocated based on their percentage of the total amount of input into the system. In the Southeast, the only wood input comes from veneer. The type of veneer used in that region is southern pine, which was considered to be two primary species. These species were Loblolly and Slash Pine. They were each given a 50% weight into the system and the carbon balance was completed based on these values. Tables 2.1 and 2.2 show the percent of carbon in each of the regions.

Table 2.1. Percent of Carbon in Wood in the Pacific Northwest.

Species	Conversion factor[1]	Input allocation	OD density lb/ft^3	Volume ft^3	Weight of wood lb	Weight of carbon lb	Carbon[2] %
Douglas-fir	15.11	1.0	30.00	1019	30,563	15,393	50.37

[1] Birdsey 1992
[2] lb carbon per lb wood

Table 2.2. Percent of Carbon in Wood in the Southeast.

Species	Conversion Factor[1]	Input allocation	OD density lb/ft^3	Volume ft^3	Weight of wood lb	Weight of Carbon lb	Carbon[2] %
SE S. Pine	16.9	1.0	34.38	1100	38,355	18,595	48.48

[1] Birdsey 1992
[2] lb carbon per lb wood

2.1 BIOGENIC CARBON BALANCE

The following is a list of wood inputs into the LVL system and the wood associated results of the LCI completed for LVL production in each region. Only the compounds containing carbon that are related or generated from wood (biogenic) are shown and it is not a complete list of all compounds involved in LVL manufacturing. The LCI results are shown for LVL only and are thus allocated by the percentage that LVL product makes up of the total process outputs. The allocation for LVL in the PNW is 95.7% and in the SE, the allocation for LVL is 91.3%. These allocations are based on the weights of the materials in the process. In order to balance the inputs and outputs, it is necessary to allocate the inputs in the same manner as the outputs. The carbon component of the input products of veneer and PLV were included in the carbon balance. A biogenic carbon balance was completed for PNW and SE plywood (Module D) the CORRIM project (Wilson and Sakimoto 2004). To perform a carbon balance for these products in this report would be redundant. The following Tables 2.3 and 2.4 show the relatively simplistic carbon balance for LVL production in each region.

Table 2.3. Biogenic Carbon Balance for LVL Production in the Pacific Northwest Region.

PNW LVL INPUTS			
Material	**lb/MCF**	**Carbon %**	**Carbon lb/MCF**
Dry Veneer	6.95E+03	50.37	3.50E+03
PLV (wood only)	2.45E+04	50.37	1.23E+04
Total			**1.58E+04**

PNW LVL OUTPUTS			
Material	**lb/MCF**	**Carbon %**	**Carbon lb/MCF**
Product:			
LVL (wood only)	3.25E+04	50.37	1.64E+04
Subtotal			1.64E+04
Co-products:			
Sawdust	5.14E+02	50.37	2.59E+02
Veneer loss	4.71E+02	50.37	2.37E+02
Lay-up scrap	3.76E+02	50.37	1.89E+02
Tested LVL	8.45E+01	50.37	4.26E+01
Panel trim	4.20E+01	50.37	2.12E+01
Subtotal			7.49E+02
Air emissions:			
Particulates	7.39E-01	50.37%	3.72E-01
Particulates (PM10)	2.98E-01	50.37%	1.50E-01
Acetaldehyde	3.33E-02	54.00%	1.80E-02
Formaldehyde	1.31E-02	40.00%	5.24E-03
Methanol	5.77E-01	37.50%	2.16E-01
Subtotal			7.61E-01
Total Carbon in Outputs			**1.71E+04**
% Difference			**7.59E+00**

Notes: Includes only those materials and emissions relating to wood, does not include energy, electricity, non-wood fuel and resin.

Table 2.4. Biogenic Carbon Balance for LVL Production in the Southeast US.

PNW LVL INPUTS			
Material	**lb/MCF**	**Carbon %**	**Carbon lb/MCF**
Dry Veneer	3.78E+04	48.48	1.83E+04
Total			**1.83E+04**

PNW LVL OUTPUTS			
Material	**lb/MCF**	**Carbon %**	**Carbon lb/MCF**
Product:			
Laminated Veneer Lumber	3.84E+04	48.48%	1.86E+04
Subtotal			1.86E+04
Co-products:			
Lay-Up Scrap	1.42E+03	48.48%	6.89E+02
Panel Trim	9.99E+02	48.48%	4.84E+02
Veneer Loss	6.94E+02	48.48%	3.36E+02
Sawdust	2.72E+02	48.48%	1.32E+02
Tested LVL	1.20E+02	48.48%	5.82E+01
Subtotal			1.70E+03
Air Emissions:			
Particulates	1.51E-01	48.48%	7.33E-02
Particulates (PM10)	3.31E+01	48.48%	1.60E+01
Formaldehyde	9.10E-02	40.00%	3.64E-02
Methanol	3.30E+00	37.50%	1.24E+00
Subtotal			1.73E+01
Total Carbon in Outputs			**2.03E+04**
% Difference			**9.72E+00**

Notes: Includes only those materials and emissions relating to wood, does not include energy, electricity, non-wood fuels and resin.

3.0 COST ANALYSIS FOR PRODUCTION

Another useful tool for analysis of LVL production is a cost analysis. The cost analysis takes a closer look at the economics of manufacturing LVL. This analysis includes (but is not limited to) material costs, fuel costs, overhead and payroll expenses, as well as revenue generated from product and co-product sales. By examining the different costs it is possible to look for ways to try and reduce costs in the manufacturing process. Another aspect of a cost analysis is that it can be used as a baseline to determine the economic impact associated with changes in the process that result in changes to its environmental performance; thus, tying economic to environmental performance. A cost analysis was completed for LVL production in the PNW and SE regions of the US.

A survey of LVL plants in each region revealed the annual production at each plant as well as the number of employees working there. This data was weighted to determine the size of a typical plant in each region and the number of employees that would work there. In the Pacific Northwest the typical LVL plant produces approximately 4.4 million cubic feet annually of LVL with an average of 64 employees. In the Southeast, the average LVL plant also produces roughly 4.4 million cubic feet annually of LVL with an average of 82 employees. The large discrepancy in the number of employees in each region is most likely due to the production of PLV and its use to make LVL in the PNW. The PLV input eliminates the need for a traditional lay-up line, which reduces the number of laborers at the LVL plant.

3.1 FIXED COSTS

Fixed costs are those costs, which do not change with production levels and are usually incurred annually. The fixed costs that were looked at in this report are capital, interest on capital, maintenance, labor, and overhead costs. The following tables (3.1, 3.2) list the fixed costs for each region.

Table 3.1. Fixed Costs to Produce 1.0 MCF of LVL in the Pacific Northwest.

Fixed Costs	Units	$/Annual	$/MCF
Capital Costs[1]	Annual	2,005,000	456.05
Interest on Capital[2]	Annual	3,208,000	729.67
Maintenance Costs	MCF	1,266,189	288.00
Labor Costs	Annual	2,895,360	658.56
Overhead	MCF	1,406,877	320.00
Total Fixed Costs			**2,452.28**

[1] $40.1 million depreciated over 20 years
[2] 8% interest on $40.1 million

Table 3.2. Fixed Costs to Produce 1.0 MCF of LVL in the Southeast.

Fixed Costs	Units	$/Annual	$/MCF
Capital[1]	Annual	2,021,250	456.37
Interest on Capital[2]	Annual	3,234,000	730.19
Maintenance	MCF	1,275,554	288.00
Labor	Annual	3,709,680	837.59
Overhead	MCF	1,417,283	320.00
Total Fixed Costs			**2,632.15**

[1] $40.4 million depreciated over 20 years
[2] 8% interest on $40.4 million

3.2 VARIABLE COSTS

Variable costs are the costs that change due to changes in production volume or due to changes in material input costs. There are several variable costs associated with LVL production including fuel (diesel, LPG, natural gas), electricity, dry veneer, PLV, and resin. All of the prices are variable in quantity purchased and the purchase price. The price used for electricity in this analysis was based on average data for each region and was based on 2001 figures. The electricity price for the Pacific Northwest was 4.25 cents per kWh based on a range of values between 3.60-5.90 cents per kWh. In the Southeast that number is very similar with an average electricity cost of 4.70 cents per kWh and a range of 3.10-6.90 cents per kWh. The natural gas prices were based on data from 1999, which represent the current and projected costs of natural gas. The 2000 values for natural gas were abnormally high and may not provide good values for this analysis. However, recently energy prices have increased once again. Based on the 1999 data the average price of natural gas in the PNW was $2.85 per million Btu (MMBTU) with a range of $2.20-$4.70 per MMBTU. In the SE, the natural gas prices were slightly lower with an average of $2.60 per MMBTU and a range of $2.00-$4.90 per MMBTU. The MMBTU is known more commonly in the industry as a Dtherm (1,000,000 Btu). The prices for wood materials are determined through industry sources and publications.

In the PNW the PLV input into the LVL process is considered to be the same as plywood. Therefore, the PLV costs will be based on the published value for CD plywood. This data comes from Crow's Weekly Market Report for Lumber and Panel Products, February 2, 2002 (Crow's 2002). The cost of dry veneer was gathered from an industry source with considerable knowledge of dry veneer. Tables 3.3 and 3.4 show the variable costs for each region.

Table 3.3. Variable costs to produce 1.0 MCF of LVL in the Pacific Northwest.

Variable Cost	Units	$/Unit	Units Annual	$/Annual	$/MCF
Energy Consumption					
Electricity	kWh	0.04	7,285,870	309,649	70.43
Liquid Propane Gas	gal	0.95	11,431	10,900	2.47
Diesel	gal	1.26	5,540	6,960	1.58
Natural Gas	MMBTU	2.85	16,841	48,000	10.90
Materials					
Purchased Dry Veneer[1]	M 3/8	182.41	32,578	5,942,557	1,351.66
PLV	M 3/8	220.00	108,154	23,793,826	5,412.00
Resin					
PF	lb	0.45	454070	204,331	46.48
PRF	lb	1.00	158274	158,000	36.00
Total Variable Costs					**6,931.52**

[1] M 3/8 is a MSF 3/8-inch basis

Table 3.4. Variable Costs to Produce 1.0 MCF of LVL in the Southeast.

Variable cost	Units	$/Unit	Units Annual	$/ Annual	$/ MCF
Energy consumption					
Electricity	kWh	0.05	8,520,534	400,465	90.42
Liquid propane gas	gals.	0.95	15,502	14,726	3.33
Diesel	gals.	1.26	11,958	15,032	3.39
Natural gas	MMBTU	2.60	48,276	125,518	28.34
Materials					
Purchased dry veneer	M 3/8	183.29	158,116	28,981,034	6,543.45
Resin					
PF	lbs.	0.45	2,904,546	1,307,046	295.11
Total variable costs					**6,964.04**

Adding the fixed and variable costs will give the total cost of producing LVL for each region. In the PNW this total is $9,383.80 and in the SE, that total is $9,596.18.

3.3 ENERGY AND CO-PRODUCTS SOLD

During the production of LVL there are a few co-products that are created. In each region, the major co-products were sawdust and various types of veneer waste and LVL waste. Since none of the surveyed plants utilized hog-fuel (wood waste) to generate energy, it was assumed that all co-products were sold. The items were sold on an oven-dry basis with the ton being the unit of weight. The following Tables 3.5 and 3.6 list the products that were sold outside of the plant.

Table 3.5. Co-Products Sold from the Production of 1.0 MCF of LVL in the Pacific Northwest.

Sold co-products	Units	$/Unit	Units Annual	$/Annual Basis	$/ MCF
Hogged fuel	lb	0.010	7,859,020	172,761	17.90
Wood waste	lb	0.015	4,202,460	138,571	14.30
Sawdust	lb	0.015	2,259,094	33,886	7.71
Panel trim	lb	0.015	184,785	2,772	0.63
Total sold					**40.54**

Table 3.6. Co-products Sold from the Production of 1.0 MCF of LVL in the Southeast.

Sold Co-products	Units	$/Unit	Units Annual	$/Annual Basis	$/MCF
Hogged fuel	lbs.	0.01	12,964,162	129,642	29.27
Sawdust	lbs.	0.015	64,221	963	0.22
Total sold					**29.49**

The selling price for hogged fuel is estimated at $20/oven dry (OD) ton and the estimated price for wood waste is $30/OD ton. The prices of these materials were adjusted to a per pound basis for this analysis. The other waste materials of sawdust and panel trim were also assigned the same price as wood waste which is $30/OD ton. Since the LVL process is very efficient and creates little material waste, there is very little co-product to sell. The amount of money made from selling these products is small even on a 1.0 MCF basis. In the PNW this value is $40.54 and in the SE the value is $29.49.

To determine the net cost of producing LVL it is necessary to take the total production cost and subtract the amount of the sold energy and co-products. The net cost of LVL production in the PNW is $9,343.26 and in the SE it is $9,566.69 per MCF.

4.0 SCENARIO ANALYSIS FOR PRODUCTION

4.1 CHANGING THE AMOUNT OF RESIN USED

Another important part of this report is the scenario analysis for LVL production in each region. So far only a base case scenario has been looked at for the production of 1.0 MCF of LVL in each region. This base case is derived from specific input values that have been averaged for each region. There are certain elements of the LVL model that can be shown to contribute significant levels of emissions to the manufacturing process. The following analyses are set up to illustrate the effects of changing the LVL process inputs in order to see how the model is affected. By showing the effects of certain input materials and fuels, the industry can work towards possibly reducing the environmental impact from the manufacturing system.

The scenario that was looked at was the case of changing the amount of PF resin that is used to produce LVL in each region. The amount of resin used was varied by +/- 10% to see the effects that it would have on the overall emissions from the LVL process. In the PNW, the base case scenario has a PF resin use value of 540 lb per 1.0 MCF. Of the 540 lb of resin, 36 pounds are phenol-resorcinol-formaldehyde resin (PRF), however, no suitable LCI database existed at the time of this analysis. As a result, the PRF is lumped together with the PF resin for the analysis in this report. It is acceptable to substitute PF for PRF since the PRF would not normally be used in the production of LVL when made straight from veneer rather than PLV. A 10% increase would lead to a usage of 594 lb per 1.0 MCF and a 10% decrease would result in a usage of 486 lb of phenol- formaldehyde resin. In the SE, the base case scenario for LVL has a PF resin input of 656 lb of resin per 1.0 MCF. An increase of 10% would lead to a usage of 721.4 lb per 1.0 MCF and a decrease in PF resin of 10% would result in an input value of 590 lb. The results if the LCI on these scenarios show that changing levels of PF resin has little significance in the overall levels of air emissions. A full listing of emissions including raw materials and water emissions are shown in Appendix A1.1 and A1.2. Although it may not be possible to reduce the amount of resin use by 10%, the effects of reducing resin input can be seen in the analysis. Tables 4.1 and 4.2 show the changes in emissions values when the level of PF resin is varied by 10% in each region.

Table 4.1. Changes in Selected Air Emissions for LVL Production in the Pacific Northwest when the Amount of Phenol-formaldehyde Resin Input is Changed.

Air Emission	Emissions for LVL (PF resin reduced 10%) lb/MCF	Difference %	Emissions for LVL (Base case PF resin) lb/MCF	Difference %	Emissions for LVL (PF resin Increased 10%) lb/MCF
CO_2 (biomass)	8.18E+03	0.0	8.18E+03	0.0	8.18E+03
CO_2 (fossil)	3.59E+03	-3.4	3.71E+03	3.2	3.84E+03
CO_2 (non-fossil)	6.02E+02	0.0	6.02E+02	0.0	6.02E+02
Methane	1.06E+01	-4.4	1.10E+01	4.1	1.15E+01
NOx	3.16E+01	-4.4	3.30E+01	4.1	3.44E+01
SO_2	3.65E-02	0.0	3.65E-02	0.0	3.65E-02
SOx	5.19E+01	-4.5	5.43E+01	4.0	5.65E+01
Acetaldehyde	3.90E-01	0.0	3.90E-01	0.0	3.90E-01
Acrolien	3.26E-05	-0.6	3.27E-05	0.6	3.29E-05
Formaldehyde	1.20E+00	-5.5	1.26E+00	5.6	1.34E+00
Methanol	4.12E+00	0.0	4.12E+00	0.0	4.12E+00
Phenol	9.36E-01	-10.0	1.03E+00	8.3	1.12E+00
CO	6.76E+01	-0.7	6.81E+01	0.8	6.87E+01
Particulates	1.22E+01	0.0	1.22E+01	0.0	1.22E+01
Particulates (PM10)	7.55E+00	-0.1	7.56E+00	0.0	7.56E+00
Particulates (unspecified)	1.15E+00	-1.6	1.17E+00	0.8	1.18E+00
Non methane VOC	1.83E+01	-6.6	1.96E+01	5.9	2.08E+01
VOC	1.99E+01	0.0	1.99E+01	0.0	1.99E+01

Data from SimaPro 5.0 LCI Analysis

Full LCI listing in Appendix A1.1 and A1.2

Table 4.2. Changes in Selected Air Emissions for LVL Production in the Southeast when the Amount of Phenol-formaldehyde Resin Input is Changed.

Air Emission	Emissions for LVL (PF resin reduced 10%) lb/MCF	Difference %	Emissions for LVL (Base case PF resin) lb/MCF	Difference %	Emissions for LVL (PF resin Increased 10%) lb/MCF
CO_2 (biomass)	1.06E+04	0.0	1.06E+04	0.0	1.06E+04
CO_2 (fossil)	9.50E+03	-1.9	9.68E+03	2.0	9.87E+03
CO_2 (non-fossil)	1.57E+03	0.0	1.57E+03	0.0	1.57E+03
Methane	2.54E+01	-2.1	2.59E+01	2.4	2.66E+01
NO_x	6.13E+01	-3.0	6.31E+01	2.8	6.50E+01
SO_2	2.12E-02	0.0	2.12E-02	0.0	2.12E-02
SO_x	1.15E+02	-2.8	1.18E+02	2.7	1.21E+02
Acetaldehyde	2.77E-02	0.0	2.77E-02	0.0	2.77E-02
Acrolien	2.82E-04	-0.4	2.83E-04	0.4	2.84E-04
Formaldehyde	9.08E-01	-8.9	9.88E-01	7.6	1.07E+00
Methanol	3.11E+00	0.0	3.11E+00	0.0	3.11E+00
Phenol	1.18E+00	-9.1	1.29E+00	7.7	1.39E+00
CO	9.94E+01	-0.6	1.00E+02	0.5	1.01E+02
Particulates	3.71E+00	-0.3	3.72E+00	0.6	3.74E+00
Particulates (PM10)	3.21E+01	0.0	3.21E+01	0.0	3.21E+01
Particulates (Unspec.)	5.65E+00	-1.1	5.71E+00	1.1	5.78E+00
Non Methane VOC	3.03E+01	-4.9	3.18E+01	4.5	3.33E+01
VOC	2.47E+00	0.0	2.47E+00	0.0	2.47E+00
Data from SimaPro 5.0 LCI Analysis					
Full LCI listing in Appendix A1.3 and A1.4					

4.2 CHANGING THE SOURCE OF FUEL FOR ELECTRICITY GENERATION

The next scenario analysis involves changing the fuel source mix for generating electricity to determine its effect on emissions for the LVL process in each region. As was mentioned earlier, the two regions generate electricity in vastly different ways. In the PNW for example, the primary energy generation method is hydroelectric dams, which makes up roughly three quarters of the electricity generation in that region. While SimaPro has essentially no burdens attached to hydroelectric generation in terms of emissions, there are other factors such as salmon runs that could have been considered. This PNW scenario is designed to illustrate the effects of reducing hydroelectric generation in the PNW by 10% of the total electricity generation in the region and making up for the difference with natural gas as the fuel source for generation of electricity. The new electricity generation profile in the PNW based on this scenario has hydroelectric generation at 64.3% and natural gas at 22.3%

In the Southeast, the primary source of electricity generation is burning coal, which has been proven to be a controversial means environmentally, because of acid rain and global warming, to produce electricity. In the SE scenario, the amount of coal as a source of electricity generation has been reduced by 10% with the difference being made up for with natural gas combustion. The analysis was completed using SimaPro to do the LCIs for each region. The new electricity profile in the SE based on this scenario has coal at 35.56% and natural gas at 33.03%.

Tables 4.3 and 4.4 demonstrate the effects of substituting natural gas for hydroelectricity in the PNW and coal in the SE on a 10% basis. In the PNW the effects of this change are mostly subtle in terms of the overall LCI results for LVL manufacturing. The noticeable changes can be seen in CO_2 (fossil), Methane and NO_x, and non Methane VOC. Each of these categories makes a significant increase when less hydroelectric power is used and more natural gas is burned. One can imagine the increase if a larger scale change was made in the PNW. In the Southeast, using more natural gas and less coal resulted in lower percentages of several key air emissions. The most dramatic change was represented by a 9.2% decrease in unspecified particulates due to the substitution of a limited amount of natural gas. When looking at these tables it is imperative to remember that these numbers represent a change in the emissions for the entire LVL process (site generated and off-site generated) not just emissions generated from producing electricity.

Table 4.3. Changes in Selected Air Emissions in the Pacific Northwest Resulting from an Increase in Natural Gas and a Decrease in Hydroelectric Sources for Generating Electricity.

Air Emission	Emissions for LVL (Hydroelectric reduced 10% and nat. gas. inc. 10%) lb/MCF	Increase or Decrease (-) in Emissions %	Total LVL Emissions (Base case) lb/MCF
O_2 (biomass)	8.18E+03	0.0	8.18E+03
CO_2 (fossil)	3.96E+03	6.1	3.71E+03
CO_2 (non-fossil)	6.02E+02	0.0	6.02E+02
Methane	1.17E+01	5.6	1.10E+01
NO_x	3.40E+01	2.8	3.30E+01
SO_2	3.65E-02	0.0	3.65E-02
SO_x	5.77E+01	6.0	5.43E+01
Acetaldehyde	3.90E-01	0.0	3.90E-01
Acrolien	3.27E-05	0.0	3.27E-05
Formaldehyde	1.26E+00	0.0	1.26E+00
Methanol	4.12E+00	0.0	4.12E+00
Phenol	1.03E+00	0.0	1.03E+00
CO	6.86E+01	0.7	6.81E+01
Particulates	1.22E+01	0.0	1.22E+01
Particulates (PM10)	7.56E+00	0.0	7.56E+00
Particulates (Unspecified)	1.17E+00	0.0	1.17E+00
Non Methane VOC	2.05E+01	4.6	1.96E+01
VOC	1.99E+01	0.0	1.99E+01

Data from SimaPro 5.0 LCI Analysis

Full LCI listing in Appendix A1.5

Table 4.4. Changes in Selected Air Emissions in the Southeast Resulting from an Increase in Natural Gas and a Decrease in Coal use for Generating Electricity.

Air Emission	Emissions for LVL (Coal reduced 10% and natural gas inc. 10%) lb/MCF	Increase or Decrease (-) in Emissions %	Total LVL Emissions (Base case) lb/MCF
CO_2 (biomass)	1.06E+04	0.0	1.06E+04
CO_2 (fossil)	9.54E+03	-1.5	9.68E+03
CO_2 (non-fossil)	1.57E+03	0.0	1.57E+03
Methane	2.58E+01	-0.4	2.59E+01
NO_x	6.26E+01	-0.9	6.31E+01
SO_2	2.12E-02	0.0	2.12E-02
SO_x	1.19E+02	0.9	1.18E+02
Acetaldehyde	2.77E-02	0.0	2.77E-02
Acrolien	2.77E-04	-2.3	2.83E-04
Formaldehyde	9.88E-01	0.0	9.88E-01
Methanol	3.11E+00	0.0	3.11E+00
Phenol	1.29E+00	0.0	1.29E+00
CO	1.00E+02	0.4	1.00E+02
Particulates	3.72E+00	0.0	3.72E+00
Particulates (PM10)	3.19E+01	-0.3	3.21E+01
Particulates (Unspecified)	5.23E+00	-9.2	5.71E+00
Non Methane VOC	3.29E+01	3.3	3.18E+01
VOC	2.47E+00	0.0	2.47E+00

Data from SimaPro 5.0 LCI Analysis
Full LCI listing in Appendix A1.6

5.0 SUMMARY OF FINDINGS

Laminated veneer lumber production is very consistent in both regions with the notable exception of one plant in the Pacific Northwest. All but one of the plants used dried veneer as an input material; the one exception used parallel laminated veneer (PLV) panels as an input. None of the surveyed plants dried veneer on site, which is not always the case in LVL manufacturing, however this does not change the output data. The data for dry veneer comes from the LCI data generated for plywood in each region and include environmental burdens to produce green veneer (data is cumulative), which would be consistent with an LVL plant that dries veneer on site. The process for drying veneer is the same between plywood and LVL operations except that the fuel source may differ between operations. This leads to similar inputs and outputs in terms of fuels, energy, electricity, and emissions. Of the plants surveyed, only one did not have an I-joist plant in the same facility. This one facility did rip LVL billets into flange stock and shipped the product to a near location where the I-joists were assembled.

The production of laminated veneer lumber contributes relatively small amounts of emissions when compared to the production of input products such as resin, dry veneer, fuel, and electricity. As Tables 1.11, 1.12, 1.13, and 1.14 illustrate, a large percentage of emissions attributed to the LVL manufacturing process come from the inputs of resin, dry veneer, and PLV. LCI results for each region that include only emissions generated at the LVL manufacturing facility (Tables 1.21, 1.22) demonstrate the small amount of emissions actually attributable to the LVL process. Given this scenario, it would make sense to look at these areas (resin, veneer, PLV) as possible factors in reducing total emissions for the process. Reducing amounts of resin used to make LVL was considered in this report and showed noticeable effects on total emissions when resin levels were increased or decreased by 10% (Tables 4.1, 4.2).

The major component of variable costs in each region is the input material of wood in either veneer or PLV form. Veneer is a cheaper input material than PLV, however the costs associated with shipping and the amount of processing required for veneer increases the costs to put them back on par with PLV. Labor in the SE and interest on capital in the PNW is the highest fixed cost associated with LVL production followed by interest on capital and capital costs. Fixed and variable costs are dependent on the size of the operation, but the relationship of the various costs should stay the same.

The types of electricity generation based on fuel source in each region contribute small but significant levels of emissions to the LVL manufacturing process. Changes in the mix of fuel sources with respective regions could contribute to the overall emissions levels. As was shown in Tables 4.3 and 4.4, changes in the major contributors to electricity generation lead to changes in the total emissions generated by producing LVL. In the PNW for example, reducing hydroelectric generation by 10% of the total for the region and making up the difference with natural gas would result in significant increases in CO_2 (fossil), NO_x, SO_x, methane, and non-methane VOC levels. In the SE, reducing the amount of coal as an input for electricity production by 10% and replacing it with natural gas results in decreases in several air emissions including CO_2 (fossil), methane, NO_x, and particulates (unspecified).

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APPENDIX 1: COMPLETE LCI OUTPUT LISTINGS FOR SCENARIO ANALYSES FOR THE PACIFIC NORTHWEST AND SOUTHEAST U.S.

The following tables are complete LCI listings for the scenario analyses competed in the LVL report that did not give full listings. The emissions reported are those allocated to the LVL and includes both site and off-site generated emissions for the production of dry veneer, PLV, an adhesive, and the production and delivery of electricity and fuel, but excludes the production and delivery of logs and other material deliveries. For the scenario involving changing the levels of PF resin input by 10% up and down, the only input that changed was the amount of resin used. Therefore, only the LCI outputs are included in the Appendix.

Table A1.1. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Pacific Northwest with Phenol-formaldehyde Resin use Increased by 10%.

Product		
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
Laminated Veneer Lumber	3.30E+04	5.29E+05
Co-products		
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
Sawdust	5.14E+02	8.23E+03
Veneer loss	4.71E+02	7.54E+03
Lay-up scrap	3.76E+02	6.02E+03
Tested LVL	8.45E+01	1.35E+03
Panel trim	4.20E+01	6.73E+02
Raw Materials		
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
PNW Bark on Logs	3.00E+03	4.80E+04
PNW Logs	2.98E+04	4.77E+05
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
Coal FAL	4.45E+02	7.13E+03
Crude oil FAL	4.57E+02	7.33E+03
Limestone	5.88E+01	9.43E+02
Natural gas FAL	1.45E+03	2.32E+04
Uranium FAL	2.31E-03	3.70E-02
Wood/wood wastes FAL	5.76E+02	9.23E+03
Other Raw Materials		
	Btu	**MJ**
Substance	**per MCF**	**per 10^3m^3**
	2.28E+06	
	8.48E+04	8.48E+04
Hogged Fuel-		
Direct Fired Fuel		

Electricity		
	Btu	**MJ**
Substance	**per MCF**	**per 10^3m^3**
Electricity from other sources	1.77E+05	6.58E+03
Energy from hydro power	1.19E+07	4.44E+05
Water Usage		
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
Municipal Water Source	1.37E+04	2.19E+05
Recycled Water	4.60E+01	7.37E+02
Well Water Source	4.10E+03	6.57E+04
Air Emissions		
	lb	**kg**
Substance	**per MCF**	**per 10^3m^3**
Acetaldehyde	3.90E-01	6.25E+00
Acetone	3.61E-01	5.79E+00
Acrolein	3.29E-05	5.28E-04
Aldehydes	3.68E-02	5.89E-01
Alpha-pinene	1.92E+00	3.07E+01
Ammonia	2.21E-02	3.54E-01
As	4.05E-04	6.49E-03
Ba	1.79E-02	2.86E-01
Be	4.72E-06	7.55E-05
Benzene	1.51E-02	2.41E-01
Beta-pinene	7.44E-01	1.19E+01
Cd	2.64E-05	4.23E-04
Cl_2	3.18E-02	5.10E-01
CO	6.87E+01	1.10E+03
CO_2 (biomass)	8.18E+03	1.31E+05
CO_2 (fossil)	3.84E+03	6.14E+04
CO_2 (non-fossil)	6.02E+02	9.64E+03
Cobalt	3.45E-05	5.53E-04
Cr	2.50E-04	4.00E-03

Air Emissions-cont.

Substance	lb per MCF	kg per 10^3m^3
Cumene	2.95E-03	4.72E-02
Dichloromethane	6.35E-05	1.02E-03
Dioxin (TEQ)	8.48E-11	1.36E-09
Fe	1.79E-02	2.86E-01
Formaldehyde	1.34E+00	2.14E+01
HCl	8.02E-02	1.28E+00
HF	1.11E-02	1.78E-01
Hg	3.30E-05	5.29E-04
K	3.17E+00	5.08E+01
Kerosene	5.06E-04	8.11E-03
Limonene	2.15E-01	3.45E+00
Metals	5.73E-04	9.19E-03
Methane	1.15E+01	1.84E+02
Methanol	4.12E+00	6.59E+01
Methyl ethyl ketone	1.70E-02	2.73E-01
Methyl i-butyl ketone	1.39E-02	2.23E-01
Mn	3.68E-02	5.89E-01
N-nitrodimethylamine	3.38E-06	5.41E-05
N_2O	9.09E-03	1.46E-01
Na	7.33E-02	1.17E+00
Naphthalene	9.73E-03	1.56E-01
Ni	2.66E-03	4.26E-02
Non methane VOC	2.08E+01	3.33E+02
NO_x	3.44E+01	5.52E+02
Organic substances	7.17E-01	1.15E+01
Particulates	1.22E+01	1.95E+02
Particulates (PM10)	7.56E+00	1.21E+02
Particulates (unspecified)	1.18E+00	1.89E+01
Pb	4.95E-03	7.93E-02
Phenol	1.12E+00	1.80E+01
Propionaldehyde	1.42E-02	2.28E-01
Sb	1.38E-05	2.20E-04
Se	1.25E-04	2.01E-03
SO_2	3.65E-02	5.85E-01
SO_x	5.65E+01	9.05E+02
Tetrachloroethene	1.52E-05	2.44E-04
Tetrachloromethane	2.73E-05	4.38E-04
THC as Carbon	4.11E+00	6.58E+01
Trichloroethene	1.52E-05	2.43E-04
VOC	1.99E+01	3.19E+02
Zn	1.79E-02	2.86E-01

Water Emissions

Substance	lb per MCF	kg per 10^3m^3
Acid as H+	4.90E-07	7.85E-06
B	4.26E-02	6.82E-01
BOD	7.53E-02	1.21E+00
Ca	4.06E-06	6.50E-05
Calcium ions	4.31E-04	6.91E-03
Cd	3.50E-03	5.61E-02
Chromate	2.05E-05	3.28E-04
Cl-	3.50E+00	5.61E+01
COD	6.83E-01	1.09E+01
Cr	3.50E-03	5.61E-02
Cyanide	5.24E-06	8.39E-05
Dissolved solids	7.66E+01	1.23E+03
Fe	6.25E-02	1.00E+00
Fluoride ions	2.02E-03	3.24E-02
H_2SO_4	1.07E-02	1.71E-01
Hg	2.74E-07	4.39E-06
Metallic ions	1.04E-02	1.66E-01
Mn	3.49E-02	5.59E-01
Na	8.02E-04	1.28E-02
NH_3	2.03E-03	3.25E-02
Nitrate	1.90E-04	3.04E-03
Oil	1.37E+00	2.19E+01
Other organics	2.27E-01	3.64E+00
Pb	8.93E-07	1.43E-05
Phenol	3.39E-05	5.43E-04
Phosphate	5.33E-03	8.54E-02
Sulphate	2.99E+00	4.80E+01
Suspended solids	1.18E+00	1.89E+01
Zn	1.21E-03	1.93E-02

Solid Waste Emission

Substance	lb per MCF	kg per 10^3m^3
Solid waste	7.08E+02	1.13E+04

Nonmaterial Emission

Substance	bq per MCF	bq per 10^3m^3
Radioactive sub. to air	2.08E+07	3.33E+08

Table A1.2. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Pacific Northwest with Phenol-formaldehyde Resin use Decreased by 10%.

Product Substance	lb per MCF	kg per 10^3m^3
Laminated Veneer Lumber	3.30E+04	5.29E+05

Co-products

Substance	lb per MCF	kg per 10^3m^3
Sawdust	5.14E+02	8.23E+03
Veneer loss	4.71E+02	7.54E+03
Lay-up scrap	3.76E+02	6.02E+03
Tested LVL	8.45E+01	1.35E+03
Panel trim	4.20E+01	6.73E+02

Raw Materials

Substance	lb per MCF	kg per 10^3m^3
PNW Bark on Logs	3.00E+03	4.80E+04
PNW Logs	2.98E+04	4.77E+05

Substance	lb per MCF	kg per 10^3m^3
Coal FAL	4.37E+02	7.00E+03
Crude oil FAL	3.80E+02	6.08E+03
Limestone	5.83E+01	9.34E+02
Natural gas FAL	1.32E+03	2.11E+04
Uranium FAL	2.27E-03	3.64E-02
Wood/wood wastes FAL	5.76E+02	9.23E+03

Other Raw Materials

Substance	Btu per MCF	MJ per 10^3m^3
Hogged Fuel-Direct Fired Fuel	2.28E+06	8.48E+04

Electricity Substance	Btu per MCF	MJ per 10^3m^3
Electricity from other sources	1.74E+05	6.47E+03
Energy from hydro power	1.17E+07	4.37E+05

Water Usage

Substance	lb per MCF	kg per 10^3m^3
Municipal Water Source	1.37E+04	2.19E+05
Recycled Water	4.60E+01	7.37E+02
Well Water Source	4.10E+03	6.57E+04

Air Emissions

Substance	lb per MCF	kg per 10^3m^3
Acetaldehyde	3.90E-01	6.25E+00
Acetone	3.61E-01	5.79E+00
Acrolein	3.26E-05	5.22E-04
Aldehydes	3.13E-02	5.02E-01
Alpha-pinene	1.92E+00	3.07E+01
Ammonia	2.13E-02	3.42E-01
As	4.03E-04	6.46E-03
Ba	1.79E-02	2.86E-01
Be	4.57E-06	7.33E-05
Benzene	1.50E-02	2.40E-01
Beta-pinene	7.44E-01	1.19E+01
Cd	2.44E-05	3.91E-04
Cl_2	3.18E-02	5.10E-01
CO	6.76E+01	1.08E+03
CO_2 (biomass)	8.18E+03	1.31E+05
CO_2 (fossil)	3.59E+03	5.76E+04
CO_2 (non-fossil)	6.02E+02	9.64E+03
Cobalt	3.27E-05	5.23E-04
Cr	2.48E-04	3.97E-03

Air Emissions-cont.

Substance	lb per MCF	kg per 10^3m^3
Cumene	2.33E-03	3.73E-02
Dichloromethane	6.22E-05	9.97E-04
Dioxin (TEQ)	8.32E-11	1.33E-09
Fe	1.79E-02	2.86E-01
Formaldehyde	1.20E+00	1.92E+01
HCl	7.87E-02	1.26E+00
HF	1.09E-02	1.75E-01
Hg	3.22E-05	5.16E-04
K	3.17E+00	5.08E+01
Kerosene	4.97E-04	7.96E-03
Limonene	2.15E-01	3.45E+00
Metals	5.23E-04	8.38E-03
Methane	1.06E+01	1.69E+02
Methanol	4.12E+00	6.59E+01
Methyl ethyl ketone	1.70E-02	2.73E-01
Methyl i-butyl ketone	1.39E-02	2.23E-01
Mn	3.68E-02	5.89E-01
N-nitrodimethylamine	3.32E-06	5.32E-05
N_2O	8.92E-03	1.43E-01
Na	7.33E-02	1.17E+00
Naphthalene	9.73E-03	1.56E-01
Ni	2.63E-03	4.21E-02
Non methane VOC	1.83E+01	2.94E+02
NO_x	3.16E+01	5.07E+02
Organic substances	7.12E-01	1.14E+01
Particulates	1.22E+01	1.95E+02
Particulates (PM10)	7.55E+00	1.21E+02
Particulates (unspecified)	1.15E+00	1.84E+01
Pb	4.95E-03	7.93E-02
Phenol	9.36E-01	1.50E+01
Propionaldehyde	1.42E-02	2.28E-01
Sb	1.31E-05	2.10E-04
Se	1.23E-04	1.96E-03
SO_2	3.65E-02	5.85E-01
SO_x	5.19E+01	8.32E+02
Tetrachloroethene	1.50E-05	2.40E-04
Tetrachloromethane	2.66E-05	4.26E-04
THC as Carbon	4.11E+00	6.58E+01
Trichloroethene	1.49E-05	2.38E-04
VOC	1.99E+01	3.19E+02
Zn	1.79E-02	2.86E-01

Water Emissions

Substance	lb per MCF	kg per 10^3m^3
Acid as H+	4.06E-07	6.50E-06
B	4.16E-02	6.67E-01
BOD	6.82E-02	1.09E+00
Ca	3.22E-06	5.16E-05
Calcium ions	4.25E-04	6.80E-03
Cd	3.18E-03	5.10E-02
Chromate	1.89E-05	3.03E-04
Cl-	3.18E+00	5.10E+01
COD	6.31E-01	1.01E+01
Cr	3.18E-03	5.10E-02
Cyanide	4.77E-06	7.64E-05
Dissolved solids	6.97E+01	1.12E+03
Fe	6.14E-02	9.83E-01
Fluoride ions	1.98E-03	3.18E-02
H_2SO_4	1.04E-02	1.66E-01
Hg	2.50E-07	4.00E-06
Metallic ions	8.62E-03	1.38E-01
Mn	3.42E-02	5.49E-01
Na	7.87E-04	1.26E-02
NH_3	1.86E-03	2.98E-02
Nitrate	1.87E-04	3.00E-03
Oil	1.24E+00	1.99E+01
Other organics	2.08E-01	3.33E+00
Pb	7.37E-07	1.18E-05
Phenol	2.80E-05	4.48E-04
Phosphate	5.21E-03	8.35E-02
Sulphate	2.74E+00	4.39E+01
Suspended solids	1.15E+00	1.84E+01
Zn	1.10E-03	1.77E-02

Solid Waste Emission

Substance	lb per MCF	kg per 10^3m^3
Solid waste	6.91E+02	1.11E+04

Nonmaterial Emission

Substance	bq per MCF	bq per 10^3m^3
Radioactive sub. to air	2.04E+07	3.26E+08

Table A1.3. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Southeast with Phenol-formaldehyde Resin use Increased by 10%.

Product Substance	lb per MCF	kg per 10^3m^3
Laminated Veneer Lumber	3.78E+04	6.06E+05

Co-products

Substance	lb per MCF	kg per 10^3m^3
Sawdust	2.72E+02	4.35E+03
Veneer loss	6.94E+02	1.11E+04
Lay-up scrap	1.42E+03	2.28E+04
Tested LVL	1.20E+02	1.92E+03
Panel trim	9.99E+02	1.60E+04

Raw Materials

Substance	lb per MCF	kg per 10^3m^3
SE Bark on Logs	3.40E+03	5.44E+04
SE Logs	3.40E+04	5.44E+05

Substance	lb per MCF	kg per 10^3m^3
Coal FAL	2.21E+03	3.54E+04
Crude oil FAL	7.40E+02	1.19E+04
Limestone	2.13E+02	3.42E+03
Natural gas FAL	2.50E+03	4.00E+04
Uranium FAL	1.13E-02	1.80E-01
Wood/wood wastes FAL	1.50E+03	2.40E+04

Air Emissions-cont.

Substance	lb per MCF	kg per 10^3m^3
CO_2 (biomass)	1.06E+04	1.71E+05
CO_2 (fossil)	9.87E+03	1.58E+05
CO_2 (non-fossil)	1.57E+03	2.51E+04
Cobalt	2.33E-04	3.73E-03
Cr	6.09E-04	9.76E-03
Cumene	3.92E-03	6.29E-02

Electricity Substance	Btu per MCF	MJ per 10^3m^3
Electricity from other sources	5.16E+05	1.92E+04
Energy from hydro power	2.68E+05	9.97E+03

Water Usage

Substance	lbs Per MCF	kg per 10^3m^3
Municipal Water Source	2.68E+05	4.29E+06
Recycled Water	1.95E+02	3.13E+03
Well Water Source	1.32E+04	2.11E+05

Air Emissions

Substance	lb per MCF	kg per 10^3m^3
Acetaldehyde	2.77E-02	4.43E-01
Acetone	8.21E-01	1.32E+01
Acrolein	2.84E-04	4.55E-03
Aldehydes	6.51E-02	1.04E+00
Ammonia	3.77E-02	6.05E-01
As	7.84E-04	1.26E-02
Ba	2.56E-02	4.10E-01
Be	2.63E-05	4.21E-04
Benzene	2.14E-02	3.44E-01
Cd	2.04E-04	3.26E-03
Cl_2	4.55E-02	7.28E-01
CO	1.01E+02	1.61E+03

Water Emissions

Substance	lb per MCF	kg per 10^3m^3
Acid as H+	7.82E-07	1.25E-05
B	2.22E-01	3.56E+00
BOD	1.29E-01	2.06E+00

Substance	lb per MCF	kg per 10^3m^3
Dichloromethane	3.21E-04	5.14E-03
Dioxin (TEQ)	4.20E-10	6.73E-09
Fe	2.56E-02	4.10E-01
Formaldehyde	1.07E+00	1.71E+01
HCl	3.98E-01	6.37E+00
HF	5.52E-02	8.85E-01
Hg	1.75E-04	2.80E-03
K	4.54E+00	7.27E+01
Kerosene	2.47E-03	3.95E-02
Metals	1.51E-03	2.42E-02
Methane	2.66E+01	4.26E+02
Methanol	3.11E+00	4.98E+01
Mn	5.30E-02	8.48E-01
N-nitrodimethylamine	1.68E-05	2.70E-04
N_2O	4.65E-02	7.45E-01
Na	1.05E-01	1.68E+00
Naphthalene	1.39E-02	2.23E-01
Ni	6.09E-03	9.76E-02
Non methane VOC	3.33E+01	5.34E+02
NO_x	6.50E+01	1.04E+03
Organic substances	1.04E+00	1.67E+01
Particulates	3.84E+00	6.15E+01
Particulates (PM10)	3.21E+01	5.14E+02
Particulates (unspecified)	5.68E+00	9.10E+01
Pb	7.30E-03	1.17E-01
Phenol	1.39E+00	2.23E+01
Sb	9.08E-05	1.45E-03
Se	6.29E-04	1.01E-02
SO_2	2.12E-02	3.40E-01
SO_x	1.21E+02	1.94E+03
Tetrachloroethene	7.70E-05	1.23E-03
Tetrachloromethane	2.09E-04	3.35E-03
Trichloroethene	7.52E-05	1.20E-03
VOC	2.47E+00	3.95E+01
Water vapor	1.64E+04	2.63E+05
Zn	2.56E-02	4.10E-01

Substance	lb per MCF	kg per 10^3m^3
Ca	5.40E-06	8.66E-05
Calcium ions	2.11E-03	3.38E-02
Cd	6.03E-03	9.65E-02
Chromate	1.61E-04	2.58E-03
Cl-	6.06E+00	9.70E+01
COD	1.15E+00	1.84E+01
Cr	6.03E-03	9.65E-02
Cyanide	9.04E-06	1.45E-04
Dissolved solids	1.32E+02	2.11E+03
Fe	3.10E-01	4.96E+00
Fluoride ions	9.82E-03	1.57E-01
H_2SO_4	5.53E-02	8.86E-01
Hg	4.73E-07	7.57E-06
Metallic ions	1.66E-02	2.66E-01
Mn	1.74E-01	2.78E+00
Na	3.90E-03	6.25E-02
NH_3	5.73E-03	9.17E-02
Nitrate	9.26E-04	1.48E-02
Oil	2.35E+00	3.76E+01
Other organics	4.21E-01	6.75E+00
Pb	1.42E-06	2.27E-05
Phenol	5.39E-05	8.64E-04
Phosphate	2.77E-02	4.43E-01
Sulphate	5.95E+00	9.53E+01
Suspended solids	4.22E+00	6.77E+01
Zn	2.08E-03	3.33E-02

Solid Waste Emission

Substance	lb per MCF	kg per 10^3m^3
Solid waste	1.76E+03	2.82E+04

Nonmaterial Emission

Substance	bq per MCF	bq per 10^3m^3
Radioactive sub. to air	5.45E+07	8.74E+08

Table A1.4. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Southeast with Phenol-formaldehyde Resin use Decreased by 10%.

Product Substance	**lb per MCF**	**kg per 10^3m^3**
Laminated Veneer Lumber	3.78E+04	6.06E+05

Co-products

Substance	**lb per MCF**	**kg per 10^3m^3**
Sawdust	2.72E+02	4.35E+03
Veneer loss	6.94E+02	1.11E+04
Lay-up scrap	1.42E+03	2.28E+04
Tested LVL	1.20E+02	1.92E+03
Panel trim	9.99E+02	1.60E+04

Raw Materials

Substance	**lb per MCF**	**kg per**
SE Bark on Logs	3.40E+03	5.44E+04
SE Logs	3.40E+04	5.44E+05

Substance	**lb per MCF**	**kg per 10^3m^3**
Coal FAL	2.17E+03	3.47E+04
Crude oil FAL	6.46E+02	1.04E+04
Limestone	2.11E+02	3.38E+03
Natural gas FAL	2.35E+03	3.76E+04
Uranium FAL	1.10E-02	1.77E-01
Wood/wood wastes FAL	1.50E+03	2.40E+04

Air Emissions-cont.

Substance	**lb per MCF**	**kg per 10^3m^3**
CO_2 (biomass)	1.06E+04	1.71E+05
CO_2 (fossil)	9.50E+03	1.52E+05
CO_2 (non-fossil)	1.57E+03	2.51E+04
Cobalt	2.27E-04	3.64E-03
Cr	6.01E-04	9.64E-03
Cumene	3.21E-03	5.14E-02

Electricity Substance	**Btu per MCF**	**MJ per 10^3m^3**
Electricity from other sources	5.06E+05	1.89E+04
Energy from hydro power	2.62E+05	9.78E+03

Water Usage

Substance	**lb per MCF**	**kg per 10^3m^3**
Municipal Water Source	6.08E+03	9.73E+04
Recycled Water	1.95E+02	3.13E+03
Well Water Source	1.32E+04	2.11E+05

Air Emissions

Substance	**lb per MCF**	**kg per 10^3m^3**
Acetaldehyde	2.77E-02	4.43E-01
Acetone	8.21E-01	1.32E+01
Acrolein	2.82E-04	4.52E-03
Aldehydes	5.84E-02	9.36E-01
Ammonia	3.67E-02	5.87E-01
As	7.78E-04	1.25E-02
Ba	2.56E-02	4.10E-01
Be	2.56E-05	4.10E-04
Benzene	2.14E-02	3.44E-01
Cd	1.98E-04	3.18E-03
Cl_2	4.55E-02	7.28E-01
CO	9.94E+01	1.59E+03

Water Emissions

Substance	**lb per MCF**	**kg per 10^3m^3**
Acid as H+	6.81E-07	1.09E-05
B	2.17E-01	3.47E+00
BOD	1.20E-01	1.92E+00

Substance	lb per MCF	kg per 10^3m^3
Dichloromethane	3.14E-04	5.03E-03
Dioxin (TEQ)	4.13E-10	6.61E-09
Fe	2.56E-02	4.10E-01
Formaldehyde	9.08E-01	1.45E+01
HCl	3.90E-01	6.25E+00
HF	5.42E-02	8.69E-01
Hg	1.72E-04	2.75E-03
K	4.54E+00	7.27E+01
Kerosene	2.41E-03	3.86E-02
Metals	1.44E-03	2.30E-02
Methane	2.54E+01	4.07E+02
Methanol	3.11E+00	4.98E+01
Mn	5.30E-02	8.48E-01
N-nitrodimethylamine	1.65E-05	2.65E-04
N_2O	4.56E-02	7.30E-01
Na	1.05E-01	1.68E+00
Naphthalene	1.39E-02	2.23E-01
Ni	6.01E-03	9.64E-02
Non methane VOC	3.03E+01	4.86E+02
NO_x	6.13E+01	9.82E+02
Organic substances	1.04E+00	1.66E+01
Particulates	3.80E+00	6.08E+01
Particulates (PM10)	3.21E+01	5.14E+02
Particulates (unspecified)	5.56E+00	8.91E+01
Pb	7.30E-03	1.17E-01
Phenol	1.18E+00	1.89E+01
Sb	8.87E-05	1.42E-03
Se	6.16E-04	9.88E-03
SO_2	2.12E-02	3.40E-01
SO_x	1.15E+02	1.84E+03
Tetrachloroethene	7.56E-05	1.21E-03
Tetrachloromethane	2.05E-04	3.28E-03
Trichloroethene	7.38E-05	1.18E-03
VOC	2.47E+00	3.95E+01
Water vapor	1.64E+04	2.63E+05
Zn	2.56E-02	4.10E-01

Substance	lb per MCF	kg per 10^3m^3
Ca	4.42E-06	7.08E-05
Calcium ions	2.08E-03	3.33E-02
Cd	5.65E-03	9.05E-02
Chromate	1.57E-04	2.51E-03
Cl-	5.67E+00	9.09E+01
COD	1.08E+00	1.73E+01
Cr	5.65E-03	9.05E-02
Cyanide	8.47E-06	1.36E-04
Dissolved solids	1.23E+02	1.98E+03
Fe	3.03E-01	4.86E+00
Fluoride ions	9.64E-03	1.54E-01
H_2SO_4	5.42E-02	8.69E-01
Hg	4.44E-07	7.11E-06
Metallic ions	1.45E-02	2.32E-01
Mn	1.70E-01	2.73E+00
Na	3.83E-03	6.13E-02
NH_3	5.47E-03	8.76E-02
Nitrate	9.08E-04	1.45E-02
Oil	2.21E+00	3.54E+01
Other organics	3.97E-01	6.35E+00
Pb	1.23E-06	1.98E-05
Phenol	4.70E-05	7.52E-04
Phosphate	2.71E-02	4.35E-01
Sulphate	5.63E+00	9.02E+01
Suspended solids	4.13E+00	6.61E+01
Zn	1.95E-03	3.13E-02

Solid Waste Emission

Substance	lb per MCF	kg per 10^3m^3
Solid waste	1.73E+03	2.77E+04

Nonmaterial Emission

Substance	bq per MCF	bq per 10^3m^3
Radioactive sub. to air	5.35E+07	8.57E+08

The following tables are for LCI data based on electricity scenarios that were completed for each region. In the PNW, the percentage of energy used to generate electricity was changed with regard to hydroelectric and natural gas use. In the SE, the changes were made regarding percentages of coal and natural gas used to generate electricity.

Table A1.5. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Pacific Northwest with the Amount of Energy Inputs to Generate Electricity in the Region Changed.

Product Substance	lb per MCF	kg per 10^3m^3
Laminated Veneer Lumber	3.30E+04	5.29E+05

Co-products

Substance	lb per MCF	kg per 10^3m^3
Sawdust	5.14E+02	8.23E+03
Veneer loss	4.71E+02	7.54E+03
Lay-up scrap	3.76E+02	6.02E+03
Tested LVL	8.45E+01	1.35E+03
Panel trim	4.20E+01	6.73E+02

Raw Materials

Substance	lb per MCF	kg per 10^3m^3
PNW Bark on Logs	3.00E+03	4.80E+04
PNW Logs	2.98E+04	4.77E+05

Substance	lb per MCF	kg per 10^3m^3
Coal FAL	4.42E+02	7.07E+03
Crude oil FAL	4.20E+02	6.73E+03
Limestone	5.86E+01	9.38E+02
Natural gas FAL	1.49E+03	2.38E+04
Uranium FAL	2.29E-03	3.67E-02
Wood/wood wastes FAL	5.76E+02	9.23E+03

Other Raw Materials

Substance	Btu per MCF	MJ per 10^3m^3
Hogged Fuel-Direct Fired Fuel	2.28E+06	8.48E+04

Electricity Substance	Btu per MCF	MJ per 10^3m^3
Electricity from other sources	1.75E+05	6.52E+03
Energy from hydro power	1.13E+07	4.20E+05

Water Usage

Substance	lb per MCF	kg per 10^3m^3
Municipal Water Source	1.37E+04	2.19E+05
Recycled Water	4.60E+01	7.37E+02
Well Water Source	4.10E+03	6.57E+04

Air Emissions

Substance	lb per MCF	kg per 10^3m^3
Acetaldehyde	3.90E-01	6.25E+00
Acetone	3.61E-01	5.79E+00
Acrolein	3.27E-05	5.25E-04
Aldehydes	3.47E-02	5.56E-01
Alpha-pinene	1.92E+00	3.07E+01
Ammonia	2.70E-02	4.33E-01
As	4.04E-04	6.47E-03
Ba	1.79E-02	2.86E-01
Be	4.67E-06	7.48E-05
Benzene	1.50E-02	2.40E-01
Beta-pinene	7.44E-01	1.19E+01
Cd	2.59E-05	4.15E-04
Cl_2	3.18E-02	5.10E-01
CO	6.86E+01	1.10E+03
CO_2 (biomass)	8.18E+03	1.31E+05
CO_2 (fossil)	3.96E+03	6.34E+04
CO_2 (non-fossil)	6.02E+02	9.64E+03
Cobalt	3.42E-05	5.49E-04
Cr	2.51E-04	4.02E-03

Air Emissions-cont.

Substance	lb per MCF	kg per $10^3 m^3$
Cumene	2.64E-03	4.23E-02
Dichloromethane	6.31E-05	1.01E-03
Dioxin (TEQ)	8.42E-11	1.35E-09
Fe	1.79E-02	2.86E-01
Formaldehyde	1.26E+00	2.02E+01
HCl	7.96E-02	1.28E+00
HF	1.10E-02	1.77E-01
Hg	3.27E-05	5.25E-04
K	3.17E+00	5.08E+01
Kerosene	5.02E-04	8.05E-03
Limonene	2.15E-01	3.45E+00
Metals	5.68E-04	9.10E-03
Methane	1.17E+01	1.87E+02
Methanol	4.12E+00	6.59E+01
Methyl ethyl ketone	1.70E-02	2.73E-01
Methyl i-butyl ketone	1.39E-02	2.23E-01
Mn	3.68E-02	5.89E-01
N-nitrodimethylamine	3.36E-06	5.38E-05
N_2O	9.03E-03	1.45E-01
Na	7.33E-02	1.17E+00
Naphthalene	9.82E-03	1.57E-01
Ni	2.65E-03	4.24E-02
Non methane VOC	2.05E+01	3.28E+02
NO_x	3.40E+01	5.44E+02
Organic substances	7.16E-01	1.15E+01
Particulates	1.22E+01	1.95E+02
Particulates (PM10)	7.56E+00	1.21E+02
Particulates (unspecified)	1.17E+00	1.87E+01
Pb	4.95E-03	7.93E-02
Phenol	1.03E+00	1.65E+01
Propionaldehyde	1.42E-02	2.28E-01
Sb	1.36E-05	2.17E-04
Se	1.26E-04	2.02E-03
SO_2	3.65E-02	5.85E-01
SO_x	5.77E+01	9.25E+02

Water Emissions

Substance	lb per MCF	kg per $10^3 m^3$
Acid as H+	4.49E-07	7.19E-06
B	4.23E-02	6.77E-01
BOD	7.71E-02	1.23E+00
Ca	3.64E-06	5.83E-05
Calcium ions	4.29E-04	6.88E-03
Cd	3.58E-03	5.74E-02
Chromate	2.01E-05	3.22E-04
Cl-	3.59E+00	5.76E+01
COD	7.33E-01	1.18E+01
Cr	3.58E-03	5.74E-02
Cyanide	5.38E-06	8.62E-05
Dissolved solids	7.87E+01	1.26E+03
Fe	6.20E-02	9.94E-01
Fluoride ions	2.00E-03	3.21E-02
H_2SO_4	1.06E-02	1.69E-01
Hg	2.82E-07	4.51E-06
Metallic ions	9.54E-03	1.53E-01
Mn	3.46E-02	5.55E-01
Na	7.95E-04	1.27E-02
NH_3	2.05E-03	3.28E-02
Nitrate	1.89E-04	3.03E-03
Oil	1.40E+00	2.25E+01
Other organics	2.33E-01	3.73E+00
Pb	8.17E-07	1.31E-05
Phenol	3.11E-05	4.98E-04
Phosphate	5.30E-03	8.48E-02
Sulphate	3.06E+00	4.90E+01
Suspended solids	1.26E+00	2.02E+01
Zn	1.24E-03	1.99E-02

Solid Waste Emission

Substance	lb per MCF	kg per $10^3 m^3$

Tetrachloroethene	1.52E-05	2.43E-04	Solid waste	7.10E+02	1.14E+04
Tetrachloromethane	2.71E-05	4.35E-04			
THC as Carbon	4.11E+00	6.58E+01	**Nonmaterial Emission**		
Trichloroethene	1.50E-05	2.40E-04		**bq**	**bq**
VOC	1.99E+01	3.19E+02	**Substance**	**per MCF**	**per 10^3m^3**
Zn	1.79E-02	2.86E-01	Radioactive sub. to air	2.47E+07	3.96E+08

Notes: Hydroelectric energy generation was decreased by 10% and natural gas was increased by 10% to make up the difference. All other factors were held constant.

Table A1.6. Life Cycle Inventory Outputs for the Production of 1.0 MCF of LVL in the Southeast with the Amount of Energy Inputs to Generate Electricity in the Region Changed.

Product Substance	lb per MCF	kg per 10^3m^3
Laminated Veneer Lumber	3.78E+04	6.06E+05

Co-products

Substance	lb per MCF	kg per 10^3m^3
Sawdust	2.72E+02	4.35E+03
Veneer loss	6.94E+02	1.11E+04
Lay-up scrap	1.42E+03	2.28E+04
Tested LVL	1.20E+02	1.92E+03
Panel trim	9.99E+02	1.60E+04

Raw Materials

Substance	lb per MCF	kg per 10^3m^3
SE Bark on Logs	3.40E+03	5.44E+04
SE Logs	3.40E+04	5.44E+05

Substance	lb per MCF	kg per 10^3m^3
Coal FAL	1.99E+03	3.19E+04
Crude oil FAL	6.93E+02	1.11E+04
Limestone	2.02E+02	3.23E+03
Natural gas FAL	2.53E+03	4.05E+04
Uranium FAL	1.12E-02	1.79E-01
Wood/wood wastes FAL	1.50E+03	2.40E+04

Air Emissions-cont.

Substance	lb per MCF	kg per 10^3m^3
CO_2 (biomass)	1.06E+04	1.71E+05
CO_2 (fossil)	9.54E+03	1.53E+05
CO_2 (non-fossil)	1.57E+03	2.51E+04
Cobalt	2.24E-04	3.59E-03
Cr	5.90E-04	9.45E-03

Electricity Substance	Btu per MCF	MJ per 10^3m^3
Electricity from other sources	5.11E+05	1.90E+04
Energy from hydro power	2.66E+05	9.90E+03

Water Usage

Substance	lb per MCF	kg per 10^3m^3
Municipal Water Source	3.51E+03	5.62E+04
Recycled Water	1.13E+02	1.81E+03
Well Water Source	7.60E+03	1.22E+05

Air Emissions

Substance	lb per MCF	kg per 10^3m^3
Acetaldehyde	2.77E-02	4.43E-01
Acetone	8.21E-01	1.32E+01
Acrolein	2.77E-04	4.43E-03
Aldehydes	6.18E-02	9.89E-01
Ammonia	4.31E-02	6.90E-01
As	7.68E-04	1.23E-02
Ba	2.56E-02	4.10E-01
Be	2.43E-05	3.90E-04
Benzene	2.14E-02	3.44E-01
Cd	2.00E-04	3.21E-03
Cl_2	4.55E-02	7.28E-01
CO	1.00E+02	1.61E+03

Water Emissions

Substance	lb per MCF	kg per 10^3m^3
Acid as H+	7.32E-07	1.17E-05
B	2.03E-01	3.25E+00

Substance	lb per MCF	kg per $10^3 m^3$
Cumene	3.56E-03	5.70E-02
Dichloromethane	2.91E-04	4.65E-03
Dioxin (TEQ)	3.80E-10	6.08E-09
Fe	2.56E-02	4.10E-01
Formaldehyde	9.88E-01	1.58E+01
HCl	3.60E-01	5.77E+00
HF	5.00E-02	8.00E-01
Hg	1.61E-04	2.58E-03
K	4.54E+00	7.27E+01
Kerosene	2.44E-03	3.92E-02
Metals	1.48E-03	2.37E-02
Methane	2.58E+01	4.14E+02
Methanol	3.11E+00	4.98E+01
Mn	5.29E-02	8.47E-01
N-nitrodimethylamine	1.52E-05	2.44E-04
N_2O	4.22E-02	6.77E-01
Na	1.05E-01	1.68E+00
Naphthalene	1.39E-02	2.23E-01
Ni	6.04E-03	9.67E-02
Non methane VOC	3.29E+01	5.27E+02
NO_x	6.26E+01	1.00E+03
Organic substances	1.04E+00	1.67E+01
Particulates	3.82E+00	6.11E+01
Particulates (PM10)	3.19E+01	5.12E+02
Particulates (unspecified)	5.14E+00	8.23E+01
Pb	7.28E-03	1.17E-01
phenol	1.29E+00	2.06E+01
Sb	8.71E-05	1.39E-03
Se	5.77E-04	9.24E-03
SO_2	2.12E-02	3.40E-01
SO_x	1.19E+02	1.91E+03
Tetrachloroethene	6.97E-05	1.12E-03
Tetrachloromethane	1.99E-04	3.19E-03
Trichloroethene	6.79E-05	1.09E-03
VOC	2.47E+00	3.95E+01
Water vapor	1.64E+04	2.63E+05
Zn	2.56E-02	4.10E-01

Substance	lb per MCF	kg per $10^3 m^3$
BOD	1.31E-01	2.10E+00
Ca	4.91E-06	7.87E-05
Calcium ions	2.10E-03	3.37E-02
Cd	6.11E-03	9.79E-02
Chromate	1.59E-04	2.54E-03
Cl-	6.13E+00	9.82E+01
COD	1.20E+00	1.92E+01
Cr	6.11E-03	9.79E-02
Cyanide	9.17E-06	1.47E-04
Dissolved solids	1.34E+02	2.15E+03
Fe	2.84E-01	4.55E+00
Fluoride ions	9.72E-03	1.56E-01
H2SO4	5.06E-02	8.11E-01
Hg	4.80E-07	7.69E-06
Metallic ions	1.55E-02	2.49E-01
Mn	1.57E-01	2.51E+00
Na	3.86E-03	6.18E-02
NH_3	5.70E-03	9.14E-02
Nitrate	9.17E-04	1.47E-02
Oil	2.38E+00	3.81E+01
Other organics	4.22E-01	6.77E+00
Pb	1.33E-06	2.13E-05
Phenol	5.05E-05	8.09E-04
Phosphate	2.53E-02	4.05E-01
Sulphate	6.00E+00	9.62E+01
Suspended solids	3.99E+00	6.39E+01
Zn	2.11E-03	3.38E-02

Solid Waste Emission

Substance	lb per MCF	kg per $10^3 m^3$
Solid waste	1.67E+03	2.68E+04

Nonmaterial Emission

Substance	bq per MCF	bq per $10^3 m^3$
Radioactive sub. to air	5.61E+07	8.99E+08

Notes: Coal was decreased by 10% and natural gas was increased by 10% to make up the difference. All other factors were held constant.

APPENDIX 2:
CORRIM SURVEY FORM TO COLLECT LCI DATA FOR THE PRODUCTIONS OF LAMINATED VENEER LUMBER.

CORRIM SURVEY
The Consortium for Research on Renewable Industrial Materials (CORRIM II)

Laminated Veneer Lumber (LVL)/Composite I-Beam Plants
6-15-2001

This CORRIM survey is designed specifically for laminated veneer lumber and composite I-beam plants. There are two sections for this survey. Complete the section(s) that apply to your facilities. The white paper section relates to the production of LVL and the green paper section involves composite I-beam production. Questions will be concentrated on annual production, electricity production and usage, fuel use, 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. Our intent is to maintain the confidentiality of the companies that supply the data for this survey.

The information from this survey will be used in a project by CORRIM II, a consortia comprised of universities, industry, and government groups. CORRIM is conducting a life-cycle assessment that will describe environmental influences of building materials and will focus our initial effort on structural building materials. CORRIM's objective is to acquire a database and produce life-cycle models of environmental performances for building materials. The database will be the basis for the scientific evaluation of feasible alternatives affecting the environmental releases and energy requirements of building materials through their life cycle. It is hoped that the output of the study will be used to competitively position wood in the marketplace over other types of building materials.

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: ______________________ E-mail: ______________________

If you have questions about the survey, contact:
Eric Dancer
Graduate Research Assistant
Department of Wood Science and Engineering
289 Richardson Hall
Oregon State University
Corvallis, OR 97331-5751
541-737-1299 or eric.dancer@orst.edu

LVL Annual Production (Please provide units of measurement if different than stated)				
				TOTAL PRODUCTION
1.	Annual LVL production, 2000		ft^3	
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. Transportation method(s) and average delivery distance for veneer			
	Truck (% of total)		Average delivery miles	
	Rail (% of total)		Average delivery miles	
	Other (% of total)		Average delivery miles	
	Total (%)	100		

3. Do you either peel/dry or dry veneer on site ____ Yes, ____ No?
   If yes, be sure to complete the relevant pages (page 9 through 11) of this survey.

Annual Energy Consumption (Please provide units of measurement if different)

If you have completed a 2000 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." Please include all fuel use data relating to forklifts, loaders, and any other equipment used in your operations.

1.	Purchased electricity	kWh	________
2.	Purchased steam	lbs (at temperature ^oF?)	________
3.	Coal	Tons	________
4.	Hog Fuel *Self-generated*	Tons	________
	Purchased	Tons	________
5.	Wood Waste	Tons	________
6.	Residual Fuel Oil	42 Gal. Bbls.	________
7.	Distillate Fuel Oil	42 Gal. Bbls.	________
8.	Liquid Propane Gas	Gallons	________
9.	Natural Gas	ft^3	________
10.	Gasoline and Kerosene	Gallons	________
11.	Diesel	Gallons	________
12.	Other (Specify)	________	________
13.	Less energy sold or transferred (if you generated any of these)		
	a. Electricity	kWh	________
	b. Steam	lbs (at temperature ^oF?)	________
	c. Hog fuel	Tons	________
	d. Wood waste	Tons	________

14. If you have a boiler, what is its heat source? Check appropriate box.

G Hogged fuel
G Oil
G Natural gas
G Other

15. If you have a boiler, how much electricity is used to operate it? kWh

Other Annual Production Data

1. Formulation and usage of resin, fillers, and other components

Component Type	**Range % of Solid by Weight**	**Total annual use (lbs.)**
Phenol formaldehyde		
Extender and filler		
Catalyst (NaOH)		
Water		
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

2. Hot Pressing

Type and number of press(es) (i.e., RF, continuous, platen, etc.)

Operating Temperature EF

Pressure applied psi

Press Time (check type) min:sec

G Continuous press

G Single opening platen press

Source of Heat for Press

G Thermal Fluid (Hot Oil) heated by		
Natural Gas	ft^3	
Electricity	kWh	
G Steam	lbs	
G Radio Frequency	kWh	
G Microwave Frequency	kWh	
G Other		

Annual Material Flow

This is a general material flow survey for LVL mills. This survey is designed to trace all wood during production. Please check the box that pertains to your mill and answer related questions.

	Veneer		
1.	Veneer loss	Tons	________

	Lay-up		
1.	Lay-up scrap	Tons	________
2.	Resin loss	lbs.	________

	Sawing & Trimming		
1.	Panel trim	Tons	________
2.	Saw dust	Tons	________

	Rip Saw		
1.	Saw dust	Tons	________

	Quality Control		
1.	Tested LVL used	$ft.^3$	________

	Water use by source		
1.	Municipal water source	Gallons	________
2.	Well water source	Gallons	________
3.	Recycled water source	Gallons	________

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 an air permit, use those numbers. Fill in all that apply and for which you have data.

Annual Emission Control Device (ECD)- Electricity, Fuel Usage, and Emission Output					
	ECD 1	**ECD 2**	**ECD 3**	**ECD 4**	**ECD 5**
Equipment controlled (i.e., boiler, press, dryer, etc.)					
Model/ Type					
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					
Annual Emission to Air (Please provide units of measurement if different)					
Organic Compound	**ECD 1**	**ECD 2**	**ECD 3**	**ECD 4**	**ECD 5**
Equipment controlled (i.e., boiler, press, etc.)					
Units	Tons/yr	Tons/yr	Tons/yr	Tons/yr	Tons/yr
CO_2					
CO					
NO_X					
SO_2					
VOC					
Acrolien*					
Methanol*					
Phenol*					
Acetaldehyde*					
Formaldehyde*					
Propionaldehyde*					
Water Vapor					

PM10					
Particulate					
*HAPS; you may want to provide total HAPS rather than specific chemicals					
Other (Please specify)					

Annual Emission to Land (please provide units of measurement)		
Emission	**Quantity (i.e. tons, lbs.)**	**Method of disposal or end use (i.e. land fill, landscaping)**
Bark/wood waste		
Boiler ash and fly ash		
Recovered particulates from pollution abatement equip.		
Water		
Other (Please specify)		

Machine Center Breakdown for Electricity and Fuel Use

Fill in all that apply and for which you have data. If you don't have a given machine center such as a co-generator, draw a line through that row and write none.

Machine Center	Model/Type Year Installed	Annual electricity Million kWh or % of the total use for mill	Fuel Usage % of total use for mill
Boiler(s)			
Co-generator			
Lay-up			
Press(es)			
Billet Cuts			
Rip Saw			

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

Complete the following pages if you peel and dry or dry veneer in your LVL operation.

Please fill in all the information that pertains to your plant. Do not provide any additional information for operations not in your plant.

Machine Center Breakdown for Electricity and Fuel Usage

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	Annual Electricity Usage	Fuel Usage
	Year Installed	kWh of % of total electricity use for mill	% of total use for mill
Debarking			
Log Conditioning			
Peeling and Clipping			
Drying			

Annual Material Flow for Bucking, Peeling, and Drying

This is a general material flow survey for LVL mills. This survey is designed to trace all wood components generated during production. Please check the box that pertains to your mill and answer related questions.

G **Debarking and Bucking**		
1. Bark produced annually	Tons	
2. Wood chips produced	Tons	

G **Peeling and Chipping**		
1. Volume of peeler core	ft^3 or pieces (give lengths)	
2. Green clippings	Tons	
G **Veneer Dryer**		
1. Veneer downfall	Tons	

1. For dryer(s), check box type, heat source and give the annual fuel consumption if known:			
G Type of dryer G longitudinal G cross flow G jet			
G Steam		lbs	
G Natural gas direct-fired		ft^3	
G Hog fuel direct-fired (fuel cell)		tons	
G Other			
2. In regard to the dryer(s):			
Wood species dried and approximate percentage of total:			
Species		%	
Species		%	
Species		%	
Average moisture content into dryer		% ovendry basis	
Average moisture content out of dryer		% ovendry basis	
Redry rate		%	

3. Transportation method used to bring in your logs for veneer (check source):

G Truck (% of total) Average delivery miles ____________________

G Rail (% of total) Average delivery miles ____________________

G Other Average delivery miles ____________________

Complete the following pages if you produce composite I-beams in your plant.

Please fill in all information relevant to producing I-beams. Do not provide any information for operations not in your plant. Please provide the data on an annual basis for the year which the data is reported.

1. Annual I-Beam Production for 2000

Product (Series)	Amount (lin.ft.)	Beam Depth (in.)	Flange dim. (in. x in.)

2. I-Beam Construction-Web

	% of total	M 3/8's
a. OSB		
b. 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		

3. I-beam Construction - Flanges

	% of total used	(ft^3 or MBF)
a. LVL	______	______
b. Finger-jointed lumber	______	______

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 Finger-Jointed Lumber

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

4. Resin Use

a. Web Joint Resin type ______

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 (%)	______	Average delivery miles	______

Please include resin used in the Web joints of the I-beam 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 ______G.

Otherwise, fill in resin use for web joint only.

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

b. Flange finger joint Resin type ______________

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 (%) ______________ Average delivery miles ______________

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

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

c. I-beam (web to flange) Resin type ______________

Transportation method and delivery distance for flange resin

Truck (% of total) ______________ Average delivery miles ______________

Rail (% of total) ______________ Average delivery miles ______________

Other (% of total) ______________ Average delivery miles

Total (%) 100

Please include resin used in the web to flange joints of the I-beam in this section. Please state whether weight is given as a wet or dry weight.		
Component Type	Range % of Solid by Weight	Total Annual Use (lbs.)
Resin		
Extender and filler		
Catalyst (NaOH)		
Water		
Other (please specify)		
Resin loss (lbs)		

Machine Center Breakdown for Electricity and Fuel Use

Fill in all that apply and for which you have data. If you don't have a given machine center that is listed here, draw a line through that row and write none.

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

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, Fuel Usage, and Emission Output					
	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment controlled (i.e., boiler, press, dryer, etc.)					
Model/Type					
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					
Annual Emission to Air (Please provide units of measurement if different)					
Organic Compound	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment controlled (i.e., boiler, press, etc.)					
Units	Tons/Yr	Tons/Yr	Tons/Yr	Tons/Yr	Tons/Yr
CO_2					
CO					
NO_X					
SO_2					
VOC					
Acrolien*					
Methanol*					
Phenol*					
Acetaldehyde*					
Formaldehyde*					
Propionaldehyde*					
Water Vapor					
PM 10					
Particulate					
*HAPS; you may want to provide total HAPS rather than specific chemicals					
Other (Please specify)					

Annual Emission to Land (Please provide units of measurement)		
Emission	Quantity (i.e., tons, lbs.)	Method of disposal or end use (i.e., land fill, landscaping)
Bark/wood waste		
Boiler ash and fly ash		
Recovered particulates from pollution abatement equipment		
Water		
Other (Please specify)		