AN ABSTRACT OF THE THESIS OF

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James B. Wilson

Softwood plywood is one of the structural wood products studied in the CORRIM II effort to document the environmental performance of wood product in residential structures. Life-cycle inventory (LCI) models were developed to provide performance data for plywood production by tracking all of its inputs and outputs in a gate-to-gate analysis. The models divided the plywood process into the primary subunit processes of debarking and bucking, log conditioning, peeling and clipping of veneer, veneer drying, lay up and hot pressing of plywood, and trimming and sawing. A hogged fuel fired boiler process and a phenol formaldehyde production model were also included. Modeling plywood production with subunit processes provided detailed analysis of the operation and enabled optimization studies. Model inputs were electricity, fuel, and materials of wood in the form of logs and adhesive, while the outputs were plywood, wood co-products, and environmental emissions to the air, land and water. SimaPro, an environmental impact assessment software package, was used to analyze the data to provide an LCI. The study was done for two major wood producing regions of the United States - the Pacific Northwest and the Southeast. Various process scenarios were modeled, providing useful information such as a sensitivity of input parameters and an impact assessment of the type of fuel used to generate heat for processing. A carbon balance of wood used in plywood manufacturing was performed to compare the amount of carbon going into plywood production with the amount of carbon coming out as materials and emissions. Finally, a cost analysis was done to compare plywood production costs with the open market selling price of plywood. Electricity, fuel, and

resin use contributed a significant amount of emissions in plywood production. Log conditioning, veneer drying, and panel pressing subunit process consumed more than half the electricity used (55%) and also used all the heat energy inputted into the process. The sensitivity analysis of switching fuel sources for heat energy indicated that natural gas used as a fuel input, resulted in higher greenhouse gases (CO_2 (fossil), methane, NO_X, SO_X) emissions when compared to hogged fuel comprised of bark and wood waste. Hogged fuel used as a fuel resulted in less CO_2 (fossil) emissions but increased in CO and phenol emissions (hazardous air pollutant) when compared to natural gas. A carbon balance documented all carbon material and compared the wood inputs with wood related outputs including plywood, co-products, air and solid emissions. The carbon balance can be used as a benchmark to continue research of the carbon cycle to reduce greenhouse gas, CO_2. The model can be used as a tool in developing useful strategies for examining the consequences of process and equipment changes, and for optimizing the environmental performance of a process.

Life-Cycle Inventory of Plywood Manufacturing in the Pacific Northwest and the Southeast United States

by
Eric T. Sakimoto

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APPROVED:

Redacted for privacy

Major Professor, representing Wood Science

Redacted for privacy

Head of Department of Wood Science and Engineering

Redacted for privacy

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Eric T. Sakimoto, Author

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INTRODUCTION

Life-cycle inventory of plywood manufacturing

Life-cycle inventories (LCI) of wood products can be used as a tool or information base when addressing the environmental impact of producing and using wood products, as well as other products. LCI provides quantitative outputs that can be used to evaluate the environmental performance of wood products and are important components of life-cycle assessments (LCA). LCI do not assess environmental impact, in that, they do not develop conclusions of the effect of effluent emissions or risk to human health, rather they provide an accounting of all inputs and outputs. The current study reports an LCI of plywood manufacturing in the United States and can be used as a benchmark to address environmental performance and as a measure for means to optimize performance.

In the 1970's, environmental studies in forest products started with the Committee on Renewable Resources for Industrial Materials (CORRIM) that researched the impact of the use of energy and raw materials in the production of wood products (CORRIM, 1976). A few decades later, in 1990, the Consortium for Renewable Resources for Industrial Materials (CORRIM II) was formed to provide an environmental assessment of structural wood products by using LCA methodology, which also includes LCI. The CORRIM II effort greatly expanded upon the goals and objectives of the original CORRIM study. In North America, LCA of wood products were initially started in Canada by Forintek, which later founded a company called ATHENA™ to continue this effort. ATHENA™ participates in the CORRIM II effort. The CORRIM II task addresses contemporary issues of materials, energy and electricity consumption, and emissions to air, water and land. As environmental regulations became stricter, studies were performed to find ways to reduce air emissions. For example, the American

Forestry and Paper Association (AF&PA) conducted a study to decide how to best control effluent emissions (Sauer, et al., 2002).

Sensitivity analysis of fuels used for heat generation

A sensitivity analysis was conducted to look at the effects of using different fuel sources for heat generation. Currently, there are two fuel sources used, hogged fuel, which is comprised of bark and wood waste and natural gas. This analysis used the plywood manufacturing model created in an LCI software program called SimaPro 5.0.009, using all natural gas and all self-produced hogged fuel for heat generation. Three scenarios were modeled, first comparing all natural gas versus the "as is" original plywood model, with no fuel changes and incorporates both, natural gas and hogged fuel. Scenario two compared using all self-produced hogged fuel verus the "as is" original plywood model, with no changes and finally, scenario three compared using all natural gas versus all self-produced hogged fuel as a fuel for heat.

Carbon balance of input of materials and outputs of products, co-products, and emissions

From the sensitivity analysis, a carbon balance was done to assign carbon mass to all wood materials going into and out of the plywood process. Information of wood inputs into plywood manufacturing came from weighted primary data, while the outputs came from SimaPro 5.0.009 LCI, using FAL database. Carbon percentage values of wood came from a separate study by R.A. Birdsey in 1994 and carbon mass values of emission compounds came from the Merck Handbook or was hand calculated based on chemical formula.

Cost analysis of the production of softwood plywood

The final study done was a cost analysis comparing the cost to produce plywood and the market price for sheathing plywood (MSF 3/8-inch basis). Production cost for plywood manufacturing included variable cost of electricity and fuel consumption (hogged fuel, natural gas, liquid propane gas and diesel) and raw materials (logs, veneer and PF resin) and fixed cost of capital, maintenance and labor. Plywood and other co-products that were sold, were added together and then subtracted from the production cost to come up with either a value of profit or loss.

LITERATURE REVIEW

Background

CORRIM I

CORRIM I was formed in 1974 at the request of the National Research Council and tasked with assessing the energy and material use on renewable resources. CORRIM I was divided into six panels, with each panel focusing on a particular renewable material, Panel II looked at Wood for Structural and Architectural Purposes.

CORRIM I's objectives were to study renewable resources and their importance as an industrial material and as an energy source. Additionally, this study focused on the energy and fuel usage of each evaluated process. They were concerned with how much energy was being consumed to produce a wood product. Wood products were also compared to non-renewable resources on energy consumption for their production (CORRIM, 1976).

CORRIM I reported that wood is the primary and only useable resource appropriate for structural and architectural uses. Secondly, the report found that energy use was the major impact related to wood product production. Finally, CORRIM I compared wood products to similar mineral-based components (i.e. steel) and found that it takes more energy to produce mineral-based components. For example, the report stated that a steel floor joist used 50 times more energy than its wood counter part and that aluminum framing required 20 times more energy than wood studs (CORRIM, 1976).

From this study, CORRIM I concluded that renewable resources could be used in place of non-renewable resources to limit energy use, conserve non-renewable material supplies and relieve dependence of imported materials and energy (CORRIM, 1976).

CORRIM II

In the 1990s, LCI and LCA were incorporated to conduct environmental analyses of wood structural products in the U.S. This was implemented to grasp an idea of how the processing and utilization of forest products affected the global environment and as a means to develop logical options to improve on the environmental performance of the industry as a whole. CORRIM II was created to conduct this research (Bethel and Bowyer, 1997).

There are four main objectives for the CORRIM II study. The first objective was to develop an adequate and proficient U.S. life-cycle database and models of wood building products. The second objective was to incorporate all wood products used in a residential home in Atlanta and Minneapolis, two cities representing climatic extremes (i.e. a hot, humid southern versus a cold northern climate, respectively). The third objective was to update and expand upon the information from the original CORRIM study done in the 1970s. The final objective was to examine management, product, and process alternatives that can improve the environmental performance.

Currently CORRIM II is in phase I of their effort, which is to create a U.S. LCI database of wood building products and an LCA of the example building structures for the two cities. The research focuses on wood products produced in two regions in the United States, the Pacific Northwest (PNW) and the Southeast (SE) with the exception of oriented strand board (OSB), which is only produced in the SE. In contrast, phase II will focus on non-structural wood products and expand the regions of the study to the North central (NC), Northeast (NE), and Inland West (CORRIM, 2001).

Environmental regulations on wood products

Federal environmental policy regulating emissions released by exhausts of boilers, dryers and hot presses has affected the forest products industry by requiring installation of emission control devices to mitigate these emissions. The 1990 amendments to the Clean Air Act (CAA) set standards for major point sources that emit greenhouse gases and Hazardous Air Pollutants (HAP). HAP are characterized as a known or suspected carcinogen and can cause damage to the nervous and respiratory systems. The 1990 amendments listed 189 substances to be regulated as HAP (Godish, 1997). All of these pollutants have different toxicity and complete information of their effects and minimum acceptable exposure levels have yet to be fully researched and evaluated. Of this list of 189 substances, only six HAPs are of concern in the forest product industry which include: acetaldehyde, acrolein, formaldehyde, methanol, phenol and propionaldehyde.

Another important aspects of the 1990 amendment were permits. Major emitters of HAP are required to file for a state Title V, if a source emits 10 tons/year of a specific HAP or 25 tons/year of any HAP combination. Also included in this permit is the requirement to install Maximum Achievable Control Technology (MACT) to maximize the reduction of the HAP of concern (Kubasek and Silverman, 2000; Williamson, 2001). In plywood manufacturing, control devices such as Regenerative Thermal Oxidizers (RTO) or Regenerative Catalytic Oxidizers (RCO) are currently being implemented as MACT (Jaasund, 2000). Also used in upstream of these control devices are bag houses and wet electrostatic precipitator (WESP) to reduce particulate emissions that can cause flow problems in RCOs and RTOs (Jaasund, 2000).

Environmental research in forest products

In Canada, Forintek conducted an LCA of wood and non-wood building products as components of a "typical exterior infill wall assembly used in light commercial structures" (Meil, 1993). This study compared products such as 20-gauge nonstructural steel studs to 2 x 4 wood studs. "The ultimate goal is to make available a simple model which will enable the building community to assess the relative environmental implications of using various building materials in defined applications" (Meil, 1993). In 1996, Forintek developed environmental LCI data for more than 35 structural products and also developed a software model for impact assessment, known as ATHENA™ (Meil and Trusty, 1996).

A preliminary U.S. LCA model of plywood and laminated veneer lumber (LVL) manufacturing was conducted, utilizing secondary data to model plywood and LVL production (Ferrari, 2000). He concluded that log conditioning, veneer drying and hot pressing of plywood processing had the greatest effect on the environment (Ferrari, 2000). This study by Ferrari was used as a basic skeleton of the model developed in this current report.

The U.S. Environmental Protection Agency (USEPA), the National Council For Air and Stream Improvement (NCASI) and AF&PA conducted a study to determine how effective each type of control device is in reducing effluent emission. This study was called the "Wood Products MACT Study" and its purpose was to assist in the development of MACT standards (NCASI, 1999).

In 2002, the AF&PA released a report on the "Life-Cycle Inventory of Emission Control Systems Used in the Manufacture of Wood Products." This report's objective was to find the environmental performance of using an end-of-line control device to limit Volatile Organic Compounds (VOC) and HAP emissions from drying and pressing processes of wood production. The three control devices evaluated included RCO, RTO and biofilters (BF). The conclusion was that major environmental burdens of LCI came from the consumption of electricity and natural gas to operate the control devices. As a result, BF had the lowest life-cycle burden, followed by RCO and RTO (FAL, 2001). Further, using no control devices had the lowest life-cycle burdens over all control devices in energy, solid waste, NO_X, SO_X and other greenhouse gases (Sauer, et al, 2002).

Energy and raw materials

In 2000, energy shortages arose in California that caused sporadic blackouts in major metropolitan areas and required assistance from neighboring states. This unexpected occurrence greatly impacted the price of electricity and natural gas towards the consumer. This event has placed more emphasis on CORRIM's LCI and LCA study of wood products. Reasonably, this study can be used as a reference for energy and electricity requirement in wood product production in the United States and help further research on energy issues, including utilization of renewable resources and alternatives to effectively conserve energy consumption.

It was also stated previously, that CORRIM I concluded that energy and electricity had the biggest impact for wood production. This was also true for plywood manufacturing and as a result, the type of fuel used in plywood manufacturing will be an important issue discussed in this current study.

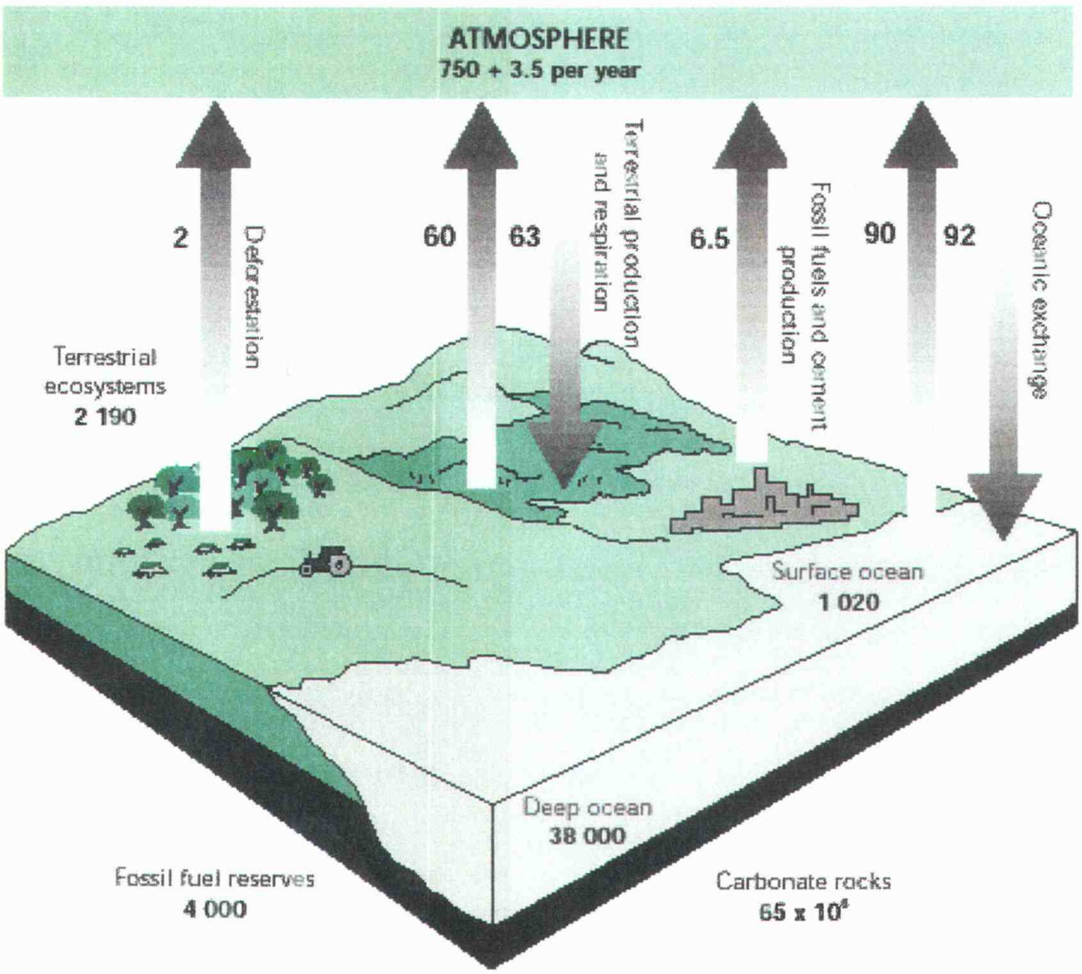
Similar conservation interest besides energy are raw material utilization. Renewable resources (i.e. wood) can be used to replace non-renewable resources to reduce energy consumption and dependance of non-renewable resources (CORRIM, 1976). For example, steel is produced from extracted iron. Once iron is extracted, it cannot be regrown like wood and therefore is limited. Energy requirement for extraction and production of steel are higher than similar wood-based products (CORRIM, 2001). Trees are renewable and can forever be used as long as consumption is balanced with regrowth. This is an extreme point, but is an important reason why material utilization was focused on in this current study.

This paper addresses one particular aspect of the life-cycle of plywood, with the primary objective of developing an LCI for the production of plywood in the Pacific Northwest and the Southeast. This information and results from this study will be useful to policy makers, wood buyers, and mill managers to facilitate the inclusion of environmental factors in their decision-making process.

The role of forests in the storage of carbon

The element carbon was tracked throughout the "gate-to-gate" study of softwood plywood manufacturing. Wood has been a storage for carbon similar to the ocean and is estimated that forest activity of carbon exchange account for more than 2/5 of the total exchange carbon between the earth and the atmosphere. Of the 2/3, forest account for 80% of the carbon exchange (FAO, 2001). With this in mind, forest management and wood products can affect the global carbon cycle in many ways, such as a carbon storage in forests, in wood products and in fossil fuels by utilizing more biomass fuel sources (Schlamadinger and Marland, 1995). Wood as a carbon storage can be very resourceful to reduce CO_2 concentration in the atmosphere. Figure 2.1 is a current estimate of the global carbon cycle.

Figure 2.1. Current Global Carbon Cycle (FAO, 2001)



[a]All numbers are in gigatonnes (Gt) of carbon (1 Gt = 1 billion tonnes).

Note: The magnitude of the fluxes between the atmosphere and the oceans and terrestrial biosphere is still uncertain and is the subject of ongoing research.

Objectives

The specific objectives of conducting an LCI for plywood in the PNW and SE are:

1. Assist CORRIM II in conducting LCA of wood building materials by creating an LCI of plywood manufacturing,
2. create a model for plywood manufacturing,
3. obtain an LCI for plywood in the PNW and SE that can be used as a benchmark,
4. obtain an LCI of plywood model in the PNW and SE based on site emissions, which exclude those associated with fuel, electricity and resin inputs and their subsequent emissions for comparison with objective #3,
5. investigate the environmental impacts of fuel, electricity, and resin use,
6. analyze major impact contributors in the plywood process by conducting a sensitivity analysis,
7. complete an LCI sensitivity analysis of fuel substitution between renewable and non-renewable resources,
8. perform a carbon balance for plywood manufacturing, and
9. conduct an annual cost analysis of plywood manufacturing

MATERIALS AND METHODS

Plywood model description for the PNW and SE

Softwood plywood sheathing

Softwood sheathing plywood is used for structural applications such as to provide lateral stability between stud members in home wall construction and also for sub-flooring and roofing construction. Softwood plywood sheathing follows specific engineering standards for plywood use and is outlined by the APA Engineered Wood Association's Voluntary Product Standard PS 1-95 and PS 2-92 (APA, 1995, 1992).

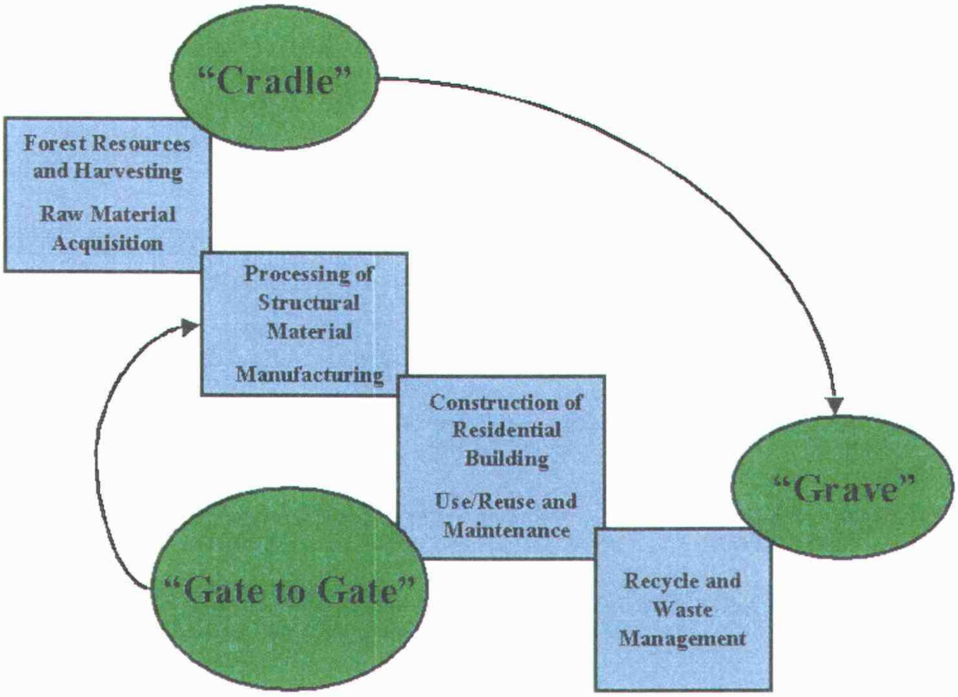
LCA and LCI description

The current study developed an LCI for plywood manufacturing in the Pacific Northwest and the Southeast regions of the U.S. While this study was not a complete LCA, in order to completely understand what and how LCI works, it needs to be addressed.

> "LCA is an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials uses and releases on the environment, and to evaluate and implement opportunities to affect environmental improvements."
>
> (SETAC 1994)

LCA is a "cradle-to-grave" study of activities or processes and can be divided into sections described as "gate-to-gate" steps. The current LCI study for softwood plywood manufacturing was a "gate-to-gate" study, starting with logs entering the mill and ending with plywood as a product. All information described in this section was based on International Organizations Standards (ISO, 1997) for conducting LCI studies. Figure 3.1 is an illustration of a life-cycle for wood products.

FIGURE 3.1. Life-Cycle Flow Diagram



The LCA describes environmental aspects as well as potential impacts that is influenced by the process of concern. An LCA can be used:

1. To identify opportunities to improve the environmental aspects of products at various points in their life-cycle;
2. For decision-making in industry, governmental or non-governmental organizations;
3. To make selections of relevant indicators of environmental performance, including measurement techniques; and
4. To market products (ISO, 1997)

The LCA of any product includes four parts: goal and scope, inventory analysis (LCI), impact assessment and interpretation of results or improvement assessment (ISO,1997). Anything else that is not included or described in the LCA framework are beyond the scope of the study.

LCI is what is done in this current study and is an important stage that requires specific data of all inputs and outputs of the process of concern. The most effective type of data can come from direct contacts to manufacturing mills through the use of surveys. Inputs include raw materials, energy consumption and electricity use. All inputs into a model have an LCI database with emission data into the environment and is allocated to each output. Outputs include product and co-products and each of these outputs have emissions into the air, land and water. For example, if you had an LCI of the product plywood, it would be a list of emissions that were released into the environment.

An LCI database is available for various raw materials and fuels and is inputted to model new processes. For example, a LCI database of different types of electricity generation have been completed and inserted into the plywood model to create its LCI. The database of electricity generation from coal would include combustion air emissions from burning coal as well as precombustion energy, electricity and transportation burdens to the power plant (PRe′ Consultants B.V., 2001). LCI databases of this sort are considered "cradle-to-gate" processing and you would input these databases into your model to complete the life-cycle for your process.

If a process is entered into the model and does not have an LCI, then the specific process will be listed in the LCI as inputted. To avoid this, information of the product to produce and transport the product is collected in a "cradle-to-gate" LCI model. An example
for softwood plywood modeling would be phenol-formaldehyde (PF) resin. There is currently no LCI database on PF production in the United States and as a result, information on the production of PF resin including raw materials, energy and transportation was gathered, from ATHENA™.

Data collection

Primary and secondary data were used to obtain the necessary information of inputs and outputs of plywood manufacturing. Primary data were gathered by surveys to specific plywood manufacturing mills and collected data on total production, inputs of raw materials, fuels, and electricity and outputs of plywood, co-products, and emissions into the air, land, and water (Wilson and Sakimoto, 2002). This information was the foundation for detailing the model of inputs and outputs in the plywood process.

Data collected from secondary sources included electricity generation by region, environmental burdens of non-wood materials, and production and combustion of fuels. This information came from the U.S. Department of Energy (USDOE), U.S. Environmental Protection Agency (USEPA), National Council for Air and Stream Improvement (NCASI), ATHENA™, and Franklin Associate, Limited (FAL) (USDOE, 2000; USEPA, 1999 and 2001; ATHENA, 1993; FAL, 2001).

The survey covered ten mills in two geographical regions: the Pacific Northwest which included Oregon and Washington and the Southeast which included Alabama, Georgia, Louisiana, Mississippi, Florida, Arkansas, and Texas. For the PNW region, the five softwood plywood mills (1,233,424 MSF 3/8-inch) that were surveyed equaled 27% of the total regional annual production of 4 billion square feet (3/8-inch basis). The total annual production of plywood surveyed, in the PNW, represented 7.1% of all U.S. production of plywood (17,475,000 MSF 3/8-inch) and 4.2% of all U.S. structural panel products (29,381,000 MSF 3/8-inch), which included (OSB). In the SE, five mills were surveyed equaling 14% of the total regional annual production of 9.8 billion square feet, 3/8-inch basis of plywood. The total annual production of plywood surveyed, in the SE, represented 7.9% of all U.S. production of plywood and 4.7% of all U.S. structural panel products, including OSB (APA, 2001). The CORRIM requirement was to attain at least 10% of production in each region. The five surveys from each region clearly surpasses the minimum requirement.

An important aspect of survey data was data quality. In order to have credible results, details should be qualified to ensure quality of data (ISO, 1997). For the modeling of plywood production, the data was recently collected in 2001. All the information collected was surveyed for the desired region. The surveys were cross referenced with each other to look for any outliers. Also, thermodynamic calculations were used for heat usage checks. Sensitivity analysis were used to signal problems in the modeling by finding outliers in the LCI. If outliers were found, changes in the inputs into the model were corrected. Any other questionable information pinpointed was corrected by contacting the specific surveyed mill to confirm or correct the data collected from the survey.

Modeling software and LCI database

A proven method to obtain an LCI for any product, process or activity, was through the use of a software computer program. For the current study, SimaPro 5.0 version 5.0.009 was used to create an LCI for plywood manufacturing. This software package was developed by PRe′, a consulting firm in the Netherlands. SimaPro 5.0 conducts LCA by the using models to imitate processes that followed ISO 14040 protocol for LCA studies (PRe′Consultants B.V., 2001). This software used LCI databases based on countries or regions because different regions use different types of fuels, electricity generations, materials and transportation methods.

In the United States, an LCI database was created by Franklin Associates, Limited. "The Franklin Associates Life Cycle Inventory data base is a leading U.S. reference resource for Life Cycle Assessment, including energy sources and a large number of products and materials" (FAL, 2002). This database is used in SimaPro 5.0 for all non-wood materials, processes and activities, including electricity and fuel burdens that release emissions into the environment.

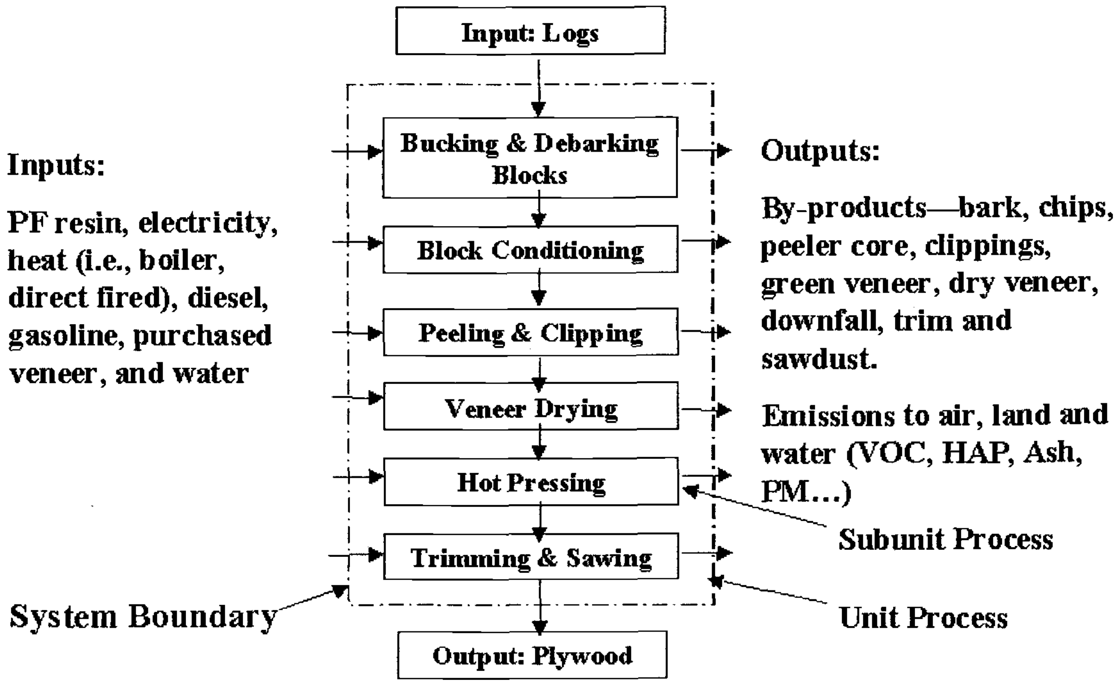
How to obtain an LCI for plywood - use a model

Since this was a gate-to-gate study, the system boundary of the plywood model included everything inside a plywood mill. All processing done inside the plywood mill was inserted into the model including the log yard and steam/heat generation. The model of plywood manufacturing was described as a unit process. Each individual process within the unit process was defined as a subunit process.

Another modeling technique that was not done in this study was a "black box" approach which does not include subunit processes. An advantage of the subunit approach over the black box approach is to identify specific subunit processes that contribute large environmental burdens and serve as a benchmark to measure the effectiveness of any process improvements. Another advantage of the subunit approach is that plywood subunit processes could be implemented into other wood product models, such as the production of laminated veneer lumber (LVL). The LVL model inputs the green end (logs to green veneer production) of plywood manufacturing and includes its associated burdens. If a black box model was used, the green end could not be incorporated into the LVL model.

Each subunit process represents a specific step to produce plywood. There are six subunit processes used to model plywood which includes debarking and bucking of logs, conditioning of logs, veneer peeling, veneer drying, layup and pressing, and trimming and sawing of plywood. Figure 3.2 depicts the system boundary and also explains each subunit process in the modeling of plywood manufacturing.

FIGURE 3.2. System boundary and subunit process of plywood manufacturing



Description of plywood subunit processes:

1. Debarking and Bucking: This process took logs and removed its bark and then bucked (sawed) them into eight-foot lengths. Co-products that were produced at this stage were bark and wood waste.
2. Log Conditioning: Used heat in the form of steam or a water bath to soften the wood so that the veneer peeler could work more efficiently, generate higher quality veneer, and reduce peeler knife wear.
3. Peeling and Clipping: The blocks were peeled into a continuous sheet of veneer by using a lathe. After the peeling of veneer, the veneer ribbon was clipped into 4' wide sheets using a veneer clipper. Co-products that were produced included peeler cores, veneer clippings and trim.

4. Veneer Drying: Veneer dryers were heated using different methods including steam, direct-fired natural gas and wood waste, and wood waste burner systems. Temperature in the veneer dryer depended on species of wood, thickness of veneer, and the specific section of the veneer dryer. On average, temperature inside a veneer dryer was around 350° F. Veneers were dried to a moisture content (MC) of 3-5%. There were a percentage of veneer that had not reached the desired MC and had to be either conditioned or re-dried. Co-products created at this stage included veneer downfall.
5. Lay up and Pressing: The veneer was coated with a thermosetting adhesive, phenol formaldehyde (PF), and pressed into panels in a multi-opening, steam-heated hot press. The press served two purposes, first, to apply pressure to have the veneers make intimate contact with each other and secondly, to transfer heat to cure the adhesive. The press platens had a temperature of 425° F and cured the adhesive at a minimum temperature of 220° F.
6. Trimming and Sawing: At this stage, the panels were trimmed to an appropriate dimension of 4' x 8'. Co-products that were created at this stage included panel trim and sawdust (Baldwin, 1995).

Model Assumptions

When the LCI model was created, conditions were identified to simplify and to set system boundaries to the model. Conditions are listed below:

1. This was a study of softwood plywood sheathing.
2. All information presented was based on a volume of plywood equal to 1.0 MSF 3/8-inch basis, which is a volume of plywood that is defined as a 1,000 square feet by 3/8-inch thickness.
3. All data gathered from primary surveys were weight averaged based on their annual production.

4. All diesel fuel was assumed to be used and consumed in the log yard and was inputted as such in the debarking and bucking subunit process.
5. Bark and wood waste is combined and labeled as "Hogged Fuel."
6. All liquid propane gas (LPG) was assumed to be used throughout the plywood process and was divided evenly among five subunit processes (20%), starting with log conditioning and ending at trimming and sawing.
7. Finished plywood panels had the dimension of 3/8" x 4' x 8'.
8. Plywood panels used PF as an adhesive resin.
9. Density value for logs were calculated from the specific gravity of wood obtained by the Wood Handbook - Wood as an Engineering Material (USDA, 1987), and based on the weighted average of percent wood use.
10. All wood materials were on an oven-dry weight with a volume at a green moisture content. Bark was the only exception and was based on a wet basis at 50% MC.
11. Co-products were defined as any product or waste that was sold outside the system boundary. All co-products have environmental impacts allocated to them based on mass percentages of their total of all products and co-products.
12. SimaPro 5.0.009 was used to obtain an LCI for plywood manufacturing (PRe´Consultants B.V., 2001). Cradle-to-gate LCI input information of wood combustion in boilers, all non-wood materials, fuels, energy and electricity use, used in the model came from FAL. The inputs from the FAL database included travel and production burdens into the environment and if combusted, included combustion emissions.
13. Propane combustion information was not available and was replaced with natural gas model for combustion emissions.
14. CO_2 emissions were divided into CO_2 (fossil) and CO_2 (biomass). These two categories separate CO_2 based on the source of fuel combusted. Fossil fuel included petroleum and natural gas products. Biomass was from self produced

hogged fuel used in boilers or direct fired fuel cells and from the wood combustion of the FAL database.

Allocation Rules

When the LCI was created for plywood, the burdens of the emissions was allocated to the product (plywood) and the co-products (wood chips, peeler core, clippings, panel trim, sawdust, wood waste, sold hogged fuel and sold veneer) based on their contribution to the total weight. The LCI that is discussed and displayed in this current report is for plywood only. The burden for the production of plywood was equal to 51% in the PNW and 48.5% for the SE of the total environmental impact.

Material flow

The materials used to produce plywood included logs (including bark), green veneer, dry veneer, and PF adhesive. Output materials from the process included plywood, bark, chips, peeler core, green clippings, dry veneer, veneer downfall, plywood trim, and sawdust.

Transportation

Transportation of logs, veneer and resin were delivered by truck. Table 3.1 shows the average mileage and lb-mile of one-way delivery for logs, veneer and resin to the mills.

TABLE 3.1. Delivery distance for one-way travel of materials for plywood production

Material Delivery	PNW Miles	SE Miles
Logs	60	97
Veneer	75	153
Resin	122	98

Wood density calculation

The mass of the wood material was calculated from log volume data collected as Scribner scale in the PNW and Doyle in the SE from the surveys and was converted to cubic feet (ft^3) (Briggs, 1994). Once converted, the volume was multiplied by the average density of the logs (lb/ft^3) to obtain the log's mass. The surveys from the PNW used four different wood species to produce plywood. The species were Douglas-fir, Spruce, Hemlock-fir, and Larch, with Hemlock-fir including Western Hemlock and true-firs. The combined densities of the species were calculated based on the percentage used in the surveys. The average wood density for the PNW was determined to be 27.3 lb/ft^3. In the SE, the species used are loblolly and slash pine. The average wood density for these pines was 31.5 lb/ft^3. Table 3.2 gives the density calculations for the PNW and the SE.

TABLE 3.2. Average density for wood species in the PNW and SE

PNW - Wood Density				
Wood Species	Percentage Use in Survey	Specific Gravity[1/]	Density[2/]	Weighted Average Density
	%		lb/ft^3	lb/ft^3
Douglas fir[3/]	67.6	0.45	28.1	19.0
Spruce[4/]	11.6	0.37	23.1	2.7
Hemlock fir[5/]	16.8	0.42	26.2	4.4
Western Larch	4.0	0.48	30.0	1.2
Total	100			27.3
SE - Wood Density				
Loblolly	50	0.47	29.3	14.7
Slash	50	0.54	33.7	16.8
Total	100			31.5

1/ Specific Gravity based on an oven dry weight and volume at green moisture content comes from the Wood Handbook: Wood as an Engineering Material (1987) 4-12 - 15

2/ Specific Gravity multiplied by the density of water (62.4 lb/ft^3) to give oven dry density

3/ Coastal West

4/ Sitka Spruce

5/ Species grouping including Western Hemlock and true-firs

Inputs and outputs

In the PNW, to produce a MSF 3/8-inch basis of plywood would require 65.6 ft^3 (see Table 3.3) of wood from the logs. Using the average density for the PNW, the mass of logs was 1,788 lb/MSF 3/8-inch basis (excludes bark). Also, other wood inputs needed for the production of plywood in the PNW included 6.0 lb and 14.2 lb of dry and green veneer, respectively. The wood inputs produced 937.1 lb. (1 MSF 3/8-inch basis) of plywood and 197.8 lb of bark (wet weight) which was used in a wood boiler to produce heat in the form of steam or in fuel cells to direct fire.

In the SE, a MSF 3/8-inch basis of plywood would require 66.0 ft^3 of logs equaling 2,080 lb. Other wood inputs used for plywood production included 8.0 lb and 10.0 lb of dry and green veneer, respectively. The wood inputs produced 1,083 lb of plywood and 247.7 lb of bark (wet weight) which was inputted into the wood boiler. The difference in plywood mass between the two regions was contributed to the wood species, each having a different density. The inputs for the PNW and SE are listed in Table 3.3 and included inputs from electricity, energy and PF resin.

TABLE 3.3. Inputs to produce 1.0 MSF 3/8-inch basis of plywood in the PNW and SE

Materials[1/]	**Units**	**PNW Plywood per MSF 3/8-inch basis**	**SE Plywood per/MSF 3/8-inch basis**
Roundwood (logs without bark)	ft^3	65.60	65.99
	lb.	1,788	2,079
Phenol-Formaldehyde Adhesive	lb.	15.88	19.70
Extender and Fillers	lb.	8.90	12.60
Catalyst[2/]	lb.	1.11	1.40
Soda Ash[2/]	lb.	0.33	1.58
Bark[3/]	lb.	197.8	247.7
Purchased			
Dry veneer	lb.	6.43	8.07
Green veneer	lb.	14.23	10.44
Electrical Usage			
Electricity	kWh	138.9	122.0
Fuel Usage			
Hogged Fuel (produced)[3/]	lb.	382.7	386.8
Hogged Fuel (purchased)[3/]	lb.	34.0	91.58
Wood waste	lb.	0.50	60.7
Liquid propane gas	Gallons	0.36	0.42
Natural gas	ft^3	163.4	242.4
Diesel	Gallons	0.40	0.27

1/ All materials unless noted, are given as an oven-dry basis or solids weights

2/ These materials were not included in the SimaPro LCI analysis; excluded based on the 2% Rule

3/ Green Weight, assumed to be 50% moisture content on wet-basis - most if not all of this material is bark, plants reported 197.8 lbs of bark

Plywood and hogged fuel were not the only outputs in plywood manufacturing. Wood co-products were also produced and sold, they included wood chips, peeler core, green clipping, veneer downfall, panel trim, sawdust, wood waste and dry veneer. All of these co-products were produced in the PNW and SE except for veneer downfall in the SE. Also included as an output, but wasn't a product or co-product was bark waste and ash. These are solid emissions reported in the survey but weren't included in the plywood modeling. The wood boiler module from FAL included solid emission waste that takes the place for bark waste and ash. Table 3.4 is a listing of wood material outputs for plywood manufacturing in the PNW and the SE.

TABLE 3.4. Wood material output for the PNW and SE

OUTPUTS		**PNW**	**SE**
Product	**Unit**	**per MSF (3/8-inch)**	**per MSF (3/8-inch)**
Plywood	lb.	937.1	1,083
Co-products			
Wood Chips	lb.	425.3	645.2
Peeler Core	lb.	95.1	112.0
Green Clippings	lb.	31.0	172.7
Veneer Downfall	lb.	3.4	0.0
Panel Trim	lb.	106.8	60.6
Sawdust	lb.	9.6	4.2
Sold Wood Waste	lb.	21.0	20.5
Sold Dry Veneer	lb.	63.1	0.17
Wood Waste (to boiler)	lb.	0.5	60.7
Total Co-Products	lb.	755.9	1,076
Material Waste			
Bark Waste	lb.	13.1	77.4
Bark Ash	lb.	7.8	11.3

Mass balance

A mass balance of wood inputs and outputs was done and displayed in Table 3.5. A mass balance is a very effective way to check data quality and show that the information gathered from primary surveys are consistent. Not included in the mass balance was bark and phenol-formaldehyde adhesive because they were not wood material of specificity. Differences in total mass values between regions was due to the weighted average densification value for the PNW and the SE. Differences between regional output values included green veneer, panel trim and wood waste to boiler. Reasons of these differences included terminology interpretations and wood output grouping. How each mill grouped its wood outputs were different between each mills. For example, a particular mill lumped all of their wood outputs into one group, wood chips and did not even report green clippings, panel trim or wood waste. Whereas, another mill would have each wood output grouped accordingly depending on were it came from. A reason why the mass of green clippings were different between the PNW and the SE regions, was that pine species have relatively more wood defects and therefore when clipping veneer, more defects were found and resulted in a higher output of green clippings.

In the PNW, the difference between wood material inputs and outputs was 137 lb of wood per MSF (3/8-inch basis). This represented approximately 7.5% more input of wood mass than output of wood mass. In the SE, the difference was -33 lb of wood per MSF (3/8-inch basis). This was 1.6% less input of wood mass than output of wood mass. These are fairly close mass balances. The difference between these parameters could be anything from inconsistent tracking in mill reports or data quality issues due to conversion of various volume units to a mass basis. Whatever occurred, the mass balance difference was below 10% in both regions, and in the SE.

The plywood product represented 50% and 51% of the total output of wood mass for the PNW and SE, respectively. The percentage of wood recovered from the logs to make plywood showed excellent efficiency, considering the smaller diameter logs currently available in industry.

TABLE 3.5. Mass balance of wood components in the PNW and the SE

Mass Balance	**PNW**	**SE**
Inputs	**lb/MSF (3/8 inch basis)**	**lb/MSF (3/8-inch basis)**
Round wood (logs)[1/]	1,788	2,079
Purchased dry veneer	6.4	8.1
Purchased green veneer	14.2	10.4
Total	1,809	2,098
Outputs	**lb/MSF (3/8 inch basis)**	**lb/MSF (3/8-inch basis)**
Plywood (wood only)[2/]	916	1,055
Wood chips	425	645
Peeler core	95.1	112
Green clippings	31	173
Veneer downfall	3.4	0.0
Panel trim	107	60.6
Sawdust	9.63	4.19
Wood waste (sold)	21.0	20.5
Wood waste to boiler	0.5	61
Dry veneer (sold)	63.1	0.0
Unaccounted wood (balanced value)	137	-33.2
Total	1,809	2,098

1/ Based on Average wood density of 27.3 lb/ft^3 and 31.5 lb/ft^3 for the PNW and SE, respectively

2/ Plywood (wood only) based on estimated weight of plywood minus 80% of resin, filler, soda ash and catalyst total use.

Phenol formaldehyde (PF) adhesive

The final material component that needed to be addressed is PF adhesive. There is currently no LCI database on PF adhesive and as a result, information on the production of PF adhesive was collected from a separate study done by ATHENA™ Sustainable Materials Institute for Canada (ATHENA™ Sustainable Materials Institute, 1993). PF resin consist of 65% formaldehyde and 35% of phenol and was used to accurately input phenol and formaldehyde into the model of PF resin. In the PNW, 15.9 lb of PF were needed to produce a MSF 3/8-inch basis of plywood and in the SE, 19.7 lb. Table 3.6 list the inputs and energy used to model the production of PF adhesive.

TABLE 3.6. PF adhesive inputs and energy use

PF Resin Inputs [1/]	**PNW**	**SE**
Material	**lb/MSF (3/8-inch basis)**	
Formaldehyde	1.03E+01	1.28E+01
Phenol	5.56E+00	6.89E+00
Fuel Usage	**BTU/MSF (3/8-inch basis)**	
Heavy Oil	9.91E+03	1.20E+04
Gasoline	6.83E+01	8.47E+04
Natural Gas	1.84E+05	2.28E+05
Electricity Usage	**kWh/MSF (3/8-inch basis)**	
Electricity	1.02E+01	1.27E+01
Energy of Feedstocks	**ft^3/MSF (3/8-inch resin)**	
Natural Gas	1.38E+02	1.70E+02
	Gallon/MSF (3/8-inch resin)	
Petroleum (Gasoline)	1.71E+00	2.13E+00

1/ data obtained from Materials Balances, Energy Profiles & Environmental Unit Factor Estimates: Structural Wood Production, Athena, 1993

2/ lb/MSF 3/8 = 4.6 kg/MSM 9mm

3/ BTU/MSF 3/8 = 0.0107 MJ/MSM 9mm

4/ kWh/MSF 3/8 = 36.6 MJ/MSM 9mm

5/ ft^3/MSF 3/8 = 0.288 m^3/MSM 9mm

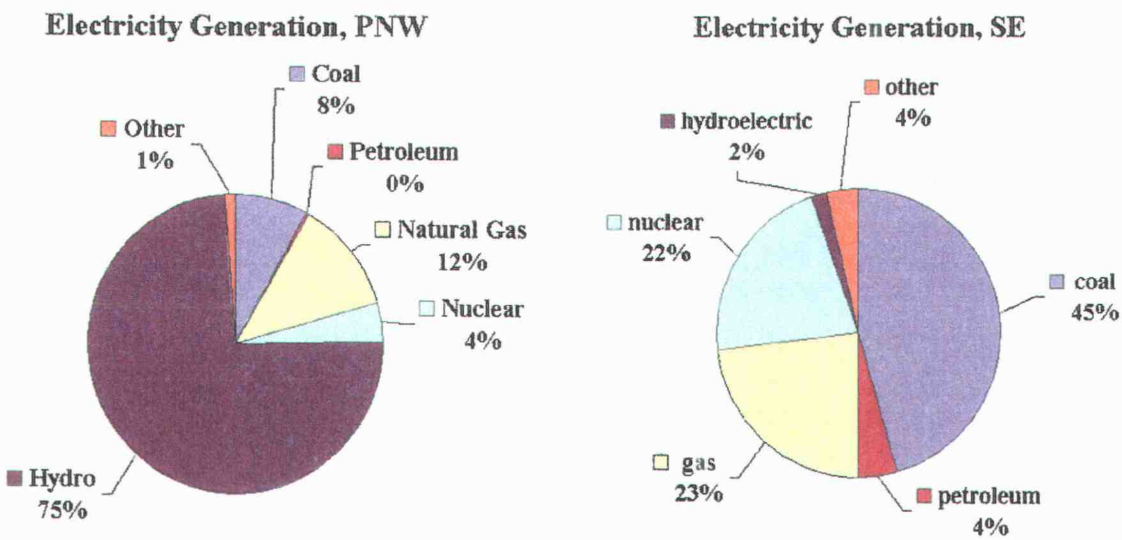
6/ gallon/MSF 3/8 = 38.54 m^3/MSM 9mm

Electricity generation and distribution

Electricity was generated by a variety of fuel sources–coal, petroleum, natural gas, nuclear, hydroelectric, and renewable energy sources. Along with the generation of electricity were environmental burdens associated with raw material acquisition and combustion emissions. Each type of electrical generation had different amounts of emission that were released into the environment. With this in mind, it would have significant results in the LCI.

For the PNW and SE regions, information on electricity generation came from the USDOE website by state (USDOE, 2000). In the PNW, the major electricity source came from hydroelectric power generation, 74.3%. In the SE, the major electricity source came from the burning of coal, approximately 43% of the total. Figure 3.3 is a pie chart that represents the distribution of electricity generation by fuel source based on the two defined regions of the United States.

FIGURE 3.3. Electricity generation by region (PNW and SE) based on fuel source



Once the electricity generation was determined, it was distributed among the six subunit processes in the plywood model. The electricity breakdown into plywood subunit processes was not included in the primary survey but was obtained from a separate study done by Oregon State University Energy Extension Office (Grist and Karmous 1998). In the production of 1.0 MSF 3/8-inch basis of plywood, 139 kWh of electricity was used in the PNW and 122 kWh in the SE. Table 3.7 describes the electricity distribution among the six subunit processes.

TABLE 3.7. Electricity distribution by subunit process for the production of plywood

Electricity Allocation by Subunit Process

Subunit Process	PNW kWh/MSF	SE[1/] kWh/MSF	Allocation Percentage [2/]
Debarking & Bucking	17.2	15.1	12.4
Log Conditioning	9.6	8.4	6.9
Peeling & Clipping	24.5	21.5	17.6
Drying	51.0	44.8	36.7
Lay-up & Sawing	15.3	13.4	11.0
Trimming & Sawing	21.4	18.8	15.4
Total	139	122	100

1/ Applied PNW electricity breakdown percentage to the SE region.

2/ Source: Ferrari, C.J., 2000. Life Cycle Assessment: Environmental modeling of plywood and Laminated veneer lumber manufacturing. Table 24, Appendix D., page 111 - Distribution of electricity use by machine centers for Oregon, applied to the PNW and SE.

Fuel usage and distribution

Fuel consumption was used for heat generation to condition logs, dry veneer and to hot press panels. The fuel inputted into plywood production included hogged fuel, wood waste, natural gas, liquid propane gasoline (LPG) and diesel. Hogged fuel, wood waste and natural gas were used for heat purposes, while diesel and LPG were used in the log yard and forklifts, respectively. Table 3.8 and 3.9 listed the total amount of each fuel type used for heat generation, its energy value in BTU's, and its percentage of the total.

In the PNW, hogged fuel accounted for 90.5% of the total energy used for heat. Hogged fuel was separated into two combustion models, wood boiler and direct-fired fuel cell because it was used in different applications and so specific models had to be devised. Hogged fuel used in the wood boiler was also separated into purchased and self-generated hogged fuel boilers. Purchased hogged fuel wood boiler included travel and production burdens (combustion data included), while self-generated hogged fuel boiler included only combustion data. Transportation of logs comprised of bark and wood were assigned to the wood for LCI modeling. CO_2 (biomass) emission came from the combustion of self-generated hogged fuel wood boiler and direct-fired fuel cell.

In the SE, hogged fuel accounted for 89% of the total energy used. Similar to the PNW, hogged fuel was separated into two boiler models for purchased and self-produced hogged fuel to address transportation burdens for purchased hogged fuel. There were no direct-fired fuel cells surveyed in the SE.

Natural gas accounted for the final 9.5% and 11% of the total energy used in the PNW and the SE, respectively, and was used in a natural gas boiler and direct-fired fuel cells. Natural gas was assigned production and transportation burdens provided by FAL database.

TABLE 3.8. Energy inputs for the production of 1.0 MSF 3/8-inch basis of plywood in the PNW.

Fuel Type	**Input**		**Heat Energy BTU**		**Fuel Source %**	
	Total	**Breakdown**	**Total**	**Breakdown**	**Total**	**Breakdown**
Hogged Fuel (lb)[1/]	4.05E+02		1.22E+06		90	
Self Generated Wood Boiler		3.35E+02		1.01E+06		83
Purchased Wood Boiler		3.80E+01		1.15E+05		9
Fuel Cell		3.16E+01		9.53E+04		8
Wood Waste (lb)[2/3/]	5.00E-01		1.51E+03		0.11	
Natural Gas (ft^3)	1.63E+02		1.33E+05		10	
Direct Fired Fuel Cell		1.29E+02		1.04E+05		79
Boiler		3.48E+01		2.83E+04		21
Total			1.36E+06		100	

1/ Wet basis (50% MC)
2/ Oven dry weight
3/ Came from primary survey and is used in self generated wood boiler

TABLE 3.9. Energy inputs for the production of 1.0 MSF 3/8-inch basis of plywood in the SE

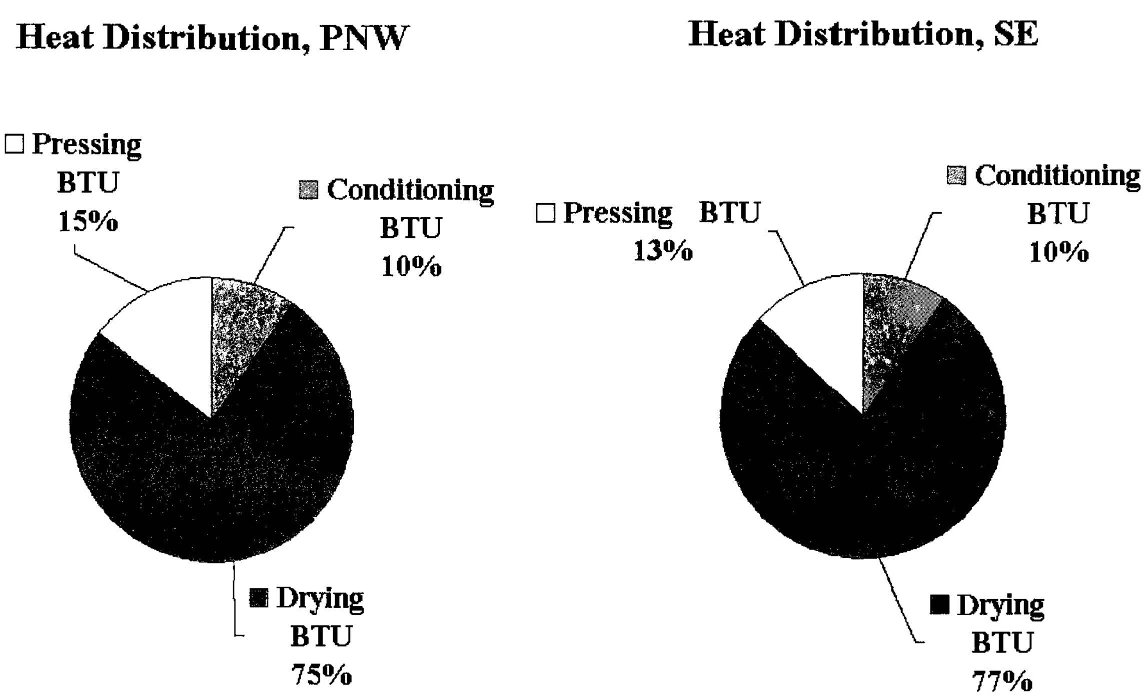
Fuel Type	**Input**		**Heat Energy BTU**		**Allocation %**	
	Total	**Breakdown**	**Total**	**Breakdown**	**Total**	**Breakdown**
Hogged Fuel (lb)[1/]	4.78E+02		1.44E+06		79	
Self Generated Wood Boiler		3.87E+02		1.17E+06		81
Purchased Wood Boiler		9.16E+01		2.76E+05		19
Wood Waste (lb)[2/]	6.07E+01		1.86E+05		10	
Natural Gas (ft^3)	2.42E+02		2.09E+05		11	
Total			1.84E+06		100	

1/ Wet basis (50% MC)
2/ Oven dry weight

The SE region used more energy for heat purposes than the PNW. Southern pine species had relatively higher moisture contents compared to Douglas-fir and as a result, required more heat energy to dry.

Three-log conditioning, veneer drying and panel pressing-out of the six subunit processes utilized hogged fuel and natural gas for heat purposes. The surveys reported energy use for drying and pressing. Heat used in log conditioning was calculated by taking the total heat from burning hogged fuel and natural gas and subtracting the energy used to dry veneer and press panels. A thermodynamic calculation for heat needed to condition a MSF (3/8-inch) of logs was also done to check heat value (Appendix A). Figure 3.4 shows the distribution of energy by subunit process.

FIGURE 3.4. Energy distribution by subunit process for the PNW and SE



Sensitivity analysis of plywood manufacturing in the PNW and SE regions of the United States

Sensitivity analyses were used to study the LCI model that represented plywood manufacturing. The analysis can be useful to understand how various process parameters contribute to environmental output factors. For instance, in plywood manufacturing, heat was used in several subunit processes, consuming hogged fuel and/or natural gas as fuel to generate the heat. Changing the fuel source can have dramatic effect on the type and quantity of emissions into the environment. This sensitivity analysis was used to compare the effects of using all self produced hogged fuel to natural gas as a fuel input. In the original model, fuel sources used for heat purposes included both natural gas and hogged fuel consisting of bark and wood waste.

In the PNW, the original model had 90.5% of the fuel from hogged fuel, self produced and purchased, and 9.5% was from natural gas. The SE was similar to the PNW in distribution, 89% hogged fuel and 11% natural gas. In all actuality, most mills use only one type of fuel source, whereas, this original study was an averaged model incorporating different fuel sources taken from primary survey information. There were three scenarios done for the mill. The first scenario used LCI results to compare fuel use of 100% natural gas only versus the weighted average fuel use from the survey, referred to as the "as is" condition. The second scenario compared 100% self generated hogged fuel versus the "as is", and the third scenario compared 100% self generated hogged fuel versus 100% natural gas.

Carbon balance for plywood manufacturing in the PNW and the SE regions of the United States

The percentage of carbon in wood was taken from a separate study done by R.A. Birdsey (1994). The percentage was specie specific and was manipulated to fit this study by allocating a percentage of each specie used in the modeling of plywood manufacturing. The PNW plywood model used four different species (Douglas-fir, Spruce, Hemlock, Larch) with the percentage of each coming from primary survey data. The weight of carbon in each wood species was calculated by multiplying the conversion factor by the volume of logs and then divided by the total weight of the logs. These percentages were weight averaged based on percent use of each species obtained from primary surveys. The percent of carbon in wood is 51.23% in the PNW and 53.63% in the SE. The carbon percentage of wood that was calculated was also used to calculate the carbon content of bark. The SE plywood model only used two wood species (Slash and Longleaf pine) with the percentage of each being equal, 50%. The output of wood emissions came from SimaPro 5.0.009 and manipulated the plywood model to only focus on plywood manufacturing and not including production and travel burdens of electricity, fuels and PF resin. Other carbon percentages besides wood materials were either taken from the Merck index or were calculated by using atomic masses of each element from their chemical formula.

The amount of carbon in wood products have yet to be fully documented. To track carbon, a checklist was devised to balance the inputs of carbon with the outputs to see if there was any carbon that was missing. This analysis followed carbon flow from the inputs of wood materials to its production into plywood, wood co-products, and wood combustion emissions into the environment. Table 3.10 and 3.11 describes the carbon content of wood in the PNW and the SE.

TABLE 3.10. Percent of carbon in wood, PNW

	Conversion factor [1/2/]	Species allocation	Specie density (lb/ft^3)	Round wood [3/] (ft^3)	Round wood (lb)	Carbon (lb)	Carbon (lb) / round wood (lb) (%)
Douglas-fir	15.11	0.68	28.08	65.60	1,842	991.22	53.81%
Spruce	9.80	0.12	23.09	65.60	1,515	642.88	42.45%
Hemlock	12.17	0.17	26.21	65.60	1,719	798.35	46.44%
Larch	14.26	0.04	29.95	65.60	1,965	935.46	47.61%
Weighted Average	**13.97**	**1.00**	**27.26**	**65.60**	**1,788**	**916.18**	**51.23%**

1/ Birdsey, R.A., 1992. Carbon storage and accumulation in US forest ecosystems. General Technical Report WO-59. Washington, D.C. USDA Forest Service

2/ Skogs, Kenneth E. and Geraldine A. Nicholson. 1998. Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. For. Prod. J. 48(7/8):75-83.

3/ 65.60 ft^3 is the volume of wood needed to produce a MSF of plywood and the co-products.

TABLE 3.11. Percent of carbon in wood, SE

	Conversion factor (1,2)	Species density (lb/ft^3)	Roundwood (ft^3)	Roundwood (lb)	Carbon (lb)	Carbon(lb)/ roundwood (lb) (%)
Southern Pine	16.9	31.51	65.99	2,079	1,115	53.63%

1/ Birdsey, R.A., 1992. Carbon storage and accumulation in US forest ecosystems. General Technical Report WO-59. Washington, D.C. USDA Forest Service

2/ Skogs, Kenneth E. and Geraldine A. Nicholson. 1998. Carbon cycling through wood products: the role of wood and paper products in carbon sequestration. For. Prod. J. 48(7/8):75-83.

3/ 65.60 ft^3 is the volume of wood needed to produce a MSF of plywood and the co-products.

Cost analysis of plywood manufacturing in the PNW and the SE regions of the United States

A cost analysis was created for plywood production in the Pacific Northwest and Southeast regions of the United States. The analysis took the cost of purchased materials, electricity and energy and subtracted it from the sold co-products and fuels to obtain the cost to manufacture a MSF 3/8-inch basis of plywood. The selling price for plywood 3/8-inch CD sheathing grade of plywood was subtracted from the manufacturing cost to obtain the profit or loss of plywood manufacturing.

This analysis looked at variable cost of purchased electricity, hogged fuel, propane, natural gas and diesel fuel and material costs of logs, dry and green veneer, and phenol formaldehyde (PF) resin. It also included fixed cost of capital, maintenance, labor, and overhead cost. These values were added together to obtain the total production cost of plywood manufacturing. Table 3.12 and 3.13 are the cost analysis for the PNW and the SE regions, respectively.

TABLE 3.12. Cost analysis for the production of MSF (3/8-inch) of softwood sheathing plywood, in the PNW

Cost Analysis	Units	$/unit	Annual Basis	$/Annual basis	MSF basis	$/MSF basis
Weighted Average			290,268			
Employees			441			
Variable Cost						
Energy Consumption						
Electricity	KWH	0.0425	40,318,281	$1,713,527	138.9	$5.90
Hogged Fuel	lbs.	0.01	9,869,126	$98,691	34	$0.34
Liquid Propane Gas	Gallons	0.95	104,177	$98,968	0.359	$0.34
Natural Gas	ft^3	2.90E-03	47,429,857	$137,309	163.4	$0.47
Diesel	Gallons	1.30E+00	114,671	$149,072	0.395	$0.51
Materials						
Logs	BF	0.47	81,878,910	$38,822,067	282	$133.75
Purchased Dry Veneer	M 3/8	194	2,192	$424,080	7.55E-03	$1.46
Purchased Green Veneer	M 3/8	170	4,847	$826,344	1.67E-02	$2.85
Resin	lb.	0.45	4,609,462	$2,074,258	1.59E+01	$7.15
Fixed Cost						
Capital Cost	Annual	1,290,081		$1,290,082		$4.44
Maintenance Cost	per MSF	9	290,268	$2,612,416		$9.00
Labor Cost	annual	19,950,840	290,268	$19,950,840		$68.73
Overhead	per MSF	10	290,268	$2,902,684		$10.00
Total cost						$244.95

TABLE 3.12. (Continued)

Cost Analysis	Units	$/unit	Annual Basis	$/Annual basis	MSF basis	$/MSF basis
Sold						
Sold Energy						
Hogged Fuel	lb.	0.01	4,673,321	$46,733	16.1	$0.16
Wood Waste	lb.	0.005	6,095,636	$30,478	21	$0.10
Sold Co-products						
Wood chips	lb.	0.030	123,451,150	$3,703,535	425	$12.76
Peeler core	lb.	0.015	27,604,525	$414,068	95.1	$1.43
Green Clippings	lb.	0.015	8,998,320	$134,975	31	$0.46
Veneer Downfall	lb.	0.015	998,523	$14,978	3.44	$0.05
Panel Trim	lb.	0.015	31,000,665	$465,010	107	$1.60
Sawdust	lb.	0.015	2,795,285	$41,929	9.63	$0.14
Sold Dry Veneer	lb.	0.234	18,316,348	$4,284,977	63.1	$14.76
Total sold						$31.05
					Net Cost	$213.90
					Selling Price for Plywood	$221.75
					Profit	$7.85

TABLE 3.13. Cost analysis for the production of MSF (3/8-inch) of softwood sheathing plywood, in the SE

Cost Analysis	**Units**	**$/unit**	**Annual Basis**	**$/Annual basis**	**MSF basis**	**$/MSF basis**
Weighted Average			286,450			
Employees			432			
Variable Cost						
Energy Consumption						
Electricity	KWH	0.047	34,958,355	$1,643,043	122	$5.74
Hogged Fuel	lb.	0.01	26,233,089	$262,331	91.6	$0.92
Liquid Propane Gas	Gallons	0.95	120,309	$114,294	0.42	$0.40
Natural Gas	ft^3	2.64E-03	69,435,474	$183,363	242	$0.64
Gasoline	Gallons	1.35	48,696	$65,740	0.17	$0.23
Diesel	Gallons	1.27	77,341	$97,837	0.27	$0.34
Materials						
Logs	BF	0.44	73,892,896	$32,882,339	258	$114.79
Purchased Dry Veneer	M 3/8	194	2,346	$453,976	8.19E-03	$1.58
Purchased Green Veneer	M 3/8	170	3,036	$517,606	1.06E-02	$1.81
Resin	lb.	0.45	5,637,335	$2,536,801	19.7	$8.86
Fixed Cost						
Capital Cost	Annual	1,273,111		$1,273,111		$20.95
Interest on capital cost	Annual			$480,000.00		$1.68
Maintenance Cost	per MSF	9	286,450	$2,578,050		$6.00
Labor Cost	Annual	19,524,864	286,450	$19,524,864		$68.16
Overhead	per MSF	10	286,450	$2,864,500		$10.00
Total Cost						$242.09

TABLE 3.13. (Continued)

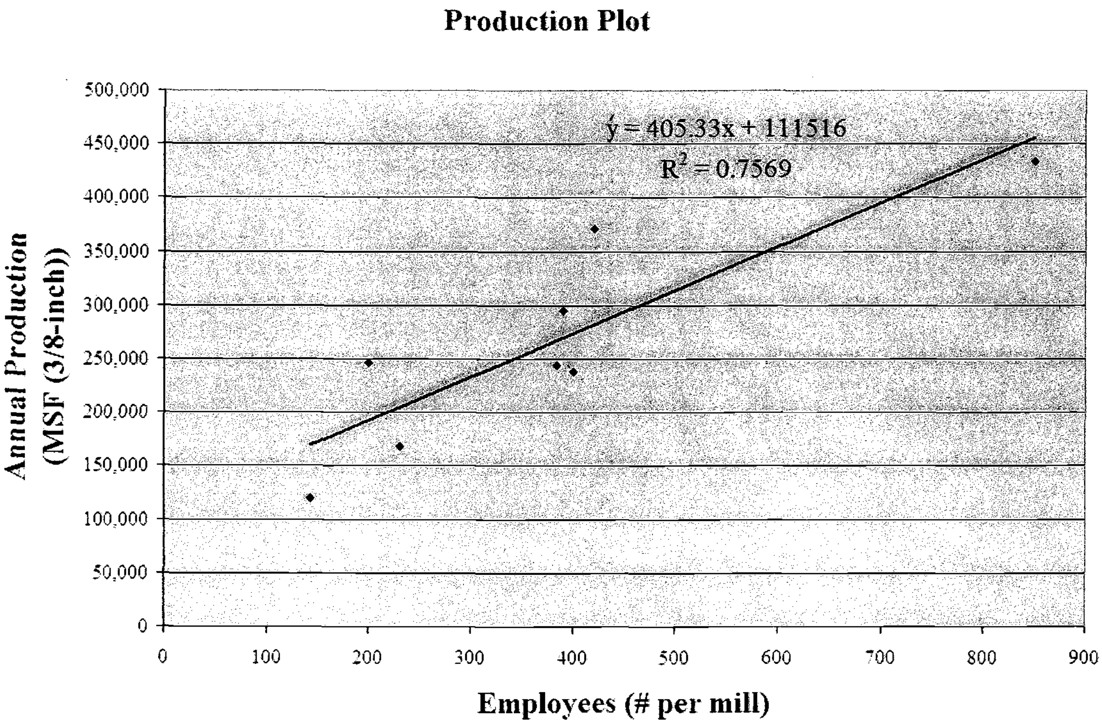
Sold						
Sold Energy						
Hogged Fuel	lb.	0.01	9,094,787	$90,948	31.8	$0.32
Wood Waste	lb.	0.005	5,866,495	$29,332	20.5	$0.10
Sold Co-products						
Wood chips	lb.	0.03	184,814,659	$5,544,440	645	$19.36
Peeler core	lb.	0.015	32,082,397	$481,236	112	$1.68
Green Clippings	lb.	0.015	49,481,369	$742,221	173	$2.59
Veneer Downfall	lb.	0.015	0	$0	0	$0.00
Panel Trim	lb.	0.015	17,350,275	$260,254	60.6	$0.91
Sawdust	lb.	0.015	1,200,225	$18,003	4.19	$0.06
Sold Dry Veneer	lb.	1.97E-01	49,787	$9,784	1.74E-01	$0.03
Total Sold						**$25.05**
					Net Cost $	**217.03**
				Selling Price for Plywood 3/8-inch CD Sheathing Grade		**$214.67**
					Profit $	**(2.37)**

Variable cost and fixed cost

In the PNW, the average price for electricity was 4.25 cents/kWh, with a range of 3.60-5.90 cents/kWh. For the SE, the average price was 4.70 cents, with a range of 3.10-6.90 cents/kWh. This data was taken in 2001. The price of natural gas in both regions, came from data taken in 1999. Both prices for electricity and natural gas came from a confidential industry source. The reason why three year-old information was used for natural gas was because data from the winter of 2000-2001 was felt to be unrealistically high because of prices that may have been impacted by actions of Enron, State of California and others, thus it was recommended that "typical" prices of 1999 be used. As a result, in the PNW, the average price for natural gas/Dtherm (a Dtherm is equal to 1,000,000 BTU) was $2.85/Dtherm, ranging between $2.20-$4.70/Dtherm. The SE average natural gas/Dtherm price was $2.60, with a range of $2.00-$4.90. Prices of wood material as logs and purchased green veneer came from Crow's Market Report publication averaging one price from every month, over a twelve month period in 2002, for both the PNW and the SE. Veneer prices from the PNW was used in the SE since pricing for SE veneer was difficult to obtain.

Fixed cost were costs that were not dependent on production and was a one-time annual cost. This analysis included fixed costs of capital, maintenance, labor and overhead cost. Source of fixed cost information came from a confidential source and is considered valid data. For a labor cost, an average number of employees used to calculate how much it would cost pay workers and was established by graphing the annual production against the number of employees in each mill. After the slope of the graph was obtained the weighted average value of production for each region was used to calculate the number of employees for this "typical" mill. In the PNW, this equaled 441 employees that manufactured 290,268.4 MSF 3/8-inch of plywood. For the SE, 432 employees produced 286,450 MSF 3/8-inch of plywood. Graph 3.1 shows the slope of annual production versus the number of employees.

GRAPH 3.1. Annual production vs. number of employees, PNW



Total cost

In the PNW, the total cost adding both, variable and fixed cost was equal to \$244.95/MSF 3/8-inch with the variable cost of energy and raw materials being \$152.77/MSF 3/8-inch and the fixed cost coming to \$92.18/MSF 3/8-inch. The SE had a total cost equaling \$242.09/MSF 3/8-inch with the variable cost of energy and raw materials coming to \$135.30/MSF 3/8-inch and the fixed cost coming to \$106.78/MSF 3/8-inch.

Energy and co-products sold

In the production of plywood there were fuels and co-products that were sold. The two types of fuel that were sold were hogged fuel and wood waste. In addition to the two fuels, there were wood co-products that were sold and included: wood chips, peeler cores, green clippings, veneer downfall, panel trim, sawdust and dry veneer. These items were sold on a ton/oven-dry (OD) weight basis.

The selling price for the hogged fuel sold was $20/green ton (50% moisture content) and the selling price for wood waste was $10/ton OD weight. Both of these prices were adjusted to a pound basis equaling $0.01/lb and $0.005/lb, respectively. For sold co-products, peeler core, green clippings, veneer downfall and panel trim was sold on a basis of $30/ton OD weight. Wood chips were mostly used for pulping and had a higher selling price equaling $60/ton OD weight. Similar to the sold energies, these two prices were converted to a pound basis. The total amount of money obtained from selling these fuels and co-products in the PNW was $31.05/MSF 3/8-inch. In the SE, the total equaled $25.05/MSF 3/8-inch.

RESULTS AND DISCUSSION

LCI results for the PNW and SE regions

The LCI results are for the production of a MSF 3/8-inch basis of plywood for the PNW and the SE regions. In the PNW, 51% of the total burdens from the production of plywood was allocated to plywood. For the SE region, 48.5% of the total burdens was assigned to plywood. Table 4.1 represents a condensed LCI for the production of plywood in terms of air emissions for the PNW and the SE regions. The table has been reduced in this report because of it length and listed below, are selected air emissions including major greenhouse gases (CO_2, Methane, NO_X, SO_2, and SO_X), HAPs (Acetaldehyde, Acrolein, Formaldehyde, Methanol, and Phenol), and other identified adverse health pollutant (CO, particulates, particulates (PM10), particulates (unspecified), non-methane VOC, and VOC). A complete listing of the LCI can be found in Appendix G.

TABLE 4.1. LCI for plywood, 51% allocated to plywood panel in the Pacific Northwest and 48% allocated to plywood panel in the Southeast

Air Emission1/	**PNW**		**SE**	
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
CO_2 (fossil)	7.78E+01	3.58E+02	2.07E+02	9.52E+02
CO_2 (biomass)2/	2.85E+02	1.31E+03	4.24E+02	1.95E+03
Methane	2.13E-01	9.80E-01	4.93E-01	2.27E+00
NO_X	6.50E-01	2.99E+00	1.52E+00	7.02E+00
SO_2	8.25E-04	3.80E-03	7.31E-05	3.36E-04
SO_X	1.06E+00	4.86E+00	2.15E+00	9.89E+00
Acetaldehyde	1.19E-02	5.49E-02	4.61E-03	2.12E-02
Acrolein	8.75E-07	4.03E-06	7.88E-06	3.62E-05
Formaldehyde	3.74E-02	1.72E-01	2.76E-02	1.27E-01
Methanol	1.36E-01	6.24E-01	1.24E-01	5.69E-01
Phenol	3.02E-02	1.39E-01	3.98E-02	1.83E-01
CO	2.08E+00	9.54E+00	3.14E+00	1.45E+01
Particulates	3.81E-01	1.75E+00	5.71E-01	2.63E+00
Particulates (PM10)	2.27E-01	1.04E+00	1.33E-01	6.12E-01
Particulates (unspecified)	2.52E-02	1.16E-01	1.33E-01	6.12E-01
Non Methane VOC	3.29E-01	1.51E+00	6.24E-01	2.87E+00
VOC	6.69E-01	3.08E+00	2.88E-01	1.32E+00

Data from SimaPro 5.0
1/ Full listing of the LCI for plywood manufacturing in Appendix G
2/ CO_2 biomass and non-fossil collaborated

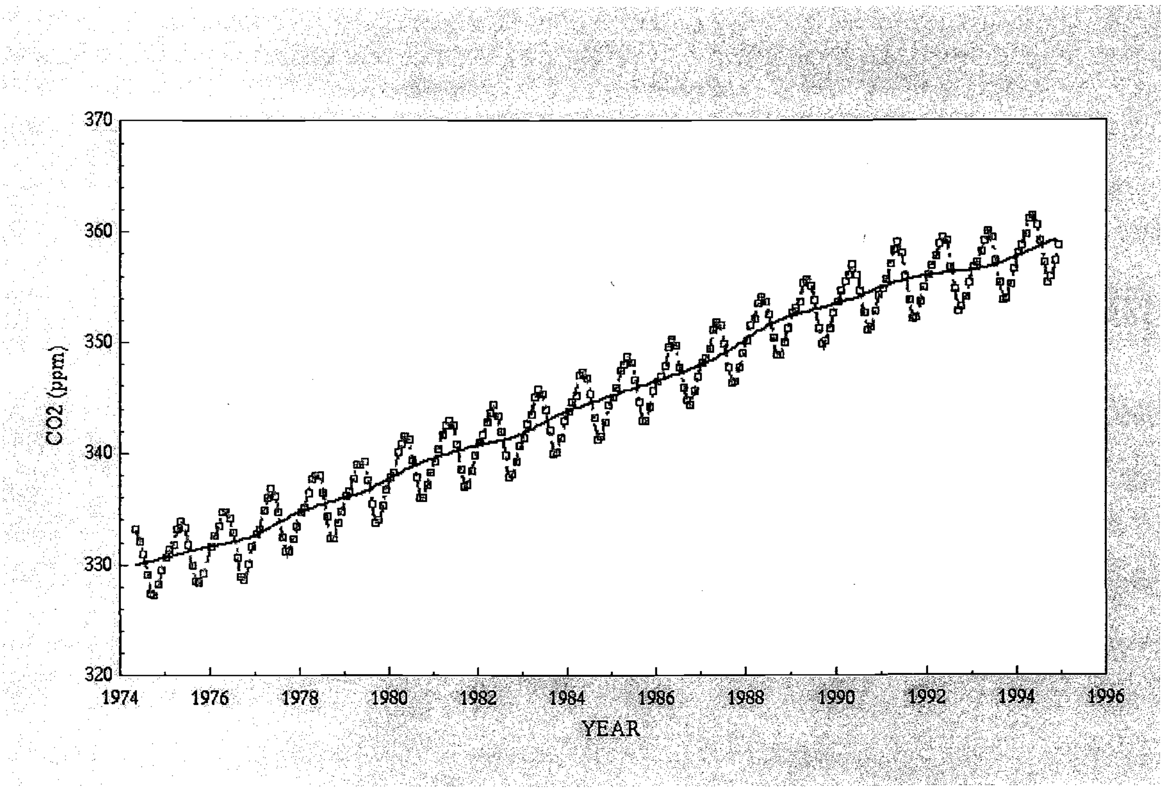
The LCI, in Table 4.1, listed selected greenhouse gases and HAPs emission into the air. Each processes, product, raw materials and activities modeled in plywood manufacturing has an LCI. Any input that does not have an LCI data is listed in the plywood LCI as inputted, with no environmental burdens of emissions. Items that did not have an LCI included logs, bark on logs, energy from other sources and hydroelectric power generation. An LCI for logs, including bark, is currently being developed in the

PNW and SE regions and will be included into the plywood models and other wood building models as part of the CORRIM II project (Johnson, 2002). Electricity from other sources include renewable sources such as solar and wind power generation. Since this is relatively a new source of energy being used commercially, an LCI for the U.S. has yet to be done.

The air emissions listed in the condensed LCI of plywood manufacturing were emissions of current concern including greenhouse gases, particulates and HAPs. The most important emission is atmospheric CO_2. CO_2 emissions come from combustion of fuels for heat, electricity and transportation purposes. In the plywood model, CO_2 emissions data came from an USEPA study on emissions generated from plywood manufacturing and from a FAL database for the combustion of fuels. CO_2 is important because it is a greenhouse gas and concentration of this gas in the atmosphere is increasing. Most of the atmospheric CO_2 is absorbed and stored by the oceans's top 70 - 100 mm layer (Godish 1997). Another important CO_2 sink is in forests in the form of biomass which is estimated to contain over half of the carbon stored in terrestrial vegetation and soils (FAO, 2001). As stated earlier, CO_2 was separated into two categories depending on the type of fuel. CO_2 (biomass) that is released from the plywood life cycle model would return to the forest, as biomass, as replanted trees in. Specifically, through a reaction called photosynthesis, CO_2 is taken up by trees and combine it with O_2 and sunlight to form simple carbon compounds. Photosynthesis takes CO_2 out of the atmosphere, thus, completing the carbon cycle of wood products. So, CO_2 (biomass) which resulted from the combustion of wood-based fuels has a neutral impact on the environment.

As shown in Graph 4.1, CO_2 emissions in the atmosphere has shown an increase in the last three decades (Lanshof, 1994). What is important in this graph is the annual increase and decrease of CO_2 throughout the year. It showed that CO_2 emissions begin to decrease around the spring and then start increasing around the fall. This indicated an annual uptake of CO_2 from the atmosphere and into biomass in the form of trees. The graph also indicated that CO_2 is continuing to increase and by planting more trees, may or may not increase uptake of CO_2 into biomass. This is the reason why CO_2 emissions from wood combustion is separated.

GRAPH 4.1. Carbon dioxide measurement in the earth's atmosphere



Many emissions that were listed in the LCI of plywood manufacturing were a surprise to see associated with wood products. One certain substance of interest was the nonmaterial emission, "radioactive substance to air." This substance appeared in any LCI that utilized nuclear power to generate electricity and was included in both regions of study. Most of the unexpected substances came from the generation or use of electricity, fuel use, and resin production. A separate analysis on the influence of electricity, fuel and resin was conducted and discussed later in this section.

Air Emission by Subunit Process

One aspect that was a focus on this study were air emissions. Emissions of concern included greenhouse gases (CO_2, NO_X, methane and SO_X), HAP emissions (formaldehyde, methanol, acetone, phenol and acetaldehyde), VOCs and also particulate matter. The greenhouse gases are of general concern for the environment, while HAP emissions of concern to human health were specifically regulated by the USEPA and have set limits from any point sources. VOC are harmful to the environment and some VOCs are also listed as HAPS. Particulate matter- wood particulates- is monitored to protect workers' respiratory health.

The LCI of air emissions were categorized based on a subunit process. Specific emissions mentioned above were identified and tracked to pinpoint which subunit processes were major contributors to these emissions. Figure 4.1 is a bar chart that separates the subunit process contribution based on the selected air emissions in the PNW. This identified that the input parameters of materials, energy and electricity along with veneer emissions for the drying and pressing subunit processes contributed the most emission among all the subunit processes. Drying subunit process contributed the highest percentage of CO_2 (biomass), acetaldehyde, acrolein, formaldehyde, all particulate matter, SO_2 CO, and VOC. The drying subunit process contributed almost all of the SO_2 emissions. Pressing subunit process contributed a high percentage of CO_2 (fossil), formaldehyde, methane, non-methane VOC, methanol, phenol and SO_X emissions.

FIGURE 4.1. Selected air emission contribution by subunit process, PNW

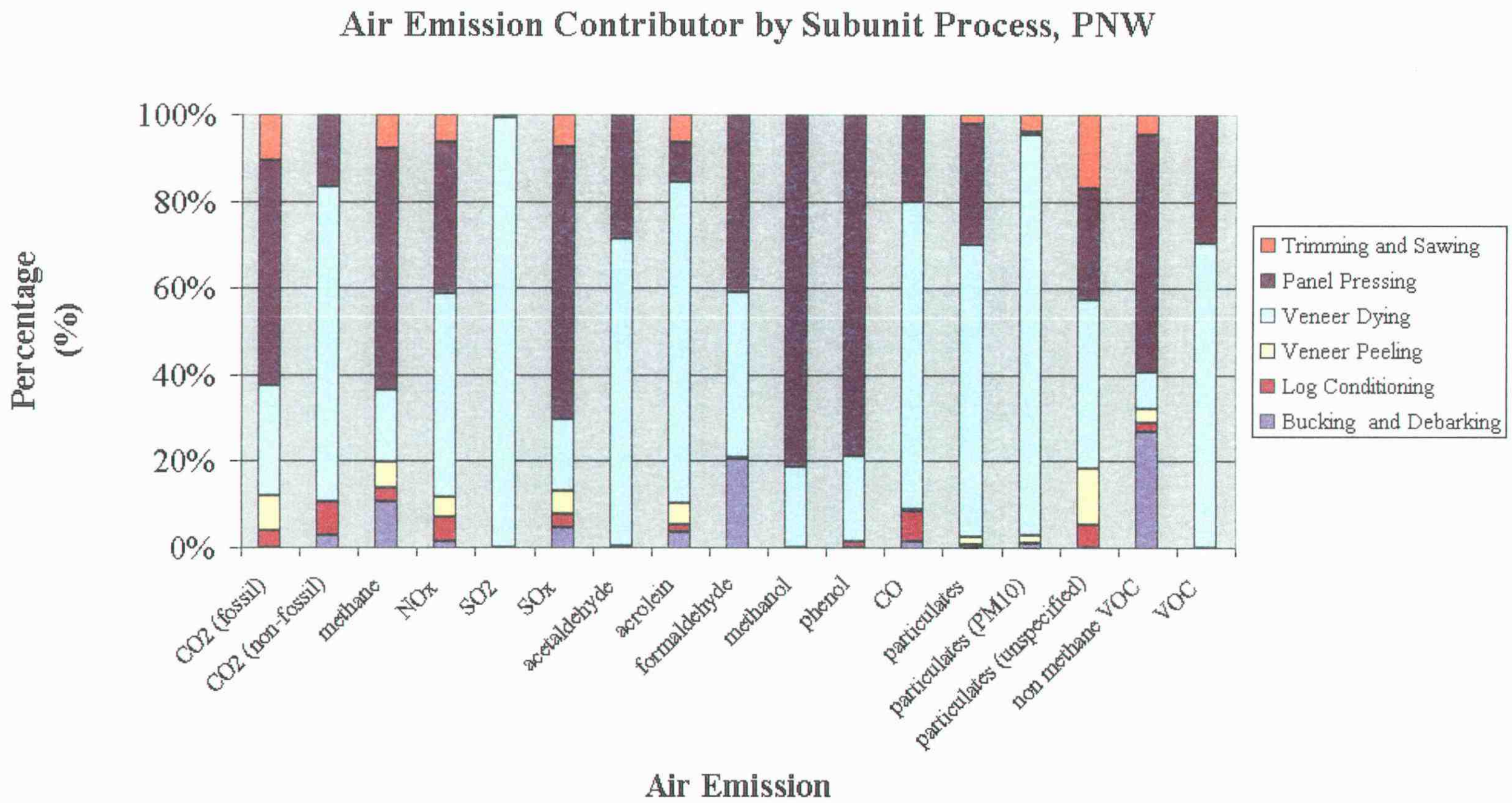


FIGURE 4.2. Selected air emission by subunit process, SE

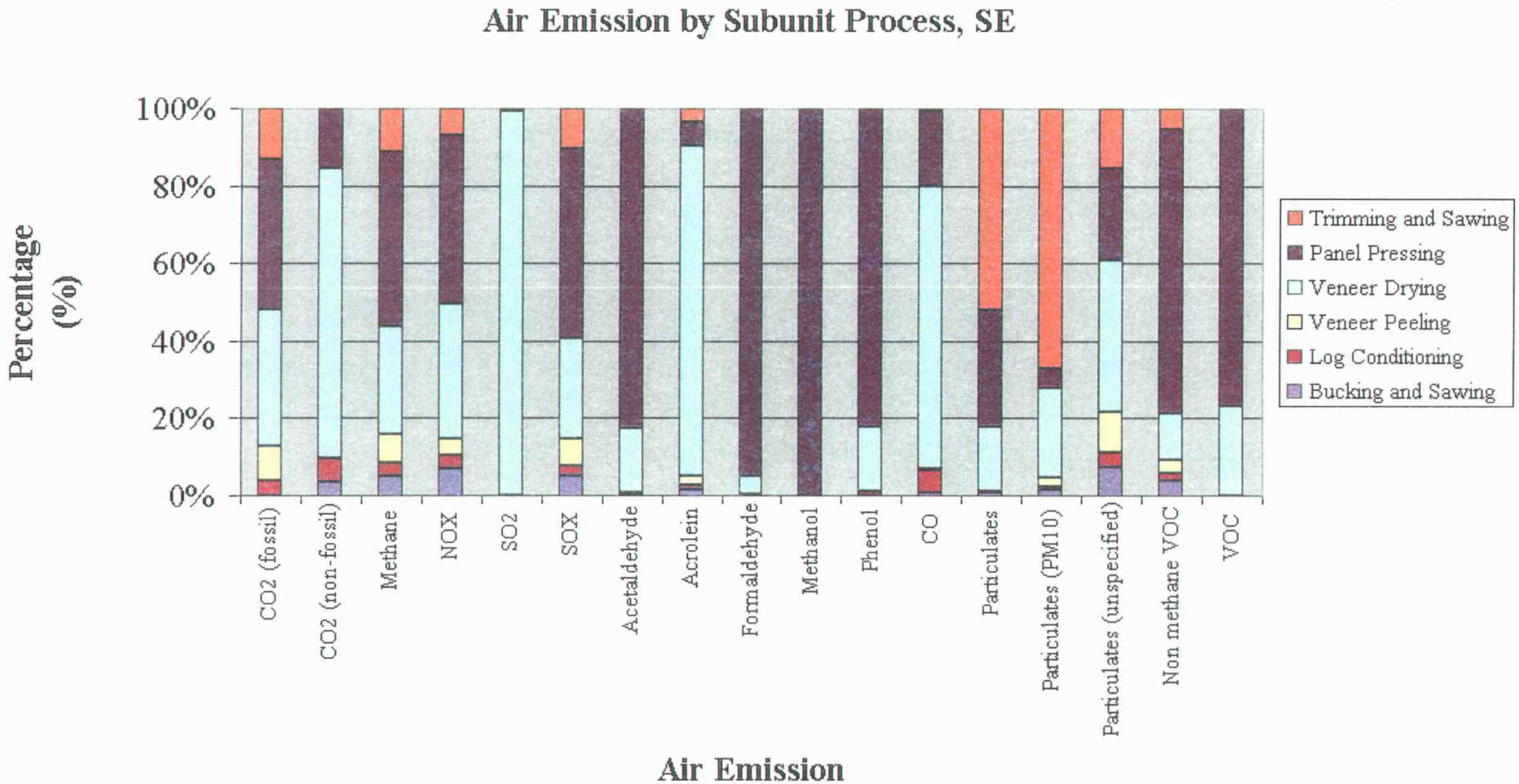


Figure 4.2 is a bar chart that separated the subunit process contribution based on selected air emissions in the SE region. This chart identified that drying, pressing and sawing and trimming had a significant impact to the air emission in the LCI. Drying subunit process contributes high percentage for acrolein, CO, CO_2 (fossil), CO_2 (biomass) methane, NO_X, particulate (unspecified), NO_X and SO_2 emissions. Pressing contributed a high percentage of acetaldehyde, CO_2 (fossil), formaldehyde, methanol, non methane VOC, NO_X , phenol, SO_X and VOC emissions. Different from the PNW, trimming and sawing also contributed significant emissions into the air. Trimming and sawing emitted a high percentage of particulate and particulate (PM10) emissions whereas in the PNW, particulate matter came mainly from drying veneer subunit process. This information came from primary data and was reported for the sander and the bag house. Wood particulate matter came from sanded plywood and taints the data output for subunit process six because sheathing plywood panels are not sanded. The particular mill that reported this produced other products besides sheathing plywood panels.

The effects of plywood manufacturing excluding LCI information from electricity, fuel and resin use.

A practical analysis for mill managers was to create another LCI of plywood production that focused on the manufacturing process itself, and did not include the environmental burdens associated with the use of electricity, fuels, and resin. This gives the emissions referred to as "site generated emissions." Table 4.2 is a comparative look between the LCI of plywood manufacturing and the LCI of plywood manufacturing without environmental burdens of electricity, fuel and resin use, in the PNW and SE. The LCI that does not include burdens of electricity, fuel and resin use is called "LCI Site Generated" and refers to the emissions generated from the plywood manufacturing process itself and not from the production and transportation burdens of electricity, fuel and resin use. The "% Difference" labeled in Table 4.2 is the percent increase when environmental burdens from electricity, fuel and resin are included in the plywood model.

TABLE 4.2. LCI air emissions of plywood manufacturing without impacts of fuel, electricity and resin in the PNW and SE

Air Emission[1/]	Pacific Northwest			Southeast		
	LCI	LCI Site Generated		LCI	LCI Site Generated	
Substance	lb/MSF (3/8-inch)	lb/MSF (3/8-inch)	% Difference	lb/MSF (3/8-inch)	lb/MSF (3/8-inch)	% Difference
CO_2 (fossil)	7.78E+01	1.20E+01	548	2.07E+02	1.01E+01	1,944
CO_2 (non-fossil)[2/]	2.85E+02	2.85E+02	0	4.24E+02	4.24E+02	0
Methane	2.13E-01	7.13E-05	299,023	4.93E-01	9.50E-05	518,321
NO_X	6.50E-01	3.79E-01	71	1.52E+00	4.09E-01	273
SO_2	8.25E-04	8.25E-04	0	7.31E-05	7.31E-05	0
SO_X	1.06E+00	1.80E-02	5,768	2.15E+00	2.15E-02	9,900
Acetaldehyde	1.19E-02	1.19E-02	0	4.61E-03	4.61E-03	0
Acrolein	8.75E-07	5.28E-07	66	7.88E-06	0.00E+00	-
Formaldehyde	3.74E-02	2.06E-02	82	2.76E-02	4.17E-03	561
Methanol	1.36E-01	1.36E-01	0	1.24E-01	1.24E-01	0
Phenol	3.02E-02	8.44E-03	258	3.98E-02	9.56E-03	316
CO	2.08E+00	1.94E+00	7	3.14E+00	2.87E+00	10
Particulates	3.81E-01	3.75E-01	1	5.71E-01	5.64E-01	1
Particulates (PM10)	2.27E-01	2.22E-01	2	1.33E-01	1.05E-01	27
Particulates (Unspecified)	2.52E-02	0.00E+00	-	1.33E-01	0.00E+00	-
Non Methane VOC	3.29E-01	2.32E-02	1,318	6.24E-01	5.19E-03	11,910
VOC	6.69E-01	6.69E-01	0	2.88E-01	2.88E-01	0

Data from SimaPro 5.0 LCI analysis
1/ Full LCI listing in Appendix G
2/ CO_2 fossil and non-fossil collaborated

For both regions CO_2 (biomass), SO_2, acetaldehyde, methanol, and VOC were not affected from the generation and use of electricity, fuel and resin and were pollutants that all came from the plywood process. Significant contribution of selected emissions in conjunction to electricity, fuel and resin included CO_2 (fossil), methane, NO_X, SO_X, acrolein, formaldehyde, phenol, particulates (unspecified) and non methane VOC. Selected emissions that were only associated with electricity, fuel and resin use included particulates in both regions and acrolein in the SE region only. The other emissions (CO and particulates) had a small influence (> 10%) from electricity, fuel and resin use. Particulate (PM10) varied from the PNW and SE. The PNW had a 2% increase from electricity, fuel and resin, while the SE particulate (PM10) increased at a higher percentage, 27%. Major particulate (PM10) emissions come from electricity generation from coal, distillate fuel oil and natural gas and were heavily used in the SE for electricity generation, while the PNW utilized hydroelectric power (75%) which contributed no particulate (PM10) emissions.

Sensitivity analysis results

Tables 4.3 and 4.4 are a summary of the three scenarios, with a partial list of air emissions for the PNW and SE, respectively. In the first two scenarios, all natural gas versus "as is" and all self-produced hogged fuel versus "as is," a negative percentage difference number indicates that the fuel source contributes less emissions than the "as is" plywood model. A positive percentage difference means that the "as is" or original model contributes less emission. In the third scenario, a negative number indicates that all natural gas contributes less emissions than all self-generated hogged fuel and a positive percentage number means that all self-produced hogged fuel contributes less emissions.

TABLE 4.3. Sensitivity analysis for the PNW. Fuel usage comparison for steam production analyzing natural gas, hogged fuel and no change (original fuel distribution)

				Scenario 1	Scenario 2	Scenario 3
	All Natural Gas	All Hogged Fuel	No Change, Original Fuel Distribution	All Natural Gas Difference	All Hogged Fuel Difference	Natural Gas versus Hogged Fuel Difference
Substance	**lbs/MSF (3/8-inch)**				**%**	
CO	5.12E-01	2.48E+00	2.08E+00	-75	19	-79
CO_2 (fossil)	1.71E+02	6.00E+01	7.78E+01	120	-23	185
CO_2 (non-fossil)[1/]	4.85E-02	3.40E+02	2.85E+02	-100	20	-100
Methane	4.84E-01	1.67E-01	2.13E-01	127	-22	190
NO_X	9.62E-01	8.50E-01	6.50E-01	48	31	13
SO_2	8.25E-04	8.25E-04	8.25E-04	0	0	0
SO_X	2.49E+00	8.06E-01	1.06E+00	136	-24	209
VOC	6.69E-01	6.69E-01	6.69E-01	0	0	0
Non methane VOC	8.12E-01	3.64E-01	3.29E-01	147	11	123
Acetaldehyde	1.16E-02	1.20E-02	1.19E-02	-3	1	-4
Acrolein	8.75E-07	8.56E-07	8.75E-07	0	-2	2
Formaldehyde	3.66E-02	3.76E-02	3.74E-02	-2	1	-3
Methanol	1.36E-01	1.36E-01	1.36E-01	0	0	0
Phenol	2.49E-02	3.14E-02	3.02E-02	-18	4	-21
Particulates	3.65E-01	3.85E-01	3.81E-01	-4	1	-5
Particulates (PM10)	2.26E-01	2.26E-01	2.27E-01	-0	-0	0
Particulates (unspecified)	2.70E-02	2.39E-02	2.52E-02	7	-5	13

1/ CO_2 biomass and non-fossil collaborated

TABLE 4.4. Sensitivity analysis for the SE. Fuel usage comparison for steam production analyzing natural gas, hogged fuel and no change (original fuel distribution)

				Scenario 1	Scenario 2	Scenario 3
	All Natural Gas	All Hogged Fuel	"As is," Original Fuel	All Natural Gas Difference	All Hogged Fuel Difference	Natural Gas versus Hogged Fuel Difference
Substance	**lbs/MSF (3/8-inch)**				**%**	
CO	8.06E-01	3.73E+00	3.14E+00	-74	19	-74
CO_2 (fossil)	3.95E+02	2.04E+02	2.07E+02	91	-1	91
CO_2 (non-fossil)[1/]	1.20E-01	5.16E+02	4.24E+02	-100	22	-100
Methane	1.04E+00	4.93E-01	4.93E-01	112	0	112
NO_X	1.82E+00	1.58E+00	1.52E+00	19	3	19
SO_2	7.31E-05	7.31E-05	7.31E-05	0	0	0
SO_X	5.06E+00	2.16E+00	2.15E+00	135	0	135
VOC	2.88E-01	2.88E-01	2.88E-01	0	0	0
Non Methane VOC	1.39E+00	6.24E-01	6.24E-01	123	0	123
Acetaldehyde	4.00E-03	4.74E-03	4.61E-03	-13	3	-13
Acrolein	1.91E-06	1.88E-06	7.88E-06	-76	-76	-76
Formaldehyde	2.62E-02	2.79E-02	2.76E-02	-5	1	-5
Methanol	1.24E-01	1.24E-01	1.24E-01	0	0	0
Phenol	3.17E-02	4.15E-02	3.98E-02	-20	4	-20
Particulates	5.50E-01	5.78E-01	5.71E-01	-4	1	-4
Particulates (PM10)	1.33E-01	1.33E-01	1.33E-01	0	0	0
Particulates (unspecified)	1.38E-01	1.33E-01	1.33E-01	4	0	4
1/ CO_2 biomass + non-fossil						

Carbon Monoxide (CO)

In the PNW, the results showed that combustion of natural gas decreased CO emissions. When hogged fuel was used, CO emissions increased slightly compared to original setup and was 78% higher than natural gas. The SE region had similar results.

Carbon Dioxide (CO_2)

For the two regions, CO_2 fossil and biomass switched because hogged fuel is a biomass fuel and natural gas is a fossil fuel. The amount of CO_2 emitted was different, having hogged fuel emitting more CO_2 into the atmosphere. CO_2 (biomass) is treated separately because it can be taken back up in biomass through photosynthesis and assumed to have a neutral impact on the environment, while CO_2 (fossil) emissions can not be readily replenished as natural gas.

Methane (CH_4)

Methane emissions significantly increased by more than 100% when natural gas was used compared to all self-generated hogged fuel and the "as is" model. In the PNW, all self-produced hogged fuel contributed less methane emissions than all natural gas and the "as is" model.

Nitrogen Oxides (NO_X)

NO_X in all three scenarios increased in emissions with natural gas having the highest increase, comparing scenarios 1 and 2. When hogged fuel and natural gas were compared, natural gas emitted more NO_X emissions (13% in the PNW and 19% in the SE) than hogged fuel.

SO_2 and SO_X

SO_2 emission had no affect of fuel sources use for heat but SO_X increased when switched to natural gas. In the PNW, SO_X decreased when fuel was switched to self-generated hogged fuel. Scenario 3 showed more pollutant emitted from natural gas use.

VOC and Non Methane VOC

VOC emissions showed no influence of heat fuel from any of the scenarios, although, non methane VOC, heavily influenced by natural gas combustion and increased over a hundred percent in both regions. Hogged fuel use did not contribute any non methane VOC. VOC emissions came from drying of veneer and also pressing emissions of plywood panel production.

HAP (including acetaldehyde, acrolein, formaldehyde, methanol, and phenol)

In the PNW, HAP emissions were not influenced by fuel inputs since the drying of wood provides all HAP emissions. Phenol was the only HAP that was influenced and it decreased when natural gas fuel was used. An analysis of the SE model indicated that using natural gas as a heat source decreased HAP emissions, with the exception of methanol which had no influence of fuel inputs. When switching to all self-produced hogged fuel, acrolein was the only HAP emission that decreased.

Particulates

Particulate emissions was hardly affected by fuel switching indicating that both fuel sources contribute similar amounts of particulates. There was a slight indication that hogged fuel contributes more particulates than all natural gas (1% more) and the "as is" (4% more) model.

Carbon balance results

For the PNW and SE regions, Table 5.5 includes a list of inputs and outputs related plywood manufacturing with a carbon percentage and weight of each item. Inputs includes logs (without bark), bark and purchased green and dry veneer. Outputs included plywood, co-products and wood related emissions into the environment. The carbon balance that had a difference compared to the LCI. For the PNW and SE, the difference between inputs and outputs were 7.49% and 1.76%, respectively.

TABLE 4.5. Carbon balance, PNW and SE

PNW PLYWOOD - INPUTS			
Materials	**lb/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Round wood (w/o bark)	1.79E+03	51.23%	9.16E+02
Bark	1.98E+02	51.23%	1.01E+02
Purchased			
Dry veneer	6.43E+00	51.23%	3.30E+00
Green veneer	1.42E+01	51.23%	7.29E+00
Total	**1.81E+03**		**1.03E+03**
PNW PLYWOOD - OUTPUTS			
Air Emission			
Substance	**lbs/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Acetaldehyde	1.19E-02	54.00%	6.45E-03
Acetone	5.11E-03	64.27%	3.29E-03
Acrolein	5.28E-07	65.00%	3.43E-07
Alpha-pinene	7.69E-02	88.16%	6.78E-02
Benzene	4.76E-04	92.25%	4.39E-04
Beta-pinene	2.99E-02	88.16%	2.63E-02
CO	1.94E+00	42.86%	8.30E-01
CO_2 (non-fossil)	2.85E+02	27.27%	7.76E+01
Formaldehyde	2.06E-02	40.00%	8.23E-03
Limonene	8.62E-03	88.16%	7.60E-03
Methane	7.13E-05	75.00%	5.34E-05
Methanol	1.36E-01	37.50%	5.09E-02

TABLE 4.5. (Continued)

Air Emission			
Substance	**lbs/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Methyl Ethyl Ketone	6.81E-04	66.63%	4.54E-04
Methyl I-butyl Ketone	1.11E-02	71.94%	8.01E-03
Naphthalene	3.18E-04	93.71%	2.98E-04
Non Methane VOC	2.32E-02	100.00%	2.32E-02
Organic Substances	2.19E-02	50.00%	1.10E-02
Particulates	3.75E-01	51.23%	1.92E-01
Particulates (PM10)	2.22E-01	51.23%	1.14E-01
Phenol	8.44E-03	76.57%	6.46E-03
THC as Carbon	1.65E-01	100.00%	1.65E-01
VOC	6.69E-01	100.00%	6.69E-01
Solid Waste Emission			
Substance	**lbs/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Solid Waste	1.19E+01	51.23%	6.08E+00
Subtotal	**3.12E+02**		**8.91E+01**
Plywood	9.37E+02	51.23%	4.80E+02
Wood chips	4.25E+02	51.23%	2.18E+02
Peeler core	9.51E+01	51.23%	4.87E+01
Green clippings	3.10E+01	51.23%	1.59E+01
Veneer downfall	3.40E+00	51.23%	1.74E+00
Panel trim	1.07E+02	51.23%	5.47E+01
Sawdust	9.63E+00	51.23%	4.93E+00
Wood waste (sold)	2.10E+01	51.23%	1.08E+01
Wood waste to boiler	5.00E-01	51.23%	2.56E-01
Dry veneer (sold)	6.31E+01	51.23%	3.23E+01
Total Output	**2.01E+03**		**9.56E+02**
% DIFFERENCE (Inputs/Outputs)			**7.50**

TABLE 4.5. (Continued)

	SE PLYWOOD - INPUTS		
Materials	**lb/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Round wood (w/o bark)	2.08E+03	53.63%	1.12E+03
Bark	2.48E+02	53.63%	1.33E+02
Purchased			
Dry veneer	8.07E+00	53.63%	4.33E+00
Green Veneer	1.04E+01	53.63%	5.60E+00
Total Inputs	**2.10E+03**		**1.26E+03**
	SE PLYWOOD - OUTPUTS		
Substance	**lb/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Acetaldehyde	4.61E-03	54.00%	2.49E-03
Acetone	5.72E-03	64.27%	3.68E-03
Alpha-pinene	8.62E-02	88.16%	7.60E-02
Benzene	7.25E-04	92.25%	6.69E-04
Beta-pinene	3.35E-02	88.16%	2.95E-02
CO	2.87E+00	42.86%	1.23E+00
CO_2 (non-fossil)	4.24E+02	27.27%	1.16E+02
Formaldehyde	4.17E-03	40.00%	1.67E-03
Limonene	9.69E-03	88.16%	8.54E-03
Methane	9.50E-05	75.00%	7.13E-05
Methanol	1.24E-01	37.50%	4.64E-02
Methyl Ethyl Ketone	7.69E-04	66.63%	5.12E-04
Methyl I-butyl Ketone	6.25E-04	71.94%	4.50E-04
Naphthalene	4.85E-04	93.71%	4.54E-04
Non Methane VOC	5.19E-03	100.00%	5.19E-03
Organic Substances	3.35E-02	50.00%	1.68E-02

TABLE 4.5. (Continued)

Air Emission			
Substance	**lbs/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Particulates	5.64E-01	51.23%	2.89E-01
Particulates (PM10)	1.05E-01	51.23%	5.38E-02
Phenol	9.56E-03	76.57%	7.32E-03
THC as Carbon	1.85E-01	100.00%	1.85E-01
VOC	2.88E-01	100.00%	2.88E-01
Solid Emission			
Substance	**lb/MSF (3/8-inch)**	**% Carbon**	**Weight of Carbon**
Solid Waste	1.82E+01	51.23%	9.32E+00
Subtotal	**4.57E+02**		**1.30E+02**
Plywood	1.08E+03	51.23%	5.55E+02
Wood chips	6.45E+02	51.23%	3.31E+02
Peeler core	1.12E+02	51.23%	5.74E+01
Green clipping	1.73E+02	51.23%	8.85E+01
Panel trim	6.06E+01	51.23%	3.10E+01
Sawdust	4.19E+00	51.23%	2.15E+00
Wood waste, sold	2.05E+01	51.23%	1.05E+01
Wood waste (to boiler)	6.10E+01	51.23%	3.13E+01
Total Output	**2.62E+03**		**1.24E+03**
% DIFFERENCE (Inputs/Outputs)			**1.77**

Cost analysis results

In the PNW region, taking the total cost to produce a MSF 3/8 inch basis and subtracting the sold energy and co-products, resulted in the net cost being $221.14. An average price was calculated by taking one price in every month, during the year 2002 for 3/8-inch, CD plywood sheathing grade from Crow's Market Report and equaled

$221.75/MSF. Subtracting the net cost to produce plywood by the selling price of plywood, result in a $7.85 profit per MSF.

For the SE, the net cost to produce a MSF 3/8-inch of plywood was equal to $217.03. An average price was calculated by taking one price every month, during the year 2002 for 3/8-inch, CD plywood sheathing grade from Crow's Market Report for three areas in the SE region: west, central and east. The average listed prices for the SE region equaled $214.67/MSF of Southern Pine plywood. Subtracting the net cost to produce plywood by the selling price of plywood, result in a $2.37 loss/MSF.

CONCLUSIONS

Life-cycle inventory conclusion

LCI of plywood manufacturing provides a valuable tool to conduct an environmental assessment of wood products. This study found that the major contributors to environmental impact for the production of plywood manufacturing is the use and generation of electricity, fuel, and resin. For the production of plywood, certain subunit processes had more of an environmental impact than others. Subunit processes generating the most impact in order of significance are drying, pressing and log conditioning. These processes also used all the fuel use for heat generation and used more than half of the electricity used in production (7% Log Conditioning, 37% Drying, and 11% Pressing, equaling 55% of the total electricity consumption).

From the results, analyzing the effects of electricity, fuel and resin furthered the conclusion of the influence of these inputs into the plywood model in relation to air emissions. These three parameters significantly influenced emissions of greenhouse gases and HAPs. In attempts to reduce these emissions would lie in the choice of fuel used to produce heat. These choice would include natural gas or hogged fuel. The sensitivity analysis in the next chapter looks at these two options. In addition to fuel options, regions of electricity generation had influence. The SE region utilized more non-renewable resources than the PNW and as a result, emitted larger qualitites of emissions into the air. This was noticeable in Table 4.2 where the mass amount of emissions were higher in the SE than in the PNW, stating that the SE region used more energy to process plywood and also used 74% more non-renewable resources for electricity generation.

Finally, this model was given to CORRIM II as a gate to gate study of plywood manufacturing. Plywood was one of the many products that had an LCI created to conduct an LCA of wood building products for used in residential homes.

Sensitivity analysis conclusion

The sensitivity analysis indicated that natural gas contributes more greenhouse gases compared to hogged fuel and the original setup. In addition, EPA concern to reduce HAP emissions indicated that natural gas fuel contributed less emissions compared to hogged fuel and the original model and so an LCA of the tradeoff with benefits and downfalls should be conducted to see which fuel contributes less environmental burdens.

Carbon balance conclusion

Carbon is an important issue related to global warming in terms of reducing CO_2 emissions. The carbon balance completed in this study will be used to track carbon in CORRIM II assessment of wood products. Knowing where carbon is in its various paths from a log to different products and co-products is important to fully understand the flow of carbon in biomass. This study can be used to increase the understanding of the carbon cycle by having a benchmark of carbon mass values for a MSF (3/8-inch basis) of plywood.

Cost analysis conclusion

For the two regions, PNW and SE, the total cost to produce a MSF (3/8-inch) of softwood plywood was very similar in comparison, the PNW having a $7.85 profit and the SE having a $2.37 loss. It is also important to say that plywood mills in the SE are relatively newer than the PNW, and as a consequence have a higher capital cost, had interest cost for the capital investments, and a lower maintenance cost.

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APPENDICES

APPENDIX A: CALCULATIONS

Calculation for heat generated from burning bark in a boiler (Example for the PNW)

Self generated bark

$$\left(382.7\ lb \times 4500\,{}^{BTU}\!\!\big/_{lb\ of\ wet\ wood\ at\ 50\%\ MC\ t\ basis}\right) \times 67\%\ efficiency$$

Purchased hogged fuel

$$\left(38\ lb \times 4500\,{}^{BTU}\!\!\big/_{lb\ of\ wet\ wood\ at\ 50\%\ mc\ wet\ basis}\right) \times 67\%\ efficiency$$

Calculation for heat generated from burning natural gas in a boiler (Example for the PNW)

Natural gas

$$\left(34.8\,ft^3 \times 1015.68\,{}^{BTU}\!\!\big/_{ft^3}\right) \times 80\%\ efficiency$$

Table 7.1 Calculating the amount of energy to dry a MSF of veneer in a plywood dryer. A calculation to check drying energy data from primary surveys

Assumptions:	1236.9 lbs of green veneer		
	20% sapwood*	60% MC	Target MC = 3%
	80% Heartwood*	25% MC	
	Specific gravity = 0.5	ρ = 500 kg/m³	
	Temperature	T1 = 15° C (60° F)	T2 = 185° C(365° F)
	*Trus-Joist LVL Mill		

Heartwood Calculation

$$\frac{123.9\ lb}{1} \times \frac{1\ kg}{2.2\ lb} = 562.2\ kg$$

$$562.2kg \times 0.5 = 449.9kg \qquad \text{(heartwood OD basis)}$$

$$wt_{25} = .25 = \frac{wt_{25} - 449.9\ kg}{449.9\ kg} \qquad 112.5\ kg = wt_{25} - 449.9\ kg$$

$$wt_{25} = 562.4\ kg$$

$$wt_3 = .03 = \frac{wt_3 - 449.9\ kg}{449.9\ kg} \qquad 13.5\ kg = wt_3 - 449.9\ kg$$

$$wt_3 = 463.4\ kg$$

H_2O heated $$562.4\ kg - 463.4\ kg = 99\ kg \times \frac{22}{25} = 87.12\ kg\ evaporated$$

O_s: Assume

$C_{wd} = 1.39 \times 10^3$ J/kg K
$C_{wa} = 4.18 \times 10^3$ J/kg K

$$Q_s = \left[C_{wd}(kg\ wood) + C_{wd}(kg\ water)\right](T_2 - T_1)$$
$$= \left[1.39 \times 10^3\ {}^{J}\!/_{kg\ K}(44.9.9kg) + 4.18 \times 10^3(99kg)\right]169.5\ K$$
$$= \left[625{,}361\ {}^{J}\!/_{K} + 413{,}820\ {}^{J}\!/_{K}\right]169.5\ K$$
$$= 176{,}141{,}179.5\ J$$

Table 7.1 (Continued)

$$Q_v = Q_o \times kg\ of\ evaporated\ water$$
$$= 2.38 \times 10^6\ {}^{J}/_{kg} \times 87.12\ kg \quad = \quad 207{,}345{,}000\ J$$

Calculating heat of wetting

$$\log w = 1.23 - 5.4mc$$
$$\log w_{25} = 1.23 - 5.4(.25)$$
$$w_{25} = 0.76\ {}^{cal}/_{g\ wood}$$
$$\log w_3 = 1.23 - 5.4(.03)$$
$$w3 = 11.69\ {}^{cal}/_{g\ wood}$$
$$w = 11.69\ {}^{cal}/_{g\ wood} - 0.76\ {}^{cal}/_{g\ wood} = 10.9\ {}^{cal}/_{g\ wood}$$

$$Qw = \left(45.6\ {}^{J}/_{g\ wood}\right)\left(100\ {}^{g}/_{kg}\right)\left(44.9kg\right) = \quad Qw = 20{,}002{,}219.5\ J$$

$$Qt = Qv = Qs = Qw$$
$$176{,}141{,}179.54\ J + 207{,}345{,}600\ J + 20{,}515{,}440\ J$$
$$= 404{,}002{,}219.5\ J$$
$$= 382{,}920\ BTU$$
$$multiplied\ 2x$$
$$= 765{,}840.4\ BTU$$

Table 7.1 (Continued)

Sapwood Calculation

$$562.2\ kg \times 0.2 = \quad 112.4\ kg \quad is\ sapwood\ OD\ basis$$

$$wt\ at\ 60\% \quad 0.6 = \frac{wt_{60} - 112.4\ kg}{112.4\ kg} = 67.5 = wt_{60} - 112.4\ kg$$

$$wt_{60} = 179.9\ kg$$

$$wt\ at\ 3 \quad .3 = \frac{wt_{3} - 112.4\ kg}{112.4\ kg} = 3.37 = wt_{3} - 112.4\ kg$$

$$wt_{3} = 115.8\ kg$$

H_20 Heated $$179.9\ kg - 115.8\ kg = 64.1\ kg \times \frac{22}{25} = 56.4\ evaporated$$

Qs Assume

Cwd = 1.39 x 10^3 J/kg K
Cwa = 4.18 x 10^3 J/kg K

$$Qs = \left[1.39 \times 103\ {}^{J}\!/_{kg}\ K(112.4\ kg) + 4.18 \times 103\ {}^{J}\!/_{kg}\ K(64.1\ kg)\right] 169.5\ K$$

$$= \left[156{,}291.6\ {}^{J}\!/_{K} + 267{,}938\ {}^{J}\!/_{K}\right] 169.5\ K$$

$$= \left[424{,}229.6\ {}^{J}\!/_{K}\right] 169.5\ K$$

$$Qs = 71{,}906{,}917\ J$$

Table 7.1 (Continued)

$$Qv = Qo \times kg\ H_2O = \left(2.38 \times 10^6\ J/_{kg}\right)\left(56.4\ kg\right)$$

$$Qv = 134{,}2332{,}000\ J$$

Calculating heat of wetting

$$\log w_{60} = 1.23 - 5.4\,(0.6)$$

$$w_{60} = 0.0098\ {cal}/_{g\ wood}$$

$$w_3 = 11.69\ {cal}/_{g\ wood}$$

$$w = 11.64 - .0098 = 11.68\ {cal}/_{g\ wood} \times 4.184\ J/_{g\ wood}$$

$$w = 48.87\ J/_{g\ wood}$$

$$Qw = 48.87\ J/_{g\ wood} \times 1000\ g/_{kg} \times 112.4\ kg = 5{,}494{,}942.8\ J$$

$$Qw = 5{,}494{,}942.8\ J$$

$$Qt = 71{,}906{,}917\ J = 134{,}232{,}000\ J + 5{,}494{,}942.8\ J$$

$$Qt = 211{,}633{,}860\ J$$

$$= 200{,}590.2\ BTU$$

$$multiplied\ 2x$$

$$Qt = 401{,}180.8\ BTU$$

Table 7.1 (Continued)

$$BTU\ total = 765{,}840.4\ BTU + 401{,}180.4\ BTU$$

$$BTU\ total = 1{,}167{,}020.8\ BTU$$

From survey

$$1240.2\ lb\ of\ steam \times 1050\ {}^{BTU}\!/\!_{lb\ steam}$$

$$= 1{,}302{,}210\ BTU$$

APPENDIX B: SIMAPRO 5.0 MODEL OF PLYWOOD MANUFACTURING FOR THE PNW AND SE REGIONS OF THE UNITED STATES

PNW Debarking and Bucking

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:06:02 PM
Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06570100001
Type	Unit process
Name	Debarking and Bucking
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/26/2001
Record	Eric T. Sakimoto
Generator	NW Plywood Mills that were surveyed in 2000-2001 and also information from EPA and DOE websites.
Literature references	
Collection method	Survey and Website information
Data treatment	
Verification	
Comment	Weighted average on a M3/8 inch basis and oven dry basis
Cluster	No
Allocation rules	Bark is not allocated because it is assumed to be in the process and not sold as a by-product.
System description	

Resources

PNW Logs	65.6 cuft	The log mass calculations is based on an average percentage of wood species multipled by the densities of each wood species used in all mills surveyed. The average wood density is equal to 27.26 lbs/ft3. 1 cuft of logs = 27.26 lb of wood + 3.015 lb of bark
PNW Bark on Logs	6.6 cuft	Assumes 10% of the volume of logs is equal to the amount of bark. What is the density

Materials/fuels

Diesel equipment (gal)	3.951E-1 gal*	All diesel from survey is placed here. This is fuel that is used in the log yard to move logs around.

Electricity/heat

Electricity Selector, PNW	17.22 kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 12.4 % of total electricity use.

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

1Logs-Debarking and Bucki	1788.3 lb	99.1 %	not defined	CORRIM PNV	Using 65.6 cuft. as the log volume and a combined density of Douglas fir, Sitka Spruce, Hemlock fir & Larch equaling 27.26 lbs./cuft. on an oven dry basis with a wet volume
Bark, PNW	197.8 lb	0 %	not defined	CORRIM PNV	If mass information is changed, then transportation information needs to also be changed. wet basis (50% MC)
Sold Bark, PNW	16.1 lb	0.9 %	not defined	CORRIM PNV	wet basis (50% MC)

Avoided products

End

PNW Log Conditioning

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:24:38 PM
Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06553700005
Type	Unit process
Name	Log Conditioning
Time period	Mixed data
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	surveys and other sources
Literature references	
Collection method	surveys, books and websites
Data treatment	
Verification	
Comment	Weighted Average on a M3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources			
Municipal Water Source	82.8	gal*	Survey Weighted Data
Well Water Source	29.4	gal*	Survey Weighted Data
Recycled Water	0.33	gal*	Survey Weighted Data
Materials/fuels			
1Logs-Debarking and Bucki	1788.3	lb	
Natural gas equipment (BTL	6.58E3	Btu	LPG substitute used for combustion emissions Equal weighting divided by five machine center (20%)
Electricity/heat			
Electricity Selector, PNW	9.584	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 6.9% of total electricity use.
Steam	125977.1	Btu	1050 BTU/lbs of steam; 4500 BTU/ lbs of OD wood (67% efficiency which gives 3000 BTU/lb of OD wood of output steam.) Wood. used information from survey and energy balance worksheet. 17/1 lbs of steam/M 11.2% of total steam use from wood boilers.
Heat from nat. gas FAL	4875.3	Btu	Natural gas boiler using FAL database, including all burdens associated with travel and others. 5% of total natural gas used. 6.0 ft^3 on a weighted average basis - MSF 3/8 1015.68*0.80 BTU/ lbs of steam

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products					
2Condition log, PNW	1788.3 lb	100 %	not defined	CORRIM PNV	Oven-dry weight, wet volume. Assumes no material lost between subunit process debarking and log conditioning.

PNW Peeling and Clipping

SimaPro 5.0 Educational	Process	Date: 11/19/2002 Time: 4:06:12 PM Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06553700006
Type	Unit process
Name	Peeling and Clipping
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Surveys and information from websites
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	M3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels			
2Condition log, PNW	1788.3	lb	
Natural gas equipment (BTL	6.58E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center (20%)
Electricity/heat			
Electricity Selector, PNW	24.45	kWh	CJ ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 17.6% of total electricity use.
Emissions to air			
particulates	1.308E-2	lb	Survey weighted data
particulates (PM10)	6.542E-3	lb	Survey weighted data

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products						
3Green Veneer, PNW	1236.9	lb	69.17 %	not defined	CORRIM PNV	
Peeler core, PNW	95.1	lb	5.32 %	not defined	CORRIM PNV	1/ Density is calculated from specific gravity from Wood Handbook: Wood as an Engineering Material Diameter = 4.62 in.; Length = 8 ft.; density = 27.26lb/cu.ft.
Green clipping, PNW	31	lb	1.73 %	not defined	CORRIM PNV	Calculated from survey from MSF to pounds
Wood chips, PNW	425.3	lb	23.78 %	not defined	CORRIM PNV	Taken straight from survey

Avoided products

End

PNW Veneer Drying

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:25:14 PM
Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06553700007
Type	Unit process
Name	Drying of veneer
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Surveys and websites
Literature references	
Collection method	survey
Data treatment	
Verification	
Comment	M 3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources			
Hogged Fuel Direct Fired Fu	95274	Btu	31.6 lbs of self generated Hogged Fuel is used in this fuel cell. The burdens of travel for wood has been removed from the fuel cell module itself.
Natural Gas Direct Fired Fu	104493.2	Btu	128.6 ft^3 of natural gas into a direct fired dryer. use survey emissions and delete FAL emissions 1015.68*0.8 conversion from ft^3 to btu
Materials/fuels			
3Green Veneer, PNW	1236.9	lb	
Veneer, purchased green Pl	15.05	lb	Added purchase green veneer to total dry veneer output.Density of species mix = 27.26 lbs/ft3 ; oven-dry weight
Natural gas equipment (BTU	6.58E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center (20%)
Electricity/heat			
Electricity Selector, PNW	50.98	kWh	CJFerrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 36.7% of total electricity use.
Steam	822298.8	Btu	1050 BTU/lbs of steam; 4500 BTU/ lbs of OD wood (67% efficiency giving 3000 BTU/ lb of OD wood output) used information from survey and energy balance worksheet. 73% of steam used from wood boilers.
Emissions to air			
CO2 (fossil)	2.707	lb	From natural gas direct-fired fuel cell Calculated from EPA Plywood Manufacturing - Emission Factor Documentation, AP-42, Chapter 10, Table 10.5, 2002
CO2 (biomass)	9.3	lb	From Hogged Fuel Direct Fired Fuel Cell Calculated from EPA Plywood Manufacturing - Emission Factor Documentation, AP-42, Chapter 10, Table 10.5, 2002
CO	1.49E-1	lb	Survey weighted data
SO2	1.103E-3	lb	Survey weighted data
NOx	4.994E-2	lb	Survey weighted data
particulates (PM10)	2.811E-1	lb	Survey weighted data
particulates	3.159E-1	lb	Survey weighted data
VOC	6.278E-1	lb	Survey weighted data
acrolein	7.05E-7	lb	Survey weighted data
acetaldehyde	1.1E-2	lb	Survey weighted data
formaldehyde	2.24E-2	lb	Survey weighted data
methanol	3.44E-2	lb	Survey weighted data
phenol	2.76E-3	lb	Survey weighted data

PNW Veneer Drying (Continued)

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:25:14 PM
Project: NW Plywood

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

4Dry Veneer, PNW	1185.5 lb	94.7 %	not defined	CORRIM PNV	
Veneer Downfall, PNW	3.44 lb	0.3 %	not defined	CORRIM PNV	Straight from surveys.
Veneer, Sold Dry PNW	63.1 lb	5 %	not defined	CORRIM PNV	This is veneer that is being sold to an outside customer. Density of species mix = 27.26 lbs/ft3; oven dry weight

Avoided products

End

PNW Pressing

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:25:05 PM
Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06553700010
Type	Unit process
Name	Pressing of plywood
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Eric Dancer survey calculations
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

4Dry Veneer, PNW	1185.5	lb	
Veneer, purchased dry PNW	6.432	lb	Density of species mix = 27.26 lbs/ft3; oven-dry weight.
Phenol formaldehyde Resin	15.88	lb	40-70% solids for phenol formaldehyde
Natural gas equipment (BTU	6.58E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center

Electricity/heat

Electricity Selector, PNW	15.28	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 11% of total electricity use.
Steam	177826.6	Btu	1050 BTU/lbs of steam; 4500 BTU/ lbs of OD wood (67% efficiency, giving 3000 BTU/lbs of OD wood output) used information from survey and energy balance worksheet. 15.8% of steam used from wood boilers.
Heat from nat. gas FAL	23401.3	Btu	Natural gas boiler using FAL database, including all burdens associated with travel and others. 24% of total natural gas used. 28.8 ft^3 on a weighted average basis - MSF 3/8

Emissions to air

particulates	1.2E-1	lb	Calculated from EPA Plywood Manufacturing - Emission Factor Documentation, AP-42, Chapter 10, Table 10.5, 2002
VOC	2.5E-1	lb	Pressing emission data is from EPA studies in 2002
acetone	6.5E-3	lb	Pressing emission data is from EPA studies in 2002
acetaldehyde	4.2E-3	lb	Pressing emission data is from EPA studies in 2002
formaldehyde	1.9E-3	lb	Pressing emission data is from EPA studies in 2002
methanol	1.4E-1	lb	Pressing emission data is from EPA studies in 2002
methyl ethyl ketone	8.7E-4	lb	Pressing emission data is from EPA studies in 2002
methyl i-butyl ketone	7.1E-4	lb	Pressing emission data is from EPA studies in 2002
phenol	1.4E-3	lb	Pressing emission data is from EPA studies in 2002
alpha-pinene	9.8E-2	lb	Pressing emission data is from EPA studies in 2002
beta-pinene	3.8E-2	lb	Pressing emission data is from EPA studies in 2002
Limonene	1.1E-2	lb	Pressing emission data is from EPA studies in 2002
THC as carbon	2.1E-1	lb	Pressing emission data is from EPA studies in 2002

Emissions to water

Solid emissions

PNW Pressing (Continued)

SimaPro 5.0 Educational	Process	Date: 11/13/2002 Time: 5:25:05 PM Project: NW Plywood

Emissions to soil

Non material emission

Waste to treatment

Products

5Layup/Press plywood, PNV	1191.9 lb	100 % not defined	CORRIM PNV

Avoided products

End

PNW Plywood - Trimming and Sawing

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:06:22 PM
Project: NW Plywood

Process

Category type	Material
Process identifier	orst01XX06553700012
Type	Unit process
Name	Trim and saw plywood
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

5Layup/Press plywood, PNV	1191.9	lb	
Natural gas equipment (BTL	6.56E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center. (20%)

Electricity/heat

Electricity Selector, PNW	21.39	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111. 15.4 of total electricity use.

Emissions to air

particulates	1.006E-2	lb	Survey weighted data
particulates (PM10)	1.006E-2	lb	Survey weighted data

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Plywood, PNW	937.1	lb	78.62 %	not defined	CORRIM PNV	Sub unit process: Trim and Sawing estimated weight using a density of 27.26 lbs/ft3 and multiplied by 1.1 for densification of plywood during pressing. 1054.5 lbs of plywood based on Material flow and balance.
Panel Trim, PNW	106.8	lb	8.96 %	not defined	CORRIM PNV	From survey
Sawdust, PNW	9.63	lb	0.81 %	not defined	CORRIM PNV	From survey
Wood Waste Sold, PNW	21	lb	1.76 %	not defined	CORRIM PNV	From survey
Wood Waste to boiler, PNW	0.5	lb	0 %	not defined	CORRIM PNV	Value from one mill, not specified from which machine center it was generated.
Unaccounted co-product	117.4	lb	9.85 %	not defined	CORRIM PNV	This assumes that the input of logs, purchased veneer is correct data and that as a result, the material outputs are off and 10% of the wood is leftover. Includes weight of resin.

PNW Phenol Formaldehyde

Process

Category type	Material
Process identifier	orst01XX06565400031
Type	Unit process
Name	Production of 1 pound (lb) of phenolic resin
Time period	1990-1994
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unspecified
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	4/3/2001
Record	Maureen Puettmann, Oregon State University, CORRIM II Study
Generator	Based on data from ATHENA, Raw Material Balances, Energy Profiles and Environmental Unit Factor Estimates: Structural Wood Products. 1993
Literature references	
Collection method	
Data treatment	
Verification	
Comment	Based on data from ATHENA, Raw Material Balances, Energy Profiles and Environmental Unit Factor Estimates: Structural Wood Products. 1993
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels			
Formaldehyde	0.65	lb	
Phenol	0.35	lb	
Natural gas FAL	8.67	cuft	Embodied Energy of Feedstock in the manufacturing of Phenolic resin. ATHENAtm. 1993
Gasoline FAL	0.1079	gal*	Embodied Energy of Feedstock in the manufacturing of Phenolic resin. ATHENAtm. 1993. conversion of energy to volume is from http://www.opm.state.ct.us/pdpd2/energy/flows94.htm
Electricity/heat			
Electricity Selector, PNW	6.45E-1	kWh	
Gasoline equipment (BTU)	4.302353	Btu	Process Energy covering transportation and combustion ATHENAtm. 1993.
Heat from nat. gas FAL	1.16E4	Btu	Process Energy covering transportation and combustion ATHENAtm. 1993.
Diesel equipment (BTU)	6.24E2	Btu	Process Energy covering transportation and combustion ATHENAtm. 1993.
Emissions to air			
formaldehyde	1.190E-3	lb	

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products						
Phenol formaldehyde Resin	1	lb	100 %	not defined	CORRIM (ME	Based on data from ATHENA, Raw Material Balances, Energy Profiles and Environmental Unit Factor Estimates: Structural Wood Products. 1993

Avoided products

End

PNW Steam

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:07:22 PM
Project: NW Plywood

Process

Category type	Energy
Process identifier	orst01XX06624000004
Type	Unit process
Name	Wood Boiler used for Plywood Production
Time period	2000-2004
Geography	North America
Technology	Mixed data
Representativeness	Average from a specific process
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	5/15/2001
Record	Eric Sakimoto
Generator	NW Plywood Mills that were surveyed in 2000-2001 and also information from EPA and DOE websites.
Literature references	
Collection method	Surveys, Publications and Websites
Data treatment	
Verification	
Comment	Wieghted average on a M 3/8 inch basis and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

Heat from wood FAL	101.7 Btu	The division of fuel usage is a percentage of 1000 BTU of steam output from the boiler. A decimal percentage is found and then multiplied by 1000. Purchased Hogged Fuel = 114570 BTU Total amount of steam used = 1126102.5 BTU
CORRIM Wood Boiler, Stea	898.3 Btu	Generated Hogged Fuel + Wood Waste = 1011532.5 BTU Gen. H.F. =1010025 BTU (This number subtracts HF sold and HF into fuel Cell); Wood Waste = 1507.5 BTU

Electricity/heat

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Steam	1000 Btu	100 %	CORRIM Boil

Avoided products

End

PNW CORRIM Wood Boiler

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:07:38 PM
Project: NW Plywood

Process

Category type	Energy
Process identifier	orst01XX06565400026
Type	Unit process
Name	Combustion of Wood in Industrial Boilers (1000 lb), at 50% wet-basis MC
Time period	1995-1999
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Unspecified
Substitution allocation	Unspecified
Cut off rules	Unspecified
Capital goods	Unspecified
Boundary with nature	Unspecified
Date	9/10/1998
Record	Sylvatica, North Berwick, Maine, USA
Generator	Based on emission in Franklin Associates, Prairie Village, Kansas, USA
Literature references	Franklin Assoc. 1998
Collection method	Drawn from a variety of 57 public and private USA statistical sources, reports, and telephone conversations with experts.
Data treatment	
Verification	Evaluation and peer review for consistency and reasonableness.
Comment	Data for the combustion of 1000 lbs of wood (4.5 Million Btu in 1996, this value from Franklin)) in industrial boilers. Average USA technology, late 1990's. (1000 pounds= 453.59 kilograms)
Cluster	No
Allocation rules	Where possible, specific unit processes have been identified for the product of interest. Where this cannot be done, allocation is on a mass basis.
System description	FAL98 USA Fuel/Electricity

Resources

Materials/fuels

Bark self generated, PNW	998.5	lb	self generated bark 335 lb/MSF (The bark or HF is the net amount after subtracting HF sold and Fuel cell HF.) Does not include purchased bark- That is in FAL boiler. 382.7 lbs-total/383.5lb= % of total equallling 1000lbs
Wood waste self generated,	1.5	lb	unknown source self generated wood waste 0.5 lb/MSF

Electricity/heat

Emissions to air

particulates	0.085	lb	All these are based on the combustion of 1000 pounds
NOx	0.75	lb	of wood at 50% MC.
organic substances	0.083	lb	So, make sure that the process input is 1000 pounds.
SOx	0.038	lb	Adjust Steam out to match boiler efficiency
CO	6.8	lb	
CO2 (biomass)	1050	lb	Field changed
phenol	0.02	lb	
Pb	6.0E-4	lb	
formaldehyde	0.0033	lb	
acetaldehyde	0.0015	lb	
benzene	0.0018	lb	
naphthalene	0.0012	lb	
As	4.4E-5	lb	
Cr	2.3E-5	lb	
Mn	0.0045	lb	
Ni	2.8E-4	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	

Emissions to water

Solid emissions

solid waste	45	lb

PNW Electricity

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:07:30 PM
Project: NW Plywood

Process

Category type	Energy
Process identifier	orst01XX06565400019
Type	Unit process
Name	Electricity, PNW
Time period	2000-2004
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	4/3/2001
Record	Eric T. Sakimoto
Generator	Plywood Mills
Literature references	
Collection method	Surveys
Data treatment	
Verification	
Comment	
Cluster	No
Allocation rules	
System description	

Resources

Electricity from other source	0.011	kWh	Other from Source: Energy Information Administration/Electric Power Annual 2000 Volume I

Materials/fuels

Electricity/heat

Electricity from coal FAL	0.081	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from DFO FAL	0.0025	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from nat. gas FAL	0.123	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from uranium FAL	0.0395	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity hydropower FAL	0.743	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Electricity, PNW	1	kWh	100 %	CORRIM Ene	This is the distribution of the type of electricity generation. These percentages are based on Washington and Oregon information from the Department of Energy.

Avoided products

End

SE Debarking and Bucking

SimaPro 5.0 Educational — Process — Date: 11/19/2002 Time: 4:17:12 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600011
Type	Unit process
Name	Debarking and Bucking
Time period	2000-2004
Geography	Mixed data
Technology	Best available technology
Representativeness	Average from a specific process
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/26/2001
Record	Eric T. Sakimoto
Generator	SE Plywood Mills that were surveyed in 2000-2001 and also information from EPA and DOE websites.
Literature references	
Collection method	Survey and Website information
Data treatment	
Verification	
Comment	Weighted average on a M3/8 inch basis and oven dry basis
Cluster	No
Allocation rules	
System description	

Resources

SE Logs	65.99	cuft	The log mass calculations is based on an average percentage of wood species multipled by the densities of each wood species used in all mills surveyed. The average wood density is equal to 31.51 lbs/ft3. 1 cuft of logs = 31.51 lbs of wood at a MC on a dry basis but on a wet volume.
SE Bark from log	6.599	cuft	This is bark on logs and is given on a ten% basis of the volume of log. Calculated.

Materials/fuels

Diesel equipment (gal)	2.7E-1	gal*	All diesel fuel from survey is placed here. This is fuel that is used inthe log yard to move logs around.

Electricity/heat

Electricity Selector, SE	15.13	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

1Logs-Debarking and Bucki	2079.5	lb	98.5 %	not defined	CORRIM SE I	Wood density = 31.51 lb/cuft
Bark, SE	247.68	lb	0 %	not defined	CORRIM SE I	Wet basis. If mass information is changed, then transportation information needs to also be changed.
Sold Bark, SE	31.75	lb	1.5 %	not defined	CORRIM SE I	Sold Hogged fuel - Less Energy sold or transferred

Avoided products

End

SE Log Conditioning

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:22:11 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600021
Type	Unit process
Name	Log Conditioning
Time period	Mixed data
Geography	North America
Technology	Best available technology
Representativeness	Average from a specific process
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	surveys and other sources
Literature references	
Collection method	surveys, books and websites
Data treatment	
Verification	
Comment	Weighted Average on a M3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Municipal Water Source	30.45	gal*	Weighted Survey Data
Well Water Source	93.01	gal*	Weighted Survey Data
Recycled Water Source	0.82	gal*	

Materials/fuels

1Logs-Debarking and Bucki	2079.5	lb	
Natural gas equipment (BTU	7.7E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center (20%)

Electricity/heat

Electricity Selector, SE	8.421	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.
Steam, SE	168010	Btu	4500 BTU/ lbs of OD wood *67% efficiency giving 3000 BTU/ lb of OD wood. used information from survey and energy balance worksheet. 10.98% of total steam used.

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

2Condition log, SE	2079.5	lb	100 %	not defined	CORRIM SE F

Avoided products

End

SE Peeling and Clipping

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:08:14 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600012
Type	Unit process
Name	Peeling and Clipping
Time period	2000-2004
Geography	North America
Technology	Best available technology
Representativeness	Average from processes with similar outputs
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Surveys and information from websites
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	M3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

2Condition log, SE	2079.5	lb	
Natural gas equipment (BTU	7.7E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center (20%)

Electricity/heat

Electricity Selector, SE	21.48	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

3Green Veneer, SE	1149.5	lb	55.3 %	not defined	CORRIM SE I	
Peeler core, SE	112	lb	5.4 %	not defined	CORRIM SE I	Diameter = 3.25 in.; Length = 8 ft.; Wood density 31.51lb/ft3 oven-dry basis.
Green clipping, SE	172.7	lb	8.3 %	not defined	CORRIM SE I	information comes from one source
Wood chips, SE	645.1	lb	31 %	not defined	CORRIM SE I	From survey

Avoided products

End

Veneer Drying

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:22:48 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600014
Type	Unit process
Name	Drying of veneer
Time period	2000-2004
Geography	North America
Technology	Best available technology
Representativeness	Average from processes with similar outputs
Multiple output allocation	Not applicable
Substitution allocation	Not applicable
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Surveys and websites
Literature references	
Collection method	survey
Data treatment	
Verification	
Comment	M 3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources			
Natural gas direct fired	209271	Btu	1015.68*0.85 BTU/ cuft of steam Direct-Fired natural gas and also fuel used in Emission Control Devices- RTO, RCO, and WESP All natural gas is used here.
Materials/fuels			
3Green Veneer, SE	1149.5	lb	
Veneer, purchased green SI	10.44	lb	Added purchase veneer to total dry veneer output. Information only comes from one source. Density of species mix = 31.51 lbs/ft3
Natural gas equipment (BTL	7.7E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center (20%)
Electricity/heat			
Electricity Selector, SE	44.79	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.
Steam, SE	1135802.04	Btu	4500 BTU/ lbs of OD wood *67% efficiency giving 3000 BTU/ lbs of OD wood. used information from survey and energy balance worksheet. 74.26% of total steam production.
Emissions to air			
CO2 (fossil)	4.4	lb	Drying emission data is from EPA studies in 2000
CO	1.216E-1	lb	Survey weighted data
SO2	8.214E-5	lb	Survey weighted data
NOx	4.055E-2	lb	Survey weighted data
particulates (PM10)	2.085E-2	lb	Survey weighted data
particulates	7.346E-2	lb	Survey weighted data
VOC	7.605E-2	lb	Survey weighted data
acrolein	6.767E-6	lb	Survey weighted data
acetaldehyde	3.383E-4	lb	Survey weighted data
formaldehyde	2.707E-4	lb	Survey weighted data
methanol	7.209E-4	lb	Survey weighted data
phenol	3.154E-4	lb	Survey weighted data
water vapor	5.445E2	lb	Survey weighted data

Emissions to water

Solid emissions

Emissions to soil

SE Veneer Drying (Continued)

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:22:48 PM
Project: SE Plywood

Non material emission

Waste to treatment

Products

4Dry Veneer, SE	1159.8 lb	99.98 %	not defined	CORRIM SE I	Dry veneer that has been produced inside the plywood mill.
Veneer, Sold Dry SE	0.2 lb	0.02 %	not defined	CORRIM SE I	This is veneer that is being sold to an outside customer Information only comes from one source. Density of species mix = 31.51 lbs/ft3

Avoided products

End

SE Pressing

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:22:55 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600022
Type	Unit process
Name	Pressing of plywood
Time period	2000-2004
Geography	North America
Technology	Best available technology
Representativeness	Average from processes with similar outputs
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Unknown
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unknown
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	Eric Dancer survey calculations
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	M 3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels			
4Dry Veneer, SE	1159.8	lb	
Veneer, purchased dry SE	8.07	lb	Density of species mix = 31.51 lbs/ft3
Phenol formaldehyde Resin	19.68	lb	
Natural gas equipment (BTL	7.7E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center
Electricity/heat			
Electricity Selector, SE	13.42	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.
Steam, SE	225757.75	Btu	4500 BTU/ lbs of OD wood*0.67% giving 3000 BTU/lbs of OD wood.; Steam from hog fuel and wood waste used information from survey and energy balance worksheet. 14.76% of total steam used
Emissions to air			
particulates	1.779E-1	lb	Pressing emission data is from EPA studies in 2000 and primary survey.
THC as Carbon	2.1E-1	lb	Pressing emission data is from EPA studies in 2000
VOC	2.5E-1	lb	Pressing emission data is from EPA studies in 2000
acetone	6.5E-3	lb	Pressing emission data is from EPA studies in 2000
acetaldehyde	4.2E-3	lb	Pressing emission data is from EPA studies in 2000
alpha-pinene	9.8E-2	lb	Pressing emission data is from EPA studies in 2000
beta-pinene	3.8E-2	lb	Pressing emission data is from EPA studies in 2000
formaldehyde	1.9E-3	lb	Pressing emission data is from EPA studies in 2000
limonene	1.1E-2	lb	Pressing emission data is from EPA studies in 2000
methanol	1.4E-1	lb	Pressing emission data is from EPA studies in 2000
methyl ethyl ketone	8.7E-4	lb	Pressing emission data is from EPA studies in 2000
methyl i-butyl ketone	7.1E-4	lb	Pressing emission data is from EPA studies in 2000
phenol	1.4E-3	lb	Pressing emission data is from EPA studies in 2000
water vapor	2.852E1	lb	Primary Survey

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

SE Pressing (Continued)

SimaPro 5.0 Educational | Process | Date: 11/13/2002 Time: 5:22:55 PM
Project: SE Plywood

Products

5Layup/Press plywood, SE	1167.9 lb	100 %	not defined	CORRIM SE I

Avoided products

End

SE Plywood - Trimming and Sawing

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:08:27 PM
Project: SE Plywood

Process

Category type	Material
Process identifier	orst01XX06768600009
Type	Unit process
Name	Trim and saw plywood
Time period	2000-2004
Geography	North America
Technology	Best available technology
Representativeness	Average from processes with similar outputs
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	3/28/2001
Record	Eric T. Sakimoto
Generator	
Literature references	
Collection method	Survey
Data treatment	
Verification	
Comment	M 3/8 inch and oven-dry basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

5Layup/Press plywood, SE	1167.9	lb	Input from previous process.
Natural gas equipment (BTL	7.7E3	Btu	LPG substitution for combustion emissions Equal weighting divided by five machine center. (20%)

Electricity/heat

Electricity Selector, SE	18.79	kWh	CJ Ferrari's thesis Table 24, Appendix D - Distribution of electrical use by Machine Centers pg 111.

Emissions to air

particulates	3.444E-1	lb	Survey weighted data
particulates (PM10)	9.791E-2	lb	Survey weighted data

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Plywood, SE	1083.2	lb	88.1 %	not defined	CORRIM SE I	As a result of the mass balance, the output is higher then the amount of mass as logs and purchased veneer. The difference = 61.30 lbs. (5% difference)
Panel Trim, SE	60.57	lb	4.9 %	not defined	CORRIM SE I	From survey
Sawdust, SE	4.19	lb	0.3 %	not defined	CORRIM SE I	From survey
Wood Waste Sold, SE	20.5	lb	1.7 %	not defined	CORRIM SE I	From survey
Wood Waste to boiler, SE	60.69	lb	5 %	not defined	CORRIM SE I	From survey

Avoided products

End

SE Phenol Formaldehyde

Process

Category type	Material
Process identifier	orst01XX06768600003
Type	Unit process
Name	Production of 1 pound (lb) of phenolic resin
Time period	1990-1994
Geography	North America
Technology	Best available technology
Representativeness	Unknown
Multiple output allocation	Unspecified
Substitution allocation	Unspecified
Cut off rules	Unspecified
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	4/3/2001
Record	Maureen Puettmann, Oregon State University, CORRIM II Study
Generator	Based on data from ATHENA, Raw Material Balances, Energy Profiles and Environmental Unit Factor Estimates: Structural Wood Products. 1993
Literature references	
Collection method	
Data treatment	
Verification	
Comment	
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

Formaldehyde	0.65	lb	.65*19.68=12.79 lb/msf
Phenol	0.35	lb	.35*19.68=6.89 lb/msf
Natural gas FAL	8.67	cuft	20.5GJ/tonne Embodied Energy of Feedstock in the manufacturing of Phenolic resin. ATHENAtm, 1993.
Gasoline FAL	0.1079	gal*	31.4GJ/tonne Embodied Energy of Feedstock in the manufacturing of Phenolic resin. ATHENAtm, 1993.

Electricity/heat

Electricity Selector, SE	6.45E-1	kWh	=12.69
Gasoline equipment (BTU)	84.67	Btu	4.302353*19.68=84.67 btu/msf
Natural gas equipment (BTL	1.16E4	Btu	1.16E4*19.68= 228,288 btu/msf
Diesel equipment (BTU)	6.24E2	Btu	6.24E2*19.68= 12280.32 btu/msf

Emissions to air

formaldehyde	1.190E-3	lb

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Phenol formaldehyde Resin	1	lb	100 %	not defined	CORRIM (ME

Avoided products

End

SE Steam

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:16:53 PM
Project: SE Plywood

Process

Category type	Energy
Process identifier	orst01XX06768600026
Type	Unit process
Name	Steam
Time period	2000-2004
Geography	North America
Technology	Mixed data
Representativeness	Average from a specific process
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	5/15/2001
Record	Eric T. Sakimoto
Generator	SE plywood mills that were surveyed in 2000-2001 and also information from EPA and DOE websites
Literature references	
Collection method	Survey and website information
Data treatment	
Verification	
Comment	Weighted Average MSF (3/8-inch) basis
Cluster	No
Allocation rules	
System description	

Resources

Materials/fuels

Heat from wood FAL	180.5	Btu	18.1% of BTU generated
CORRIM Wood Boiler, Stea	819.5	Btu	81.9% of BTU generated - self generated hogged fuel + wood waste generated

Electricity/heat

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Steam, SE	1000	Btu	100 %	CORRIM Boil

Avoided products

End

SE CORRIM Wood Boiler

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:08:51 PM
Project: SE Plywood

Process

Category type	Energy
Process identifier	orst01XX06768600008
Type	Unit process
Name	Combustion of Wood in Industrial Boilers (1000 lb), at 50% wet-basis MC
Time period	1995-1999
Geography	North America
Technology	Average technology
Representativeness	Mixed data
Multiple output allocation	Unspecified
Substitution allocation	Unspecified
Cut off rules	Unspecified
Capital goods	Unspecified
Boundary with nature	Unspecified
Date	9/10/1998
Record	Sylvatica, North Berwick, Maine, USA
Generator	Based on emission in Franklin Associates, Prairie Village, Kansas, USA
Literature references	Franklin Assoc. 1998
Collection method	Drawn from a variety of 57 public and private USA statistical sources, reports, and telephone conversations with experts.
Data treatment	
Verification	Evaluation and peer review for consistency and reasonableness.
Comment	Data for the combustion of 1000 lbs of wood (4.5 Million Btu in 1996, this value from Franklin)) in industrial boilers. Average USA technology, late 1990's. (1000 pounds= 453.59 kilograms)
Cluster	No
Allocation rules	Where possible, specific unit processes have been identified for the product of interest. Where this cannot be done, allocation is on a mass basis.
System description	FAL98 USA Fuel/Electricity

Resources

Materials/fuels			
Bark self generated, SE	854	lb	self generated hogged fuel 386.8 lb/MSF representing 247.6 lb of bark/MSF. Percentage allocated
Wood waste self generated,	146	lb	self generated wood waste 60.69 lb/MSF
Electricity/heat			
Electricity Selector, SE	0	kWh	
Emissions to air			
particulates	0.085	lb	All these are based on the combustion of 1000 pounds
NOx	0.75	lb	of wood at 50% MC.
organic substances	0.083	lb	So, make sure that the process input is 1000 pounds.
SOx	0.038	lb	Adjust Steam out to match boiler efficiency
CO	6.8	lb	
CO2 (biomass)	1050	lb	Field changed
phenol	0.02	lb	
Pb	6.0E-4	lb	
formaldehyde	0.0033	lb	
acetaldehyde	0.0015	lb	
benzene	0.0018	lb	
naphthalene	0.0012	lb	
As	4.4E-5	lb	
Cr	2.3E-5	lb	
Mn	0.0045	lb	
Ni	2.8E-4	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	
Emissions to water			
Solid emissions			
solid waste	45	lb	

SE Electricity

SimaPro 5.0 Educational | Process | Date: 11/19/2002 Time: 4:08:44 PM
Project: SE Plywood

Process

Category type	Energy
Process identifier	orst01XX06768600004
Type	Unit process
Name	Electricity, PNW
Time period	2000-2004
Geography	North America
Technology	Best available technology
Representativeness	Average from processes with similar outputs
Multiple output allocation	Physical causality
Substitution allocation	Unspecified
Cut off rules	Less than 5% (physical criteria)
Capital goods	Second order (material/energy flows including operations)
Boundary with nature	Unspecified
Date	4/3/2001
Record	Eric T. Sakimoto
Generator	Plywood Mills
Literature references	
Collection method	Surveys
Data treatment	
Verification	
Comment	
Cluster	No
Allocation rules	
System description	

Resources

Electricity from other source	0.0353	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I

Materials/fuels

Electricity/heat

Electricity from coal FAL	0.4556	kWh	DOE information Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from DFO FAL	0.0449	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from nat. gas FAL	0.2303	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from uranium FAL	0.2157	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity hydropower FAL	0.0183	kWh	Source: Energy Information Administration/Electric Power Annual 2000 Volume I

Emissions to air

Emissions to water

Solid emissions

Emissions to soil

Non material emission

Waste to treatment

Products

Electricity, SE	1	kWh	100 %	CORRIM Ene

Avoided products

End

APPENDIX C: NATIONAL AMBIENT AIR QUALITY STANDARDS AND A LIST OF HAZARDOUS AIR POLLUTANTS UNDER THE CLEAN AIR ACT AMENDMENTS OF 1990

TABLE 7.2. National Ambient Air Quality Standards

National Ambient Air Quality Standards

Pollutant	Standard Value*				Standard Type
Carbon Monoxide (CO)					
8 - hour average	9	ppm	10	ug/m3	Primary
1 - hour average	35	ppm	40	ug/m3	Primary
Nitrogent Dioxide					
Annual Arithmetic Mean	0.05	ppm	100	ug/m3	Primary & Secondary
Ozone (O3)					
1 - hour average	0.12	ppm	235	ug/m3	Primary & Secondary
8 - hour average	0.08	ppm	157	ug/m3	Primary & Secondary
Lead (Pb)					
Quarterly Average	1.5	ug/m3			Primary & Secondary
Particulate (PM10)					
Annual Arithmetic Mean	50	ug/m3			Primary & Secondary
24 - hour average	150	ug/m3			Primary & Secondary
Particulate (PM2.5)					
24 - hour average**	65	ug/m3			Primary & Secondary
Sulfur Dioxide (SO2)					
Annual Arithmetic Mean	0.03	ppm	80	ug/m3	Primary
24 - hour average	0.14	ppm	356	ug/m3	Primary
3 - hour average	0.5	ppm	1300	ug/m3	Secondary

*Parenthetical value is an approximately equivalent concentration

**The ozone 8-hour standard and the PM 2.5 standards are included for information only. A 1999 federal court ruling blocked

implementation of these standards, which EPA proposed in 1997. EPA has asked the U.S. Supreme Court to reconsider

that decision. The Updated air quality standards website has additional information

1/ information comes from the EPA website

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990

Chemical Abstracts Service Number Pollutant

1. 75-07-0 Acetaldehyde
2. 60-35-5 Acetamide
3. 75-05-8 Acetonitrile
4. 98-86-2 Acetophenone
5. 53-96-3 2-Acetylaminofluorene
6. 107-02-8 Acrolein
7. 79-06-1 Acrylamide
8. 79-10-7 Acrylic acid
9. 107-13-1 Acrylonitrile
10. 107-05-1 Allyl chloride
11. 92-67-1 4-Aminobiphenyl
12. 62-53-3 Aniline
13. 90-04-0 o-Anisidine
14. 1332-21-4 Asbestos
15. 71-43-2 Benzene (including benzene from gasoline)
16. 92-87-5 Benzidine
17. 98-07-7 Benzotrichloride
18. 100-44-7 Benzyl chloride
19. 92-52-4 Biphenyl
20. 117-81-7 Bis(2-ethylhexyl)phthalate (DEHP)
21. 542-88-1 Bis(chloromethyl) ether
22. 75-25-2 Bromoform
23. 106-99-0 1,3-Butadiene
24. 156-62-7 Calcium cyanamide
25. 105-60-2 Caprolactam (Removed 6/18/96, 61FR30816)
26. 133-06-2 Captan
27. 63-25-2 Carbaryl
28. 75-15-0 Carbon disulfide
29. 56-23-5 Carbon tetrachloride
30. 463-58-1 Carbonyl sulfide
31. 120-80-9 Catechol
32. 133-90-4 Chloramben
33. 57-74-9 Chlordane
34. 7782-50-5 Chlorine
35. 79-11-8 Chloroacetic acid

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990 (Continued)

36. 532-27-4 2-Chloroacetophenone
37. 108-90-7 Chlorobenzene
38. 510-15-6 Chlorobenzilate
39. 67-66-3 Chloroform
40. 107-30-2 Chloromethyl methyl ether
41. 126-99-8 Chloroprene
42. 1319-77-3 Cresol/Cresylic acid (mixed isomers)
43. 95-48-7 o-Cresol
44. 108-39-4 m-Cresol
45. 106-44-5 p-Cresol
46. 98-82-8 Cumene
47. N/A 2,4-D (2,4-Dichlorophenoxyacetic Acid) (including salts and esters)
48. 72-55-9 DDE (1,1-dichloro-2,2-bis(p- chlorophenyl) ethylene)
49. 34-88-3 Diazomethane
50. 132-64-9 Dibenzofuran
51. 96-12-8 1,2-Dibromo-3-chloropropane
52. 84-74-2 Dibutyl phthalate
53. 106-46-7 1,4-Dichlorobenzene
54. 91-94-1 3,3'-Dichlorobenzidine
55. 111-44-4 Dichloroethyl ether (Bis[2-chloroethyl]ether)
56. 542-75-6 1,3-Dichloropropene
57. 62-73-7 Dichlorvos
58. 111-42-2 Diethanolamine
59. 64-67-5 Diethyl sulfate
60. 119-90-4 3,3'-Dimethoxybenzidine
61. 60-11-7 4-Dimethylaminoazobenzene
62. 121-69-7 N,N-Dimethylaniline
63. 119-93-7 3,3'-Dimethylbenzidine
64. 79-44-7 Dimethylcarbamoyl chloride
65. 68-12-2 N,N-Dimethylformamide
66. 57-14-7 1,1-Dimethylhydrazine
67. 131-11-3 Dimethyl phthalate
68. 77-78-1 Dimethyl sulfate
69. N/A 4,6-Dinitro-o-cresol (including salts)
70. 51-28-5 2,4-Dinitrophenol

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990 (Continued)

71. 121-14-2 2,4-Dinitrotoluene
72. 123-91-1 1,4-Dioxane (1,4-Diethyleneoxide)
73. 122-66-7 1,2-Diphenylhydrazine
74. 106-89-8 Epichlorohydrin (l-Chloro-2,3-epoxypropane)
75. 106-88-7 1,2-Epoxybutane
76. 140-88-5 Ethyl acrylate 1
77. 00-41-4 Ethylbenzene
78. 51-79-6 Ethyl carbamate (Urethane)
79. 75-00-3 Ethyl chloride (Chloroethane)
80. 106-93-4 Ethylene dibromide (Dibromoethane)
81. 107-06-2 Ethylene dichloride (1,2-Dichloroethane)
82. 107-21-1 Ethylene glycol
83. 151-56-4 Ethyleneimine (Aziridine)
84. 75-21-8 Ethylene oxide
85. 96-45-7 Ethylene thiourea
86. 75-34-3 Ethylidene dichloride (1,1-Dichloroethane)
87. 50-00-0 Formaldehyde
88. 76-44-8 Heptachlor
89. 118-74-1 Hexachlorobenzene
90. 87-68-3 Hexachlorobutadiene
91. N/A 1,2,3,4,5,6-Hexachlorocyclohexane (all stereo isomers, including lindane)
92. 77-47-4 Hexachlorocyclopentadiene
93. 67-72-1 Hexachloroethane
94. 822-06-0 Hexamethylene diisocyanate
95. 680-31-9 Hexamethylphosphoramide
96. 110-54-3 Hexane
97. 302-01-2 Hydrazine
98. 7647-01-0 Hydrochloric acid (Hydrogen Chloride)
99. 7664-39-3 Hydrogen fluoride (Hydrofluoric acid)
100. 123-31-9 Hydroquinone
101. 78-59-1 Isophorone
102. 108-31-6 Maleic anhydride
103. 67-56-1 Methanol
104. 72-43-5 Methoxychlor
105. 74-83-9 Methyl bromide (Bromomethane)

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990 (Continued)

106. 74-87-3 Methyl chloride (Chloromethane)
107. 71-55-6 Methyl chloroform (1,1,1-Trichloroethane)
108. 78-93-3 Methyl ethyl ketone (2-Butanone)
109. 60-34-4 Methylhydrazine
110. 74-88-4 Methyl iodide (Iodomethane)
111. 108-10-1 Methyl isobutyl ketone (Hexone)
112. 624-83-9 Methyl isocyanate
113. 80-62-6 Methyl methacrylate
114. 1634-04-4 Methyl tert-butyl ether
115. 101-14-4 4,4'-Methylenebis (2-chloroaniline)
116. 75-09-2 Methylene chloride (Dichloromethane)
117. 101-68-8 4,4'-Methylenediphenyl diisocyanate (MDI)
118. 101-77-9 4,4'-Methylenedianiline
119. 91-20-3 Naphthalene
120. 98-95-3 Nitrobenzene
121. 92-93-3 4-Nitrobiphenyl
122. 100-02-7 4-Nitrophenol
123. 79-46-9 2-Nitropropane
124. 684-93-5 N-Nitroso-N-methylurea
125. 62-75-9 N-Nitrosodimethylamine
126. 59-89-2 N-Nitrosomorpholine
127. 56-38-2 Parathion
128. 82-68-8 Pentachloronitrobenzene (Quintobenzene)
129. 87-86-5 Pentachlorophenol
130. 108-95-2 Phenol
131. 106-50-3 p-Phenylenediamine
132. 75-44-5 Phosgene
133. 7803-51-2 Phosphine
134. 7723-14-0 Phosphorus
135. 85-44-9 Phthalic anhydride
136. 1336-36-3 Polychlorinated biphenyls (Aroclors)
137. 1120-71-4 1,3-Propane sultone
138. 57-57-8 beta-Propiolactone
139. 123-38-6 Propionaldehyde
140. 114-26-1 Propoxur (Baygon)

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990 (Continued)

141. 78-87-5 Propylene dichloride (1,2-Dichloropropane)
142. 75-56-9 Propylene oxide
143. 75-55-8 1,2-Propylenimine (2-Methylaziridine)
144. 91-22-5 Quinoline
145. 106-51-4 Quinone (p-Benzoquinone)
146. 100-42-5 Styrene
147. 96-09-3 Styrene oxide
148. 1746-01-6 2,3,7,8-Tetrachlorodibenzo-p-dioxin
149. 79-34-5 1,1,2,2-Tetrachloroethane
150. 127-18-4 Tetrachloroethylene (Perchloroethylene)
151. 7550-45-0 Titanium tetrachloride
152. 108-88-3 Toluene
153. 95-80-7 Toluene-2,4-diamine
154. 584-84-9 2,4-Toluene diisocyanate
155. 95-53-4 o-Toluidine
156. 8001-35-2 Toxaphene (chlorinated camphene)
157. 120-82-1 1,2,4-Trichlorobenzene
158. 79-00-5 1,1,2-Trichloroethane
159. 79-01-6 Trichloroethylene
160. 95-95-4 2,4,5-Trichlorophenol
161. 88-06-2 2,4,6-Trichlorophenol
162. 121-44-8 Triethylamine
163. 1582-09-8 Trifluralin
164. 540-84-1 2,2,4-Trimethylpentane
165. 108-05-4 Vinyl acetate
166. 593-60-2 Vinyl bromide
167. 75-01-4 Vinyl chloride
168. 75-35-4 Vinylidene chloride (1,1-Dichloroethylene)
169. 1330-20-7 Xylenes (mixed isomers)
170. 95-47-6 o-Xylene
171. 108-38-3 m-Xylene
172. 106-42-3 p-Xylene
173. Antimony Compounds
174. Arsenic Compounds (inorganic including arsine)
175. Beryllium Compounds

Hazardous Air Pollutants Designated under the Clean Air Act Amendments of 1990 (Continued)

176. Cadmium Compounds
177. Chromium Compounds
178. Cobalt Compounds
179. Coke Oven Emissions
180. Cyanide Compounds[1]
181. Glycol ethers[2]
182. Lead Compounds
183. Manganese Compounds
184. Mercury Compounds
185. Fine mineral fibers[3]
186. Nickel Compounds
187. Polycyclic Organic Matter[4]
188. Radionuclides (including radon)[5]
189. Selenium Compounds

APPENDIX D: PHENOL FORMALDEHYDE PRODUCTION

TABLE 7.3. Phenol formaldehyde production for 1.0 MSF (3/8-inch) of plywood manufacturing (ATHENA Sustainable Materials Institute, 1993)

PF Resin Inputs [1/]	**PNW**	**SE**
Material	**lb/MSF (3/8-inch) basis**	
Formaldehyde	1.03E+01	1.28E+01
Phenol	5.56E+00	6.89E+00
Fuel Usage	**BTU/MSF (3/8-inch) basis**	
Heavy Oil	9.91E+03	1.20E+04
Gasoline	6.83E+01	8.47E+04
Natural Gas	1.84E+05	2.28E+05
Electricity Usage	**kWh/MSF (3/8-inch) basis**	
Electricity	1.02E+01	1.27E+01
Energy of Feedstocks	**ft^3/MSF (3/8-inch) resin**	
Natural Gas	1.38E+02	
	Gallon/MSF (3/8-inch) resin	
Petroleum (Gasoline)	1.71E+00	
PF Resin Outputs [1/]		
Formaldehyde Production	**lb/MSF (3/8-inch) basis**	
Formaldehyde	3.12E-03	3.87E-03
Phenol Production	**lb/MSF (3/8-inch) basis**	
Phenol	7.90E-02	9.79E-02
Benzene	3.18E-05	3.94E-05
Cumene	2.70E-04	3.35E-04
Phenol Formaldehyde Production	**lb/MSF (3/8-inch) basis**	
Formaldehyde	1.89E-02	2.34E-02

1/ data obtained from Materials Balances, Energy Profiles & Environmental Unit Factor

APPENDIX E: ELECTRICITY GENERATION BY STATE

TABLE 7.4. Electricity Generation by State in the Pacific Northwest

PNW - Electricity % Share
Percentage Share, 2000[1/]

Fuel Source	**OR**	**WA**	**Average**
Coal	7.4	8.8	8.1
Petroleum	0.1	0.4	0.25
Natural Gas	17.1	7.5	12.3
Nuclear	0	7.9	3.95
Hydro	74.3	74.3	74.3
Others	1.1	1.1	1.1
Total	100	100	100

SE - Electricity % Share

Fuel	**AL**	**GA**	**LA**	**MS**	**FL**	**AR**	**TX**	**AVG**
Coal	61.90	64.80	25.60	37.00	37.90	54.70	37.00	45.56
Petroleum	0.20	1.30	2.30	7.90	18.50	0.50	0.70	4.49
Gas	4.30	2.70	49.60	22.50	22.70	7.80	51.60	23.03
Nuclear	25.20	26.40	17.60	28.50	16.90	26.50	9.90	21.57
Hydroelectric	4.70	1.90	0.60	0.00	0.00	5.40	0.20	1.83
Other	3.70	2.90	4.30	4.10	4.00	5.10	0.60	3.53
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

1/Source: Energy Information Administration/Electric Power Annual 2000 Volume I
http://www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html
http://www.eia.doe.gov/cneaf/electricity/epav1/epav1_sum.html

APPENDIX F: AIR EMISSIONS BY SUBUNIT PROCESS

TABLE 7.5. Total Air Emissions by Subunit Process in the PNW Region of the United States

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Acetaldehyde	0.00E+00	3.18E-05	0.00E+00	8.51E-03	3.41E-03	0.00E+00	1.20E-02
Acetone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.10E-03	0.00E+00	5.10E-03
Acrolein	3.02E-08	1.65E-08	4.20E-08	6.53E-07	8.04E-08	5.51E-08	8.77E-07
Aldehydes	1.05E-04	6.73E-06	1.32E-05	3.89E-05	6.79E-04	1.75E-05	8.60E-04
Alpha-pinene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.69E-02	0.00E+00	7.69E-02
Ammonia	4.55E-05	2.10E-05	5.35E-05	1.61E-04	1.36E-04	7.02E-05	4.87E-04
As	8.99E-08	9.72E-07	1.07E-07	9.03E-06	2.35E-06	1.39E-07	1.27E-05
Ba	0.00E+00	4.67E-05	0.00E+00	4.36E-04	1.01E-04	0.00E+00	5.83E-04
Be	9.02E-09	4.52E-09	1.14E-08	3.40E-08	2.84E-08	1.50E-08	1.02E-07
Benzene	4.38E-08	3.82E-05	5.85E-08	3.56E-04	9.18E-05	7.69E-08	4.86E-04
Beta-pinene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.98E-02	0.00E+00	2.98E-02
Cd	5.30E-08	1.75E-08	4.16E-08	1.24E-07	2.80E-07	5.48E-08	5.71E-07
Cl_2	3.16E-07	8.27E-05	1.42E-08	7.72E-04	1.81E-04	1.88E-08	1.04E-03
CO	2.59E-02	1.49E-01	6.97E-03	1.48E+00	4.11E-01	9.44E-03	2.08E+00

TABLE 7.5. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
CO_2 (fossil)	8.73E+00	2.76E+00	5.46E+00	1.78E+01	3.60E+01	7.26E+00	7.80E+01
CO_2 (non-fossil) [1/]	2.37E-03	2.22E+01	1.71E-03	2.15E+02	4.85E+01	2.26E-03	2.85e+02
cobalt	6.82E-08	2.71E-08	6.62E-08	1.98E-07	3.02E-07	8.70E-08	7.49E-07
Cr	1.21E-07	5.47E-07	1.47E-07	4.99E-06	1.47E-06	1.94E-07	7.47E-06
Cumene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.41E-05	0.00E+00	7.41E-05
Dichloromethane	1.20E-07	6.53E-08	1.65E-07	4.96E-07	3.12E-07	2.17E-07	1.38E-06
Dioxin (TEQ)	1.60E-13	8.74E-14	2.22E-13	6.66E-13	4.13E-13	2.91E-13	1.84E-12
Fe	0.00E+00	4.67E-05	0.00E+00	4.36E-04	1.01E-04	0.00E+00	5.83E-04
Formaldehyde	1.43E-03	7.03E-05	7.61E-07	1.74E-02	1.85E-02	1.00E-06	3.74E-02
HCl	1.51E-04	8.27E-05	2.10E-04	6.30E-04	3.90E-04	2.76E-04	1.74E-03
HF	2.09E-05	1.15E-05	2.92E-05	8.74E-05	5.39E-05	3.82E-05	2.41E-04
Hg	6.27E-08	3.26E-08	8.25E-08	2.48E-07	1.82E-07	1.08E-07	7.16E-07
K	9.54E-07	8.27E-03	0.00E+00	7.72E-02	1.80E-02	0.00E+00	1.03E-01
Kerosene	9.63E-07	5.27E-07	1.34E-06	4.02E-06	2.38E-06	1.76E-06	1.10E-05
Limonene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.63E-03	0.00E+00	8.63E-03
Metals	0.00E+00	3.19E-07	6.87E-07	2.01E-06	6.98E-06	9.09E-07	1.09E-05
Methane	9.30E-03	6.98E-03	1.34E-02	3.83E-02	1.28E-01	1.79E-02	2.14E-01

TABLE 7.5. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Methanol	0.00E+00	0.00E+00	0.00E+00	2.57E-02	1.10E-01	0.00E+00	1.36E-01
Methyl Ethyl Ketone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.83E-04	0.00E+00	6.83E-04
Methyl I-butyl Ketone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.57E-04	0.00E+00	5.57E-04
Mn	2.30E-07	9.54E-05	2.98E-07	8.92E-04	2.09E-04	3.92E-07	1.20E-03
N-nitrodimethylamine	6.38E-09	3.49E-09	8.86E-09	2.66E-08	1.64E-08	1.16E-08	7.32E-08
N_2O	1.71E-05	9.35E-06	2.37E-05	7.12E-05	4.44E-05	3.11E-05	1.97E-04
Na	0.00E+00	1.91E-04	0.00E+00	1.79E-03	4.15E-04	0.00E+00	2.39E-03
Naphthalene	8.51E-09	2.54E-05	1.03E-08	2.37E-04	5.54E-05	1.35E-08	3.18E-04
Ni	7.55E-07	6.19E-06	5.96E-07	5.72E-05	1.68E-05	7.84E-07	8.24E-05
Non Methane VOC	2.47E-02	9.28E-03	1.38E-02	3.53E-02	2.27E-01	1.90E-02	3.29E-01
NO_X	1.11E-01	3.16E-02	2.54E-02	2.58E-01	1.94E-01	3.47E-02	6.55E-01
Organic Substances	7.80E-05	1.78E-03	2.66E-05	1.65E-02	4.47E-03	3.54E-05	2.29E-02
Particulates	6.85E-03	1.85E-03	6.86E-03	2.53E-01	1.05E-01	7.93E-03	3.82E-01
Particulates (PM10)	4.41E-04	2.48E-04	4.06E-03	2.12E-01	2.16E-03	8.72E-03	2.28E-01
Particulates (unspecified)	2.41E-03	1.19E-03	2.98E-03	8.95E-03	5.86E-03	3.92E-03	2.53E-02
Pb	1.24E-07	1.28E-05	1.37E-07	1.20E-04	2.81E-05	1.81E-07	1.61E-04

TABLE 7.5. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Phenol	1.00E-07	4.24E-04	1.10E-07	6.02E-03	2.37E-02	1.45E-07	3.02E-02
Sb	2.69E-08	1.13E-08	2.78E-08	8.30E-08	1.13E-07	3.65E-08	2.99E-07
Se	2.37E-07	1.26E-07	3.21E-07	9.63E-07	6.56E-07	4.21E-07	2.72E-06
SO_2	0.00E+00	0.00E+00	0.00E+00	8.24E-04	4.44E-06	0.00E+00	8.28E-04
SO_X	4.80E-02	3.28E-02	5.85E-02	1.74E-01	6.64E-01	7.81E-02	1.06e+00
Tetrachloroethene	2.88E-08	1.58E-08	4.00E-08	1.20E-07	7.45E-08	5.25E-08	3.31E-07
Tetrachloromethane	5.00E-08	2.66E-08	6.65E-08	1.99E-07	1.58E-07	8.73E-08	5.88E-07
THC as carbon	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.65E-01	0.00E+00	1.65E-01
Trichloroethene	2.85E-08	1.56E-08	3.96E-08	1.19E-07	7.33E-08	5.20E-08	3.28E-07
VOC		0.00E+00	0.00E+00	4.68E-01	1.98E-01	0.00E+00	6.67E-01
Zn		4.67E-05	0.00E+00	4.36E-04	1.01E-04	0.00E+00	5.83E-04

CO_2 biomass and non fossil added together

TABLE 7.6. Total Air Emissions by Subunit Process in the SE Region of the United States

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Veneer Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Acetaldehyde				7.40E-04	3.63E-03	0.00E+00	4.37E-03
Acetone				0.00E+00	5.48E-03	0.00E+00	5.48E-03
Acrolein	1.30E-07	7.32E-08	1.87E-07	6.45E-06	4.65E-07	2.76E-07	7.58E-06
Aldehydes	9.40E-05	2.09E-05	5.14E-05	1.91E-04	9.85E-04	7.63E-05	1.42E-03
Alpha-pinene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.26E-02	0.00E+00	8.26E-02
Ammonia	6.20E-05	3.22E-05	8.22E-05	3.09E-04	2.48E-04	1.21E-04	8.55E-04
As	4.39E-07	1.34E-06	6.20E-07	1.57E-05	4.28E-06	9.18E-07	2.33E-05
Ba	0.00E+00	5.48E-05	0.00E+00	6.65E-04	1.36E-04	0.00E+00	8.55E-04
Be	4.24E-08	2.36E-08	6.04E-08	2.26E-07	1.47E-07	8.92E-08	5.89E-07
Benzene	1.38E-07	4.49E-05	1.97E-07	5.45E-04	1.23E-04	2.90E-07	7.13E-04
Beta-pinene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.20E-02	0.00E+00	3.20E-02
Cd	3.23E-07	1.75E-07	4.45E-07	1.67E-06	1.26E-06	6.59E-07	4.54E-06
Cl_2	2.55E-07	9.73E-05	9.55E-08	1.18E-03	2.44E-04	1.42E-07	1.52E-03

TABLE 7.6. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
CO	2.06E-02	1.75E-01	1.18E-02	2.21E+00	6.37E-01	1.78E-02	3.07E+00
CO_2 (fossil)	1.44E+01	6.78E+00	1.65E+01	6.49E+01	7.13E+01	2.45E+01	1.98E+02
CO_2 (non-fossil)[1/]	4.83E-03	2.62E+01	5.96E-03	3.17E+02	6.50E+01	8.83E-03	4.09E+02
cobalt	3.71E-07	2.03E-07	5.16E-07	1.94E-06	1.40E-06	7.63E-07	5.19E-06
Cr	5.52E-07	8.79E-07	7.81E-07	9.85E-06	3.37E-06	1.15E-06	1.66E-05
Cumene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.85E-05	0.00E+00	9.85E-05
Dichloromethane	5.24E-07	2.94E-07	7.51E-07	2.83E-06	1.72E-06	1.11E-06	7.23E-06
Dioxin (TEQ)	6.86E-13	3.87E-13	9.85E-13	3.70E-12	2.25E-12	1.46E-12	9.47E-12
Fe	0.00E+00	5.48E-05	0.00E+00	6.65E-04	1.36E-04	0.00E+00	8.55E-04
Formaldehyde	8.82E-04	8.27E-05	1.30E-06	1.24E-03	2.42E-02	1.92E-06	2.64E-02
HCl	6.51E-04	3.66E-04	9.33E-04	3.51E-03	2.13E-03	1.38E-03	8.96E-03
HF	9.03E-05	5.08E-05	1.30E-04	4.86E-04	2.95E-04	1.92E-04	1.24E-03
Hg	2.85E-07	1.59E-07	4.06E-07	1.52E-06	9.59E-07	6.00E-07	3.92E-06
K	0.00E+00	9.72E-03	0.00E+00	1.18E-01	2.41E-02	0.00E+00	1.52E-01
Kerosene	4.03E-06	2.27E-06	5.80E-06	2.18E-05	1.31E-05	8.57E-06	5.55E-05
Limonene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.28E-03	0.00E+00	9.28E-03
Metals	1.96E-06	9.67E-07	2.41E-06	8.97E-06	1.29E-05	3.56E-06	3.08E-05
Methane	2.44E-02	1.49E-02	3.58E-02	1.32E-01	2.11E-01	5.32E-02	4.71E-01

TABLE 7.6. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Methanol	0.00E+00	0.00E+00	0.00E+00	6.11E-04	1.18E-01	0.00E+00	1.19E-01
Methyl Ethyl Ketone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.34E-04	0.00E+00	7.34E-04
Methyl I-butyl Ketone	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.99E-04	0.00E+00	5.99E-04
Mn	9.95E-07	1.12E-04	1.42E-06	1.37E-03	2.82E-04	2.10E-06	1.77E-03
N-nitrodimethylamine	2.75E-08	1.55E-08	3.94E-08	1.48E-07	8.98E-08	5.83E-08	3.78E-07
N_2O	7.59E-05	4.27E-05	1.09E-04	4.10E-04	2.49E-04	1.61E-04	1.05E-03
Na	0.00E+00	2.25E-04	0.00E+00	2.72E-03	5.57E-04	0.00E+00	3.50E-03
Naphthalene	1.41E-08	2.99E-05	1.92E-08	3.62E-04	7.43E-05	2.85E-08	4.67E-04
Ni	4.49E-06	9.40E-06	6.17E-06	1.07E-04	3.49E-05	9.13E-06	1.71E-04
Non Methane VOC	2.28E-02	1.10E-02	2.14E-02	7.20E-02	4.38E-01	3.26E-02	5.98E-01
NO_X	1.01E-01	5.00E-02	6.60E-02	5.09E-01	6.37E-01	9.95E-02	1.46E+00
Organic Substances	8.60E-05	2.10E-03	7.26E-05	2.53E-02	6.08E-03	1.08E-04	3.37E-02
Particulates	4.21E-03	2.16E-03	2.48E-05	8.82E-02	1.62E-01	2.76E-01	5.33E-01
Particulates (PM10)	1.98E-03	1.11E-03	2.85E-03	2.84E-02	6.40E-03	8.26E-02	1.23E-01
Particulates (unspecified)	9.33E-03	5.17E-03	1.32E-02	4.94E-02	3.04E-02	1.95E-02	1.27E-01
Pb	5.29E-07	1.53E-05	7.38E-07	1.84E-04	3.91E-05	1.09E-06	2.41E-04
Phenol	3.32E-07	4.98E-04	4.58E-07	6.31E-03	3.13E-02	6.77E-07	3.81E-02

TABLE 7.6. (Continued)

Substance	Debarking and Bucking lb/MSF (3/8-inch)	Log Conditioning lb/MSF (3/8-inch)	Veneer Peeling lb/MSF (3/8-inch)	Veneer Drying lb/MSF (3/8-inch)	Pressing lb/MSF (3/8-inch)	Plywood lb/MSF (3/8-inch)	Total
Sb	1.46E-07	7.98E-08	2.03E-07	7.62E-07	5.38E-07	3.00E-07	2.03E-06
Se	1.02E-06	5.75E-07	1.47E-06	5.50E-06	3.42E-06	2.17E-06	1.42E-05
SO_2	0.00E+00	0.00E+00	0.00E+00	6.97E-05	4.82E-07	0.00E+00	7.02E-05
SO_X	1.00E-01	6.10E-02	1.42E-01	5.32E-01	0.00E+00	2.12E-01	1.05E+00
Tetrachloroethene	1.26E-07	7.08E-08	1.80E-07	6.78E-07	4.12E-07	2.67E-07	1.73E-06
Tetrachloromethane	3.39E-07	1.90E-07	4.85E-07	1.82E-06	1.13E-06	7.18E-07	4.69E-06
THC as Carbon	1.23E-07	6.91E-08	1.76E-07	6.62E-07	1.77E-01	0.00E+00	1.77E-01
Trichloroethene		0.00E+00	0.00E+00	6.46E-02	0.00E+00	2.61E-07	6.46E-02
VOC		0.00E+00	0.00E+00	0.00E+00	2.12E-01	0.00E+00	2.12E-01
Water Vapor		5.48E-05	0.00E+00	6.65E-04	0.00E+00	0.00E+00	7.20E-04
Zn					1.36E-04	0.00E+00	1.36E-04

CO_2 biomass and non fossil added together

APPENDIX G: LIFE-CYCLE INVENTORY AND LIFE-CYCLE INVENTORY (SITE GENERATED EMISSIONS) WITHOUT BURDENS OF ELECTRICITY, FUEL AND RESIN FOR THE PNW AND THE SE REGIONS OF THE UNITED STATES

TABLE 7.6. LCI for the PNW Region of the United State, 51% of the total LCI is Allocated to 1.0 MSF (3/8-inch) of Plywood. Includes Burdens from Electricity, Fuel and Resin.

Raw Materials		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
PNW Bark on Logs	9.35E+01	4.30E+02
PNW Logs	9.27E+02	4.27E+03
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Bark self generated, PNW	2.38E+01	1.09E+02
Coal FAL	9.44E+00	4.34E+01
Crude oil FAL	3.82E+00	1.76E+01
Limestone	1.62E+00	7.48E+00
Natural gas FAL	2.34E+01	1.08E+02
Uranium FAL	4.95E-05	2.28E-04
Wood/wood wastes FAL	1.87E+01	8.60E+01
Electricity		
Substance	**kWh/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Electricity from other sources	1.12E+00	4.10E+01
Energy from hydro power	7.57E+01	2.77E+03
Water Usage		
Substance	**ft^3/MSF (3/8-inch)**	**m^3/MSM (9mm)**
Municipal Water Source	5.80E+00	1.67E+00
Recycled Water	2.31E-02	6.67E-03
Well Water Source	2.06E+00	5.93E-01
Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Acetaldehyde	1.19E-02	5.49E-02
Acetone	5.11E-03	2.35E-02
Acrolein	8.69E-07	4.00E-06
Aldehydes	3.79E-04	1.74E-03
Alpha-pinene	7.69E-02	3.54E-01
Ammonia	4.45E-04	2.05E-03
As	1.36E-05	6.27E-05

TABLE 7.6. (Continued)

Air Emission Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Ba	6.31E-04	2.90E-03
Be	9.63E-08	4.43E-07
Benzene	5.28E-04	2.43E-03
Beta-pinene	2.99E-02	1.37E-01
Cd	4.43E-07	2.04E-06
Cl_2	1.12E-03	5.17E-03
CO	2.36E+00	1.08E+01
CO_2 (biomass)	2.85E+02	1.31E+03
CO_2 (fossil)	7.32E+01	3.37E+02
CO_2 (non-fossil)	1.95E+01	8.97E+01
Cobalt	6.31E-07	2.90E-06
Cr	7.88E-06	3.62E-05
Cumene	7.44E-05	3.42E-04
Dichloromethane	1.34E-06	6.18E-06
Dioxin (TEQ)	1.80E-12	8.28E-12
Fe	6.31E-04	2.90E-03
Formaldehyde	3.75E-02	1.72E-01
HCl	1.71E-03	7.85E-03
HF	2.36E-04	1.09E-03
Hg	6.88E-07	3.16E-06
K	1.12E-01	5.18E-01
Kerosene	1.08E-05	4.97E-05
Limonene	8.62E-03	3.97E-02
Metals	9.06E-06	4.17E-05
Methane	1.96E-01	9.03E-01
Methanol	1.36E-01	6.24E-01
Methyl ethyl ketone	6.81E-04	3.13E-03
Methyl i-butyl ketone	5.58E-04	2.57E-03
Mn	1.30E-03	5.98E-03
N-nitro-dimethylamine	7.19E-08	3.31e-07

TABLE 7.6. (Continued)

Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
N_2O	1.93E-04	8.88E-04
Na	2.59E-03	1.19E-02
Naphthalene	3.46E-04	1.59E-03
Ni	8.69E-05	4.00E-04
Non methane VOC	8.12E-01	3.74E+00
NO_X	8.75E-01	4.03E+00
Organic substances	2.44E-02	1.12E-01
Particulates	6.17E-01	2.84E+00
Particulates (PM10)	2.27E-01	1.04E+00
Particulates (unspecified)	2.51E-02	1.15E-01
Pb	1.74E-04	8.02E-04
Phenol	3.07E-02	1.41E-01
Sb	2.58E-07	1.18E-06
Se	2.63E-06	1.21E-05
SO_2	1.65E-03	7.59E-03
SO_X	9.50E-01	4.37E+00
Tetrachloroethene	3.25E-07	1.50E-06
Tetrachloromethane	5.62E-07	2.59E-06
THC as carbon	1.65E-01	7.59E-01
Trichloroethene	3.22E-07	1.48E-06
VOC	6.69E-01	3.08E+00
Zn	6.31E-04	2.90E-03
Water Emission		
Substance	**lb/MSF(3/8-inch)**	**kg/MSM (9mm)**
Acid as H+	3.96E-09	1.82E-08
B	8.88E-04	4.08E-03
BOD	1.18E-03	5.40E-03
Ca	1.36E-08	6.24E-08
Calcium ions	9.31E-06	4.28E-05
Cd	5.63E-05	2.59E-04

TABLE 7.6. (Continued)

Water Emission		
Substance	**lb/MSF(3/8-inch)**	**kg/MSM (9mm)**
Chromate	3.38E-07	1.56E-06
Cl-	5.64E-02	2.60E-01
COD	1.18E-02	5.43E-02
Cr	5.63E-05	2.59E-04
Cyanide	8.44E-08	3.88E-07
Dissolved solids	1.23E+00	5.66E+00
Fe	1.33E-03	6.12E-03
Fluoride ions	4.31E-05	1.98E-04
H_2SO_4	2.23E-04	1.02E-03
Hg	4.43E-09	2.04E-08
Metallic ions	8.44E-05	3.88E-04
Mn	7.44E-04	3.42E-03
Na	1.71E-05	7.88E-05
NH_3	3.27E-05	1.50E-04
Nitrate	4.07E-06	1.87E-05
Oil	2.19E-02	1.01E-01
Other Organics	3.71E-03	1.70E-02
Pb	7.06E-09	3.25E-08
Phenol	2.73E-07	1.26E-06
Phosphate	1.11E-04	5.12E-04
Sulphate	4.95E-02	2.28E-01
Suspended solids	2.47E-02	1.14E-01
Zn	1.94E-05	8.91E-05
Solid Waste Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Solid waste	1.95E+01	8.97E+01
Nonmaterial Emission		
Substance	**Ci/MSF (3/8-inch)**	**Bq/MSM (9mm)**
Radioactive substance to air	1.20E-05	4.53E+06

TABLE 7.7. LCI for the SE Region of the United State, 48.5% of the total LCI is Allocated to 1.0 MSF (3/8-inch) of Plywood. Includes Burdens from Electricity, Fuel and Resin.

SE Plywood - Life-cycle inventory		
Raw Materials		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
SE Bark from log	1.01E+02	4.67E+02
SE Logs	1.01E+03	4.66E+03
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Coal FAL	5.21E+01	2.40E+02
Crude Oil FAL	1.84E+01	8.45E+01
Limestone	6.01E+00	2.76E+01
Natural Gas FAL	3.83E+01	1.76E+02
Uranium FAL	2.65E-04	1.22E-03
Wood/wood Wastes FAL	5.21E+01	2.39E+02
Electricity		
Substance	**kWh/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Electricity from Other Sources	3.58E+00	1.31E+02
Energy from Hydro Power	1.86E+00	6.81E+01
Energy		
Substance	**BTU/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Natural Gas Direct Fired	1.85E+05	1.99E+09
Water Source		
Substance	**cuft/MSF (3/8-inch)**	**m^3/MSM (9mm)**
Municipal Water Source	2.01E+00	5.79E-01
Well Water Source	6.15E+00	1.77E+00
Recycled Water Source	5.43E-02	1.56E-02
Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Acetaldehyde	4.61E-03	2.12E-02
Acetone	5.72E-03	2.63E-02
Acrolein	7.88E-06	3.62E-05
Aldehydes	1.48E-03	6.78E-03
Alpha-pinene	8.62E-02	3.97E-01

TABLE 7.7. (Continued)

Air Emission Substance	lb/MSF (3/8-inch)	kg/MSM (9mm)
Ammonia	8.94E-04	4.11E-03
As	2.42E-05	1.11E-04
Ba	8.88E-04	4.08E-03
Be	6.16E-07	2.83E-06
Benzene	7.44E-04	3.42E-03
Beta-pinene	3.35E-02	1.54E-01
Cd	4.74E-06	2.18E-05
Cl_2	1.58E-03	7.27E-03
CO	3.14E+00	1.45E+01
CO_2 (fossil)	2.07E+02	9.52E+02
CO_2 (non-fossil)	4.24E+02	1.95E+03
Cobalt	5.43E-06	2.50E-05
Cr	1.73E-05	7.96E-05
Cumene	1.03E-04	4.74E-04
Dichloromethane	7.56E-06	3.48E-05
Dioxin (TEQ)	9.94E-12	4.57E-11
Fe	8.88E-04	4.08E-03
Formaldehyde	2.76E-02	1.27E-01
HCl	9.38E-03	4.31E-02
HF	1.31E-03	6.01E-03
Hg	4.11E-06	1.89E-05
K	1.58E-01	7.24E-01
Kerosene	5.81E-05	2.67E-04
Limonene	9.69E-03	4.46E-02
Metals	3.22E-05	1.48E-04
Methane	4.93E-01	2.27E+00
Methanol	1.24E-01	5.69E-01
Methyl Ethyl Ketone	7.69E-04	3.54E-03
Methyl I-butyl Ketone	6.25E-04	2.88E-03
Mn	1.83E-03	8.42E-03

TABLE 7.7. (Continued)

Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
N-nitrodimethylamine	3.96E-07	1.82E-06
N_2O	1.09E-03	5.03E-03
Na	3.64E-03	1.67E-02
Naphthalene	4.85E-04	2.23E-03
Ni	1.79E-04	8.22E-04
Non Methane VOC	6.24E-01	2.87E+00
NO_X	1.52E+00	7.02E+00
Organic Substances	3.51E-02	1.62E-01
Particulates	5.71E-01	2.63E+00
Particulates (PM10)	1.33E-01	6.12E-01
Particulates (unspecified)	1.33E-01	6.12E-01
Pb	2.50E-04	1.15E-03
Phenol	3.98E-02	1.83E-01
Sb	2.12E-06	9.78E-06
Se	1.48E-05	6.81E-05
SO_2	7.31E-05	3.36E-04
SO_X	2.15E+00	9.89E+00
Tetrachloroethene	1.81E-06	8.34E-06
Tetrachloromethane	4.91E-06	2.26E-05
THC as Carbon	1.85E-01	8.51E-01
Trichloroethene	1.78E-06	8.16E-06
VOC	2.88E-01	1.32E+00
Water Vapor	5.08E+02	2.34E+03
Zn	8.88E-04	4.08E-03
Water Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Acid as H+	1.94E-08	8.91E-08
B	5.21E-03	2.40E-02
BOD	2.09E-03	9.63E-03
Ca	1.43E-07	6.56E-07

TABLE 7.7. (Continued)

Water Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Calcium Ions	4.99E-05	2.30E-04
Cd	9.25E-05	4.26E-04
Chromate	3.74E-06	1.72E-05
Cl-	9.31E-02	4.28E-01
COD	2.04E-02	9.40E-02
Cr	9.25E-05	4.26E-04
Cyanide	1.38E-07	6.35E-07
Dissolved Solids	2.03E+00	9.34E+00
Fe	7.31E-03	3.36E-02
Fluoride Ions	2.32E-04	1.07E-03
H_2SO_4	1.31E-03	6.01E-03
Hg	7.25E-09	3.34E-08
Metallic Ions	4.12E-04	1.89E-03
Mn	4.09E-03	1.88E-02
Na	9.19E-05	4.23E-04
NH_3	1.36E-04	6.24E-04
Nitrate	2.19E-05	1.01E-04
Oil	3.63E-02	1.67E-01
Other Organics	6.81E-03	3.13E-02
Pb	3.53E-08	1.62E-07
Phenol	1.34E-06	6.15E-06
Phosphate	6.50E-04	2.99E-03
Sulphate	1.01E-01	4.66E-01
Suspended Solids	9.81E-02	4.51E-01
Zn	3.21E-05	1.48E-04
Solid Waste Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Solid Waste	4.54E+01	2.09E+02
Nonmaterial Emission		
Substance	**Ci/MSF (3/8-inch)**	**Bq/MSM (9mm)**
Radioactive Substance to Air	3.49E-05	1.31E+07

TABLE 7.8. LCI (Self Generated Emissions), Not Including Burdens from Electricity, Energy and PF resin for the PNW region of the United State, 51% of the Total LCI is Allocated to 1.0 MSF (3/8-inch) of Plywood.

PNW Plywood -LCI Stand Alone		
Raw Materials		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
PNW Bark on Logs	9.35E+01	4.30E+02
PNW Logs	9.27E+02	4.27E+03
Substance	**lbs/MSF (3/8-inch)**	**kg/MSM (9mm)**
Phenol Formaldehyde Resin	1.25E+01	5.75E+01
Wood	1.86E+01	8.54E+01
Substance	**ft^3/MSF (3/8-inch)**	**m^3/MSM (9mm)**
Destillate Fuel Oil (DFO)	2.74E-02	7.90E-03
Natural Gas (vol)	4.19E+01	1.21E+01
Electricity		
Substance	**kWh/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Electricity from Athena	9.38E+01	3.43E+03
Energy		
Substance	**BTU/MSF (3/8-inch)**	**J/MSM (9mm)**
Hogged Fuel Direct Fired Fuel Cell	7.13E+04	7.65E+08
Natural Gas Direct Fired Fuel Cell	7.81E+04	8.38E+08
Water Usage		
Substance	**ft^3/MSF (3/8-inch)**	**m^3/MSM (9mm)**
Municipal Water Source	5.80E+00	1.67E+00
Recycled Water	2.31E-02	6.67E-03
Well Water Source	2.06E+00	5.93E-01
Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Acetaldehyde	1.19E-02	5.49E-02
Acetone	5.11E-03	2.35E-02
Acrolein	5.28E-07	2.43E-06
Alpha-pinene	7.69E-02	3.54E-01
As	1.16E-05	5.35E-05
Ba	5.82E-04	2.68E-03

TABLE 7.8. (Continued)

Air Emission Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Benzene	4.76E-04	2.19E-03
Beta-pinene	2.99E-02	1.37E-01
Cl_2	1.03E-03	4.74E-03
CO	1.94E+00	8.91E+00
CO_2 (fossil)	1.20E+01	5.52E+01
CO_2 (non-fossil)	2.85E+02	1.31E+03
Cr	6.08E-06	2.80E-05
Fe	5.82E-04	2.68E-03
Formaldehyde	2.06E-02	9.46E-02
K	1.03E-01	4.74E-01
Limonene	8.62E-03	3.97E-02
Methane	7.13E-05	3.28E-04
Methanol	1.36E-01	6.24E-01
Methyl Ethyl Ketone	6.81E-04	3.13E-03
Methyl I-butyl Ketone	1.11E-02	5.12E-02
Mn	1.19E-03	5.46E-03
Na	2.38E-03	1.10E-02
Naphthalene	3.18E-04	1.46E-03
Ni	7.44E-05	3.42E-04
Non Methane VOC	2.32E-02	1.07E-01
NO_X	3.79E-01	1.75E+00
Organic Substances	2.19E-02	1.01E-01
Particulates	3.75E-01	1.72E+00
particulates (PM10)	2.22E-01	1.02E+00
Pb	1.59E-04	7.30E-04
Phenol	8.44E-03	3.88E-02
SO_2	8.25E-04	3.80E-03
SO_X	1.80E-02	8.28E-02
THC as carbon	1.65E-01	7.59E-01
VOC	6.69E-01	3.08E+00
Zn	5.82E-04	2.68E-03

TABLE 7.8. (Continued)

Water Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
BOD	5.69E-06	2.62E-05
COD	4.88E-04	2.25E-03
Dissolved Solids	9.56E-04	4.40E-03
NH_3	1.10E-06	5.06E-06
Suspended Solids	1.02E-03	4.69E-03
Solid Waste Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Solid Waste	1.19E+01	5.46E+01

Data from SimaPro 5.0 LCI analysis

TABLE 7.9. LCI (Self Generated), Not Including Burdens from Electricity, Energy and PF Resin for the SE Region of the United State, 48.5% of the Total LCI is Allocated to 1.0 MSF (3/8-inch) of Plywood.

SE Plywood - Stand Alone Life-Cycle Inventory		
Raw Materials		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
SE Bark from log	1.01E+02	4.67E+02
SE Logs	1.01E+03	4.66E+03
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Phenol Formaldehyde Resin	1.73E+01	7.96E+01
Wood	5.18E+01	2.38E+02
Substance	**cuft/MSF (3/8-inch)**	**m3/MSM (9mm)**
Destillate Fuel Oil (DFO) Stand alone	1.76E-02	5.07E-03
LPG stand alone	5.56E-03	1.60E-03
Natural Gas (vol)	2.73E+01	7.85E+00
Electricity		
Substance	**kWh/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Electricity from Athena	9.03E+01	3.30E+03
Energy		
Substance	**BTU/MSF (3/8-inch)**	**MJ/MSM (9mm)**
Natural Gas Direct Fired	1.85E+05	1.99E+09
Water Source		
Substance	**cuft/MSF (3/8-inch)**	**m^3/MSM (9mm)**
Municipal Water Source	2.01E+00	5.79E-01
Recycled Water Source	5.43E-02	1.56E-02
Well Water Source	6.15E+00	1.77E+00
Air Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Acetaldehyde	4.61E-03	2.12E-02
Acetone	5.72E-03	2.63E-02
Alpha-pinene	8.62E-02	3.97E-01
As	1.78E-05	8.16E-05
Ba	8.88E-04	4.08E-03

TABLE 7.9. (Continued)

Air Emission Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Benzene	7.25E-04	3.34E-03
Beta-pinene	3.35E-02	1.54E-01
Cl_2	1.58E-03	7.24E-03
CO	2.87E+00	1.32E+01
CO_2 (fossil)	1.01E+01	4.66E+01
CO_2 (non fossil)[1/]	4.24e+02	1.95e+03
Cr	9.31E-06	4.28E-05
Fe	8.88E-04	4.08E-03
Formaldehyde	4.17E-03	1.92E-02
K	1.58E-01	7.24E-01
Limonene	9.69E-03	4.46E-02
Methane	9.50E-05	4.37E-04
Methanol	1.24E-01	5.69E-01
Methyl Ethyl Ketone	7.69E-04	3.54E-03
Methyl I-butyl Ketone	6.25E-04	2.88E-03
Mn	1.82E-03	8.37E-03
Na	3.64E-03	1.67E-02
Naphthalene	4.85E-04	2.23E-03
Ni	1.13E-04	5.20E-04
Non Methane VOC	5.19E-03	2.39E-02
NO_X	4.09E-01	1.88E+00
Organic Substances	3.35E-02	1.54E-01
Particulates	5.64E-01	2.60E+00
Particulates (PM10)	1.05E-01	4.83E-01
Pb	2.43E-04	1.12E-03
Phenol	9.56E-03	4.40E-02
SO_2	7.31E-05	3.36E-04
SO_X	2.15E-02	9.89E-02
THC as Carbon	1.85E-01	8.51E-01
VOC	2.88E-01	1.32E+00
Zn	8.88E-04	4.08E-03

TABLE 7.9. (Continued)

Water Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
BOD	7.62E-06	3.51E-05
COD	6.50E-04	2.99E-03
Dissolved Solids	1.28E-03	5.89E-03
NH_3	1.47E-06	6.76E-06
Suspended Solids	1.36E-03	6.27E-03
Solid Emission		
Substance	**lb/MSF (3/8-inch)**	**kg/MSM (9mm)**
Solid Waste	1.82E+01	8.37E+01

APPENDIX H: SENSITIVITY ANALYSIS LCI

TABLE 7.10. Sensitivity Analysis Using All Natural Gas in the PNW Region of the United States

Raw Materials	**All Natural Gas**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
PNW Bark on Logs	9.35E+01	0	9.35E+01
PNW Logs	9.27E+02	0	9.27E+02
Coal FAL	9.62E+00	0	9.62E+00
Crude Oil FAL	1.17E+01	2	1.14E+01
Limestone	5.56E-01	-66	1.63E+00
Natural Gas FAL	6.70E+01	160	2.58E+01
Uranium FAL	4.46E-05	-11	5.01E-05
Wood/wood Wastes FAL	3.96E-02	-100	1.87E+01
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Non-utility	7.43E+00	563	1.12E+00
Energy from Hydro Power	7.89E+01	4	7.57E+01
Energy			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**BTU/MSF (3/8-inch)**
Hogged Fuel Direct Fired Fuel Cell	0.00E+00	-100	7.13E+04
Natural Gas Direct Fired Fuel Cell	0.00E+00	-100	7.81E+04
Water Source			
Substance	**cuft/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	5.80E+00	0	5.80E+00
Recycled Water	2.31E-02	0	2.31E-02
Well Water Source	2.06E+00	0	2.06E+00

TABLE 7.10. (Continued)

Air Emissions	**All Natural Gas**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acetaldehyde	1.16E-02	-3	1.19E-02
Acetone	5.11E-03	0	5.11E-03
Acrolein	8.75E-07	0	8.75E-07
Aldehydes	1.10E-03	28	8.56E-04
Alpha-pinene	7.69E-02	0	7.69E-02
Ammonia	2.03E-04	-58	4.85E-04
As	1.03E-06	-92	1.26E-05
Ba		-100	5.82E-04
Be	1.04E-07	2	1.02E-07
Benzene	9.12E-06	-98	4.86E-04
Beta-pinene	2.99E-02	0	2.99e-02
Cd	6.19E-07	9	5.69E-07
Cl2	2.44E-06	-100	1.03E-03
CO	5.12E-01	-75	2.08E+00
CO_2 (fossil)	1.71E+02	120	7.78E+01
CO_2 (non-fossil)	4.85E-02	-100	2.85E+02
Cobalt	7.88E-07	6	7.44E-07
Cr	1.32E-06	-82	7.44E-06
Cumene	7.44E-05	0	7.44E-05
Dichloromethane	1.38E-06	0	1.37E-06
Dioxin (TEQ)	1.84E-12	1	1.83E-12
Fe		-100	5.82E-04
Formaldehyde	3.66E-02	-2	3.74E-02
HCl	1.74E-03	0	1.73E-03
HF	2.41E-04	0	2.40E-04
Hg	7.25E-07	2	7.12E-07
K		-100	1.03E-01
Kerosene	9.81E-06	-10	1.09E-05
Limonene	8.62E-03	0	8.62E-03

TABLE 7.10. (Continued)

Air Emissions Substance	All Natural Gas lb/MSF (3/8-inch)	% Difference	No Change, Original Setup lb/MSF (3/8-inch)
Metals	1.93E-05	62	1.19E-05
Methane	4.84E-01	127	2.13E-01
Methanol	1.36E-01	0	1.36E-01
Methyl Ethyl Ketone	6.81E-04	0	6.81E-04
Methyl I-butyl Ketone	5.58E-04	0	5.58E-04
Mn	2.71E-06	-100	1.19E-03
N-nitrodimethylamine	7.31E-08	0	7.31E-08
N_2O	1.96E-04	0	1.96E-04
Na		-100	2.38E-03
Naphthalene	7.63E-08	-100	3.18E-04
Ni	8.88E-06	-89	8.19E-05
Non Methane VOC	8.12E-01	147	3.29E-01
NO_X	9.62E-01	48	6.50E-01
Organic Substances	1.48E-03	-94	2.28E-02
Particulates	3.65E-01	-4	3.81E-01
Particulates (PM10)	2.26E-01	-0	2.27E-01
Particulates (Unspecified)	2.70E-02	7	2.52E-02
Pb	1.43E-06	-99	1.60e-04
Phenol	2.49E-02	-18	3.02E-02
Sb	3.14E-07	6	2.97E-07
Se	2.64E-06	-3	2.71E-06
SO_2	8.25E-04	0	8.25E-04
SO_X	2.49E+00	136	1.06E+00
Tetrachloroethene	3.31E-07	0	3.30E-07
Tetrachloromethane	5.54E-07	-5	5.85E-07
THC as carbon	1.65E-01	0	1.65E-01
Trichloroethene	3.28E-07	0	3.27E-07
VOC	6.69E-01	0	6.69E-01
Zn		-100	5.82E-04

TABLE 7.10. (Continued)

Water Emissions Substance	All Natural Gas lb/MSF (3/8-inch)	% Difference	No Change, Original Setup lb/MSF (3/8-inch)
Acid as H+	1.26E-08	3	1.23E-08
B	9.31E-04	1	9.19E-04
BOD	3.51E-03	144	1.44E-03
Ca	1.03E-07	0	1.03E-07
Calcium Ions	8.31E-06	-11	9.31E-06
Cd	1.62E-04	160	6.23E-05
Chromate	4.88E-07	10	4.43E-07
Cl-	1.62E-01	160	6.24E-02
COD	4.39E-02	163	1.67E-02
Cr	1.62E-04	160	6.23E-05
Cyanide	2.43E-07	160	9.31E-08
Dissolved Solids	3.56E+00	159	1.38E+00
Fe	1.33E-03	-1	1.35E-03
Fluoride Ions	3.91E-05	-10	4.36E-05
H_2SO_4	2.33E-04	1	2.30E-04
Hg	1.27E-08	160	4.89E-09
Metallic Ions	2.68E-04	3	2.61E-04
Mn	7.56E-04	0	7.56E-04
Na	1.55E-05	-10	1.73E-05
NH_3	8.62E-05	58	5.45E-05
Nitrate	3.69E-06	-10	4.11E-06
Oil	6.31E-02	158	2.45E-02
Other Organics	1.03E-02	153	4.08E-03
Pb	2.29E-08	2	2.24E-08
Phenol	8.69E-07	2	8.50E-07
Phosphate	1.17E-04	2	1.15e-04
Sulphate	1.32E-01	143	5.43E-02
Suspended Solids	6.44E-02	97	3.27E-02
Zn	5.58E-05	158	2.16E-05

TABLE 7.10. (Continued)

Solid Waste Emissions	**All Natural Gas**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	1.08E+01	-43	1.88E+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	6.41E-06	-47	1.21E-05

TABLE 7.11. Sensitivity Analysis Using All Natural Gas in the SE Region of the United States

Raw Materials	All Natural Gas		No Change, Original Setup
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
SE Bark from log	1.01E+02	0	1.01E+02
SE Logs	1.01E+03	0	1.01E+03
Coal FAL	5.29E+01	2	5.21E+01
Crude Oil FAL	1.91E+01	4	1.84E+01
Limestone	3.05E+00	-49	6.01E+00
Natural Gas FAL	1.21E+02	216	3.83E+01
Uranium FAL	2.67E-04	1	2.65E-04
Wood/wood Wastes FAL	9.44E-02	-100	5.21E+01
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Other Sources	3.58E+00	0	3.58E+00
Energy from Hydro Power	1.86E+00	0	1.86E+00
Energy			
Substance	**BTU/MSF (3/8-inch)**	**% Difference**	**BTU/MSF (3/8-inch)**
Natural Gas Direct Fired		-100	1.85E+05
Water Source			
Substance	**cuft/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	2.01E+00	0	2.01E+00
Well Water Source	5.43E-02	0	5.43E-02
Recycled Water Source	6.15E+00	0	6.15E+00

TABLE 7.11. (Continued)

Air Emissions	**All Natural Gas**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acetaldehyde	4.00E-03	-13	4.61E-03
Acetone	5.72E-03	0	5.72E-03
Acrolein	1.91E-06	-76	7.88E-06
Aldehydes	1.98E-03	34	1.48E-03
Alpha-pinene	8.62E-02	0	8.62E-02
Ammonia	9.06E-04	1	8.94E-04
As	6.69E-06	-72	2.42E-05
Ba	0.00E+00	-100	8.88E-04
Be	6.38E-07	3	6.16E-07
Benzene	1.43E-05	-98	7.44E-04
Beta-pinene	3.35E-02	0	3.35E-02
Cd	5.13E-06	8	4.74E-06
Cl_2	4.09E-06	-100	1.58E-03
CO	8.06E-01	-74	3.14E+00
CO_2 (fossil)	3.95E+02	91	2.07E+02
CO_2 (non-fossil)	1.20E-01	-100	4.24E+02
cobalt	5.79E-06	7	5.43E-06
Cr	8.38E-06	-52	1.73E-05
Cumene	1.03E-04	0	1.03E-04
Dichloromethane	7.69E-06	2	7.56E-06
Dioxin (TEQ)	1.01E-11	1	9.94E-12
Fe	0.00E+00	-100	8.88E-04
Formaldehyde	2.62E-02	-5	2.76E-02
HCl	9.50E-03	1	9.38E-03
HF	1.32E-03	1	1.31E-03
Hg	4.22E-06	3	4.11E-06
K	0.00E+00	-100	1.58E-01
Kerosene	5.88E-05	1	5.81E-05
Limonene	9.69E-03	0	9.69E-03
Metals	4.79E-05	49	3.22E-05

TABLE 7.11. (Continued)

Air Emissions	All Natural Gas		No Change, Original Setup
Substance	lb/MSF (3/8-inch)	% Difference	lb/MSF (3/8-inch)
Methane	1.04E+00	112	4.93E-01
Methanol	1.24E-01	0	1.24E-01
Methyl Ethyl Ketone	7.69E-04	0	7.69E-04
Methyl I-butyl Ketone	6.25E-04	0	6.25E-04
Mn	1.49E-05	-99	1.83E-03
N-nitrodimethylamine	4.02E-07	1	3.96E-07
N_2O	1.11E-03	2	1.09E-03
Na		-100	3.64E-03
Naphthalene	2.61E-07	-100	4.85E-04
Ni	7.13E-05	-60	1.79E-04
Non Methane VOC	1.39E+00	123	6.24E-01
NO_X	1.82E+00	19	1.52E+00
Organic Substances	2.81E-03	-92	3.51E-02
Particulates	5.50E-01	-4	5.71E-01
Particulates (PM10)	1.33E-01	0	1.33E-01
Particulates (unspecified)	1.38E-01	4	1.33E-01
Pb	8.12E-06	-97	2.50E-04
Phenol	3.17E-02	-20	3.98E-02
Sb	2.25E-06	6	2.12E-06
Se	1.51E-05	2	1.48E-05
SO_2	7.31E-05	0	7.31E-05
SO_X	5.06E+00	135	2.15E+00
Tetrachloroethene	1.84E-06	2	1.81E-06
Tetrachloromethane	5.07E-06	3	4.91E-06
THC as Carbon	1.85E-01	0	1.85E-01
Trichloroethene	1.80E-06	1	1.78E-06
VOC	2.88E-01	0	2.88E-01
Water Vapor		-100	5.08E+02
Zn		-100	8.88E-04

TABLE 7.11. (Continued)

Water Emissions	All Natural Gas		No Change, Original Setup
Substance	lb/MSF (3/8-inch)	% Difference	lb/MSF (3/8-inch)
Acid as H+	2.03E-08	5	1.94E-08
B	5.33E-03	2	5.21E-03
BOD	6.38E-03	204	2.09E-03
Ca	1.43E-07	0	1.43E-07
Calcium Ions	5.05E-05	1	4.99E-05
Cd	2.92E-04	216	9.25E-05
Chromate	4.06E-06	9	3.74E-06
Cl-	2.93E-01	215	9.31E-02
COD	8.19E-02	301	2.04E-02
Cr	2.92E-04	216	9.25E-05
Cyanide	4.39E-07	218	1.38E-07
Dissolved Solids	6.44E+00	217	2.03E+00
Fe	7.38E-03	1	7.31E-03
Fluoride Ions	2.34E-04	1	2.32E-04
H_2SO_4	1.33E-03	2	1.31E-03
Hg	2.30E-08	217	7.25E-09
Metallic Ions	4.32E-04	5	4.12E-04
Mn	4.15E-03	1	4.09E-03
Na	9.31E-05	1	9.19E-05
NH_3	2.20E-04	62	1.36E-04
Nitrate	2.21E-05	1	2.19E-05
Oil	1.14E-01	213	3.63E-02
Other Organics	1.94E-02	184	6.81E-03
Pb	3.68E-08	4	3.53E-08
Phenol	1.40E-06	5	1.34E-06
Phosphate	6.69E-04	3	6.50E-04
Sulphate	2.59E-01	156	1.01E-01
Suspended Solids	1.78E-01	81	9.81E-02
Zn	1.01E-04	213	3.21E-05

TABLE 7.11. (Continued)

Solid Waste Emissions	All Natural Gas		No Change, Original Setup
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	3.55E+01	-22	4.54e+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	3.54E-05	2	3.49E-05

TABLE 7.12. Sensitivity Analysis Using Self Generated Hogged Fuel in the PNW Region of the United States

Raw Materials	**All Self Produced Hogged Fuel**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
PNW Bark on Logs	9.35E+01	0	9.35E+01
PNW Logs	9.27E+02	0	9.27E+02
Coal FAL	9.19E+00	-5	9.62E+00
Crude Oil FAL	1.11E+01	-3	1.14E+01
Limestone	5.30E-01	-68	1.63E+00
Natural Gas FAL	1.91E+01	-26	2.58E+01
Uranium FAL	4.28E-05	-15	5.01E-05
Wood/wood Wastes FAL	2.06E-02	-100	1.87E+01
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Non-utility	7.43E+00	563	1.12E+00
Energy from Hydro Power	8.43E+00	-89	7.57E+01
Energy			
Substance	**BTU/MSF (3/8-inch)**	**% Difference**	**BTU/MSF (3/8-inch)**
Hogged Fuel Direct Fired Fuel Cell		-100	7.13E+04
Natural Gas Direct Fired Fuel Cell		-100	7.81E+04
Water Source			
Substance	**ft^3/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	5.80E+00	0	5.80E+00
Recycled Water	2.31E-02	0	2.31E-02
Well Water Source	2.06E+00	0	2.06E+00

TABLE 7.12. (Continued)

Air Emissions **Substance**	**All Self Produced Hogged Fuel** **lb/MSF (3/8-inch)**	**% Difference**	**No Change, Original Setup** **lb/MSF (3/8-inch)**
Acetaldehyde	1.20E-02	1	1.19E-02
Acetone	5.11E-03	0	5.11E-03
Acrolein	8.56E-07	-2	8.75E-07
Aldehydes	8.12E-04	-5	8.56E-04
Alpha-pinene	7.69E-02	0	7.69E-02
Ammonia	1.96E-04	-60	4.85E-04
As	1.51E-05	20	1.26E-05
Ba	7.13E-04	22	5.82E-04
Be	9.25E-08	-9	1.02E-07
Benzene	5.92E-04	22	4.86E-04
Beta-pinene	2.99E-02	0	2.99E-02
Cd	3.96E-07	-30	5.69E-07
Cl_2	1.26E-03	22	1.03E-03
CO	2.48E+00	19	2.08E+00
CO_2 (fossil)	6.00E+01	-23	7.78E+01
CO_2 (non-fossil)[1/]	3.40E+02	20	2.85E+02
Cobalt	5.79E-07	-22	7.44E-07
Cr	8.56E-06	15	7.44E-06
Cumene	7.44E-05	0	7.44E-05
Dichloromethane	1.30E-06	-5	1.37E-06
Dioxin (TEQ)	1.75E-12	-4	1.83E-12
Fe	7.13E-04	22	5.82E-04
Formaldehyde	3.76E-02	1	3.74E-02
HCl	1.66E-03	-4	1.73E-03
HF	2.30E-04	-4	2.40E-04
Hg	6.63E-07	-7	7.12E-07
K	1.26E-01	22	1.03E-01
Kerosene	9.44E-06	-14	1.09E-05
Limonene	8.62E-03	0	8.62E-03

TABLE 7.12. (Continued)

Air Emissions Substance	All Self Produced Hogged Fuel lb/MSF (3/8-inch)	% Difference	No Change, Original Setup lb/MSF (3/8-inch)
Metals	1.02E-05	-14	1.19E-05
Methane	1.67E-01	-22	2.13E-01
Methanol	1.36E-01	0	1.36E-01
Methyl Ethyl Ketone	6.81E-04	0	6.81E-04
Methyl I-butyl Ketone	5.58E-04	0	5.58E-04
Mn	1.46E-03	22	1.19E-03
N-nitrodimethylamine	7.00E-08	-4	7.31E-08
N_2O	1.86E-04	-5	1.96E-04
Na	2.91E-03	22	2.38E-03
Naphthalene	3.88E-04	22	3.18E-04
Ni	9.62E-05	18	8.19E-05
Non Methane VOC	3.64E-01	11	3.29E-01
NO_X	8.50E-01	31	6.50E-01
Organic Substances	2.76E-02	21	2.28E-02
Particulates	3.85E-01	1	3.81E-01
Particulates (PM10)	2.26E-01	-0	2.27E-01
Particulates (unspecified)	2.39E-02	-5	2.52E-02
Pb	1.96E-04	22	1.60E-04
Phenol	3.14E-02	4	3.02E-02
Sb	2.41E-07	-19	2.97E-07
Se	2.46E-06	-9	2.71E-06
SO_2	8.25E-04	0	8.25E-04
SO_X	8.06E-01	-24	1.06E+00
Tetrachloroethene	3.14E-07	-5	3.30E-07
Tetrachloromethane	4.63E-07	-21	5.85E-07
THC as carbon	1.65E-01	0	1.65E-01
Trichloroethene	3.12E-07	-4	3.27E-07
VOC	6.69E-01	0	6.69E-01
Zn	7.13E-04	22	5.82E-04

TABLE 7.12. (Continued)

Water Emissions	**All Self Produced Hogged Fuel**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acid as H+	1.21E-08	-2	1.23E-08
B	8.62E-04	-6	9.19E-04
BOD	1.05E-03	-27	1.44E-03
Ca	1.03E-07	0	1.03E-07
Calcium Ions	8.00E-06	-14	9.31E-06
Cd	4.60E-05	-26	6.23E-05
Chromate	3.06E-07	-31	4.43E-07
Cl-	4.61E-02	-26	6.24E-02
COD	8.31E-03	-50	1.67E-02
Cr	4.60E-05	-26	6.23E-05
Cyanide	6.88E-08	-26	9.31E-08
Dissolved Solids	1.01E+00	-26	1.38E+00
Fe	1.28E-03	-6	1.35E-03
Fluoride Ions	3.75E-05	-14	4.36E-05
H_2SO_4	2.15E-04	-7	2.30E-04
Hg	3.61E-09	-26	4.89E-09
Metallic Ions	2.56E-04	-2	2.61E-04
Mn	7.19E-04	-5	7.56E-04
Na	1.49E-05	-14	1.73E-05
NH_3	3.76E-05	-31	5.45E-05
Nitrate	3.54E-06	-14	4.11E-06
Oil	1.82E-02	-26	2.45E-02
Other Organics	3.05E-03	-25	4.08E-03
Pb	2.20E-08	-2	2.24E-08
Phenol	8.31E-07	-2	8.50E-07
Phosphate	1.08E-04	-7	1.15E-04
Sulphate	4.07E-02	-25	5.43E-02
Suspended Solids	1.86E-02	-43	3.27E-02
Zn	1.61E-05	-26	2.16E-05

TABLE 7.12. (Continued)

Solid Waste Emissions	**All Self Produced Hogged Fuel**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	2.06e+01	10	1.88e+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	6.11E-06	-50	1.21E-05

1/ CO_2 biomass and non-fossil collaborated

TABLE 7.13. Sensitivity Analysis Using Self Generated Hogged Fuel in the SE Region of the United States

Raw Materials	All Self Produced Hogged Fuel		No Change, Original Setup
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
SE Bark from log	1.01E+02	0	1.01E+02
SE Logs	1.01E+03	0	1.01E+03
Coal FAL	5.21E+01	0	5.21E+01
Crude Oil FAL	1.81E+01	-2	1.84E+01
Limestone	3.01E+00	-50	6.01E+00
Natural Gas FAL	3.82E+01	-0	3.83E+01
Uranium FAL	2.64E-04	-0	2.65E-04
Wood/wood Wastes FAL	6.16E-02	-100	5.21E+01
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Other Sources	3.58E+00	0	3.58E+00
Energy from Hydro Power	1.86E+00	0	1.86E+00
Energy			
Substance	**BTU/MSF (3/8-inch)**	**% Difference**	**BTU/MSF (3/8-inch)**
Natural Gas Direct Fired		-100	1.85E+05
Water Source			
Substance	**cuft/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	2.01E+00	0	2.01E+00
Recycled Water Source	5.43E-02	0	5.43E-02
Well Water Source	6.15E+00	0	6.15E+00

TABLE 7.13. (Continued)

Air Emissions	**All Self Produced Hogged Fuel**		**No Change, Original Setup**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acetaldehyde	4.74E-03	3	4.61E-03
Acetone	5.72E-03	0	5.72E-03
Acrolein	1.88E-06	-76	7.88E-06
Aldehydes	1.48E-03	0	1.48E-03
Alpha-pinene	8.62E-02	0	8.62E-02
Ammonia	8.94E-04	0	8.94E-04
As	2.80E-05	16	2.42E-05
Ba	1.08E-03	22	8.88E-04
Be	6.16E-07	0	6.16E-07
Benzene	9.00E-04	21	7.44E-04
Beta-pinene	3.35E-02	0	3.35E-02
Cd	4.74E-06	0	4.74E-06
Cl_2	1.92E-03	21	1.58E-03
CO	3.73E+00	19	3.14E+00
CO_2 (fossil)	2.04E+02	-1	2.07E+02
CO_2 (non-fossil)	5.16E+02	22	4.24E+02
cobalt	5.43E-06	0	5.43E-06
Cr	1.93E-05	12	1.73E-05
Cumene	1.03E-04	0	1.03E-04
Dichloromethane	7.56E-06	0	7.56E-06
Dioxin (TEQ)	9.94E-12	0	9.94E-12
Fe	1.08E-03	22	8.88E-04
Formaldehyde	2.79E-02	1	2.76E-02
HCl	9.38E-03	0	9.38E-03
HF	1.31E-03	0	1.31E-03
Hg	4.11E-06	0	4.11E-06
K	1.92E-01	22	1.58E-01
Kerosene	5.81E-05	0	5.81E-05
Limonene	9.69E-03	0	9.69E-03

TABLE 7.13. (Continued)

Air Emissions Substance	All Self Produced Hogged Fuel lb/MSF (3/8-inch)	% Difference	No Change, Original Setup lb/MSF (3/8-inch)
Metals	3.22E-05	0	3.22E-05
Methane	4.93E-01	0	4.93E-01
Methanol	1.24E-01	0	1.24E-01
Methyl Ethyl Ketone	7.69E-04	0	7.69E-04
Methyl I-butyl Ketone	6.25E-04	0	6.25E-04
Mn	2.23E-03	22	1.83E-03
N-nitrodimethylamine	3.96E-07	0	3.96E-07
N2O	1.09E-03	0	1.09E-03
Na	4.43E-03	22	3.64E-03
Naphthalene	5.90E-04	22	4.85E-04
Ni	2.04E-04	14	1.79E-04
Non Methane VOC	6.24E-01	0	6.24E-01
NO_X	1.58E+00	3	1.52E+00
Organic Substances	4.24E-02	21	3.51E-02
Particulates	5.78E-01	1	5.71E-01
Particulates (PM10)	1.33E-01	0	1.33E-01
Particulates (unspecified)	1.33E-01	0	1.33E-01
Pb	3.03E-04	21	2.50E-04
Phenol	4.15E-02	4	3.98E-02
Sb	2.12E-06	0	2.12E-06
Se	1.48E-05	0	1.48E-05
SO_2	7.31E-05	0	7.31E-05
SO_X	2.16E+00	0	2.15E+00
Tetrachloroethene	1.81E-06	0	1.81E-06
Tetrachloromethane	4.91E-06	0	4.91E-06
THC as Carbon	1.85E-01	0	1.85E-01
Trichloroethene	1.78E-06	0	1.78E-06
VOC	2.88E-01	0	2.88E-01
Water Vapor		-100	5.08E+02
Zn	1.08E-03	22	8.88E-04

TABLE 7.13. (Continued)

Water Emissions Substance	All Self Produced Hogged Fuel lb/MSF (3/8-inch)	% Difference	No Change, Original Setup lb/MSF (3/8-inch)
Acid as H+	1.94E-08	0	1.94E-08
B	5.21E-03	0	5.21E-03
BOD	2.09E-03	0	2.09E-03
Ca	1.43E-07	0	1.43E-07
Calcium Ions	4.99E-05	0	4.99E-05
Cd	9.25E-05	0	9.25E-05
Chromate	3.74E-06	0	3.74E-06
Cl-	9.31E-02	0	9.31E-02
COD	2.04E-02	0	2.04E-02
Cr	9.25E-05	0	9.25E-05
Cyanide	1.38E-07	0	1.38E-07
Dissolved Solids	2.03E+00	0	2.03E+00
Fe	7.31E-03	0	7.31E-03
Fluoride Ions	2.32E-04	0	2.32E-04
H_2SO_4	1.31E-03	0	1.31E-03
Hg	7.25E-09	0	7.25E-09
Metallic Ions	4.12E-04	0	4.12E-04
Mn	4.09E-03	0	4.09E-03
Na	9.19E-05	0	9.19E-05
NH_3	1.36E-04	0	1.36E-04
Nitrate	2.19E-05	0	2.19E-05
Oil	3.63E-02	0	3.63E-02
Other Organics	6.81E-03	0	6.81E-03
Pb	3.53E-08	0	3.53E-08
Phenol	1.34E-06	0	1.34E-06
Phosphate	6.50E-04	0	6.50E-04
Sulphate	1.01E-01	0	1.01E-01
Suspended Solids	9.81E-02	0	9.81E-02
Zn	3.21E-05	0	3.21E-05

TABLE 7.13. (Continued)

Solid Waste Emissions	All Self Produced Hogged Fuel		No Change, Original Setup
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	4.93E+01	9	4.54E+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	3.49E-05	0	3.49E-05

TABLE 7.14. Sensitivity Analysis Comparing All Natural Gas Versus Self Generated Hogged Fuel in the PNW Region of the United States

Raw Materials	**All Natural Gas**		**All Self Produced Hogged Fuel**
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
PNW Bark on Logs	9.35E+01	0	9.35E+01
PNW Logs	9.27E+02	0	9.27E+02
Coal FAL	9.62E+00	5	9.19E+00
Crude Oil FAL	1.17E+01	5	1.11E+01
Limestone	5.56E-01	5	5.30E-01
Natural Gas FAL	6.70E+01	251	1.91E+01
Uranium FAL	4.46E-05	4	4.28E-05
Wood/wood Wastes FAL	3.96E-02	92	2.06E-02
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Non-utility	7.43E+00	0	7.43E+00
Energy from Hydro Power	7.89E+01	836	8.43E+00
Water Source			
Substance	**cuft/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	5.80E+00	0	5.80E+00
Recycled Water	2.31E-02	0	2.31E-02
Well Water Source	2.06E+00	0	2.06E+00

TABLE 7.14. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acetaldehyde	1.16E-02	-4	1.20E-02
Acetone	5.11E-03	0	5.11E-03
Acrolein	8.75E-07	2	8.56E-07
Aldehydes	1.10E-03	35	8.12E-04
Alpha-pinene	7.69E-02	0	7.69E-02
Ammonia	2.03E-04	4	1.96E-04
As	1.03E-06	-93	1.51E-05
Ba	0.00E+00	-100	7.13E-04
Be	1.04E-07	12	9.25e-08
Benzene	9.12E-06	-98	5.92E-04
Beta-pinene	2.99E-02	0	2.99E-02
Cd	6.19E-07	57	3.96E-07
Cl_2	2.44E-06	-100	1.26E-03
CO	5.12E-01	-79	2.48E+00
CO_2 (fossil)	1.71E+02	185	6.00E+01
CO_2 (non-fossil)[1/]	4.85E-02	-100	3.40E+02
Cobalt	7.88E-07	36	5.79E-07
Cr	1.32E-06	-85	8.56E-06
Cumene	7.44E-05	0	7.44E-05
Dichloromethane	1.38E-06	6	1.30E-06
Dioxin (TEQ)	1.84E-12	5	1.75E-12
Fe	0.00E+00	-100	7.13E-04
Formaldehyde	3.66E-02	-3	3.76E-02
HCl	1.74E-03	5	1.66E-03
HF	2.41E-04	5	2.30E-04
Hg	7.25E-07	9	6.63E-07
K	0.00E+00	-100	1.26E-01
Kerosene	9.81E-06	4	9.44E-06

TABLE 7.14. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Limonene	8.62E-03	0	8.62E-03
Metals	1.93E-05	89	1.02E-05
Methane	4.84E-01	190	1.67E-01
Methanol	1.36E-01	0	1.36E-01
Methyl Ethyl Ketone	6.81E-04	0	6.81E-04
Methyl I-butyl Ketone	5.58E-04	0	5.58E-04
Mn	2.71E-06	-100	1.46E-03
N-nitrodimethylamine	7.31E-08	4	7.00E-08
N2O	1.96E-04	5	1.86E-04
Na	0.00E+00	-100	2.91E-03
Naphthalene	7.63E-08	-100	3.88E-04
Ni	8.88E-06	-91	9.62E-05
Non Methane VOC	8.12E-01	123	3.64E-01
NOx	9.62E-01	13	8.50e-01
Organic Substances	1.48E-03	-95	2.76E-02
Particulates	3.65E-01	-5	3.85E-01
Particulates (PM10)	2.26E-01	0	2.26E-01
Particulates (unspecified)	2.70E-02	13	2.39E-02
Pb	1.43E-06	-99	1.96E-04
Phenol	2.49E-02	-21	3.14E-02
Sb	3.14E-07	31	2.41E-07
Se	2.64E-06	7	2.46E-06
SO_2	8.25E-04	0	8.25E-04
SO_X	2.49E+00	209	8.06E-01
Tetrachloroethene	3.31E-07	5	3.14E-07
Tetrachloromethane	5.54E-07	20	4.63E-07
THC as carbon	1.65E-01	0	1.65E-01
Trichloroethene	3.28E-07	5	3.12E-07

TABLE 7.14. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
VOC	6.69E-01	0	6.69E-01
Zn	0.00E+00	-100	7.13E-04
Water Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acid as H+	1.26E-08	5	1.21E-08
B	9.31E-04	8	8.62E-04
BOD	3.51E-03	235	1.05E-03
Ca	1.03E-07	0	1.03E-07
Calcium Ions	8.31E-06	4	8.00E-06
Cd	1.62E-04	252	4.60E-05
Chromate	4.88E-07	60	3.06E-07
Cl-	1.62E-01	251	4.61E-02
COD	4.39E-02	428	8.31E-03
Cr	1.62E-04	252	4.60E-05
Cyanide	2.43E-07	253	6.88E-08
Dissolved Solids	3.56E+00	252	1.01E+00
Fe	1.33E-03	4	1.28E-03
Fluoride Ions	3.91E-05	4	3.75E-05
H_2SO_4	2.33E-04	8	2.15E-04
Hg	1.27E-08	251	3.61E-09
Metallic Ions	2.68E-04	4	2.56e-04
Mn	7.56E-04	5	7.19E-04
Na	1.55E-05	4	1.49E-05
NH_3	8.62E-05	129	3.76E-05
Nitrate	3.69E-06	4	3.54E-06
Oil	6.31E-02	247	1.82E-02
Other Organics	1.03E-02	238	3.05E-03

TABLE 7.14. (Continued)

Water Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Pb	2.29E-08	4	2.20E-08
Phenol	8.69E-07	5	8.31E-07
Phosphate	1.17E-04	9	1.08E-04
Sulphate	1.32E-01	224	4.07E-02
Suspended Solids	6.44E-02	246	1.86E-02
Zn	5.58E-05	247	1.61E-05
Solid Waste Emission			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	1.08E+01	-48	2.06E+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	6.41e-06	5	6.11E-06

TABLE 7.15. Sensitivity Analysis Comparing All Natural Gas Versus Self Generated Hogged Fuel in the SE Region of the United States

Raw Materials	All Natural Gas		All Self Produced Hogged Fuel
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
SE Bark from log	1.01E+02	0	1.01E+02
SE Logs	1.01E+03	0	1.01E+03
Coal FAL	5.29E+01	2	5.21E+01
Crude Oil FAL	1.91E+01	6	1.81E+01
Limestone	3.05E+00	1	3.01E+00
Natural Gas FAL	1.21E+02	217	3.82E+01
Uranium FAL	2.67E-04	1	2.64E-04
Wood/wood Wastes FAL	9.44E-02	53	6.16E-02
Electricity			
Substance	**kWh/MSF (3/8-inch)**	**% Difference**	**kWh/MSF (3/8-inch)**
Electricity from Other Sources	3.58e+00	0	3.58E+00
Energy from Hydro Power	1.86E+00	0	1.86E+00
Water Source			
Substance	**cuft/MSF (3/8-inch)**	**% Difference**	**cuft/MSF (3/8-inch)**
Municipal Water Source	2.01E+00	0	2.01E+00
Well Water Source	5.43E-02	0	5.43E-02
Recycled Water Source	6.15E+00	0	6.15E+00

TABLE 7.15. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acetaldehyde	4.00E-03	-16	4.74E-03
Acetone	5.72E-03	0	5.72E-03
Acrolein	1.91E-06	2	1.88E-06
Aldehydes	1.98E-03	34	1.48E-03
Alpha-pinene	8.62E-02	0	8.62E-02
Ammonia	9.06E-04	1	8.94E-04
As	6.69E-06	-76	2.80E-05
Ba		-100	1.08E-03
Be	6.38E-07	3	6.16E-07
Benzene	1.43E-05	-98	9.00E-04
Beta-pinene	3.35E-02	0	3.35E-02
Cd	5.13E-06	8	4.74E-06
Cl_2	4.09E-06	-100	1.92E-03
CO	8.06E-01	-78	3.73E+00
CO_2 (fossil)	3.95E+02	94	2.04E+02
CO_2 (non-fossil)[1/]	1.20E-01	-100	5.16E+02
Cobalt	5.79E-06	7	5.43E-06
Cr	8.38E-06	-57	1.93E-05
Cumene	1.03E-04	0	1.03E-04
Dichloromethane	7.69E-06	2	7.56E-06
Dioxin (TEQ)	1.01E-11	1	9.94E-12
Fe		-100	1.08E-03
Formaldehyde	2.62E-02	-6	2.79E-02
HCl	9.50E-03	1	9.38E-03
HF	1.32E-03	1	1.31E-03
Hg	4.22E-06	3	4.11E-06
K		-100	1.92E-01
Kerosene	5.88E-05	1	5.81E-05

TABLE 7.15. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Limonene	9.69E-03	0	9.69E-03
Metals	4.79E-05	49	3.22E-05
Methane	1.04E+00	112	4.93E-01
Methanol	1.24E-01	0	1.24E-01
Methyl Ethyl Ketone	7.69E-04	0	7.69E-04
Methyl I-butyl Ketone	6.25E-04	0	6.25E-04
Mn	1.49E-05	-99	2.23E-03
N-nitrodimethylamine	4.02E-07	1	3.96E-07
N_2O	1.11E-03	2	1.09E-03
Na		-100	4.43E-03
Naphthalene	2.61E-07	-100	5.90E-04
Ni	7.13E-05	-65	2.04E-04
Non Methane VOC	1.39E+00	123	6.24E-01
NO_X	1.82E+00	15	1.58E+00
Organic Substances	2.81E-03	-93	4.24E-02
Particulates	5.50E-01	-5	5.78E-01
Particulates (PM10)	1.33E-01	0	1.33E-01
Particulates (unspecified)	1.38E-01	4	1.33E-01
Pb	8.12E-06	-97	3.03E-04
Phenol	3.17E-02	-24	4.15E-02
Sb	2.25E-06	6	2.12E-06
Se	1.51E-05	2	1.48E-05
SO_2	7.31E-05	0	7.31E-05
SO_X	5.06E+00	135	2.16E+00
Tetrachloroethene	1.84E-06	2	1.81E-06
Tetrachloromethane	5.07E-06	3	4.91E-06
THC as Carbon	1.85E-01	0	1.85E-01
Trichloroethene	1.80E-06	1	1.78E-06

TABLE 7.15. (Continued)

Air Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
VOC	2.88E-01	0	2.88E-01
Zn		-100	1.08E-03
Water Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Acid as H+	2.03E-08	5	1.94E-08
B	5.33E-03	2	5.21E-03
BOD	6.38E-03	204	2.09E-03
Ca	1.43E-07	0	1.43E-07
Calcium Ions	5.05E-05	1	4.99E-05
Cd	2.92E-04	216	9.25E-05
Chromate	4.06E-06	9	3.74E-06
Cl-	2.93E-01	215	9.31E-02
COD	8.19E-02	301	2.04E-02
Cr	2.92E-04	216	9.25E-05
Cyanide	4.39E-07	218	1.38E-07
Dissolved Solids	6.44E+00	217	2.03E+00
Fe	7.38E-03	1	7.31E-03
Fluoride Ions	2.34E-04	1	2.32E-04
Mn	4.15E-03	1	4.09E-03
Na	9.31E-05	1	9.19E-05
NH_3	2.20E-04	62	1.36E-04
Nitrate	2.21E-05	1	2.19E-05
Oil	1.14E-01	213	3.63E-02
Other Organics	1.94E-02	184	6.81E-03
Pb	3.68E-08	4	3.53E-08
Phenol	1.40E-06	5	1.34E-06
Phosphate	6.69E-04	3	6.50E-04

TABLE 7.15. (Continued)

Water Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Sulphate	2.59E-01	156	1.01E-01
Suspended Solids	1.78E-01	81	9.81E-02
Zn	1.01E-04	213	3.21E-05
Solid Waste Emissions			
Substance	**lb/MSF (3/8-inch)**	**% Difference**	**lb/MSF (3/8-inch)**
Solid Waste	3.55E+01	-28	4.93E+01
Substance	**Ci/MSF (3/8-inch)**	**% Difference**	**Ci/MSF (3/8-inch)**
Radioactive Substance to Air	3.54E-05	2	3.49E-05

APPENDIX I: LOG, PLYWOOD, VENEER, AND FUEL PRICES

Table 7.18. Calculation for Cost Analysis

Log Mass	Percentage				
Species	%		$		
Douglas Fir	67.6	0.676	530	358.28	2S
Spruce	11.6	0.116	355	41.18	2S
Hemlock Fir	16.8	0.168	360	60.48	2S
Larch	4	0.04	355	14.2	Spruce 2S
Total	100			474.14	
http://www.odf.state.or.us:80/tmbrmgt/LOGP401.HTML					
Willamette Region 4th quarter, 2001					

Log Prices for Douglas-fir, Spruce, Hemlock and Larch for the PNW Region.

Log Price Information

Oregon Department of Forestry
Forest Management Division, Salem
503-945-7381

LOG PRICES
Domestically Processed Logs
(Delivered to a mill; "Pond Value")

2001 4th QUARTER

REGION 1 - NORTHWEST OREGON &

WILLAMETTE

Species & Grade	4th QUARTER 2001	
Douglas-Fir	POND VALUE	NUMBER OF QUOTES
1P	$ 985	5 or less
2P	$ 880	5 or less
3P	$ 740	5 or less
SM	$ 580	8
2S	$ 530	19
3S	$ 495	18
4S	$ 430	16
SC	$ 285	5 or less
Utility	$ 65	5 or less
Hemlock		
P	$ 450	5 or less
SM	$ 375	5 or less
2S	$ 360	15
3S	$ 330	15
4S	$ 295	12
Utility	$ 65	5 or less
Spruce		
SM	$ 365	5 or less
2S	$ 355	6
3S	$ 320	6
4S	$ 305	5 or less
Utility	$ 60	5 or less

Log Price for Pine Timber, Delivered from Mississippi State University Extension Services

DELIVERED PRICES[5]

	North		Central		South		Delta and River	
	Low-High	Average	Low-High	Average	Low-High	Average	Low-High	Average
Pine sawtimber	420-440	435	435-450	442	430-470	445	-	448*
Chip-n-saw pine	-	-	80-112	95	82-99	90	-	-
Poles (pine)	-	-	-	-	-	-	-	-
Mixed hardwood sawtimber[2]	230-275	265	294-331	312	225-260	245	200-253	230
Oak sawtimber	360-420	380	370-552	410	340-390	365	385-552	430
Other hardwood sawtimber	-	-	-	-	-	-	-	-
Pine pulpwood	35-62	49	36-52	48	35-59	48	33-52	41
Hardwood pulpwood	28-58	35	29-64	39	26-52	35	30-60	34

[1]Prices reported are for timber market transactions during the two-month period listed, sawtimber and standing pole prices in $/MBF Doyle, chip-n-saw and pulpwood prices in $/cord, delivered pine poles in $/ton.

[2]"Mixed Hardwoods" are mostly: Low-grade Oak, Beech, Cottonwood, Willow, Elm, Gums, Locust, Hackberry, Magnolia, Pecan, Hickory, Sycamore, Tupelo and Birch.

[3]"Soft Hardwoods" are mostly: Cottonwood. Willow, Poplar and Gum.

[4]"Rare Hardwoods" are mostly: Walnut, Cherry, Royal Paulownia, Persimmon, some species and grades of Cypress, certain prime grades of Cherrybark and White Oaks.

[5]Delivered prices are values given at the sawmill or pulpwood yard gate.

Mississippi weight conversion factors for shortwood pulpwood by law are: pine = 2.6 tons/cord. ; mixed hardwood = 2.8 tons/cord.

There is no statutory weight conversion for sawlogs in Mississippi. Pine sawlog weight to lumber volume conversions vary by log diameter and range from 6.5 tons of logs/MBF of lumber to 12 or 13 tons/MBF. Most mills in Mississippi use weight conversion factors of 8 to 10 tons/MBF for southern pine. For hardwood logs (comprised mostly of oak and hickory), most mills use a conversion factor

Plywood and Green Veneer Prices for the PNW and SE Regions, January 18, 2002

Plywood & Panels

Prices are net F. O. B. mill to wholesalers

Sheathing

WEST	CD COAST	CD INLAND	NON CERT	CD STRUC	CC EXT	CC PTS
5/16"	185	185	170	195	210	—
3/8"	225	223	175	235	245	300
1/2" 3 ply	263	260	180	—	—	—
1/2" 4/5 ply	285/297	285/295	200/200	310	320	365
5/8" 4/5 ply	317/332	315/325	195/195	370	295	450
3/4" 5/7 ply	374	368	295	430	485	535

SOUTH	WEST CD	MILL CERT	CNTRAL CD	MILL CERT	EAST CD	MILL CERT
3/8"	194	168	220	165	212	165
15/32" 3 ply	242	170	248	160	255	169
15/32" 4 ply	256	175	264	180	272	188
19/32"	305	210	313	200	322	215
23/32"	360	300	370	293	383	309

Sanded Plywood Group 1

	West EXTERIOR AC	BC	AB	AA	West INTERIOR AD	BD	AB	AA	South AC EXTERIOR WEST	EAST	South BC EXTERIOR WEST	EAST
1/4"	324	284	459	474	314	279	449	464	300	321	295	313
11/32"	362	315	497	512	372	305	492	502	275	282	230	229
15/32"	423	379	563	478	418	369	553	568	367	372	307	330
19/32"	506	455	641	656	496	445	631	646	444	447	425	424
23/32"	558	517	703	718	448	507	693	723	529	545	448	515

Underlayment C, X-Band T&G*

	WEST	INLAND	SW	SO. CTRL	SE
19/32"	377	375	345	350	377
23/32"	436	435	405	410	426
1 - 1/8"	653	—	625	—	—

Concrete Form BB class 1 exterior

	WEST		SW	SE
5/8" 5ply/7ply	595	19/32"	460	452
3/4" 5ply/7ply	690	23/32"	512	532

Siding

6 PATCH: 9' ADD 220.00; 10' ADD 230.00

	West 6 PATCH 8'	West 18 PATCH 8'	West 9'	West 10'	South WEST	South EAST
11/32"	460	350	470	480	343	380
19/32"	635	550	670	680	525	568
19/32"RBB	700	620	740	750	580	605

Fir Veneer

	CD 8' 75%	CD 8' 54"	CD 8' 27"	CD 8' RW	CD F/T	WS 27"	WS RW	AB 54"	AB 27"		CD 4' 1/6"	CD 4' 3/16"
1/10"	41.50	47.00	34.50	23.50	17.00	27.00	16.00	115.00	111.00	Hem-Fir	45.50	—
1/8"								125.00	121.00	Doug-Fir	49.50	64.00
1/6"		63.00	60.00	43.00	34.00	40.50	34.50					

Particleboard

*Industry spread

	COASTAL IND.	INLAND IND.*	U/L	U/L Del'd Chicago	SW IND.	SO. CTRL. IND.	SE IND.	MDF WEST	MDF EAST
3/8"	165	165	140	175	175	175	175		
1/2"	185	195	150	185	175	175	175		
5/8"	205	200	160	200	200	205	200	330	305
11/16"	220	215	—	—	225	225	225		
3/4"	235	230	185	235	230	230	230	360	345
1-1/8"	400	405	—	—	400	400	405		

OSB[1]

	N.C.	N.E.	E.CN	W.CN	MID ATL	S.E.	S.W.
1/4"	122	98	82/92*	110	115	120	122
3/8"	126	120	119	114	128	134	125
7/16" 24/16	136	129	131	120	143	146	139
15/32"	146	140	140	132	153	166	158
1/2"	156	151	150	142	167	179	167
19/32" T&G	209	190	180	175	215	225	194
23/32" T&G	230	235	216	223	235	230	230

[1]F.O.B.mill pricing U. S. Funds [2]Canadian Funds, GST excluded
*Mix C/L prices/Straight C/L Prices

Delivered OSB Prices to Selected Destinations

*T&G

	3/8"	7/16"	15/32"	19/32"*	23/32"*
SEATTLE	131	141	154	214	243
PORTLAND	133	143	156	216	245
SACRAMENTO	155	161	174	230	267
LOS ANGELES	157	166	177	233	276
PHOENIX	157	166	177	233	276
SALT LAKE CITY	143	153	164	229	263
DENVER	142	151	163	228	263
BOISE	135	145	158	218	247
ALBUQUERQUE	158	168	179	235	278
VANCOUVER BC[2]	205	215	235	335	390
CALGARY[2]	195	205	225	330	380
SASK./MAN.[2]	195	205	225	330	380
TORONTO[2]	210	220	240	320	390

Gasoline and Diesel Fuel Prices for April 22, 2002

eia.doe.gov

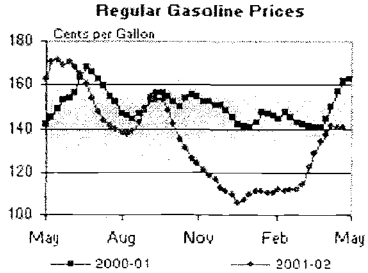
Gasoline and Diesel Fuel Update

Home > Petroleum > Gasoline and Diesel Fuel Update

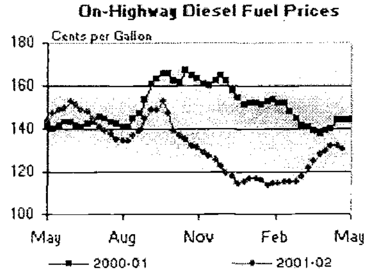
Gasoline | Diesel | Histor

U.S. Gasoline and Diesel Fuel Prices, 04/22/02

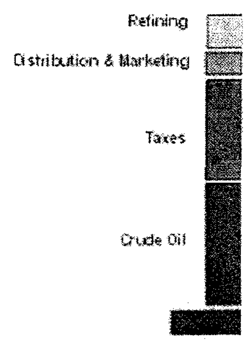
Regular Gasoline Prices



On-Highway Diesel Fuel Prices



What We Pay For in a G
Gasoline
(March 20
Retail Price: $1.25/



Meti

Previous Mor

Gasoline		Change from		Diesel Fuel		Change from	
	Price	Week Ago	Year Ago		Price	Week Ago	Year Ago
U.S.	140.4	0.0	↓ -21.5	U.S.	130.4	↓ -1.6	↓ -13.9
East Coast	138.4	0.0	↓ -17.7	East Coast	130.8	↓ -1.2	↓ -14.5
New England	141.9	↑ 1.0	↓ -16.4	New England	138.8	↑ 0.1	↓ -16.3
Central Atlantic	141.5	↑ 0.8	↓ -17.2	Central Atlantic	139.3	↓ -1.2	↓ -15.7
Lower Atlantic	135.0	↓ -0.8	↓ -19.3	Lower Atlantic	126.5	↓ -1.3	↓ -13.8
Midwest	137.9	0.0	↓ -29.4	Midwest	128.5	↓ -2.4	↓ -13.9
Gulf Coast	134.3	↓ -0.2	↓ -19.9	Gulf Coast	126.9	↓ -0.9	↓ -11.6
Rocky Mountain	138.8	↓ -0.2	↓ -16.2	Rocky Mountain	135.6	↓ -0.1	↓ -14.7
West Coast	154.1	↓ -0.1	↓ -16.5	West Coast	139.0	↓ -1.5	↓ -16.2
California	161.3	↓ -0.4	↓ -21.5	California	142.7	↓ -2.5	↓ -18.6

Note: Price in Cents per Gallon.

This Week In Petroleum

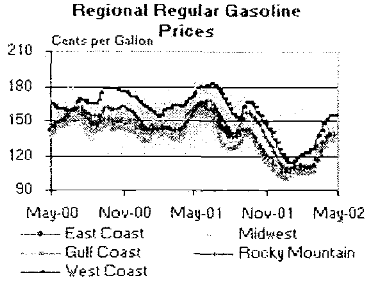
This Week In Gasoline

Summer 2002 Motor Ga

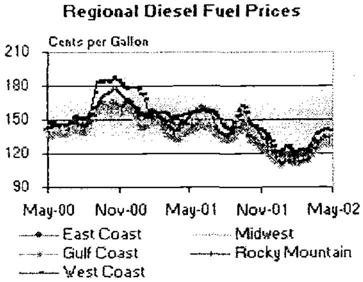
Factors Impacting Gasc
Areas for Further Study

A Primer on Gasoline Pı

Regional Regular Gasoline Prices



Regional Diesel Fuel Prices



APPENDIX J: SURVEY

CORRIM SURVEY

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

Softwood Plywood Mills
1-15-2001

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

This CORRIM survey is designed specifically for softwood plywood mills. Questions will be concentrated on annual production, electricity production and usage, fuel use, material flows, and environmental emissions. We realize that you may not have all the information requested, especially when it comes to specific equipment/processing groups or what we call 'machine centers.' The data you are able to provide will be appreciated. Our intent is to maintain the confidentiality of the companies that supply the data for this survey.

Company: ______________________________

Facility Site (city, state): ______________________________

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

Name: ____________________ Title: ____________________

Telephone: ____________________ E-mail: ____________________

If you have questions about the survey, contact:
Eric Sakimoto
Graduate Research Assistant
Department of Forest Products
289 Richardson Hall
Oregon State University

Annual Production (Please provide units of measurement if different than stated.)

			TOTAL PRODUCTION
1.	Plywood production in 1999 or 2000	MSF 3/8-inch basis	______
	Give production year		______
2.	Log volume consumption	BF	______
	Give log scale (i.e., Scribner, Doyle)		______
3.	Veneer		
	a. Purchased veneer:		
	i. Dry	MSF 3/8-inch basis	______
	ii. Green	MSF 3/8-inch basis	______
	b. Produced veneer:		
	i. Used in mill	MSF 3/8-inch basis	______
	ii. Sold	MSF 3/8-inch basis	______

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

If you completed a 1999 Annual Fuel and Energy Survey for AF&PA, you may want to attach the survey and skip to the next section entitled "Other related information."

1.	Purchased electricity		KWH	______
2.	Purchased steam		lbs. (at temperature °F?)	______
	If you know fuel source used to generate steam, please state type, i.e. natural gas, hog fuel			______
3.	Coal		Tons	______
4.	Hog fuel	*Self-generated*	Tons	______
		Purchased	Tons	______
5.	Wood waste		Tons	______
6.	Residual Fuel Oil		42 Gal. Bbls.	______
7.	Distillate Fuel Oil		42 Gal. Bbls.	______
8.	Liquid Propane Gas		Gallons	______
9.	Natural Gas		$ft.^3$	______
10.	Gasoline and Kerosene		Gallons	______
11.	Diesel		Gallons	______
12.	Other (Specify)		______	______
13.	Less energy sold or transferred			
	a. Electricity		KWH	______
	b. Steam		lbs. (at temperature °F?)	______
	c. Hog fuel		Tons	______
	d. Wood waste		Tons	______

Note: please list fuel (i.e., propane, diesel, etc.) consumption in appropriate category above for use of fork lifts in yard and mill.

14. If you have a boiler, what is its heat source? Check appropriate box.
    - ☐ Hogged fuel
    - ☐ Oil
    - ☐ Natural gas
    - ☐ Other

Other Related Information on an annual basis

1. For dryer(s), check box for the heat source type and state the annual fuel consumption if known:

☐ Steam	lbs.	________
☐ Natural gas direct-fired	$ft.^3$	________
☐ Hog fuel direct-fired	Tons (50% m.c.)	________
☐ Other (please specify)		________

2. For dryer(s) specify the following:

    - ♦ Type of dryer(s) (i.e. jet, longitudinal, cross flow) ________
    - ♦ How is dryer(s) heated (direct–such as a fuel cell, heat exchanger, etc.) ________
    - ♦ Do you recycle dryer exhaust, if so to where ________

3. For dryer(s):

- ♦ Wood species dried and approximately percentage of total

  wood species % of total veneers ____________

  wood species % of total veneers ____________

  wood species % of total veneers ____________

- ♦ Average moisture content into dryer % ovendry basis ____________
- ♦ Average moisture content out of dryer % ovendry basis ____________
- ♦ Percentage of redry % ____________

4. For hot press(es), check box for heat source type and state the annual fuel consumption if known:

- ☐ Steam lbs. ____________
- ☐ Oil 42 gal. bbls. ____________
- ☐ Electricity KWH ____________
- ☐ Other ____________

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

Component type	range % solids by weight	total annual use (lbs.) on a solids or wet basis–please state basis
phenol formaldehyde		
extender and filler		
catalyst (NaOH)		
water		
other (please specify)		

6. Annual water use (check source and give amount):

- ☐ Municipal water source — Gallons ____________
- ☐ Well water source — Gallons ____________
- ☐ Recycled water — Gallons ____________

7a. Transportation method and distance to deliver logs (check method(s)):
(note - if you only purchase veneer please skip to question 7b.)

Log delivery method	% of Total
☐ Truck	____________
☐ Rail	____________
☐ Other	____________
	Total = 100%

Average distance to deliver logs — Miles ____________

7b. Transportation method and distance to deliver veneer

Veneer delivery method	% of Total
☐ Truck	____________
☐ Rail	____________
☐ Other	____________
	Total = 100%

Average distance of delivery for veneer — Miles ____________

8. Transportation method used to deliver resin

- ☐ Truck ____________
- ☐ Rail ____________
- ☐ Other ____________

Average distance to deliver resin to mill — Miles ____________

Annual Material Flow

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

☐ Debarking and Bucking

1.	Bark produced annually	Tons	______
2.	Wood chips produced	Tons	______

☐ Peeling and Chipping (give unit used)

1.	Volume of peeler core	ft^3., pieces, etc.	______
2.	Green clippings	Tons	______

☐ Veneer Dryer

1.	Veneer downfall	Tons	______

☐ Lay-up

1.	Lay-up scrap	Tons	______
2.	Resin use	lbs	______

☐ Sawing and Trimming

1.	Panel trim	Tons	______
2.	Saw dust	Tons	______

Emission Control Device and Environmental Emission

The following is a chart of emission control devices and on page seven (7) is a listing of chemical compounds that are observed and/or permitted. Please fill in all information related to the control devices. Then list all compounds that are collected and known for the mill from all control device sources. If you recently applied for an air permit, use those numbers. Fill in all that apply and for which you have data. If you have more than five devices, please make a copy of this page and the next, change numbers from 1 to 6, i.e. ECD 1 to ECD 6, complete form and attach.

Emission Control Device (ECD) - Electricity, Fuel Usage and Emission Output					
	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment type controlled (boiler, dryer, press, etc.)					
Type of device (i.e., RTO, RCO, Scrubber, WESP, cyclone, baghouse, etc.)					
Manufacturer and year installed					
ECD exhaust temperature (°F) and flow rate (acfm)					
Electricity use in % of total mill use or KWH, please state units					
Natural gas use in % of total mill use or ft.^{3}, please state units					

Annual Emission to Air (provide data for same device identified on prior page; please provide unit of measurement for each.)					
Organic Compound	ECD 1	ECD 2	ECD 3	ECD 4	ECD 5
Equipment type controlled (boiler, dryer, press, etc.)					
Units	Ton/year	Ton/year	Ton/year	Ton/year	Ton/year
CO_2					
CO					
NO_X					
SO_2					
VOC					
Particulate					
PM10					
Acrolien*					
Acetaldehyde*					
Propionaldehyde*					
Formaldehyde*					
Methanol*					
Phenol*					
Water Vapor					
* HAPS; you may want to provide total HAPS rather than specific chemicals					
Other (Please Specify					

Solid emissions from all known sources (please provide units of measurement)		
Emission	Quantity (i.e., tons, lbs.)	Method of disposal or end use (i.e., land fill, landscaping, sewer)
Bark/wood waste		
Boiler ash and fly ash		
Recovered particulates from pollution abatement equipment		
Water (BOD, COD, suspended solids, etc.)		
Other (please specify)		

Machine Center Breakdown for Electricity and Fuel Use

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

Machine Center	Model/ Type	Annual Electricity Usage	Fuel Usage
	Year Installed	Million KWH or % of total electricity use for mill	% of total use for mill
Boiler			
Co-generator			
Debarker			
Log conditioning			
Peeling and Clipping			
Dryer			
Lay-Up			
Press			
Trimming			