CORRIM: Phase I Final Report

Module E

SOUTHEASTERN ORIENTED STRANDBOARD PRODUCTION

June 1, 2004

Prepared by

D. Earl Kline[1]

[1] Author is Associate Professor, Department of Wood Science and Forest Products, Virginia Polytechnic Institute and State University.

EXECUTIVE SUMMARY

The objective of this study was to develop a life cycle inventory (LCI) for the production of oriented strand board (OSB) as manufactured in the Southeast (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia). OSB is considered a structural panel product, and is used for roof, wall and floor sheathing and sub-flooring in residential and commercial construction. Roundwood used for flakes to make OSB in the Southeast include 75 percent softwoods (southern pine) and 25 percent hardwoods (yellow poplar and a mix of other hardwood species). OSB plants were surveyed in this region to record the amount of all inputs and outputs associated with the production process. Input data collected consisted of transportation distances and the use of wood, bark and other wood by-products, electricity, fuel and resin. Output data was comprised of OSB product, by-products of screening fines, bark, trimmings, and sawdust, as well as land, water and air emissions.

Four OSB manufacturing plants were surveyed in the Southeast. The survey responses represented 1999 production data and these plants represented approximately 18 percent in terms of total production for the survey region. The surveyed plants produced 1.41 billion square feet (MMMSF) 3/8-in basis in the Southeast.

Southeast OSB manufacturing had a wood recovery of 71 percent as determined by the output of wood in the OSB product as a percentage of the wood raw material (wood and bark) input to the plant. It took 49.5 ft^3 (1,701 lb oven-dry wood and bark) of wood raw material in the logs to produce a MSF 3/8-inch of OSB (1,203 lb oven-dry wood). The amount of bark generated during the debarking process was 8 percent based on the weight of bark to total weight of roundwood input. The remaining 29 percent of the wood and bark input ends as wood residue for fuel (25 percent) and co-products for sale (4 percent). Major co-products found during the time of the survey included bark mulch, screening fines, and sawdust.

The major use of electricity and heat (generated with both wood and fossil fuel) were the drying and pressing machine centers. These centers also were the major source of emissions. All inputs and outputs were found per thousand square feet (MSF) 3/8-inch basis of OSB. Based on the survey, Southeast OSB used 2.7 million BTU of heat in processing, of which 85 percent was from wood fuel generated on-site and the other 15 percent was from fossil fuels such as natural gas and fuel oil purchased off-site. The electricity use per MSF 3/8-in basis of OSB is 182 kWh. Very small amounts of fossil fuels were used to support processing activities such as log handling and forklifts. Significant fossil fuel (natural gas) is used to reduce VOC emissions.

A carbon cycle analysis showed that 920 lb of carbon is involved in the manufacture of one MSF OSB (3/8-inch basis). Of this carbon input, 95.5 percent comes from wood raw material and the remaining is utilized in the form of resins, wax and fuels. The major percentage of the carbon (69.8 percent) is held in the final OSB product. The significant portion of carbon that is returned back to nature is in the form of non-fossil CO2 (24 percent). The carbon cycle in this study excludes forestry processes and transportation of logs and other ancillary materials to the manufacturing site.

All CO_2 from biomass and a majority of CO (78 percent), VOC (58 percent) and particulates (62 percent) are generated on site. All methane, and a majority of SO_x (99 percent), CO_2 from fossil (81 percent), and NO_x (78 percent) air emissions are generated off-site for the production and delivery of fuels, resin, wax, and electricity. Sixty-one (61) percent of total CO_2 (generated both on- and off-site) is from biomass. However when considering the amount of CO_2 generated on-site only, the percentage from biomass is much higher at 89 percent.

The significant contributions to air emissions are a result of either the drying, pressing, or emission control processes. The flaking and finishing processes contribute very little to air emissions. When considering both on- and off-site impacts, all processes have some contribution to these air emissions either directly or indirectly. However considering the direct impacts from only on-site generated air emissions, the emission control process has the greatest impact on a majority of emissions released to air.

Burdens, a method of assigning allocations of emissions to products, were assigned to OSB products and by-products on a mass basis. Burdens for air emissions for finished OSB ranged from 97.8 percent to 99.3 percent depending on which OSB material sub-processes generated the emission. The average burden for finished OSB air emissions was about 98.5 percent with remaining burdens assigned to the co-products of bark mulch, screening fines, and sawdust.

Sensitivity studies showed that while the latest emission control technologies employing Regenerative Thermal Oxidizers (RTO) is very effective at removing particulate, CO, and VOC emissions, it comes at a cost in terms of additional energy input, and an overall increase in other greenhouse gases released to air such as fossil CO_2, SO_2, NO_x, and methane. The LCI data developed for OSB manufacturing can provide LCI information to weigh the advantages and disadvantages of different emission control technologies from an overall life cycle perspective.

The study procedures and report is in conformity with the applicable standards included in ISO 14,040 and ISO 14,041. This report was independently reviewed by an external reviewer to assure that the study procedures are scientifically and methodologically sound and that the report is representative, transparent, and complete for life cycle inventory data for the OSB production processes.

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1.0 INTRODUCTION AND SCOPE

Oriented strand board (OSB) evolved from waferboard in the late 1970s. OSB is manufactured by processing a log into strands of predetermined length, width, and uniform thickness. These strands are oriented, not randomly placed, to create a final panel product that can be used for structural applications. These applications include wall sheathing, roof sheathing, sub floors, underlayment, structural insulated panels, I-joists, and rim boards. Today, all building codes in the U.S. and Canada recognize OSB panels for the same uses as plywood on a thickness-by-thickness basis. Although OSB comes in a variety of grade and thickness, its production is based on a thousand square feet (MSF) of 3/8-inch thickness equivalence. Panels are normally produced in 4- x 8-foot sheets. In 2000, the reported total annual OSB production for the US was 11.9 million MSF 3/8-inch (APA 2001).

The goal of this study was to document the life cycle inventory (LCI) of manufacturing OSB based on resources from the Southeast OSB manufacturing region. The output of this study is intended for use by researchers and practitioners as an input to the life cycle analysis (LCA) of structural building materials in a cradle-to-grave analysis. This study considers those impacts associated primarily with the manufacture of OSB (gate-to-gate), documenting all inputs and outputs. The precise system boundary, functional units, and associated input/outputs will be discussed in Section 2.0. Primary data was collected by direct survey of OSB manufacturers. The survey questionnaire is included in Appendix 1 of this report. Supplemental secondary data was obtained for impacts associated with the manufacture, delivery, and consumption of electricity and all fuels (Franklin and Associates 1998, Pre´ Consultants 2001, USDOE 2000), resins (Athena 1993, Boustead 1999) and wax additives (PWMI 1993, EPA 1995a, EPA 1995b).

This report focuses on OSB production practices in the southeast region of the US, which includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia (see Figure 1.1). Almost two-thirds of total OSB production (7.9 million MSF) was reported in the south region (APA 2001). To conduct the survey of OSB manufacturers in this region, all OSB manufacturing plants (22 plants for the southeast region) were sent a LCI survey in October, 2000. Of these, four plants (18 percent) responded with complete data in terms of OSB and by-products production, raw materials, electricity and fuel use, and emissions. Surveyed LCI data represents 1999 production data. The study procedures and report is in conformity with the applicable standards included in ISO 14,040 (IS0, 1997). This report was independently reviewed by external reviewer Frank Werner from Environment and Development in Zurich, Switzerland. The external review was to assure that the study procedures are scientifically and methodologically sound and that the report is representative, transparent, and complete for life cycle inventory data for the OSB production processes.

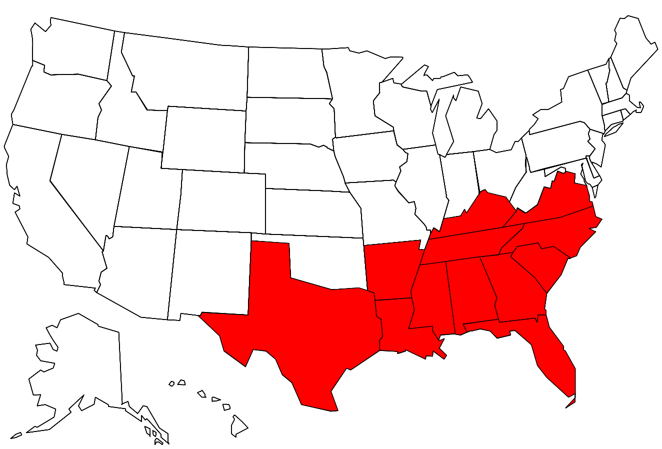

Figure 1.1. Survey region for OSB production practices in the southeast.

1.1 SOUTHEAST OSB PRODUCTION

The size of production facilities from the survey ranged from about 340,000 to 380,000 MSF 3/8-inch basis annually. The surveyed plants in the southeast produced 1.4 million MSF 3/8-in basis. This production represents about 18.0 percent of the total production in the South and 11.8 percent of total US production. An average OSB facility employs 153 persons and operates 8358 hours per year with 2 or 3 production shifts per day. Reported plant ages ranged from 5 to 15 years. Southern US OSB mill production cost (net) and mill price (FOB) for 2001 is reported to be $115 and $133, respectively, per MSF 3/8" basis (Global Wood Services Group 2001).

With southeast OSB processing technology, an average of 71 percent of the wood fiber input ends in the final OSB panel products (dry weight basis). OSB panels manufactured at the surveyed plants end up in products such as structural sheathing and flooring (65 percent), manufactured housing (10 percent), I-joists or box beams (9 percent), and other products such as shop panels (16 percent). While OSB can be shipped worldwide, on average it tends to be distributed locally within a radius of 230 miles. The primary methods of transporting finished OSB product to market are by truck (89 percent) and by rail (11 percent). Co-products sold by the surveyed mills include bark mulch (2.6 percent of wood input) and sawdust/fines (1.6 percent of wood input).

1.2 INPUT CHARACTERIZATION

OSB for the Southeast region is made from both softwood and hardwood species depending on the surrounding forest resources. Surveyed mills in the southeast reported a species mix of 75 percent softwood and 25 percent hardwood. Softwood species come from a group of wood species referred as southern pine, the dominant species in this group are slash and loblolly. The dominant hardwood species is yellow poplar but can also include a mixture of other species such as oak and maple. Location of the timber resource is within 150 miles to the mill and the transportation method is by truck.

Heat energy is a major input for the manufacture of OSB. Wood residues generated in the manufacture of OSB (e.g. bark, screening fines, board trimmings, and sawdust) are utilized as the primary fuel source to generate heat energy in the mill. This heat energy is used to dry OSB flakes and to press OSB mats. Self generated wood residues provide for 85 percent of the total heat demand. Natural gas, LPG gas and fuel oil are used as secondary fuel sources in the surveyed mills.

In addition to heat energy sources, OSB manufacturing purchases electricity to supply its mill operations. The surveyed manufacturers reported no co-generation of electricity. Other fuels used for VOC emission control, log loaders, forklifts and other transport equipment include natural gas, diesel fuel, and propane.

Other raw material inputs used in the manufacture of OSB are resins and slack wax. Resins used include phenol-formaldehyde (PF) resin, polymeric methyl-di-isocyanate (MDI). These raw materials are typically shipped to the plant by truck. Shipping distances for these raw materials can sometimes be over 1000 miles. Very little water input is used in the manufacture of OSB. Some water use was reported only in those mills utilizing wet Electrostatic Precipitators for particulate emission control.

1.3 EMISSION AND WASTE CHARACTERIZATION

Because OSB manufacturing utilizes self-generated wood residue to meet its heat energy demand, greenhouse gas emissions such as CO_2, CO, NH_4, and NO_x are generated directly at the plant. Particulate emission is also a concern with combustion of wood residue. Also, hazardous air pollutants (HAPs) and volatile organic compounds (VOCs) generated from the various OSB processes (e.g. drying and pressing) are of concern. In response to the 1990 Clean Air Act Amendments, the National Council for Air and Stream Improvement, Inc (NCASI 1999) began to characterize HAPs and VOCs from OSB manufacturing facilities and removal efficiencies of various emission control technologies.

Emission control measures currently employed use wet or dry Electro-Static Precipitators (ESP) to reduce particulates and Regenerative Thermal Oxidizers (RTO) to reduce VOC emissions. All mills surveyed reported significant capital improvements within the past 5 years. Most of the recent capital improvements involved the installation of emission control technologies. Highlighting recent concern for air emissions, upgrading emission control technology and purchasing a new emission control system was reported by one mill as a major capital improvement planned for 2001.

The only significant solid waste emission disposed to landfills was boiler/fly ash. While small amounts of other solid waste materials (sander dust, trimmings, solids collected from ESPs, etc.) can end in the landfills, it is a general practice of the OSB industry to recycle these materials or sell them as by-products.

Emissions to water were not reported by the OSB industry. One likely source of emissions to water is runoff from the OSB log yard during rain events. However, the mills surveyed did not collect any data on runoff to the watershed. As mentioned earlier, the OSB manufacturing process does not involve significant water input and, consequently, little emissions to water are likely due to OSB processing operations.

2.0 DETAILED DESCRIPTION OF OSB PROCESSING

The overall OSB manufacturing system consists of 10 primary processes. The interrelationships between these processes are shown in Figure 2.1. The following describes these processes and discusses significant inputs and outputs.

1. *Log Handling.* The log handling process includes sorting, storage, bucking, and debarking. The primary input to this process is roundwood from the forest. Other inputs include diesel fuel for log loaders and electricity for powering material handling systems and the debarker. The output is debarked logs or log bolts that proceed to the next process. Bark and other wood residues are also an output of this process and are used as fuel for drying and heating press oil. This wood residue can also be sold as a by-product. Another potential source of emissions to the environment is water runoff from the log yard.

2. *Flaking*. The flaking process strives to achieve a uniform flake thickness up to 6 inches long and about 1 inch wide. The material inputs to the system are debarked logs. Energy inputs include electricity to power the flakers. The material output is green flakes that are stored in wet bins until needed. No significant emissions or wastes are produced during this process.

3. *Drying.* Green flakes with moisture content of about 100 percent are dried until the appropriate moisture content is reached, usually between 4 to 8 percent. Removing this amount of moisture takes a large amount of heat. The drying process demands up to 80 percent of the heat requirement in an OSB plant (Lees 1993). The primary heat source input for this drying process is from wood fuel, which consists mostly of screening fines from the screening process but can also include bark, OSB trimmings from the finishing process, and other wood residues. Heat from wood fuel is generated typically by direct-fired heating methods. Backup heating from fuels such as natural gas, propane, or fuel oil is often used in this process when wood fuel is unavailable for drying. Since the drying process requires a high temperature heating energy input, it will contribute significantly to airborne emissions such as greenhouse gases, airborne particles, and VOCs.

4. *Screening.* This process screens out fine wood materials from the dried flakes that are considered too small for OSB mat formation. Screening uses electricity to power the process. The output of this process is flakes of appropriate size for subsequent manufacturing. The screening fines are used as fuel for drying and heating press oil.

5. *Blending.* This process blends strands with resin binders (PF and MDI) and a small amount of wax, which improves the efficiency of the resin binder and enhances the panel's resistance to moisture and water absorption. Additional material inputs in this process include PF and/or MDI resin and slack wax. Electricity powers the process. No significant emissions or wastes are produced during this process.

6. *Mat Formation.* The blend of strands, resin, and wax go through the forming line where cross-directional layers are formed in the OSB mat. Electricity is used to power the mat forming line. Small amounts of VOCs and HAPs can be released during mat formation.

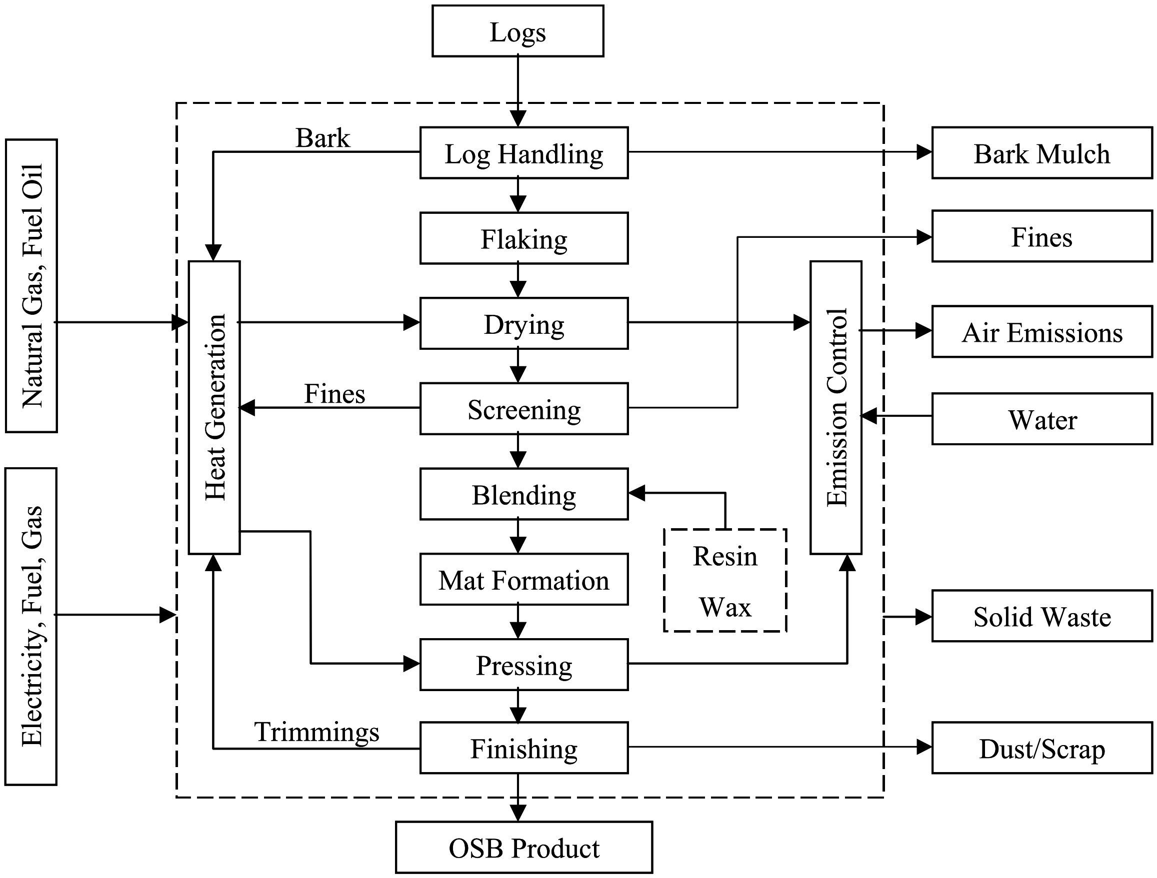

Figure 2.1. Description of the OSB manufacturing processes. System boundary for OSB processes is represented by dashed line

7. *Pressing*. The OSB mat is pressed under intense heat and pressure to form a rigid, dense structural panel of oriented strand board. Presses are typically multiple opening allowing 8 to 16 master panels to be pressed in one operation. Continuous pressing technology is also available to form a continuous ribbon of OSB. A significant source of energy is required to supply heat for the press. As with the drying process, most of this heat is generated using wood fuel. Oftentimes, the same wood-fueled heating system provides heat for both the dryer and heated thermal oil for the presses. If a separate heating system is used for press oil, hot flue gas from this system is usually directed to the dryer to recover any remaining heat not used by the press. The emissions from the press include VOCs and HAPs such as formaldehyde emissions from the heated OSB.

8. *Finishing*. In this process, panels are cooled, cut to size, grade stamped, stacked in bundles and packaged for shipping. Energy inputs include electricity for powering material handling and processing systems. Also, fuel for powering forklifts is used in this process. Waste material output is also generated in this process as OSB trimmings, sawdust, sander dust, and rejected boards. This material is used as a heating fuel or sold as a by-product. Residual VOC and HAP emissions can be released during finishing.

9. *Heat Generation*. In this process, wood fuel or fossil fuel input is converted to heat to supply the drying and mat pressing heat demand. The output of this process includes air emissions from combustion and solid waste (ash). Suspension burners are used to combust the wood fuel. These burners direct hot flue gas of up to 1200 ^{o}F through the flake dryers. Heat exchangers from the same heat generation system are often used to supply the heat to the press.

10. *Air Pollution Control.* In OSB manufacturing operations, significant processing technology is devoted to air pollution control including Regenerative Thermal Oxidizer (RTO), Electrostatic Precipitator (ESP), Regenerative Catalytic Oxidizer (RCO), Bio Filters, and other such technologies. While these processes are effective at minimizing levels of air emissions, they require significant inputs such as electricity and fuel.

2.1 UNIT PROCESS APPROACH

As described in the previous section, Figure 2.1 provides a systems overview of the entire system boundary and the interrelationships between the 10 processes. These 10 processes were then organized into six functional sub-unit processes. These sub-unit processes are shown in Figure 2.2 and serve as the basic models to analyze OSB processing efficiency and study potential areas to reduce environmental impact. While part of the rationale for these six basic sub-unit processes was due to limited allocation data of the various fuel and electricity inputs to all of the processes, the most important processes are represented in terms of both processing function importance and environmental impact.

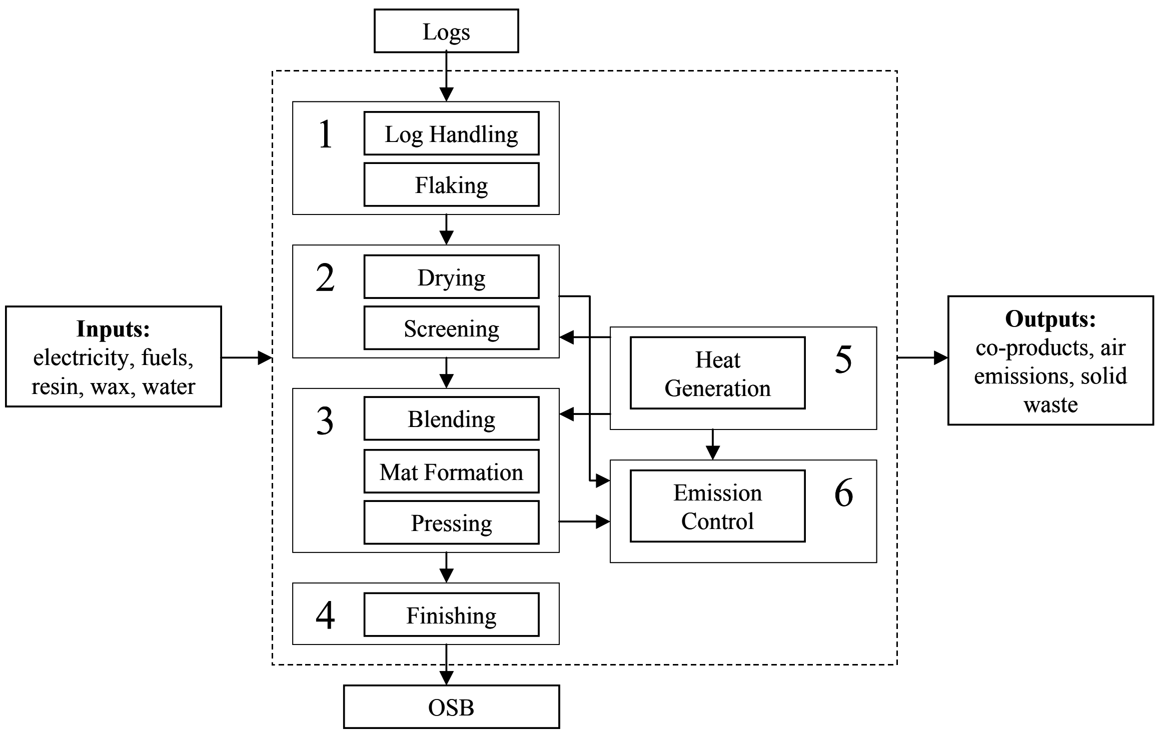

Figure 2.2. Sub-unit processes used to model the OSB manufacturing process.

The following describes each of the sub-unit processes (Figure 2.2) and rationale for their use in terms of analyzing ways to improve efficiency and reduce environmental impacts.

1. *Log Handling/Flaking*. Includes log handling operations, debarking, bucking, and flaking of logs. This sub-unit demands over 25 percent of the electrical needs of OSB processing and significant fossil fuels for log handling operations. The primary co-product produced is bark mulch. This process can be used to study the impact of different input log species, quality, and size as well as different technologies comparing tree-length vs. log bolt processing.

2. *Drying and Screening*. Includes drying of green flakes and screening operations to separate materials that are too small for OSB manufacturing. This sub-unit requires a large electrical input and demands up to 80 percent of the heat requirements of OSB processing. Due to high temperature drying, this sub-unit is the primary source of VOC. Sometimes screening fines are sold as a co-product or disposed of to landfills. This process can be used to study the impact of different drying technologies (e.g. low temperature drying)

and screening methods (e.g. green flake screening to reduce drying load).

3. *Blending and Pressing*. Includes blending, mat formation and pressing operations. This sub-unit demands the remainder of the heat needs to produce OSB panels. This operation also requires the resin raw materials to bond OSB flakes. Resins used contain hazardous air pollutants such as formaldehyde that can be released during pressing as VOC compounds. This process can be used to study the impact of employing different press emission collection systems.

4. *Finishing*. Includes all final operations to complete panels before their distribution to market. This sub-unit demands the least amount of energy resources but produces a stream of OSB board scrap and sander/machining dust. This scrap and dust is sometimes sold as a co-product or disposed of in landfills.

5. *Heat Generation*. Includes combustion of all fuel sources to provide the heating requirements for OSB processing. Because this sub-unit uses wood residue as a primary fuel source, significant amount of particulates and VOC gases can be generated due to incomplete/inefficient combustion. Also, wood ash is generated that must be disposed of to landfills. All wood residues generated in sub-units 1 through 4 above can be used as fuel for Heat Generation. Also, fossil fuels can be used as a fuel source. When residues are used for fuel, they are considered to remain within the system boundary for the LCI analysis. This process can be used to study the impact of employing different drying technologies as well as different fuel mixes.

6. *Emission Control*. Includes all technologies used to collect significant process emissions and treat them for reduced environmental impact before releasing them to the atmosphere. In treating various process emissions, this sub-unit can consume substantial resources such as fossil fuel, electricity, and water. With recent Maximum Achievable Control Technology (MACT) standards required by the 1990 Clean Air Act Amendments, this process can be used to study the life-cycle impact of employing different emission control technologies.

2.2 MATERIAL FLOWS

Those materials considered in the LCI analysis included those listed in Table 2.1. Input materials considered were logs (includes wood and bark), phenol-formaldehyde (PF) resin, polymeric methyldiisocyanate (MDI), and wax. Outputs were OSB and co-products consisting of bark, fines, and sawdust. All flow analyses of wood in the process were determined on an oven-dry weight basis. To derive the wood and bark weights and to determine how much water was “dried” from the wood and bark, the following assumptions were made: bark and other "green" wood was at 50 percent moisture content (MC) on a wet-basis and dry flakes and "dry" wood waste at 5 percent MC on an oven-dry basis.

Table 2.1. Listing of input materials, co-product, and products for producing OSB.

Input Materials	Co-products Produced	Products
Logs	Bark Mulch (green)	OSB
PF resin	Fines (dry)	
MDI resin	Dust/Scrap (dry)	
Wax		

While the percentage of hardwood species and softwood species used varied from mill to mill, the predominant was southern pine (see Table 2.2). The survey data provided wood input data in either cords or green weight. Data given in cords was converted to cubic feet (ft^3) of wood by multiplying by 75 ft^3/cord (Toennisson and Hadden 1993). Based on the survey data, 8.9 percent of the log volume was reported as bark, which is a little low compared to the literature (Lees 1993). Conversion from ft^3 to mass (lb) was made by multiplying by the appropriate densities (hardwood, softwood, or bark) as given by the survey. Table 2.2 shows the wood density used for softwood and hardwood log input into OSB processing. Bark density was assumed to be 30.6 lb/ft^3 (Haygreen and Bowyer 1996).

Table 2.2. Average density of wood species used to calculate mass of wood from logs.

Wood Species	Percentage Use in Survey	Density1/
	%	lb/ft^3
Softwood	75	35.1
Hardwood	25	33.7
	Weighted Average:	34.8

1/ Wood density values are from the Wood Handbook (1999).

Delivery of the input materials was by truck. The one-way delivery distance for logs, resin, and wax are given in Table 2.3. These distances are weighted averages of the survey data.

Table 2.3. Southeast delivery distance (one-way) for OSB production.

Material	Delivery Distance (miles)
Logs (Roundwood)	89
PF Resin	579
MDI Resin	825
Wax	714

2.3 ASSUMPTIONS

The data collection, analysis, and assumptions followed protocol as defined in "Consortium for Research on Renewable Industrial Materials (CORRIM)--Research Guidelines for Life Cycle Inventories" dated April 18, 2001. Additional conditions include:

- All data from the survey was weight averaged for the four plants based on their production in comparison to the total production for the year. Where appropriate, missing data from various plants were not included in weight averages.
- Log inputs that were provided in Cords were converted to ft3 by multiplying the factor 75 ft3/lb solid wood and bark. This value is assumed to be typical for the southern region (Toennisson and Hadden 1993).
- OSB board density, which can vary somewhat depending on species used and products produced, was assumed to be 40.5 lb/ft3. This density was based on informal discussions with mill personnel at two of the survey mill locations. This density also falls within the range reported by in Southern OSB mills studied by NCASI (1999).
- 100 percent of the diesel fuel reported was allocated for mobile equipment in the Log Handling/Flaking sub-unit process
- 100 percent of the liquid propane gas (LPG) and gasoline was allocated to the Finishing sub-unit process.
- The heat value of wood is assumed to occur at a 67 percent combustion efficiency or 3000 BTU/lb wood at 50 percent MC (wet-basis). Since wood residue used for heating is exclusively generated within the OSB system boundary, there is no burden assigned due to transportation. Heat values, burdens, and emissions for the combustion of other fuels are provided by Franklin Associates (FAL)

- Unaccounted wood mass of 2.2 percent was established by the difference between reported input and output wood material flows (see Section 3.1 for material balance analysis). Unaccounted wood is the result of survey error between reported input and reported output.
- Electricity consumption reported for OSB mills was not clearly separated between processes and administration. To be conservative, all reported electricity consumption was allocated to process-related data.
- Transportation of logs, resin, wax, and other ancillary materials related to OSB processing is excluded from the life cycle inventory in this study.
- Air emission data related to the effectiveness of various emission control technologies was taken from the National Council for Air and Stream Improvement Technical Bulletin No. 772 (NCASI 1999).
- Cost data used was taken from Spelter et al. 1996, North American Lumber and Panel Annual Report (Global Wood Services Group 2001), and a variety of case studies from *Panel World* (e.g. Lees, 1993).
- CO_2 emissions originating from fossil fuel sources and non-fossil fuel sources (e.g. combustion of wood residues) are reported separately in this study. This separate reporting is done because it is assumed that CO_2 from non-fossil sources has a neutral impact on the environment.
- SimaPro5, a software package designed for analyzing the environmental impact of products during their whole life cycle, was used to input the OSB life cycle inventory (LCI). Developed in The Netherlands by PRé Consultants B.V., SimaPro5 contains a U.S. database for a number of materials, including paper products, fuels, and chemicals. The U.S. database is provided by Franklin Associates (FAL 1998).

3.0 OSB PRODUCTION SUMMARY

3.1 INPUT AND OUTPUT SUMMARY

The input to produce a thousand square feet (MSF) of OSB 3/8-inch basis consists of 49.5 ft^3 or 1,570 lb (based on wood densities given in Table 2.3 and material flow assumptions stated in Sections 1.2.2 and 1.2.3) of wood from logs. 135 lbs of bark was produced during debarking operation. 42.4 lbs of PF resin, 8.16 lbs MDI resin, and 19.3 lbs wax were added to wood flakes to produce OSB (density assumed to be 40.5 lb/ft^3). Tables 3.1 and 3.2 summarize all inputs and outputs associated with the production of one MSF of OSB including electricity and fuel inputs. Material inputs per MSF are reasonable and appear to align with other material inputs reported in the literature for OSB (e.g. Lees 1993).

Table 3.1. Overall gate-to-gate life-cycle inputs for a MSF 3/8-inch basis OSB in the Southeast.

INPUTS		
Materials[1/]	**Units**	**per/MSF 3/8-in basis**
Round wood	ft^3	49.5
Wood	lb	1566
Bark	lb	135
Phenol Formaldehyde	lb	42.4
MDI Resin	lb	8.16
Wax	lb	19.3
Water Input		
Ground water	gal	8.48
Electricity Input		
Electricity	kWh	182
Fuel Input		
Wood fuel (produced) [1/2/]	lb	389
Natural gas	ft^3	747
Liquid Propane gas	gal	0.708
Diesel	gal	0.019
Fuel Oil	gal	0.186
Gasoline	gal	0.0077

1/ All materials and wood fuel are given as oven-dry or solids weights
2/ Wood fuel includes bark, screening fines, and OSB trimmings that are produced within the OSB system boundary
Notes: Results do not include inputs for the production and delivery of wood, fuel, electricity, resins or wax.

Table 3.2. Overall gate-to-gate life-cycle outputs for a MSF 3/8-inch basis OSB in the Southeast.

OUTPUTS		
Product		
OSB	lb	1266
Co-products		
Bark Mulch	lb	44.7
Fines	lb	18.2
Dust/Scrap	lb	9.53
Material		
Wood Waste	lb	0.11
Wood Ash	lb	4.22
Air Emission		
CO_2 (non fossil)	lb	8.41E+02[1,2/]
CO_2 (fossil)	lb	1.02E+02[1/]
CO	lb	2.49E+00
SO_2	lb	5.89E-02
NO_x	lb	6.97E-01
Particulates (PM10)	lb	6.15E-01
VOC[3/]	lb	2.18E+00
Methanol[4/]	lb	3.97E-01
Formaldehyde[4/]	lb	1.12E-01
Acetaldehyde[4/]	lb	1.31E-01
Acrolein[4/]	lb	4.71E-02
Phenol[3/]	lb	2.42E-02
MDI[3/]	lb	1.60E-04

1/ Not from survey data; calculated from FAL Database 1998.
2/ Includes 24 lb CO_2 (non fossil) from combustion of VOCs assuming a 64% average VOC removal efficiency
3/ VOCs weight average as reported by survey mills
4/ VOCs only reported for one mill --- weight average based on average emission control technology used
Notes: Results do not include emissions for the production and delivery of wood, fuel, electricity, resins or wax

An overall wood mass balance is given in the Table 3.3. The difference between the total wood input and output is 36 lb (more in than out), which was labeled as the "Unaccounted Wood". The unaccounted for wood is 2.2 percent of the total wood input. While this small amount of unaccounted wood is relatively small, it is important to note that it is based on several assumptions noted in Sections 1.2.2 and 1.2.3. Any relatively small change in these assumptions could yield more or less unaccounted wood. Nevertheless, this mass balance appears to verify that the material information provided from the survey information is reasonable.

Table 3.3. Wood mass balance for OSB production from the Southeast region per MSF 3/8-in basis.

Inputs	lb/MSF 3/8-in basis
Round wood (logs)	1701 1/
Outputs	**lb/MSF 3/8" basis**
OSB (wood only)	1203 2/
Wood Fuel (produced)	389
Bark Mulch Sold	45
Fines Sold	18
Dust/Scrap Sold	10
Wood Waste Landfilled 3/	---
Total Output:	1665
Unaccounted Wood	37 4/

1/ Includes weight of both bark and solid wood from Table 3.1.
2/ OSB is 95.1 % wood fiber and 4.9 % resin/wax based on survey data
3/ Less than 1 lb per MSF reported
4/ 2.2% less wood output than reported wood input
Notes: all weights are on an oven-dry basis

3.2 MANUFACTURING ENERGY SUMMARY

Energy for the production of OSB comes from electricity, diesel, liquid propane gas (LPG), natural gas, and wood fuel from bark, fines and other wood residue (See Table 3.1). The electricity is used to operate all the systems described in Section 2.0. Diesel fuel use is assumed to be by log loaders in the "log handling" process. Forklift trucks used small amounts of LPG primarily in the "finishing" process.

3.3 ELECTRICITY USAGE SUMMARY

The overall electrical usage reported per MSF of OSB is 182 kWh. The source of fuel used to generate the electricity used in the manufacturing process is very important in determining the type and amount of impact in the LCI analysis. The breakdown of electricity use in the Southeast by fuel source is given in Table 3.4. The source of this data is the U.S. Department of Energy (DOE). In 1998, the dominant form of fuel source in the region was coal, representing 49.2 percent of the total, followed by nuclear at 25.6 percent, natural gas at 9.6 percent, petroleum at 3.7 percent and hydro at 3.4 percent. In the SimaPro 5 analysis using the FAL database, combusting of coal contributes significant impact values, as does nuclear and petroleum, whereas natural gas contributes relatively less.

Table 3.4. Electric power industry generation of electricity by primary energy sources and state for the Southeast region as defined by the U.S. Department of Energy (2000).

	Percentage Share, 1998[1/]												
Fuel Source	AL[2]	AR	FL	GA	KY	LA	MS	NC	SC	TN	TX	VA	Avg
Coal	59.5	50.7	34.6	60.6	95.7	23.2	34.1	56.9	37.1	56.4	37.4	43.6	49.2
Petroleum	0.2	0.3	21.6	0.6	0.1	0.7	15.7	0.2	0.4	0.7	0.0	3.7	3.7
Gas	2.0	8.1	16.7	1.5	0.6	31.6	16.4	0.8	0.5	0.6	33.9	3.0	9.6
Nuclear	23.9	28.7	16.4	27.2	0.0	18.3	26.7	31.9	55.9	29.0	10.9	37.7	25.6
Hydro	8.8	6.8	0.1	4.4	3.6	0.0	0.0	3.4	2.9	9.6	0.4	0.4	3.4
Non utility	5.5	5.4	10.6	5.7	0.0	26.2	7.1	6.8	3.3	3.7	17.4	11.6	8.5

1/ *Source*: Energy Information Administration/State Electric Profiles 2000, Department of Energy.
http://www.eia.doe.gov/cneaf/electricity/st_profiles/toc.html
2/ Abbreviations of Southeastern States

3.4 HEAT GENERATION SUMMARY

Table 3.5 provides a breakdown of heat energy fuel sources used in Southeast OSB production. Just over 2.7 million BTU of heat energy is required per MSF OSB. This heat energy requirement falls in the range reported by Lees (1993). Wood fuel was by far the dominant fuel sources providing over 85 percent of the total heat energy requirements. In addition to wood fuel for heat generation, natural gas is the primary fuel used for back-up or secondary heat generation providing 12 percent of the heating requirements. Other fuel sources reported include liquid propane (LP) gas and fuel oil were also used but provide for only a small portion of the heating requirements.

Wood fuel includes bark generated during debarking, OSB fines from the screening process, and OSB trimmings/dust during the finishing process. As such, wood fuel used in OSB consists of a mixture of different moisture contents. Moisture contents (wet basis) of wood fuel mixtures for heat generation ranged from 5 to 24 percent based on the data reported from the survey mills. However, to be consistent conservative and with the FAL database for the combustion of wood for heat, wood weight was modeled as green weight and assumed to be 50 percent moisture content on a wet-weight basis. Future studies are needed to determine the representative moisture content of wood residues used for heating purposes in OSB manufacturing. The weighted average total wood fuel burned for heat was 778 lb at 50 percent moisture content on a wet basis (389 lb oven-dry).

Table 3.5. Southeast heat energy fuel sources per MSF 3/8-in basis OSB production.

Fuel Type	Input	Heat Energy BTU	Allocation %
Wood Fuel (lb)	778[1/]	2.33E+06[2/]	85.2
Natural Gas (ft^3)	319	3.29E+05[3/]	12.0
LP Gas (gal)	0.512	4.89E+04[4/]	1.8
Fuel Oil (gal)	0.186	2.79E+04[5/]	1.0
Total		2.74E+06	100.0

1/ Weight green wood fuel (50% MC wet basis)
2/ Weight of green wood multiplied by 4500 BTU/lb and an efficiency of 67%
3/ Volume of natural gas multiplied by 1030 BTU/ft3
4/ Volume of LP gas multiplied by 95500 BTU/gal
5/ Volume of fuel oil multiplied by 150,000 BTU/gal

3.5 AIR EMISSIONS SUMMARY

Most emissions are generated from the heat generation process used to supply heat for the dryers and the presses. Since all of the plants surveyed had direct-fired heating systems for dryer and press heat, the emissions have components of CO, CO_2 (fossil and non-fossil), NOx, SO2, particulates (PM10), and others. Dryers are used to take the moisture content of green OSB flakes from about 100 percent down to about 5 percent (oven-dry basis) and have an inlet temperature ranging from 1100 to 1300 ^{o}F. Because of such high temperature drying, VOC compounds are released from the wood flakes during the drying process. Hot pressing is done in the OSB manufacturing process to provide intimate contact between oriented flakes while the phenol-formaldehyde and/or MDI adhesive cures as a result of temperature in the 360-400 ^{o}F range. Similarly VOC compounds are also generated during pressing but since resins are included in the press operation, hazardous air pollutants (HAP) such as formaldehyde would be more prevalent from press emissions.

All OSB plants surveyed included some type of air emission control system. The technologies used in the survey mills included Electrostatic Precipitators (ESP), Regenerative Thermal Oxidizers (RTO), or both. In OSB manufacturing, emissions from dryers and hot press are collected and processed through pollution control systems such as described in Section 2.0. Emissions are monitored through these pollution control systems. Table 3.2 lists weighted average emissions output as surveyed from OSB manufacturers.

Mills with RTO technologies reported significantly less VOC emissions than mills without RTO. While it is important to note that RTO systems are very effective in reducing emissions resulting from incomplete combustion, they consume significant amounts of additional fossil fuel and other resources. Section 4.7 will detail and discuss primary and secondary data specific to emission control impacts and Section 6.0 will consider the benefit of various air emission technologies from a life cycle perspective.

3.6 ADHESIVE USAGE IMPACT SUMMARY

Phenol-formaldehyde (PF) resin and or MDI are the adhesives used in OSB production. The manufacture of these resins is particularly energy intensive. The total fuel energy requirement for the production of 42.4 lb of PF resin needed for MSF 3/8-in basis OSB from the Southeast is 6.99E+05 BTU's. Electricity requirements for phenol-formaldehyde production per MSF 3/8-in basis are 27.4 kWh in addition to that required in the OSB manufacturing process. The phenol-formaldehyde resin used is comprised of 65 percent formaldehyde and 35 percent phenol by weight. All the material, fuel use, and electricity used to produce the phenol-formaldehyde resin are listed in Table 3.6.

The total energy requirement for the production of 8.16 lb of MDI needed for MSF 3/8-in basis OSB from the Southeast is 2.85E+05 BTU's. Electricity requirements for MDI production per MSF 3/8-in basis are 14.4 kWh in addition to that required in the OSB manufacturing process. MDI resin used is comprised of many different materials by weight. Table 3.7 lists some of the more significant materials along with, fuel use, and electricity used to produce the MDI resin. A complete listing can be found in Boustead (1999).

Finally, the impact of wax on the total energy requirement in the production of OSB is shown in Table 3.8. The relative impact of the production of wax is small compared to PF and MDI. The transportation distances of PF, MDI, and wax can be quite far as previously indicated in Table 2.3.

Table 3.6. Production requirements[1/] for the 42.4 lb of phenol-formaldehyde resin needed to manufacture MSF 3/8-in basis OSB in the Southeast region.

INPUTS		
Materials	**Units**	**per MSF 3/8-in basis**
Formaldehyde	lb	2.76E+01
Phenol	lb	1.48E+01
Fuel Usage		
Diesel Fuel	BTU	2.65E+04
Gasoline	BTU	1.82E+02
Natural Gas	BTU	4.91E+05
Electrical Usage		
Electricity	kWh	2.74E+01

1/ *Source*: Material, Energy & Environmental Unit Factor Emissions: Structural Wood Production, Athena, 1993.

Table 3.7. Production requirements[1/] for the 8.16 lb of MDI resin needed to manufacture MSF 3/8-in basis OSB in the Southeast region.

INPUTS		
Materials[2/]	**Units**	**per MSF 3/8-in basis**
Crude Oil	lb	4.07E+00
Gas/Condensate	lb	8.95E+00
Coal	lb	2.77E+00
Lignite	lb	8.32E-01
Fuel Usage		
Oil Fuels	BTU	7.58E+04
Other Fuels	BTU	2.08E+05
Electrical Usage		
Electricity	kWh	1.44E+01

1/*Source*: I Boustead. Ecoprofiles of chemicals and polymers, 1999
2/Partial listing of Materials

Table 3.8. Production requirements[1/] for the 19.3 lb of wax additive needed to manufacture MSF 3/8-in basis OSB in the Southeast region.

INPUTS		
Materials	**Units**	**per MSF 3/8-in basis**
Crude Oil	lb	1.97E+01
Fuel Usage		
Fuel Oil	BTU	1.10E+04
Natural Gas	BTU	2.77E+04
Electrical Usage		
Electricity	kWh	2.43E-02

1/*Source*: PWMI (1993) and US EPA (1995a, 1995b)

3.7 PRODUCTION COST SUMMARY

Survey data in this study did not include cost information. However, cost data for OSB manufacturing published in recent sources is summarized in Table 3.9 (Global Wood Services 2001, Spelter et al. 1996). Total manufacturing cost for OSB in the south was reported to be $115 per MSF. Over 50 percent of the manufacturing cost comes from purchase of raw materials (35 percent from wood, 20 percent from resin/wax). Capital costs for OSB production is high compared to other wood products (Today, the cost of new OSB facilities exceed $100 million dollars), leading to fairly high depreciation costs of over 10 percent of total manufacturing cost.

Table 3.9. OSB manufacturing costs in the South.

Cost	$/MSF
Logs	40
Resin/Wax	23
Fuel/Electricity	9
Labor/Management	13
Depreciation	12
Supplies/Maintenance	18
Total Manufacturing:	**$115**
FOB mill price:	**$133**

4.0 OSB SUB-UNIT PROCESSES

Site-generated life cycle inventory results to produce one MSF 3/8-inch of OSB in the Southeast were given in the previous section. These results are an overall summary of the inputs and outputs to and from the system boundary defined in Figure 2.1. This section details the inputs and outputs to each of the six functional sub-unit process defined in Figure 2.2.

4.1 ELECTRICITY ALLOCATION TO SUB-UNIT PROCESSES

Table 4.1 lists the electrical energy use for each modeled process. Over 50 percent of the OSB electricity demand is from the first two processes, Log Handling/Flaking and Drying and Screening. These areas of the OSB process are where the largest motors are used for moving and handling green wood materials. Blending and Pressing has the next higher electrical load. Only one of the four mills responded to the survey for electricity allocation. However, the data appears to be representative since all mills list similar types of equipment in the various manufacturing processes except for emission control. As mentioned earlier, the types of emission control technology varied significantly between mills. Close to 10 percent of the electrical demand is used for other utilities including office equipment, lighting, air-conditioning, etc. This electrical demand was considered as overhead and was weight allocated to each of the six processes based on their original electrical demand.

Table 4.1. Southeast (SE) electricity allocation to each of the modeled sub-unit processes.

Sub-Unit Process	Original Survey	Allocation[1/]	Allocation
	%	%	KWh/MSF
1-Log Handling/Flaking	25.5	28.2	51.2
2-Drying and Screening	29.5	32.6	59.2
3-Blending and Pressing	14.1	15.6	28.4
4-Finishing	8.8	9.7	17.6
5-Heat Generation	6.7	7.5	13.5
6-Emission Control	5.8	6.4	11.7
Other Utilities (overhead)	9.6	---	---
Total:	**100.0**	**100.0**	**181.6**

1/Weighted allocation of overhead electrical load to all sub-unit processes.

4.2 LOG HANDLING/FLAKING PROCESS

Table 4.2 lists all inputs and outputs for the Log Handling/Flaking process. As shown, the major non-wood input to this process is 51.2 kWh electricity per MSF. The green wood materials (50% MC wet-basis) are reported on an oven-dry basis. This reporting will allow for easier mass balance comparison since moisture content can vary throughout the many stages of OSB manufacturing.

Table 4.2. Inputs and outputs for the Log Handling/Flaking sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
Roundwood	ft^3	49.5
Wood 1/	lb	1567
Bark 1/	lb	135
Energy Input		
SE Electricity	kWh	51.2
Fuel Input		
Diesel	gal	0.019
Product Output		
Green Flakes 1/	lb	1567
Co-product Output		
Bark (Heat) 2/	lb	90.2
Bark Mulch (Sale) 2/	lb	44.7

1/ Green wood (50 % MC wet-basis) is reported on an oven-dry basis.
2/ Bark residues reported as oven-dry weight.

4.3 DRYING AND SCREENING PROCESS

Table 4.3 lists all inputs and outputs for the Drying and Screening process. For each MSF of OSB produced, this process utilizes the 1567 lb of green flakes generated from Log Handling/Flaking (Table 4.2) to produce 1343 lb of dry flakes (5 percent MC oven dry basis). Based on the mill survey, 14.3 percent screening fines are generated during this process, most of which (over 92 percent) are used to supply the heating requirements. This process demands the largest energy need in OSB manufacturing both in terms of electricity (59.2 kWh/MSF), heat (2.17 million BTU/MSF), and emission control.

The Emission Control Input listed for the Drying and Screening process involves the processing of hydrocarbons (THC, reported as weight of carbon) that are released during typical OSB high temperature drying (NCASI 1999). The rationale behind using THC as an input from the techno-sphere is to make the data easier to study the impact of different air emission control technologies. The use of an emission control input will be explained further in Section 4.7.

Table 4.3. Inputs and outputs for the Drying and Screening sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
Green Flakes[1/]	lb	1567
Energy Input		
SE Electricity	KWh	59.2
Self-Generated Heat	BTU	2.17E+06
Emission Control Input		
Hydrocarbons (THC) [2/]	lb	8.9
Product Output		
Dry Flakes [3/]	lb	1343
Co-product Output		
Fines (Heat) [4/]	lb	206
Fines (Sale) [2/]	lb	17.3

1/ Green wood is reported on an oven-dry basis.
2/ Total carbon weight of VOC emissions from OSB flake dryers, average NCASI (1999) data
3/ Dry flakes and fines sold (5 % MC) reported as oven dry.
4/ Fines used internally for heat generation reported as oven dry weight

4.4 BLENDING AND PRESSING PROCESS

Table 4.4 lists all inputs and outputs for the Blending and Pressing process. For each MSF of OSB produced, this process mixes 1343 lb of dry flakes with wax and resin to produce 1413 lb of pressed OSB (5 percent MC oven dry basis). As discussed in Section 3.6, there are additional burdens associated with wax and resins. The data used to model the impacts associated with the production and delivery of wax and resins are summarized in Tables 3.6 through 3.8. Blending and Pressing also demands 28.4 kWh/MSF of electricity and the remainder of self-generated heat (0.57 million BTU/MSF). A small amount of THC (1.35 lb/MSF) is also released during typical OSB pressing (NCASI 1999). As with the Drying and Screening process, this emission is collected internally and directed as a mass input to the Emission Control process (see Section 4.7).

Table 4.4. Inputs and outputs for the Blending and Pressing sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
Dry Flakes[1/]	lb	1343
Wax	lb	19.3
MDI Resin	lb	8.16
PF Resin	lb	42.4
Energy Input		
SE Electricity	kWh	28.4
Self-Generated Heat	BTU	5.70E+05
Emission Control Input		
Hydrocarbons (THC) [2/]	lb	1.35
Product Output		
OSB After Press[3/]	lb	1413

1/ Dry flakes (5 % MC) are reported oven dry.

2/ Total carbon weight of VOC emissions from OSB press, average NCASI (1999) data

3/ OSB (5 % MC) reported oven dry.

4.5 FINISHING PROCESS

Table 4.5 lists all inputs and outputs for the Finishing process. For each MSF of OSB produced, 1413 lb of pressed board is processed to produce 1263 lb of finished OSB (5 percent MC oven dry basis). The final density of the board is assumed to be 40.5 lb/ft^3. Based on the mill survey, most of the scrap resulting from machining OSB into its final form (140.3 lb/MSF) is used to supply the heating energy requirements. This process also demands relatively small amounts of electricity, propane, and gasoline. A very small amount of OSB scrap was reported to be landfilled (0.11 lb/MSF).

Table 4.5. Inputs and outputs for the Finishing sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
OSB After Press[1/]	lb	1413
Liquid Propane Gas	gal	0.195
Gasoline	gal	0.0076
Energy Input		
SE Electricity	kWh	17.6
Product Output		
Finished OSB[1/]	lb	1263
Co-product Output		
Dust/Scrap (Heat) [2/]	lb	140.3
Dust/Scrap (Sold) [3/]	lb	9.5
Emission to Land		
OSB Dust/Scrap [3/]	lb	0.11

1/ OSB (5 % MC) reported as oven dry.
2/ Dust/Scrap used internally for heat generation reported as oven dry weight
3/ OSB Dust/Scrap sold or land filled (5 % MC) reported as oven dry.

4.6 HEAT GENERATION PROCESS

Table 4.6 lists all inputs and outputs for the Heat Generation process. For each MSF of OSB produced, wood residue, natural gas, propane, and fuel oil are combusted to produce 2.74 million BTU of heat required. Table 3.5 lists the individual contribution of each of the fuel sources to the total heat requirement. Heat generation also consumes electricity (13.5 kWh/MSF). The mill surveys reported a weighted average of 4.2 lb/MSF of ash sent to the landfill.

Table 4.6. Inputs and outputs for the Heat Generation sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
Wood Residue[1/]	lb	389
Natural Gas	ft^3	319
Liquid Propane Gas	gal	0.512
Fuel Oil	gal	0.186
Energy Input		
SE Electricity	kWh	13.5
Product Output		
Self-Generated Heat	BTU	2.74E+06
Emission to Land		
Ash [3/]	lb	4.2

1/ OSB reported at oven dry-basis.
2/ Dust/Scrap used internally for heat generation reported as oven dry weight
3/ OSB Dust/Scrap sold or land filled reported at 5 % MC oven dry-basis

The moisture content of the wood residue in Table 4.6 is reported as oven dry. Because wood fuel used in OSB consists of a mixture of wood residues at different moisture contents, the true moisture content can vary. The weighted average moisture content of wood fuel found from the survey data was 18.5 percent (wet basis). Moisture contents (wet basis) of wood fuel mixtures for heat generation ranged from 5 to 24 percent depending on the primary source of the plants wood fuel. To be consistent with the heat energy content in the FAL database for the combustion of wood for heat, wood weight was modeled as green weight and assumed to be 50 percent moisture content on a wet-weight basis. Future work is needed to develop a more robust module for wood combustion in OSB production that can include varying moisture contents of wood fuel.

During combustion of the fuel input materials, the Heat Generation process assumes emissions output based on the Franklin database (FAL) combustion of various fuels. Table 4.8 compares mill survey emissions to the FAL database emissions for the combustion of each fuel source. Survey data is very close to the FAL database for SOx, and NOx emission compounds and suggests that the FAL database is appropriate for these emissions. VOCs generated in the combustion of wood and other fuels are practically non-existent in the FAL database. As shown in Section 4.7, the primary source of VOCs is during flake drying and mat pressing. Also particulate emissions are reported to be much larger in the mill surveys. The reason for this difference is unknown. Suspension wood burners generate more particulates and/or some additional particulates are produced during flake drying or from other sources in OSB production. Section 4.7, describes how VOC and particulate emission differences are accounted in the Emission Control sub-unit process.

CO is reported by the mills is almost half of that in the FAL database. The reason for this difference can be due to emission control technologies used by the mills which can reduce CO emissions (NCASI, 1999). However, even untreated CO emissions from NCASI (1999) in southern OSB mills ranged from 1.6 lb to 6.3 lb indicating that CO emissions can be quite variable. Both FAL and the survey data fall within this range. Ash waste disposed is also reported to be over 10 times less than the solid waste disposal given by the FAL database. This difference can also be due to suspension burning technology vs. boiler technology.

Table 4.7. Comparison of mill survey emission to FAL emissions for the combustion of the various fuel sources to supply the heat requirement per MSF 3/8-inch basis OSB

Emission Compound	Emissions Contribution from FAL Database (lb/MSF) Wood	Natural Gas	Propane	Fuel Oil	Total	Survey Emissions (lb/MSF)
CO_2	816.9	88.1	7.0	4.2	916.2	NA
CO	5.30	0.04	---	---	5.34	2.49
SOx	0.03	0.05	---	0.01	0.09	0.06
NOx	0.58	0.23	0.01	---	0.82	0.70
Particulates	0.07	---[3/]	---	---	0.07	0.62
VOC[1/]	0.02	---	---	---	0.02	2.18
Trace Elements[2/]	0.32	---	---	---	0.32	NA
Solid Waste (ash)	35.0	---	---	---	35.0	4.22

1/ Includes Phenol, formaldehyde, benzene, methane, and naphthalene (FAL)
2/ 0.30 lbs potassium and less than 0.02 lb other elements (FAL)
3/ Less than 0.005 lb.

4.7 EMISSION CONTROL PROCESS

Attaining representative emission control related data for southeast OSB production is difficult without a full detailed survey of emissions at all stages in OSB manufacturing. This detailed survey was not possible in this study. All of the mills reported different emission control methods ranging from using RTO only, wet ESP only, or a combination of both RTO and wet ESP. Part of the reason for such a wide variation in emission control methods used is EPA's standards and regulations based on "Maximum Achievable Control Technology" (MACT) were evolving during the time of the survey. The survey data also showed some gaps and inconsistencies on the various emissions of interest for this study. As such, some assumptions are made to develop representative emission control data.

To develop representative emission control data, the sources and amounts of VOC emissions are shown in Table 4.8. Based on NCASI emission data for southern OSB manufacturing, a total of almost 8 lb/MSF of VOC are reported. Of this amount, 84 percent of the VOC emissions are produced during the flake drying process. Also, the hazardous air pollutants (HAP) as classified by NCASI (1999) make up approximately 16 percent of the total VOCs. Table 4.8 lists the top five HAP compounds in terms of overall mass detected. Only one mill reported enough emission details on the specific makeup of VOC compounds. While this particular mill only used wet ESPs for their flake dryer emissions, the reported emissions should be comparable. Average removal rates for individual VOCs are reported to be less than 10 percent for wet ESPs (NCASI, 1999). As can be seen in Table 4.8, reported total HAP and total VOC emissions are 43 percent higher and 35 percent lower than NCASI data, respectively. NCASI (1999) reports greater HAP emissions and lower VOC emissions with hardwood flake drying. Since the reporting mill processed a higher percentage of hardwood timber than those surveyed by NCASI, the reported emissions are consistent with NCASI emissions.

Table 4.8. Analysis of VOC drying and press emissions per MSF 3/8-inch basis OSB

Emission	Emissions Contribution NCASI Database (lb/MSF)			Reported
	Flake Dryer	OSB Press	Total	Emissions (lb/MSF) [2/]
Total HAP[1/]	**0.8989**	**0.4150**	**1.3139**	**1.8850**
Acetaldehyde	0.1660	0.0100	0.1760	0.3100
Acrolein	0.0940	0.0000	0.0940	0.1100
Formaldehyde	0.3655	0.0420	0.4075	0.2660
Methanol	0.1546	0.3500	0.5046	0.9390
Phenol	0.0230	0.0130	0.0360	0.0297
Other VOC	**5.8401**	**0.8230**	**6.6631**	NA
Total VOC	**6.7390**	**1.2380**	**7.9769**	**5.1600**
THC [3/]	**8.8768**	**1.3500**	**10.227**	NA

1/ Hazardous Air Pollutants (HAP) as defined by NCASI, 1999. Highest top 5 HAP individual compounds by volume listed.
2/ Survey results from Mill #4 only.
3/ Total Hydrocarbons (THC) is a total organic VOC analysis measured based on the molecular weight of Carbon (NCASI 1999). THC is measured using different methods than HAPs and VOCs.

THC emissions listed in Table 4.8 are used by NCASI to report the total detected organic hydrocarbons. HAPs and other VOCs listed in Table 4.8 are actually a sum of specifically targeted VOC compounds. While, the listed HAP and other VOC emissions are a subset of THC, they are not directly comparable since different measurement methods are used. Also, THC is measured on a molecular weight of carbon (12) basis. Recall that THC is used by the Drying/Screening and Blending/Pressing processes as an internal mass input to the Emission Control module. There are two reasons for using THC in this manner. First, THC is a representative mass measure of the relative VOC emissions that are produced in drying and press operations. Second, since THC is measured based on the molecular weight of carbon, the mass of CO_2 can easily be estimated given the effectiveness of different VOC reduction methods.

Table 4.9 presents an analysis of the effectiveness of the different emission control technologies used by the surveyed mills. NCASI (1999) data indicates that RTO removal efficiency for total VOC emissions were highly effective, ranging from 80 to 97 percent. Wet ESPs were judged to be ineffective for removing VOC compounds from rotary OSB flake dryers. Comparing NCASI data in Tables 4.8 and 4.9, the difference of the effectiveness of VOC removal efficiencies is clear between RTO and wet ESP. The NCASI data is contrasted with a comparison of the different technologies used by the four mills in this study. No obvious trends are observed between the various methods used at the four mills except that Mill 3 reports the lowest emissions and falls within the range found in the NCASI data for RTO methods. However, Mill 1, which also uses RTO removal methods, produces quite high VOCs compared to NCASI RTO treated emissions data. Given the weighted average of the total VOCs reported by the 4 mills of 2.86 lb (see Table 3.2) and assuming the total untreated VOCs generated by OSB mill operations is 7.98 lb (see Table 4.8), the overall VOC removal efficiency representative of southeast OSB is 64 percent.

Table 4.9. Analysis of different emissions treated with different control methods

Emission	**Reported Emissions (lb/MSF)**				**NCASI Emissions (lb/MSF)** [2/]	
	Mill 1 (wet ESP + RTO)	**Mill 2 (wet ESP)**	**Mill 3 (RTO)**	**Mill 4 (wet ESP)**	**RTO**	**Wet ESP**
Total HAP [1/]	NA	NA	NA	**1.8850**	**0.0582**	**1.3797**
Acetaldehyde	NA	NA	NA	0.3100	0.0102	0.2168
Acrolein	NA	NA	NA	0.1100	0.0000	0.1564
Formaldehyde	NA	NA	NA	0.2660	0.0205	0.4101
Methanol	NA	NA	NA	0.9390	0.0046	0.4874
Phenol	0.0000	0.0333	0.0334	0.0297	0.0567	0.0152
Total VOC	**2.9600**	**2.7400**	**0.5980**	**5.1600**	**0.0782**	**8.8639**
Particulates	**0.7700**	**0.7150**	**0.5240**	**0.9290**	NA	NA
CO	**3.4900**	**3.2400**	**0.7150**	**5.8500**	**0.3782**	NA
THC [3/]	NA	NA	NA	NA	**0.4203**	**10.068**

1/ Hazardous Air Pollutants (HAP) as defined by NCASI, 1999. Highest top 5 HAP individual compounds listed.

2/ Average NCASI (1999) VOC emissions measured after RTO and wet ESP treatments

3/ Total Hydrocarbons (THC) is a total organic VOC analysis measured based on the molecular weight of Carbon (NCASI 1999).

Table 4.10 lists all inputs and outputs for the Emission Control process. For each MSF of OSB produced, 10.2 lbs of hydrocarbons are processed (8.9 lb from the Drying and Screening process and 1.4 lb from the Blending and Pressing process) to reduce VOC emissions. Based on all mills surveyed, 2.9 lb of VOCs are released to the air. Processing VOCs is energy intensive, requiring 11.7 kWh of electricity and 428 ft3 of natural gas to reduce organic compounds into carbon dioxide and water. Emission control adds approximately 24 lb of non-fossil CO_2 to the air by burning these organic compounds. Based on the survey data from Mill 4, the methonol, formaldehyde, Acetaldehyde, and Acrolein components of VOC are listed in Table 4.10. These are the most significant individual compounds, in terms of mass, that contribute to "hazardous" VOC emissions as classified by NCASI (1999).

It is important to note that Table 4.10 represents average emission control technology for 1999 OSB production (except for HAPs). This average technology includes a mixture of different methods employed such as RTO and wet ESP. Since the HAPs reported are from one mill without RTO emission control, these values are not representative of the average technology used.

Table 4.10. Inputs and outputs for the Emission Control sub-unit process.

Material/Fuel Input	Units	per/MSF 3/8-in basis
Hydrocarbons (THC)[1/]	lb	10.2
Natural Gas	ft^3	428.3
Input from Nature		
Water	lb	70.9
Energy Input		
SE Electricity	kWh	11.7
Emission to Air		
CO_2 (non fossil) [2/]	lb	2.40E+01
Particulates[3/]	lb	6.15E-01
VOC (total) [3/]	lb	2.18E+00
Methanol [4/]	lb	3.97E-01
Formaldehyde [4/]	lb	1.12E-01
Acetaldehyde [4/]	lb	1.31E-01
Acrolein [4/]	lb	4.71E-02
Phenol [3/]	lb	2.42E-02
MDI [3/]	lb	1.60E-04

1/ Total carbon weight of VOC emissions from OSB flake dryers and press. Based on NCASI (1999) data.

2/ Weight of input THC multiplied by 3.67 (ratio of CO_2 and Carbon molecular weights) and assuming 64% VOC removal efficiency.

3/ Weighted average of surveyed mills

4/ Survey results from Mill #4 only (weighted based on the ratio of average survey VOC and Mill #4 VOC) and are not representative of average emission control technology

4.8 SIMAPRO MODEL

The Life-Cycle-Inventory (LCI) data for each of the six functional sub-unit process explained above was used to develop a SimaPro Model. Two were developed for Southeast OSB. The first model considers a cradle-to-gate LCI, which includes both on-site impacts and all off-site impacts including the production and delivery of resin, wax, electricity, fuel, etc. The second model considers a gate-to-gate LCI, which includes only on-site impacts for OSB production. The specific SimaPro models process tree and detailed inputs and outputs for each of the developed material processes are given in Appendix 2. Note that in either model, impacts related to forestry processes and to the transport of logs, resins, wax, and other ancillary materials are not modeled in SimaPro. Future use of the SimaPro LCI results must note the absence of these impacts.

5.0 SOUTHEASTERN OSB ANALYSIS

Using the southeastern database described in the previous sections, decision makers can make consistent and systematic comparisons of options for improving the overall life cycle performance of OSB processes and products. This section presents an analysis of OSB manufacturing in terms of wood utilization, energy utilization, and carbon cycle and utilizes the SimaPro database to conduct a life cycle inventory (LCI) on the impact of OSB manufacturing.

5.1 WOOD UTILIZATION

One MSF of southeastern OSB (3/8-inch basis) requires 1701 lb (OD basis) of wood raw material input (1567 lb wood and 135 lb bark). As shown earlier in Table 3.3, 1203 lbs of this input ends in final OSB product giving a total wood recovery of 71 percent. The remaining 29 percent of this input ends as wood residue for fuel (25 percent), wood residues sold as co-products (4 percent), and wood waste sent to the landfill (less than 0.01 percent). Figure 5.1 shows wood utilization at the various stages of OSB manufacturing. Note that the only wood waste ending in the landfill was during the Finishing sub-unit process and was reported to be very small (0.1 lb per MSF OSB). Also note that no residues or wastes were reported during the Blending and Pressing sub-unit process. Typically, any trimmed or dumped OSB mat material generated during this process is recycled back into the system to produce products or co-products.

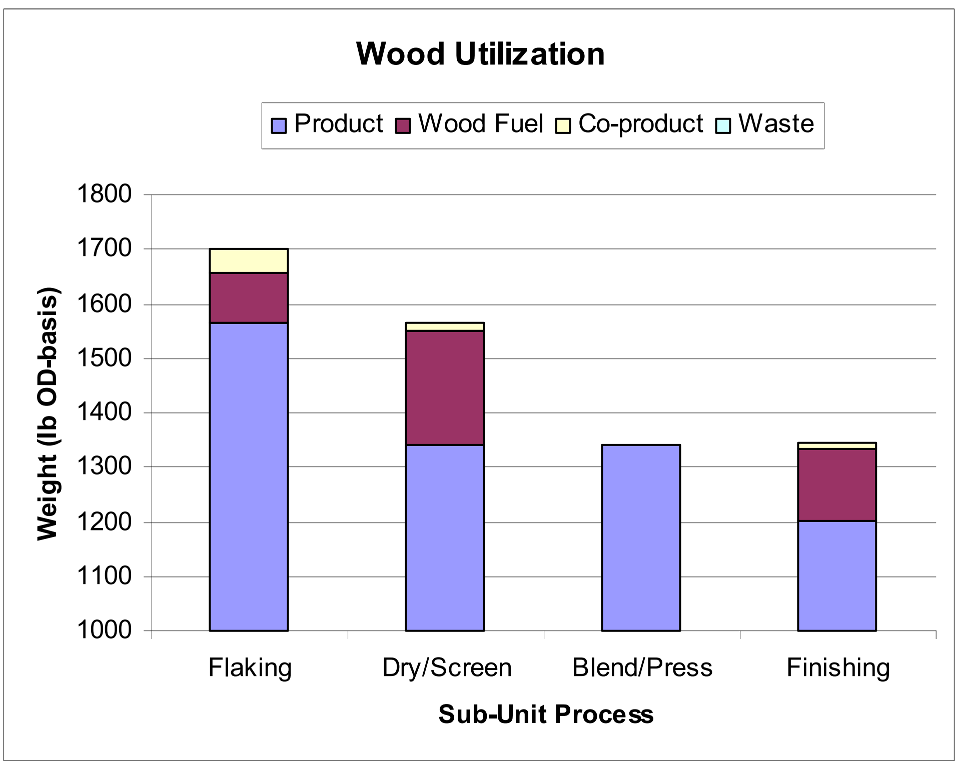

Figure 5.1. Wood utilization to produce 1 MSF OSB during the various process stages.

5.2 ENERGY UTILIZATION

One MSF of southeastern OSB (3/8-inch basis) requires 2.7 million BTU heat, 85 percent of which generated from combustion of wood residues and the remaining generated from fossil fuels. 182 kWh (620,000 BTU equivalent) per MSF of electricity is required for processing OSB. Figure 5.2 shows the relative requirements of energy from different sources for each of the sub-unit processes. Very small amounts of fossil fuels are needed to support processing activities such as log handling and forklifts. The highest use of fossil fuel (natural gas) is required to reduce VOC emissions in the Emission Control process.

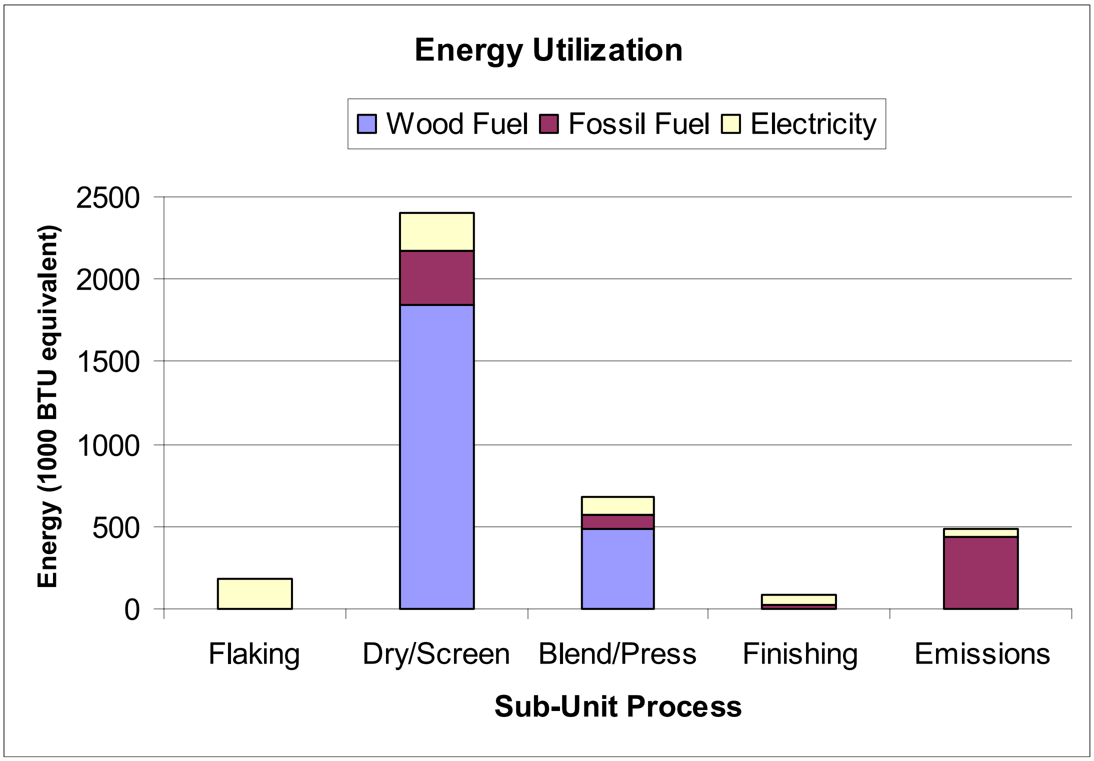

Figure 5.2. Comparison of energy requirements to produce 1 MSF OSB for the various process stages.

5.3 CARBON CYCLE

Approximately 930 lbs of carbon are involved in the manufacture of one MSF OSB (3/8-in basis). Table 5.1 lists the carbon content assumptions used for the various material inputs involved in the manufacture of OSB. Based on data from Skog and Nicholson (1998), the weighted average carbon content used for southeastern roundwood input (75 percent softwood and 25 percent hardwood) was 51.3 percent. The carbon cycle study in this section excludes forestry processes and transportation of logs and other ancillary materials to the manufacturing site.

Table 5.1. Percent carbon content (mass basis) assumptions for raw material and fuel inputs used in the calculation of carbon involved in OSB manufacturing.

INPUTS	
Raw Material	**Percent Carbon**
Round wood	51.3
Phenol Formaldehyde	6.0
MDI Resin	72.0
Wax	85.2
Fuel Input	
Natural gas	75.0
Liquid Propane gas	81.8
Diesel	85.0
Fuel Oil	85.0
Gasoline	86.0

A carbon transfer from raw material inputs to OSB product and emission outputs is shown in Figures 5.3 and 5.4. For each MSF of OSB, 873 lb (94.4 percent of total carbon input) of carbon from wood raw material is utilized. Other carbon input is utilized in the form of resins/wax (25 lb) and fuels (27 lb). One MSF of OSB holds 640 lb (69 percent of total carbon input) carbon. A very small percentage of carbon (4 percent) is held in the form of co-products (e.g. mulch and other wood residues). The remainder of carbon is released back to nature in the form of non-fossil CO_2 (24 percent), fossil CO_2 (3 percent), VOCs and other emissions (0.4 percent).

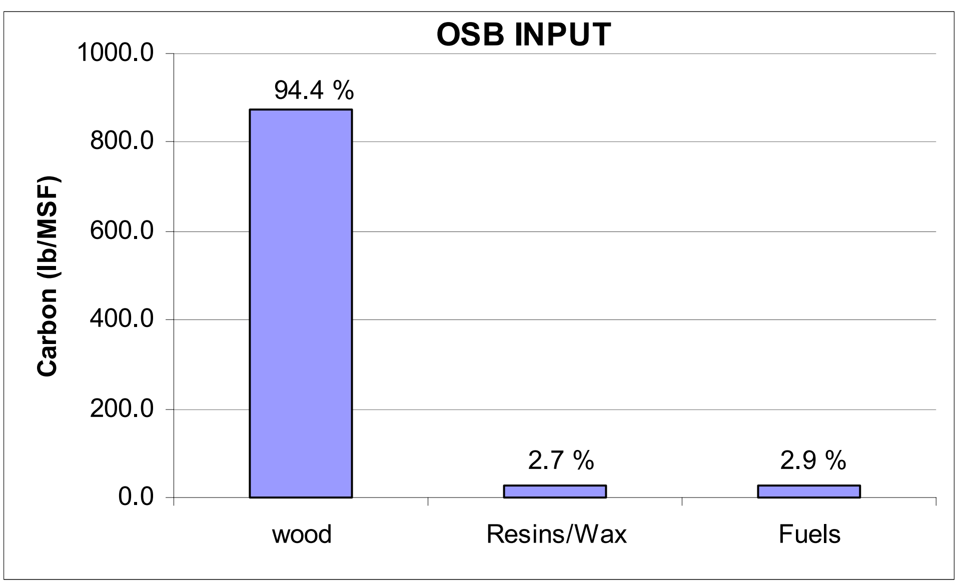

Figure 5.3. Carbon from raw material input sources for 1 MSF OSB.

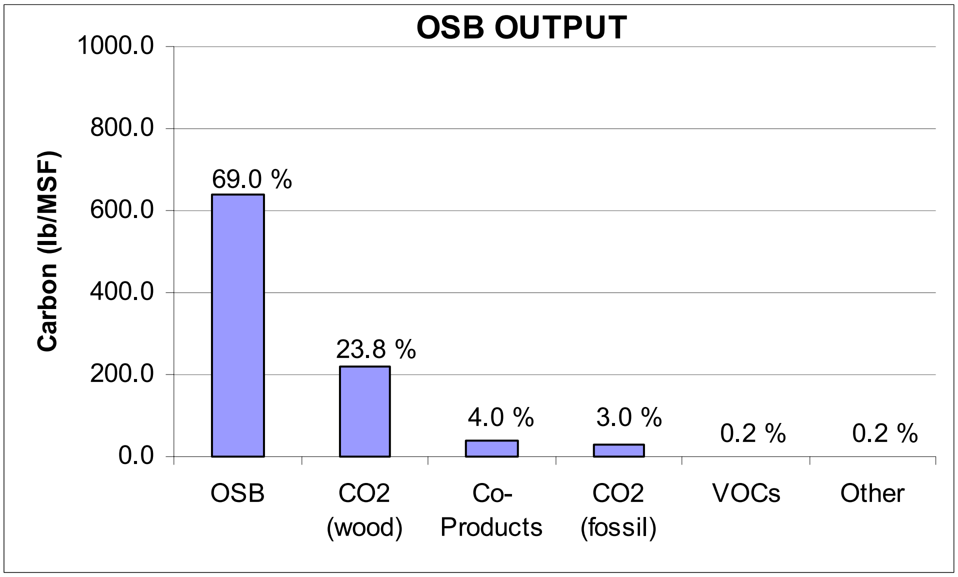

Figure 5.4. Carbon output destinations for 1 MSF OSB.

5.4 EMISSIONS TO AIR, WATER, AND LAND

Two Life Cycle Inventory (LCI) scenarios are used to study emissions generated to air, water and land for Southeast OSB. The first scenario considers a cradle-to-gate LCI, which includes both on-site impacts and all off-site impacts including the production and delivery of resin, wax, electricity, fuel, etc. The second scenario considers a gate-to-gate LCI, which includes only on-site impacts for OSB production. A complete listing of emissions to air, water, and land is itemized in Appendix 3 for both of these LCI scenarios. Compared to water and land emissions, air emissions influenced by OSB manufacturing contribute much larger impacts and is further discussed in the following paragraphs.

Figure 5.5 graphically shows the significant[1] air emissions generated to produce one MSF of southeastern OSB. All CO_2 from biomass and a majority of CO (78 percent), VOC (58 percent) and particulates (62 percent) are generated on site. All methane, and a majority of SO_x (99 percent), CO_2 from fossil (81 percent), and NO_x (78 percent) air emissions are generated off-site (e.g. for the production and delivery of fuels, resin, wax, and electricity). Sixty-one (61) percent of total CO_2 (generated both on- and off-site) is from biomass. However when considering the amount of CO_2 generated on-site only, the percentage from biomass is much higher at 89 percent.

[1] Significant emissions are those emissions considered essential to all industry evaluations according to CORRIM protocol (CORRIM, 2001).

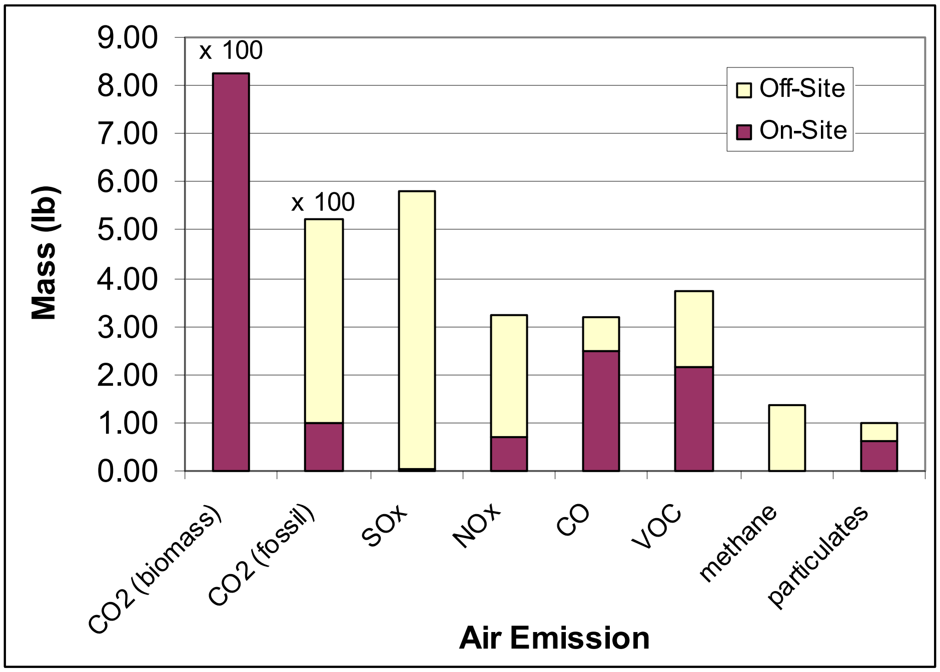

Figure 5.5. **Off-site and on-site air emissions generated in the production of 1 MSF OSB. CO_2 weight is obtained by multiplying the shown mass by 100.**

Figures 5.6 (both on- and off-site emissions considered) and 5.7 (only on-site emissions considered) show the contribution to air emissions for each OSB sub-unit process. In Figure 5.6, significant portions of these emissions are a result of either the drying, pressing, or emission control processes. The flaking and finishing processes contribute very little to air emissions. Because Figure 5.6 considers off-site impacts, all processes have some contribution to these air emissions either directly or indirectly. Figure 5.7 shows only the direct impacts due to only on-site contributions to air emissions. As expected, the emission control process has the greatest impact on a majority of emissions released to air.

Burdens, a method of assigning allocations of emissions to products, were assigned to OSB products and by-products on a mass basis (See SimaPro model in Appendix 2). Emissions for the various products reported for OSB in Appendix 3 had varying burdens depending at which sub-unit process an emission occurred. For example, if an emission would arise only at the OSB finishing stage, then a higher burden of 99.3% would be assigned to finished OSB since very little co-product is produced during this stage. However, if an emission would occur for each of the OSB processing stages, this burden for finished OSB could be less because more mass of co-products are produced in earlier stages of OSB manufacturing. Burdens for air emissions for finished OSB ranged from 97.8 percent to 99.3 percent with an average burden of about 98.5 percent. The remaining burdens are assigned to the co-products of bark mulch, screening fines, and sawdust.

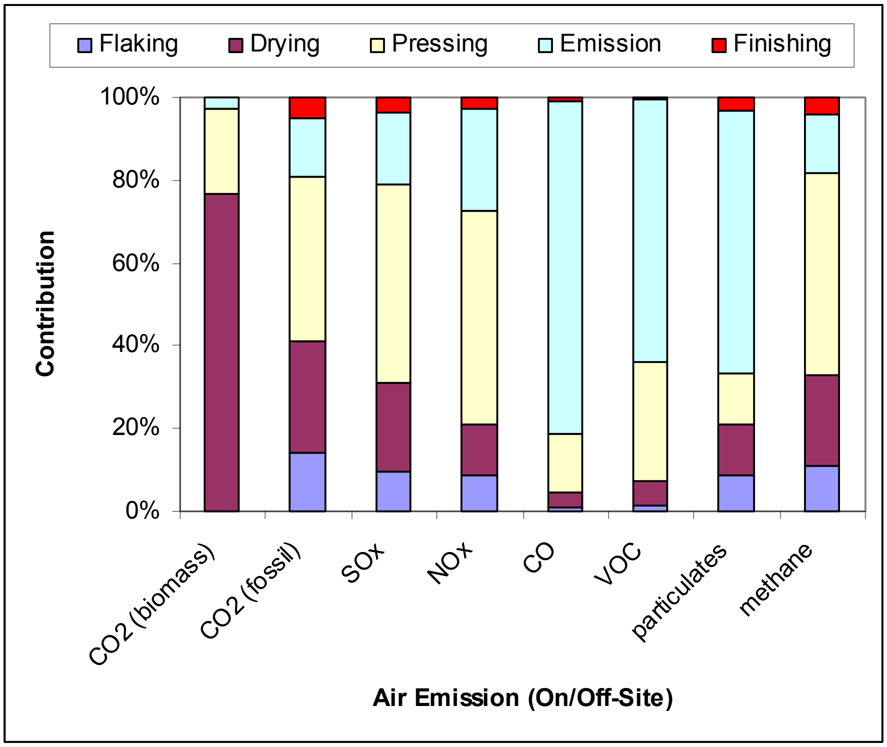

Figure 5.6. **OSB product sub-unit process stages and their contribution to air emissions (both on- and off-site emissions considered).**

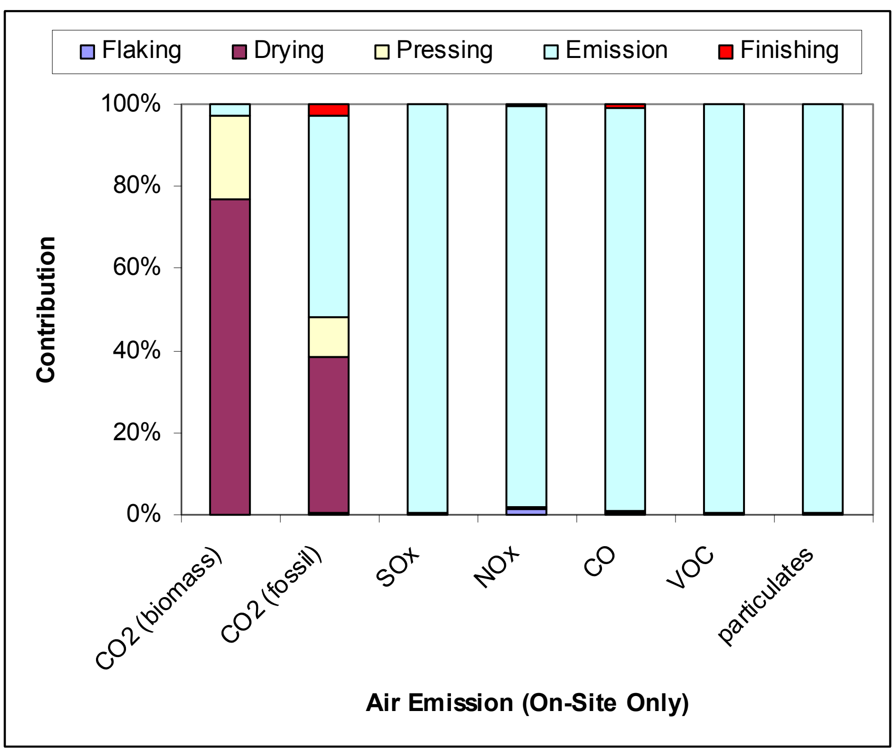

Figure 5.7. **OSB product sub-unit process stages and their contribution to air emissions (only on-site emissions considered).**

5.5 AIR EMISSION SENSITIVITY ANALYSIS

As mentioned in Section 1.0, southeast OSB production employs various emission control measures in response to the 1990 Clean Air Act Amendments. Emission control measures employed during the survey period used wet or dry Electro-Static Precipitators (ESP) and Regenerative Thermal Oxidizers (RTO) to reduce particulate, CO, and VOC emissions. The above analysis with SimaPro used the weighted average emission values of all mills, which represents the average emission control technology utilized by the survey mill respondents. From the surveyed mills, two mills utilized only ESP emission control technology and two mills utilized RTO technology. NCASI (1999) reports that RTO is the most effective emission control technology, removing 80 to 94 percent of total VOC emissions. However, to remove VOCs, RTO systems require significant amounts of heat energy to completely combust volatile organic compounds. As such, a sensitivity analysis is used to study the relative trade-offs in utilizing such an energy intensive RTO emission control technology.

Table 5.2 shows the emission values used earlier (weighted average) and those values used in the sensitivity analysis to compare mills that utilize RTO technology to those mills that do not. While ESP technology is effective at removing some VOCs (NCASI 1999), it is assumed that any VOC removal is due to other means instead of combustion and, therefore, no additional CO_2 is generated from ESP emission control technology. Due to the lack of detailed electricity data for RTO and ESP systems, the sensitivity analysis assumes that there is no change in electricity consumption for the different comparisons.

Table 5.2. SimaPro emission values used in the sensitivity analysis.

Substance	Unit	Weighted Average[4/]	RTO	ESP
Nat. Gas[1/]	ft^3	4.283E+02	8.73E+02	0.00E+00
CO_2 (biomass)[2/]	lb	2.400E+01	3.26E+01	0.00E+00
CO_2 (fossil)[3/]	lb	5.054E+01	1.03E+02	0.00E+00
CO[1/]	lb	2.490E+00	4.20E-01	4.55E+00
SO_2[1/]	lb	5.890E-02	4.40E-02	7.13E-02
NO_x[1/]	lb	6.970E-01	9.07E-01	4.98E-01
Particulates[1/]	lb	6.150E-01	4.08E-01	8.22E-01
VOC[1/]	lb	2.180E+00	4.07E-01	3.95E+00

1/ RTO and ESP values from mill survey data

2/ CO_2 (biomass) from VOC combustion where VOC removal efficiency is assumed to be 87% (NCASI 1999) for RTO and 0% for ESP

3/ CO_2 (fossil) from combustion of natural gas (FAL 1998).

4/ The weighted average values are the base values used in the earlier LCI scenarios.

Figure 5.8 compares the LCI results (both on-site and off-site) for air emissions for each of the emission control technologies. Results show particulate, CO, and VOC emissions, respectively, to be 34.1, 75.8, and 57.9 percent less for RTO than for ESP. While RTO technology is effective at removing some key emissions, it comes at a cost in terms of energy (natural gas), and an overall increase in other greenhouse gases released to air such as CO_2, SO_2, NO_x, and methane. Figure 5.8 shows CO_2 (biomass), CO_2 (fossil), SO_x, NO_x, and methane emissions, respectively, to be 4.0, 24.7, 36, 16.7, and 26.2 percent greater, for RTO technology than for ESP technology. As expected, the average emission technology during the time of the survey falls in between the LCI results for RTO and ESP. As emission control measures are employed in the OSB manufacturing industry to respond the 1990 Clean Air Act Amendments, all state-of-the-art emission control will ultimately utilize RTO technology. As such, future impacts for airborne emissions for southeast OSB may likely be closer to the RTO emission results shown in Figure 5.8.

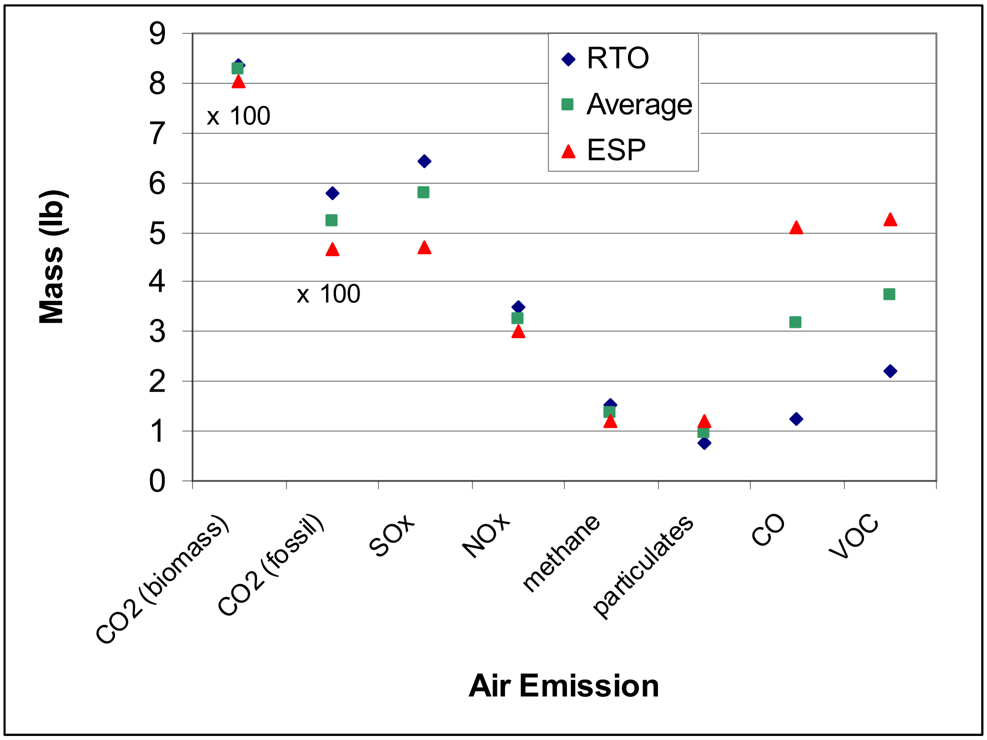

Figure 5.8. **Off-site and on-site air emissions generated in the production of 1 MSF OSB for RTO, Average, and ESP emission control technologies. CO_2 weight is obtained by multiplying the shown mass by 100.**

6.0 SUMMARY

Studies to conduct a Life Cycle Inventory for southeast OSB manufacturing were conducted by surveying four OSB manufacturing plans in the Southeast. The survey responses represented 1999 production data and represented approximately 18 percent of OSB production in the survey region.

One MSF of southeastern OSB (3/8-inch basis) requires 1701 lb (OD basis) of wood raw material input (1567 lb wood and 135 lb bark). 1203 lbs of this input ends in final OSB product giving a total wood recovery of 71 percent. The remaining 29 percent of this input ends as wood residue for fuel (25 percent), wood residues sold as co-products (4 percent), and wood waste sent to the landfill (less than 0.01 percent).

One MSF of southeastern OSB (3/8-inch basis) requires 2.7 million BTU heat, 85 percent of which generated from combustion of wood residues and the remaining generated from fossil fuels. 182 kWh per MSF of electricity is required for processing OSB. Very small amounts of fossil fuels are needed to support processing activities such as log handling and forklifts. The highest use of fossil fuel (natural gas) is used to reduce VOC emissions in the Emission Control process.

Considering the carbon cycle for on-site OSB production, each MSF of OSB requires 873 lb of carbon from wood raw material (94.4 percent of total carbon input). Other carbon input is utilized in the form of resins/wax (25 lb) and fuels (27 lb). One MSF of OSB holds 640 lb (69 percent of total carbon input) carbon. A very small percentage of carbon (4 percent) is held in the form of co-products (e.g. mulch and other wood residues). The remainder of carbon is released back to nature in the form of non-fossil CO_2 (24 percent), fossil CO_2 (3 percent), VOCs and other emissions (0.4 percent).

All CO_2 from biomass and a majority of CO (78 percent), VOC (58 percent) and particulates (62 percent) are generated on site. All methane, and a majority of SO_x (99 percent), CO_2 from fossil (81 percent), and NO_x (78 percent) air emissions are generated off-site for the production and delivery of fuels, resin, wax, and electricity. Sixty-one (61) percent of total CO_2 (generated both on- and off-site) is from biomass. However when considering the amount of CO_2 generated on-site only, the percentage from biomass is much higher at 89 percent.

The significant contributions to air emissions are a result of either the drying, pressing, or emission control processes. The flaking and finishing processes contribute very little to air emissions. When considering both on- and off-site impacts, all processes have some contribution to these air emissions either directly or indirectly. However considering the direct impacts from only on-site generated air emissions, the emission control process has the greatest impact on a majority of emissions released to air.

Burdens, a method of assigning allocations of emissions to products, were assigned to OSB products and by-products on a mass basis. Burdens for air emissions for finished OSB ranged from 97.8 percent to 99.3 percent depending on which OSB material sub-processes generated the emission. The average burden for finished OSB was about 98.5 percent with remaining burdens assigned to the co-products of bark mulch, screening fines, and sawdust.

Sensitivity studies showed that while the latest emission control technologies employing Regenerative Thermal Oxidizers (RTO) is very effective at removing particulate, CO, and VOC emissions, it comes at a cost in terms of additional energy input, and an overall increase in other greenhouse gases released to air such as fossil CO_2, SO_2, NO_x, and methane. The LCI data developed for OSB manufacturing can provide LCI information to weigh the advantages and disadvantages of different emission control technologies from an overall life cycle perspective.

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APPENDIX 1: SURVEY INSTRUMENT FOR SOUTHEAST OSB MANUFACTURING

ORIENTED STRAND BOARD PROCESSES DESCRIPTION

Virginia Tech is participating in an industry-supported study to establish environmental, energy, and economic performance measures for renewable building materials. The ultimate goal of these measures is to help the wood products industry systematically identify attractive management and technology alternatives that can improve environmental performance in a cost-effective manner. This information is critical for establishing a scientifically sound database that will maintain wood products as one of the most sustainable and "environmentally friendly" building resources. Please take a few minutes to answer the following questions. Thank you for your time and valuable input.

1. **How many years has this facility manufactured OSB?**

_______________ Years

2. **What volume of OSB was produced at your facility in 1999?** (Single facility number, not the corporate or multiple facility number.)

_______________ Production volume (include standard units of measure, e.g. million sq. ft. on a 3/8 inch basis)

3. **How many hours or days per year is your plant scheduled to be in production?**

_______________ Hours/Year or Days/Year (circle units that apply)

4. **How many production shifts do you operate per day?**

_______________ Shifts/Day

5. **What is the total number of employees at your plant?** (Single facility number, not corporate or multiple facility number.)

_______________ Number of employees

6. **What is your average annual log volume consumption?**

_______________ Log volume (include standard units of measure, e.g. tons)

7. **What species mix do you typically maintain in your log supply?**

_______________ % Soft hardwoods

_______________ % Hard hardwoods

_______________ % Pine and other softwoods

Total = 100%

8. **What size logs do you accept?**

_______________ Minimum log diameter (inches)

_______________ Maximum log diameter (inches)

_______________ Minimum log length (feet)

_______________ Maximum log length (feet)

9. **What transportation methods are used to bring in your log supply?**

		% of Total
☐	Truck	________ %
☐	Rail	________ %
☐	Other _________________	________ %

		Total = 100%

10. List the equipment manufacturer and model year of your major processing equipment (include all manufacturers if multiple units are used; include model number if known)**.**

Equipment	Manufacturer(s) and model (or type)	Model Year
Debarker		
Flaker		
Dryer		
Primary dryer heat		
Backup dryer heat		
Emission control		
Screen		
Blender		
Mat Former		
Hot-press		
Heat energy system		

11. What is the average radius or distance to your log supply?

___________ Miles

12. What is the maximum radius or distance to your log supply?

___________ Miles

13. What mobile transport equipment does your mill use for moving materials?

		#of vehicles
☐	Crane	_______
☐	Log stacker/Log loader	_______
☐	Forklift	_______
☐	Truck	_______
☐	Other_______________	_______

14. What transportation methods are used for shipping your board product?

		% of Total
☐	Truck	_______ %
☐	Rail	_______ %
☐	Other_______________	_______ %

		Total = 100%

15. What is the average radius or distance you ship your board product?

______________ Miles

16. What is the maximum radius or distance you ship your board product?

______________ Miles

17. What is your overall plant conversion efficiency or material recovery (include all products sold)**?**

______________ Efficiency (include standard units of measure)

How do you calculate efficiency (e.g. ft^2 / ft^3 of log)?

____

18. Estimate the percentage of your board product that goes into the following structural products.

______________ % Structural panels

______________ % I-joists and box beams

______________ % Manufactured housing

______________ % Other (including shop panels)

19. What energy and fuel sources do you use to supply all your energy needs (processing, drying, material handling, transport, etc., check all that apply)?

- ☐ Electricity from power company
- ☐ Electricity co-generation
- ☐ Wood residues
- ☐ Natural gas
- ☐ Propane
- ☐ Fuel oil
- ☐ Diesel
- ☐ Gasoline
- ☐ Other ____________

20. What emission control measures are used at your plant? (check all that apply)

- ☐ Regenerative thermal oxidizer (RTO)
- ☐ Electrostatic precipitator (ESP)
- ☐ Regenerative catalytic oxidizer (RCO)
- ☐ Other______________________________

21. Annual production and plant capacity. Please provide units of measurement.

Product	1999 Production	1999 Plant Capacity
Example: OSB	*300 MMSF/yr (3/8" basis)*	*320 MMSF/yr (3/8" basis)*

22. 1999 Plant operating hours. Please provide units of measurement.

Product	hr/day	day/wk	wk/yr
Example: OSB	*16*	*5*	*50*

OSB Manufacturing Inputs. Please provide units of measurement.

23. What volume of roundwood is consumed per thousand square feet of board product produced?

____

24. What is the average annual electricity consumption for the entire plant, (office and manufacturing)?

____

25. Is electricity generated at this facility? Yes / No If yes, what volume of wood waste (hogfuel) is used to generate electrical power? ____

____

26. Formulation and usage of resins, waxes, additives, and other compounds. Please provide units of measurement.

Resin/adhesive or additive type	Range in percent solids by weight (% Non-volatile)	Density (lb/gal)	Total annual usage	Range in Hazardous Air Pollutants content and percent by weight
Example: liquid phenol formaldehyde resin	***35-40%***	***10.8 lb/gal***	***951,282 gal/yr***	***0.1-0.3% free formaldehyde 1-1.5% phenol***
Liquid phenol formaldehyde resin				
Powdered phenol formaldehyde Resin				
PMDI				
Waxes				
Additives				
Other (Please Specify)				

OSB Manufacturing Outputs (Total)

27. Best scientific estimate of 1999 Air Emission data from all known sources. Please provide units of measurement.

Output	Quantity
Example: CO2	***10 lb/hour***
CO2	
CO	
CH4	
Nox	
SO2	
VOC	
Particulates	
Phenol	
MDI	
Other (Please Specify)	

28. Solid emission data from all known sources. Only include items that are <u>not</u> used or consumed at this location. <u>Please provide units of measurement</u>.

Output	Quantity	End use/method of disposal
Example: Bark / wood waste	***5000 tons/year***	***Sent to landscape co.***
Bark / wood waste		
Boiler ash / fly ash		
Recovered particulates from pollution abatement equipment		
Other (Please Specify)		

29. Power generation. <u>Please provide units of measurement</u>.

	Primary System	Secondary System	Example
Type of Energy System This Plant Operates: (Check All That Apply)			
Boiler			
Thermal Fluid (Hot Oil)			
Other (Please Specify)			
Manufacturer and Model #			
What Machines Does This System Provide Thermal Energy For? (Please List All)			
1999 Fuel or Power Consumption Used For Power Generation: (If Any)			
Electricity			
Wood Waste			
Fuel Oil			
Natural Gas			
Other (Please Specify)			

30. Oriented strand board flake dryers. **Please provide units of measurement.**

	Dryer No. 1	***Dryer No. 2***	***Dryer No. 3***	***Dryer No. 4***	***Dryer No. 5***
1999 Dryer Throughput: (Dry Weight Basis)					
1999 Wood Species Mix Coming Into The Log Yard:					
% Softwood					
% Soft Hardwood					
% Hard Hardwood					
1999 Dryer Fuel Consumption:					
Wood Waste (Hog Fuel)					
Natural Gas					
Fuel Oil					
Heating Method: (Check all That Apply)					
Direct-Fired					
Indirect-Fired (Employs a Heat Exchanger)					
Dryer Type: (Check all That Apply)					
Single Pass					
Double Pass					
Triple Pass					
Conveyor					

Flake Dryers Continued	***Dryer No. 1***	***Dryer No. 2***	***Dryer No. 3***	***Dryer No. 4***	***Dryer No. 5***
Average Moisture Content Range:					
Dryer Inlet					
Dryer Outlet					
Operating Temperature Range:					
Dryer Inlet					
Dryer Outlet					
Exhaust Gas Flow Rate at Dryer Outlet: *Example: 45000 acfm at 190℉*					
Are Dryer Exhaust Gases Recycled in Any Manner? *Yes / No*					
If Yes, Please Fill in The Following:					
% Recycled to Blend Chamber					
% Routed to Combustion Unit					
% Exhausted to Atmosphere					
% Exhausted to Control Device					
% Other (Please Specify)					
Type of Air Pollution Control Device or Method					

31. Presses. <u>Please provide units of measurement.</u>

	Press No.1	***Press No.2***	***Press No. 3***
General			
1999 Press Throughput			
Operating Temperature Range			
Heating Method: (Check All That Apply)			
Thermal Fluid (Hot Oil)			
Steam			
Radio Frequency			
Other (Please Specify)			
Type of Air Pollution Control Device or Method			
How is The Press Ventilated: (Check All That Apply)			
Roof Fans			
Other (Please Specify)			
Does This Mill Use an Enclosure Around the Press? Yes / No			
If Yes, Where Are the Exhaust Gases Routed?			
Continous Press			
Width of Mat Entering Press			
Batch Process			
# of Openings			
Size of Mat Pressed, (Length x Width)			

32. All Air Pollution Control (APC) devices. List all devices separately. <u>Please provide units of measurement.</u>

	APC No.1	*APC No. 2*	*APC No. 3*	*APC No. 4*	*APC No. 5*	*APC No. 6*
Type of Control Device; (RTO, RCO, Dry ESP, Wet ESP, etc.)						
Manufacturer and Model #						
APC Device Collects Exhaust From What Equipment?						
Month and Year of Installation						
Exhaust Gas Flow Rate at Control Device Inlet: *Example: 100 acfm at 100 °F*						
Average Pressure Drop Through Device: *Example: 4 inches of water*						
Amount of Solid Material Collected That is Not Reused at On-Site						
End Use / Method of Disposal For Material Not Reused On-Site						
Annual Water Consumption						
1999 Annual Fuel Consumption						
Type of Fuel						
1999 Annual Power Consumption						

If The Number of APC Devices Exceeds 6, More Space is Provided on The Following Page.

(31. Continued) All Air Pollution Control (APC) devices. List all devices separately. <u>Please provide units of measurement.</u>

	APC No.7	*APC No. 8*	*APC No. 9*	*APC No. 10*	*APC No. 11*	*APC No. 12*
Type of Control Device, (RTO, RCO, Dry ESP, Wet ESP, etc.)						
Manufacturer and Model #						
APC Device Collects Exhaust From What Equipment?						
Month and Year of Installation						
Exhaust Gas Flow Rate at Control Device Inlet: *Example: 100 acfm at 100 °F*						
Average Pressure Drop Through Device: *Example: 4 inches of water*						
Amount of Solid Material Collected That is Not Reused at On-Site						
End Use / Method of Disposal For Material Not Reused On-Site						
Annual Water Consumption						
1999 Annual Fuel Consumption						
Type of Fuel						
1999 Annual Power Consumption						

APPENDIX 2: SIMAPRO MODEL

A2.1 CRADLE-TO-GATE SIMAPRO MODEL

The Cradle to Gate SimaPro model considers both on-site and off-site impacts for the manufacturing of each MSF 3/8-inch basis OSB. Figure A2.1 shows the process tree for the model. The primary sub-processes developed in this module for Southeast OSB include, OSB after Pressing, OSB Flakes (dry), OSB Flakes (green), Emission Control, Electricity SE, and OSB Direct Fired Heat. All other sub-processes include the production and delivery of raw materials, fuels, and energy required to support OSB production. All of these supporting sub-processes are already included in the SimaPro database (e.g. Athena and Franklin databases). Tables A2.1 through A2.8 list the SimaPro material processes developed for Southeast OSB. Forestry processes and the transportation of logs, resin, wax, and other ancillary materials related to OSB processing is excluded from the life cycle inventory in this model.

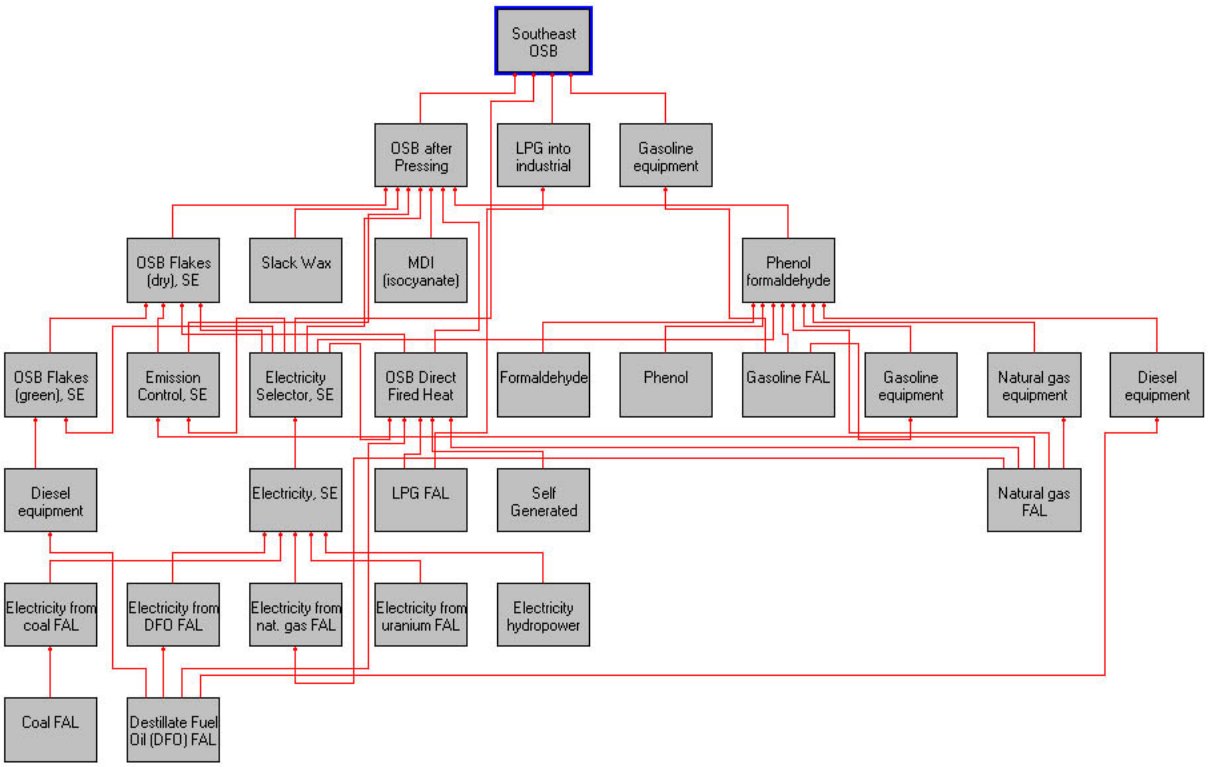

Figure A2.1. Process tree for both on-site and off-site impacts for Southeast OSB manufacturing. On-site impacts are depicted by the following six processes: Southeast OSB, OSB after Pressing, OSB Flakes (dry), OSB Flakes (green), Emission Control, and OSB Direct Fired Heat processes.

Table A2.1. SimaPro data for the total emissions resource requirements for the flaking of 1567 lb of OSB flakes and bark mulch co-product - Log Handling/Flaking process.

Products			
OSB Flakes (green), SE	1567 lb	97.2 %	Green flakes (50% MC wet basis) are reported as oven dry weight
Bark (co-product), SE	44.7 lb	2.8 %	Co-product sold, also reported as oven dry weight
Resources			
SE Logs [1/]	49.5 cuft		Wet basis including both wood and bark. SE OSB survey participants used 75% pine and 25% hardwood.
Materials/fuels			
Diesel equipment (gal)	0.0189 gal		Diesel loaders for log handling.
Electricity/heat			
Electricity Selector, SE	51.23 kWh		SE survey region uses 49% coal, 25% uranium, 9.7% natural gas, 3.7% DFO, and 3.4% hydro from FAL.

1/ Forestry processes and transportation of logs to the mill not considered in SimaPro model

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.2. SimaPro data for the total emissions resource requirements for the drying of 1567 lb of green OSB flakes from 100% MC to 5% MC (od basis) and screening out fine materials - Drying and Screening process.

Products			
OSB Flakes (dry), SE	1343 lb	98.7 %	5% MC od basis, reported ovendry weight
Screen Fines (co-product), SE	17.3 lb	1.3 %	5% MC od basis, reported ovendry weight
Materials/fuels			
OSB Flakes (green), SE	1567 lb		Green flakes (reported oven dry weight) from Log Handling/Flaking Process
Emission Control, SE [1/]	8.9 lb		87% of VOCs generated by flake drying and subsequently handled by emission control.
Electricity/heat			
Electricity Selector, SE	59.2 kWh		
OSB Direct Fired Heat	2.17E6 BTU		79.2 % of heat from OSB SE direct fired systems used

1/ While Emission control is not directly providing electricity or heat to the process, it is a required input from the technosphere.

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.3. SimaPro data for the total emissions resource requirements for the forming and pressing of OSB panel product - Blending and Pressing process.

Products			
OSB after Pressing	1413 lb	100 %	5% MC od basis, reported oven dry weight
Materials/fuels			
OSB Flakes (dry), SE	1343 lb		Dry flakes from Drying and Screening process
Slack Wax [1/]	19.29 lb		Slack Wax usage
MDI (isocyanate) [1/]	8.164 lb		MDI usage
Phenol formaldehyde Resin [1/]	42.45 lb		PF resin usage
Electricity/heat			
Electricity Selector, SE	28.41 kWh		
OSB Direct Fired Heat	5.70E5 Btu		20.8 % of OSB generated heat used in pressing panel product
Emission Control, SE [2/]	1.35 lb		13% VOCs generated by OSB press to be processed by emission control

1/ Transportation of Resins and Wax to Mill not considered in SimaPro model.

2/ While Emission control is not directly providing electricity or heat to the process, it is a required input from the technosphere.

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.4. SimaPro data for the total emissions resource requirements and emissions for the production of 1 MSF (3/8 inch basis) of OSB panel product - Finishing process.

Products			
Southeast OSB	1263 lb	99.25 %	1 MSF 3/8-inch basis finished OSB product, reported oven dry weight
Dust/Scrap (co-product)	9.5 lb	0.75 %	
Materials/fuels			
OSB after Pressing	1413 lb		
LPG into industrial boilers	0.195 gal*		LPG substitution for combustion emissions Propane for forklift
Gasoline equipment (gal)	0.0076 gal*		Gasoline used by OSB plant for general needs
Electricity/heat			
Electricity Selector, SE	17.64 kWh		
Solid emissions			
Wood	0.11 lb		

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.5. SimaPro data for the total emissions fuel and energy requirements and emissions for the generation of 2.74 million BTU of heat energy for OSB production needs - Heat Generation process

Products		
OSB Direct Fired Heat	2.74E6 BTU	100 % CORRIM Boiler Selector
Materials/fuels		
LPG FAL	0.5123 gal*	Amount of LPG used for heat. FAL database.
Destillate Fuel Oil (DFO) FAL	0.1856 gal*	Amount of DFO used for heat. FAL database
Natural gas FAL	319.2 cuft	Amount of Natural Gas used for heat. FAL database
Self Generated Wood Fuel, SE	778.3 lb	Amount of self generated wood residue used for heat.
Electricity/heat		
Electricity Selector, SE	13.54 kWh	
Emissions to air		
CO2 (biomass)	817 lb	CO2 (biomass) from wood residue combustion. 1050 lb CO2 generated per 1000 lb of wood residue combusted. Survey found 778 lb wood residue combusted per MSF. 1050*778/1000 = 817 lb CO2 per MSF. (Assume efficiency of 66.7% in terms of BTU generated per 1000 lb of wood at 50% MC)
CO2 (fossil)	7 lb	CO2 (fossil) from LPG combustion. 13600 * .5123/1000 = 7.0 lb.
CO2 (fossil)	4.2 lb	CO2 (fossil) from DFO combustion. 22400 * .1856/1000 = 4.2 lb.
CO2 (fossil)	37.7 lb	CO2 (fossil) from Natural Gas combustion. 118 * 319.2/1000 = 37.7 lb.
Solid emissions		
slags/ash	4.22 lb	Boiler Ash reported in survey

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.6. SimaPro data for the total emissions impacts for the emission control for 10.2 lb of VOCs generated in OSB production - Emission Control process

Products			
Emission Control, SE	10.2 lb	100 %	10.2 lb (THC carbon) of VOC emissions are processed per MBF OSB
Resources			
water (well, for processing)	70.9 lb		
Materials/fuels			
Natural gas FAL	428.3 cuft	Natural gas used for RTO systems	
Electricity/heat			
Electricity Selector, SE	11.69 kWh		
Emissions to air			
CO_2 (biomass)	24 lb	Combustion of removed VOCs using SE 64% average VOC removal efficiency (Secondary data based on NCASI, 1999, data)	
CO_2 (fossil)	50.54 lb	CO2 (fossil) from Natural Gas combustion in RTOs. 118 * 428.3/1000 = 50.54	
CO	2.49 lb	Survey data (weighted average)	
SO_2	0.0589 lb	Survey data (weighted average)	
NO_x	0.697 lb	Survey data (weighted average)	
particulates (PM10)	0.615 lb	Survey data (weighted average)	
VOC	2.18 lb	Survey data (weighted average)	
Methanol	0.397 lb	Mill #4 Survey (VOC adjusted weighted average)	
Acetaldehyde	0.131 lb	Mill #4 Survey (VOC adjusted weighted average)	
Formaldehyde	0.112 lb	Mill #4 Survey (VOC adjusted weighted average)	
Acrolein	0.0471 lb	Mill #4 Survey (VOC adjusted weighted average)	
Phenol	0.0242 lb	Survey data (weighted average)	
MDI (isocyanate)	0.00016 lb	Survey data (weighted average)	

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.7. Electricity Selector for Southeast OSB. By selecting Electricity, SE, all impacts for generating electricity are included in the total emissions analysis.

Products			
Electricity Selector, SE	1 kWh	100 %	CORRIM Elect. Selector
Resources			
Electricity from Athena	0 kWh	Athena – no burdens	
Electricity/heat			
Electricity, SE	1 kWh	CORRIM – burdens	

Table A2.8. SimaPro data southeast electricity impact for utilization of 1 kWh of electricity.

Products			
Electricity, SE	1 kWh	100 %	CORRIM Energy
Resources			
Electricity from other sources	0.085 kWh		Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity/heat			
Electricity from coal FAL	0.492 kWh		DOE information Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from DFO FAL	0.037 kWh		Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from nat. gas FAL	0.096 kWh		Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity from uranium FAL	0.256 kWh		Source: Energy Information Administration/Electric Power Annual 2000 Volume I
Electricity hydropower FAL	0.034 kWh		Source: Energy Information Administration/Electric Power Annual 2000 Volume I

Notes: Average Southeastern USA, US Department of Energy (2000).

A2.2 GATE TO GATE SIMAPRO MODEL

The Gate to Gate SimaPro model considers only on-site impacts for the manufacturing of each MSF 3/8-inch basis OSB. All off-site impacts are treated as resources from nature. Figure A2.2 shows the process tree for the Gate-to-Gate model. The primary sub-processes developed in this module for Southeast OSB include, OSB after Pressing, OSB Flakes (dry), OSB Flakes (green), Emission Control, and OSB Direct Fired Heat. Tables A2.9 through A2.14 list the SimaPro processes developed to model these primary sub-processes. Other on-site sub-processes include the impact of electricity and mechanical equipment on-site such as Electricity Selector, LPG equipment, gasoline equipment, and diesel equipment. These other sub-processes are a modification of existing FAL processes where fuel is treated as a resource from nature. These mechanical sub-processes are shown in Tables A2.15 through A2.18.

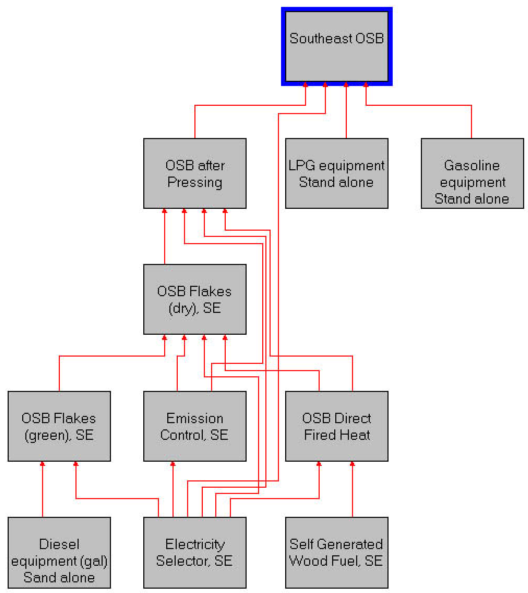

Figure A2.2. Process tree for only on-site impacts for Southeast OSB manufacturing.

Table A2.9. SimaPro data for the gate-to-gate resource requirements for the flaking of 1567 lb of OSB flakes and bark mulch co-product - Log Handling/Flaking process.

Products			
OSB Flakes (green), SE	1567 lb	97.2 %	Green flakes (50% MC wet basis) are reported as oven dry weight
Bark (co-product), SE	44.7 lb	2.8 %	Co-product sold, also reported as oven dry weight
Resources			
SE Logs	49.5 cuft	Wet basis including both wood and bark. SE OSB survey participants used 75% pine and 25% hardwood.	
Materials/fuels			
Diesel equipment (gal) Stand alone	0.0189 gal	Diesel loaders for log handling.	
Electricity/heat			
Electricity Selector, SE	51.23 kWh	SE survey region uses 49% coal, 25% uranium, 9.7% natural gas, 3.7% DFO, and 3.4% hydro from FAL.	

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.10. SimaPro data for the gate-to-gate resource requirements for the drying of 1567 lb of green OSB flakes from 100% MC to 5% MC (od basis) and screening out fine materials - Drying and Screening process.

Products			
OSB Flakes (dry), SE	1343 lb	98.7 %	5% MC od basis, reported ovendry weight
Screen Fines (co-product), SE	17.3 lb	1.3 %	5% MC od basis, reported ovendry weight
Materials/fuels			
OSB Flakes (green), SE	1567 lb	Green flakes (reported oven dry weight) from Log Handling/Flaking Process	
Emission Control, SE	8.9 lb	87% of VOCs generated by flake drying and subsequently handled by emission control.	
Electricity/heat			
Electricity Selector, SE	59.2 kWh		
OSB Direct Fired Heat	2.17E6 BTU	79.2 % of heat from OSB SE direct fired systems used	

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.11. SimaPro data for the gate-to-gate resource requirements for the forming and pressing of OSB panel product - Blending and Pressing process.

Products			
OSB after Pressing	1413 lb	100 %	5% MC od basis, reported oven dry weight
Resources			
Slack Wax Stand alone	19.29 lb	Slack Wax usage	
MDI Stand alone	8.164 lb	MDI usage	
Phenol formaldehyde Resin	42.45 lb	PF resin usage	
Materials/fuels			
OSB Flakes (dry), SE	1343 lb	Dry flakes from Drying and Screening process	
Electricity/heat			
Electricity Selector, SE	28.41 kWh		
OSB Direct Fired Heat	5.70E5 BTU	20.8 % of OSB generated heat used in pressing panel product	
Emission Control, SE	1.35 lb	13% VOCs generated by OSB press to be processed by emission control	

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.12. SimaPro data for the gate-to-gate resource requirements and emissions for the production of 1 MSF (3/8 inch basis) of OSB panel product - Finishing process.

Products			
Southeast OSB	1263 lb	99.25 %	1 MSF 3/8-inch basis finished OSB product, reported oven dry weight
Dust/Scrap (co-product)	9.5 lb	0.75 %	
Materials/fuels			
OSB after Pressing	1413 lb		
LPG equipment Stand Alone	0.195 gal*	LPG for forklift	
Gasoline equipment (gal) Stand alone	0.0076 gal*	Gasoline used by OSB plant for general needs	
Electricity/heat			
Electricity Selector, SE	17.64 kWh		
Solid emissions			
Wood	0.11 lb		

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.13. SimaPro data for the gate-to-gate fuel and energy requirements and emissions for the generation of 2.74 million BTU of heat energy for OSB production needs - Heat Generation process.

Products		
OSB Direct Fired Heat	2.74E6 BTU	100 % CORRIM Boiler Selector
Resources		
LPG Stand alone	0.5123 gal*	Amount of LPG used for heat. FAL database.
Destillate Fuel Oil (DFO) Stand alone	0.1856 gal*	Amount of DFO used for heat. FAL database
Natural gas Stand alone	319.2 cuft	Amount of Natural Gas used for heat. FAL database
Materials/fuels		
Self Generated Wood Fuel, SE	778.3 lb	Amount of self generated wood residue used for heat.
Electricity/heat		
Electricity Selector, SE	13.54 kWh	
Emissions to air		
CO_2 (biomass)	817 lb	CO2 (biomass) from wood residue combustion. 1050 lb CO2 generated per 1000 lb of wood residue combusted. Survey found 778 lb wood residue combusted per MSF. 1050*778/1000 = 817 lb CO2 per MSF. (Assume efficiency of 66.7% in terms of BTU generated per 1000 lb of wood at 50% MC)
CO_2 (fossil)	7 lb	CO2 (fossil) from LPG combustion. 13600 * .5123/1000 = 7.0 lb.
CO_2 (fossil)	4.2 lb	CO2 (fossil) from DFO combustion. 22400 * .1856/1000 = 4.2 lb.
CO_2 (fossil)	37.7 lb	CO2 (fossil) from Natural Gas combustion. 118 * 319.2/1000 = 37.7 lb.
Solid emissions		
Slags/ash	4.22 lb	Boiler Ash reported in survey

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.14. SimaPro data for the gate-to-gate impacts for the emission control for 10.2 lb of VOCs generated in OSB production - Emission Control process.

Products			
Emission Control, SE	10.2 lb	100 %	10.2 lb (THC carbon) of VOC emissions are processed per MBF OSB
Resources			
water (well, for processing)	70.9 lb		
Natural gas Stand alone	428.3 cuft	Natural gas used for RTO systems	
Electricity/heat			
Electricity Selector, SE	11.69 kWh		
Emissions to air			
CO_2 (biomass)	24 lb	Combustion of removed VOCs using SE 64% average VOC removal efficiency (Secondary data based on NCASI, 1999, data)	
CO_2 (fossil)	50.54 lb	CO2 (fossil) from Natural Gas combustion in RTOs. 118 * 428.3/1000 = 50.54	
CO	2.49 lb	Survey data (weighted average)	
SO_2	0.0589 lb	Survey data (weighted average)	
NO_x	0.697 lb	Survey data (weighted average)	
particulates (PM10)	0.615 lb	Survey data (weighted average)	
VOC	2.18 lb	Survey data (weighted average)	
methanol	0.397 lb	Mill #4 Survey (VOC adjusted weighted average)	
acetaldehyde	0.131 lb	Mill #4 Survey (VOC adjusted weighted average)	
formaldehyde	0.112 lb	Mill #4 Survey (VOC adjusted weighted average)	
acrolein	0.0471 lb	Mill #4 Survey (VOC adjusted weighted average)	
phenol	0.0242 lb	Survey data (weighted average)	
MDI (isocyanate)	0.00016 lb	Survey data (weighted average)	

Notes: Average Southeastern USA technology, 1999 survey data.

Table A2.15. Electricity Selector for Southeast OSB. By selecting Electricity from Athena, a resource from nature, impacts for generating electricity are excluded in the Gate-to-Gate analysis.

Products			
Electricity Selector, SE	1 kWh	100 %	CORRIM Elect. Selector
Resources			
Electricity from Athena	1 kWh	Athena – no burdens	
Electricity/heat			
Electricity, SE	0 kWh	CORRIM – burdens	

Table A2.16. Data for the gate-to-gate resource requirements and emissions for the combustion of 1000 gallons of diesel fuel (138.7 Million BTU) in industrial equipment (on-site impact only).

Products			
Diesel equipment (gal) Sand alone	1000 gal*	100 %	
Resources			
Destillate Fuel Oil (DFO) Stand alone	1000 gal*		
Emissions to air			
particulates	33.5 lb		
NO_x	469 lb		
non methane VOC	37.5 lb		
SO_x	31.2 lb		
CO	102 lb		
CO_2 (fossil)	23005 lb		
formaldehyde	7 lb		

Notes: Average USA technology, late 1990's survey data.
1000 US liquid gallons= 3785.4 liters

Table A2.17. Data for the gate-to-gate resource requirements and emissions for the combustion of 1000 gallons of Liquid Propane (95.5 Million BTU or 146193 MJ) in industrial equipment (on-site impact only).

Products			
LPG equipment Stand alone	1000 gal*	100 %	(1000 US liquid gallons= 3785.4 liters)
Resources			
LPG stand alone	1000 gal*		
Emissions to air			
particulates	0.6 lb		
NO_x	20 lb		
non methane VOC	0.26 lb		
SO_x	0.017 lb		
CO	3.4 lb		
CO_2 (fossil)	13600 lb		
Pb	0.28 lb		

Notes: Average USA technology, late 1990's survey data.
1000 US liquid gallons= 3785.4 liters

Table A2.18. Data for the gate-to-gate resource requirements and emissions for the combustion of 1000 gallons of gasoline (125 Million BTU) in industrial equipment (on-site impact only).

Products			
Gasoline equipment Stand alone	1000 gal*	100 %	(1000 US liquid gallons= 3785.4 liters)
Resources			
Gasoline Stand alone	1000 gal*		
Emissions to air			
particulates	6.47 lb		
NO_x	102 lb		
non methane VOC	132 lb		
SO_x	5.31 lb		
CO	3940 lb		
CO_2 (fossil)	12844 lb		
formaldehyde	4.36 lb		

Notes: Average USA technology, late 1990's survey data.
1000 US liquid gallons= 3785.4 liters

APPENDIX 3: SIMAPRO EMISSIONS TO AIR, WATER, AND LAND

Table A3.1. Emissions to air for cradle-to-gate (on-site and off-site impact) for the production of 1 MSF (3/8 inch basis) of Southeast OSB panel product.

				--- Coproduct Allocation ---			
			SE	Dust		Screen	
Substance	Com	Unit	OSB	Scrap	Bark	Fines	Total
CO2 (biomass)	Air	lb	8.26E+02	6.24E+00	0.00E+00	8.68E+00	8.41E+02
CO2 (fossil)	Air	lb	4.96E+02	3.75E+00	2.07E+00	3.65E+00	5.05E+02
CO2	Air	lb	2.55E+01	1.93E-01	0.00E+00	0.00E+00	2.57E+01
SOx	Air	lb	5.56E+00	4.20E-02	1.55E-02	3.44E-02	5.65E+00
NOx	Air	lb	3.24E+00	2.45E-02	7.88E-03	1.80E-02	3.29E+00
CO	Air	lb	3.18E+00	2.41E-02	9.18E-04	3.12E-02	3.24E+00
VOC	Air	lb	2.15E+00	1.62E-02	0.00E+00	2.47E-02	2.19E+00
non methane VOC	Air	lb	1.59E+00	1.20E-02	1.25E-03	6.02E-03	1.61E+00
methane	Air	lb	1.38E+00	1.04E-02	4.31E-03	8.19E-03	1.40E+00
particulates (PM10)	Air	lb	6.70E-01	5.06E-03	4.45E-04	7.50E-03	6.83E-01
methanol	Air	lb	3.91E-01	2.96E-03	0.00E+00	4.50E-03	3.98E-01
particulates (unspecified)	Air	lb	2.90E-01	2.19E-03	1.99E-03	2.38E-03	2.97E-01
SO2	Air	lb	2.37E-01	1.79E-03	0.00E+00	6.68E-04	2.39E-01
CO2 (non-fossil)	Air	lb	1.96E-01	1.48E-03	8.66E-04	1.28E-03	2.00E-01
formaldehyde	Air	lb	1.67E-01	1.27E-03	3.80E-06	1.27E-03	1.70E-01
acetaldehyde	Air	lb	1.29E-01	9.76E-04	0.00E+00	1.49E-03	1.31E-01
phenol	Air	lb	9.72E-02	7.34E-04	6.89E-08	2.75E-04	9.82E-02
acrolein	Air	lb	4.64E-02	3.51E-04	2.84E-08	5.34E-04	4.73E-02
dust	Air	lb	3.84E-02	2.90E-04	0.00E+00	0.00E+00	3.87E-02
CxHy	Air	lb	3.23E-02	2.44E-04	0.00E+00	0.00E+00	3.25E-02
particulates	Air	lb	2.37E-02	1.79E-04	1.77E-05	1.33E-05	2.39E-02
HCl	Air	lb	2.16E-02	1.63E-04	1.42E-04	1.68E-04	2.21E-02
H2	Air	lb	1.46E-02	1.10E-04	0.00E+00	0.00E+00	1.47E-02
n-nitrodimethylamine	Air	lb	9.27E-03	7.00E-05	6.00E-09	7.10E-09	9.34E-03
organic substances	Air	lb	4.46E-03	3.37E-05	8.13E-06	1.81E-05	4.52E-03
aldehydes	Air	lb	3.63E-03	2.74E-05	6.25E-06	1.25E-05	3.68E-03
HF	Air	lb	2.90E-03	2.19E-05	1.97E-05	2.33E-05	2.96E-03
N2O	Air	lb	2.38E-03	1.80E-05	1.64E-05	1.94E-05	2.43E-03
ammonia	Air	lb	1.26E-03	9.48E-06	5.09E-06	6.27E-06	1.28E-03
CxHy aromatic	Air	lb	5.88E-04	4.44E-06	0.00E+00	0.00E+00	5.92E-04
Cumene	Air	lb	2.51E-04	1.89E-06	0.00E+00	0.00E+00	2.53E-04
ash	Air	lb	1.77E-04	1.34E-06	0.00E+00	0.00E+00	1.78E-04
MDI (isocyanate)	Air	lb	1.58E-04	1.19E-06	0.00E+00	1.81E-06	1.61E-04
kerosene	Air	lb	1.39E-04	1.05E-06	9.67E-07	1.14E-06	1.42E-04
metals	Air	lb	1.34E-04	1.01E-06	3.51E-07	5.16E-07	1.36E-04
H2SO4	Air	lb	1.29E-04	9.75E-07	0.00E+00	0.00E+00	1.30E-04
Ni	Air	lb	1.18E-04	8.91E-07	7.32E-07	9.01E-07	1.21E-04
CxHy chloro	Air	lb	9.85E-05	7.44E-07	0.00E+00	0.00E+00	9.92E-05
Pb	Air	lb	7.20E-05	5.44E-07	1.03E-07	1.24E-07	7.28E-05
benzene	Air	lb	3.34E-05	2.52E-07	2.63E-08	3.15E-08	3.37E-05
Se	Air	lb	3.14E-05	2.37E-07	2.16E-07	2.56E-07	3.21E-05
Mn	Air	lb	3.07E-05	2.32E-07	2.08E-07	2.49E-07	3.14E-05
CFC (soft)	Air	lb	2.35E-05	1.77E-07	0.00E+00	0.00E+00	2.37E-05
dichloromethane	Air	lb	1.64E-05	1.24E-07	1.13E-07	1.34E-07	1.68E-05
Cr	Air	lb	1.60E-05	1.21E-07	1.07E-07	1.28E-07	1.64E-05
Cl2	Air	lb	1.41E-05	1.06E-07	1.24E-08	2.38E-08	1.42E-05
As	Air	lb	1.32E-05	9.95E-08	8.51E-08	1.02E-07	1.35E-05
Hg	Air	lb	1.20E-05	9.07E-08	5.94E-08	7.07E-08	1.22E-05
cobalt	Air	lb	1.02E-05	7.68E-08	6.50E-08	7.91E-08	1.04E-05
tetrachloromethane	Air	lb	9.30E-06	7.03E-08	6.34E-08	7.56E-08	9.51E-06
Cd	Air	lb	8.62E-06	6.51E-08	5.24E-08	6.44E-08	8.80E-06
H2S	Air	lb	4.19E-06	3.17E-08	0.00E+00	0.00E+00	4.22E-06
Sb	Air	lb	4.06E-06	3.07E-08	2.62E-08	3.18E-08	4.15E-06
tetrachloroethene	Air	lb	3.95E-06	2.98E-08	2.73E-08	3.23E-08	4.04E-06
trichloroethene	Air	lb	3.87E-06	2.93E-08	2.68E-08	3.17E-08	3.96E-06
Zn	Air	lb	1.41E-06	1.07E-08	0.00E+00	0.00E+00	1.42E-06
Be	Air	lb	1.27E-06	9.63E-09	8.61E-09	1.03E-08	1.30E-06
mercaptans	Air	lb	5.88E-07	4.44E-09	0.00E+00	0.00E+00	5.92E-07
Na	Air	lb	5.29E-07	4.00E-09	0.00E+00	0.00E+00	5.33E-07
naphthalene	Air	lb	3.29E-07	2.49E-09	1.72E-09	2.33E-09	3.36E-07
F2	Air	lb	2.23E-08	1.68E-10	0.00E+00	0.00E+00	2.25E-08
CS2	Air	lb	2.02E-09	1.53E-11	0.00E+00	0.00E+00	2.04E-09
1,2-dichloroethane	Air	lb	2.11E-10	1.59E-12	0.00E+00	0.00E+00	2.13E-10
vinyl chloride	Air	lb	2.10E-10	1.59E-12	0.00E+00	0.00E+00	2.12E-10
dioxin (TEQ)	Air	lb	2.17E-11	1.64E-13	1.50E-13	1.78E-13	2.22E-11
HCN	Air	lb	4.62E-34	3.49E-36	0.00E+00	0.00E+00	4.65E-34

Notes: Allocation of emissions is listed for both primary OSB product and OSB co-products.

Table A3.2. Emissions to air for gate-to-gate (on-site impact only) for the production of 1 MSF (3/8 inch basis) of Southeast OSB panel product.

				--- Coproduct Allocation ---			
			SE	Dust		Screen	
Substance	Com	Unit	OSB	Scrap	Bark	Fines	Total
CO2 (biomass)	Air	lb	8.26E+02	6.24E+00	0.00E+00	8.68E+00	8.41E+02
CO2 (fossil)	Air	lb	1.01E+02	7.63E-01	1.22E-02	1.08E+00	1.03E+02
CO	Air	lb	2.49E+00	1.88E-02	5.40E-05	2.83E-02	2.54E+00
VOC	Air	lb	2.15E+00	1.62E-02	0.00E+00	2.47E-02	2.19E+00
NOx	Air	lb	7.00E-01	5.29E-03	2.48E-04	8.02E-03	7.14E-01
particulates (PM10)	Air	lb	6.06E-01	4.58E-03	0.00E+00	6.98E-03	6.18E-01
methanol	Air	lb	3.91E-01	2.96E-03	0.00E+00	4.50E-03	3.98E-01
acetaldehyde	Air	lb	1.29E-01	9.76E-04	0.00E+00	1.49E-03	1.31E-01
formaldehyde	Air	lb	1.11E-01	8.36E-04	3.70E-06	1.27E-03	1.13E-01
SO2	Air	lb	5.81E-02	4.39E-04	0.00E+00	6.68E-04	5.92E-02
acrolein	Air	lb	4.64E-02	3.51E-04	0.00E+00	5.34E-04	4.73E-02
phenol	Air	lb	2.39E-02	1.80E-04	0.00E+00	2.75E-04	2.44E-02
non methane VOC	Air	lb	1.72E-03	1.30E-05	1.98E-05	8.96E-06	1.76E-03
particulates	Air	lb	7.68E-04	5.80E-06	1.77E-05	8.00E-06	8.00E-04
SOx	Air	lb	6.05E-04	4.57E-06	1.65E-05	7.45E-06	6.34E-04
MDI (isocyanate)	Air	lb	1.58E-04	1.19E-06	0.00E+00	1.81E-06	1.61E-04
Pb	Air	lb	5.42E-05	4.10E-07	0.00E+00	0.00E+00	5.46E-05

Notes: Allocation of emissions is listed for both primary OSB product and OSB co-products.

Table A3.3. Emissions to water for cradle-to-gate (on-site and off-site impact) for the production of 1 MSF (3/8 inch basis) of Southeast OSB panel product.

				--- Coproduct Allocation ---			
			SE	Dust		Screen	
Substance	Compa	Unit	OSB	Scrap	Bark	Fines	Total
dissolved solids	Water	lb	5.75E+00	4.35E-02	5.14E-03	3.10E-02	5.83E+00
Cl-	Water	lb	1.42E+00	1.07E-02	2.41E-04	1.43E-03	1.43E+00
Na	Water	lb	7.77E-01	5.87E-03	1.53E-06	1.81E-06	7.83E-01
sulphate	Water	lb	3.22E-01	2.43E-03	6.63E-04	1.68E-03	3.27E-01
suspended solids	Water	lb	2.18E-01	1.65E-03	1.31E-03	1.59E-03	2.23E-01
oil	Water	lb	1.02E-01	7.70E-04	9.12E-05	5.51E-04	1.03E-01
COD	Water	lb	8.80E-02	6.65E-04	7.40E-05	2.46E-04	8.90E-02
other organics	Water	lb	1.97E-02	1.49E-04	2.93E-05	1.07E-04	2.00E-02
Fe	Water	lb	1.62E-02	1.22E-04	1.12E-04	1.33E-04	1.66E-02
BOD	Water	lb	1.23E-02	9.33E-05	5.56E-06	2.92E-05	1.24E-02
B	Water	lb	1.11E-02	8.41E-05	7.63E-05	9.06E-05	1.14E-02
Mn	Water	lb	8.95E-03	6.76E-05	6.20E-05	7.34E-05	9.15E-03
K	Water	lb	2.99E-03	2.26E-05	0.00E+00	0.00E+00	3.01E-03
dissolved organics	Water	lb	2.98E-03	2.25E-05	0.00E+00	0.00E+00	3.00E-03
metallic ions	Water	lb	2.90E-03	2.19E-05	1.12E-06	2.29E-06	2.93E-03
H2SO4	Water	lb	2.78E-03	2.10E-05	1.91E-05	2.27E-05	2.84E-03
NH4+	Water	lb	1.66E-03	1.25E-05	0.00E+00	0.00E+00	1.67E-03
phosphate	Water	lb	1.39E-03	1.05E-05	9.53E-06	1.13E-05	1.42E-03
nitrate	Water	lb	1.30E-03	9.80E-06	3.64E-07	4.30E-07	1.31E-03
carbonate	Water	lb	1.19E-03	9.03E-06	0.00E+00	0.00E+00	1.20E-03
calcium ions	Water	lb	1.03E-03	7.80E-06	8.33E-07	9.84E-07	1.04E-03
Acid as H+	Water	lb	8.20E-04	6.19E-06	5.22E-11	1.07E-10	8.26E-04
fluoride ions	Water	lb	5.55E-04	4.19E-06	3.86E-06	4.56E-06	5.68E-04
N-tot	Water	lb	5.14E-04	3.88E-06	0.00E+00	0.00E+00	5.18E-04
Zn	Water	lb	5.06E-04	3.82E-06	8.07E-08	4.89E-07	5.10E-04
C0Hy	Water	lb	3.16E-04	2.39E-06	0.00E+00	0.00E+00	3.18E-04
detergent/oil	Water	lb	3.15E-04	2.38E-06	0.00E+00	0.00E+00	3.17E-04
NH3	Water	lb	3.04E-04	2.30E-06	1.62E-06	2.02E-06	3.10E-04
Cd	Water	lb	2.60E-04	1.96E-06	2.32E-07	1.42E-06	2.64E-04
Cr	Water	lb	2.60E-04	1.96E-06	2.32E-07	1.42E-06	2.64E-04
Mg	Water	lb	1.19E-04	8.98E-07	0.00E+00	0.00E+00	1.20E-04
Cl2	Water	lb	9.05E-05	6.84E-07	0.00E+00	0.00E+00	9.12E-05
P2O5	Water	lb	7.65E-05	5.78E-07	0.00E+00	0.00E+00	7.71E-05
Al	Water	lb	6.82E-05	5.15E-07	0.00E+00	0.00E+00	6.87E-05
Ni	Water	lb	6.18E-05	4.67E-07	0.00E+00	0.00E+00	6.23E-05
phenol	Water	lb	4.23E-05	3.20E-07	3.60E-09	7.39E-09	4.26E-05
C0Hy chloro	Water	lb	2.67E-05	2.02E-07	0.00E+00	0.00E+00	2.69E-05
chromate	Water	lb	6.62E-06	5.00E-08	4.09E-08	5.04E-08	6.76E-06
sulphide	Water	lb	5.65E-06	4.27E-08	0.00E+00	0.00E+00	5.69E-06
Hg	Water	lb	2.62E-06	1.98E-08	1.82E-11	1.11E-10	2.64E-06
Cu	Water	lb	1.31E-06	9.89E-09	0.00E+00	0.00E+00	1.32E-06
cyanide	Water	lb	4.99E-07	3.77E-09	3.47E-10	2.13E-09	5.05E-07
Ca	Water	lb	3.85E-07	2.91E-09	0.00E+00	2.95E-10	3.88E-07
Pb	Water	lb	8.92E-08	6.74E-10	9.32E-11	1.91E-10	9.02E-08
As	Water	lb	2.27E-09	1.71E-11	0.00E+00	0.00E+00	2.29E-09
vinyl chloride	Water	lb	1.76E-31	1.33E-33	0.00E+00	0.00E+00	1.77E-31

Notes: Allocation of emissions is listed for both primary OSB product and OSB co-products.

Table A3.4. Emissions to land for cradle-to-gate (on-site and off-site impact) for the production of 1 MSF (3/8 inch basis) of Southeast OSB panel product.

				--- Coproduct Allocation ---			
			SE	Dust		Screen	
Substance	Comp	Unit	OSB	Scrap	Bark	Fines	Total
solid waste	Land	lb	6.20E+01	4.68E-01	3.66E-01	4.79E-01	6.33E+01
slags/ash	Land	lb	4.31E+00	3.26E-02	0.00E+00	4.34E-02	4.39E+00
mineral waste	Land	lb	6.79E-01	5.13E-03	0.00E+00	0.00E+00	6.84E-01
wood	Land	lb	1.09E-01	8.25E-04	0.00E+00	0.00E+00	1.10E-01
industrial waste	Land	lb	8.52E-02	6.44E-04	0.00E+00	0.00E+00	8.58E-02
chemical waste (regulated)	Land	lb	3.78E-02	2.85E-04	0.00E+00	0.00E+00	3.81E-02
chemical waste (inert)	Land	lb	2.30E-02	1.74E-04	0.00E+00	0.00E+00	2.32E-02
waste in incineration	Land	lb	1.36E-02	1.03E-04	0.00E+00	0.00E+00	1.37E-02
special waste	Land	lb	5.36E-03	4.05E-05	0.00E+00	0.00E+00	5.40E-03
waste to recycling	Land	lb	2.97E-03	2.25E-05	0.00E+00	0.00E+00	2.99E-03
plastics packaging	Land	lb	1.32E-03	9.94E-06	0.00E+00	0.00E+00	1.33E-03
construction waste	Land	lb	6.35E-04	4.80E-06	0.00E+00	0.00E+00	6.40E-04
metal scrap	Land	lb	1.20E-04	9.05E-07	0.00E+00	0.00E+00	1.21E-04
unspecified	Land	lb	9.63E-05	7.28E-07	0.00E+00	0.00E+00	9.70E-05
wood packaging	Land	lb	6.43E-05	4.86E-07	0.00E+00	0.00E+00	6.48E-05
paper/board packaging	Land	lb	3.95E-05	2.98E-07	0.00E+00	0.00E+00	3.98E-05

Notes: Allocation of emissions is listed for both primary OSB product and OSB co-products.

Table A3.5. Emissions to land for gate-to-gate (on-site impact only) for the production of 1 MSF (3/8 inch basis) of Southeast OSB panel product.

				--- Coproduct Allocation ---			
			SE	Dust		Screen	
Substance	Comp	Unit	OSB	Scrap	Bark	Fines	Total
slags/ash	Solid	lb	4.15E+00	3.13E-02	0.00E+00	4.34E-02	4.22E+00
wood	Solid	lb	1.09E-01	8.25E-04	0.00E+00	0.00E+00	1.10E-01

Notes: Allocation of emissions is listed for both primary OSB product and OSB co-products.