CORRIM: Phase I Final Report

Module B

SOFTWOOD LUMBER - PACIFIC NORTHWEST REGION

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EXECUTIVE SUMMARY

The goal of this work was to develop a gate-to-gate life cycle inventory for the production of framing lumber from logs in western Oregon and Washington. Dimension lumber and studs are used in the framing of residential structures. A large portion of this type of lumber is Douglas-fir or hemlock. The functional unit is the sawmill complex which produces planed dry lumber from logs. This includes log handling, sawing, drying, planing, and generating steam for the dryer. The system boundary begins with the logs entering the mill complex and ends with products (lumber) or co-products (chips, sawdust, shavings, bark, hog fuel) leaving the mill complex. The burdens for all substances and energy are allocated among the products and co-products based on dry mass. This report is intended for use in developing life cycle inventories for various construction practices in residential housing.

Four mills which produced dimension lumber as a primary product were surveyed according to the CORRIM research guidelines. One of these produced only green lumber, one produced only dry lumber, and the other two produced a combination. The annual total production from these mills was 13 percent of the stud and dimension lumber volume produced in the survey region. The mills provided detailed data about the inputs and outputs to their operations for either calendar year 1999 or 2000. Over 99.5% of the material inputs and outputs were collected as primary data. An additional ten mills in the region were sampled to obtain steam production and drying data only. The boiler data represents mills that produce almost two billion board feet of lumber annually. The survey data are presented as average values derived by weighting production at each reporting facility or 20% of the region's lumber production.

The process of producing lumber was modeled in SimaPro 5 as four unit processes: sawing, drying, planing, and energy generation (boiler). Each of these was made as independent as possible so that the resulting model could be used with varying inputs and outputs. Individual processes are also necessary for proper allocation because both green and dry products are produced.

Sawing. To produce one Mbf[2] of rough sawn green lumber required approximately 3.06 m^3 (108 ft^3) of logs with a recovery of about 62% of the wood as rough green lumber. Co-products included chips, sawdust, hog fuel, and bark. Energy use was 240 MJ/Mbf. Emissions from the site were minor.

Energy generation. This process produced the steam for drying, 58.2% from wood and bark, 41.7% from natural gas, and 0.1% from diesel. 7.1 kJ of electricity was produced as an avoided product per 1 MJ of steam. Emissions consisted mainly of CO_2 from biomass.

Drying. This process (and energy generation for it) consumed 86.8% of the energy used in lumber manufacturing, mainly due to steam use to evaporate water. Energy use was 2892MJ/Mbf to produce rough dry lumber. Steam use was 4.54E6 J/kg (1,960 BTU/lb) of water removed.

Planing. To produce one Mbf of planed dry lumber required 1.04 Mbf of rough dry lumber and 86% of the rough lumber entering the planing process left as planed lumber. The energy required to produce planed dry lumber was 2663 MJ/Mbf. This is less than energy to manufacture one Mbf of rough dry lumber because some of the mass of the rough dry lumber becomes shavings. The energy from sawing and drying allocated to the shavings is greater than that added to the planed dry lumber in the planing process.). Materials used in packaging were less than 0.5% of the total product and co-product mass. Emissions from planing were minor. Overall, 51% of the wood in the log ends up as planed lumber.

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[2] Mbf = one thousand board feet

A sensitivity analysis indicated that fossil CO_2 emissions (from natural gas) decreased as the fraction of steam generated using wood fuels increased. If wood based-fuel were used for all steam production, the energy required to dry lumber would be 879 MJ/Mbf. If natural gas were used for all steam production, the energy required to dry lumber would be 4720 MJ/Mbf. As dryer efficiency increased, all emissions decreased.

The biomass carbon in and out of the processes balanced within 3%. Most of the carbon that enters with the logs leaves in products and co-products. Approximately 10% leaves as atmospheric CO_2.

A cost analysis on the process demonstrates the effect of lumber prices on profitability.

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1.0 INTRODUCTION

The goal of this work was to develop a gate-to-gate life cycle inventory for the production of dry framing lumber from logs in western Oregon and Washington. Dimension lumber and studs are used in the framing of residential structures. A large portion of this type of lumber is Douglas-fir or hemlock. The intended audiences for the life cycle inventory developed in this report are those individuals or groups wanting to develop life cycle inventories for products in which dimension lumber is a component. These might include commodity products, such as laminated beams or residential housing.

The functional unit is the sawmill complex which includes handling delivered logs, sawing, drying, planing, generating steam for the dryer, and loading the product onto rail or truck. The system boundary begins with the logs entering the mill complex and ends with products (lumber) or co-products (chips, sawdust, shavings, bark, hog fuel, electricity) leaving the mill complex. All substances and energy are allocated to the products and co-products based on dry mass.

Dimension lumber and studs are typically used for framing in residential construction and consist mainly of lumber that is nominally (see page 5 for discussion of nominal sizes) 2 inches in thickness and 4 to 12 inches in width. Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) dominate the species mix in western Oregon and Washington. Other species such as larch, pine, and the true firs enter the mix if the entire west is considered. The production region from which data was collected in this work included only western Oregon and Washington.

There are approximately 200 mills in Oregon and Washington that produce lumber products. Many of these are small and make specialty products. Only larger mills can be competitive in producing framing lumber, a commodity product. A large mill may produce from 75 to 500 million bf annually, although both larger and smaller mills can be found. Approximately 10.3 billion board feet of Douglas-fir and western hemlock are produced in the two states, approximately 70% of which is Douglas-fir and hemlock light framing lumber (studs and dimension). Table 1.1 shows the production of these two species in Oregon and Washington.

Table 1.1. Lumber production in Oregon and Washington for 1999.

State Lumber production (billion bf)	Oregon	Washington	OR and WA Combined
Douglas-fir	3.905	1.749	5.654
Hemlock	1.332	1.597	2.929
Combined	5.237	3.346	8.583
State total (all species)	6.056	4.224	10.280

Notes State data includes all products, not just dimension lumber. This is most recent data available. Values are in billion board feet.

Source: WWPA, 2000 and Bernhardt, 2001.

Table 1.2 shows the relative amounts of stud and dimension products produced from Douglas-fir and western hemlock in Washington, Oregon, and northern California. A large portion of Douglas-fir (81.5%) is sold green and nearly all hemlock, 94.5%, is sold dry in the dimension and stud grades. California accounts for approximately 11% of the total production reported in Table 1.2.

Table 1.2. Coastal Douglas-fir and western hemlock lumber production by product and species, Washington, Oregon, and Northern California.

Species	Studs		Dimension		Total
	Green	Dry	Green	Dry	
Coastal Douglas-fir, billion bf	0.559	0.124	3.458	0.784	4.927
Hemlock (hem-fir), billion bf	0.017	0.409	0.132	1.839	2.399
Combined by product, billion bf	0.576	0.533	3.590	2.623	7.326
Percent of total	7.9	7.3	49.0	35.8	100.0

Notes: Dimension and stud data is 11% due to production in California.

In this study, data was collected from representative mills that largely or exclusively produce softwood dimension lumber. Seven mills were identified as mills to be surveyed based on production capacity and how well they represented the industry. Four of the seven responded and provided detailed data about the inputs and outputs to their operations for either the calendar years 1999 or 2000. The total production from these mills was 862 million board feet (MMbf) per year, 11.8% of total regional production; without California, this value is 13%. One of the mills produced only green lumber, one produced only dry lumber, and the other two produced a combination. The mill producing green lumber provided information about sawing and planing only.

The data appears to be representative of industry as demonstrated in Table 1.3. The survey over-represents hemlock by 9%. For Douglas-fir, most is sold green while hemlock is most often sold dry, and the survey does an excellent job of representing this mix. The survey did not ask for a breakdown by lumber size; however production was modeled as nominal 2” by 6” stock. The weighted mean width of the values in Table 1.3, 6.5”, supports this decision.

Although the four responding mills reflected the industry averages for lumber production, they did not seem to represent energy production based on the author’s experience. Therefore, additional surveys covering only steam production were sent to 14 mills in the spring of 2002. These were all of the Western Wood Products Association member mills that listed dry dimension lumber as a product. Ten of the mills responded (plus the four original mills) for a total of 14 mills representing almost two billion board feet of production. Thus the boiler and drying energy data represent over 20% of the lumber production in the region.

Table 1.3. Comparison of survey coverage to published statistics.

Product	WWPA %	CORRIM Survey %
Douglas-fir	67.3	59.0
Hemlock	32.7	41.0
Total	100.0	100.0
Douglas-fir, dry	18.5	19.5
Douglas-fir, green	81.5	80.5
Total	100.0	100.0
Hemlock, dry	94.5	100.0
Hemlock, green	5.5	0.0
Total	100.0	100.0
2" (width)	0.0	-
3"	0.1	-
4"	37.1	-
5"	0.02	-
6"	29.2	-
8"	9.6	-
10"	14.4	-
12"	9.0	-
Random	0.5	-
Total	100.0	-

Notes: All data is for the dimension and stud grades only. Data is for 1999, the most recent year available.

Source: WWPA, 2000 and Bernhardt, 2001.

1.1 UNIT PROCESS APPROACH

For the survey, lumber production was broken down into four unit processes: sawing, drying, and planing and steam production. These are described as follows:

Sawing. The system boundary for this unit process encompasses the log storage area and the sawmill where the breakdown of the logs into rough green lumber occurs. The main input is logs. The outputs are rough green lumber, pulp chips, bark, sawdust, and hog fuel. The following occur within the boundary:

- in-yard conveyance of logs from the point of unloading to the deck;
- sorting and storage of logs;
- in-yard conveyance of logs from the deck to the optimizer or debarker;
- cutting to length of logs (bucking);
- debarking of logs;
- breakdown of logs into rough lumber, pulp chips, bark and sawdust;
- stacking, stickering, and in-yard conveyance of rough lumber to kilns or planer facilities;
- saw filing and maintenance of equipment and yard transportation vehicles; and

- treatment of process air, liquids, and solids.

Drying. The system boundary for this unit process encompasses the dryers, loading area, and unloading/cooling areas. The main input is rough green lumber. The output is rough dry lumber. The following occur within the boundary:

- loading of stickered lumber into a kiln facility;
- heat treatment, drying, equalizing and conditioning of lumber within the kiln;
- maintenance of all kiln equipment and related yard transportation vehicles;
- treatment of process air, liquids and solids; and
- unloading and conveyance of kiln-dried lumber to the planer mill.

Planing The system boundary for this unit process encompasses the unstacker, planer, and packaging areas. The main input is rough dry lumber. The outputs are 1) planed, dry, packaged lumber sorted by size and grade, 2) pulp chips, and 3) sawdust. Planed green lumber could be produced. The following occur within the boundary:

- sticker removal and/or unstacking of lumber ;
- planing (surfacing) of lumber;
- trimming, grading, and sorting of lumber;
- stacking, strapping, and packaging of lumber;
- conveyance of lumber within the planer operation and loading for shipping;
- maintenance of equipment and associated yard transportation vehicles; and
- treatment of process air, liquids and solids.

Steam production. The system boundary for this unit process encompasses the fuel storage, the boiler, and steam distribution system. The main inputs are hog fuel, bark, and sawdust for a wood-fire boiler. Natural gas and diesel boilers are also used. The outputs are steam and in some cases, electricity. The following occur within the boundary:

- fuel handling;
- addition of water to the boiler;
- addition of chemicals to the boiler or to steam lines;
- distribution of the steam;
- distribution of electricity; and
- the treatment of process air, liquids, and solids.

The surveys are presented in Appendices 1 and 2. These were for the calendar year 1999. Infrastructure (construction of the facilities) is not considered in this study. Nor, in accordance with CORRIM guidelines, were materials and energy associated with overhead and administration surveyed. However, electrical consumption for the overhead and administration is probably included with the process electrical use because of the way in which mills record electrical usage.

1.2 MILL SURVEYS

All raw material inputs and outputs from the mill surveys are summarized in Table 1.4 on a per Mbf or per BTU basis. This table represents a composite of the survey, rather than data for any one mill. These are presented with the inputs first, followed by the outputs. Similar materials are grouped together. This table forms the basis for the tables in the subsequent sections and input to the SimaPro 5 life cycle program. Each material and energy value is a weighted average of the four production facilities surveyed determined by

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i * f_i}{\sum_{i=1}^{n} f_i}$$

where X_i is the value reported by mill i, f_i is the fraction of production at mill i, n is the number of mills reporting a value for the material or energy value (X_i). Missing values were carefully noted so they were not averaged as zeros. For reference, the high and low values reported are also shown in Table 1.4. Where values of 1.0 occur in the table, it is often because that value is the calculation basis in that process. For example, all values for rough green lumber in the sawing process are 1.0 because all values were divided by the quantity of rough green lumber produced.

It should also be noted that a board foot is a nominal measurement only indirectly related to actual volume. There are small differences in the mass of wood in one board foot. For pieces of the same length, two 2”x4” pieces of planed dry lumber contain about 3.5% less wood than one 2”x8” piece. This allows for the saw kerf when a 2x8 is ripped into two 2x4s. The industry practice is to use these nominal sizes, much like the term 1” schedule 40 steel pipe describes pipe for which neither the inside nor outside diameter is 1”. Nominal 2”x 6” planed, dry dimension lumber, for example, has actual dimensions of 1.5 x 5.5 inches. Rough lumber is thicker and wider than the final product to allow for shrinkage in the dry kiln and smoothing of the surface during planing. The dimensions of rough sawn lumber vary by mill. Mills with more variabilities in the process need larger rough sizes to have the wood leave the planer with a smooth surface. The dimensions of rough green lumber have been assumed to be 1.65” by 5.9” for analysis purposes. Because the rough green lumber is an intermediate product, this assumption is not critical to the accuracy of the report. Reporting of cubic meters of lumber in this report is based on the actual volume of wood.

Table 1.4. Summary of all data from 1999 mill surveys.

		Sawing, per Mbf rough green lumber			Energy generation, per BTU of steam produced			Drying, per Mbf of rough dry lumber			Planing, per Mbf of planed lumber		
		Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High
Wood (in)													
Sawlogs	ft^3	9.70E+01	9.04E+01	1.05E+02									
Rough green lumber	Mbf							1.00E+00	1.00E+00	1.00E+00	1.05E+00	1.02E+00	1.12E+00
Rough dry lumber	Mbf										1.03E+00	1.00E+00	1.07E+00
Redry	Mbf												
Mean											1.04E+00	1.01E+00	1.07E+00
Other Materials (in)													
Hydraulic fluids	lb	1.83E-01	1.10E-01	3.10E-01	2.06E-09	2.06E-09	2.06E-09	0.00E+00	0.00E+00	0.00E+00	2.77E-02	5.02E-03	5.28E-02
Greases	lb	1.97E-02	8.29E-05	4.98E-02	4.33E-10	4.33E-10	4.33E-10	5.00E-04	5.00E-04	5.00E-04	6.29E-04	6.58E-05	9.85E-04
Motor oil	gal	5.21E-02	2.26E-02	1.03E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.80E-03	0.00E+00	1.99E-02
Paints, oil-based	gal	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.08E-03	0.00E+00	2.68E-02
Waxes	gal	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solvents	gal	1.13E-02	1.10E-04	2.12E-02	0.00E+00	0.00E+00	0.00E+00	8.38E-05	0.00E+00	2.50E-04	2.31E-04	0.00E+00	1.65E-03
Sum used as SimaPro input	gal	9.16E-02	0.00E+00	1.54E-01	3.46E-10	0.00E+00	3.46E-10	1.53E-04	0.00E+00	3.19E-04	1.27E-02	0.00E+00	2.12E-02
Anti-stain chemicals	gal	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.85E-02	0.00E+00	4.82E-02
Antifreeze	gal	3.60E-04	0.00E+00	7.05E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Water treatment Chemicals	gal	0.00E+00	0.00E+00	0.00E+00	8.17E-09	4.52E-09	1.31E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Caustic soda	gal	0.00E+00	0.00E+00	0.00E+00	4.06E-10	0.00E+00	9.52E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Paints, water-based	gal	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E-02	0.00E+00	8.26E-02
Sum used as SimaPro input	gal	3.60E-04	0.00E+00	7.05E-04	8.58E-09	4.52E-09	1.40E-08	0.00E+00	0.00E+00	0.00E+00	4.32E-02	0.00E+00	8.35E-02
Wraps	lbs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.31E-01	0.00E+00	6.89E-01
Linerboard	lbs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E-02	0.00E+00	1.26E-01
Strapping	lbs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.24E-01	0.00E+00	1.08E+00
Alloys	lb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	lb	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.24E-01	0.00E+00	1.08E+00

		Sawing, per Mbf rough green lumber			Energy generation, per BTU of steam produced			Drying, per Mbf of rough dry lumber			Planing, per Mbf of planed lumber		
		Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High
Water Consumption (in)													
Log yard surface water	lbs	2.40E+02	0.00E+00	5.32E+02									
Log yard ground water	lbs	3.62E+02	0.00E+00	2.68E+03									
Other surface water	lbs	5.97E+00	0.00E+00	2.80E+01	1.01E-04	3.93E-05	1.47E-04	8.01E+00	0.00E+00	2.39E+01	2.91E-01	0.00E+00	1.36E+00
Other ground water	lbs	4.14E+00	0.00E+00	3.06E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum, surface water	lbs	2.46E+02	0.00E+00	5.32E+02	1.01E-04	3.93E-05	1.47E-04	8.01E+00	0.00E+00	2.39E+01	2.91E-01	0.00E+00	1.36E+00
Sum, ground water	lbs	3.66E+02	0.00E+00	2.71E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Energy (In)													
Gasoline	BTUs	5.86E+03	0.00E+00	1.34E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Diesel fuel, forklift	BTUs	6.42E+04	4.77E+04	8.88E+04	3.60E-03	0.00E+00	6.27E-03	8.92E+03	3.31E+03	1.48E+04	2.02E+04	1.44E+04	2.82E+04
Propane	BTUs	1.15E+01	0.00E+00	3.16E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.89E+00	0.00E+00	1.08E+01
Diesel, boiler	BTUs	0.00E+00	0.00E+00	0.00E+00	9.40E-03	0.00E+00	1.35E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Natural gas	BTUs	0.00E+00	0.00E+00	0.00E+00	6.74E-01	1.02E+00	1.24E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog fuel	BTUs	0.00E+00	0.00E+00	0.00E+00	7.73E-01	0.00E+00	13.5E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Electricity (purchased)	kW-hr	8.68E+01	4.80E+01	1.24E+02	7.43E-06	4.13E-06	1.23E-05	2.78E+01	2.55E+01	3.00E+01	2.72E+01	2.16E+01	3.41E+01
Steam (self-generated)	BTUs	0.00E+00	0.00E+00	0.00E+00	2.18E-06	0.00E+00	5.60E-05	3.13E+06	6.67E+05	1.88E+07	0.00E+00	0.00E+00	0.00E+00
Wood (out)													
Rough green lumber	Mbf	1.00E+00	1.00E+00	1.00E+00									
Rough dry lumber	Mbf							1.00E+00	1.00E+00	1.00E+00			
Planed dry lumber	Mbf										5.07E-01	0.00E+00	1.00E+00
Planed green lumber	Mbf										4.93E-01	0.00E+00	1.00E+00
Heat treated lumber	Mbf										0.00E+00	0.00E+00	0.00E+00
Logs	Mbf	0.00E+00	0.00E+00	0.00E+00									
Pulp chips	Dry lbs	8.45E+02	7.52E+02	8.99E+02				0.00E+00	0.00E+00	0.00E+00	1.02E+02	0.00E+00	2.11E+02
Bark	OD lbs	2.46E+02	6.98E+01	3.33E+02				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hog fuel	OD lbs	4.03E+01	0.00E+00	1.51E+02				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sawdust	Dry lbs	2.33E+02	2.00E+02	3.31E+02				0.00E+00	0.00E+00	0.00E+00	2.48E+01	0.00E+00	6.80E+01
Shavings	Dry lbs	0.00E+00	0.00E+00	0.00E+00				0.00E+00	0.00E+00	0.00E+00	1.30E+02	6.84E+01	2.16E+02

		Sawing, per Mbf rough green lumber			Energy generation, per BTU of steam produced			Drying, per Mbf of rough dry lumber			Planing, per Mbf of planed lumber		
		Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High	Weighted Average	Low	High
Energy (out)													
Steam	BTUs				1.00E+00	1.00E+00	1.00E+00						
Electricity	kW-hrs				8.74E-06	0.00E+00	0.00E+00						
Air Emissions, (out)													
Dust (PM10)	lbs	4.82E-01	0.00E+00	1.64E+00	2.02E-08	0.00E+00	9.49E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Particulates (PM)	lbs	4.68E-01	0.00E+00	1.84E+00	2.15E-07	0.00E+00	5.79E-07	1.92E-01	0.00E+00	5.60E-01	8.12E-02	0.00E+00	3.12E-01
SO_2	lbs	0.00E+00	0.00E+00	0.00E+00	3.09E-08	8.66E-09	6.61E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NO_x	lbs	0.00E+00	0.00E+00	0.00E+00	1.62E-07	6.53E-08	2.75E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO	lbs	0.00E+00	0.00E+00	0.00E+00	6.35E-07	3.39E-09	1.83E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
VOC	lbs	1.28E-01	0.00E+00	3.21E-01	7.79E-08	7.79E-08	7.79E-08	1.97E-01	1.66E-01	2.21E-01	3.54E-02	0.00E+00	2.57E-01
Acetaldehyde	lbs	1.94E-03	0.00E+00	1.44E-02				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Acrolein	lbs	2.99E-06	0.00E+00	2.21E-05				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Formaldehyde	lbs	2.99E-07	0.00E+00	2.21E-06				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Methanol	lbs	3.31E-03	0.00E+00	2.45E-02				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Phenol	lbs	3.43E-04	0.00E+00	2.54E-03				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Propionaldehyde	lbs	2.69E-04	0.00E+00	1.99E-03				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HAPs (other)	lbs	3.37E-03	0.00E+00	2.50E-02				0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Liquid Emissions (out)													
Suspended solids	mg/L	9.71E-05	0.00E+00	7.18E-04	2.88E-12	0.00E+00	5.02E-12	2.93E-04	0.00E+00	1.38E-03	1.16E-04	0.00E+00	8.56E-04
BOD	mg/L	3.73E-05	0.00E+00	2.76E-04	4.32E-12	0.00E+00	7.53E-12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
COD		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Oil & grease	mg/L	7.47E-06	0.00E+00	5.52E-05	0.00E+00	0.00E+00	0.00E+00	2.25E-05	0.00E+00	1.06E-04	8.89E-06	0.00E+00	6.58E-05
HAPs	lbs	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Solid Waste (out)													
Wood	OD lbs	1.03E-02	0.00E+00	4.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bark	OD lbs	3.02E-02	0.00E+00	1.23E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Inorganic materials	lbs	3.95E+00	3.97E-01	7.67E+00	2.08E-07	0.00E+00	4.88E-07	2.25E-02	0.00E+00	1.06E-01	8.89E-03	0.00E+00	6.58E-02
Non-wood organic materials	lbs	3.57E-01	0.00E+00	1.68E+00	0.00E+00	0.00E+00	0.00E+00	4.51E-02	0.00E+00	2.12E-01	1.78E-02	0.00E+00	1.32E-01

Notes: Values are presented per unit of production indicated (this varies for each unit process). Missing values are indicated by a blank. Blanks have also been inserted for zeros where it is clear that there was a zero value (e.g., logs from planer). When low value is zero, at least one mill reported zero. CO_2 was not in survey because it is not consider a pollutant and mills are not required to report it. Values for fossil and biogenic CO_2 used later in report are based on carbon content of fuel reported. Even though mills report some BOD or COD values, they operate under zero water discharge regulations.

2.0 PRODUCT YIELDS

2.1 SAWING

The only reported wood input to the sawing process was sawlogs; for example, no mills resawed cants. All four mills reported sawlogs in Mbf based on Scribner, west side scaling practice. An overall factor of 4.3 is given in Table 2-6 of Briggs (1994) to convert this to an interagency cubic foot. Using this provides very good agreement among the four mills, with a range of 90.4 to 105.0 ft^3 of logs per Mbf of lumber; however, the mass is not sufficient for the product and co-products. Variability in the conversion factor can be expected because, depending on log diameter and taper, the actual factor for conversion of Mbf log scale to ft^3 can vary from 2.46 to 6.28 for sawlogs. Therefore, the log volume was adjusted to 106.8 ft^3/Mbf for Douglas-fir and 109.4 ft^3/Mbf for hemlock to make the log mass equal to the mass of the wood products and co-products (one half of the hog fuel was assumed to be wood). The co-products are often measured by weight making them much more reliable than log volume. The volume measurement of logs was converted to a mass measurement using a wood density of 28.08 lbs/ft^3 for Douglas-fir and 26.21 lbs/ft^3 for hemlock (USDA 1999).

Rough green lumber was the primary product from the sawmill. Green lumber typically becomes an input to the drying process or the planer process at the same production facility (although this may be at a different site). Douglas-fir often goes directly to the planer and did so 80.5% of the time in the mills surveyed. Rough green lumber is occasionally sold off-site and in the survey this accounted for less than 4% of the lumber sawn. Rough, green, nominal 2x6 lumber was assumed to have a size of 1.65" by 5.9" and unit masses of 1898 and 1772 lbs/Mbf for Douglas-fir and hemlock, respectively. The wood density is the same as for logs and the unit mass was calculated based on this and the target size. As noted above the unit mass refers only to the weight of the wood substance, and does not include the water contained within the wood.

The co-products from the sawing process include chips for pulp mills or composite manufacturing, bark for landscaping or fuel, hog fuel for wood boilers, and sawdust. The term hog fuel was used by mills for material destined for the boiler. Hog fuel is assumed to be at 50% moisture content (wet-basis), a value corroborated by two of the mills. The pulp chips come from the sides of logs and from ends trimmed off boards. Bark quantity varies with species; however, surveys were not detailed enough to discern this. It was noted that mills producing more Douglas-fir reported more bark, as would be expected. The mass reported as bark might be intended for use in bark products, such as landscaping, or it might go to the boiler. Similarly, sawdust might be sold or go to the boiler. It is important to note that a co-product from the sawing process might not be a co-product from the mill complex if some or all of it is an input for another unit process. For example, some sawdust was sold and some was burned. When burned, all of the material and energy burdens allocated to the fuels in the sawing process are transferred to the steam generation process and eventually become allocated to the products or co-products that pass through the dryer process which uses steam from the boiler.

A summary of wood material entering and leaving the sawing process is shown in Table 2.1. Note that the mass of the logs is equal to the sum of the wood products plus one-half of the hog fuel. Bark would not be included in the calculated log weight entering the mill so products containing bark are omitted from the subtotal in Table 2.1. The wood weight equals the log weight when one-half of the hog fuel is considered to be wood and added to the subtotal.

Table 2.1. Summary of wood products in and out of the sawing process.

	Douglas-fir			Hemlock		
	lbs/Mbf	**kg/m^3**	**%**	**lbs/Mbf**	**kg/m^3**	**%**
Input						
Logs	3.00E+03	7.41E+02	1.00E+02	2.87E+03	7.09E+02	1.00E+02
Outputs						
Lumber	1.90E+03	4.50E+02	5.82E+01	1.77E+03	4.20E+02	5.65E+01
Chips	8.45E+02	2.00E+02	2.59E+01	8.45E+02	2.00E+02	2.69E+01
Sawdust	2.33E+02	5.52E+01	7.14E+00	2.33E+02	5.52E+01	7.43E+00
Subtotal, wood	2.98E+03	7.05E+02	9.12E+01	2.85E+03	6.75E+02	9.09E+01
Hog fuel	4.03E+01	9.55E+00	1.24E+00	4.03E+01	9.55E+00	1.29E+00
Bark	2.46E+02	5.83E+01	7.54E+00	2.46E+02	5.83E+01	7.84E+00
Total Outputs	**3.26E+03**	**7.73E+02**	**1.00E+02**	**3.14E+03**	**7.43E+02**	**1.00E+02**

Notes: Values are exclusive of water and are expressed per Mbf (or m^3) of rough green lumber leaving the process.

2.2 DRYING

The rough green lumber entering the kilns was equal to the rough dry lumber leaving the kilns because no mills reported any wood loss in the kilns. This is consistent with expectations because the mass of wood in and out are the same and only water is removed at the dryer. What might be called loss due to drying occurred when the lumber was surfaced at the planer.

2.3 PLANING

The rough green lumber that went directly to the planer was not analyzed separately from the rough dry lumber to the planer. There is insufficient data to separate dry planing from green planing. For example, mills cannot partition their electrical use to this level of detail. The two processes (green and dry planing) are similar. Dry planing might require more energy at the planer; however, green planing should require more for conveyors. Dry planing might have higher particulate emissions. One might expect less trim loss for green lumber. Most mills did report both green and dry trim loss; however, the results are too variable to include in the model at this time.

Planed dry lumber is manufactured to 1.5" by 5.5" (38 mm x 140 mm) and has a unit mass of 1698 and 1591 lbs/Mbf for Douglas-fir and hemlock, respectively (Table 2.2). This unit mass, for 15% moisture content, was calculated using the Wood Handbook (USDA 1999) values for the specific gravity of these species at green and 12% moisture content.

Planed green lumber is manufactured to 1.5625" by 5.5625" (40 mm x 141 mm) and has a unit mass of 1714 and 1600 lbs/Mbf for Douglas-fir and hemlock, respectively (Table 2.3). This unit mass, for any moisture content above fiber saturation, was calculated using Wood Handbook (USDA 1999) values for the specific gravity of green wood.

Mills reported from 1% to 7% trim loss, with a mean of 4.14%. Thus the value of 1980 lbs of Douglas-fir into the planing process per Mbf of planed lumber (Table 2.2 and 2.3) comes from 1.0414 times the unit mass of rough dry lumber, 1898 lbs per Mbf.

Table 2.2. Summary of wood products in and out of the planing process for dry lumber.

	Douglas-fir			Hemlock		
	lbs/Mbf	**kg/m^3**	**%**	**lbs/Mbf**	**kg/m^3**	**%**
Input						
Rough lumber (1.0414 Mbf_{in}/Mbf_{out})	1.98E+03	5.53E+02	1.00E+02	1.85E+03	5.17E+02	1.00E+02
Outputs						
Planed dry lumber	1.70E+03	4.75E+02	8.68E+01	1.59E+03	4.46E+02	8.60E+01
Chips	1.02E+02	2.85E+01	5.21E+00	1.02E+02	2.86E+01	5.51E+00
Sawdust	2.48E+01	6.93E+00	1.26E+00	2.48E+01	6.95E+00	1.34E+00
Shavings	1.32E+02	3.69E+01	6.75E+00	1.32E+02	3.70E+01	7.14E+00
Total Outputs	**1.96E+03**	**5.47E+02**	**1.00E+02**	**1.85E+03**	**5.19E+02**	**1.00E+02**

Notes: Values are exclusive of water and are expressed per Mbf (or m^3) of planed dry lumber leaving the process.

Table 2.3. Summary of wood products in and out of the planing process for green lumber.

	Douglas-fir			Hemlock		
	lbs/Mbf	**kg/m^3**	**%**	**lbs/Mbf**	**kg/m^3**	**%**
Input						
Rough lumber (1.0414 Mbf_{in}/Mbf_{out})	1.98E+03	5.19E+02	1.00E+02	1.85E+03	4.84E+02	1.00E+02
Outputs						
Planed dry lumber	1.71E+03	4.50E+02	8.69E+01	1.60E+03	4.20E+02	8.61E+01
Chips	1.02E+02	2.68E+01	5.17E+00	1.02E+02	2.68E+01	5.49E+00
Sawdust	2.48E+01	6.51E+00	1.26E+00	2.48E+01	6.51E+00	1.33E+00
Shavings	1.32E+02	3.47E+01	6.69E+00	1.32E+02	3.47E+01	7.10E+00
Total Outputs	**1.97E+03**	**5.18E+02**	**1.00E+02**	**1.86E+03**	**4.88E+02**	**1.00E+02**

Notes: Values are exclusive of water and are expressed per Mbf (or m^3) of planed green lumber leaving the process.

The overall mass balance as calculated for this process was excellent, within 1% of a perfect balance. Of the volume of rough dry lumber entering the planing process, 86% leaves as lumber (Table 2.2). The major co-product is shavings. Table 2.3 shows similar data for green lumber. Combining 86% recovery at the planer, 62% recovery at the sawmill, and a 4% trim loss gives an overall yield of approximately 51% for planed lumber from logs.

2.4 OVERALL PROCESS

The processes presented in sections 2.1 to 2.3 show material balances for each process based on 1 Mbf of lumber (or 1 BTU of steam) out of the process. However, for each 1 Mbf through the planer process 1.0414 Mbf are made in the sawing process and dried in the drying process. The boiler selector process operates 1.0437 times (provide 3,131,000 BTU) for each 1 Mbf of rough green lumber.

The basis differences among the tables make it very difficult to follow all of the material flows based on the unit process information. It is especially difficult for the co-products that are generated at the sawmill and used at the boilers. Table 2.4 may make this clearer. Here the wood-based inputs and outputs for each unit process are shown for 1 Mbf of planed dry Douglas-fir lumber produced. The mass values in and out of the sawing process are 1.0414 times the values in Table 2.1 because of trim at the planer. Similarly, the wood into the boiler has been adjusted so that just enough energy is provided to dry 58.2% (the percent of energy from wood-based fuels) of 1.0414 Mbf of rough green lumber (1 Mbf of planed dry lumber). This table will be used later in this report to help explain how the allocations within processes influence the life cycle inventory. A similar table for hemlock would have slight differences due to the density difference between the species.

Table 2.4. Summary of wood products in and out of all processes for the manufacture of one Mbf of planed dry Douglas-fir lumber.

Material (values in lbs)	Sawing Process Out	Boiler Process In	Dryer Process In	Dryer Process Out	Planer Process In	Planer Process Out	All Process Combined In	All Process Combined Out	All Process Combined Difference
Bark	256	256	0	0	0	0	256	256	0
Hog fuel	42	42	0	0	0	0	42	42	0
Sawdust	243	18	0	0	0	0	18	243	224
Chips	880	0	0	0	0	0	0	880	880
Rough green lumber	1977	0	1977	0	0	0	1977	1977	0
Rough dry lumber	0	0	0	1977	1977	0	1977	1977	0
Planed dry lumber	0	0	0	0		1698	0	1698	1698
Shavings	0	0	0	0	0	130	0	130	130
Chips (dry)	0	0	0	0	0	102	0	102	102
Sawdust (dry)	0	0	0	0	0	25	0	25	25
Sum	3397	316	1977	1977	1976	1955	4269	7329	3060

Notes: The values for the overall process indicate that 256 lbs of bark and 42 lbs of hog fuel are produced and burned. Of the 243 lbs of sawdust produced, 18 lbs were burned and 224 lbs were sold. All other co-products were sold.

3.0 NON-WOOD MATERIAL INPUTS TO SAWING, DRYING, ENERGY GENERATION, AND PLANING

The survey (Appendix 1) asked fairly extensive questions about non-wood materials used in the processes of sawing, energy generation, drying, and planing. A listing of these is shown in Table 1.4. The mills' responses to these questions varied. Two of the mills were able to provide precise information regarding materials consumed, whereas the other two were unable to answer some questions. Nevertheless, the responses provide a firm basis for establishing that non-wood materials combined comprise less than 2% of the mass of the input to the process.

3.1 ORGANIC

This category includes hydraulic fluids, greases, motor oil, oil-based paints, waxes, and solvents. Some mills provided values for organic materials in pounds, and in this case they were converted to gallons assuming a density of 7.2 pounds per gallon. Three of four mills provided data in this category and the range was considerable. However, based on the data obtained, organics appear to compose only about 0.02% and 0.005% of the mass of the products and co-products for sawing and planing, respectively. There is probably no need to collect this data in any future surveys.

In cases where the average equals the high or low value (Table 1.4), it is because some mills reported zero for some items and left others blank. In some cases zeros were inserted into the survey when it was known that a particular mill did not use a certain item (for example, paints in the sawmill or caustic soda at the planer). However, missing data for items that were known to be used (for example, grease in all areas) were treated as such and weighted averages were based only on mills reporting a value.

3.2 WATER-BASED PRODUCTS

This category includes anti-stain chemicals (on planed green lumber only), antifreeze, steam treatment chemicals (boiler), caustic soda (boiler), and the water-based paints used for logos and the ends of lumber packages. Anti-stain chemicals accounted for almost half of the mass of materials reported in this category. The mass of these combined is 0.42 pounds or approximately 0.013% of the weight of the products and co-products for sawing and 0.02% for planing. Most of the 0.42 pounds is water. On a dry basis, the percent of product mass would be considerably less because some of the solutions are as low as 4.5% in solids content.

3.3 OTHER MATERIALS

Mills reported plastic wrap, which is used to protect planed dry lumber from rain and humidity, on a square foot (ft^2) basis. A 50-ft^2 piece of wrap was weighed to convert the reported values to mass. The mass of the plastic wrap is 0.016% of the mass of the products and co-products.

Mills reported linerboard, which is used to make paper corners to protect lumber from strap damage, on a square foot basis. A 10-ft^2 piece of linerboard was weighed to convert the reported values to mass. The linerboard mass is 0.002% of the mass of the products and co-products.

Strapping and alloys were combined, although no mills actually reported alloy use. Strapping was reported in pounds. Strapping is used to hold the packages of planed lumber together. Alloys are used to retip saws. The strapping mass is 0.02% of the mass of the products and co-products. Alloy use would be much less.

3.4 SURFACE AND GROUND WATER

The greatest water use occurs in the sprinkling of logs, amounting to approximately 73 gallons per Mbf of rough sawn green lumber (Table 1.4). The second greatest use is in the boiler, where about 9 lbs of make-up water is consumed per 100 pounds of steam. This use is equivalent to 20 gallons per Mbf of dry lumber. Although this value seems high, some loss does occur due to flash steam at the condensate tank, steam spray in the kilns, and boiler blowdown. Much smaller amounts of water are sometimes used at the sawmill and planer for cooling, and in the dryer for maintaining the wet-bulb and, in rare cases, for water spray.

4.0 MANUFACTURING ENERGY SUMMARY

Energy for the manufacture of lumber comes from steam, electricity, diesel, gasoline, and propane. Wood-based fuels, natural gas, and diesel are used in boilers. The electricity is used to operate saws, planers, pneumatic and mechanical conveying equipment, and pumps. In the mills surveyed, electricity was used in all processes; however, it was difficult for mills to obtain an exact breakdown of electricity use by process. Three of the four mills were able to separate energy use in the sawmill from energy consumed in the boiler, dryers, and planer. In these three cases 61%, 70.7%, and 66% of the electrical energy was used at the sawmill. We therefore assumed that 66% of the electrical energy for the fourth mill was for the sawmill and 34% to the rest of the operation. Of the three mills that had boilers and dryers, only two were able to apportion electrical energy among the boiler, dryer, and planer. For the third mill, the data was apportioned to be the average of the other two mills (20% to boiler, 37% to dryers, and 43% to planer).

Diesel machinery, including forklifts and log yard equipment, is used to move products within and between processes. Vehicles and machinery also used small amounts of gasoline and propane in one or more of the process areas. Mills reported these values in gallons. These were converted to energy units using 135.2 MBTU/gallon (37.82 MJ/L) for gasoline, 138.3 MBTU/gallon (38.68 MJ/L) for diesel, and 91.3 MBTU/gallon (25.53 MJ/L) for propane.

4.1 SAWING

In the sawing process the primary energy used in the mills examined was electrical (Table 4.1) (86.8 MJ = 296,400 BTU). The range of sawing energy consumed varied considerably among the mills, from a low of 48 kWh per Mbf to a high of 124 kWh per Mbf of rough green lumber. Diesel used at the sawmill showed less variation with values ranging from 47,700 to 88,800 BTU/Mbf (averaging 0.46 gal/Mbf). Diesel use was closely related to log yard distance at a given mill so that the consumption per foot of movement for a Mbf was somewhat consistent among mills.

Table 4.1. Energy inputs to the sawing process based on weighted production averages in Table 1.4.

Input	Energy	
Electricity (purchased)	8.68E+01 kWh/Mbf	45.2E+01 kWh/m^3
Fuels into machinery		
Gasoline	5.86E+03 BTU/Mbf	3.22E+06 J/m^3
Diesel	6.42E+04 BTU/Mbf	3.53E+07 J/m^3
Propane	1.15E+01 BTU/Mbf	6.32E+03 J/m^3

Notes: Values are per Mbf or m^3 of rough sawn green lumber.

4.2 ENERGY GENERATION

The boilers were fired with hog fuel, bark, sawdust, natural gas, or diesel (Table 4.2). Wood-based fuels into the boiler were assumed to be at 50% moisture content (wet-basis); based on input from the mills, this is a reasonable assumption. In actual practice, fuel moisture content can vary considerably depending on species, season of the year, and the manner of fuel storage (i.e. covered vs. uncovered). Mills had from one to four boilers using various combinations of fuels. One of the 14 reporting mills had switched from wood to natural gas part way through the reporting year but was unable to provide data for hog fuel use and steam production for wood. In this case the natural gas use and steam production were scaled to represent the entire year to represent the current operating condition. Overall, 58.2% of the thermal energy consumed in the dryers at reporting mills came from hog fuel. This is believed to be close to the overall industry average. However, the average changes from year to year depending on natural gas prices, markets for sawdust and other residue, and the need to reduce boiler emissions in some regions.

Per BTU of steam produced, 1.381 BTUs of diesel, natural gas, and hog fuel combined were used (last line of Table 4.2). Thus, the survey indicates an overall efficiency of 72.4%. A natural gas boiler should have an efficiency of 80 to 82%. The wood boilers should have a lower efficiency which depends on fuel moisture content. As a combined efficiency, 72.4% appears to be a reasonable value.

Two of the mills reported cogeneration facilities. These mills created electricity as an avoided product. They operated on wood fuel and produced 0.00218 kWhr per pound of total steam or 0.038 kWhr per pound of steam from wood boilers. Four kWhr per Mbf of planed dry lumber were produced.

Table 4.2. Energy inputs to the energy generation process based on weighted production averages in Table 1.4.

Input	Energy	
Electricity (purchased)	7.43E-06 kWh/BTU	7.05E-09 kWh/J
Fuels into machinery		
Diesel	0.0036 BTU/BTU	0.0036 J/J
Fuels into boiler		
Diesel	0.0094 BTU/BTU	0.0094 J/J
Natural gas	0.647 BTU/BTU	0.647 J/J
Wood-based fuels	0.733 BTU/BTU	0.733 J/J
Sum of fuels into boilers	1.38 BTU/BTU	1.38 J/J

Notes: Values are per BTU or J of steam produced making the two columns numerically the same.

4.3 DRYING

Steam is used as heat in the dryers (Table 4.3). Steam is the common form of heat for lumber dry kilns in the western US; however, in other areas of the country, the combustion products of natural gas or wood waste might be introduced directly to the dryer. Hot oil or water is sometimes used, but not commonly in the western US.

Electricity is also used in the drying process to operate kiln fans, compressors, computers, and lighting. This was remarkably consistent among mills, ranging from 2.55 to 3.00 kWh/Mbf. Diesel fuel is used to move wood in the yard and to load and unload the kiln.

Steam use ranged from 6.67E+5 to 1.88E+7 BTU/Mbf. The weighted average reported steam use, 3.13 E+6 BTU/Mbf is consistent with what is believed to be the energy efficiency of the process. If the average moisture change is 90%, then approximately 1560 pounds of water are removed per Mbf. The value shown in Table 4.3 would then correspond to 1966 BTUs per pound of water removed. A value of 1800 to 2000 BTU/lb_{H2O} is often cited for softwood lumber. A theoretical calculation by the author supports a value of 1800 to 1900 BTU/lb_{H2O}.

Table 4.3. Energy inputs to the drying process based on weighted production averages in Table 1.4.

Input	Energy	
Electricity (purchased)	2.78E+01 kWh/Mbf	1.61E+01 kWh/m^3
Diesel into machinery	8.92E+03 BTU/Mbf	5.47E+06 J/m^3
Steam	3.13E+06 BTU/Mbf	1.06E+09 J/m^3

Notes: Values are per Mbf or m^3 of rough sawn dry lumber.

4.4 PLANING

In the planing process the main energy use is electrical (Table 4.3). The range of this value did vary somewhat among the mills, from a low of 21.6 to a high of 34.1 kWh/Mbf of planed lumber. The diesel use is consistent, ranging from 20,200 to 28,200 BTU/Mbf. Differences in diesel use are easily explained by hauling distance. Energy inputs to the planing process are shown in Table 4.4.

Table 4.4. Energy inputs to the planing process based on weighted production averages in Table 1.4.

Input	Energy	
Electricity (purchased)	2.72E+01 kWh/Mbf	1.673E+01 kWh/m^3
Fuels		
Diesel	2.02E+04 BTU/Mbf	1.31E+07 J/m^3
Propane	4.89E+00 BTU/Mbf	3.17E+03 J/m^3

Notes: Values are per Mbf or m^3 of planed lumber.

5.0 EMISSIONS TO AIR, WATER, SOIL, AND LANDFILL

5.1 AIR EMISSIONS

From sawing, mills reported PM (particulate matter) and PM_{10} (PM < 10μm) and a small quantity of VOC (volatile organic compound) emissions. Data on other chemicals may not appear on the mill's operating permit and hence were either reported as zero or left blank. Presumably some of the emissions are due to solvent use and some may come from the wood, especially from the dryers. The reader can refer to Table 1.4 for air emissions.

For the other processes, it appears that mills do not know their emissions as well as the sawing process. Perhaps as a result, in several cases boiler and dryer emissions were reported together and associated with the sawmill.

Dryer VOC emissions were reported to be 0.2 lb/Mbf. For hemlock, the species dried in greatest percentage, the author would expect a value in the range of 0.2 to 0.5 $lb/Mbf_{as\ carbon}$.

5.2 WATER EMISSIONS

Although mills provided concentrations shown in Table 1.4 for effluents, all were operating under zero discharge so there were no reported water emissions from the processes. This is a common restriction on sawmills dating back approximately 30 years. Sprinkling water is ponded and recycled in the warm months. Logs are not sprinkled in the winter and rainfall run off is not considered process water.

5.3 EMISSIONS TO SOIL

No emissions to soil were reported.

5.4 SOLID EMISSIONS

Other solid wastes produced during the manufacturing of lumber are shown in Table 5.1. Wood and bark solid wastes that are sent to a landfill presumably arise during cleanup operations in which dirt is mixed in with the wood material necessitating that it be sent to a landfill. The wood and bark comprised less than 0.00034% of the mass of the products and co-products. A surprising quantity of inorganic materials was reported from the sawing process: 4 pounds per Mbf of rough green lumber produced (over 0.1%). This may be as high as it is because the inorganic material included some dirt, or perhaps because reporting was for the entire mill rather than for the sawing operation only. Non-wood organic material presumably includes containers and other general trash and may include some dirt as noted above.

Table 5.1. Summary of solid wastes generated during the manufacture of lumber based on weighted averages in Table 1.4.

	Wood		Bark		Inorganic materials		Non-wood organic materials	
	lb	kg	lb	kg	lb	kg	lb	kg
Sawing, per volume of rough green lumber	1.03E-02	2.44E-03	3.02E-02	7.16E-03	3.95E+00	9.36E-01	3.57E-01	8.46E-01
Energy generation, per unit of steam	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.08E-07	8.97E-04	0.00E+00	0.00E+00
Drying, per volume of rough dry lumber	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.25 E-02	5.95E-01	4.51E-02	1.19E+00
Planing, per volume of planed lumber	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.89 E-03	2.49E+00	1.78 E-02	4.98E-01

Notes: Values are per unit of production: per Mbf or m3 of rough green lumber for sawing, per BTU or J of steam for energy generation, per Mbf or m3 of rough dry lumber for drying, and per Mbf or m3 of planed dry lumber for planing.

6.0 STRUCTURE AND INPUT, SIMAPRO MODEL

SimaPro 5.0.9, a software package designed for analyzing the environmental impact of products during their whole life cycle, was used to perform the life cycle analysis. Developed in the Netherlands by PRé Consultants B.V., SimaPro5 contains a US database for a number of materials, including paper products, fuels, and chemicals. Franklin Associates (FAL) provides an additional US database (Franklin, 2001).

Four processes were defined in SimaPro 5: sawing, energy generation (boilers), drying, and planing. These are related to each other as shown in Figure 6.1. There are separate processes for each species because each species has a different unit mass. The weighted average unit mass could be represented in one set of processes; however, setting up a different process for each species allows greater future flexibility in the model. In instances where the species mix (or green to dry lumber ratio) changes, the ratio of the lumber entering the lumber selector (see next paragraph) could be changed and thus the processes do not need to be changed.

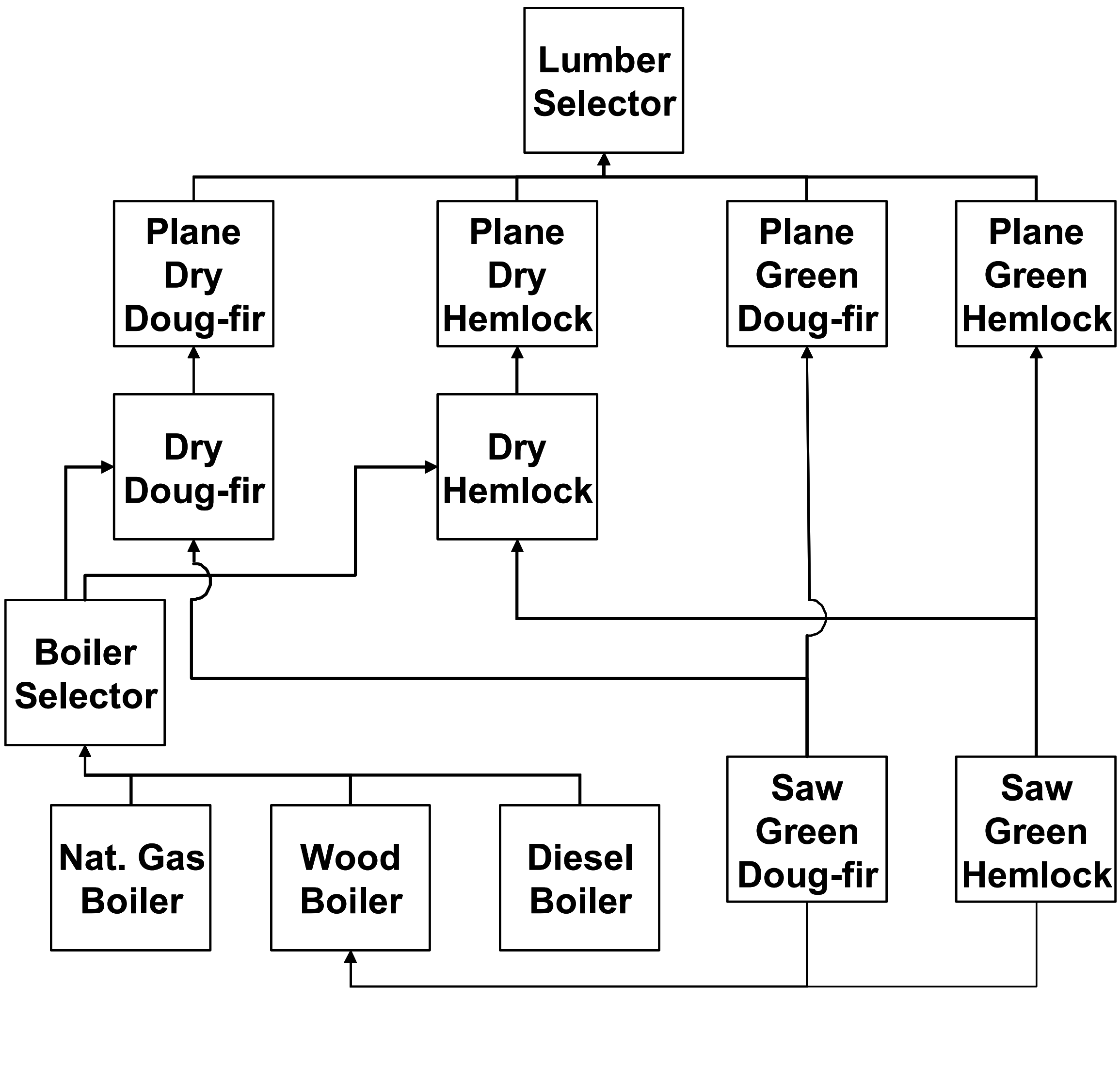

Figure 6.1. Overview of relationships among wood processing processes in SimaPro 5 model.
Notes: Material inputs are not shown. Lines represent flows within the model.

The lumber selector was used to select the quantity of each type of wood produced. The process inputs to the lumber selector total 1 Mbf and were entered as the mass equivalent to a certain number of board feet. For the LCI analysis in this report, planed dry Douglas-fir was set to 371.86 lbs (the mass equivalent to 219 board feet) and planed dry hemlock was set to 1255.3 lbs (equivalent to 781 board feet). Thus, for every 1000 board feet of planed dry lumber produced, 21.9% was Douglas-fir and 78.1% was hemlock. Because SimaPro 5 works on a kg basis, the output of the lumber selector process was set to 1 kg. We then retitled the SimaPro 5 output based on 1 kg, back to 1 Mbf of the selected product mix, the desired reporting basis.

Both planed green lumber masses were set to zero since that product was not considered in this analysis, consistent with the project goal. It is believed, however, that the data in each process are robust enough that the mix of lumber in the selector could be changed to include the green lumber produced in the Pacific Northwest and the output would reflect the effects of the production. Similarly, the dry lumber species ratio could be changed to reflect other western lumber statistics and the model results would be no less valid.

The inputs for all SimaPro 5 processes were taken from Table 1.4 and the other tables already presented and will only be discussed in the next sections in cases where they differ or need additional explanation. These values are production-weighted averages of the values reported by the mills. Over 99.5% of the materials and energy are accounted for with primary data. Wood materials have been abbreviated in the SimaPro 5 outputs: DF or H for Douglas-fir or hemlock, R or P for rough or planed, and G or D for green or dry. In some cases there is no significance to these differences at the mill. They are separated because the output from each SimaPro 5 process must be unique, resulting in the very large array of names that appear in the subsequent tables.

An electricity selector was placed in SimaPro 5 so that electricity could be a flow from nature (a resource) or come from the Pacific Northwest power grid (the technosphere). The selector is simply a process for which the output is 1 kWh and the input is 1 kWh either as a resource or from the technosphere. When resource is selected, there are no consequences from using the electricity. When the technosphere is selected (as it was for this report), the electricity comes from a process called PNW electricity. The PNW electricity process has an output of 1 kWh and inputs which total to 1 kWh and represent DOE estimates for the electricity produced in Oregon and Washington during 2000. These are 74.3% hydropower (FAL), 4% uranium (FAL) (nuclear), 0.3% oil (DFO FAL), 12.3% natural gas (FAL), 8.1% coal (FAL), and 1.1% as an undefined resource. FAL indicates that the Franklin database (updated in June of 2002 to account for inefficiencies in electricity generation and transmission) was used to determine the effects associated with electricity generation.

6.1 SAWING

The inputs and outputs for the Douglas-fir and hemlock sawing processes are shown in Table 6.1. Logs are listed in SimaPro 5 as a flow from nature so that no environmental impacts for log production are considered at this time.

Table 6.1. Exported SimaPro 5 input for sawing processes.

Resources			
Logs, PNW	106.8	cuft	(109.4 for Hemlock)
Water (surface, for cooling)	239.87	lb	
Water (well, for cooling)	361.88	lb	
Materials/fuels			
Distillate fuel oil (DFO) FAL	0.0916	gal*	Surrogate for all organics
Electricity/heat			
Electricity, PNW Selector	86.8	kW-hr	
Natural gas equipment (BTU)	11.5	BTU	Surrogate for propane
Gasoline equipment (BTU)	5860	BTU	
Diesel equipment (BTU)	62400	BTU	
Emissions to air			
Dust (coarse)	0.482	lb	
Dust (PM10)	0.0468	lb	
VOC	0.128	lb	
Acetaldehyde	0.00194	lb	
Acrolein	2.99E-06	lb	
Formaldehyde	2.99E-07	lb	
Methanol	0.00331	lb	
Phenol	0.000343	lb	
Solid emissions			
Wood	0.0103	lb	
Wood	0.0302	lb	As a surrogate for bark
Inorganic general	3.95	lb	
Paper/board packaging	0.357	lb	For "other non-wood organic materials"
Products and Co-products(Douglas-fir process)			
Bark, DF, R, G	246	lb	7.54 % oven-dry mass
Hog fuel, DF, R, G	40.3	lb	1.24 %
Sawdust, DF, R, G	233	lb	7.14 %
Chips, DF, R, G	845	lb	25.9 %
Lumber, DF, R, G	1898	lb	58.18 %
Products and Co-products (Hemlock process)			
Bark, H, R, G	246	lb	7.84 % oven-dry mass
Hog fuel, H, R, G	40.3	lb	1.29 %
Sawdust, H, R, G	233	lb	7.43 %
Chips, H, R, G	845	lb	26.94 %
Lumber, H, R, G	1772	lb	56.5 %
Only one set of products is produced; percentages are allocations			

Notes: Data is for the production of one Mbf of rough, green Douglas-fir or hemlock dimension lumber from ~108 ft^3 of logs to a target size of 1.65" x 5.9".

The weighted averages for organic materials were input to SimaPro 5 as distillate fuel oil (as in the Franklin database) because it appeared to be the closest surrogate for these products. The impacts of diesel, gasoline, and propane used in forklifts and other equipment were selected from the Franklin database processes for the cradle-to-grave combustion of fuels for machinery. The Franklin database lacked a machinery process for propane, so natural gas was used.

Because of the difficulty in specifying the water-based materials and the small mass involved, it was decided to not enter this information in SimaPro 5 at this time. While some of the materials in this category require special handling, none are extremely toxic or fall within the HAPs category.

All emissions were in the SimaPro 5 list and entered as reported except that wood was used as a surrogate for bark (to landfill) and paper/board packaging was used as a surrogate for what the survey called “other non-wood organic materials”.

The inputs and products for the Douglas-fir and hemlock sawing processes are identical except for the unit mass of the lumber. This is due to an inability to separate the co-products by species in the survey. These were entered to SimaPro 5 as shown in Table 2.1. The allocations were assigned on the basis of product or co-product mass, as shown in Table 2.1

6.2 ENERGY GENERATION

Three types of boilers were reported. To avoid specifying energy use among these boilers in several SimaPro 5 processes, a boiler selector process (Table 6.2) was developed. The product of this process is one BTU of steam and the inputs total one BTU of steam, apportioned among the three boiler types according to the survey results. The Douglas-fir and hemlock drying processes use the boiler selector as the steam source. Electrical use is included in the boiler selector because the survey data did not distinguish among the boiler types. It is also convenient because electrical use is reported as kWh per BTU of steam produced and the output of the boiler selector is one BTU of steam supplied to the dryer. Should more data become available about the electrical consumption associated with the different boiler types, then this could be moved to the individual boiler processes.

The wood boiler process is based on the Franklin wood boiler database (Table 6.3). In the Franklin boiler, 1000 pounds of wood (at 50% wet basis moisture content) are burned to produce 4.5E6 BTUs of steam and the air emissions shown. The inputs in the model were set to 500 pounds of dry wood-based material, the equivalent of 1000 pounds at 50% moisture content. The steam output for burning 1000 pounds of wood was set at 3,000,000 BTUs. This is a 67% efficiency, compared to Franklin’s value. The type of wood material entering the boiler was set to first burn all hog fuel reported in the survey (and produced when 1.0414 Mbf of rough green lumber are produced), then burn all the bark, and finally burn enough sawdust to total 500 lbs. These selections were made because hog fuel was definitely produced for the boiler and the sawdust has a higher value than bark. Thus, the lowest value co-product is the first to be burned. The mass of each fuel input was divided between the species to match the ratio of planed lumber produced. The solid emissions (ash) were modified to match the survey.

The Franklin database emissions were used for the natural gas boiler (Table 6.4) by specifying 1000 ft^3 “natural gas into industrial boilers” as the input. Based on the efficiency in the survey, the output was set to 816,000 BTU, 80% of the Franklin value for the fuel energy.

In an analogous manner, the Franklin database emissions were used for the diesel boiler (Table 6.5) by specifying 139,000 BTUs (1 gallon) of “heat from DFO FAL” as the input where DFO stands for distillate fuel oil. SimaPro 5 then provided the cradle-to-grave effects of using this resource. Based on the efficiency in the survey, the output was set to 111,200 BTU, 80% of the Franklin value for the fuel energy.

Table 6.2. Exported SimaPro 5 input for boiler selector process.

Electricity/heat		
Electricity, PNW selector	7.43 E-6	kWh
CORRIM wood boiler, steam	0.582	BTU
Steam from diesel boiler	0.001	BTU
Steam from natural gas boiler	0.417	BTU
Products		
Boiler, PNW selector	1.0	BTU

6.3 DRYING

SimaPro 5 entries to the drying process (Table 6.6) were made in a similar manner to the previous processes. Steam was input from the boiler selector and this in turn brought it from the three boiler types in the proportions reported in the survey. The trailer diesel appears because some mills dry and plane at a different site and transport the rough green lumber there by truck. The weighted average distance was 15.5 miles, which is probably high compared to what the industry average would be. The product unit mass out is equal to that of the rough green lumber in because no wood machining occurs in the process.

6.4 PLANING

SimaPro 5 entries to the planing process (Table 6.7) were made in a similar manner to the previous processes. The table includes the wood inputs and outputs for four planing process (two species, green and dry). Other inputs and outputs are the same among the four processes. In some cases, materials were not available in the Franklin database. LDPE film from the Franklin database was specified for the wrap mass used during planing. Corrugated cardboard from the Franklin database was used as a surrogate for linerboard in SimaPro 5. Steel, cold rolled, BOF (basic oxygen furnace) from the Franklin database was used to represent the strapping in SimaPro 5.

Table 6.3. Exported SimaPro 5 input for a wood boiler process.

Materials/fuels			
Hog fuel, DF, R, G	14.5	lb	oven-dry mass
Hog fuel, H, R, G	51.8	lb	These should add to 500 lbs (OD)
Bark, DF, R, G	88.7	lb	The Douglas-fir is 21.9% of each type
Bark, H, R, G	316.3	lb	The hemlock is 78.9% of each type
Sawdust, DF, R, G	6.3	lb	All hogfuel and bark are burned, then
Sawdust, H, R, G	22.4	lb	sawdust is used, as needed, to get 500 lbs
Avoided Products			
Electricity from coal FAL	3.64	BTU	8.1% of PNW electricity
Electricity from DFO FAL	0.135	BTU	0.3% These %s times 0.015 kWhr/lb of steam
Electricity from nat. gas FAL	5.53	BTU	12.3 % This is 45 kWhr per 3E6 BTU of steam
Electricity from uranium FAL	1.8	BTU	4% These are due to cogeneration in PNW
Electricity hydropower FAL	33.4	BTU	74.3%
Emissions to air			
Particulates	0.085	lb	Emissions based on 1000
NOx	0.75	lb	pounds of wood at 50% MC.
Organic substances	0.083	lb	Process input must be 1000 pounds.
SOx	0.038	lb	Adjust Steam out to match boiler efficiency
CO	6.8	lb	
CO_2 (biomass)	1050	lb	Field changed
Phenol	0.02	lb	
Pb	0.0006	lb	
Formaldehyde	0.0033	lb	
Acetaldehyde	0.0015	lb	
Benzene	0.0018	lb	
Naphthalene	0.0012	lb	
As	4.4E-05	lb	
Cr	2.3E-05	lb	
Mn	0.0045	lb	
Ni	0.00028	lb	
K	0.39	lb	
Zn	0.0022	lb	
Ba	0.0022	lb	
Na	0.009	lb	
Fe	0.0022	lb	
Cl2	0.0039	lb	
Solid emissions			
Solid waste	1.04	lb	0.6 to 1.5 lb reported in survey (ash)
Products			
CORRIM Wood Boiler, Steam	3000000	BTU	100 % (allocation)

Notes: Input of 1000 pounds of wood fuel (50% wb moisture content) and the emissions are based on the Franklin database. The output is based on an efficiency of 67% and a fuel value of 4500 BTU/lb.

Table 6.4. Exported SimaPro 5 input for a natural gas boiler process.

Electricity / heat		
Nat. gas into industr. boilers	1000	Cuft
Products		
Steam from natural gas boiler	816000	BTU

Notes: BTUs out uses Franklin value of 1.02. MMBTU per 1000 ft3 and 80% efficiency.

Table 6.5. Exported SimaPro 5 input for a diesel boiler process.

Electricity/heat		
Heat from DFO FAL	139000	BTU
Products		
Steam from diesel boiler	111200	BTU

Notes: BTUs out uses Franklin value of 139,000. BTU per gallon and 80% efficiency.

Table 6.6. Exported SimaPro 5 input for rough dry lumber.

Resources			
Water (surface, for cooling)	8.01	lb	
Materials/fuels			
Distillate Fuel Oil (DFO) FAL	0.000153	gal*	Surrogate for all organics
Lumber, DF, R, G	1898	lb	Lumber, H, R, G is 1772
Electricity/heat			
Electricity, PNW selector	27.8	kWh	
Diesel equipment (BTU)	8920	BTU	
Boiler, PNW selector	3131000	BTU	Divides this among boiler types
Trailer diesel FAL	26.1	tmi*	1772*1.9(90%mc)* 15.5 miles/2000lb/ton
Emissions to air			
Dust (coarse)	0.0192	lb	
VOC	0.197	lb	
Solid emissions			
inorganic general	0.0225	lb	
paper/board packaging	0.0451	lb	For "other non-wood organic materials"
Products (Douglas-fir)			
Lumber, DF, R, D	1898	lb	100 % (allocation)
Products (hemlock)			
Lumber, H, R, D	1772	lb	100 % (allocation)
Only one set of products is produced.			

Table 6.7. Exported SimaPro 5 input for the planing processes.

Resources			
water (surface, for cooling)	0.291	lb	
Materials/fuels			
Lumber, DF, R, D	1976	lb	1898 times 1.0414 for trim loss (for dry Douglas-fir)
Lumber, H, R, D	1845	lb	1772 times 1.0414 for trim loss (for dry hemlock)
Lumber, DF, R, G	1976	lb	1898 times 1.0414 for trim loss (for green Douglas-fir)
Lumber, H, R, G	1845	lb	1772 times 1.0414 for trim loss (for green hemlock)
Only one of the above four is an input, depending on the planer process			
Distillate Fuel Oil (DFO) FAL	0.0127	gal*	Surrogate for all organics
LDPE film FAL	0.131	lb	
Corrugated cardboard FAL	0.0377	lb	Surrogate for linerboard
Steel cold rolled, BOF FAL	0.324	lb	Surrogate for strapping
Electricity/heat			
Electricity, PNW Selector	27.2	kWh	
Natural gas equipment (BTU)	4.89	BTU	Surrogate for propane
Diesel equipment (BTU)	20200	BTU	
Emissions to air			
dust (coarse)	0.0812	lb	
VOC	0.0354	lb	
Solid emissions			
inorganic general	0.00889	lb	
paper/board packaging	0.0178	lb	For "other non-wood organic materials"
Products and co-products (dry Douglas-fir)			
Shavings, DF, P, D	130	lb	6.75 % (allocations)
Sawdust, DF, P, D	24.8	lb	1.26 %
Chips, DF, P, D	102	lb	5.21 %
Lumber, DF, P, D	1698	lb	86.78 %
Products and co-products (dry hemlock)			
Shavings, H, P, D	130	lb	7.14 % (allocations)
Sawdust, H, P, D	24.8	lb	1.34 %
Chips, H, P, D	102	lb	5.51 %
Lumber, H, P, D	1591	lb	86.01 %
Products and co-products (green Douglas-fir)			
Shavings, DF, P, G	130	lb	6.59 % (allocations)
Sawdust, DF, P, G	24.8	lb	1.26 %
Chips, DF, P, G	102	lb	5.18 %
Lumber, DF, P, G	1714	lb	86.97 %
Products and co-products (green hemlock)			
Shavings, H, P, G	130	lb	7.01 % (allocations)
Sawdust, H, P, G	24.8	lb	1.33 %
Chips, H, P, G	102	lb	5.49 %
Lumber, H, P, G	1600	lb	86.17 %
Only one of the four product sets are output, depending on the planer process			

Notes: Wood inputs and outputs for all four planing processes are shown.

7.0 UNIT FACTOR ESTIMATES FOR MAIN PRODUCTS

Unit factors for environmental impacts will be presented for each stage in the manufacturing process. Tables 7.1 to 7.5 show at the left "western lumber" which is 1 Mbf composed of 21.9% Douglas-fir and 78.1% hemlock. This is the mix of the planed dried lumber in the survey. The contribution of each species is shown in the next sets of columns. In practice, the exact mix makes only minor differences in the result because the data collection does not allow production differences, if any, to be determined. For example, mills that produce both species cannot accurately attribute electrical or diesel use between them. Unit factors are shown without the effects of purchased electricity use in the "A" set of tables (e.g. Table 7.1A) and with in the "B" tables.

The unit factors are shown in Tables 7.1 to 7.5 for at three stages in the manufacturing process - planed dry, rough dry, and rough green - for the manufacture of one Mbf of planed dry lumber. When interpreting these tables it is important to note that the quantity of rough green and rough dry western lumber is 1.0414 Mbf due to trim loss at the planer.

For most unit factors, (for example, logs in Table 7.1) the values per Mbf of planed lumber are less than for rough dry lumber because allocations are assigned based on the mass of products and co-products. Thus, the log allocation to planed dry lumber is 86% of rough dry lumber (1.82 m^3 versus 2.14 m^3) because 86 percent the rough dry lumber ends up as planed dry lumber. More logs are associated with rough dry lumber than rough green lumber because of the portion of the log burned as fuel to dry the wood.

7.1 RAW MATERIALS

The raw materials used are shown in Table 7.1. Logs are the greatest material input followed by water and natural gas. The value of 1.82 m^3 of logs per Mbf of planed dry lumber means that a 59.7% of the log input to sawing (3.08 m^3/Mbf) either ends up as lumber or fuel to dry it. This is in good agreement with the mass balance in Table 2.3 which indicates approximately 59.3% - 1699 lbs of lumber, 256 lbs of bark, 42 lbs of hog fuel, and 18 lbs of sawdust from 3397 lbs of inputs to the sawmill. The difference is actually slightly greater than indicated because some of the fuels in Table 2.3 dry the planer shavings and planer chips, not the lumber. Also, only one species is shown in Table 2.3 in the interest of clarity. The other 40.3% of the log is in co-products. SimaPro 5 reports 1.82 m^3 of logs per Mbf of rough green lumber. This comes from 3.08 m^3 of logs (average weighted by species from Table 6.1) times 1.0414 for trim loss times 0.569 (average weighted by species from Table 6.1) for the allocation. The hog fuel entering the wood boiler makes the rough dry lumber higher, 2.13 m^3 per Mbf, because part of the log is used as boiler fuel.

Natural gas use is primarily at the boiler, thus its impact appears for the rough dry lumber, but not the rough green lumber when off-site electrical effects are not considered (Table 7.1A). The increased natural gas, crude oil, and coal use in Table 7.1B are associated with the off-site electrical production. Approximately 12% of the off-site electricity is from natural gas, 8% from coal, and 3% from oil.

Materials associated only with planed dry lumber are most likely attributable to the packaging materials (cardboard corners, steel strapping, and lumber covers).

Table 7.1A. Exported results from SimaPro LCI for raw materials from the gate-to-gate production of one Mbf of planed dry lumber without electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Logs, PNW	m3	1.82	2.13	1.84	0.40	0.47	0.41	1.42	1.66	1.43
Water (well, for cooling)	kg	97.2	113.6	97.9	21.8	25.4	22.0	75.4	88.2	75.9
Water (surface, for cooling)	kg	64.4	79.1	68.3	14.4	17.6	15.3	50.0	61.4	52.9
Natural gas FAL	kg	0.1	44.0	38.0	0.0	9.6	8.4	0.1	34.4	29.6
Crude oil FAL	kg	1.2	3.1	3.1	0.3	0.6	0.6	0.9	2.4	2.5
Coal FAL	g	20.3	450.6	517.4	4.5	97.7	113.2	15.7	352.9	404.2
Iron (ore)	g	x	x	151.4	x	x	33.4	x	x	118.0
Limestone	g	1.2	25.9	47.9	0.3	5.6	10.5	0.9	20.3	37.4
Scrap, external	g	x	x	53.3	x	x	11.8	x	x	41.6
Wood/wood wastes FAL	g	0.9	19.2	31.1	0.2	4.2	6.8	0.7	15.0	24.3
Natural gas (feedstock) FAL	g	x	x	39.6	x	x	8.7	x	x	30.9
Wood for fiber (feedstock) FAL	g	x	x	16.4	x	x	3.6	x	x	12.8
Crude oil (feedstock) FAL	g	x	x	13.0	x	x	2.9	x	x	10.1
Oxygen	g	x	x	12.5	x	x	2.8	x	x	9.8

Notes: 10 substances less than 1g have been omitted. "x" indicates that substance did not appear at that stage.

Table 7.1B. Exported results from SimaPro LCI for raw materials from the gate-to-gate production of one Mbf of planed dry lumber with electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Logs, PNW	m^3	1.82	2.13	1.84	0.40	0.47	0.41	1.42	1.66	1.43
Water (well, for cooling)	kg	97.2	113.6	97.9	21.8	25.4	22.0	75.4	88.2	75.9
Water (surface, for cooling)	kg	64.4	79.1	68.3	14.4	17.6	15.3	50.0	61.4	52.9
Natural gas FAL	kg	2.0	48.1	42.4	0.4	10.5	9.4	1.5	37.6	33.1
Coal FAL	kg	2.1	5.1	5.5	0.5	1.1	1.2	1.7	4.0	4.3
Crude oil FAL	kg	1.3	3.3	3.3	0.3	0.7	0.7	1.0	2.6	2.6
Iron (ore)	g	123.6	295.6	336.2	27.7	65.3	74.6	95.9	230.3	261.6
Limestone	g	x	x	151.4	x	x	33.4	x	x	118.0
Scrap, external	g	3.1	24.1	36.4	0.7	5.3	8.0	2.4	18.9	28.4
Wood/wood wastes FAL	g	x	x	53.3	x	x	11.8	x	x	41.6
Natural gas (feedstock) FAL	g	x	x	39.6	x	x	8.7	x	x	30.9
Wood for fiber (feedstock) FAL	g	x	x	16.4	x	x	3.6	x	x	12.8
Crude oil (feedstock) FAL	g	x	x	13.0	x	x	2.9	x	x	10.1
Oxygen	g	x	x	12.5	x	x	2.8	x	x	9.8

Notes: 10 substances less than 1g have been omitted. "x" indicates that substance did not appear at that stage.

7.2 AIRBORNE EMISSIONS

CO_2 was emitted in greater quantity than the other compounds (Table 7.2A and B). Fossil CO_2 may be from on- or off-site but is mainly from the natural gas burned at the boiler. Biomass CO_2 ,, as defined here, is generated on-site from the wood-fired boiler. Non-fossil CO_2 comes from all processes and is mostly associated with natural gas extraction, manufacturing paper corners for packaging, and purchased electricity. Non-fossil CO_2 is from processes or materials in the Franklin database and may be biomass CO_2; however, it is not possible to tell this from the SimaPro 5 output. Fossil CO_2 is much greater when the effects of off-site electrical generation are included. The CO_2 (both fossil and biomass) associated with dry lumber is much greater than that associated with green lumber because natural gas and wood-based material are burned at the boiler to generate steam for the drying process. Combined, the CO_2 emissions total 357 kg/Mbf of planed lumber produced or 378 kg/Mbf if off-site electrical generation is included. For example, if planed green lumber had been produced, CO_2 emissions would have been 98 kg/Mbf. If 100% allocation were placed on lumber, CO_2 would have been 495 kg/Mbf (301 kg/Mbf from biomass, 143 kg/Mbf from fossil, and 51 kg/Mbf non-fossil) per Mbf of planed dry lumber.

Most other emissions are also attributable to the energy generation, either the boiler process or off-site natural gas extraction and electrical generation. The sulfur emissions are mostly from the extraction of the natural gas whereas the NO_x emissions come from both the extraction and the combustion. CO also comes from the boilers, but on a per BTU basis, the wood boiler has greater CO emissions than the other two boiler types

7.3 WATERBORNE EMISSIONS

The waterborne emissions (effluents) (Table 7.3A and B) are off-site; for example, the dissolved solids are attributable mostly to the extraction of natural gas and to a lesser extent off-site electricity generation.

7.4 SOLID EMISSIONS

The solid emissions (Table 7.4) are mainly attributable to ash from the wood boiler and the extraction of natural gas. The other materials comprising solid emissions are mainly those shown in Table 6.1. In rare cases, the ash is used in agricultural applications. There were no differences in the results in Table 7.4 when off-site electricity generation was included.

Table 7.2A. Exported results from SimaPro LCI for air emissions from the gate-to-gate production of one Mbf of planed dry lumber without electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
CO_2 (biomass)	kg	x	301.1	259.5	x	65.9	57.2	x	235.2	202.3
CO_2 (fossil)	kg	3.3	108.7	95.6	0.7	23.6	20.9	2.6	85.1	74.7
CO	kg	0.06	2.27	1.97	0.01	0.50	0.43	0.05	1.77	1.53
SOx	kg	0.01	1.57	1.36	0.00	0.34	0.30	0.01	1.23	1.06
NOx	kg	0.06	0.65	0.59	0.01	0.14	0.13	0.05	0.51	0.46
Non methane VOC	g	14.0	436.5	382.9	3.1	94.9	83.9	10.9	341.6	299.1
Methane	g	0.6	291.0	252.6	0.1	63.7	55.7	0.5	227.3	196.9
Dust (coarse)	g	129.4	160.4	170.0	29.0	35.8	38.0	100.4	124.6	131.9
VOC	g	34.4	133.2	128.7	7.7	29.3	28.5	26.7	103.9	100.1
K	g	x	111.8	96.4	x	24.5	21.3	x	87.4	75.1
Particulates	g	4.1	40.5	37.6	0.9	8.6	8.1	3.2	31.8	29.5
Organic substances	g	0.0	36.8	31.7	0.0	7.1	6.2	0.0	29.7	25.6
CO_2 (non-fossil)	g	1.0	23.2	35.2	0.2	5.0	7.7	0.7	18.1	27.5
Dust (PM10)	g	12.6	14.7	12.7	2.8	3.3	2.8	9.8	11.4	9.8
Phenol	g	0.1	5.8	5.0	0.0	1.3	1.1	0.1	4.6	3.9
Particulates (unspecified)	g	0.2	3.4	3.3	0.1	0.7	0.7	0.2	2.7	2.6
Formaldehyde	g	0.9	2.2	2.3	0.2	0.5	0.5	0.7	1.7	1.8
Na	g	x	2.6	2.2	x	0.6	0.5	x	2.0	1.7
Methanol	g	0.89	1.04	0.90	0.20	0.23	0.20	0.69	0.81	0.69
Acetaldehyde	g	0.52	1.04	0.90	0.12	0.23	0.20	0.40	0.81	0.70
Mn	g	0.00	1.29	1.11	0.00	0.28	0.25	0.00	1.01	0.87
Cl_2	g	0.00	1.12	0.96	0.00	0.25	0.21	0.00	0.87	0.75
Aldehydes	g	0.07	1.00	0.90	0.02	0.17	0.15	0.06	0.83	0.74
Zn	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Fe	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Ba	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Acrolein	mg	0.80	0.95	0.82	0.18	0.21	0.19	0.62	0.74	0.64

Notes: 28 substances less than 1g have been omitted. Acrolein is included because it is a surrogate HAP under the new MACT rule. “x” indicates that substance did not appear at that stage.

Table 7.2B. Exported results from SimaPro LCI for air emissions from the gate-to-gate production of one Mbf of planed dry lumber with electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
CO_2 (biomass)	kg	x	301.1	259.5	x	65.9	57.2	x	235.2	202.3
CO_2 (fossil)	kg	12.5	128.8	117.1	2.8	28.1	25.7	9.7	100.8	91.4
CO	kg	0.07	2.29	1.99	0.02	0.50	0.44	0.06	1.79	1.55
SOx	kg	0.10	1.78	1.59	0.02	0.39	0.35	0.08	1.39	1.24
NOx	kg	0.09	0.72	0.67	0.02	0.16	0.15	0.07	0.57	0.52
Non methane VOC	g	31.8	475.6	424.7	7.1	103.6	93.2	24.6	372.0	331.6
Methane	g	22.8	339.8	304.7	5.1	74.5	67.3	17.7	265.3	237.4
Dust (coarse)	g	129.4	160.4	170.0	29.0	35.8	38.0	100.4	124.6	131.9
VOC	g	34.4	133.2	128.7	7.7	29.3	28.5	26.7	103.9	100.1
K	g	x	111.8	96.4	x	24.5	21.3	x	87.4	75.1
Particulates	g	4.1	40.5	37.6	0.9	8.6	8.1	3.2	31.8	29.5
CO_2 (non-fossil)	g	3.9	29.7	42.2	0.9	6.5	9.3	3.0	23.2	32.9
Organic substances	g	0.1	36.9	31.9	0.0	7.1	6.2	0.1	29.8	25.7
Dust (PM10)	g	12.6	14.7	12.7	2.8	3.3	2.8	9.8	11.4	9.8
Particulates (unspecified)	g	5.7	15.3	16.1	1.3	3.4	3.6	4.4	12.0	12.5
Phenol	g	0.1	5.8	5.0	0.0	1.3	1.1	0.1	4.6	3.9
Particulates (PM10)	g	1.2	2.6	2.7	0.3	0.6	0.6	0.9	2.0	2.1
Formaldehyde	g	0.9	2.2	2.3	0.2	0.5	0.5	0.7	1.7	1.8
Na	g	x	2.58	2.22	x	0.57	0.49	x	2.02	1.73
Methanol	g	0.89	1.04	0.90	0.20	0.23	0.20	0.69	0.81	0.69
Acetaldehyde	g	0.52	1.04	0.90	0.12	0.23	0.20	0.40	0.81	0.70
Mn	g	0.00	1.29	1.11	0.00	0.28	0.25	0.00	1.01	0.87
HCl	g	0.39	0.92	0.98	0.09	0.20	0.22	0.30	0.72	0.76
Aldehydes	g	0.10	1.05	0.95	0.02	0.18	0.17	0.07	0.87	0.78
Cl_2	g	0.00	1.12	0.96	0.00	0.25	0.21	0.00	0.87	0.75

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Zn	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Fe	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Ba	g	x	0.63	0.54	x	0.14	0.12	x	0.49	0.42
Acrolein	mg	0.88	1.12	1.00	0.20	0.25	0.23	0.68	0.87	0.78

Notes: 26 substances less than 1g have been omitted. Acrolein is included because it is a surrogate HAP under the new MACT rule. "x" indicates that substance did not appear at that stage. Similar values for Zn, Fe, and Ba are from SimaPro 5, not a typo in report.

Table 7.3A. Exported results from SimaPro 5 LCI for water emissions from the gate-to-gate production of one Mbf of planed dry lumber without electricity.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
dissolved solids	kg	0.0	2.3	2.0	0.0	0.5	0.4	0.0	1.8	1.6
Cl-	g	0.2	106.2	91.8	0.0	23.2	20.2	0.2	82.9	71.6
Sulphate	g	0.2	83.4	72.2	0.0	18.3	15.9	0.1	65.2	56.3
Suspended solids	g	0.1	42.1	36.6	0.0	9.2	8.1	0.1	32.9	28.6
Oil	g	0.1	41.1	35.5	0.0	9.0	7.8	0.1	32.1	27.7
COD	g	0.1	32.8	28.5	0.0	7.2	6.3	0.1	25.6	22.2
Other organics	g	0.0	6.7	5.8	0.0	1.5	1.3	0.0	5.2	4.5
BOD	g	0.0	2.3	2.0	0.0	0.5	0.4	0.0	1.8	1.6

Notes: 28 substances less than 1g have been omitted. "x" indicates that substance did not appear at that stage.

Table 7.3B. Exported results from SimaPro 5 LCI for water emissions from the gate-to-gate production of one Mbf of planed dry lumber with electricity.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Dissolved solids	kg	0.1	2.6	2.3	0.0	0.6	0.5	0.1	2.0	1.8
Cl-	g	4.8	116.2	102.5	1.1	25.5	22.6	3.7	90.8	79.9
Sulphate	g	4.9	94.0	83.4	1.1	20.6	18.4	3.8	73.4	65.0
Suspended solids	g	5.1	53.2	48.5	1.2	11.7	10.7	4.0	41.5	37.8
Oil	g	1.9	44.9	39.6	0.4	9.8	8.7	1.5	35.1	30.9
COD	g	1.5	35.8	31.8	0.3	7.8	7.0	1.2	28.0	24.8
Other organics	g	0.3	7.4	6.5	0.1	1.6	1.4	0.3	5.8	5.1
BOD	g	0.1	2.5	2.3	0.0	0.5	0.5	0.1	2.0	1.8
Fe	g	0.302	0.720	0.782	0.068	0.159	0.174	0.234	0.561	0.609
B	g	0.202	0.508	0.535	0.045	0.112	0.119	0.157	0.396	0.416
Mn	g	0.168	0.402	0.433	0.038	0.089	0.096	0.131	0.313	0.337

Notes: 25 substances less than 1g have been omitted.

Table 7.4. Exported results from SimaPro LCI for solid emissions from the gate-to-gate production of one Mbf of planed dry lumber with or without electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
		Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Solid waste	kg	0.0	4.7	4.5	0.0	1.0	1.0	0.0	3.7	3.5
Inorganic general	kg	1.1	1.3	1.1	0.2	0.3	0.2	0.8	1.0	0.8
Paper/board packaging	g	95.9	133.4	121.9	21.5	29.7	27.3	74.4	103.7	94.6
Wood	g	10.9	12.7	11.0	2.4	2.8	2.5	8.4	9.9	8.5

Notes: Electrical use did not affect these values.

7.5 ENERGY

With purchased electricity not included (Table 7.5A), 2362.5 MJ of energy are used in manufacturing 1 Mbf of planed dry lumber. With purchased electricity included (Table 7.5B), 2663.5 MJ of energy are used. This demonstrates that purchased electricity accounts for approximately 11% of the energy required to produce planed dry lumber. Of the total energy (2663.5 MJ), 14.2% is used in the sawmill , 79.4% in dryer/boiler, and 6.4% at the planer. These energy percentages were obtained from an energy tree (flow diagram) in Sima Pro 5. The 14.2% in the sawmill includes energy allocated to that portion of the co-products which become fuel for the boiler. If 100% of the allocation was to the lumber, 3307.4 MJ would be required. None of these total energy values includes the energy produced internally by burning wood-based material because wood is a material into the process.

If planed green lumber had been produced, only 485 MJ (approximately) per Mbf would have been required (from separate SimaPro 5 analysis for planed green lumber, not shown). Most of the difference between this and the energy required for planed dry lumber (2663 MJ) is due to not drying; however, some difference is due to the energy allotted to co-products which are sold rather than burned.

After applying allocations, 43.2% of the purchased electrical energy is used in sawing, 19.8% in drying, 17.4% at the boiler, and 19.5% in planing (compared to 66%, 19% to the dryer/boilers, and 15% to the planer before allocation as reported in section 4.0). The 43.2% used in sawing included electricity allocated to the rough green lumber and the portion of the co-products that go to the boiler for fuel. These percentages do not reflect any energy produced through cogeneration, although they would not change if one assumed that electricity produced internally was used in proportion to purchased electricity. The negative value in the hydropower line for rough green lumber in Table 7.5A is due to cogeneration.

Of the crude oil used, 18% is attributable to natural gas extraction, 5% is burned in the boiler, and the remaining 78% is used to power machinery such as skidders and forklifts. The coal is 13% attributable to the production of steel to make the strapping and 66% to the extraction of natural gas. Similarly, uranium is 78% attributed to natural gas extraction and 5% attributed to steel production.

Natural gas is by far the largest source of purchased energy for the manufacture of western lumber.

Table 7.5A. Exported results from SimaPro LCI for energy from the gate-to-gate production of one Mbf of planed dry lumber without electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
	LHV	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Natural gas FAL	MJ	3.9	2058.7	1778.0	0.9	450.6	391.9	3.0	1608.1	1386.2
Energy (undef.)	MJ	185.0	407.6	435.7	41.5	90.2	96.9	143.6	317.4	338.8
Crude oil FAL	MJ	50.0	128.4	131.0	11.2	25.7	26.8	38.8	102.7	104.2
Coal FAL	MJ	0.5	11.9	13.7	0.1	2.6	3.0	0.4	9.3	10.7
Uranium FAL	MJ	0.19	4.21	4.08	0.04	0.91	0.89	0.15	3.29	3.19
Energy from hydro power	MJ	0.00	-0.02	0.04	0.00	0.00	0.01	0.00	-0.02	0.03
Sum	MJ	239.6	2610.8	2362.5	53.7	570.0	519.4	185.9	2040.8	1843.1

Table 7.5B. Exported results from SimaPro LCI for energy from the gate-to-gate production of one Mbf of planed dry lumber with electrical use.

Substance	Unit	Western Lumber			Douglas-fir			Hemlock		
	LHV	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry	Rough Green	Rough Dry	Planed Dry
Natural gas FAL	MJ	91.7	2252.2	1984.8	20.5	493.4	437.9	71.1	1758.7	1547.0
Energy (undef.)	MJ	137.5	302.8	323.8	30.8	67.0	72.0	106.7	235.8	251.8
Crude oil FAL	MJ	56.6	135.4	145.7	12.7	29.9	32.3	43.9	105.5	113.3
Coal FAL	MJ	53.8	136.8	140.0	12.1	27.6	28.8	41.8	109.3	111.2
Uranium FAL	MJ	25.83	60.69	64.46	5.79	13.41	14.32	20.04	47.28	50.14
Energy from hydro power	MJ	2.04	4.48	4.79	0.46	0.99	1.07	1.58	3.49	3.73
Sum	MJ	367.4	2892.4	2663.5	82.3	632.3	586.4	285.1	2260.1	2077.2

8.0 SENSITIVITY

A sensitivity analysis was done on selected variables likely to have the greatest impact on the LCI results. These were the steam use at the dry kiln and the amount of wood-generated steam compared to natural gas-generated steam. Other variables would yield very straightforward results because the SimaPro inputs and outputs are based on the lumber production. If lumber recovery from the log were changed, all inputs and outputs would remain the same except logs. Electricity from the Pacific Northwest power grid was used in these analyses.

8.1 FUEL USED TO GENERATE STEAM

The steam for drying was 58.2% from wood fuel, 41.7% from natural gas, and a small amount from diesel based on the survey. The diesel was mainly used in backup boilers, not in steady production. Changing the model to 68.2% wood fuel, then 48.2% wood fuel tested the sensitivity of the fuel ratio. This is an approximate 16% increase or decrease in the wood fuel used. The natural gas was changed to offset changes in the wood fuel. The diesel use was 0.1% in each case. This analysis is shown in Table 8.1.

The logs to produce one Mbf of planed dry lumber increases as the percent of wood fuel increases because the wood fuel comes from the log and is allocated to the lumber. Increases in other materials, such as water use, are due to the greater utilization of the log. For example, in the "48%" case (Table 8.1), some of the logyard water is assigned to hog fuel which is sold and in the "68%" case it is assigned to hog fuel that is burned. Natural gas use decreases, as do materials associated with its extraction such as crude oil and coal.

Fossil CO_2 emissions decrease due to lower natural gas use while biomass CO_2 increases. CO increases as wood fuel use increases. Water emissions tend to be associated with the natural gas extraction and decrease as wood fuel use increases. Solid wastes increase due to ash from the boiler and the burdens assigned to the wood fuel.

Table 8.1. Sensitivity analysis for boiler fuel type. Base case is 58% wood fuel, low is 48% wood fuel, and high is 68% wood fuel. The balance is natural gas and 0.1% diesel.

Substance list		Wood for thermal energy		
Raw Materials		48%	58%	68%
Logs, PNW	m3	1.79	1.84	1.88
Water (well, for cooling)	kg	95.5	97.9	100.3
Water (surface, for cooling)	kg	66.7	68.3	69.9
Natural gas FAL	kg	51.4	42.4	33.4
Airborne emissions				
CO_2 (biomass)	kg	215	260	304
CO_2 (fossil)	kg	138	117	97
SOx	kg	1.9	2.0	2.2
CO	kg	1.7	1.6	1.3
NOx	g	699	666	634
Non methane VOC	g	508	425	341
Methane	g	364	305	245
K	g	79.8	96.4	113.0
CO_2 (non-fossil)	g	46.5	42.2	39.9
Waterborne emissions				
Dissolved solids	kg	2.7	2.3	1.8
Cl-	g	124.3	102.5	80.8
Sulphate	g	100.5	83.4	66.4
Suspended solids	g	57.0	48.5	39.9
Oil	g	48.0	39.6	31.3
COD	g	38.5	31.8	25.1
Other organics	g	7.9	6.5	5.2
BOD	g	2.7	2.3	1.8
Solid waste				
Solid waste	kg	8.0	7.2	6.4
Energy				
Natural gas FAL (LHV)	MJ	2406	1985	1563

Notes: Values are per Mbf of planed dry lumber. Value with less than 5% difference have been omitted.

Energy consumption is reduced because the mill becomes more energy self sufficient as additional wood fuel is used. The green residues produced would be nearly sufficient to provide all the steam generated for drying and if some of the planer residuals were burned, the mill could provide all of its own thermal energy. This can be verified from the SimaPro 5 inputs and outputs as well as the survey (Table 2.3).

If 100% wood fuel was burned, 879 MJ of total energy would be needed and CO_2 emissions would be 459.6 (88.1% biomass, 6.6% fossil, 5.5% non-fossil). If 100% natural gas was burned, 4730 MJ of total energy would be needed and CO_2 emissions would be 280 kg (0% biomass, 77.5% fossil, 22.5% non-fossil).

8.2 DRYER ENERGY EFFICIENCY

The steam required for drying was 3,130,050 BTU/Mbf (base case). Increasing and decreasing this in the model by 10% tested the sensitivity of analysis to dryer efficiency. These results are shown in Table 8.2.

Table 8.2. Sensitivity analysis for dryer efficiency. Base case is 3,130,050 BTU/Mbf, low is 2,817,045 BTU/Mbf, and high is 3,443,055 BTU/Mbf used as thermal energy to dry lumber.

Substance list		Energy use in drying		
		10% less	Survey	10% more
Raw materials				
Logs, PNW	m3	1.81	1.84	1.86
Natural gas FAL	kg	38.9	42.4	46.3
Airborne emissions				
CO_2 (biomass)	kg	236	260	285
CO_2 (fossil)	kg	109	117	126
CO	kg	1.8	2.0	2.2
SOx	kg	1.5	1.6	1.7
NOx	g	622	666	716
Non methane VOC	g	392	425	461
Methane	g	281	305	331
CO_2 (non-fossil)	g	40.4	42.2	44.2
Particulates	g	35.1	37.6	40.4
Phenol	g	4.6	5.0	5.5
Waterborne emissions				
Dissolved solids	kg	2.1	2.3	2.5
Cl-	g	94	103	112
Sulphate	g	77	83	91
Suspended solids	g	45	48	52
Oil	g	36	40	43
COD	g	29	32	35
Other organics	g	6.0	6.5	7.1
BOD	g	2.1	2.3	2.5
Solid emissions				
Solid waste	kg	6.8	7.2	7.7
Energy (LHV)				
Total of all compartments	MJ	2483	2664	2862
natural gas FAL	MJ	1820	1985	2166

Notes: Values are per Mbf of planed PNW dry lumber.

Dryer energy use is the major factor affecting material and energy use during the manufacturing of planed dry lumber. This is evident in Table 8.2 because most values increase with energy use at the dryer. Energy use and pollutants are dominated by the drying and energy generation processes. Values associated with producing the hog fuel, sawdust, or bark fuels (logs, water, packaging, etc.) increase to a lesser extent as fuel consumption increases at the boiler because 58% of the energy comes from wood. Log use increases with energy use because more of the sawmill co-products are burned meaning that the mill complex produces lesser amounts of co-products (such as sawdust) for sale.

9.0 CARBON BALANCE

A biomass carbon balance on the wood-based material into the process is shown in Table 9.1. Inputs at the top of the table include logs and fuel to the boiler. The fuel into the boiler (in italics) is also listed as an input to the sawmill because it originates in the logs. Therefore it is not included in the total. Outputs appear below in Table 9.1 and similarly the carbon leaving the boiler (in italics) is not included in the total because it is included in the sawmill outputs of hog fuel, bark, and sawdust.

The left column in Table 9.1 is the material. The second column is the amount in or out of the unit process in SimaPro 5. The third column, the unit process factor, scales the values to 1000 Mbf of planed dry lumber. For example, 1041.4 Mbf of rough green lumber must be sawn and dried for every 1 Mbf of planed dry lumber. The fourth column adjusts for the Douglas-fir to hemlock ratio in the Pacific Northwest Lumber mix. Most of the values in this column are unity because the level of detail in the survey does not permit discrimination between, for example, Douglas-fir sawdust and hemlock sawdust. The fifth column is the ratio of the mass of carbon to the total mass of the compounds or materials. For chemicals, these are based on their respective formulae. The carbon content values for Douglas-fir and hemlock wood and bark came from Georgia Institute of Technology, 1984.

Table 9.1. A Carbon Balance for Pacific Northwest Lumber Production.

Material	Mass to or from the unit process lbs	Unit process factor per Mbf PDL	Production factor %/100	Carbon ratio in material	Carbon lb/Mbf
Inputs					
Sawing					
Douglas-fir logs (wood)	3210	1.0414	0.219	0.523	382.9
Hemlock logs (wood)	2990	1.0414	0.781	0.504	1225.7
Douglas-fir logs (bark)	447	1.0414	0.219	0.512	52.2
Hemlock logs (bark)	447	1.0414	0.781	0.530	192.7
Energy generation					
Wood and bark fuel	*500*	*1.087*	*1*	*0.520*	*282.6*
Sum of Inputs					**1853.4**
Outputs					
Products (planed, dry)					
Douglas-fir lumber	1700	1	0.219	0.523	194.7
Hemlock lumber	1590	1	0.781	0.504	625.9
Co-products					
Sawmill					
Chips	845	1.0414	1	0.520	457.6
Sawdust	233	1.0414	1	0.520	126.2
Hog fuel	403	1.0414	1	0.520	21.8
Bark	246	1.0414	1	0.520	133.2
Planer					
Chips	102	1	1	0.520	53.0
Sawdust	248	1	1	0.520	129.0
Shavings	132	1	1	0.520	68.6
Air emissions					
Sawing					
Dust or particulate	0.95	1.0414	1	0.520	0.5
Drying					
Dust or particulate	0.192	1.0414	1	0.520	0.1
VOC	0.197	1.0414	1	0.882	0.2
Energy generation					
Dust or particulate	*2.3E-07*	*1.087*	*0.582*	*0.520*	*0.0*
CO	*6.8*	*1.087*	*0.582*	*0.429*	*1.82*
CO_2	*1050*	*1.087*	*0.582*	*0.278*	*184.7*
Organic substances	*0.038*	*1.087*	*0.582*	*0.882*	*0.0*
Phenol	*0.020*	*1.087*	*0.582*	*0.770*	*0.0*
Formaldehyde	*0.003*	*1.087*	*0.582*	*0.400*	*0.0*
Acetaldehyde	*0.002*	*1.087*	*0.582*	*0.540*	*0.0*
Benzene	*0.002*	*1.087*	*0.582*	*0.920*	*0.0*
Naphthalene	*0.001*	*1.087*	*0.582*	*0.940*	*0.0*
Planing					
Dust or particulate	0.081	1	1	0.520	0.0
Solid waste					

Material	Mass to or from the unit process lbs	Unit process factor per Mbf PDL	Production factor %/100	Carbon ratio in material	Carbon lb/Mbf
Sawing					
Wood	0.010	1.0414	1	0.520	0.0
Bark	0.030	1.0414	1	0.520	0.0
Sum of Outputs					**1997.5**

Notes: Italicized items are not included in totals because they are counted in the other products or co-products.

The carbon in and out balance is within 3%. The sum of the carbon out of all unit processes is 1998 lbs/Mbf. Of this, 820 lbs are in the products and 670 lbs are in the co-products. The other significant output of carbon is in the CO_2 from wood combustion, 186 lbs/Mbf.

10.0 COST ANALYSIS

A cost analysis was done for the sawing, drying, energy generation and planing processes combined. This was based on a 120,000 Mbf/yr sawmill and was a composite of the PNW dimension lumber mills surveyed.

The assumptions for this analysis are shown in Table 10.1. Estimates of capital costs were obtained from a manufacturer for a mill of average technology. Material and energy costs were set to match other CORRIM modules, where possible. Lumber prices came from Crow's June 7, 2002 report. Insurance, maintenance, and labor costs were estimated based on conversations with mill managers. The mill description items are derived from the inputs and outputs in this report.

The results shown in Table 10.2 are based on the assumptions in Table 10.1. The column farthest to the right is on a basis of one Mbf of total production. Some of the numbers may appear in error. For example, hemlock lumber is sold at $267/Mbf, but in the table this appears at $211/Mbf because only 79% of the total production is hemlock lumber. Clearly, profitability is closely tied to the log and lumber prices as these are the greatest values in the table. Lumber prices were very low at the time of this writing. One year ago, the price of dimension lumber was $111 /Mbf higher and even two months earlier the lumber price was $32/mbf higher. There evidently is a slim profit margin in the business at certain times.

Table 10.1. Assumptions for cost analysis.

Capital cost of sawmill		**Unit**
Sawmill	40,000,000	$
Kilns	3,000,000	$
Boiler	2,000,000	$
Planer	12,000,000	$
Salvage value	20	% of new cost
Service life of capital	20	years
Interest rate	8	%
Wood material costs		
Douglas-fir logs	550	$/Mbf log
Hemlock logs	450	$/Mbf log
Douglas-fir, 2&btr lumber	300	$/Mbf
Douglas-fir, 3 lumber	230	$/Mbf
Hemlock, 2&btr lumber	267	$/Mbf
Hemlock, 3 lumber	225	$/Mbf
Chips	48	$/odt
Bark	30	$/odt
Hog fuel	10	$/odt
Planer shavings	30	$/odt
Sawdust	10	$/odt
Other materials		
Natural gas	0.285	$ / therm
Electricity purchased	0.0425	$ / kWhr
Electricity sold	0.0425	$ / kWhr
Diesel	0.65	$ / gal
Gasoline	0.90	$/gal
Propane	0.90	$/gal
Water	0.05	$/gal
Insurance	76,800	$/year
Maintenance	2,400,000	$/year

Labor		
People	0.0005	# / Mbf
Wages	45,000	$ / yr
Mill description		
Production	120,000	Mbf per year
Planed dry Douglas-fir lumber	25,200	Mbf/yr
Planed dry hemlock lumber	94,800	Mbf/yr
Logs purchased	0.511	Mbf log / Mbf pdl
Chips sold	0.49	odt/Mbf pdl
Bark produced	0.13	odt/Mbf pdl
Hog produced	0.022	odt/Mbf pdl
Planer shavings produced	0.066	odt/Mbf pdl
Sawdust produced	0.13	odt/Mbf pdl
Electrical used	171.0	kWhr/Mbf
Electricity sold	28.5	kWhr/Mbf
Natural gas	22.0	therMs/Mbf
Diesel	0.70	gal/Mbf pdl
Water	47.229	gal/Mbf pdl
Gasoline	0.044	gal/Mbf pdl
Propane	0.000122	gal/Mbf pdl
Bark used internally	0.032	odt/Mbf pdl
Hog used internally	0.022	odt/Mbf pdl
Planer shavings used internally	0.066	odt/Mbf pdl
Sawdust used internally	0.13	odt/Mbf pdl
Inventory	5,110.00	Mbf logs

Table 10.2. Cost analysis for a 120 MMbf sawmill.

Item	$/yr	$/Mbf of production
Fixed costs		
Interest on capital	4,560,000	38
Insurance	76,800	0.64
Maintenance	2,400,000	20
Variable costs		
Material		
Water	283,374	2.36
Douglas-fir logs	7,082,460	59.02
Hemlock logs	21,799,260	181.66
Energy		
Electricity	726,750	6.06
Natural gas	751,374	6.26
Diesel	54,600	0.46
Gasoline	4,752	0.04
Propane	13	0.00
Labor	2,700,000	22.50
Interest on inventory	183,960	1.53
Total costs	**40,623,343**	**338.53**
Income		
Planed dry Douglas-fir lumber	7,560,000	63.00
Planed dry hemlock lumber	25,311,600	210.93
Chips sold	2,828,160	23.57
Bark sold	345,600	2.88
Hog fuel	0	0.00
Planer shavings	0	0.00
Total income	**36,045,360**	**300.38**
PrE-depreciation profit or (loss)	**(4,577,983)**	**(38.15)**
Depreciation		
Cost new	$57,000,000	0.00
Salvage value	$11,400,000	0.00
Depreciation	2,280,000	19.00
Pre tax profit or (loss)	**(6,857,983)**	**(57.15)**

11.0 CONCLUSIONS

The data collected on sawing and planing represents 13% of the dimension lumber produced in the survey region. The product mix closely mirrors that shown in WWPA annual reports. The energy use and boiler data are much more extensive, covering over 40% of all lumber produced in the region.

The lumber manufacturing process has few on-site emissions from sawing and planing. The dryer emits small amounts of VOCs from wood and the boiler has emissions associated with burning wood and natural gas. Total energy use in lumber manufacturing is driven by the drying process which consumes over 85% of all energy. Over 50% of electrical energy is used in sawing and the balance divided among planing, drying, and energy generation.

The sawing and planing data accurately represent the dimension lumber industry in the PNW region. It is difficult, however, to accurately survey energy use because multiple products (such as dimension lumber, lamstock, and appearance grades) and species are often produced at a single facility. Record keeping, such as a monthly fuel bills, does not provide sufficient information to isolate all inputs and outputs for only one product. For wood fuels, some mills do not track the usage. Some products are dried to lower moisture contents and higher initial moisture contents occur in some species affecting the energy use.

The level of detail obtained in this report is approaching what is possible to obtain by survey given the number of products produced at a single mill and the level at which mills track material and energy usage.

12.0 REFERENCES

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APPENDIX 1: MAIN SURVEY

The original survey is in this appendix. The text of the survey has been condensed to 30 pages from 51 pages by removing the spaces left for mills to respond. The footer which indicated the survey section (sawing, boiler, drying , planing, or general information) has been removed and tables have been allowed to run across pages (they did not in the original).

CORRIM SURVEY

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

LIFE CYCLE INVENTORY ANALYSIS OF THE WESTERN SOFTWOOD DIMENSION LUMBER INDUSTRY

The information from this survey will be used by CORRIM II, a consortia of university, industry, and government groups. CORRIM II is conducting a life-cycle assessment that will describe the environmental influences of building materials. The objective is to acquire a database and produce life-cycle models of the environmental performances for building materials. This will allow construction practices to be compared, for example, comparing the overall environmental benefits of wood versus steel or concrete walls.

This CORRIM survey is designed specifically for western softwood lumber mills. Questions will be focused on annual production, energy use and generation, material inputs, and environmental emissions. We realize that you may not have all the information requested, but 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.

Company Name: ______________________________

Mill Address: ______________________________

____

Mill ID code ________________

Contact Person: ______________________________

Position/Title: ______________________________

Telephone: ____________ **Fax:** ______________

AF&PA Member **Y** **N**

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LIFE CYCLE INVENTORY ANALYSIS OF THE WESTERN SOFTWOOD DIMENSION LUMBER INDUSTRY

We have divided the mill into four unit processes. This division is like drawing a boundary around a part of the process. We want to find out everything that crosses the boundary. We would like to get information for each unit process; however, if the arrangement your mill makes this impossible, please contact Mike Milota before proceeding.

This survey is divided into five parts.

- Part I deals with a basic description of the mill and its operations.
- Parts II-V focus on the inputs and outputs for each unit processes. These are:
  - Part II - **Sawing**
  - Part III - **Energy generation**
  - Part IV - **Drying**
  - Part V - **Planing** (planing and packaging of lumber)

Within each of the last four parts, the survey contains series of tables organized as follows:

- Inputs
  - Materials
  - Water
  - Energy
- Outputs,
  - Products
  - Air emissions
  - Liquid emissions
  - Solid waste
- Emissions control equipment
- Transportation within the unit process and to next process

Please complete the tables by either printing or typing responses in the spaces provided. Provide as much detail as possible. Please contact Mike Milota if you have questions.

Space is provided throughout the questionnaire for any additional comments, clarifications or observations you might care to add.

Units are generally specified, but if you have other units which are easier to use, please cross off our units and add yours.

If you do not know the quantities at the level of detail requested, group by category. For example, provide a value for all HAPs if the quantities of individual compounds are not known.

Thank you for the time and effort to fill in the blanks. We hope the number of pages does not scare you away. Not all mills have everything on the list and it should be easier than it looks to complete.

PART I - Operation Overview

Life Cycle Inventory Analysis Data Availability and Input Sheet		
Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

General mill information

Mill type (please check one):

o Dimension mill

o Stud mill

o Other (specify)____________________

2. Lumber Production
   - for reporting year __________ million board feet
   - percent kiln dried __________ %
3. Which of the following does this mill have?

log storage	
o	dry deck
o	sprinkled deck
o	pond
o	other: __________________________
log handling	
o	log sorter/merchandizer
o	debarker
o	
o	
sawmill	
o	head rig(s) specify type
o	resaws, how many: ______
o	edgers, how many: ______
o	edger optimizer
o	trimmer optimizer
o	trimmer
o	sorter, # bins: ______
o	sticker stacker
o	stain control equipment
o	
o	
dryers	

o	conventional steam
o	high temperature steam
o	direct-fired
o	dehumidification
o	transfer car system
o	air drying yard
o	
o	

boiler

o	wood-fired boiler
o	gas-fired boiler
o	cogeneration facility
o	bag house
o	
o	

planer

o	in-line moisture meter
o	grading station
o	trimmer
o	end paint/seal
o	
o	

other mill equipment

o	
o	
o	

4. Please provide a schematic of the basic plant layout:

5. If present, please indicate the capacity of every process heat boiler:

Boiler	Size (BTU/hr, hp, or lbs/hr of steam)	Fuel type
#1		
#2		
#3		

6. If present, please indicate the cogeneration facility capacity:

Electricity (kW or MW)	Process heat (BTU/hr)	Fuel type	% used or sold off site	
			electricity	process heat

Inputs

1. What log scaling method(s) is used?

 ____

2. Which of the following best describes the timber harvesting method used:
   - o manual (chainsaw felling and cable skidder)
   - o mechanized logging (feller, forwarder, delimber)
   - o other (describe) ____

3. For the selected reporting year, what was the total timber input to your mill?

Quantity	Units	Scaling method

4. Please complete the following table showing the breakdown of the tree species and approximate sizes processed by your mill.

Species	% of total timber input	Average log length (ft)	Average log diameter (in)

5. If any biomass fuel used on-site is purchased from other sources, please indicate the amounts by type in the spaces provided below. Please make sure you show the units of measure (e.g. green or dry tons).

Input	Quantity	Units
Planer shavings		
Sawdust		
Bark		

Production

1. Please complete column1 and **either** column 2 **or** column 3 in the following table for the selected reporting year. By product, we mean dimension, boards, siding, etc., but not broken down by size

Lumber			Production per year
Species	Product	Dry or Green	Volume in million bf / other units specify:

2. Please indicate product and coproduct recovery for the selected reporting year. If you measure in different units than those indicated, please cross out the units provided and show your units in the right-hand column.

Product	Volume Recovered		Alternate Units
Pulp chips		dry tons/yr	
Planer shavings		dry tons/yr	
Sawdust		dry tons/yr	
Bark		dry tons/yr	

3. For each product, please indicate the percentages of total production for the reporting period that are shipped to other users, used internally, landfilled or stockpiled for future use.

Product	Shipped	Used internally	Landfilled	Stockpiled	Total
	%	%	%	%	%
Lumber (green)					100
Lumber (KD)					100
Pulp chips					100
Planer shavings					100
Sawdust					100
Bark					100
					100
					100
					100
					100

PART II - Sawing

Life Cycle Inventory Analysis Data Availability and Input Sheet		
Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

Description of Unit Process

This unit process begins with logs in the mill yard and includes:

- in-yard conveyance of logs from the point of unloading to the deck;
- sorting and storage of logs;
- in-yard conveyance of logs from the deck to the optimizer or debarker;
- cutting to length of logs or treelengths;
- debarking of the log input into the sawmill;
- breakdown of logs into rough lumber, pulp chips, bark and sawdust;
- stacking, stickering, and in-yard conveyance of rough lumber to kilns or planer facilities;
- sawfiling and maintenance of all sawmill equipment and yard transportation vehicles; and
- treatment of process air, liquids, and solids.

The outputs of this unit process are rough green lumber, pulp chips, bark, and sawdust.
Notes, exceptions, or additions to this description:

INPUTS TO SAWING - Materials

Material inputs to logyard, sawmill, filing room, and conveyance to kilns or planer		Quantity	Units	Further describe
Main materials processed	Sawlogs		Mbf	
Other materials	Hydraulic Fluids		lb	
	Greases		lb	
	Motor Oil		gal	
	Paints		gal	% solids =
	Waxes		gal	% solids =
	Anti-stain chemicals		gal	chemicals and concentrations =
	Alloys		lbs	type =
	Solvents		gal	type =

Description (heading over Quantity, Units and Further describe)

Additional notes or comments:

INPUTS TO SAWING - Water

Location	Water Consumption	Quantity	Units
Logyard	Surface water		gal
	Ground water		gal
Sawmill, filing room, and conveyance to kilns or planer	Surface water		gal
	Ground water		gal

Note: If the source of water used is surface water, then only report net consumption. If the source water is groundwater, then the total water removed from the water table should be reported.

Additional notes or comments:

INPUTS TO SAWING - Energy

If you have filled out the AF&PA energy survey, please attach.

Energy Inputs[1]		Units	Quantity
Logyard, sawmill, filing room, and conveyance to kilns or planer	Heavy Fuel Oil	gal	
	Medium Fuel Oil	gal	
	Light Fuel Oil	gal	
	Kerosene	gal	
	Gasoline	gal	
	Diesel Fuel	gal	
	Propane	gal	
	Natural gas	1000 ft^3	
	Electricity (purchased)	kW-hr	
	Electricity[2] (self-generated)	kW-hr	
	Steam (purchased)	lbs	
	Steam[2] (self-generated)	lbs	

Notes: [1] Include all sources of energy such as fuels for yard equipment, forklifts, carriers, electricity for mill equipment and lights, and fuels for heating (not included in section III)

[2] Indicate if this is from the boiler/cogeneration facility described in section III of survey.

Additional notes or comments:

OUTPUTS FROM SAWING - Products

Product Outputs		Quantity	Units	Where does it go?
Logyard, sawmill, filing room, and conveyance to kilns or planer The products include anything that leaves the sawmill. Include, for example, hog fuel, even if it is used at the boiler on site. It will be counted as an energy input to the boiler.	Rough green lumber	Mbf		
	Logs	Mbf		
	Pulp chips	dry tons		
	Bark	dry tons		
	Hog fuel	dry tons		
	Sawdust	dry tons		

[1]For logs, please briefly describe scaling method used:

____

Additional notes or comments:

OUTPUTS FROM SAWING - Air Emissions

The values for air emissions in the following table come from the sawmill=s operating permit (s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Air Emissions[1]		Quantity	Units	Sampling Procedure[2]
Logyard, sawmill, filing room, and conveyance to kilns or planer (but not kilns, boiler or planer)	Dust		lbs	
	Particulate		lbs	
	SO_2		lbs	
	NO_x		lbs	
	CO_2		lbs	
	CO		lbs	
	VOC		lbs	
	Acetaldehyde		lbs	
	Acrolein		lbs	
	Formaldehyde		lbs	
	Methanol		lbs	
	Phenol		lbs	
	Propionaldehyde		lbs	
	Other HAPS[3]		lbs	
	Other[3] organics3			
	Other[3]			

Notes: [1]The following are examples of other air emissions: Cl_2, F_2, H_2S, H_2SO_4, HCl, HF, Hg, N_2O, NH_3, Pb, SO.

[2] Such as EPA or State method or indicate source of value such as AP-42.

[3] Please list compounds included in these categories

Additional notes or comments:

OUTPUTS FROM SAWING - Liquid Emissions

The values for liquid emissions in the following table come from the sawmill=s operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions		Quantity	Concen-tration	Units	Sampling Procedure
Logyard, sawmill, filing room, and conveyance to kilns or planer. (but not kilns, boiler or planer)	Suspended solids				
	BOD				
	COD				
	Oil and Grease			gal	
	HAPs			lbs	

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

OUTPUTS FROM SAWING - Solid waste

Solid Waste		Quantity	Units	MC, % (dry basis)	How measured
Logyard, sawmill, filing room, and conveyance to kilns or planer. (but not kilns, boiler or planer)	Wood		lbs	%	
	Bark		lbs	%	
	Inorganic[1] materials		lbs		
	Non-wood organic materials		lbs		
	Other organic materials		lbs		

[1]Metals, plastics, etc.

Additional notes or comments:

EMISSIONS CONTROL IN SAWING EQUIPMENT

Include devices for air emissions such as cyclones, baghouses, ESPs, and RTOs. For water emissions, explain how runoff or other water discharges are controlled.

Emission control device (ECD) - Electricity and fuel usage					
		ECD 1	ECD 2	ECD 3	ECD 4
Type of device					
Manufacturer and year installed					
Equipment controlled					
Electrical	[1]usage, kW-hrs				
	included in energy table, Y or N				
Natural gas	[1]usage, 10^6 ft^3				
	included in energy table, Y or N				
Type of emissions controlled					

[1]Or state other units

TRANSPORTATION WITHIN SAWMILL AND TO PLANER OR KILNS

Transportation within or from sawmill (but not off-site shipping)	Distance (feet)	Type of equipment used	Fuel	
			Type	Included in energy inputs? Y or N
Logs to deck				
Logs to optimizer or bucking				
Green lumber to kilns				
Green lumber to planer				
Chips to ____________				
Hog fuel to ____________				
Bark to _______________				

Additional notes or comments:

PART III - ENERGY GENERATION

Life Cycle Inventory Analysis Data Availability and Input Sheet		
Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

Description of Unit Process

This unit process provides heat and in some cases electricity for use in other parts of the mill or to be sold. A fuel such as wood or natural gas is burned.

- fuel handling;
- water added to the boiler;
- chemicals added at the boiler or to steam lines;
- distribution of the steam;
- distribution of electricity; and
- the treatment of process air, liquids, and solids.

The outputs of this unit process are process steam and electricity.
Notes, exceptions, or additions to this description:

INPUTS TO ENERGY GENERATION - Materials

Material inputs for fuel handling, boiler and steam and electrical distribution[1]	Description		
	Quantity	Units	Further describe
Hydraulic Fluids		lb	
Greases		lb	
Motor Oil		gal	
Water and steam treatment chemicals		gal	chemicals and concentrations =
Solvents		gal	type =

[1] The wood or other fuel is and energy input and is not included in this table.
Additional notes or comments:

INPUTS TO ENERGY GENERATION - Water

Location	Water Consumption	Quantity	Units
Fuel storage, boiler/cogen and distribution system	Surface water		gal
	Ground water		gal

Note: If the source of water used is surface water, then only report net consumption. If the source water is groundwater, then the total water removed from the water table should be reported.

Additional notes or comments:

INPUTS TO ENERGY GENERATION - Energy

If you have filled out the AF&PA energy survey, please attach.

Energy Inputs[1]	Units	Quantity
Wood-based material	lbs	
Heavy Fuel Oil	gal	
Medium Fuel Oil	gal	
Light Fuel Oil	gal	
Kerosene	gal	
Diesel Fuel	gal	
Propane	gal	
Natural gas	1000 ft^3	
Electricity (purchased)	kW-hr	
Electricity[2] (self-generated)	kW-hr	
Steam (purchased)	lbs	
Steam[2] (self-generated)	lbs	

Notes: [1] Include all sources of energy such as fuels for wood handling equipment, electricity for boiler and lights.
[2] Indicate if this is from the boiler/cogeneration facility described herein

Additional notes or comments:

OUTPUTS FROM ENERGY GENERATION - Products

Products	Quantity[1]	Pressure	Units	Where does it go?	% sold or sent off site
Steam			lbs / psig		
Electricity			kW-hrs		

[1] Quantities from the various survey sections should add; that is, the amount of steam or electricity generated should equal what is reported in sections II, IV, and V plus what is sent off site.

Additional notes or comments:

OUTPUTS FROM ENERGY GENERATION - Air Emissions

The values for air emissions in the following table come from the sawmill=s operating permit (s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Air Emissions[1]		Quantity	Units	Sampling Procedure[2]
Boiler/ cogen, fuel handling, and distribution only	Dust		lbs	
	Particulate		lbs	
	SO_2		lbs	
	NO_x		lbs	
	CO_2		lbs	
	CO		lbs	
	VOC		lbs	
	Acetaldehyde		lbs	
	Acrolein		lbs	
	Formaldehyde		lbs	
	Methanol		lbs	
	Phenol		lbs	
	Propionaldehyde		lbs	
	Other HAPS[3]		lbs	
	Other[3] organics3			

Notes: [1]The following are examples of other air emissions: Cl_2, F_2, H_2S, H_2SO_4, HCl, HF, Hg, N_2O, NH_3, Pb, SO.

[2] Such as EPA or state method or indicate source of value such as AP-42.

[3] Please list compounds included in these categories

Additional notes or comments:

OUTPUTS FROM ENERGY GENERATION - Liquid Emissions

The values for liquid emissions in the following table come from the sawmill=s operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions		Quantity	Concen-tration	Units	Sampling Procedure
Boiler/ cogen, fuel handling, and distribution only	Suspended solids				
	BOD				
	COD				
	Oil and Grease			gal	
	HAPs			lbs	

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

OUTPUTS FROM ENERGY GENERATION - Solid waste

Solid Waste		Quantity	Units	How measured
Boiler/ cogen, fuel handling, and distribution only	Wood		dry tons	
	Bark		dry tons	
	Ash		tons	
	Inorganic materials		tons	
	Non-wood organic materials		tons	
	Other organic materials		dry tons	

Additional notes or comments:

EMISSIONS CONTROL ON ENERGY GENERATING EQUIPMENT

Include devices for air emissions such as cyclones, baghouses, ESPs, and RTOs. For water emissions, explain how runoff or other water discharges are controlled.

Emission control device (ECD) - Electricity and fuel usage					
		ECD 1	ECD 2	ECD 3	ECD 4
Type of device					
Manufacturer and year installed					
Equipment controlled					
Electrical	[1]usage, kW-hrs				
	included in energy table, Y or N				
Natural gas	[1]usage, 10^6 ft^3				
	included in energy table, Y or N				
Type of emissions controlled					

[1]Or state other units

TRANSPORTATION WITHIN BOILER AREA AND DISTRIBUTION

Transportation within unit process or to loading for external shipment (but not off-site shipping)	Distance (feet)	Type of equipment used	Fuel	
			Type	Included in energy inputs? Y or N
Fuel from storage to boiler				
Ash to ______________				

Additional notes or comments:

PART IV - Drying

Life Cycle Inventory Analysis Data Availability and Input Sheet		
Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

Description of Unit Process

This unit process begins with rough green lumber and includes:

- loading of stickered lumber into a kiln facility;
- heat treatment, drying, equalizing and conditioning of lumber within the kiln;
- maintenance of all kiln equipment and related yard transportation vehicles;
- treatment of process air, liquids and solids; and
- unloading and conveyance of kiln-dried lumber to the planer mill.

The output of this unit process is stickered, rough kiln-dry lumber delivered to the planer mill. Notes, exceptions, or additions to this description: ______________________________

INPUTS TO DRYING - Materials

Material inputs to kilns		Description		
		Quantity	Units	Further describe
Main materials processed	Rough green lumber		Mbf	average moisture content:_____%
	Redry		Mbf	average moisture content:_____%
Other materials	Hydraulic Fluids		lb	
	Greases		lb	
	Motor Oil		gal	
	Paints		gal	% solids =
	Waxes		gal	% solids =
	Anti-stain chemicals		gal	chemicals and concentrations =
	Solvents		gal	type =

Additional notes or comments:

INPUTS TO DRYING - Water

Location	Water Consumption	Quantity	Units
Kilns	Surface water		gal
	Ground water		gal

Note: If the source of water used is surface water, then only report net consumption. If the source water is groundwater, then the total water removed from the water table should be reported.

Additional notes or comments:

INPUTS TO DRYING - Energy

If you have filled out the AF&PA energy survey, please attach.

Energy Inputs[1]	Units (per year)	Quantity
Heavy Fuel Oil	gal	
Medium Fuel Oil	gal	
Light Fuel Oil	gal	
Kerosene	gal	
Gasoline	gal	
Diesel Fuel	gal	
Propane	gal	
Natural gas	1000 ft^3	
Hog fuel	dry tons	
Electricity (purchased)	kW-hr	
Electricity[2] (self-generated)	kW-hr	
Steam[3] (purchased)	lbs	
Steam[2] (self-generated)	lbs	

Notes: [1] Include all sources of energy such as fuels for yard equipment, forklifts, carriers, electricity for mill fans and lights, and steam, gas, or hog fuel for heating (not included in section III).

[2] Indicate if this is from the boiler/cogeneration facility described in section III of survey.

[3] How was this generated?

Additional notes or comments:

OUTPUTS FROM DRYING - Products

Products	Quantity	Units	Where does it go?
Rough dry lumber	Mbf		average moisture content: %
Heat treated lumber	Mbf		
Bark	dry tons		
Hog fuel	dry tons		
Sawdust	dry tons		

Additional notes or comments:

OUTPUTS FROM DRYING - Air Emissions

The values for air emissions in the following table come from the sawmill=s operating permit (s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Air Emissions[1]	Quantity	Units	Sampling Procedure[2]
Dust		lbs	
Particulate		lbs	
SO_2		lbs	
NO_x		lbs	
CO_2		lbs	
CO		lbs	
VOC		lbs	
Acetaldehyde		lbs	
Acrolein		lbs	
Formaldehyde		lbs	
Methanol		lbs	
Phenol		lbs	
Propionaldehyde		lbs	
Other HAPS[3]		lbs	
Other[3] organics			
Other[3] inorganics			

Notes: [1]The following are examples of other air emissions: Cl_2, F_2, H_2S, H_2SO_4, HCl, HF, Hg, N_2O, NH_3, Pb, SO.

[2] Such as and EPA or state method or indicate source of value such as AP-42.

[3] Please list compounds included in these categories

Additional notes or comments:

OUTPUTS FROM DRYING - Liquid Emissions

The values for liquid emissions in the following table come from the sawmill=s operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions	Quantity	Conc-entration	Units	Sampling Procedure
Suspended solids				
BOD				
COD				
Oil and Grease			gal	
HAPs			lbs	

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

OUTPUTS FROM DRYING - Solid waste

Solid Waste		Quantity	Units	MC, % (dry basis)	How measured
Logyard, sawmill, filing room, and conveyance to kilns or planer. (but not kilns, boiler or planer)	Wood		lbs	%	
	Bark		lbs	%	
	Inorganic materials		lbs		
	Non-wood organic materials		lbs		
	Other organic materials		lbs		

Additional notes or comments:

EMISSIONS CONTROL ON DRYING EQUIPMENT

Include devices for air emissions such as cyclones, baghouses, ESPs, and RTOs. For water emissions, explain how runoff or other water discharges are controlled.

Emission control device (ECD) - Electricity and fuel usage					
		ECD 1	ECD 2	ECD 3	ECD 4
Type of device					
Manufacturer and year installed					
Equipment controlled					
Electrical	[1]usage, kW-hrs				
	included in energy table, Y or N				
Natural gas	[1]usage, 10^6 ft^3				
	included in energy table, Y or N				
Type of emissions controlled					

[1]Or state other units

TRANSPORTATION WITHIN DRYING AREA AND TO PLANER

Transportation within or from sawmill (but not off-site shipping)	Distance (feet)	Type of equipment used	Fuel	
			Type	Included in energy inputs? Y or N
Lumber from green yard to kilns				
Lumber from kilns to dry yard				
Dry lumber to planer				
Heat treated lumber to _____				

Additional notes or comments:

PART V - PLANER

Life Cycle Inventory Analysis Data Availability and Input Sheet		
Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

Description of Unit Process

This unit process begins with either rough green lumber or stickered, rough kiln-dried lumber .

The operations associated with this unit process include:

- de-stickering and/or unstacking of lumber ;
- planing (surfacing) of lumber;
- trimming, grading, and sorting of lumber;
- stacking, strapping, and packaging of lumber.
- conveyance of lumber within the planer operation and loading for shipping
- maintenance of all planer equipment and associated yard transportation vehicles; and
- treatment of process air, liquids and solids.

The output of this unit process is surfaced and packaged lumber, sorted by type, size and grade as well as planer shavings, sawdust, pulp chips, and/or lumber trim ends.
Notes, exceptions, or additions to this description:

INPUTS TO PLANING - Materials

Material inputs to planing, and conveyance to shipping point		Description		
		Quantity	Units	Further describe
Main materials processed	Rough green lumber		Mbf	
	Rough dry lumber		Mbf	
Other materials	Hydraulic Fluids		lb	
	Greases		lb	
	Motor Oil		gal	
	Paints		gal	% solids =

	Waxes		gal	% solids =
	Anti-stain[1] chemicals		gal	chemicals and concentrations =
	Alloys[1]		lbs	type =
	Solvents		gal	type =
	Wraps			
	Linerboard			
	Strapping			

[1]do not include if these were included in sawing section

Additional notes or comments:

INPUTS TO PLANING - Water

Location	Water Consumption	Quantity	Units
Planing, and conveyance to shipping point	Surface water		gal
	Ground water		gal

Note: If the source of water used is surface water, then only report net consumption. If the source water is groundwater, then the total water removed from the water table should be reported.

Additional notes or comments:

INPUTS TO PLANING - Energy

If you have filled out the AF&PA energy survey, please attach.

Energy Inputs[1]		Units	Quantity
Planer and conveyance to shipping point	Heavy Fuel Oil	gal	
	Medium Fuel Oil	gal	
	Light Fuel Oil	gal	
	Kerosene	gal	
	Gasoline	gal	
	Diesel Fuel	gal	
	Propane	gal	
	Natural gas	1000 ft^3	
	Electricity (purchased)	kW-hr	
	Electricity[2] (self-generated)	kW-hr	
	Steam (purchased)	lbs	
	Steam[2] (self-generated)	lbs	

Notes: [1] Include all sources of energy such as fuels for yard equipment, forklifts, carriers, electricity for mill equipment and lights, and fuels for heating (not included in section III)
[2] Indicate if this is from the boiler/cogeneration facility described in section III of survey.

Additional notes or comments:

OUTPUTS FROM PLANING - Products

1. Please fill out the following table of products.

Product outputs	Quantity	Units	Where does it go?
Planed dry lumber	Mbf		
Planed green lumber	Mbf		
Rough green lumber[1]	Mbf		

Pulp chips	dry tons	
Bark	dry tons	
Hog fuel	dry tons	
Sawdust	dry tons	

[1]For example, a wet board drop out.

Additional notes or comments:

OUTPUTS FROM PLANING - Air Emissions

The values for air emissions in the following table come from the sawmill=s operating permit (s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Air Emissions[1]	Quantity	Units	Sampling Procedure[2]
Dust		lbs	
Particulate		lbs	
SO_2		lbs	
NO_x		lbs	
CO_2		lbs	
CO		lbs	
VOC		lbs	
Acetaldehyde		lbs	
Acrolein		lbs	
Formaldehyde		lbs	
Methanol		lbs	
Phenol		lbs	
Propionaldehyde		lbs	
Other HAPS[3]		lbs	
Other[3] organics			
Other[3] inorganics			

Notes: [1]The following are examples of other air emissions: Cl_2, F_2, H_2S, H_2SO_4, HCl, HF, Hg, N_2O, NH_3, Pb, SO.

[2] Such as EPA or state method or indicate source of value such as AP-42.

[3] Please list compounds included in these categories

Additional notes or comments:

OUTPUTS FROM PLANING - Liquid Emissions

The values for liquid emissions in the following table come from the sawmill=s operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions	Quantity	Con--centration	Units	Sampling Procedure
Suspended solids				
BOD				
COD				
Oil and Grease			gal	
HAPs			lbs	

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

OUTPUTS FROM PLANING - Solid waste

Solid Waste	Quantity	Units	MC, % (dry basis)	How measured
Wood		lbs	%	
Bark		lbs	%	
Inorganic materials		lbs		
Non-wood organic materials		lbs		
Other organic materials		lbs		

Additional notes or comments:

EMISSIONS CONTROL ON PLANING EQUIPMENT

Include devices for air emissions such as cyclones, baghouses, ESPs, and RTOs. For water emissions, explain how runoff or other water discharges are controlled.

Emission control device (ECD) - Electricity and fuel usage					
		ECD 1	ECD 2	ECD 3	ECD 4
Type of device					
Manufacturer and year installed					
Equipment controlled					
Electrical	[1]usage, kW-hrs				
	included in energy table, Y or N				
Natural gas	[1]usage, 10^6 ft^3				
	included in energy table, Y or N				
Type of emissions controlled					

[1]Or state other units

TRANSPORTATION WITHIN PLANERMILL AND TO SHIPPING POINT

Transportation within or from planer (but not off-site shipping)	Distance (feet)	Type of equipment used	Fuel	
			Type	Included in energy inputs? Y or N
From planer to shipping				

Additional notes or comments:

APPENDIX 2: BOILER SURVEY

The second survey designed to obtain additional boiler and drying information is in this appendix. The text of the survey has been condensed to 13 pages from 16 pages by removing the spaces left for mills to respond. The footer has been removed and tables have been allowed to run across pages (they did not in the original). Some fonts have been reduced from the original. Some fonts have been reduced from the original.

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

LIFE CYCLE INVENTORY ANALYSIS OF THE
WESTERN SOFTWOOD DIMENSION LUMBER INDUSTRY

The information from this survey will be used by CORRIM II, a consortia of university, industry, and government groups. CORRIM II is conducting a life-cycle assessment that will describe the environmental influences of building materials. The objective is to acquire a database and produce life-cycle models of the environmental performances for building materials. This will allow construction practices to be compared, for example, comparing the overall environmental benefits of wood versus steel or concrete walls.

Company Name: ____
Mill Address: ____
____

Mill ID code ______________________
Contact Person:____
Position/Title: ____
Telephone: ________________ Fax: ____________________
AF&PA MemberY N

Questions should be directed to :

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Phone (541) 737-4210
FAX (541) 737-3385

Mike.Milota@orst.edu

LIFE CYCLE INVENTORY ANALYSIS OF THE
WESTERN SOFTWOOD DIMENSION LUMBER INDUSTRY

Please complete the tables for any convenient 12-month period (a calendar year or your fiscal year). Provide as much detail as possible. Please contact Mike Milota if you have questions. Any additional comments, clarifications or observations you might care to add would be appreciated. Units are generally specified, but if you have other units that are easier to use, please cross off our units and add yours. If you do not know the quantities at the level of detail requested, group by category. For example, provide a value for all HAPs if the quantities of individual compounds are not known.

Thank you for the time and effort to fill in the blanks.

Why this is important: When wood is burned, non fossil CO_2 is emitted. When natural gas is burned, fossil CO_2 is emitted (the carbon comes from mines). Nonfossil CO_2 is recycled back into the trees that the forest industry grows and has no net effect on global warming, an advantage over the steel and concrete industries. We want to quantify this as accurately and completely as possible. We have already surveyed the material and energy inputs and outputs for most aspects of lumber production, but we felt our boiler data was not representative of the industry. We are therefore surveying more mills, but for boiler information only.

Confidentiality: In the past, we have reported industry average numbers. Where individual data is cited, we list it on a unit of production basis, so there's no indication of what mill it came from. For example, we might present lbs of wood burned per pound of steam produced for an unnamed mill. This way a reader does not have enough information (such as mill size, or species produced) to determine the origin of the data.

Mill ID Code:		
Reporting year:	**Starting Month:**	**Ending Month:**

Mill type (please check one):

- o Dimension mill
- o Stud mill
- o Other (specify)____________________

Lumber Production

- ! for reporting year __________ million board feet
- ! percent of production that is kiln dried __________ %
- ! percent of production that is dimension lumber __________ %

Indicate the capacity of each boiler:

Boiler	Size (BTU/hr, hp, or lbs/hr of steam)	Fuel type	Year of Construction
#1			
#2			
#3			

% of steam produced that is used to dry lumber ___________ %
(This is very important for mills with other dryers, presses, steaming vats, etc. so that the correct proportion of the energy and emissions can be assigned to lumber drying)

If present, please indicate the cogeneration facility capacity:

Electricity (kW or MW)	Process heat (BTU/hr)	Fuel type	% sold off site	
			electricity	process heat

Energy inputs to Boiler #1

Fuels	Units	Quantity
Wood, bark, etc.	lbs	**WET WEIGHT: ___________ LBS** **APPROXIMATE MC ____ %** **IS THIS WET- OR DRY-BASIS? WET DRY** For clarity, please estimate the bone-dry weight of fuel: _______ lbs
Natural gas	1000 ft^3	
Diesel Fuel	gal	
Propane	gal	
Electricity (purchased)	kW-hr	
Electricity (self-generated)	kW-hr	

Energy outputs from Boiler #1

Products	Quantity	Pressure	Units	Where does it go?	% sold or sent off site
Steam			lbs / psig		
Electricity			kW-hr		

Additional notes or comments:

Energy inputs to Boiler #2

Fuels	Units	Quantity
Wood, bark, etc.	lbs	**WET WEIGHT: __________ LBS** **APPROXIMATE MC ________ %**
Natural gas	1000 ft^3	
Diesel Fuel	gal	
Propane	gal	
Electricity (purchased)	kW-hr	
Electricity (self-generated)	kW-hr	

Energy outputs from Boiler #2

Products	Quantity	Pressure	Units	Where does it go?	% sold or sent off site
Steam			lbs / psig		
Electricity			kW-hr		

Additional notes or comments:

Energy inputs to Boiler #3

Fuels	Units	Quantity
Wood, bark, etc.	lbs	**WET WEIGHT: _________ LBS** **APPROXIMATE MC ________ %**
Natural gas	1000 ft^3	
Diesel Fuel	gal	
Propane	gal	
Electricity (purchased)	kW-hr	
Electricity (self-generated)	kW-hr	

Energy outputs from Boiler #3

Products	Quantity	Pressure	Units	Where does it go?	% sold or sent off site
Steam			lbs / psig		
Electricity			kW-hrs		

Additional notes or comments:

EMISSIONS CONTROL ON ENERGY GENERATING EQUIPMENT

Include devices for air emissions such as cyclones, baghouses, ESPs, and RTOs. For water emissions, explain how runoff or other water discharges are controlled.

		Boiler #1	Boiler #2	Boiler #3
Type of device				
Manufacturer and year installed				
Electrical	usage, kW-hrs			
	included with boiler energy use?	Y N	Y N	Y N
Natural gas	[1]usage, 10^6 ft^3			
	included with boiler energy use?	Y N	Y N	Y N
Type of emissions controlled				

Air Emissions from Boiler #1

The values for air emissions in the following table come from the sawmills operating permit(s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide sampling procedure)

Air Emissions	Quantity	Units	Sampling Procedure[1]
Dust		lbs	
Particulate		lbs	
SO_2		lbs	
NO_x		lbs	
CO_2		lbs	
CO		lbs	
VOC		lbs	
Acetaldehyde		lbs	
Acrolein		lbs	
Formaldehyde		lbs	
Methanol		lbs	
Phenol		lbs	
PROPIONALDEHYEDE		lbs	
Other HAPS[2]		lbs	
OTHER ORGANICS[2]			
Other inorganics[2]			

Notes: [1]Such as EPA or state method or indicate source of value such as AP-42.

[2] Please list compounds included in these categories

Additional notes or comments:

Liquid Emissions from Boiler #1

The values for liquid emissions in the following table come from the sawmill's operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions	Quantity	Concen-tration	Units	Sampling Procedure
Suspended solids				
BOD				
COD				
Oil and Grease			gal	
HAPs			lbs	
Other				

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

Solid waste from Boiler #1

Solid Waste	Quantity	Units	How measured
Ash		tons	
Inorganic materials		tons	
Non-wood organic materials		tons	
Other organic materials		dry tons	

Additional notes or comments:

Air Emissions from Boiler #2

The values for air emissions in the following table come from the sawmills operating permit(s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide sampling procedure)

Air Emissions	Quantity	Units	Sampling Procedure[1]
Dust		lbs	
Particulate		lbs	
SO_2		lbs	
NO_x		lbs	
CO_2		lbs	
CO		lbs	
VOC		lbs	
Acetaldehyde		lbs	
Acrolein		lbs	
Formaldehyde		lbs	
Methanol		lbs	
Phenol		lbs	
PROPIONALDEHYEDE		lbs	
Other HAPS[2]		lbs	
OTHER ORGANICS[2]			
Other inorganics[2]			

Notes:[1] Such as EPA or state method or indicate source of value such as AP-42.

[2] Please list compounds included in these categories

Additional notes or comments:

Liquid Emissions from Boiler #2

The values for liquid emissions in the following table come from the sawmill's operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

	Water Emissions	Quantity	Concen-tration	Units	Sampling Procedure
	Suspended solids				
	BOD				
	COD				
	Oil and Grease			gal	
	HAPs			lbs	
	Other				

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

Solid waste from Boiler #2

	Solid Waste	Quantity	Units	How measured
	Ash		tons	
	Inorganic materials		tons	
	Non-wood organic materials		tons	
	Other organic materials		dry tons	

Additional notes or comments:

Air Emissions from Boiler #3

The values for air emissions in the following table come from the sawmills operating permit(s).

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide sampling procedure)

AIR EMISSIONS	Quantity	Units	Sampling Procedure[1]
Dust		lbs	
Particulate		lbs	
SO_2		lbs	
NO_x		lbs	
CO_2		lbs	
CO		lbs	
VOC		lbs	
Acetaldehyde		lbs	
Acrolein		lbs	
Formaldehyde		lbs	
Methanol		lbs	
Phenol		lbs	
PROPIONALDEHYEDE		lbs	
Other HAPS[2]		lbs	
OTHER ORGANICS[2]			
Other inorganics[2]			

Notes: [1] Such as EPA or state method or indicate source of value such as AP-42.

[2] Please list compounds included in these categories

Additional notes or comments:

Liquid Emissions from Boiler #3

The values for liquid emissions in the following table come from the sawmill's operating permit

o Yes (if possible, provide a copy of the pertinent sections)

o No (provide details in sampling procedure)

Water Emissions	Quantity	Concen-tration	UNITS	Sampling Procedure
Suspended solids				
BOD				
COD				
Oil and Grease			gal	
HAPs			lbs	
Other				

Note: The following are other examples of the data categories associated with water effluent: Acids as H^+, Cl^-, CN^-, detergents, dissolved organics, F^-, Fe ions, Hg, hydrocarbons , Na^+, NH_4^+, NO_3, organo-chlorine, metals, N, phenols, phosphates, SO_4.

Additional notes or comments:

Solid waste from Boiler #3

Solid Waste	Quantity	Units	How measured
Ash		tons	
INORGANIC materials		tons	
Non-wood organic materials		tons	
Other organic materials		dry tons	

Additional notes or comments: