

**Assessing the Availability of Wood Residues
And Residue Markets in Virginia**

by

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Masters thesis submitted to the Faculty of the Virginia Polytechnic Institute and State
University in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE

in

Wood Science and Forest Products

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March 22, 1998
Blacksburg, Virginia

Keywords: Wood Residues, Residue Markets, Primary and Secondary
Manufacturers, Residue Availability, Wood Residues in Landfills

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ABSTRACT

A statewide mail survey of primary and secondary wood product manufacturers was undertaken to quantify the production and consumption of wood residues in Virginia. Two hundred and sixty-six wood product manufacturers responded to the study and they provided information on the production, consumption, markets, income or disposal costs, and disposal methods of wood residues. Hardwood and pine sawmills produce approximately 66 percent of Virginia's wood residues. Virginia's wood product manufacturers produce three primary residues: chips, bark, and sawdust. These three residues comprised nearly 83 percent of Virginia's total residue production in 1996. Approximately 200,000 tons or 6 percent of Virginia's wood residues appear not to have adequate markets.

A second survey was directed to all municipal waste, construction and demolition, and "other" waste facilities in Virginia. The focus of this survey was to quantify the volume of solid wood residues received at the facilities. In addition, the study was conducted to ascertain tipping fees, did the landfill(s) actively market wood residues, were wood residues recycled, were wood residues restricted from being landfilled, and disposal methods for wood residues. Additionally, the survey was conducted to determine the type of waste facility operated, the quantity of all wastes directed to each landfill, and tipping fees.

Seventy-five respondents provided information on the total and solid wood waste volumes received at their respective facilities, recycling efforts, and disposal practices. Approximately 689,000 tons of solid wood, or 8 percent of all wastes, was received at Virginia's landfills in 1996. Virginia's waste facilities reported processing or recycling approximately 406,000 tons or 59 percent of the solid wood received in 1996.

DEDICATION

This study is dedicated to my parents, Delton and Mary Alderman, Sr., who have given their love and have supported my efforts through the most difficult of times. From childhood to this day, they have forged my appreciation and love for God, our Father, my values, and character. They sacrificed personal gain so that my sister and myself could have the opportunity to attain a better station in life. I will never be able to repay them for everything they have done for me. Thank you.

ACKNOWLEDGEMENTS

I would like to acknowledge the following people and agencies for their support of this project:

My sincere appreciation and thanks to **Dr. Robert L. Smith** for his efforts on my behalf, support, guidance, assistance, and encouragement during the past two years.

My sincere appreciation to **Dr. Geza Ifju**, who gave me the opportunity to continue my education.

My thanks to the **Southeastern Regional Biomass Energy Program of the Tennessee Valley Authority, Virginia Department of Mines, Minerals, and Energy, and the Powell River Project of Virginia Tech** for their financial support of this project. In addition, the Virginia Department of Forestry, the Virginia Forest Products Association, and industry executives who gave their consultation and advice on this project.

My thanks to **Drs. Fred Lamb and A.L. “Tom” Hammett, III** for serving on my advisory committee.

My thanks to **Joanne Buckner, Drs. Marshall S. White and Robert Bush, and Kuei-Ling Christina Hu** for their advice and help on this project.

My thanks to fellow graduate Marketing students: **Ren-Jye Marshall Shiau, Matt Bumgardner, Warren Spradlin, Curt Alt, Jim Chamberlain, Scott Bowe, Sarah Jensen, and Norchahaya Hashim** for their invaluable support, advice, friendship, and humor during the past two years.

My thanks to fellow graduate students: **Hal Mitchell, Brian Via, Chris Heine and Balazs Zombori** for their counsel, camaraderie, and humor during the past two years.

PREFACE

This thesis consists of four sections. Chapter One describes problems the research addressed, defines the objectives of the research, and reviews literature relevant to the topics of wood residue production and characterization, current markets and disposal methods for wood residues, and wood residue directed to landfills. The remainder of the thesis consists of three sections. Chapter Two discusses primary Virginia's wood product manufacturers production of wood products and secondary wood products manufacturers consumption of wood products, wood residues production, current markets, and disposal methods. Chapter Three discusses solid wood waste disposal in Virginia, recycling, and marketing of wood residues received. Chapter Four is a summary of the results and conclusions, and prescribes recommendations for the wood products industry and waste facilities

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CHAPTER 1

ASSESSING THE AVAILABILITY OF WOOD RESIDUES AND RESIDUE MARKETS IN VIRGINIA

Project Need

An understanding of the factors that affect the production and utilization of wood residues in Virginia is critical to maximizing the economic values of these renewable resources. For government officials and business leaders to take advantage of the market opportunities that exist for wood residues, information is needed on the availability, quantity and production rates, types of wood residues being produced, current markets, and current disposal practices of wood residues. Although wood residues produced by primary and secondary wood products industries are being utilized for pulp chips, composite production, and fuel for energy production, a significant amount of wood residues enters the waste stream, thus rendering these renewable natural resources underutilized.

With the number of landfills decreasing, landfill tipping fees increasing, and limitations being placed on the types of materials which can be landfilled, it is vital that wood residues currently directed to landfills be recycled. This will extend the life of our natural resources, enhance manufacturing profitability, and reduce the demand on the nation's landfills. Another factor for ascertaining the quantity and types of wood residues entering landfills is the discrepancy between wood residue estimates gathered by other organizations.

Virginia is not immune to the national trend of wood residues entering landfills and thus being underutilized. There is a lack of quantitative information on wood residues available in Virginia. This may preclude decision-makers the opportunity to make decisions on the availability and uses of these underutilized resources. Additionally, Virginia manufacturers have limited information on markets for wood residues. Several manufacturers indicated that a directory of wood residue users would be beneficial for their company.

Identification of the types and quantities of wood residues generated in Virginia and how they are being utilized is vital to addressing issues associated with the generation and management of wood residues. Once wood residues have been characterized, manufacturers that utilize wood residues can plan business strategies that incorporate utilization of wood residues and make policy decisions to ensure the utilization of wood residues.

Wood by-products entering Virginia landfills have the potential of serving as raw material for a variety of uses. There are many potential markets for wood residues; an example is the use of these materials for fuel for the production of power. There is a strong motivation by the power industry to develop alternatives to sulfur fuels due to increased environmental laws. While there is potential for

the market development of wood residues, questions remain on the quantities, characteristics, and the types of wood residues that are available in Virginia. How are wood residues managed and where are wood residues being utilized? Where are the potential markets for wood residues? To address these important questions, this study has the following mission:

Objectives

1. Estimate the quantity of wood residues generated in Virginia by primary and secondary wood products industries.
2. Evaluate the current markets for wood waste in Virginia.
3. Quantify the amount of wood material entering waste handling facilities that may be available for use by wood products manufacturers and others in the Virginia.

Literature Review

Introduction

Virginia's forest products industries contributed nearly \$10 billion dollars to the Commonwealth's economy, ranking it first in the state in terms of employment and fourth in value-added dollars generated (Foreman 1995). On an annual basis Virginia's forest products manufacturers contribute nearly \$5 billion dollars or 6 percent to the gross state product (Federal Reserve Bank of Richmond 1996). With a 1993-harvest value of \$416 million dollars, when transported to the first point of delivery, harvested timber ranked second behind poultry when comparing Virginia's agricultural crops. Primary forest product manufacturers contributed approximately \$1.3 billion dollars and secondary forest product manufacturers contributed approximately \$1.4 billion dollars to Virginia's economy in 1994 (Foreman 1995).

Virginia has approximately 15.4 million acres of commercial timberland or 61 percent of Virginia's total land area. Hardwood types constitute 78 percent of the total acreage and pine forests comprise the remaining 22 percent. Since 1940 the total volume of Virginia's forests has increased by 81 percent, from 14.7 to 26.6 billion cubic feet (Foreman 1995).

The USDA Forest Service (1958) estimated 673 million board feet of pine and 784 million board feet of hardwood were produced in Virginia in 1958. It was estimated that between 1976 and 1995, annual production was 507.3 million board feet of pine and 648 million board feet of hardwood in Virginia. Between 1987 and 1995, the estimated annual production was 526.5 million board feet of pine and 740 million board feet of hardwood in Virginia (USDA Forest Service 1997). The Virginia Department of Forestry (1998) estimated 772.1 million board feet of hardwood and 531.7 million board feet of pine were produced in 1996. Nearly 186,000 acres or 1.2 percent of Virginia's forestland is harvested annually, generating an estimated \$200 million dollars for Virginia's forest landowners (Shaffer 1997).

The forest products industry directly and indirectly employs over 228,000 Virginian's. In 1994, primary manufacturers employed approximately 23,000 and secondary manufacturers employed approximately 40,000 people. The construction industry is estimated to consume 75 percent of all the softwood lumber and wood composite panels utilized in Virginia. In addition, the construction industries utilization of forest products contributes approximately \$686 million to

Virginia's economy. Transportation of Virginia's forest products contributed approximately \$640 million and employed nearly 7,300 people. The marketing of Virginia's forest products added approximately \$1.3 billion to Virginia's economy and employed 35,000 people (Virginia Department of Forestry 1995).

The magnitude of Virginia's wood products industry illustrates its breadth and diversity. Twenty-two types of wood products industries are located in Virginia and they produce over two hundred different products (Foreman 1995). These firms vary from sawmills, furniture, truss and composite manufacturers, integrated paper manufacturers to bark processors. Domestic uses of Virginia's forest products include hardwood and softwood lumber, furniture, piles and posts, wood chips, flooring, siding, millwork, treated lumber, railroad ties, softwood and hardwood veneers, pallets, softwood and hardwood plywood, and trusses. Exports are a significant market for the Virginia forest products industry. Hardwood lumber accounts for 54 percent of the total value of forest products exports, hardwood veneer 14 percent, hardwood logs 13 percent, softwood lumber 9 percent, and secondary wood products account for the remaining percentages of exports (Virginia Department of Agriculture and Consumer Services 1996).

Wood Residue Production and Characterization

Wood residue is produced from the processing or breakdown of logs and/or roundwood into lumber or other wood products. Common wood residues produced from primary processing include: bark, slabs, sawdust, chips, coarse residues, planer shavings, peeler log cores, and end trimmings. Secondary manufacturers typically produce the following types of wood residues: chips, sawdust, sanderdust, end trims, used or scrapped pallets, coarse residues, and planer shavings. Coarse residues, for both manufacturing groups, include slabs, edgings, trims, and cores.

Lumber recovery factor (LRF) is a ratio of board feet recovered per cubic foot of log. Generally the LRF for hardwood logs average 7 or less and pine logs average 8, with 12 being the maximum LRF attainable, based on the International ¼-inch log rule (White 1997). Volumetric recovery of rough green lumber, as a percentage of green log volume, is generally less than 50 percent in pine and hardwood logs (as log diameter increases, the lumber recovery percentage increases). Lumber recovery factors in hardwood mills are less than in softwood mills, primarily because hardwood lumber is processed with larger saw kerfs than softwood lumber (Koch 1985).

Bark, on a percentage volume basis, averages 8 to 12 percent of the total volume of a log, sawdust averages 11 to 15 percent, and chippables (slabs, edgings or material large enough to merit size reduction before further utilization) average 30 to 40 percent. Generally, during the sawing of a log at a typical sawmill, approximately 50 percent of the initial log volume is converted into wood products and 50 percent is converted into wood residues. The aforementioned rule-of-thumb can vary ± 10 to 15 percent, depending on the species, saw kerf, board thickness, sawing accuracy, and log breakdown methods (White 1997).

Circle or circular type saws produce more sawdust than bandsaws, which typically have thinner saw kerfs. For example, when black oak was sawn into 4/4 lumber on a bandsaw with 3/16-inch kerf, sawdust averaged 12 to 13 percent of green log weight. When sawn on a circle saw with 1/4-inch kerf, sawdust percentages were 17 to 22 percent of green log weight (Massengale 1971).

May and Barrett (1971) conducted a survey of primary and secondary wood products manufacturers in Virginia in 1971. They reported approximately 2.6 million tons of wood residues were produced, which included: 568,000 tons of hardwood chips, 691,000 tons of pine chips; 361,600 tons of hardwood sawdust, 263,400 tons of pine sawdust; 280,400 tons of hardwood bark, 274,000 tons of pine bark, 59,000 tons of hardwood planer shavings, 44,800 tons of softwood planer shavings; 70,500 tons of hardwood "other" residues, and 11,400 tons of pine "other" residues were produced in Virginia in 1970.

The Lumber Manufacturers Association of Virginia (1959) reported 453,000 tons of pine chips and 549,000 tons of hardwood chips were available for utilization in Virginia. The authors noted that in 1958 very few sawmill operators utilized debarkers or chippers. They also acknowledged estimates of wood residue production and availability were probably conservative.

Nationally, an estimated 28 million tons of bark and 82 million tons of wood by-products were produced in 1991. It was estimated that 5 percent of the bark and 6 percent of wood by-products were not used and all unused wood by-products were deemed recoverable in 1991 (McKeever 1995).

The Commonwealth of Virginia has approximately 800 primary and secondary wood products companies. Primary wood processors are responsible for the conversion of logs or roundwood into lumber, crossties, veneer, chips or flakes, strandboard, laminated veneer lumber, and other wood products. Secondary wood processors convert cants, squares, lumber, or wood fiber into finished

value-added products such as furniture, novelties, pallets, log homes, millwork, cabinet parts, mulch, and flooring.

Current Markets for Wood Residues

Wood residues can be utilized to manufacture a variety of products. Currently, the majority of chips, planer shavings, and coarse residues are used in the production of paper and paper-based products, composite wood products, and sold for fuel or used at the facility for fuel. Bark is primarily ground and processed for landscape uses. This material is sold to local customers and landscaping contractors. Sawdust, sanderdust, and mixed residues are sold for the production of energy and to the composites industry for the manufacture of particleboard and medium density fiberboard. Slabs and end trims are primarily sold to local customers for fuel. The marketing and associated transportation costs of wood residues is a limitation to many Virginia wood product manufacturers due to the remote location of many mills.

Nationally and regionally, wood residues are being utilized to manufacture a variety of new products. In North Carolina, one manufacturer has patented a process that converts end-trims, construction and demolition waste, scrap pallets, and yard trimmings into topsoil or a product similar to traditional compost. Raw material is obtained from area companies and municipalities who direct wood residue to this facility. This company charges a tipping fee that currently is \$22.00 per ton less than municipal landfills. The owner states that he cannot meet the demand for his products (Gray 1994). One company estimated that they saved approximately \$100,000 annually by directing their waste to this type of facility (Chamis 1997).

A rapidly expanding market for sawdust is the production of wood fuel pellets for use in residential stoves. Sawdust is dried and compressed by a pelletizing machine. Wood pellets produce approximately 8,500 BTU's per pound, are clean burning, and ash free (Pickering 1996). Wood pellet sales were estimated to be 600,000 tons in 1995 and are expected to increase by 10 to 15 percent per year (Pickering 1996). Prices range from \$90 to \$128 dollars per ton in the United States, with the highest prices in the Northeast (BioCycle 1997). There are an estimated 400,000 wood pellet stoves in the United States and the pellet market is considered unsaturated (Pickering 1996). Pickering (1996) estimates that there are 50 pellet-manufacturing plants in the United States. Since pellet fuel is a cheap commodity, the effective market area for a plant is approximately 500 miles.

Therefore, new pellet manufacturing plants may be built rather than expanding existing plants. McElvenny (1994) reports sawdust can be compressed to produce non-wax fireplace logs, which yield about \$160.00 per ton. No petroleum is used in production and availability is increasing on both coasts of the United States.

A Pacific Northwest company has created a niche market by producing fuel pellets for residential use; cooking and smoking pellets that are used by restaurants or sold in retail outlets; landscape mulch; and animal bedding. In 1985 the company produced 600 bags of pellets per month and this increased to 70,000 bags per month by 1996. The company imports hickory chips from the Eastern United States to produce the cooking and smoking pellets (Christianson 1997).

Recently, a recycled threadlike fiber has been produced from recycled wood waste. Fiber bundles are combined and molded with inorganic thermoplastics for reinforcement of the finished product. The recycled wood fibers not only reduce the amount of petroleum necessary to produce plastics, but also typically can increase the overall stiffness and strength of a material by as much as 50 percent. The composition of the product can be engineered to project what the actual fiber bundle percentage should be in advance of manufacturing the product (McElvenny 1997). This development appears as a good future market for sawdust, sanderdust, and fines as a result of the growth the wood composites industry.

Several companies are producing wood plastic composite products that can be used as decking material or in fencing. Sawdust and wood fibers are mixed with plastic resins and are extruded at elevated temperatures. "Plastic wood" is typically 52 percent wood residue and 48 percent plastic resin (Environmental Building News 1997). A major window frame manufacturer is producing wood-plastic composite windows and door frames. The company reports wood plastic composite frames have no water absorption and significantly less warping than traditional wood frames (BioCycle 1996).

Researchers at the USDA Forest Products Laboratory in Madison, Wisconsin have begun production of a wide variety of wood plastic composite products. Sawdust and plastic resins are injection molded and extruded to manufacture automobile parts; window frames paint brushes, grips, hangers, and toys (Lavendel 1996). Other molded products produced from conventional wood particles and containing less than 25 percent binding resin are exterior sidings, door jambs, window sills, table tops, pallets, and casket tops. The use of finer particles (which approximate flour size) and

binding resins may be used to produce toilet seats and croquet balls using a compression molding technique (USDA Forest Service Wood Handbook 1987).

Wood residues can be used to co-fire large coal fired utility boilers. Wood contains a low-sulfur content and can be used to reduce sulfur dioxide emissions produced by coal fired energy production plants. In addition, wood reduces the amount of fossil carbon dioxide emissions and allows producers to meet the voluntary carbon dioxide reduction plans, such as the Climate Change Action Plan. Experiments indicate that approximately 4 percent (BTU basis) of coal can be replaced by wood residues without adding additional wood handling and feeding equipment (Badger 1996). Some manufacturing facilities are installing co-generation systems to produce electricity to operate their plants. Several furniture manufacturers and sawmills are installing boilers, along with gasifiers, to produce steam to dry lumber (BioEnergy 1996). The Virginia Biomass Energy Program estimates that if sawdust and logging residue production annually were combined with the annual growth of low-quality unmerchantable trees, enough biomass exists to provide 42 percent of Virginia's industrial and commercial oil and gas consumption needs (Southeastern Regional Biomass Energy Program 1994).

Wood ash and particles can be used to manufacture bricks, cement blocks and slabs, roof planks, exterior wall panels, highway noise barriers, and asphalt. Wood ash historically was used to manufacture cinder blocks (Moslemi 1997). Wood fibers, combined with water and cement, can be used to produce cement-bonded particleboard. Wood fiber can also be mixed with gypsum to produce gypsum board (Pieper 1991).

Wood fiber, specifically sawmill shavings, can be used to produce wood panel products. Shavings require no further processing before being put through a hammermill and processed through conventional composite manufacturing procedures. A British company has developed a complete, modular mini-composite mill to produce particleboard. This firm reports that particleboard produced is substantially stronger in strength characteristics compared to conventional particleboard. The mini-composite mill is a low-capacity plant designed to operate cost-effectively on a scale suited to the seasonal availability of raw materials (Cress 1997).

Scrap or non-repairable pallets are converted and used to manufacture recycled wood mulch and playground cushion material. The pallet scraps are machined, sized, and can be colored. The mulch is either bagged or sold in bulk quantities. End trims, larger edgings, and blocks can be utilized to produce finger jointed wood products.

Wood residues have been shown to be amenable to upgrading by steam explosion. Steam explosion involves the application of high-pressure steam to organic materials, which include wood residues, for brief periods of time (one to five minutes), in a pressurized autoclave. The resulting wood residues are homogenized by steam explosion into a fibrous form useful for a range of products. These products can be used for soil amendments, microbial or enzymatic conversion to products such as ethanol, and “fractionation” into individual polymer constituents. These constituents can be cellulose, lignin, chitin, xylan, etc., which can be used in the production of melt-processible esters, biodegradable polymers, adhesives, fillers, pigments, and hydrogel sorbants for water purification systems and protein separations (Glasser 1995).

Wood Residue in Landfills

The Center for Forest Products Marketing and Management at Virginia Tech conducted a national landfill survey in 1995 to quantify all types of waste, particularly pallets, entering landfills. An estimated 293 million tons of all waste entered municipal solid waste landfills and 42.2 million tons entered construction and demolition waste landfills in 1995. Approximately 21 million tons (7.3 percent) and 16 million tons (37.8 percent) of wood waste, respectively, entered these landfills. Wood waste included pallets, boxes, dunnage, packaging, yard trimmings, and other non-industrial wood discards (Araman, Bush, and Reddy 1996).

Wood and wood fiber products (including paper and paper-based products) are the largest component of the municipal waste stream in the United States. In 1995, the United States Environmental Protection Agency (EPA) estimated that 208 million tons of municipal solid wastes were generated. Of this total, 125.8 million tons or 60 percent were wood and wood fiber products. Paper and paperboard products accounted for 39 percent, by weight, yard trimmings made up 14 percent, and wood products accounted for 7 percent of the wood by-products in 1995 (EPA 1997). In 1995, the EPA estimates that 40 percent of paper and paperboard products, 30 percent of yard trimmings, and 9.6 percent of wood by-products were utilized for recycling (EPA 1997). All studies indicate that the Southern United States generates and landfills the most municipal solid waste, including wood by-products.

The EPA municipal solid waste totals did not include materials that were directed to construction and demolition waste facilities. Rathje (1992) estimated that 60 million tons of wood by-products enter into construction and demolition facilities. Brickner (1997) estimates the volume of waste directed to construction and demolition landfills exceeds 100 million tons annually.

The number of landfills in the United States accepting municipal solid waste is declining at a rapid rate. There were an estimated 3,558 municipal solid waste landfills operating in 1994, down from 4,482 in 1993 (Steuteville 1995). Araman, Bush, and Reddy (1996) found that approximately 3,500-landfill facilities were in operation in the United States in 1995. Approximately 140 waste management facilities are located in Virginia. The national average tipping fee for municipal solid waste in 1994 was \$31.00 per ton, an increase of \$1.00 per ton from 1993 (Steuteville 1995). Araman, Bush, and Reddy (1996) estimated that the national average tipping fee was \$32.22 per ton at municipal solid waste facilities and \$29.00 per ton at construction and demolition landfills in 1995.

The decline in municipal solid waste facilities is due in part to increased federal and state waste reduction legislation. Additionally, numerous landfills have reached capacity. Three types of waste reduction legislative initiatives are prominent in the United States:

- 1) Mandating local governments to source separate and recycle specific materials;
- 2) Mandating local governments to provide recycling services, however this initiative type does not require mandatory recycling by companies or the public
- 3) Waste reduction legislation, where local governments must attain prescribed waste reduction goals by developing recycling programs or by instituting mandatory ordinances (Glenn and Riggle 1991).

These initiatives may restrict the types of materials that can be landfilled and new landfill construction is subject to stricter and more expensive engineering requirements. Virginia legislative initiative HB 1743-1989 required municipalities to develop recycling programs with the goal of reducing all waste entering landfills by 25 percent, on or before December 31, 1995.

New regulations may prohibit the burning of wood residue onsite and the trend of increasing tipping fees at landfills inhibits companies to continue with previous waste disposal practices. The Virginia wood products industry is increasingly concerned that restricted wood residue markets present the industry with a serious impediment to future expansion (Zipper and Muench 1993). In addition, new regulations regarding certain government purchases are dictating the types of materials that may be purchased by these agencies. For example, the EPA has developed recycled material

content guidelines that apply to purchases exceeding \$10,000. These guidelines apply to federal agencies and for construction projects that receive federal funds. Recovered material requirements are 80 to 100 percent for structural fiberboard, 100 percent for wood-based hydraulic mulch, and 50 percent for office paper (Environmental Building News 1995).

Although there is a developing trend for municipal solid waste facilities to separate wood by-products before landfilling, significant amounts of wood are still being landfilled. Several Virginia municipal solid waste facilities are offering reduced tipping fees for wood by-products separated from other waste. Some facilities work directly with companies by having them sell wood by-products directly to recyclers instead of delivering it to their facilities. The reduction of wood residues sent to landfills could increase company profitability by eliminating tipping fees and from the generation of income from the sale of wood residues.

Solid wood reaches landfill facilities in several forms: construction and demolition waste, pallets, crates, furniture, bark, sawdust, tree limbs, and yard waste, etc. Much of this waste could be used in the manufacture of composites (oriented strandboard, medium density fiberboard, particleboard, etc.), fuel for co-generation systems, landscaping mulch, animal bedding, and different types of composts. Present markets prefer wood pallet and yard waste because of their relative cleanliness, (i.e., these wastes are mixed with the least amount of non-wood materials). For the purpose of this study, “wood residues” include wood by-products that enter landfills and raw wood by-products such as sawdust, chips, bark, slabs, end trims, coarse and mixed residues, pallets, and planer shavings.

Several states have commissioned studies to quantify the availability of wood by-products that could be recycled and used in other manufacturing processes. Studies by Illinois, Iowa, Minnesota, and Wisconsin have identified the species and types, disposition, and energy potential of wood by-products located in large metropolitan areas of these states. Researchers at North Carolina State University (Deal and Jahn 1995) found that approximately 38 percent yard waste, 28 percent stumps, 27 percent construction and demolition material (C&D) and 7 percent pallets constituted the total wood based products reaching North Carolina landfills in 1994.

Significant portions of wood by-products entering municipal waste facilities, nationally and locally, are wood pallets. In 1996, the Center for Forest Products Marketing and Management at Virginia Tech conducted a study to quantify the number of pallets entering landfills and to determine the amount of pallets being recovered. According to Araman, Bush, and Reddy (1996) an estimated

223.6 million pallets or 5.1 million tons entered municipal solid waste and construction and demolition facilities in 1995. Only 37.9 million pallets (16.9 percent) were recovered and recycled, and not directed to a landfill. Only 2 million out of 18 million pallets produced in Georgia were recovered, with the remainder disposed in landfills (Bouffer, Downing, and Riall 1995). In Wisconsin a similar pattern emerged; an estimated 18.6 million pallets are landfilled in municipal solid waste and C&D landfills (Gruder and Green 1994).

In conclusion, literature relevant to wood residue production, markets, and disposal were reviewed in this chapter. There exists minute or no information on the quantity, types, markets or disposal methods for wood residues produced in Virginia. In addition, the same holds true for the quantity and types of wood residues directed to Virginia's waste facilities.

Without characterization of Virginia's wood residues, it is extremely difficult for policy makers and business leaders to plan for utilization of these natural resources. Once determination and quantification of Virginia's wood residues occurs, it may provide information for companies to establish businesses in Virginia, and allow them to take advantage of these available resources.

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CHAPTER 2

WOOD PRODUCTS PRODUCTION AND CONSUMPTION AND WOOD RESIDUE PRODUCTION IN VIRGINIA

Methods

In 1996 an extensive literature review was conducted to gain an understanding of the various issues relevant to wood residues and to ascertain if similar studies have been conducted in other states. A well-established method for determination and quantification of materials such as wood residues, is the direct mail survey method. This method serves to provide facts that can be generalized, is efficient, and cost effective (Dillman 1978).

First, all primary and secondary wood product manufacturers in Virginia were contacted to gather relevant data. To estimate the quantity and types of wood residues generated and evaluate current wood residue markets, a questionnaire was developed to gather the necessary data. Eight hundred fourteen primary and secondary wood product manufacturers in Virginia were mailed the questionnaire in February of 1997. The manufacturers' list was obtained from a directory of wood product manufacturers in Virginia (Virginia Department of Forestry 1992). The manufacturers' list was supplemented with current information from other sources, which are maintained at the Center for Forest Products Marketing and Management at Virginia Tech.

A questionnaire, administered through the mail, was used to collect data and was directed to the individual within the company responsible for manufacturing operations. All responses remained confidential. The first section of the questionnaire used categorical questions to identify if the firm generated wood residues, type of manufacturing facility, species used, number of employees, product type produced and volumes, and the amount and types of wood residues produced in 1996. The second section of the questionnaire used percentage scales to measure how wood residue generated was disposed. The third section of the questionnaire asked if companies sent wood residues to landfills, what type of landfill they utilized, if the lack of wood residue markets hindered production, and if the cost of wood residue disposal hindered production. The final section of the questionnaire utilized categorical questions to identify the quantity, identity, and location of wood residue customers, the prices received for each type of wood residues, and their comments pertaining to wood residues (Appendix A).

Personal interviews with a number of wood product manufacturers in Virginia were conducted to gather the needed information for the questionnaire. Before administering the survey, the questionnaire was evaluated by knowledgeable faculty members at Virginia Tech in the Department of Wood Science and Forest Products. The questionnaire was pre-tested with manufacturers to clarify question wording, order, and if additional questions needed to be asked. The questionnaires, along with signed cover letters, were mailed in February of 1997. This was followed two weeks later with a postcard being mailed requesting non-respondents to answer the questionnaire. This mailing sequence was conducted three more times over a three-month period modeled after the Dillman method (Dillman 1978).

To determine if the data provided by respondents were representative of the industry, we investigated non-response bias. Thirty non-respondent manufacturers were contacted by telephone to ask for their participation and answer specific questions from the survey. This data was compared to information provided by respondents with corresponding data obtained from the random sample of non-respondents. A Student T-test was used to determine if non-respondent data were significantly different from respondent data. In no case could the hypothesis of no difference between respondents and non-respondents be rejected ($\alpha < 0.05$). This suggests that respondents were representative of the industry.

Estimation Procedure

Wood residues produced in Virginia by wood product manufacturers were extrapolated to estimate the total wood residue volumes produced in each Standard Industrial Classification (SIC) code. The following steps outline the procedure used in this extrapolation:

1. The Virginia State Employment Commission was contacted to attain the number of employees working in the forest products industry by Standard Industrial Classification (SIC) code. These sample frames included sawmills (SIC code 2421), engineered wood manufacturers (SIC code 2493), hardwood plywood manufacturers (SIC code 2435), paper manufacturers (SIC codes 2621, 2631), rough mill operations (SIC codes 2426, 2431, 2434), pallet manufacturers (SIC code 2448), other manufacturers (SIC codes 2429, 2499, 5211), furniture manufacturers (SIC codes 25111, 2512, 2519,

2521, 2531, 2599), and housing manufacturers (SIC code 2439, 2451 and 2452). This estimation procedure is similar to that used by Bush, Reddy, Bumgardner, Chamberlain, and Araman (1997) to estimate pallet production. The focus of their research was to estimate the number of pallets disposed of in landfills, the wood volume contained in those pallets, and pallet recovery.

2. The reported wood residue volume of each residue type (e.g., chips, bark, and sawdust) was divided by the reported number of employees of each respondent sample frame to calculate wood residues production per employee for each SIC code classification.
3. Average (mean) wood residue production per employee, for each sample frame, was multiplied by total employment within each forest products SIC code sample frame provided by the Virginia State Employment Commission. For example, responding Virginia hardwood plywood manufacturers (SIC code 2435) reported producing 12,125 tons of dry mixed residues in 1996. This total was divided by 726 (reported total number of employees for hardwood plywood manufacturers), yielding an average of 16.7 tons per employee. The Virginia State Employment Commission reported 1,321 persons were employed by SIC code 2435 in 1996. The average per employee, 16.7 tons, was multiplied by 1,321, yielding an estimated 22,061 tons of dry mixed residues produced in 1996.

Repeating this calculation for each sample frame and adding up each sample frame provided an estimate of the wood residue volume produced in Virginia in 1996. Board footage, square footage, lineal footage, tonnage production and consumption estimates, for each sample frame, were made by the same method, with the exception of hardwood and pine sawmills.

To estimate the total hardwood and pine sawmill lumber and wood residues production in Virginia, a factor was derived by dividing Virginia Department of Forestry (VDF) 1996 board footage production estimates by the reported board footage from respondent hardwood and pine sawmills, respectively. This factor was then multiplied by reported residues produced, for each residue type, to estimate wood statewide residue production. This procedure was necessitated

because SIC code sawmill data is aggregate; (i.e., hardwood and pine sawmill employment data are not compiled separately).

For example, the VDF estimated hardwood sawmills in 1996 (Virginia Department of Forestry 1998) produced 772,102,000 million board feet of hardwood. This total was divided by 347,780,986 board feet (the responding mills total reported 1996 hardwood lumber production). This yielded a factor of 2.2201. Responding hardwood sawmills reported producing 300,721 tons of sawdust in 1996. To estimate hardwood sawmill sawdust production, 2.2201 was multiplied by 300,721 tons, yielding an estimated 667,600 tons of sawdust in 1996.

Respondents

The wood residue questionnaire was mailed to 814 wood product manufacturers in Virginia. Four hundred and eighteen companies responded; 266 stated they generated wood residues in their operations, 132 indicated that they did not generate wood residues, and 20 had closed their business or the company was a retail store only. There were 100 bad addresses out of the 814 mailed questionnaires. The initial response rate was approximately 33 percent and the adjusted response rate was 46 percent.

Sixty-five hardwood sawmills, 36 pine sawmills, 58 rough mill operations, 6 engineered wood manufacturers, 6 hardwood plywood manufacturers, 26 “other” manufacturers, 26 furniture manufacturers, 20 pallet manufacturers, 18 housing manufacturers, and 5 paper manufacturers responded to the mail survey (Table 1).

Rough mill operations included box spring, cabinet and cabinet components, edge glued panels, flooring, millwork, furniture parts, planer mills, and laminated furniture manufacturers. These manufacturers were grouped together as a function of SIC codes; they have related manufacturing processes, and utilize similar wood products in manufacturing.

“Other” manufacturers were an eclectic group and as a result, they were grouped together because of this diversity. “Other” manufacturers included firms that produced chips, mulch, posts and pilings, travel trailers, steam, electricity, novelties, pipe organs, handles, wood preservers, or they repaired boats.

Engineered wood manufacturers included laminated veneer lumber, oriented strandboard, particleboard, structural plywood, and hardboard. These manufacturers were grouped together because they produce similar panel products and taking into consideration the typical usage of the end product (which is used in support of a structure or manufactured product).

Hardwood plywood manufacturers included hardwood plywood, veneer, or face grade veneer manufacturers. These manufacturers were grouped together because the end product is typically applied in products where aesthetics are of vital importance.

Housing manufacturers included log homes, modular housing, post and frame buildings, prefabricated wall panels, utility buildings, and truss manufacturers. These manufacturers were grouped together because the end product was either a structure or used in the construction of a structure.

Respondents were asked to list the names and addresses of their customers for each type of wood residue they produced (Question 13, Appendix A). Haul distances from the producer plant to residue customer was calculated and summed for each producer. The summed or aggregate mileage was divided by the total number of markets wood residues were delivered to in order to derive an average residue haul distance.

Results and Discussion

Production and Current Markets, Primary Manufacturers

Responding primary manufacturers reported producing approximately 720 million board feet of lumber and engineered lumber, 678 million square feet of wood composite products, and 2.6 million tons of paper and paper-based products in 1996 (Table 1). Responding primary manufacturers reported producing approximately 2.5 million tons of wood residues in 1996. This total included approximately 1.1 million tons of chips, 622,000 tons of bark, and 536,000 tons of sawdust or 66 percent of total responding primary manufacturers wood residues production in 1996.

Primary manufacturers produced an estimated 1.3 billion board feet of lumber, 1.2 billion square feet of engineered lumber and hardwood plywood, 6.1 million tons of paper and paper based products in 1996. This total included an estimated 1.9 million tons of chips, 1.3 million tons of bark, and 1.0 million tons of sawdust. Primary manufacturers produced an estimated 80 percent or 4.6 million tons of Virginia's wood residues in 1996 (Table 2).

Hardwood Sawmills

The responding hardwood sawmills 1996 production was approximately 5.3 million board feet per mill, 232,000 board feet per employee, with a total reported production of 348 million board feet (Table 3).

Hardwood mills reported producing approximately 465,000 tons of chips or 46 percent of total hardwood sawmill residues. Sawdust production was approximately 301,000 tons or 29 percent of total hardwood sawmill residues. Bark production was approximately 228,000 tons or 22 percent of the total hardwood sawmill residues. These three residues constitute nearly 98 percent of total wood residues produced by hardwood sawmills. The estimated hardwood sawmill residues average haul distance to residue markets was 77 miles (one-way).

Hardwood sawmill production was estimated to be 772 million board feet of hardwood in 1996 (Virginia Department of Forestry 1998). The estimated hardwood sawmill residue production was 1.0 million tons of chips, 667,600 tons of sawdust, and 506,700 tons of bark (Table 4).

Responding hardwood sawmills produced approximately 39 percent of Virginia's wood residues (Table 2). Nearly 45 percent of hardwood sawmill residues production were green chips (Table 3). Approximately 425,000 tons or 91 percent of hardwood chips were sold to pulp or paper manufacturers (Figure 1, Table 4). The average price received for chips was \$17.25 per ton delivered, with one mill reporting a disposal cost of \$25.00 per ton for chips.

Approximately 29 percent of hardwood sawmill residues were green sawdust (Table 3). Nearly 131,000 tons or 44 percent of sawdust were sold to others as fuel, 84,000 tons or 28 percent were sold to pulp or paper manufacturers, and 63,000 tons or 21 percent were sold as livestock bedding (Figure 2, Table 4). The average price received for sawdust was \$8.10 per ton delivered, with one mill reporting a disposal cost of \$11.00 per ton.

Twenty-two percent of hardwood sawmill residues were bark (Table 3). Nearly 159,000 tons or 69 percent of bark were sold to bark or mulch companies, 53,000 tons or 23 percent were disposed of by other methods and 10,000 tons or 4 percent were sold as livestock bedding (Figure 3, Table 4). The average price reported received for bark was \$14.20 per ton delivered, with one mill reporting a disposal cost of \$12.00 per ton for bark.

Nearly 1.5 percent of hardwood sawmill residues were planer shavings (Table 3). Approximately 10,000 tons or 60 percent of planer shavings were sold to pulp or paper manufacturers, 3,500 tons or 21 percent were sold to others as fuel, and 2,000 tons or 12 percent were sold to bark or mulch companies (Figure 4, Table 4). The average price reported received for planer shavings was \$20.00 per ton delivered.

Approximately 1 percent of hardwood sawmill residues was other green and dry residues (Table 3). Nearly 5,900 tons 52 percent of other residues were sold or given away to a wholesaler or broker, 5,000 tons or 44 percent were sold to bark or mulch companies, and 500 tons or 4 percent were sold to others as fuel (Figure 5, Table 4). The average price reported received for other green and dry residue was not reported.

Nearly 1 percent of hardwood sawmill residues were mixed residues (Table 3). Fifty-eight percent or 6,500 tons of mixed residues were disposed of by other methods, nearly 3,500 tons or 31 percent were sold to others as fuel, 500 tons or 4.5 percent were sold to bark or mulch companies, and 500 tons or 4.5 percent were used at the facility for fuel (Figure 6, Table 4). The average price reported received for mixed residues was \$10.00 per ton delivered.

Approximately 0.2 percent of hardwood sawmill residues were coarse residues (Table 3). Nearly 1,800 tons or 98 percent of coarse residues were sold to others as fuel (Figure 7, Table 4). The average price reported received for coarse residues was \$13.00 per ton delivered.

Fifty percent of hardwood sawmill residues were sold to pulp or paper manufacturers, 17 percent were sold to bark or mulch companies, 15 percent were sold to others as fuel, 7 percent were sold as livestock bedding, 6 percent were disposed of by “other” methods, and 5 percent were disposed of by a combination of methods (Figure 8). “Other” disposal methods included sales to local individuals, landscape contractors, and composting.

Very nearly 66,500 tons or 6.4 percent of hardwood sawmill residues were not utilized. Nearly 58,400 tons or 85 percent of these residues were bark, 6,600 tons or 9.6 percent were mixed residues, and 3,000 tons or 4.3 percent were sawdust. Of this total, 60,000 tons or 90 percent were disposed of by other methods (other disposal methods included sales to local individuals, landscape contractors, and composting), 5,800 tons or 9 percent were sent to landfills, 745 tons or 1 percent or were landfilled at the facility, and 2 tons or less than 0.1 percent were burned as waste.

Approximately 5 percent of the responding hardwood sawmills reported directing wood residues to landfills. Of this total, 66 percent reported that a lack of markets was the primary reason they directed residues to landfills and 33 percent reported that it was more economical to direct residues to landfills. All hardwood sawmills directing residues to landfills reported sending wood residues to company landfills.

Approximately 25 percent of the responding hardwood sawmills reported the lack of markets for wood residues restricted production in 1996. Of this total, 40 percent reported the lack of markets reduced daily production and 40 percent reported production stopped completely. Nearly 13 percent reported production was restricted due to a lack of consistent markets. Seven percent were concerned about consistent markets and how it would effect future plans to increase production.

Nearly 8 percent of responding hardwood sawmills reported the cost of disposing wood residues restricted production in 1996. Of this total, 75 percent reported disposal costs restricted daily production and 25 percent reported the cost of disposing wood residues completely stopped production.

Pine Sawmills

The responding pine sawmills 1996 production averaged 10.3 million board feet per mill, 340,000 board feet per employee, with a total reported production of 370.5 million board feet (Table 1).

Pine sawmills reported producing approximately 635,000 tons of chips or 59 percent of total pine sawmill residues. Sawdust production was nearly 235,600 tons or 22 percent of total pine sawmill residues. Bark production was approximately 131,200 tons or 12 percent of total pine sawmill residues. Planer shaving production was nearly 74,500 tons or 7 percent of total pine sawmill residues. These four residues constitute 100 percent of the total wood residues produced by

pine sawmills (Table 5). The estimated pine sawmill residues average haul distance to residue markets was 74 miles (one-way).

Pine sawmill production was estimated to be 531.7 million board feet in 1996 (Virginia Department of Forestry 1998). The estimated pine sawmill residues production was about 911,200 tons of chips, 338,100 tons of sawdust, 188,300 tons of bark, and 107,000 tons of planer shavings (Table 5).

Responding pine sawmills produced nearly 27 percent of Virginia's wood residues (Table 2). Pine sawmill chip production accounts for the largest percentage of wood residues, followed by sawdust, and bark.

Nearly 59 percent of pine sawmill residues were green chips (Table 5). Nearly 615,000 tons or 97 percent of pine chips were sold to pulp or paper manufacturers (Figure 9, Table 6). The average price reported received for green chips was \$21.00 per ton delivered.

Nearly 22 percent of pine sawmill residues was sawdust (Table 5). Approximately 95,200 tons or 40 percent of pine sawdust were sold to composite manufacturers, 81,500 tons or 35 percent were sold to pulp or paper manufacturers, 27,200 tons or 12 percent were sold to others as fuel, 15,000 tons or 6 percent were used at the facility for fuel, and 12,500 tons or 5 percent were sold as livestock bedding (Figure 10, Table 6). The average selling price reported received for sawdust was \$9.00 per ton delivered.

Nearly 12 percent of pine sawmill residues was bark (Table 5). Nearly 67,000 tons or 52 percent of bark were sold to bark or mulch companies, 58,500 tons or 45 percent were sold to pulp and paper manufacturers for fuel, 4,200 tons or 3 percent were used at the facility for fuel (Figure 11, Table 6). The average selling price reported received for bark was \$14.00 per ton delivered.

Nearly 7 percent of pine sawmill residues were planer shavings (Table 5). Approximately 61,000 tons or 82 percent of planer shavings were sold to composite manufacturers, 9,600 tons or 13 percent were sold as livestock bedding, 4,000 tons or 5 percent were used at the facility for fuel (Figure 12, Table 6). The average price reported received for planer shavings was \$33.00 per ton delivered.

Less than 1 percent of pine sawmill residues were mixed residues (Table 5). One hundred percent or 2,500 tons of mixed residues were sold or given away to wholesalers or brokers (Figure 13, Table 6). The average price reported received for mixed residues was \$5.00 per ton delivered.

Less than 1 percent of pine sawmill residues were coarse residues (Table 5). Approximately 600 tons or 86 percent of coarse residues were disposed of by other means, 50 tons or 7 percent were landfilled at the facility, 25 tons or 4 percent were burned as waste, and 25 tons or 4 percent were sold to composite manufacturers (Figure 14, Table 6). The average price reported received for coarse residues was \$5.00 per ton delivered.

Thirty-five percent of pine sawmill residues were sold to pulp or paper manufacturers, 32 percent were sold to composite manufacturers, 16 percent were sold to bark or mulch companies, 6 percent were sold to others as fuel, 5 percent were used at the facility for fuel, 5 percent were sold as livestock bedding, and less than 1 percent were disposed of by a combination of methods (Figure 15).

Approximately 2,700 tons or 0.4 percent of pine sawmill residues are potentially available for utilization. Nearly 1,100 tons or 40 percent was sawdust, 970 tons or 35 percent was bark, and 675 tons or 25 percent were coarse residues. Of this total, 1,685 tons or 62 percent were disposed of by other means, 1,000 tons or 36 percent were burned as waste, and 50 tons or 2 percent were landfilled at the facility.

Nearly 8 percent of responding pine sawmills directed wood residues to landfills in 1996. The lack of consistent markets for wood residues was the principal reason for directing residues to landfills. These mills directed residues to a company landfill. Nearly 8 percent of responding pine sawmills reported the lack of consistent markets for wood residues and wood residue disposal costs restricted daily production.

Engineered Wood Manufacturers

The responding engineered wood manufacturers average 1996 production was approximately 86 million square feet and 17,500 lineal feet per mill, 570,000 square feet and 116 lineal feet per employee, with a total reported production of 515 million square feet and 105,000 lineal feet of engineered wood products (Table 1).

Engineered wood manufacturers reported producing approximately 48,000 tons of bark or 40 percent of total engineered wood manufacturers' residues. Sanderdust production was approximately 27,000 tons or 22 percent of total engineered wood manufacturers' residues. Mixed residue production was approximately 26,800 tons or 22 percent of total engineered wood manufacturers' residues. Coarse residue production was 11,000 tons or nearly 9 percent of total engineered wood manufacturers' residues. Chip production was 8,000 tons or nearly 7 percent of total engineered wood manufacturers' residues. These five residues constitute approximately 100 percent of the total wood residues produced by engineered wood manufacturers (Table 7). The estimated-engineered wood manufacturers' residues average haul distance to residue markets was 86 miles (one-way).

The estimated-engineered wood production was 963 million square feet and 196,400 lineal feet of engineered wood products in 1996. The estimated engineered wood residues production was approximately 90,000 tons of bark, 50,400 tons of sanderdust, 40,000 tons of mixed residues, 20,500 tons of coarse residues, and 15,000 tons of chips in 1996 (Table 7).

Responding engineered wood manufacturers produced approximately 4 percent of Virginia's wood residues (Table 3). Engineered wood manufacturers' bark production accounts for the largest percentage of wood residues, followed by mixed residues, dry sanderdust, and coarse residues.

Nearly 40 percent of engineered wood manufacturers' residues production was bark (Table 7). Approximately 27,300 tons or 57 percent of bark were disposed of by other means. Nearly 8,300 tons or 17 percent were sold to others for fuel, and 8,300 tons or 17 percent were used at the facility for fuel (Figure 16, Table 8). The average price reported received for bark was \$15.00 per ton delivered.

Approximately 22 percent of engineered wood manufacturers' residues production were mixed residues (Table 7). Nearly 10,000 tons or 38 percent of mixed residues were sold to others for fuel, 9,700 tons or 36 percent were sent to landfills, 5,000 tons or 19 percent were landfilled at the facility, and 2,100 tons or 8 percent were disposed of by other methods (Figure 17, Table 8). The average price reported received for mixed residues was \$12.00 per ton delivered.

Nearly 22 percent of engineered wood manufacturers' residues production was sanderdust (Table 7). About 26,000 tons or 96 percent of sanderdust were used at the facility for fuel and 1,000 tons or 4 percent were sold to others as fuel (Figure 18, Table 8). The average price reported received for sanderdust was \$12.00 per ton delivered.

Approximately 9 percent of engineered wood manufacturers' residues production were coarse residues (Table 7). Nearly 6,000 tons or 55 percent of coarse residues were sold to composite manufacturers and 5,000 tons or 45 percent were used at the facility for fuel (Figure 19, Table 8). The average reported price received for coarse residues was \$12.00 per ton delivered.

Nearly 7 percent of engineered wood manufacturers' residues production were chips (Table 7). One hundred percent or 8,000 tons of chips were sold to pulp and paper manufacturers (Figure 20, Table 8). The average selling price for chips was not reported delivered.

Less than 1 percent of engineered wood manufacturers' residues production were other green and dry residues (Table 7). One hundred percent or 140 tons of other green and dry residues were sold to others as fuel (Figure 21, Table 8). The average selling price for other green and dry residues was not reported.

Thirty-one percent of engineered wood manufacturers' residues were disposed of by other methods, 20 percent were sold to others as fuel, 14 percent were used at the facility for fuel, 13 percent were sent to a landfill, 9 percent were sold to pulp or paper manufacturers, 6 percent were sold to composite manufacturers, 5 percent were landfilled at the facility, and 2 percent were sold to bark or mulch companies (Figure 22). "Other" disposal methods primarily included giving bark or mixed residues away to local citizens.

Approximately 46,000 tons or 38 percent of engineered wood manufacturers' residues were not utilized. Nearly 29,400 tons or 64 percent were coarse residues, 16,700 tons or 36 percent were mixed residues, and 2 tons or less than 0.1 percent was sawdust. Of this total, 29,400 tons or 64 percent were disposed of by other methods, 11,750 tons or 25 percent were sent to landfills, and 5,000 tons or 11 percent were landfilled at the facility.

Very nearly 50 percent of responding engineered wood manufacturers directed wood residues to landfills in 1996. Of this total, 66 percent reported lack of consistent markets for wood residues and 33 percent reported that a lack of wood recyclers in the region were the principal reasons for directing residues to landfills. Sixty-six percent directed residues to a municipal landfill and 33 percent directed residues to industrial landfills.

Nearly 17 percent of responding engineered wood manufacturers reported the lack of consistent markets for wood residues stopped daily production. Seventeen percent reported that wood residue disposal costs reduced daily production (as a result of high residue disposal costs) and 17 percent reported that disposal costs precluded plant expansion.

Paper Manufacturers

Virginia's responding paper manufacturers average 1996 production was reported as 515,000 tons per mill or 765 tons per employee, with a total reported production of 2.6 million tons (Table 9).

Responding paper manufacturers produced approximately 9 percent of Virginia's wood residues (Table 2). Paper manufacturers' bark production accounts for the largest percentage of wood residues, followed by scrap pallets. The estimated paper manufacturers' average residues haul distance to residue markets was 60 miles (one-way).

Paper manufacturers estimated total production was 6.1 million tons of paper and paper-based products. The estimated residue production was approximately 508,000 tons of bark and 70 tons of scrap pallets (Table 9).

Responding paper manufacturers reported producing approximately 214,000 tons of bark or 99.9 percent of total paper manufacturers' residues. Scrap pallet production was approximately 30 tons or 0.1 percent of total paper manufacturers' residues. These two residues constitute 100 percent of total wood residues produced by paper manufacturers (Table 9). Scrap pallets are pallets deemed not suitable for further use.

Approximately 139,000 tons or 65 percent of bark residues were sold to pulp or paper manufacturers for fuel, 41,300 tons or 19 percent were used at the facility for fuel, and 34,000 tons or 16 percent were sold to bark or mulch companies (Figure 23, Table 10). The average price reported received for bark was \$11.00 per ton delivered.

One hundred percent or 30 tons of scrap pallet residues were sold or given away to a wholesaler or broker (Figure 24, Table 10). One mill reported a disposal cost of \$12.00 per ton for scrap pallets.

Approximately 65 percent of pulp or paper manufacturers' residues were sold to pulp or paper manufacturers, 19 percent were sold to others as fuel, and 16 percent were utilized at the facility for fuel (Figure 25).

Responding paper manufacturers did not direct wood residues to landfills in 1996 or report wood residue disposal problems. Responding paper manufacturers reported that wood residue disposal did not restrict production and they did not experience associated disposal costs for wood residues.

Hardwood Plywood Manufacturers

The responding hardwood plywood manufacturers average 1996 production was approximately 27.2 million square feet and 307,600 board feet per mill, 224,700 square feet and 2,500 board feet per employee, with a total reported production of 163 million square feet and 1.85 million board feet of hardwood plywood (Table 11).

Responding hardwood plywood manufacturers reported production of other dry residues (end trims, edgings, blocks, cores, etc.) was 22,500 tons or nearly 39 percent of total hardwood plywood manufacturers' residues. Scrap pallet production was approximately 14,500 tons or 25 percent of total hardwood plywood manufacturers' residues. Mixed residue production was approximately 12,000 tons or 21 percent of total hardwood plywood manufacturers' residues. Coarse residue production was approximately 2,900 tons or 4.9 percent of total hardwood plywood manufacturers' residues. Sawdust production was approximately 2,100 tons or 3.7 percent of total hardwood plywood manufacturers' residues. These five residues constitute approximately 93 percent of total wood residues produced by hardwood plywood manufacturers (Table 11). The estimated hardwood plywood manufacturers' residues average haul distance to residue markets was 116 miles (one-way).

The estimated hardwood plywood manufacturers production was 297 million square feet and 3.4 million board feet of hardwood plywood. The estimated other dry residue production was 41,000 tons, 26,400 tons of scrap pallet residue, 22,000 tons of mixed residues, 5,200 tons of coarse residues, and 3,900 tons of sawdust in 1996 (Table 11).

Responding hardwood plywood manufacturers produced approximately 2 percent of Virginia's wood residues (Table 2). Hardwood plywood manufacturers' other green and dry residue production accounts for the largest percentage of wood residues, followed by scrap pallets, and mixed residues.

Nearly 39 percent of hardwood plywood manufacturers' residues production were other green and dry residues (Table 11). Approximately 11,000 tons or 49 percent of other dry residues were used at the facility for fuel, 10,900 tons or 48 percent were sold to others for fuel, and 675 tons or 3 percent were sent to landfills (Figure 26, Table 12). The responding companies did not report selling or disposal costs for other green and dry residues.

Twenty-five percent of hardwood plywood manufacturers' residues production was scrap pallets (Table 11). One hundred percent or 14,490 tons of scrap pallets were disposed of by other methods (Figure 27, Table 12). The average price reported received for scrap pallet residue was \$18.00 per ton delivered.

Nearly 21 percent of hardwood plywood manufacturers' residues were dry mixed residues (Table 11). Ninety-nine percent or 12,000 tons of dry mixed residues were sent to landfills and 125 tons or 1 percent were used at the facility for fuel (Figure 28, Table 12). The average price reported received for dry mixed residues was \$18.00 per ton delivered.

Approximately 5 percent of hardwood plywood manufacturers' residues were coarse residues (Table 11). Nearly 2,800 tons or 99 percent of coarse residues were used at the facility for fuel and 50 tons or 1 percent were landfilled at the facility (Figure 29, Table 12). The average price reported received for coarse residues was \$22.00 per ton delivered.

Nearly 4 percent of hardwood plywood manufacturers' residues was sawdust (Table 11). Approximately 1,200 tons or 57 percent of sawdust were used at the facility for fuel, 900 tons or 42 percent were sold to others as fuel, and 10 tons or less than 1 percent were sent to landfills (Figure 30, Table 12). The average price for sawdust disposal was \$9.00 per ton. The high price reported received for sawdust was \$7.00 per ton delivered.

Three and one-half percent of hardwood plywood manufacturers' residues were chips (Table 11). Approximately 1,100 tons or 54 percent of chips were used at the facility for fuel, 900 tons or 45 percent were sold to others as fuel, and less than 1 percent were sent to landfills (Figure 31, Table 12). The average reported price received for chips was \$22.00 per ton delivered.

Nearly 3 percent of hardwood plywood manufacturers' residues was sanderdust (Table 11). Nearly 900 tons or 55 percent of hardwood plywood manufacturers' sanderdust residues were used at the facility for fuel and 750 tons or 45 percent were sold to others as fuel (Figure 32, Table 12). The responding companies did not report selling or disposal costs for sanderdust.

Less than 1 percent of hardwood plywood manufacturers' residues were planer shavings (Table 11). One hundred percent or 250 tons of planer shavings were used at the facility for fuel (Figure 33, Table 12). The responding companies did not report selling or disposal costs for planer shavings.

Less than 1 percent of hardwood plywood manufacturers' residues was bark (Table 11). One hundred percent or 125 tons of bark were used at the facility for fuel (Figure 34, Table 12). The responding companies did not report selling or disposal costs for bark.

Approximately 30 percent of hardwood plywood manufacturers' residues were used at the facility for fuel, 25 percent were disposed of by other methods, 23 percent were used at the facility for fuel, and 22 percent were sent to a landfill (Figure 35). "Other" disposal methods include giving away residues to local citizens or farmers.

Nearly 47 percent or 27,000 tons of hardwood plywood manufacturers' residues were available for utilization. Approximately 14,500 tons or 53 percent were scrap pallets, 12,000 tons or 44 percent were mixed residues, 675 tons or 2.5 percent were other green and dry residues, and less than 1 percent were chips, coarse residues, and sawdust. Of this total, approximately 14,500 tons or 53 percent were disposed of by other methods, and 12,700 tons or 47 percent were directed to landfills.

Approximately 50 percent of responding hardwood plywood manufacturers directed wood residues to landfills in 1996. Of this total, 33 percent reported lack of consistent markets for wood residues, 33 percent reported that it was due to a lack of wood recyclers in the region, and 33 percent reported it was more economical to direct wood residues to landfills.

Responding hardwood plywood manufacturers reported that the disposal of wood residues and associated disposal costs did not hinder production.

Consumption, Production, and Current Markets, Secondary Manufacturers

Secondary manufacturers reported consuming approximately 333.6 million board feet of lumber, 18.3 million square feet of wood composite products, 561,600 tons of wood composite products, and 1.5 million lineal feet of wood products (Table 1). Responding secondary manufacturers produced approximately 20 percent or an estimated 1.1 million tons of Virginia's wood residues in 1996 (Table 2).

Rough Mill Operations

The responding rough mill operations average 1996 consumption was approximately 2.3 million board feet of lumber, 79,300 square feet of wood composite products, and 26,000 lineal feet of wood products per mill. The reported average consumption per employee was approximately 44,900 board feet of lumber, 1,550 square feet of wood composite products, and 507 lineal feet of wood products. The reported total consumption was approximately 132.7 million board feet of lumber, 4.6 million square feet of wood composite products, and 1.5 million lineal feet of wood products in 1996 (Table 13).

Responding rough mill operations reported producing approximately 71,900 tons of sawdust or 29 percent of total rough mill operations residues. Chip production was approximately 71,200 tons or 28 percent of total rough mill operations residues. Mixed residues production were approximately 51,000 tons or 20 percent of total rough mill operations residues. Planer shaving production was approximately 26,200 tons or 10 percent of total rough mill operations residues. Coarse residue production was approximately 20,900 tons or 8 percent of total rough mill operations residues. These six residues constitute approximately 97 percent of total wood residues produced by rough mill operations (Table 13). The estimated rough mill operations' residues average haul distance to residue markets was 74 miles (one-way).

Rough mills estimated total consumption was 388 million board feet of lumber, 13.4 million square feet of wood composite products, and 4.4 million lineal feet of wood products. Rough mills estimated residue production was approximately 210,000 tons of sawdust, 208,000 tons of chips, 149,500 tons of mixed residues, 77,000 tons of planer shavings, and 61,000 tons of coarse residues in 1996 (Table 13).

Responding rough mill operations produced approximately 13 percent of Virginia's wood residues (Table 2). Rough mill operations sawdust production accounts for the largest percentage of wood residues, followed by chips, and mixed residues.

Nearly 29 percent of rough mill operations residue production was sawdust (Table 13). Approximately 19,300 tons or 27 percent of sawdust were used at the facility for fuel, 14,500 tons or 20 percent were sold to others as fuel, 13,000 tons or 18 percent were sent to landfills, 11,100 tons or 15 percent were burned as waste, and 9,600 tons or 13 percent were sold to composite manufacturers (Figure 36, Table 14). The average reported price received for green and dry sawdust was \$4.00 per

ton. One responding rough mill reported a disposal cost of \$15.00 per ton for both green and dry sawdust delivered.

Approximately 28 percent of rough mill operations residues production were chips (Table 13). Approximately 35,000 tons or 49 percent of chips were sold to others as fuel, 26,000 tons or 36 percent were sold to pulp or paper manufacturers, and 8,000 tons or 11 percent were used at the facility for fuel (Figure 37, Table 14). Responding rough mill operations reported the average price received for chips was \$22.00 per ton delivered.

Approximately 20 percent of rough mill operations residues were green and dry mixed residues (Table 13). Sixty-one percent or 31,100 tons of dry mixed residues were sold to composite manufacturers, nearly 9,300 tons or 18 percent were disposed of by other means, 6,000 tons or 12 percent were sold as livestock bedding, 2,900 tons or 6 percent or were used at the facility for fuel, and 1,600 tons or 3 percent were burned as waste (Figure 38, Table 14). Responding rough mill operations reported the average price received for green and dry mixed residues was \$10.00 per ton delivered.

Approximately 10 percent of rough mill operations residues were dry planer shavings (Table 13). Nearly 11,400 tons or 44 percent of dry planer shavings were sold to composite manufacturers, 6,600 tons or 25 percent were sold as livestock bedding, 5,600 tons or 21 percent were sold or given away to a broker, and 2,500 tons or 10 percent were disposed of by other means (Figure 39, Table 14). Responding rough mill operations reported the average price received for dry planer shavings was \$21.00 per ton delivered.

Nearly 9 percent of rough mill operations residues were green and dry coarse residues (Table 13). Approximately 13,400 tons or 64 percent of green and dry coarse residues were used at the facility for fuel, 5,100 tons or 24 percent were sold to composite manufacturers, 900 tons or 4 percent were sold to others as fuel, and 70 tons or 3 percent were landfilled at the facility (Figure 40, Table 14). Responding rough mill operations reported the average price received for green and dry coarse residues was \$12.00 per ton delivered.

Approximately 3 percent of rough mill operations residues were bark residues (Table 13). Approximately 100 percent or 7,700 tons of bark were sold to bark or mulch companies (Figure 41, Table 14). Responding rough mill operations did not report selling or disposal prices for bark residues.

Less than 1 percent of rough mill operations residues were other dry residues (Table 13). Ninety-one percent or 1,700 tons of other dry residues were sent to a landfill and 9 percent were burned as waste (Figure 42, Table 14). Responding rough mill operations reported the average disposal cost for other dry and green residues was \$32.00 per ton delivered.

Less than 1 percent of rough mill operations residues were scrap pallets (Table 13). One hundred percent or 5 tons of scrap pallets were sent to landfills (Figure 43, Table 14). Responding rough mill operations reported average disposal costs were \$9.00 per ton for scrap pallets.

Less than 1 percent of rough mill operations residues was sanderdust (Table 13). Sixty-seven percent or 2 tons of sanderdust were sent to landfills and 1 ton or 33 percent was disposed of by other means (Figure 44, Table 14). The responding rough mill operations did not report selling or disposal costs for sanderdust.

Nearly 24 percent of rough mill operations wood residues were sold to composite manufacturers, 20 percent were sold as fuel, 17 percent were sold to others as fuel, 10 percent were sold to pulp or paper manufacturers, 7 percent were sold as livestock bedding, 6 percent were sent to landfills, 5 percent were burned as waste, 5 percent were disposed of by other disposal methods, 3 percent were sold to bark or mulch companies, 2 percent were sold or given away to a wholesaler or broker, and less than 1 percent were landfilled at the facility (Figure 45). "Other" disposal methods included giving away residues to customers for garden use, fuel, or livestock bedding.

Nearly 40,600 tons or 16 percent of rough mill operations residues were not utilized. Approximately 24,000 tons or 60 percent was sawdust, 11,000 tons or 27 percent were mixed residues, 2,500 tons or 6 percent were planer shavings, 1,900 tons or 5 percent were other green and dry residues, 700 tons or 1.7 percent were coarse residues, and the remaining percentage was comprised of bark, sanderdust, and scrap pallets. Of this total, approximately 25,000 tons or 37 percent were sent to landfills, 13,000 tons or 32 percent were burned as waste, 12,000 tons or 30 percent were disposed of by other means, and 700 tons or 1 percent were landfilled at the facility.

Approximately 38 percent of rough mill operations responding directed wood residues to landfills in 1996. Of this total, 41 percent reported it was more economical to direct wood residues to landfills, 36 percent reported that they directed residues to landfills because of a lack of wood recyclers in the region, and 27 percent reported this was due to a lack of consistent markets. Of this total, 73 percent directed wood residues to municipal, 14 percent to industrial, 9 percent to other (company), and construction and demolition landfills, respectively.

Nine percent of responding rough mill operations reported that the lack of markets for wood residues restricted company production. Of this total, 80 percent reported a reduction in production and 20 percent reported manufacturing operations were completely halted due to the lack of wood residue markets.

Nine percent of responding rough mill operations reported that the cost of wood residue disposal restricted company production. Of this total, 60 percent reported that daily production was reduced and 40 percent reported that production was stopped completely for a few days.

Pallet Manufacturers

The responding pallet manufacturers average 1996 consumption was approximately 4.4 million board feet of lumber and 16,000 square feet of wood composite products per mill. The reported pallet manufacturers average consumption per employee was approximately 116,400 board feet of lumber and 430 square feet of wood composite products. Pallet manufacturers total reported consumption was approximately 87.4 million board feet of lumber and 326,000 square feet of wood composites in 1996 (Table 15).

Pallet manufacturers reported producing approximately 32,000 tons of mixed residues or 28 percent of total pallet manufacturers' residues. Scrap pallet residue production was nearly 23,600 tons or 21 percent of total pallet manufacturers' residues. Sawdust production was approximately 23,300 tons or 20 percent of total pallet manufacturers' residues. Chip production was nearly 22,200 tons or 19 percent of total pallet manufacturers' residues. Bark production was approximately 7,400 tons or 6.5 percent of total pallet manufacturers' residues. These five residues constitute nearly 95 percent of the total wood residues produced by pallet manufacturers (Table 15). The estimated pallet manufacturers' residues average haul distance to residue markets was 59 miles (one-way).

Pallet manufacturers estimated total consumption was 164 million board feet of lumber and 611,000 square feet of wood composite products. Responding pallet manufacturers estimated mixed residue production was 60,100 tons, 44,300 tons of scrap pallets, 43,700 tons of sawdust, 41,800 tons of chips, and 14,000 tons of bark (Table 15).

Responding pallet manufacturers produced approximately 4 percent of Virginia's wood residues (Table 2). Pallet manufacturers' green mixed residue production accounts for the largest percentage of wood residues, followed by scrap pallets, and sawdust.

Nearly 28 percent of pallet manufacturers' residues production were green mixed residues (Table 15). Approximately 29,500 tons or 92 percent of green mixed residues were sold to others for fuel and 2,500 tons or 8 percent were burned as waste (Figure 46, Table 16). Responding pallet manufacturers reported average price received for green mixed residues was \$12.00 per ton delivered.

Approximately 21 percent of pallet manufacturers' residues were scrap pallets (Table 15). Nearly 19,600 tons or 83 percent of scrap pallets were sold to others as fuel, 2,600 tons or 11 percent were ground and sold as livestock bedding, 500 tons or 2 percent were used at the facility for fuel, 2 percent were sent to landfills, and less than 2 percent were disposed of by a combination of methods (Figure 47, Table 16). The responding pallet manufacturers reported the average price received for scrap pallets was \$5.00 per ton delivered.

Approximately 20 percent of pallet manufacturers' residues were sawdust (Table 15). Nearly 22,000 tons or 94 percent of sawdust were sold to others as fuel, 1,300 tons or 6 percent were sold as livestock bedding (Figure 48, Table 16). The responding pallet manufacturers average reported price received for sawdust was \$8.00 per ton delivered.

Approximately 20 percent of pallet manufacturers' residue production were chips (Table 15). Nearly 21,000 tons or 95 percent of chips were sold to pulp or paper manufacturers and 1,200 tons or 5 percent were sold to others as fuel (Figure 49, Table 16). Responding pallet manufacturers did not report a price for chips.

Approximately 6 percent of pallet manufacturers' residues were bark residues (Table 15). Nearly 3,800 tons or 52 percent of bark residues were sold to others as fuel, 3,000 tons or 40 percent were sold to bark or mulch companies, and 600 tons or 8 percent were used at the facility for fuel (Figure 50, Table 16). The responding pallet manufacturers reported average price received for bark was \$11.00 per ton delivered.

Nearly 2 percent of pallet manufacturers' residues were green planer shavings (Table 15). Approximately 100 percent or 2,700 tons of planer shavings were sold to composite manufacturers (Figure 51, Table 16). The responding pallet manufacturers reported average price for planer shavings was \$18.00 per ton delivered.

Approximately 2 percent of pallet manufacturers' residues were other dry residues (Table 15). Approximately 2,000 tons or 76 percent of other residues were sold to others as fuel and 620 tons or 24 percent were disposed of by other means (Figure 52, Table 16). The responding pallet manufacturers reported average price received for other dry residues was \$12.00 per ton delivered.

Nearly 69 percent of pallet manufacturers' wood residues were sold as fuel, 18 percent were sold to pulp or paper manufacturers, 3 percent was ground and sold livestock bedding, 3 percent were sold to bark or mulch companies, 2 percent were sold to composite manufacturers, 2 percent were burned as waste, and less than 1 percent were sent to landfills (Figure 53).

Approximately 3,750 tons or 3 percent of pallet manufacturers' residues were not utilized. Nearly 2,500 tons or 67 percent were mixed residues, 625 tons or 17 percent were scrap pallets, and 620 tons or 16 percent were other green and dry residues.

Of this total, approximately 2,500 tons or 67 percent were burned as waste, 720 tons or 19 percent were disposed of by other methods, and 500 tons or 13 percent were sent to landfills. "Other" disposal methods included giving away residues to local citizens or residues were sold as firewood.

Approximately 15 percent of pallet manufacturers responding directed wood residues to landfills in 1996. Of this total, 33 percent reported it was more economical to direct wood residues to landfills, 33 percent reported that they directed residues to landfills because of a lack of wood recyclers in the region, and 33 percent reported this was due to a lack of consistent markets for wood residues. Of this total, 66 percent directed wood residues to municipal and 33 percent to industrial landfills, respectively.

Responding pallet manufacturers reported that wood residue disposal and associated disposal costs did not hinder production.

Furniture Manufacturers

The responding furniture manufacturers average 1996 reported consumption was approximately 1.7 million board feet of lumber, 292,600 square feet of wood composites, and 2,400 tons of wood composite products per mill. The responding furniture manufacturers average reported consumption was approximately 5,100 board feet of lumber per employee, 859 square feet of wood composites per employee, and 7 tons of wood composite products per employee. The responding furniture manufacturers total reported consumption was 45 million board feet of lumber, 7.6 million square feet of wood composites, and 63,500 tons of wood composite products (Table 17).

Furniture manufacturers reported producing approximately 46,400 tons of mixed residues or 90 percent of total furniture manufacturers' residues, 2,000 tons of sawdust or 4 percent of total

furniture manufacturers' residues, 1,200 tons of planer shavings or 2 percent of total furniture manufacturers' residues. These three residues constitute approximately 96 percent of total wood residues produced by furniture manufacturers (Table 17). The estimated furniture manufacturers' residues average haul distance to residue markets was 15 miles (one-way).

Furniture manufacturers consumed an estimated 101 million board feet of lumber, 17 million square feet of wood composites, and 138,700 tons of composite wood products in 1996. Responding furniture manufacturers produced an estimated 104,000 tons of mixed residues, 4,200 tons of sawdust, and 2,800 tons of planer shavings in 1996 (Table 17).

Responding furniture manufacturers produced 2 percent of Virginia's wood residues (Table 2). Furniture manufacturers' green and dry mixed residue production accounts for the largest percentage of wood residues, followed by green and dry planer shavings, and sanderdust.

Nearly 90 percent of furniture manufacturers' residue production were green and dry mixed residues (Table 17). Approximately 33,300 tons or 72 percent of mixed residues were used at the facility for fuel, 6,200 tons or 13 percent were sold or given away to a broker or wholesaler, 5,800 tons or 12 percent were sold to others for fuel, and 960 tons or 2 percent were sold to composite manufacturers, and 40 tons or less than 1 percent were disposed of by a combination of methods (Figure 54, Table 18). The responding furniture manufacturers reported average price received for green and dry mixed residues was \$23.00 per ton delivered.

Approximately 4 percent of furniture manufacturers' residues were sawdust (Table 17). Nearly 1,200 tons or 65 percent of sawdust were used at the facility for fuel, 500 tons or 27 percent were sold to others as fuel, and 140 tons or 7 percent were sold to composite manufacturers (Figure 55, Table 18). The responding furniture manufacturers reported the average price for sawdust was \$14.00 per ton delivered.

Approximately 2 percent of furniture manufacturers' residues were green and dry planer shavings (Table 17). Nearly 1,100 tons or 89 percent of planer shavings were used at the facility for fuel, 120 tons or 10 percent were sold to pulp or paper manufacturers, and 19 tons or 2 percent were disposed of by other methods (Figure 56, Table 18). Responding furniture manufacturers did not report a price for green planer shavings.

Less than 2 percent of furniture manufacturers' residue production was sanderdust (Table 17). Nearly 770 tons or 90 percent of sanderdust were used at the facility for fuel and 85 tons or 10

percent were sold to pulp or paper manufacturers (Figure 57, Table 18). Responding furniture manufacturers did not report a price for sanderdust.

Less than 2 percent of furniture manufacturers' residues were chips (Table 17). One hundred percent or 690 tons of chips were used at the facility for fuel (Figure 58, Table 18). Responding furniture manufacturers did not report a price for chips.

Less than 1 percent of furniture manufacturers' residues were dry coarse residues (Table 17). Approximately 180 tons or 87 percent of coarse residues were sold to others as fuel, 20 tons or 11 percent were disposed of by other methods, and 2 percent were landfilled at the facility (Figure 59, Table 18). Responding furniture manufacturers did not report a price for dry coarse residues.

Less than 1 percent of furniture manufacturers' residues was bark (Table 17). One hundred percent or 124 tons of bark were sold to bark or mulch companies (Figure 60, Table 18). Responding furniture manufacturers did not report a price for bark.

Less than 1 percent of furniture manufacturers' residues were other dry residues (Table 17). One hundred percent or 3 tons of other residues were disposed of by other means (Figure 61, Table 18). The responding furniture manufacturers reported the average disposal cost for other dry residues was \$4.00 per ton delivered.

Less than 1 percent of furniture manufacturers' residues were scrap pallets (Table 17). Thirty-three percent or 7 tons of scrap pallets were used at the facility for fuel, 7 tons or 33 percent 33 percent were burned as waste, 6 tons or 29 percent were sent to landfills, and 5 percent were disposed of by other means (Figure 62, Table 18). Responding furniture manufacturers did not report a price for scrap pallets.

Nearly 70 percent of furniture manufacturers' wood residues were used as fuel for the facility, 13 percent were sold to others as fuel, 12 percent were given or sold to brokers or wholesalers, 2.5 percent were sold to composite manufacturers, 1.5 percent were burned as waste, and less than 1 percent were sold to bark or mulch companies, sent to landfills, or disposed of by other methods (Figure 63). "Other" disposal methods included giving away residues to local citizens.

Less than 1-percent (0.2) or 103 tons of furniture manufacturers' residues were available for utilization. Nearly 37 tons or 36 percent were mixed residues, 26 tons or 25 percent were coarse residues, 19 tons or 18 percent were planer shavings, 19 tons or 14 percent were scrap pallets, 3 tons or 3 percent were other green and dry residues, and 2 tons or 2 percent were sanderdust and sawdust, respectively.

Approximately 31 percent of furniture manufacturers responding directed wood residues to landfills in 1996. Of this total, 42 percent reported it was due to wood contamination (nails, resins, and coatings), insufficient volume, fines, or buyer quotas. Twenty-five percent reported that they directed residues to landfills because of a lack of wood recyclers in the region, and 13 percent reported it was more economical to direct wood residues to landfills. Of this total, 42 percent directed wood residues to municipal, and 12.5 percent to industrial, company, and construction and demolition landfills, respectively.

Approximately 4 percent of responding furniture manufacturers reported that wood residue disposal cost restricted production due to associated trucking costs.

Responding furniture manufacturers reported a lack of markets for wood residues did not hinder production.

Housing Manufacturers

The responding housing manufacturers reported 1996 average consumption was approximately 1.4 million board feet of lumber and 17,600 square feet of wood composite products per mill. Responding housing manufacturers reported consumption was approximately 30,900 board feet of lumber and 400 square feet of wood composite products per employee. The responding housing manufacturers total reported consumption was approximately 25 million board feet of lumber and 317,000 square feet of wood composite products (Table 19).

Responding housing manufacturers reported producing approximately 2,100 tons of other dry residues (end trims, edgings, blocks, cores, etc.) or 41 percent of total housing manufacturers' residues. Chip production was approximately 1,900 tons or 36 percent of total housing manufacturers' residues. Mixed residue production was 745 tons or approximately 14 percent of total housing manufacturers' residues. Coarse residue production was approximately 190 tons or 4 percent of total housing manufacturers' residues. These four residues constitute approximately 95 percent of total wood residues produced by housing manufacturers (Table 19). The estimated housing manufacturers' residues average haul distance to residue markets was 77 miles (one-way).

Housing manufacturers total estimated consumption was approximately 91.1 million board feet of lumber and 1.2 million square feet of wood composite products in 1996. Housing

manufacturers estimated other dry residue production was 8,100 tons, 7,200 tons of chips, 2,800 tons of mixed residues, and 700 tons of coarse residues were produced in 1996 (Table 19).

Responding housing manufacturers produced less than 1 percent of Virginia's wood residues (Table 2). Housing manufacturers' other dry residue production accounts for the largest percentage of wood residues, followed by chips, and dry mixed residues.

Nearly 41 percent of housing manufacturers' residue production were other dry residues (Table 19). Approximately 2,000 tons or 94 percent of other residues were sent to landfills, 116 tons or 5 percent were disposed of by other methods, and 15 tons or less than 1 percent were used at the facility for fuel (Figure 64, Table 20). Responding housing manufacturers did not report a price for other dry residues.

Approximately 36 percent of housing manufacturers' residues were chips (Table 19). Nearly 53 percent or 1,000 tons of chips were sold to others for fuel, 700 tons or 37 percent were sent to landfills, 160 tons or 8 percent were sold or given away to wholesalers or brokers, and 2 percent were used at the facility for fuel (Figure 65, Table 20). The responding housing manufacturers reported average price for chips was \$13.00 per ton delivered.

Approximately 14 percent of housing manufacturers' residues were dry mixed residues (Table 19). Eighty-eight percent or 660 tons of mixed residues were sent to landfills, 50 tons or 7 percent were disposed of by other methods, and 40 tons or 5 percent were burned as waste (Figure 66, Table 20). The responding housing manufacturers average reported price for dry mixed residues was \$3.00 per ton delivered.

Approximately 4 percent of housing manufacturers' residue production were dry coarse residues (Table 19). Nearly 150 tons or 80 percent of coarse residues were sold to composite manufacturers, 30 tons or 17 percent were disposed of by other methods, and 6 tons or 3 percent were used at the facility for fuel (Figure 67, Table 20). The responding housing manufacturers reported average price received for dry coarse residues was \$10.00 per ton delivered.

Nearly 2 percent of housing manufacturers' residues were dry planer shavings (Table 19). Fifty tons or 50 percent of planer shavings were sold to composite manufacturers and 50 tons or 50 percent were disposed of by other methods (Figure 68, Table 20). The responding housing manufacturers reported average price reported for dry planer shavings was \$10.00 per ton delivered.

Less than 2 percent of housing manufacturers' residues was dry sawdust (Table 19). Approximately 60 tons or 74 percent of sawdust were sold to composite manufacturers, 15 tons or 19

percent were sent to landfills, and 6 tons or 7 percent were used at the facility for fuel (Figure 69, Table 20). Responding housing manufacturers did not report a price for dry sawdust.

One percent of housing manufacturer's residues was green sanderdust (Table 19). One hundred percent or 50 tons of sanderdust were burned as waste (Figure 70, Table 20). Responding housing manufacturers did not report a price for green sanderdust.

Nearly 65 percent of housing manufacturers' wood residues were sent to landfills, 19 percent were sold to composite manufacturers, 5 percent were sold to pulp or paper manufacturers, 5 percent were disposed of by other means, 3 percent were given away or sold to brokers or wholesalers, 2 percent were burned as waste, and 1 percent were used as fuel at the facility (Figure 71). "Other" disposal methods included giving residues away to local citizens or employees, selling residues to landscape contractors, or they were utilized for livestock bedding.

Approximately 3,700 tons or 71 percent of housing manufacturer's residues were not utilized. Nearly 2,100 tons or 57 percent were other green and dry residues, 750 tons or 20 percent were mixed residues, 700 tons or 19 percent were chips, and 147 tons or 4 percent consisted of planer shavings, sawdust, coarse residues, and sanderdust. Of this total, nearly 3,400 tons or 91 percent were directed to landfills, 250 tons or 7 percent were disposed of by other methods, and 9 tons or 2 percent were burned as waste.

Approximately 61 percent of responding housing manufacturers directed wood residues to landfills in 1996. Of this total, 32 percent reported that they directed residues to landfills because of a lack of wood recyclers in the region, 27 percent reported it was due to wood contamination (nails and mixed with other non-wood residues), 18 percent reported it was more economical to direct wood residues to landfills, and 18 percent reported it was due to a lack of markets for wood residues. Of this total, 100 percent directed wood residues to municipal landfills.

Responding housing manufacturers reported that a lack of wood residue markets or associated disposal costs did not hinder production.

Other Manufacturers

“Other” manufacturers included firms that produced chips, mulch, posts and pilings, travel trailers, steam, electricity, novelties, pipe organs, handles, wood preservers, or they repaired boats.

The responding other manufacturers reported 1996 average consumption was approximately 1.7 million board feet of lumber, 211,500 square feet of wood composites, and 19,100 tons of wood composite products per mill. Responding other manufacturers reported consuming approximately 42,000 board feet of lumber, 5,300 square feet of wood composites, and 480 tons of wood composite products per employee. The responding other manufacturers reported consumption was approximately 43.7 million board feet of lumber, 5.5 million square of wood composites, and 498,000 tons of wood composite products in 1996 (Table 21).

Other manufacturers reported producing approximately 21,000 tons of other green and dry residues (end trims, edgings, blocks, cores, etc.) or 38 percent of total other manufacturers’ residues. Scrap pallet production was approximately 17,000 tons or 31 percent of total other manufacturers’ residues. Chip production was approximately 6,100 tons or 11 percent of total other manufacturers’ residues. Sawdust production was approximately 3,800 tons or 7 percent of total other manufacturers’ residues. Bark production was approximately 2,800 tons or 5 percent of total other manufacturers’ residues. These five residues constitute approximately 92 percent of total wood residues produced by other manufacturers (Table 21). The estimated other manufacturers’ residues average haul distance to residue markets was 72 miles (one-way).

Other manufacturers estimated total consumption was 51.2 million board feet of lumber, 6.4 million square feet of wood composites, and 584,000 tons of wood composite products. Other manufacturers estimated residue production was 24,900 tons of other green and dry residues, 20,000 tons of scrap pallets, 7,200 tons of chips, 4,400 tons of sawdust, and 3,300 tons of bark (Table 21).

Responding other manufacturers produced approximately 1 percent of Virginia’s wood residues (Table 2). Other manufacturers’ other green and dry residues production accounts for the largest percentage of wood residues followed by scrap pallets, and green chips.

Approximately 38 percent of other manufacturer’s residues were other green and dry residues (Table 21). Nearly 10,000 tons or 47 percent of other residues were sold to others for fuel, 5,000 tons or 24 percent were landfilled at the facility, 5,000 tons or 24 percent were sold or given away to wholesalers or brokers, and 1,200 tons or 5 percent were used at the facility for fuel (Figure 72, Table

22). The responding other manufacturers average price reported received for other dry residues was \$10.00 per ton and \$5.00 per ton for other green residues delivered.

Nearly 31 percent of other manufacturers' residue production were scrap pallets (Table 21). Fifty percent or 8,500 tons of scrap pallets were sold to others as fuel, 4,250 tons or 25 percent were used at the facility for fuel, and 4,250 tons or 25 percent were sold or given away to wholesalers or brokers (Figure 73, Table 22). The responding other manufacturers reported average price received for scrap pallets was \$15.00 per ton delivered.

Approximately 11 percent of other manufacturers' residues were green chips (Table 21). Nearly 4,000 tons or 65 percent of green chips were sold to others as fuel, 1,100 tons or 19 percent were sold to pulp or paper manufacturers, and 950 tons or 16 percent were used at the facility for fuel (Figure 74, Table 22). The responding other manufacturers reported average price received for dry chips was \$2.00 per ton delivered. The responding other manufacturers reported average price reported received for green chips was \$12.00 per ton delivered.

Approximately 7 percent of other manufacturers' residue production were green and dry sawdust (Table 21). Nearly 3,000 tons or 80 percent of sawdust were sold to others as fuel, and 750 tons or 20 percent were disposed of by other means (Figure 75, Table 22). The responding other manufacturers reported an average disposal cost for dry sawdust was \$15.00 per ton. The responding other manufacturers reported average price received for green sawdust was \$8.00 per ton delivered.

Five percent of other manufacturers' residues were bark (Table 21). One hundred percent or 2,775 tons of bark were sold to bark or mulch companies (Figure 76, Table 22). The other manufacturers reported the average price for bark was \$7.00 per ton delivered.

Approximately 3 percent of other manufacturers' residues were green and dry coarse residues (Table 21). Approximately 1,200 tons or 74 percent of coarse residues were sold to others as fuel, 325 tons or 20 percent were used at the facility for fuel, 60 tons or 4 percent were burned as waste, and 2 percent or 40 tons were sent to landfills (Figure 77, Table 22). The other manufacturers reported the average price for green coarse residues was \$5.00 per ton delivered.

Nearly 3 percent of other manufacturers' residues were green and dry planer shavings (Table 21). Approximately 100 percent or 1,550 tons of planer shavings were sold as livestock bedding (Figure 78, Table 22). The other manufacturers reported the average price for green planer shavings was \$16.00 per ton delivered. The other manufacturers reported the average price for dry planer shavings was \$20.00 per ton delivered.

Approximately 2 percent of other manufacturers' residues were green mixed residues (Table 21). Seventy-seven percent or 837 tons of green mixed residues were sold to others as fuel, 225 tons or 21 percent were sold to pulp or paper manufacturers, and 25 tons or 2 percent were sold as livestock bedding (Figure 79, Table 22). The other manufacturers reported the average price for green mixed residues was \$1.00 per ton delivered.

Nearly 65 percent of other manufacturers' wood residues were sent to landfills, 20 percent were sold to composite manufacturers, 5 percent were sold to pulp or paper manufacturers, 5 percent were disposed of by other means, 3 percent were given away or sold to brokers or wholesalers, 2 percent were burned as waste, and 2 percent were used as fuel for the facility (Figure 80). "Other" disposal methods included giving away residues to farmers or customers for garden use.

Nearly 5,100 tons or 9 percent of other manufacturers' residues were available for utilization. Approximately 5,000 tons or 97 percent were other green and dry residues, 100 tons or 2 percent were coarse residues, 30 tons or less than 1 percent were sawdust, and 5 tons or less than 0.1 percent were planer shavings. Of this total, approximately 5,000 tons or 97 percent were landfilled at the facility, 60 tons or 1 percent were burned as waste 48 tons or , less than 1 percent were directed to landfills, and 25 tons or less than 1 percent were disposed of by other methods.

Approximately 23 percent of responding other manufacturers directed wood residues to landfills in 1996. Of this total, 66 percent reported that they directed residues to landfills because of a lack of markets for wood residues, 17 percent reported it was more economical to direct wood residues to landfills, and 17 percent reported it was due to a lack of recyclers in the region. Of this total, 50 percent directed wood residues to municipal landfills, 33 percent to company landfills, and 13 percent to construction and demolition landfills.

Responding other manufacturers reported a lack of markets and disposal costs did not hinder production.

Conclusions

This study sought to quantify the volume and types of wood residues generated by Virginia wood product manufacturers in 1996. Three primary wood residues were produced in 1996: chips, bark, and sawdust. The estimated green and dry chip residue production was 2.2 million tons or 38 percent of the total wood residues produced by primary and secondary manufacturers in 1996. The

estimated bark production was 1.3 million tons or 23 percent, with green and dry sawdust 1.2 million tons or 22 percent of the total wood residues produced by primary and secondary manufacturers in 1996. These three residues comprised approximately 83 percent or 4.7 million tons of the estimated wood residues produced by primary and secondary manufacturers in 1996 (Table 23).

Our estimates indicate that hardwood sawmills (primary manufacturer) produced an estimated 2.3 million tons or 39 percent of Virginia's total wood residues produced in 1996 (Table 2). This included a reported average production of 7,175 tons of chippables (slabs, edgings or material large enough to merit size reduction before further utilization), 4,626 tons of sawdust, and 3,512 tons of bark per responding mill. The Tennessee Valley Authority (TVA 1984) developed conversion factors for estimating hardwood sawmill wood residues. Utilizing TVA conversion factors, hardwood sawmills producing 5.3 million board feet of hard hardwood annually should produce approximately 8,100 tons of bark, 7,100 tons of chippables, and 2,650 tons of sawdust annually. Hardwood sawmills utilizing soft hardwoods should produce approximately 5,600 tons of bark, 4,800 tons of chippables, and 2,750 tons of sawdust annually. Both estimates are based on an average sawlog diameter of 12-inches, green weight, and utilization of a circle saw, edger, and trimmer.

In addition, chippables average 30 to 40 percent (percentage volume basis), bark 8 to 12 percent, and sawdust 11 to 15 percent (White 1997). Our hardwood sawmill estimates indicate that chippables were approximately 24 percent, bark 11 percent, and sawdust 14.5 percent, respectively, of the total hardwood sawmill residue volume produced in 1996. Our estimates fall within the suggested ranges of volumetric residue production. However, one should note the hardwood sawmill chippables percentage (24 percent), is significantly lower than expected. The decrease in chippable volume can probably be attributed to hardwood sawmill operators' efforts to increase recovery and ultimately increase yield. May and Barrett (1970) estimated 255,000 tons of sawdust and 156,000 tons of chippables produced by Virginia hardwood sawmills were not utilized in 1970.

Our estimates indicate that pine sawmills (primary manufacturer) produced an estimated 1.5 million tons or 27 percent of Virginia's total wood residues produced in 1996 (Table 2). Utilizing TVA (1984) conversion factors, pine sawmills producing approximately 10.3 million board feet of pine lumber annually should produce approximately 4,300 tons of bark, 12,150 tons of chippables, and 9,500 tons of sawdust annually. Our pine sawmill estimates indicate that chippables were approximately 17,650 tons or 33 percent, bark 3,650 tons or 11 percent, and sawdust 6,450 tons or 11

percent, respectively of the total pine sawmill residue volume produced in 1996. Our pine sawmill estimates fall within the estimated ranges of volumetric residue production.

Our study indicates that hardwood and pine sawmills combined, appear to have approximately 69,000 tons of wood residues without adequate markets. May and Barrett (1970) estimated chippables, bark, and sawdust (produced by hardwood and pine sawmills) had approximately 633,000 tons without adequate markets in 1970.

Primary manufacturers also included engineered wood, hardwood plywood, and paper manufacturers, who produced nearly 708,000 tons or 13 percent of the total estimated wood residues. Primary manufacturers produced approximately an estimated 4.5 million tons or 80 percent of Virginia's wood residues in 1996 (Table 2).

Hardwood sawmills appear to have inadequate markets for approximately 66,000 tons, pine sawmills 2,700 tons, engineered wood manufacturers 46,600 tons, and hardwood plywood manufacturers 27,600 tons of wood residues. Primary manufacturers disposed of inadequate market residues by utilizing other disposal methods for approximately 105,400 tons, sending 30,700 tons to landfills, landfilling 5,800 tons at the facility, and burning 980 tons.

Based on volume, hardwood sawmills appear to have the most difficulty in acquiring adequate markets for their wood residues. However, hardwood plywood and engineered wood manufacturers, on a percentage basis, appear to have inadequate markets for 38 and 46 percent, respectively, of their wood residues produced in 1996.

Our study indicates that secondary manufacturers, which included roughmill operations, pallet, furniture, other, and housing manufacturers produced approximately an estimated 1.1 million tons or 20 percent of Virginia's wood residues in 1996 (Table 2).

Rough mill operations appear to have inadequate markets for approximately 40,600 tons, pallet manufacturers 3,750 tons, furniture manufacturers 100 tons, housing manufacturers 3,700 tons, and other manufacturers 5,100 tons. Secondary manufacturers disposed of inadequate market residues by sending approximately 19,000 tons to landfills, burning 15,600 tons, utilizing other disposal methods for 12,900 tons, and landfilling 5,700 tons at the facility.

Based on volume, rough mill operations appear to have the most difficulty in acquiring adequate markets for their wood residues. However, housing manufacturers, on a percentage basis, appear to have inadequate markets for 71 percent of their wood residues produced in 1996.

The first objective of this study was to quantify the amount of wood residues produced by Virginia's wood product manufacturers that enter waste handling facilities or are available for utilization. Virginia's primary and secondary wood product manufacturers disposed of inadequate market residues by sending 49,700 tons to landfills, landfilling 11,500 tons at the facility, burning 16,900 tons, and utilizing other disposal methods for approximately 118,300 tons.

The second objective of this study was to evaluate the current markets for Virginia's wood residues. This study indicates that pulp and paper manufacturers consume approximately 50 percent of Virginia's wood residues. Fuel markets and fuel used for the facility (19 percent), mulch or bark companies (10 percent), composite manufacturers (9 percent), livestock bedding (4 percent), and combinations of other disposal methods constitutes the remaining 8 percent or market share of Virginia's wood residues (Figure 81).

This research indicates that approximately 200,000 tons or 6 percent of the reported wood residue production in Virginia appears not to have adequate markets. Responding primary manufacturers report having approximately 143,000 tons of wood residues without adequate markets and responding secondary manufacturers have nearly 53,000 tons of wood residues without adequate markets.

Virginia's wood product manufacturers reported receiving approximately \$44.1 million dollars for their wood residues in 1996. Virginia's responding wood product manufacturers reported receiving approximately \$23 million dollars for chips, \$8.2 million dollars for bark, \$5.1 million dollars for sawdust, \$3.4 million dollars for planer shavings, \$2.6 million dollars for mixed residues, \$630 thousand dollars for scrap pallets, \$480 thousand dollars for coarse residues, \$320 thousand dollars for sanderdust, and \$190 thousand dollars for other residues (Table 24).

We estimate, in 1996, Virginia's wood product manufacturers received nearly \$83 million dollars for their wood residues. This includes approximately \$41.8 million for chips, \$16.9 million for bark, \$9.7 million for sawdust, \$6.0 million for planer shavings, \$5.6 million for mixed residues, \$1.2 million for coarse residues, \$774 thousand dollars for scrap pallets, \$605 thousand for sanderdust, and \$242 thousand dollars for other residues (Figure 82).

Primary manufacturers reported receiving approximately \$38.6 million dollars for their wood residues in 1996. Primary manufacturers reported receiving approximately \$21.4 million dollars for chips, \$8.1 million for bark, \$4.6 million for sawdust, \$2.8 million for planer shavings, \$660

thousand dollars for mixed residues, \$320 thousand dollars for sanderdust, \$261 thousand dollars for scrap pallets, and \$200 thousand dollars for coarse residues (Table 25).

Primary manufacturers reported receiving approximately \$19.00 dollars per ton for chips, \$13.00 dollars per ton for bark, \$8.50 dollars per ton for sawdust, \$12.60 dollars per ton for mixed residues, \$12.00 per ton for coarse residues, \$30.60 dollars per ton for planer shavings, \$18.00 dollars per ton for scrap pallets, and \$11.00 dollars per ton for sanderdust.

Secondary manufacturers reported receiving approximately \$5.7 million dollars for their wood residues in 1996. Secondary manufacturers reported receiving approximately \$2 million for mixed residues, \$1.7 million dollars for chips, \$625 thousand dollars for planer shavings, \$530 thousand dollars for sawdust, \$370 thousand dollars for scrap pallets, \$260 thousand dollars for coarse residues, \$187 thousand dollars for other residues, and \$100 thousand dollars for bark (Table 26).

Secondary manufacturers reported receiving approximately \$16.00 dollars per ton for chips, \$5.60 dollars per ton for bark, \$5.00 dollars per ton for sawdust, \$15.00 dollars per ton for mixed residues, \$11.00 per ton for coarse residues, \$20.00 dollars per ton for planer shavings, \$9.00 dollars per ton for scrap pallets, and \$11.00 dollars per ton for other residues.

Several opportunities appear to exist for Virginia's wood product manufacturers of wood residues. We found a developing trend towards fingerjointing large, green wood residues for millwork products. If manufacturers are not interested in acquiring the equipment necessary for fingerjointing, they should explore markets that utilize larger sized wood residues in fingerjoint production (e.g., endtrims, blocks, and scrap pallets). This research indicates that dry planer shavings received the highest delivered prices, approximately \$25.00 per ton in 1996. Wood product manufacturers should consider processing their large wood residues to meet planer shaving requirements if other markets are not available for their wood residues. Virginia has large poultry and equine markets that utilize substantial volumes of planer shavings for bedding. The pellet fuel and fuel markets are expanding in the region and these industries utilize substantial volumes of sawdust and/or fines in their manufacturing operations.

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Table 1. Summary Totals of Virginia Respondents

Mill Type	Number of Mills	Estimated Employment by SIC Code	Number of Respondent Employees	Reported Total Production ¹	Average Production per Mill	Average Production per Employee
Hardwood Sawmills ²	65	3,151	1,497	347,780,986 bf	5,350,477 bf	232,319 bf
Pine Sawmills ³	36	1,609	1,090	370,532,379 bf	10,292,566 bf	339,938 bf
Engineered Wood Manufacturers ⁴	6	1,689	903	514,648,895 ft ² 105,000 lf	85,774,816 bf 17,500 lf	569,932 bf 116 lf
Hardwood Plywood Manufacturers ⁵	6	1,321	726	163,126,441 ft ² 1,845,533 bf	27,187,740 ft ² 307,589 bf	224,692 ft ² 2,542 bf
Paper Mills	5	7,981	3,367	2,574,500 tons	514,900 tons	764 tons
Mill Type	Number of Mills	Estimated Employment by SIC Code	Number of Respondent Employees	Reported Total Consumption ¹	Average Consumption per Mill	Average Consumption per Employee
Rough Mill Operations ⁶	58	8,643	2,956	132,680,074 bf 4,599,623 ft ² 1,500,000 lf	2,287,587 bf 79,304 ft ² 25,862 lf	44,885 bf 1,556 ft ² 507 lf
Pallet Manufacturers	20	1,409	751	87,401,154 bf 325,872 ft ²	4,370,058 bf 16,294 ft ²	116,380 bf 433 ft ²
“Other” Manufacturers ⁷	26	1,224	1,045	43,703,742 bf 498,057 tons 5,500,000 ft ²	1,680,913 bf 19,156 tons 211,538 ft ²	41,822 bf 477 tons 5,263 ft ²
Furniture Manufacturers	26	19,816	8,852	45,156,719 bf 7,607,382 ft ² 63,546 tons	1,736,797 bf 292,592 ft ² 2,444 tons	5,101 bf 859 ft ² 7 tons
Housing Manufacturers ⁸	18	2,951	800	24,693,000 bf 317,624 ft ²	1,371,833 bf 17,626 ft ²	30,866 bf 397 ft ²

1. bf-board feet, ft²-square feet, lf-lineal feet

2. Pine sawmills produced approximately 8 percent of the hardwood total.

3. Hardwood sawmills produced approximately 5 percent of the pine total.

4. Engineered wood manufacturers included: hardboard, laminated veneer lumber, oriented strandboard, and particleboard.

5. Hardwood plywood manufacturers included: hardwood plywood, face grade veneers, and veneer.

6. Rough mill operations included: box springs, cabinets and cabinet components, doors, edge glued panels, flooring, furniture parts, laminated furniture parts, millwork, and timbers.

7. “Other” manufacturers included: mulch, chip, post, piling, steam, travel trailers, novelties, electricity, pipe organ, handle, stake manufacturers, boat repairing, wood preservers, and building supplies.

8. Housing manufacturers included: log homes, modular housing, post frame buildings, prefabricated wall panels, trusses, and utility buildings.

Table 2. Total Estimated Virginia Residues Produced by SIC Code^{1,2}

Primary Manufacturers (SIC Code)	Estimated Production (Tons)	Percentage of All Estimated Wood Residues
Hardwood Sawmills 2421	2,297,149	39.4%
Pine Sawmills 2421	1,549,144	26.6%
Engineered Wood Manufacturers 2493	226,309	3.9%
Hardwood Plywood Manufacturers 2435	105,650	1.8%
Paper Manufacturers 2621, 2631	507,663	8.7%
Secondary Manufacturers		
Rough Mill Operations 2431, 2434, 2426	733,816	12.6%
Pallet Manufacturers 2448	213,905	3.7%
Other Manufacturers 5211, 2429, 2499	64,662	1.1%
Furniture Manufacturers 2511, 2512, 2519, 2521, 2531, 2599	115,297	2.0%
Housing Manufacturers 2451, 2452, 2439	19,772	0.3%
Total	5,758,622	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

Table 3. Virginia Hardwood Sawmill Production and Estimated Production

Product Type	Reported Total Production¹	Mill Average	Average per Employee	Estimated Production²	
Hardwood lumber	347,780,986 bf	5,350,477 bf	232,109 bf	772,102,000 bf	
Residue Type (Tons)	Reported Total Production¹	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Green chips	464,671	7,149	310.4	1,031,607	44.9%
Green coarse residues	1,846	28.4	1.2	4,098	0.2%
Green sawdust	300,721	4,626	201	667,625	29.1%
Green planer shavings	16,600	255	11.1	36,853	1.6%
Bark	228,254	3,512	152.5	506,742	22.1%
Green mixed residues	11,200	172.3	7.5	24,865	1.1%
Other green residues	6,422	98.8	4.3	14,257	0.6%
Other dry residues	5,000	76.9	3.3	11,104	0.5%
Total	1,034,714			2,297,149	100%

1. Pine sawmills produced approximately 8 percent of hardwood total.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

Table 4. Current Markets for Virginia Hardwood Sawmill Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	424,834	91.4			84,021	27.9	10,000	60.2						
Sold to composite manufacturers	22,114	4.7			2,155	0.7								
Sold to others as fuel	15,755	3.4	1,800	97.5	131,242	43.6	3,510	21.1	1,240	0.6	3,500	31.3	472.5	4.1
Sold as livestock bedding					63,431	21.1	1,085	6.5	10,000	4.4	120	1.1		
Sold to bark or mulch companies	782	0.2			6,246	2.1	2,000	12	158,642	69.4	500	4.5	5,000	43.8
Used at our facility for fuel			40	2	10,000	3.3					500	4.5		
Burned as waste									2	0.1				
Sent to landfills					2,832	1			3,000	1.3				
Landfilled at our facility							5	0.3	660	0.3	80	0.6		
Sold or given away to wholesaler or broker	1,186	0.3			652	0.2			1,540	0.7			5,897	51.6
Other disposal methods			6	0.3	142	<0.1			53,170	23.3	6,500	58	52.5	0.5
Total	464,671		1,846		300,721		16,600		228,254		11,200		11,422	

1. Numbers may not total due to rounding.

Table 5. Virginia Pine Sawmill Production and Estimated Production

Product Type	Reported Total Production¹	Mill Average	Average per Employee	Estimated Production²	
Softwood lumber	370,532,379	10,292,566 bf	339,938 bf	546,986,107 bf	
Residue Type (Tons)	Reported Total Production¹	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Green chips	634,981	17,638	582.5	911,193	58.8%
Green coarse residues	700	19.4	0.6	1,004	0.1%
Green sawdust	235,593	6,544	216.1	338,074	21.8%
Green planer shavings	32,325	897.9	29.7	46,386	3.0%
Dry planer shavings	42,235	1,173	38.7	60,607	3.9%
Bark	131,215	3,645	120.4	188,792	12.2%
Green mixed residues	2,500	69.4	2.3	3,587	0.2%
Total	1,079,549			1,549,144	100%

1. Hardwood sawmills produced approximately 5 percent of total softwood.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

Table 6. Current Markets for Virginia Pine Sawmill Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	614,560	96.8			81,459	34.			58,530	44.6		
Sold to composite manufacturers	11,030	1.7	25	3.6	95,193	40.4	60,915	81.7				
Sold to others as fuel	4,891	0.8			27,266	11.6			350	0.3		
Sold as livestock bedding					12,560	5.3	9,618	12.9				
Sold to bark or mulch companies					1,250	0.5			67,166	51.8		
Used at our facility for fuel	4,500	0.7			14,780	6.3	4,026	5.4	4,200	3.2		
Burned as waste			25	3.6					969	0.7		
Landfilled at our facility			50	7.1								
Sold or given away to wholesaler or broker					2,000	0.8					2,500	100
Other disposal methods			600	85.7	1,085	0.5						
Total	634,981		700		235,593		74,560		131,215		2,500	

1. Numbers may not total due to rounding.

Table 7. Virginia Engineered Wood Manufacturers¹ Production and Estimated Production

Product Type	Reported Total Production²	Mill Average	Average per Employee	Estimated Production³	
Boards, square feet	514,648,895	85,774,816	569,932	962,615,707	
Boards, lineal feet	105,000	17,500	116	196,395	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production³	Percentage of Total Estimated Residues
Green chips	8,000	1,333	8.9	14,964	6.6%
Green coarse residues	11,000	1,833	12.2	20,572	9.1%
Bark	48,091	8,015	53.3	89,956	39.7%
Dry sanderdust	26,957	4,493	29.8	50,417	22.3%
Dry mixed residues	14,136	2,356	15.6	26,433	11.7%
Green mixed residues	12,670	2,112	14	23,697	10.5%
Other dry residues ⁴	140	23.3	0.2	270	0.1%
Total	120,994			226,309	100%

1. Engineered wood manufacturers included: hardboard, laminated veneer lumber, oriented strandboard, and particleboard.
2. Square footage was reported on 3/16, 3/8, and 3/4-inch basis.
3. Extrapolated using data provided by Virginia Employment Commission by SIC code, as of 12/31/96.
4. "Other" green and dry residues included: slabs, edgings, end trims, blocks, cores, etc.

Table 8. Current Markets for Virginia Engineered Wood Manufacturers Wood Residues

Wood Residue User	Chips		Coarse Residues		Bark		Mixed Residues		Other Green and Dry Residues		Sanderdust	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	8,000	100										
Sold to composite manufacturers			6,050	55								
Sold to others as fuel					8,316	17.3	10,071	37.6	140	100	1,000	2.7
Sold to bark or mulch companies					2,079	4.3						
Used at our facility for fuel			4,950	45	8,316	17.3					25,957	96.3
Sent to landfills					2,079	4.3	9,664	36			8	1
Landfilled at our facility							5,000	8.6				
Other disposal methods					27,300	56.8	2,071	7.7				
Total	8,000		11,000		48,091		26,806		140		26,957	

1. Numbers may not total due to rounding.

Table 9. Virginia Paper Manufacturers Production and Estimated Production

Product Type	Reported Total Production (Tons)	Mill Average	Average per Employee	Estimated Production ¹	
Paper	2,574,500	514,900	764.6	6,102,273	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production ¹	Percentage of Total Estimated Residues
Green bark	214,000	42,800	63.6	507,592	99.9%
Pallets	30	6	<0.1	71	0.1%
Total	214,030			507,663	100%

1. Extrapolated using data provided by Virginia Employment Commission by SIC code, as of 12/31/96.

Table 10. Current Markets for Virginia Paper Manufacturers Wood Residues

Wood Residue User	Bark		Pallets	
	Tons	%	Tons	%
Sold to pulp or paper manufacturer	138,700	64.8		
Used at our facility for fuel	34,000	15.9		
Sold or given away to wholesaler or broker			30	100
Sold to bark or mulch companies	41,300	19.3		
Total	214,000		30	

1. Numbers may not total due to rounding.

Table 11. Virginia Hardwood Plywood Manufacturers¹ Production and Estimated Production

Product Type	Reported Total Production	Mill Average	Average per Employee	Estimated Production²	
Hardwood Plywood, square feet	163,126,441 ft ²	27,187,740 ft ²	224,692 ft ²	296,818,221 ft ²	
Hardwood Plywood, board feet	1,845,533 bf	307,589 bf	2,542 bf	3,357,982 bf	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Dry chips	2,015	336	2.8	3,672	3.5%
Green coarse residues	1,875	312	2.6	3,408	3.2%
Dry coarse residues	1,000	167	1.4	1,833	1.7%
Dry mixed residues	12,125	2,021	16.7	22,061	20.8%
Pallets	14,490	2,415	19.9	26,367	25%
Dry sanderdust	1,653	275	2.3	3,012	2.8%
Dry sawdust	2,015	336	2.8	3,672	3.5%
Green sawdust	125	21	0.2	225	0.2%
Bark	125	21	0.2	225	0.2%
Green planer shavings	250	42	0.3	449	0.4%
Other dry residues ³	22,500	3,750	30.9	40,951	38.7%
Total	58,173			105,650	100%

1. Hardwood plywood manufacturers included: hardwood plywood, face grade veneers, and veneer.

2. Extrapolated using data provided by Virginia Employment Commission by SIC code, as of 12/31/96.

Table 12. Current Markets for Virginia Hardwood Plywood Manufacturers Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues		Sanderdust		Pallets		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to others as fuel	908	45.1			908	42.4							751	45.4			10,867	48.3
Used at our facility for fuel	1,097	54.4	2,825	98.6	1,222	57.1	250	100	125	100	125	1	902	54.6			10,958	48.7
Sent to landfills	10	0.4			10	0.5					12,000	99					675	3.0
Landfilled at our facility			50	1.4														
Other disposal methods															14,490	100		
Total	2,015		2,875		2,140		250		125		12,125		1,653		14,490		22,500	

1. Numbers may not total due to rounding.

Table 13. Virginia Rough Mill¹ Operations Consumption and Estimated Consumption

Product Type	Reported Total Consumption	Mill Average	Average per Employee	Estimated Consumption²	
Lumber	132,680,074 bf	2,287,587 bf	44,885 bf	387,941,096 bf	
Composites	4,599,623 ft ²	79,304 ft ²	1,556 ft ²	13,448,762 ft ²	
Lineal feet	1,500,000	25,862	507	4,385,825 lf	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Dry chips	71,256	1,228.5	24.1	208,344	28.4%
Green coarse residues	550	9.5	0.2	1,729	0.2%
Dry coarse residues	20,354	254	6.9	59,513	8.1%
Dry sawdust	40,448	697	13.7	118,409	16.1%
Green sawdust	31,424	542	10.6	91,616	12.5%
Dry planer shavings	26,166	451	8.9	76,923	10.5%
Bark	7,764	133.9	2.6	22,472	3.1%
Dry sanderdust	3	0.1	<0.1	9	<0.1%
Pallets	5	0.9	<0.1	15	<0.1%
Green mixed residues	9,800	169	3.3	28,522	3.9%
Dry mixed residues	41,287	712	14.0	121,002	16.5%
Other dry residues ³	1,893	32.6	0.6	5,186	0.7%
Total	250,950			733,816	100%

1. Rough mill operations included: box springs, cabinets and cabinet components, doors, edge glued panels, flooring, furniture parts, laminated furniture parts, millwork, and timbers.

2. Extrapolated using data provided by Virginia Employment Commission by SIC code, as of 12/31/96.

Table 14. Current Markets for Virginia Rough Mill Operations Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues		Sanderdust		Pallet		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	25,637	36																
Sold to composite manufacturers	2,018	2.8	5,100	4.4	9,601	13.4	11,412	43.6			31,155	61						
Sold to others as fuel	35,029	49.2	918	4.4	14,482	20.1												
Sold as livestock bedding	168	0.2	600	2.9	4,246	5.9	6,590	25.2			6,000	11.7						
Sold to bark or mulch companies									7,729	99.5								
Used at our facility for fuel	8,155	11.4	13,431	64.2	19,338	26.9	20	<0.1			2,879	5.6						
Burned as waste			0.5	0.1	11,136	15.5					1,622	3.2					174	9.2
Sent to landfills	250	0.3			13,042	18.1	3	<0.1			31	<0.1	2	66.7	5	100	1,719	90.8
Landfilled at our facility			689	3.3					35	0.5								
Sold or given away to wholesaler or broker			164	0.8			5,629	21.5			52	0.1						
Other disposal methods			1.5	<0.1	26	<0.1	2,512	9.6			9,348	18.3	1	33.3				
Total	71,526		20,904		71,872		26,166		7,764		51,087		3		5		1,893	

1. Numbers may not total due to rounding.

Table 15. Virginia Pallet Manufacturers Consumption and Estimated Consumption

Product Type	Reported Total Consumption	Mill Average	Average per Employee	Estimated Consumption¹	
Lumber	87,401,154 bf	4,370,058 bf	116,380	163,978,996 bf	
Composites	325,872 ft ²	16,294 ft ²	433 ft ²	611,390 ft ²	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production¹	Percentage of Total Estimated Residues
Green chips	22,266	1,113	29.6	41,777	19.5%
Green sawdust	23,284	1,164	31	43,685	20.4%
Green shavings	2,708	135	3.6	5,086	2.4%
Bark	7,453	373	9.9	13,977	6.5%
Pallets	23,633	1,182	31.5	44,341	20.7%
Green mixed residues	32,046	1,602	42.7	60,122	28.2%
Other dry residues	2,620	131	3.5	4,917	2.3%
Total	114,010			213,905	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

Table 16. Current Markets for Virginia Pallet Manufacturers Wood Residues

Wood Residue User	Chips		Sawdust		Planer Shavings		Bark		Mixed Residues		Other Green and Dry Residues		Pallets	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	21,066	94.6												
Sold to composite manufacturers					2,700	99.7								
Sold to others as fuel	1,200		21,984	94.4			3,846	51.7	29,542	92.2	2,000	76.3	19,642	83.1
Sold as livestock bedding			1,300	5.6									2,607	11
Sold to bark or mulch companies							3,000	40.2					235	1.0
Used at our facility for fuel							607	8.1					524	2.2
Burned as waste									2,500	7.7			24	0.1
Sent to landfills									4	<0.1			504	2.1
Sold or given away to wholesaler or broker			2	<0.1	8	0.3								
Other disposal methods											23.7	0.4	620	97.0
Total	22,266		23,284		2,708		7,453		32,046		2,620		23,633	

1. Numbers may not total due to rounding.

Table 17. Virginia Furniture Manufacturers Consumption/Production and Estimated Consumption/Production

Product Type	Reported Total Consumption	Mill Average	Average per Employee	Estimated Consumption¹	
Lumber	45,156,719 bf	1,736,797 bf	5,101 bf	101,081,386 bf	
Composites	7,607,382 bf	292,592 ft ²	859 ft ²	17,021,944 ft ²	
Tons ²	63,546 tons	2,444 tons	7 tons	138,712 tons	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production¹	Percentage of Total Estimated Residues
Dry chips	690	26.5	<0.1	1,585	1.4%
Dry coarse residues	206	7.9	<0.1	456	0.4%
Dry sawdust	1,888	72.6	0.2	4,221	3.7%
Dry planer shavings	1,215	47	0.1	2,774	2.4%
Green planer shavings	1	<0.1	<0.1	2	<0.1 %
Bark	124	4.8	<0.1	277	0.2 %
Dry sanderdust	856	33	0.1	1,902	1.6%
Pallets	21	0.8	<0.1	40	<0.1 %
Dry mixed residues	40,268	1,549	4.5	90,163	78.2%
Green mixed residues	6,200	238	0.7	13,871	12.0%
Other dry residues ³	3	0.1	<0.1	6	<0.1 %
Total	51,472			115,297	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

2. Included tons of other composite products used in furniture manufacture.

Table 18. Current Markets for Virginia Furniture Manufacturers Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues		Pallets		Sanderdust		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to composite manufacturers					137	7.3	120	9.9			962	2.1			85	9.9		
Sold to others as fuel			180	87.4	520	27.5	0.4	<0.1			5,862	12.6						
Sold as livestock bedding											95	0.2						
Sold to bark or mulch companies							0.2	<0.1	124	100	10	<0.1						
Used at our facility for fuel	690	100			1,229	65.1	1,076	88.5			33,302	71.7	7	33.3	769	89.9		
Burned as waste													7	33.3				
Sent to landfills											37	<0.1	6	28.6				
Landfilled at our facility			4	1.9			0.3	<0.1										
Sold or given away to wholesaler or broker											6,200	13.3						
Other disposal methods			22	10.7	2	0.1	1.6	19					1	4.7	2	0.2	3	100
Total	690		206		1,888		1,216		124		46,468		21		856		3	

1. Numbers may not total due to rounding.

Table 19. Virginia Housing Manufacturers¹ Consumption/Production and Estimated Consumption/Production

Product Type	Reported Total Consumption	Mill Average	Average per Employee	Estimated Consumption²	
Lumber	24,693,000 bf	1,371,833 bf	30,866 bf	91,085,566 bf	
Composites	317,264 ft ²	17,626 ft ²	397 ft ²	1,171,547 ft ²	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Dry chips	1,891	105	2.4	7,230	36.3%
Dry coarse residues	188	10.4	0.2	708	4.0%
Dry sawdust	80	4.4	0.1	295	1.5%
Dry planer shavings	100	5.5	0.1	384	1.9%
Green sanderdust	50	2.8	<0.1	177	1.0%
Dry mixed residues	745	41.4	1.0	2,833	14.3%
Other dry residues ³	2,131	118	2.7	8,144	41.0%
Total	5,185			19,772	100%

1. Housing manufacturers included: log homes, modular housing, post frame buildings, prefabricated wall panels, trusses, and utility buildings.

2. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

Table 20. Current Markets for Virginia Housing Manufacturers Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Mixed Residues		Sanderdust		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to composite manufacturers			150	79.8	59	73.8	50	50						
Sold to others as fuel	1,000	53												
Used at our facility for fuel	36	1.9	6	3.2	6	7.5							15	0.7
Burned as waste									40	5.4	50	100		
Sent to landfills	695	36.6			15	18.7			656	88.0			2,000	93.9
Sold or given away to wholesaler or broker	160	8.5												
Other disposal methods			32	17			50	50	49	6.6			116	5.4
Total	1,891		188		80		100		745		50		2,131	

1. Numbers may not total due to rounding.

Table 21. Virginia “Other¹” Manufacturers Consumption/Production and Estimated Consumption/Production

Product Type	Total Consumption and Production	Mill Average	Average per Employee	Estimated Consumption² and Production	
Lumber	43,703,742 bf	1,680,913 bf	41,822 bf	51,190,128 bf	
Composites	5,500,000 ft ²	211,538 ft ²	5,263 ft ²	6,441,912 ft ²	
Tons ³	498,057 ft ²	19,156 tons	477 tons	583,848 tons	
Residue Type (Tons)	Reported Total Production	Mill Average	Average per Employee	Estimated Production²	Percentage of Total Estimated Residues
Green chips	6,136	236	5.9	7,222	11.1%
Green coarse residues	330	12.7	0.3	367	0.6%
Dry coarse residues	1,285	49	1.2	1,469	2.3%
Dry sawdust	30	1.1	<0.1	35	<0.1%
Green sawdust	3,770	145	3.6	4,406	6.8%
Green planer shavings	1,030	40	1.0	1,224	1.9%
Dry planer shavings	523	20	0.5	612	1.0%
Bark	2,775	107	2.7	3,305	5.0%
Pallets	17,001	654	16.3	19,951	30.8%
Green mixed residues	1,087	42	1.0	1,224	2.0%
Other dry residues ⁴	10,000	385	9.6	11,750	18.1%
Other green residues ⁴	11,200	431	10.7	13,097	20.3%
Total	55,167			64,662	100%

1. “Other” manufacturers included: mulch, chip, post, piling, steam, travel trailers, novelties, electricity, pipe organs, handle, stake manufacturers, boat repairing, and building supplies.
2. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.
3. Included tons of bark, sawdust, chips, shavings, etc. used in the manufacture of products.

Table 22. Current Markets for Virginia “Other” Manufacturers Wood Residues

Wood Residue User	Chips		Coarse Residues		Sawdust		Planer Shavings		Bark		Mixed Residues		Pallets		Other Green and Dry Residues	
	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%	Tons	%
Sold to pulp or paper manufacturer	1,147	18.7									225	20.7				
Sold to others as fuel	4,002	65.2	1,190	73.8							837	77	8,500	50	10,000	47.2
Sold as livestock bedding							1,550	99.8			25	2.3				
Sold to bark or mulch companies									2,775	100						
Used at our facility for fuel	957	15.6	325	20.1	3,020	79.5							4,250	25	1,200	5.6
Burned as waste			57	3.5	3	<0.1										
Sent to landfills			43	2.7	5	<0.1										
Landfilled at our facility															5,000	23.6
Sold or given away to wholesaler or broker	30	0.5			750	19.7							4,250	50	5,000	23.6
Other disposal methods					22	0.6	3	0.2								
Total	6,136		1,615		3,800		1,553		2,775		1,087		17,000		21,200	

1. Numbers may not total due to rounding.

Table 23. Virginia Wood Residues Estimated Production

Residue Type	Reported Tons Produced	Estimated Tons ^{1,2}	Percentage of Total Estimated Wood Residues Produced
Green chips	1,136,054	2,006,763	38.2%
Dry chips	75,852	220,783	
Green bark	639,801	1,311,717	22.8%
Green sawdust	594,917	1,145,631	21.8%
Dry sawdust	44,461	126,632	
Green mixed residues	75,503	155,888	7.2%
Dry mixed residues	108,561	262,492	
Green planer shavings	52,914	89,420	4.0%
Dry planer shavings	70,239	143,041	
Other green residues ³	17,622	26,614	1.9%
Other dry residues ³	44,287	81,748	
Green coarse residues	16,301	31,886	1.6%
Dry coarse residues	23,033	63,395	
Pallets	55,180	90,785	1.6%
Green sanderdust	50	177	0.9%
Dry sanderdust	29,469	55,339	
Total	2,984,244	5,758,622	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

3. "Other" green and dry residues included: slabs, edgings, end trims, blocks, cores, etc.

Table 24. Virginia Wood Product Manufacturers' 1996 Reported Wood Residue Revenues

Residue Type	Hardwood Sawmills	Pine Sawmills	Engineered Wood Manufacturer	Paper Manufacturer	Hardwood Plywood Manufacturer	Rough Mill Operations	Pallet Manufacturers	Furniture Manufacturers	Housing Manufacturers	Other Manufacturers	Total
Green chips	8,015,575	13,334,601								73,632	21,423,808
Dry chips					44,330	1,567,632			24,583		1,636,545
Green coarse residues	23,998	3,500	132,000		41,250	6,600				1,650	208,998
Dry coarse residues					22,000	244,248			1,880	6,425	274,553
Green sawdust	2,435,840	2,120,337			875	125,696	186,272			30,160	4,899,180
Dry sawdust					14,105	161,792		26,432			202,329
Green sanderdust											
Dry sanderdust			323,484								323,484
Green mixed residues	112,000	12,500	152,040			98,000	384,552	142,600		1,087	901,692
Dry mixed residues			169,632		218,250	412,870		926,164	2,235		1,730,238
Scrap pallets					260,820		118,165			255,015	634,000
Green planer shavings	332,000	1,066,725				549,486	48,744			16,480	1,463,949
Dry planer shavings		1,393,755							1,000	10,460	1,954,701
Bark	3,241,207	1,837,010	721,365	2,354,000			81,983			19,425	8,254,990
Green other residues										56,000	56,000
Dry other residues							31,440			100,00	131,440
Total	14,160,620	19,768,428	1,498,521	2,354,000	601,630	3,166,324	851,156	1,095,196	29,698	570,334	44,095,907

Table 25. Virginia Primary Manufacturers' 1996 Reported Wood Residue Revenues

	Hardwood Sawmill	Pine Sawmill	Engineered Wood Manufacturer	Paper Manufacturer	Hardwood Plywood Manufacturer	Total
Residue Type						
Green chips	8,015,575	13,334,601				21,350,176
Dry chips					44,330	44,330
Green coarse residues	23,998	3,500	132,000		41,250	176,989
Dry coarse residues					22,000	22,000
Green sawdust	2,435,840	2,120,337			875	4,557,052
Dry sawdust					14,105	14,105
Green sanderdust						323,484
Dry sanderdust			323,484			
Green mixed residues	112,000	12,500	152,040			276,540
Dry mixed residues			169,632		218,250	387,882
Scrap pallets					260,820	260,820
Green planer shavings	332,000	1,066,725				1,398,725
Dry planer shavings		1,393,755				1,393,755
Bark	3,241,207	1,837,010	721,365	2,354,000		8,153,582
Total	14,160,620	19,768,428	1,498,521	2,354,000	601,630	38,359,440

Table 26. Virginia Secondary Product Manufacturers' 1996 Reported Wood Residue Revenues

	Rough Mill Operations	Pallet Manufacturers	Furniture Manufacturers	Housing Manufacturers	Other Manufacturers	Total
Residue Type						
Green chips					73,632	73,632
Dry chips	1,567,632			24,583		1,592,215
Green coarse residues	6,600				1,650	8,250
Dry coarse residues	244,248			1,880	6,425	252,553
Green sawdust	125,696	186,272			30,160	342,128
Dry sawdust	161,792		26,432			188,224
Green mixed residues	98,000	384,552	142,600		1,087	626,239
Dry mixed residues	412,870		926,164	2,235		1,341,269
Scrap pallets		118,165			255,015	373,180
Green planer shavings	549,486	48,744			16,480	65,224
Dry planer shavings				1,000	10,460	560,946
Bark		81,983			19,425	101,408
Green, other residues					56,000	56,000
Dry, other residues		31,440			100,00	131,440
Total	3,166,324	851,156	1,095,196	29,698	570,334	5,712,708

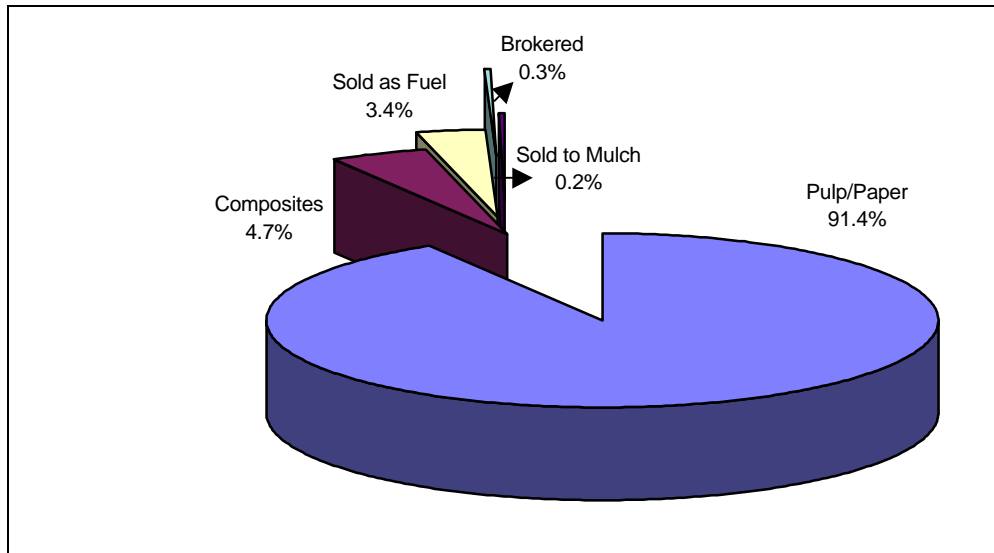


Figure 1. Current Markets and Market Share for Hardwood Sawmill Chips

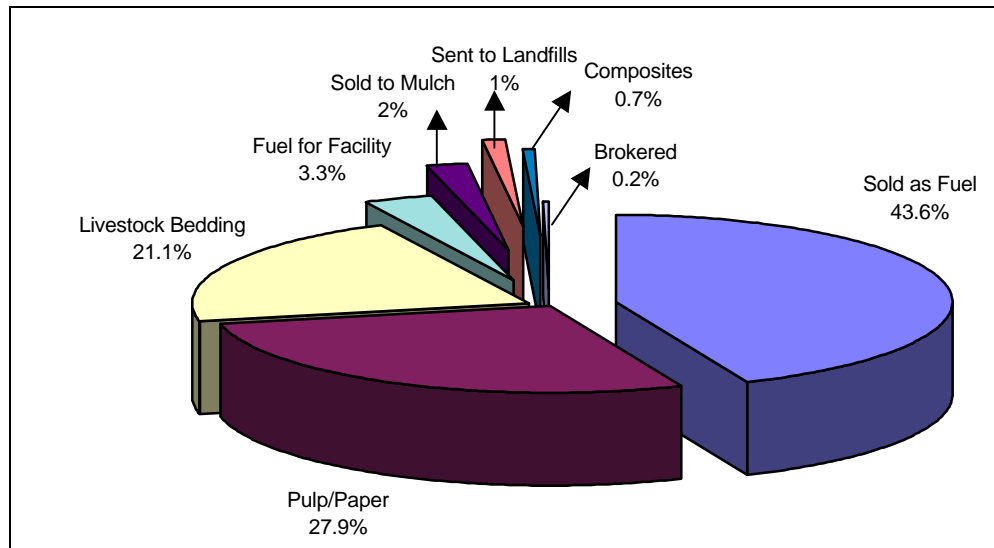


Figure 2. Current Markets and Market Share for Hardwood Sawmill Sawdust

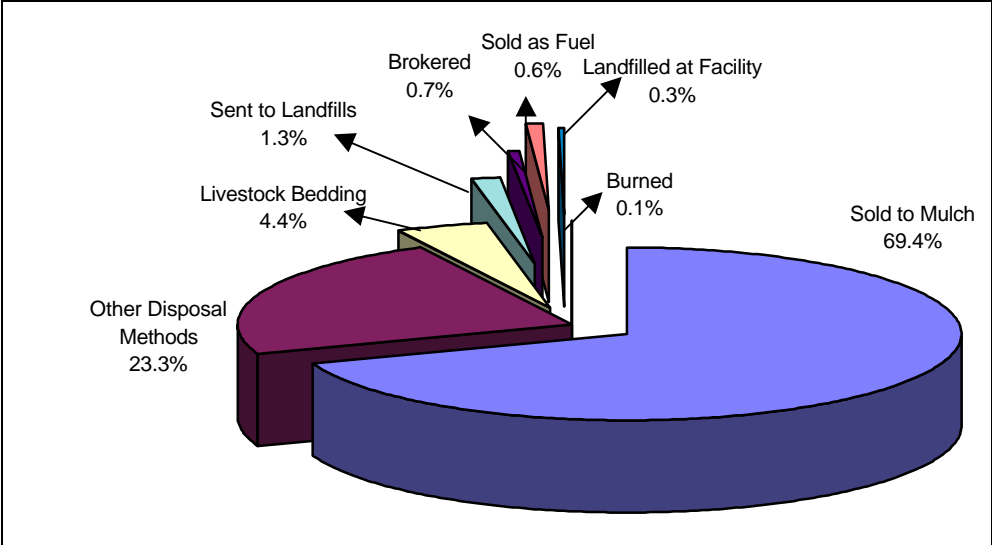


Figure 3. Current Markets and Market Share for Hardwood Sawmill Bark

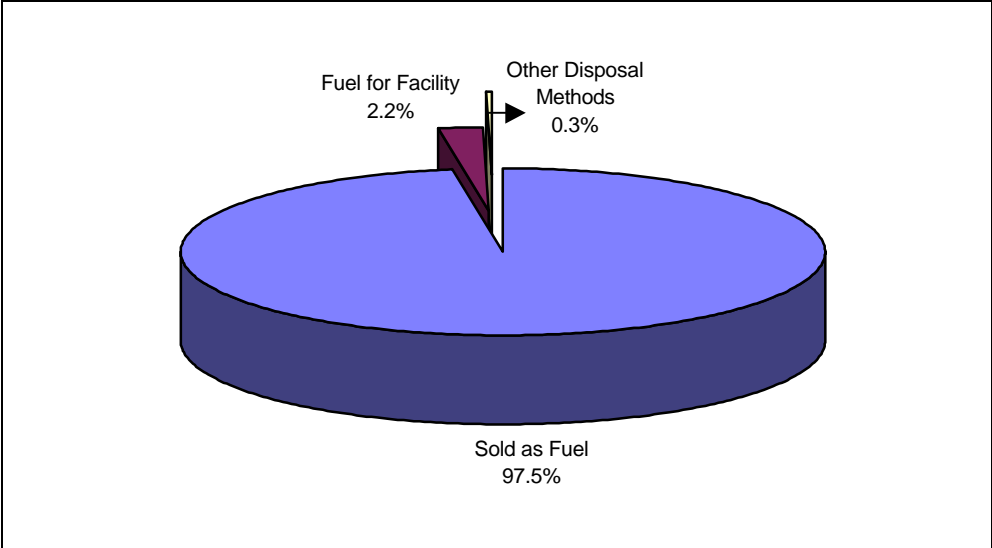


Figure 4. Current Markets and Market Share for Hardwood Sawmill Coarse Residues

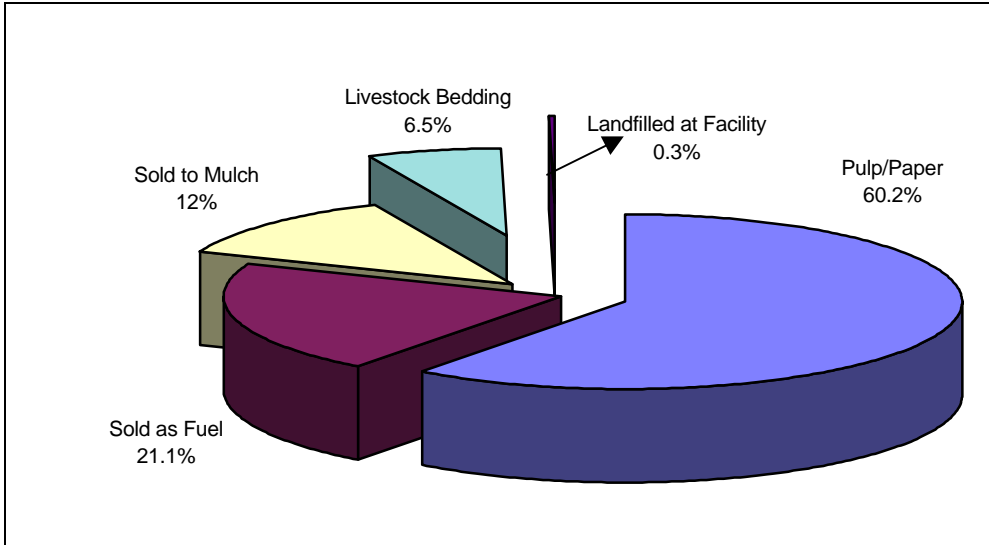


Figure 5. Current Markets and Market Share for Hardwood Sawmill Planer Shavings

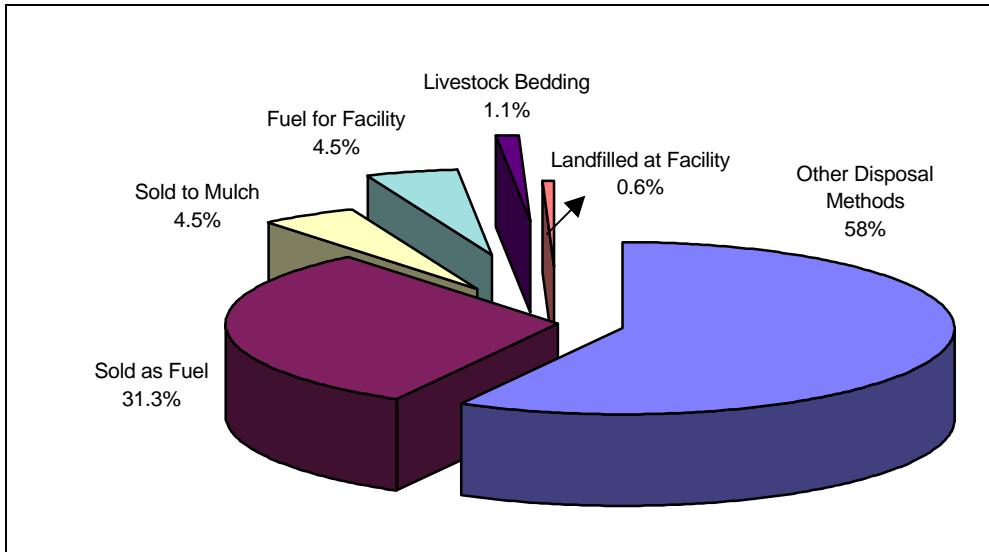


Figure 6. Current Markets and Market Share for Hardwood Sawmill Mixed Residues

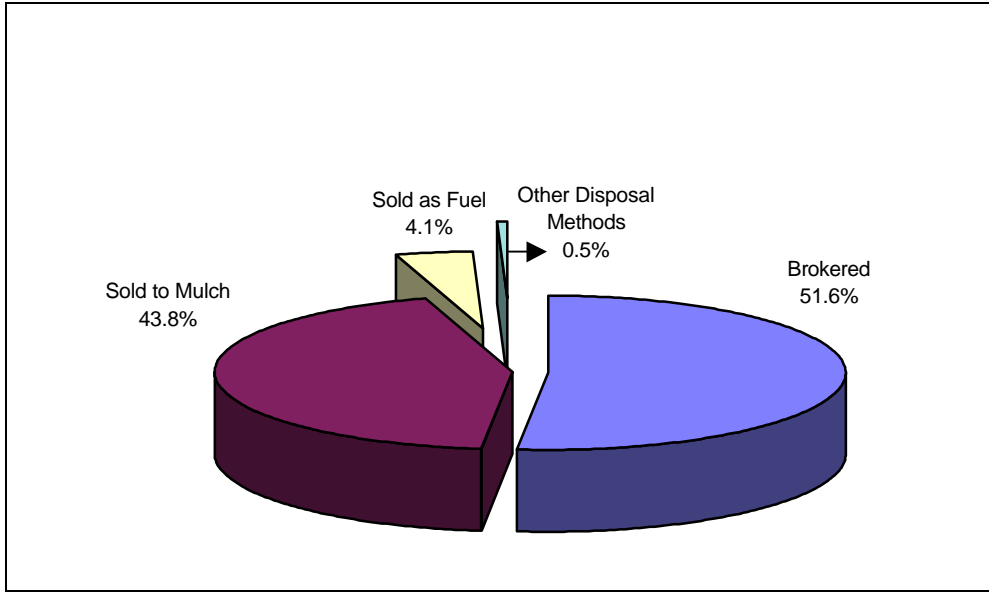


Figure 7. Current Markets and Market Share for Hardwood Sawmill Other Green and Dry Residues

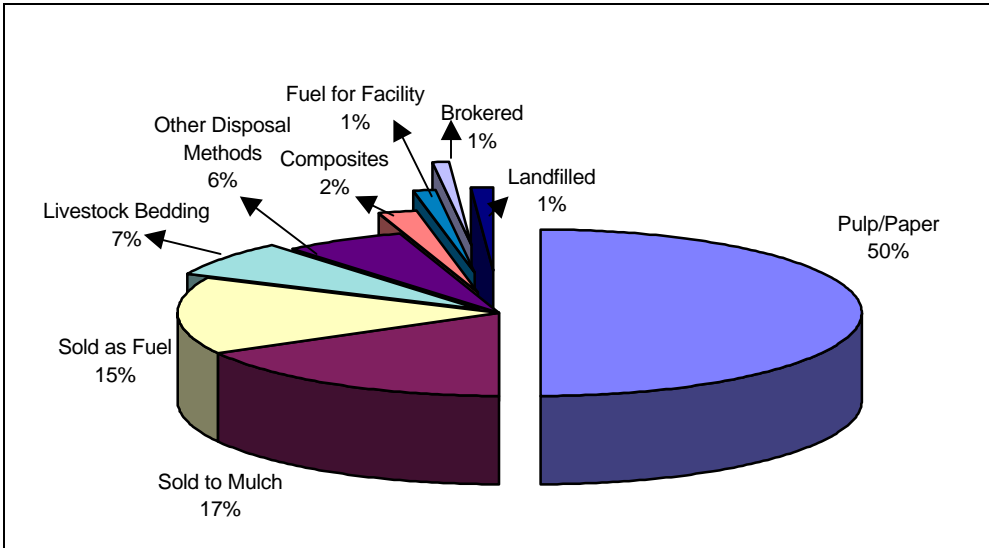


Figure 8. Current Markets and Market Share for Hardwood Sawmill Wood Residues

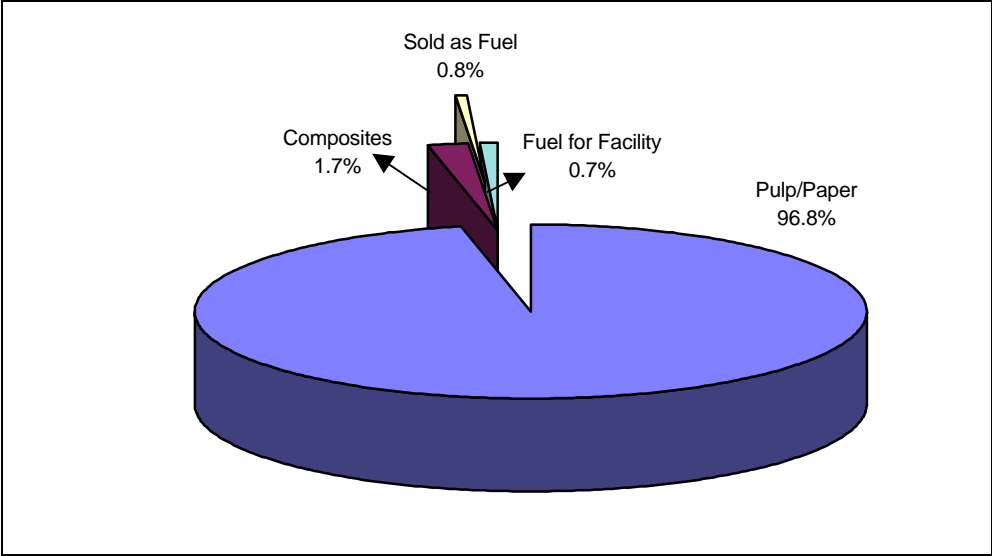


Figure 9. Current Markets and Market Share for Pine Sawmill Chips

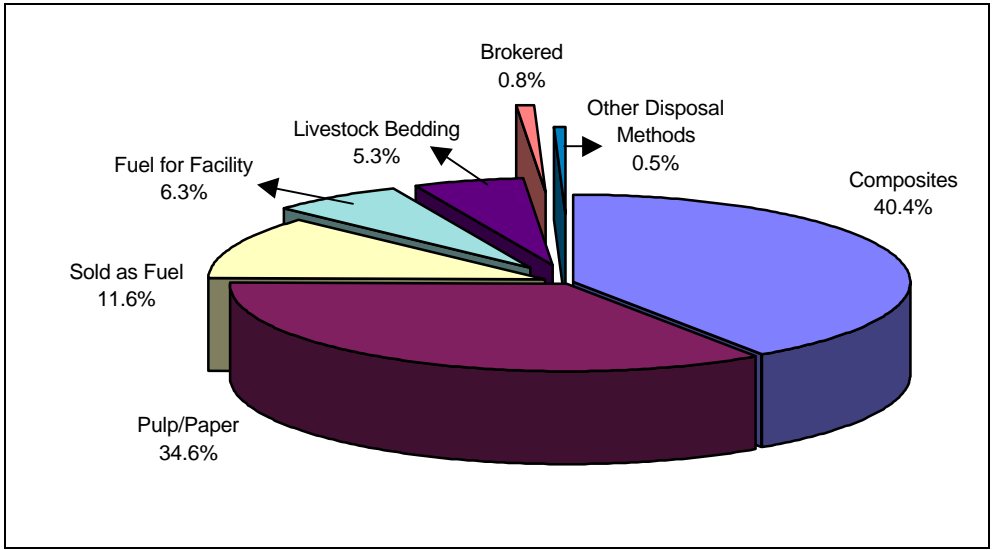


Figure 10. Current Markets and Market Share for Pine Sawmill Sawdust

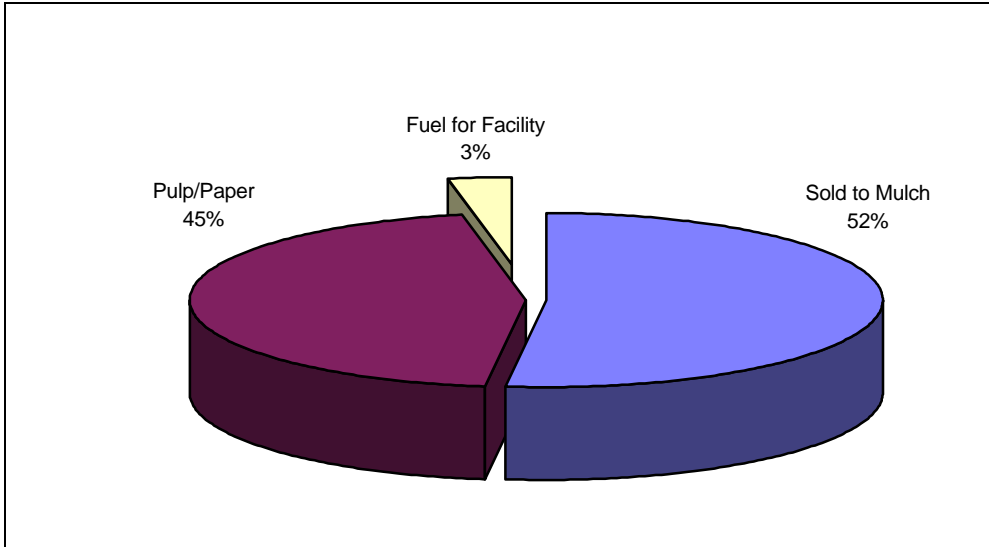


Figure 11. Current Markets and Market Share for Pine Sawmill Bark

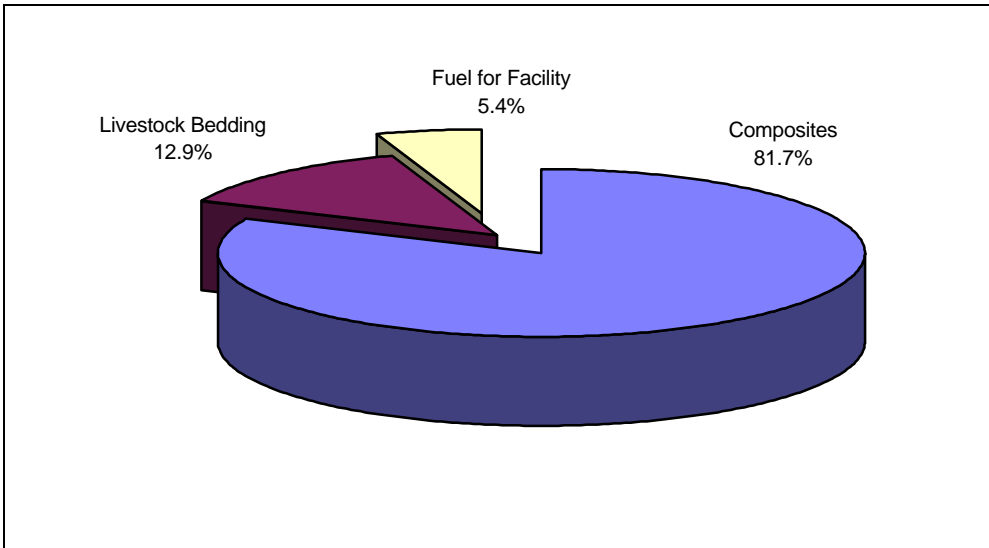


Figure 12. Current Markets and Market Share for Pine Sawmill Planer Shavings

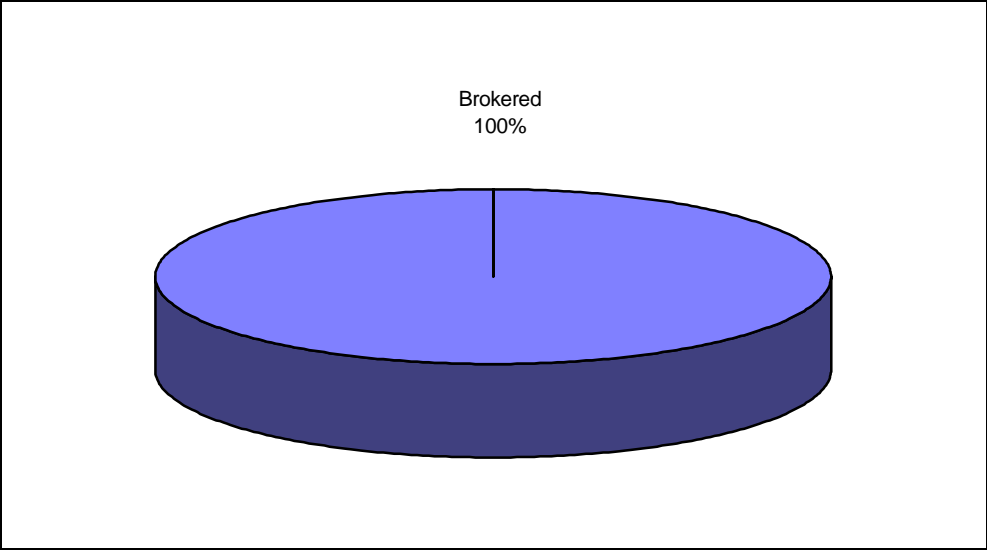


Figure 13. Current Markets and Market Share for Pine Sawmill Mixed Residues

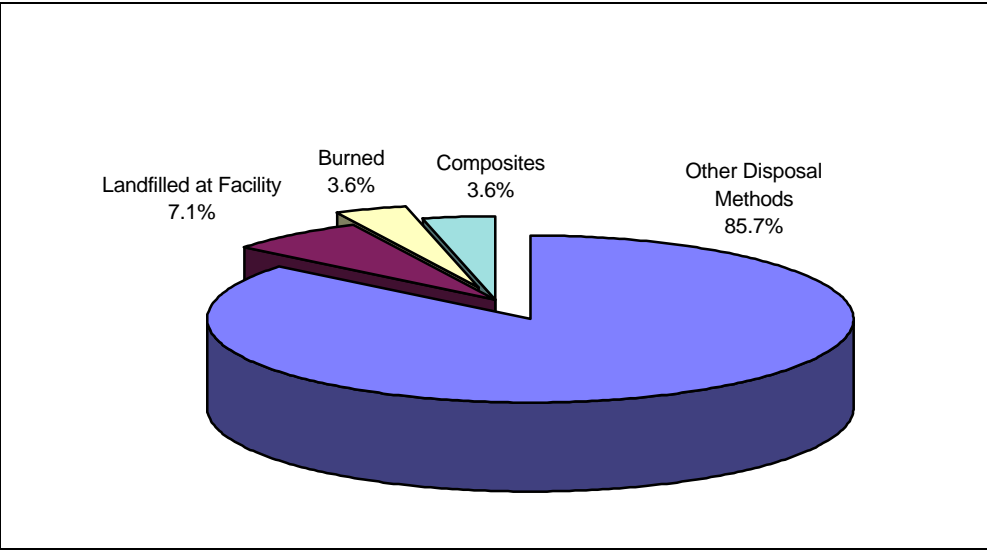


Figure 14. Current Markets and Market Share for Pine Sawmill Coarse Residues

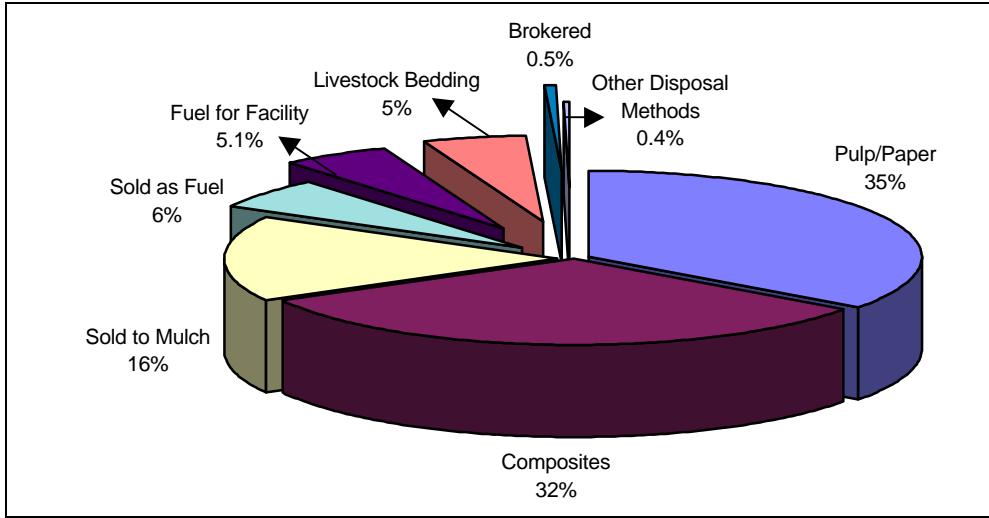


Figure 15. Current Markets and Market Share for Pine Sawmill Wood Residues

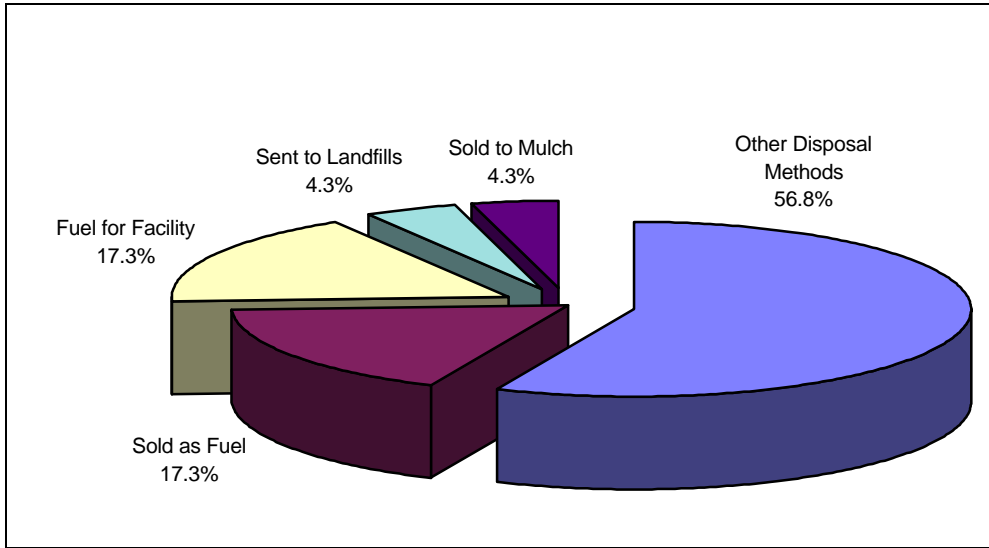


Figure 16. Current Markets and Market Share for Engineered Wood Manufacturers Bark

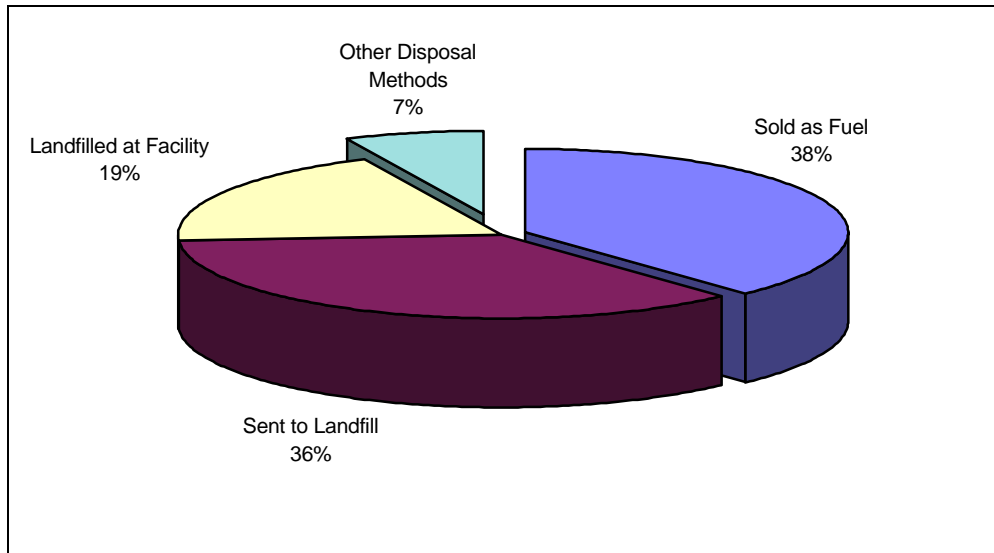


Figure 17. Current Markets and Market Share for Engineered Wood Manufacturers Mixed Residues

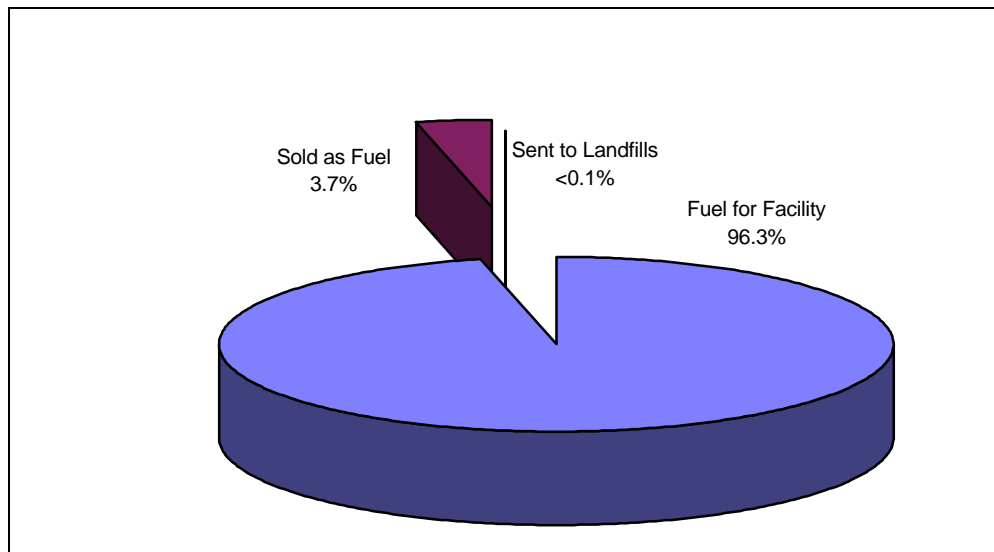


Figure 18. Current Markets and Market Share for Engineered Wood Manufacturers Sanderdust

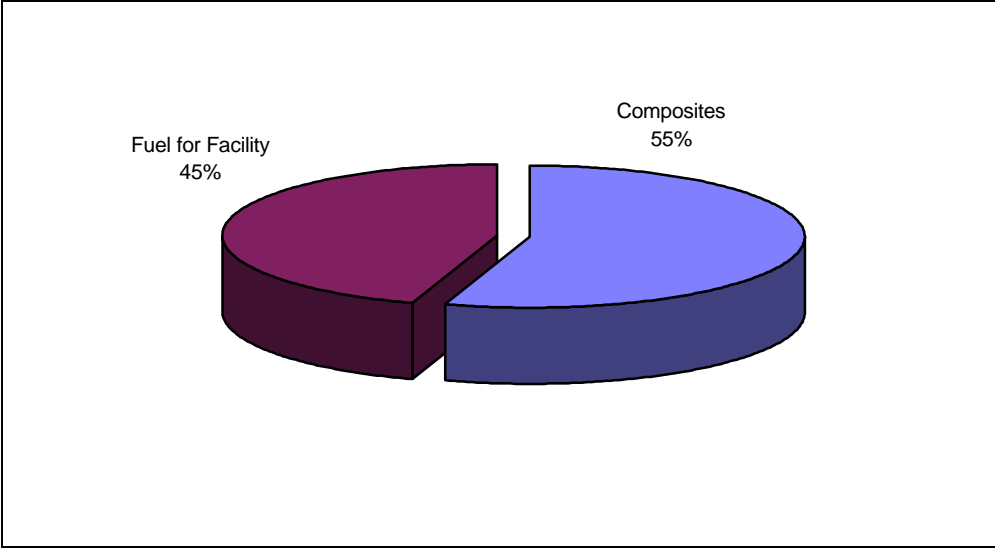


Figure 19. Current Markets and Market Share for Engineered Wood Manufacturers Coarse Residues

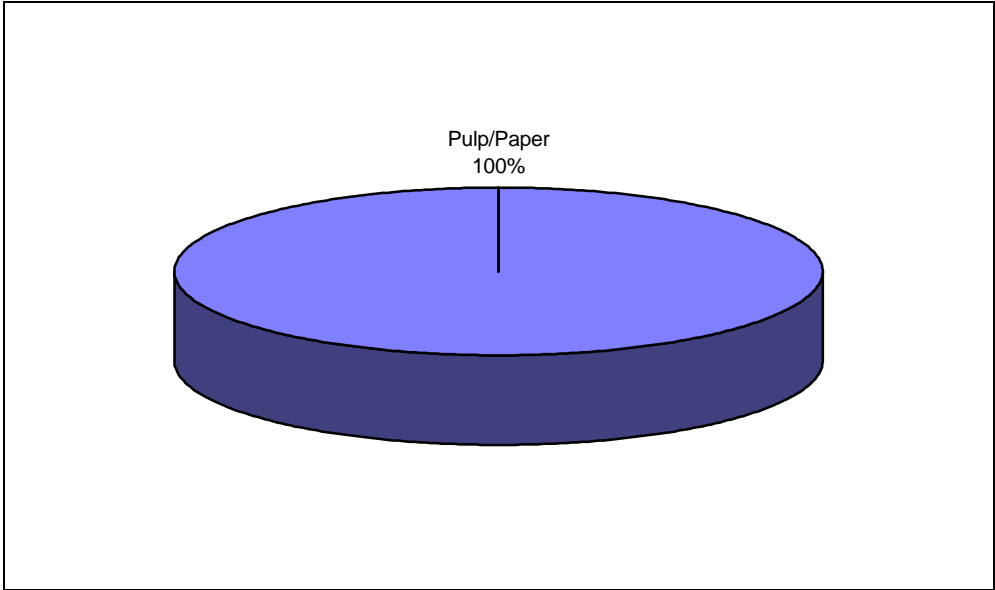


Figure 20. Current Markets and Market Share for Engineered Wood Manufacturers Chips

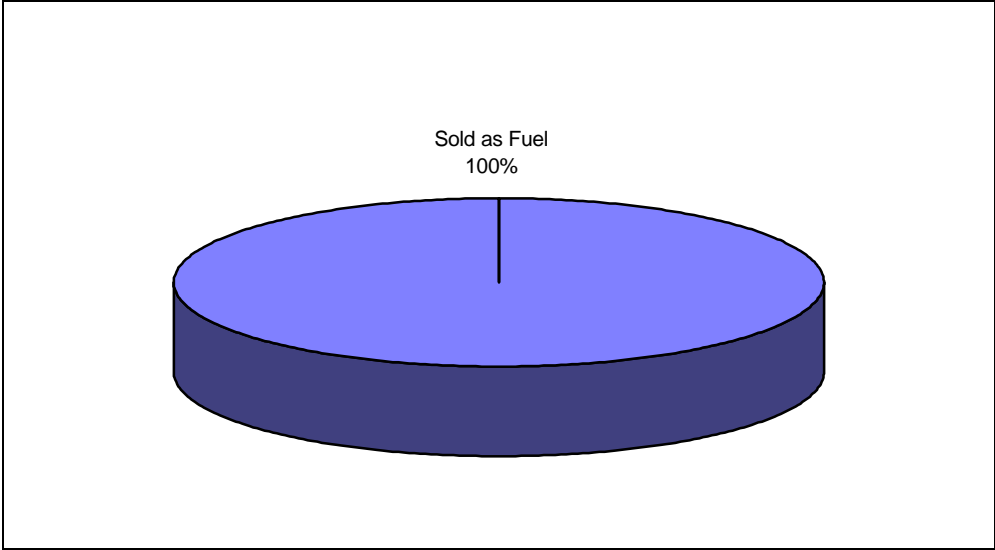


Figure 21. Current Markets and Market Share for Engineered Wood Manufacturers Other Green and Dry Residues

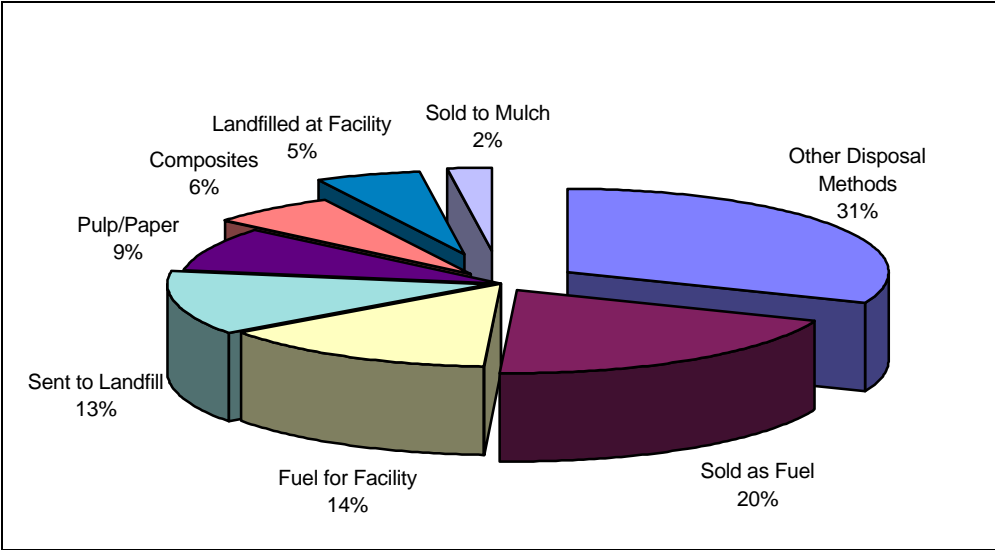


Figure 22. Current Markets and Market Share for Engineered Wood Manufacturers Wood Residues

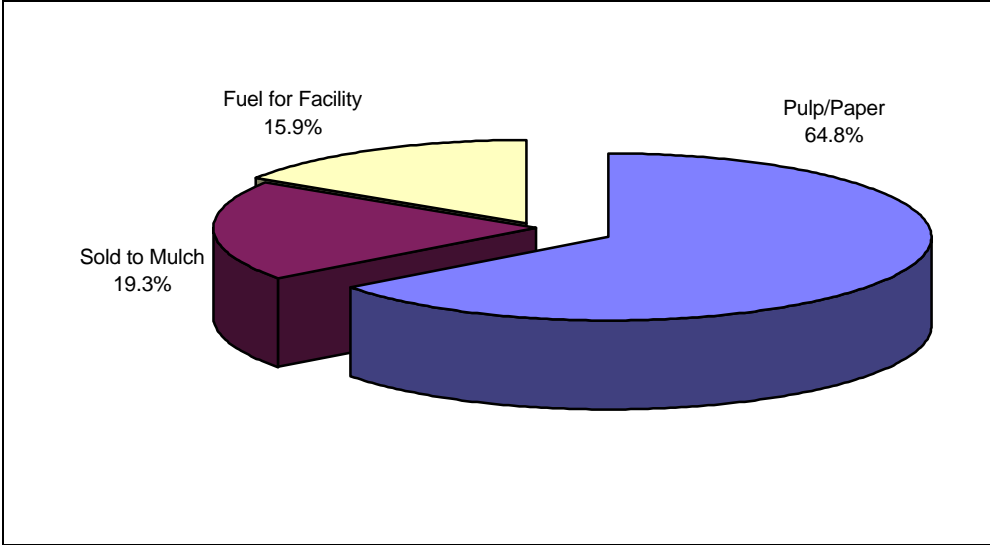


Figure 23. Current Markets and Market Share for Paper Manufacturers Bark

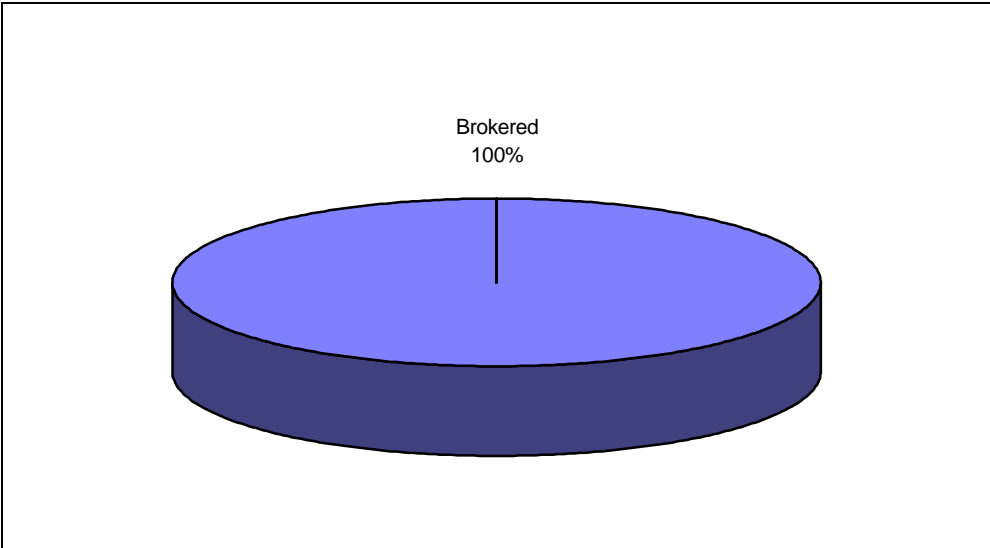


Figure 24. Current Markets and Market Share for Paper Manufacturers Scrap Pallets

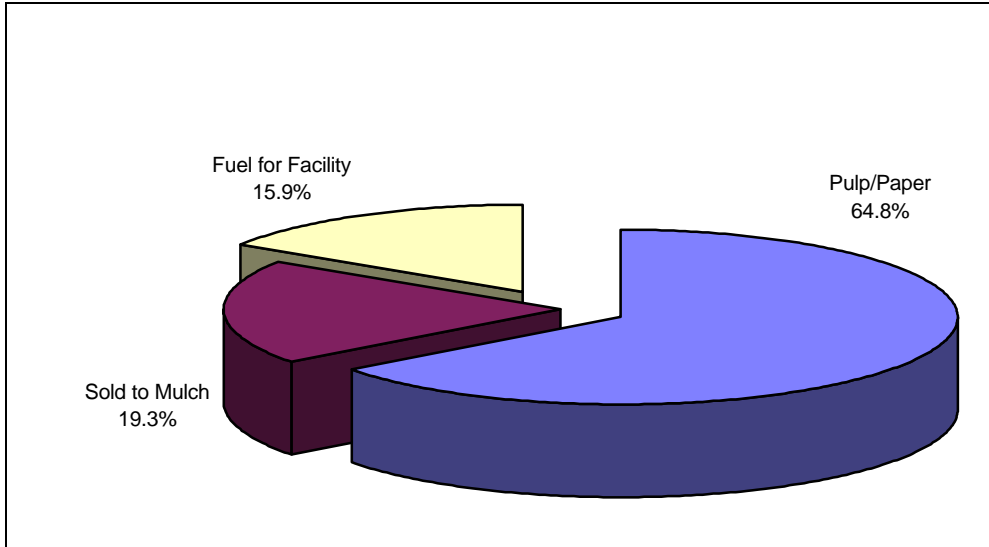


Figure 25. Current Markets and Market Share for Paper Manufacturers Wood Residues

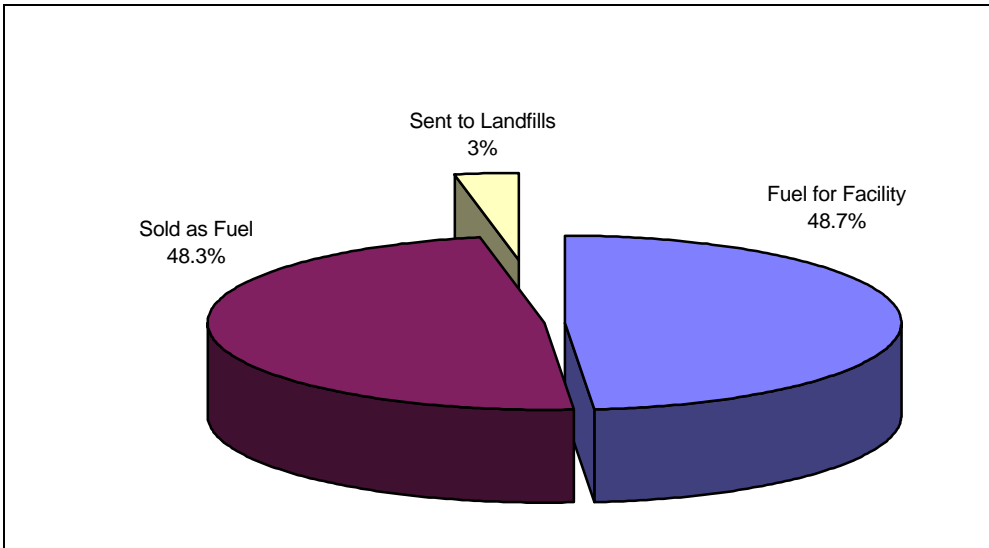


Figure 26. Current Markets and Market Share for Hardwood Plywood Manufacturers Other Dry Residues

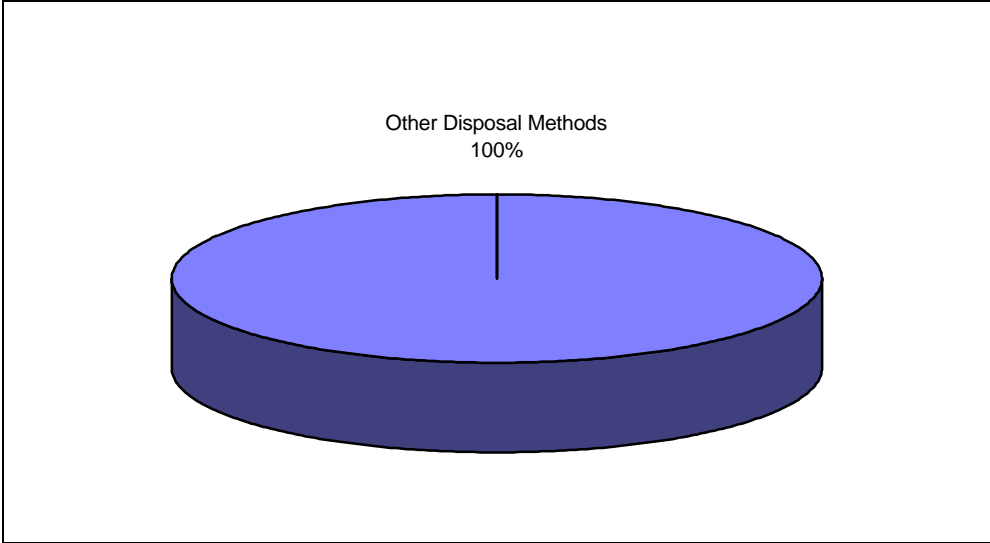


Figure 27. Current Markets and Market Share for Hardwood Plywood Manufacturers Scrap Pallets

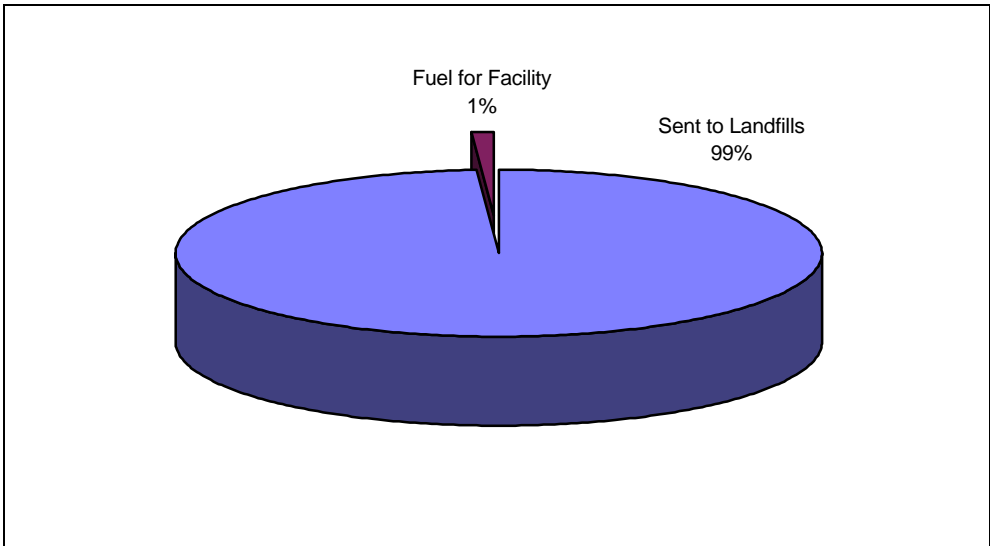


Figure 28. Current Markets and Market Share for Hardwood Plywood Manufacturers Mixed Residues

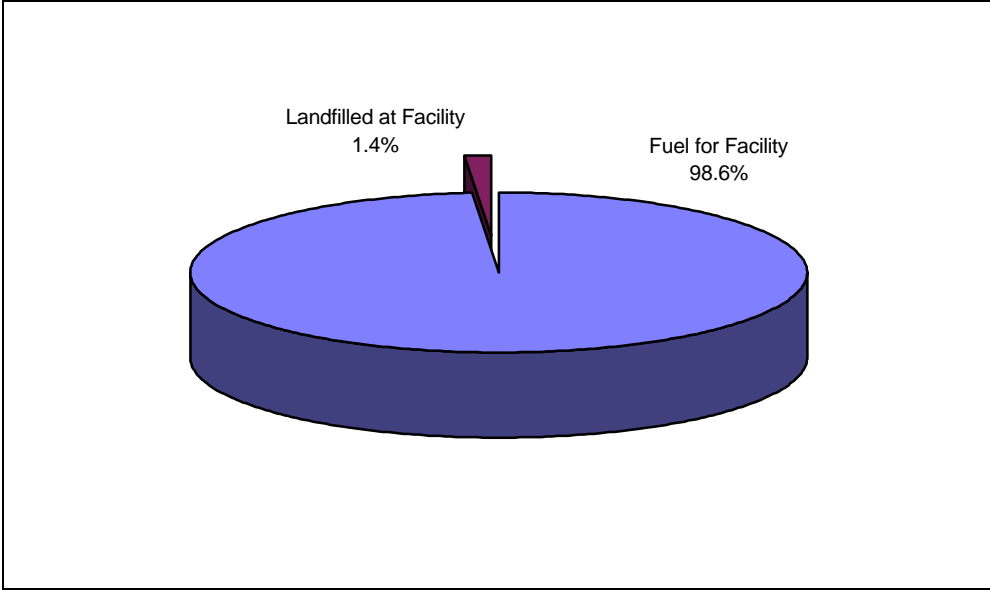


Figure 29. Current Markets and Market Share for Hardwood Plywood Manufacturers Coarse Residues

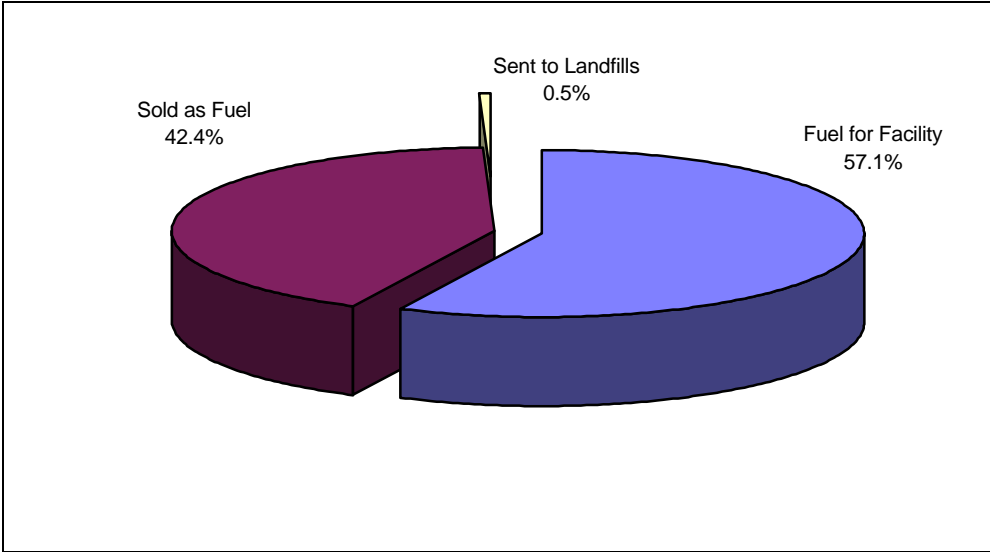


Figure 30. Current Markets and Market Share for Hardwood Plywood Manufacturers Sawdust

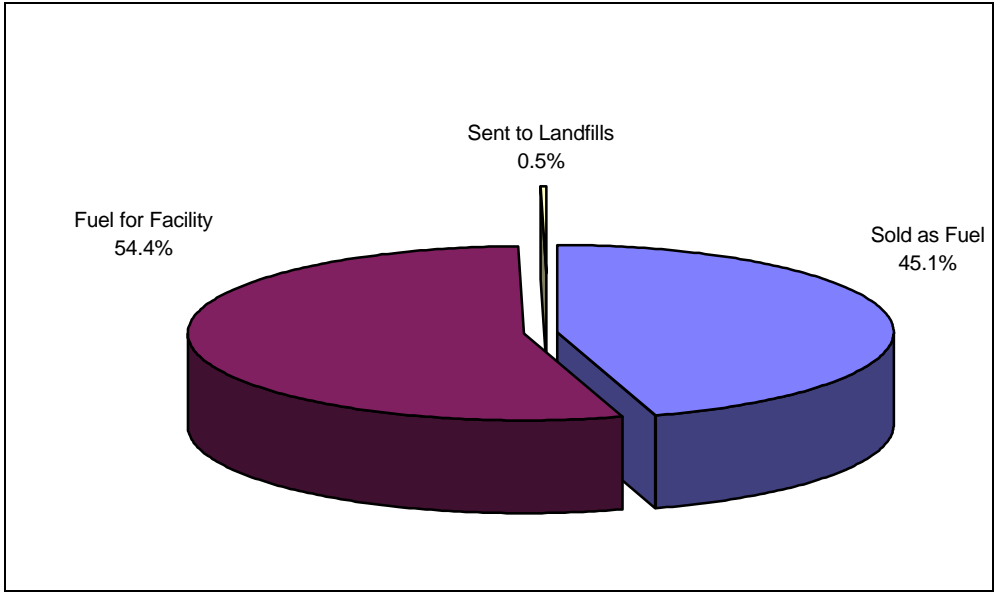


Figure 31. Current Markets and Market Share for Hardwood Plywood Manufacturers Chips

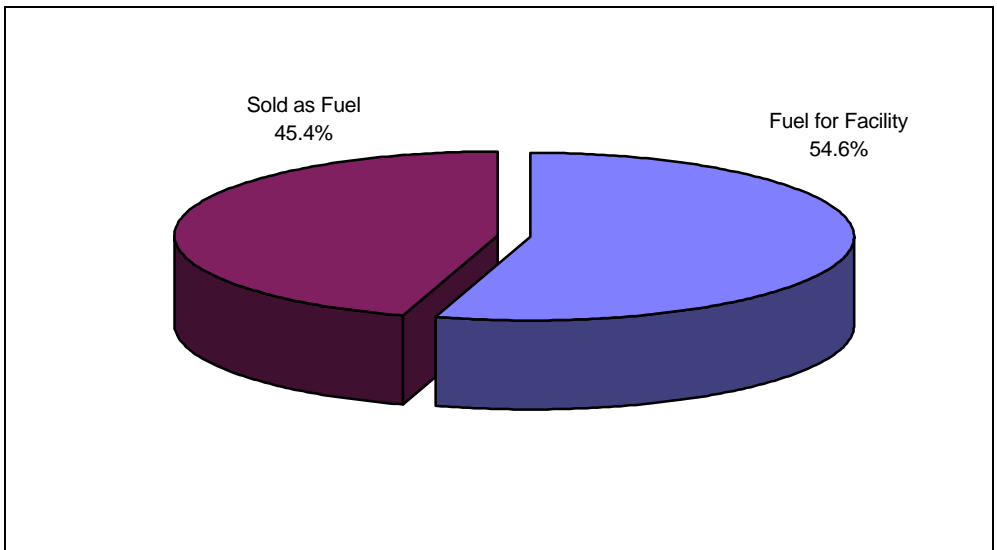


Figure 32. Current Markets and Market Share for Hardwood Plywood Manufacturers Sanderdust

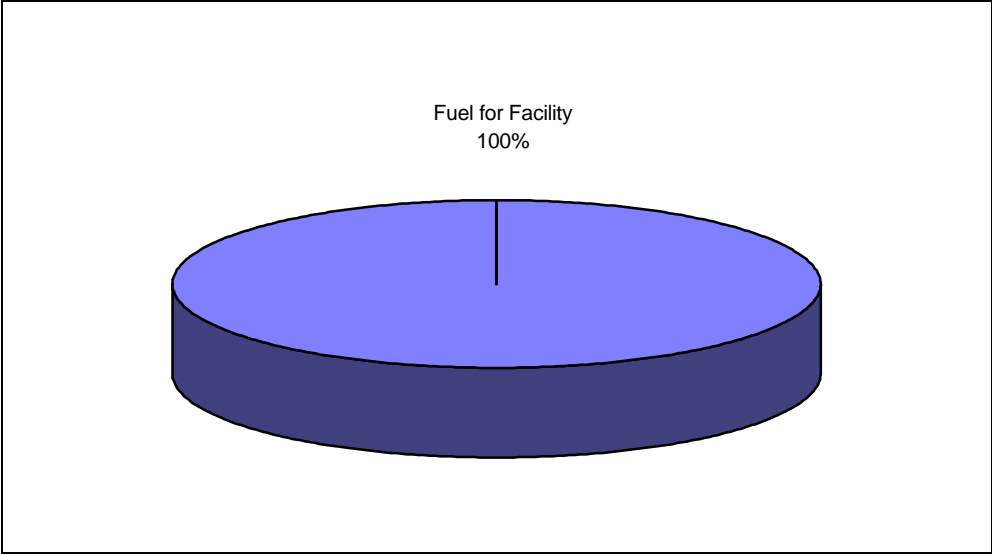


Figure 33. Current Markets and Market Share for Hardwood Plywood Manufacturers Planer Shavings

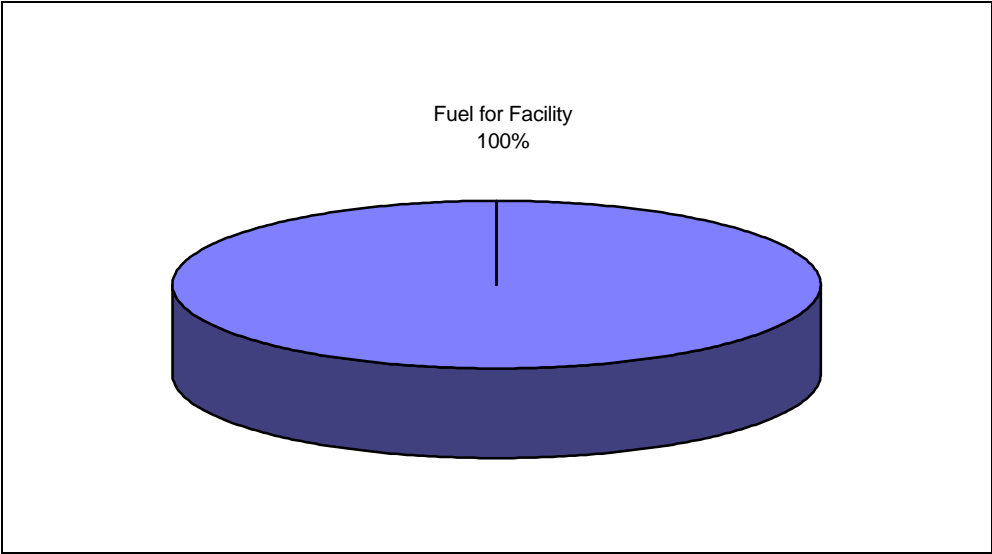


Figure 34. Current Markets and Market Share for Hardwood Plywood Manufacturers Bark

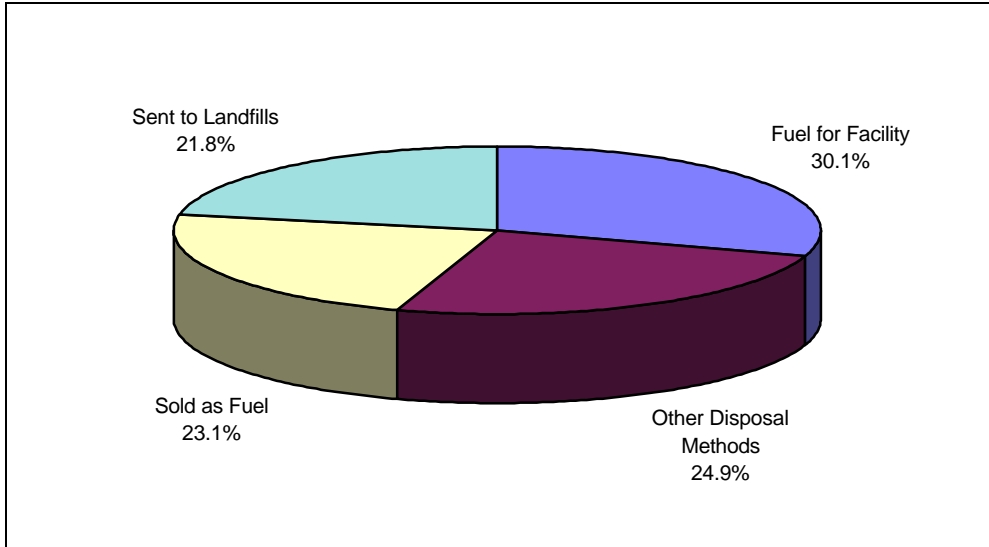


Figure 35. Current Markets and Market Share for Hardwood Plywood Manufacturers Wood Residues

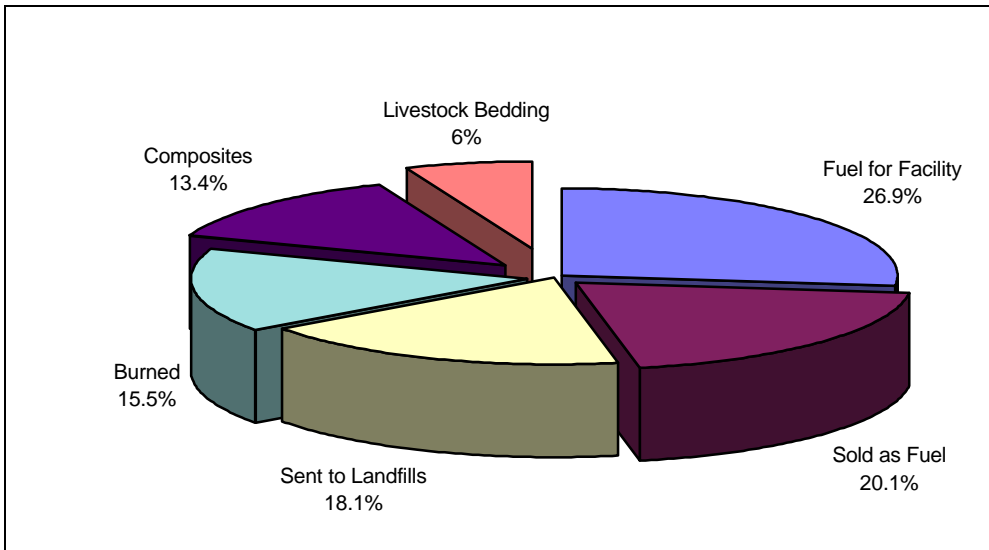


Figure 36. Current Markets and Market Share for Rough Mill Operations Sawdust

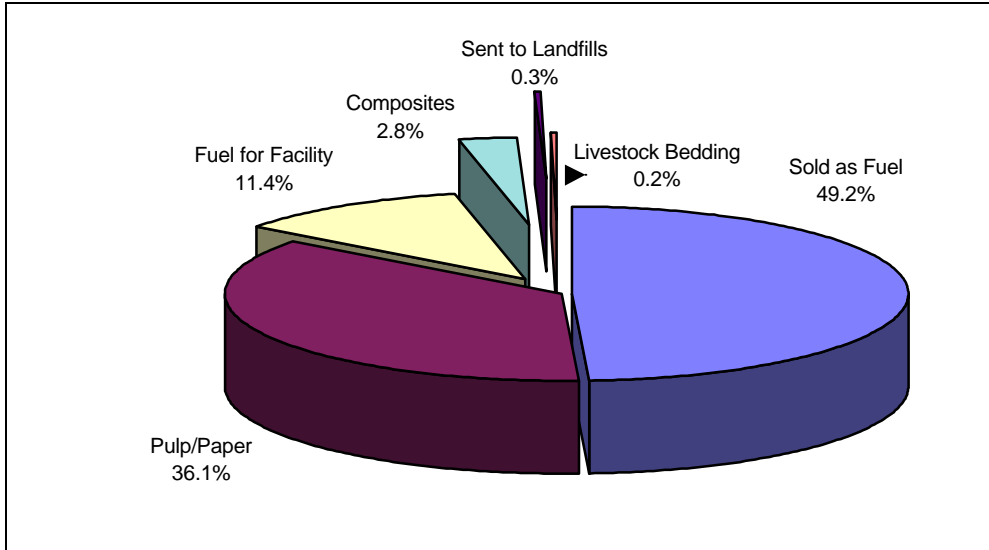


Figure 37. Current Markets and Market Share for Rough Mill Operations Chips

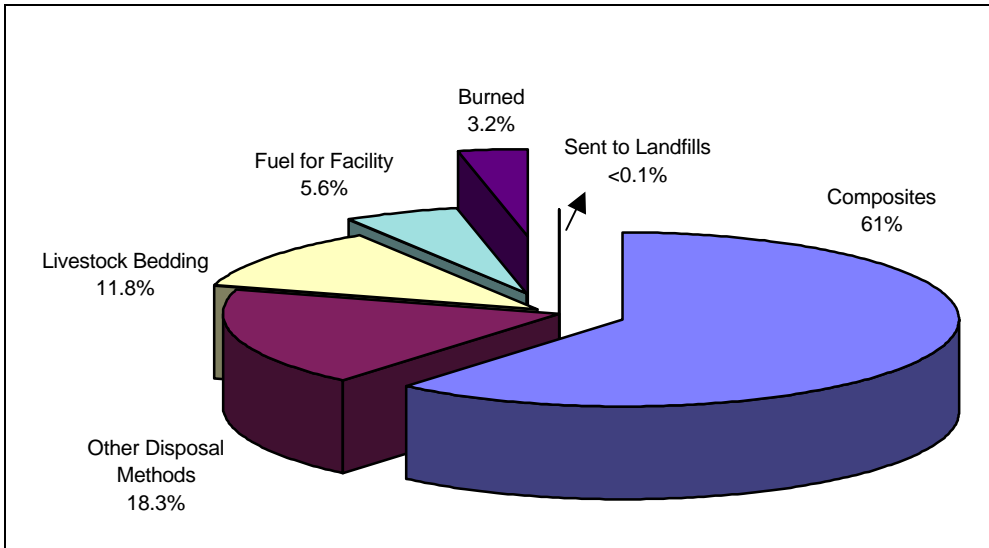


Figure 38. Current Markets and Market Share for Rough Mill Operations Mixed Residues

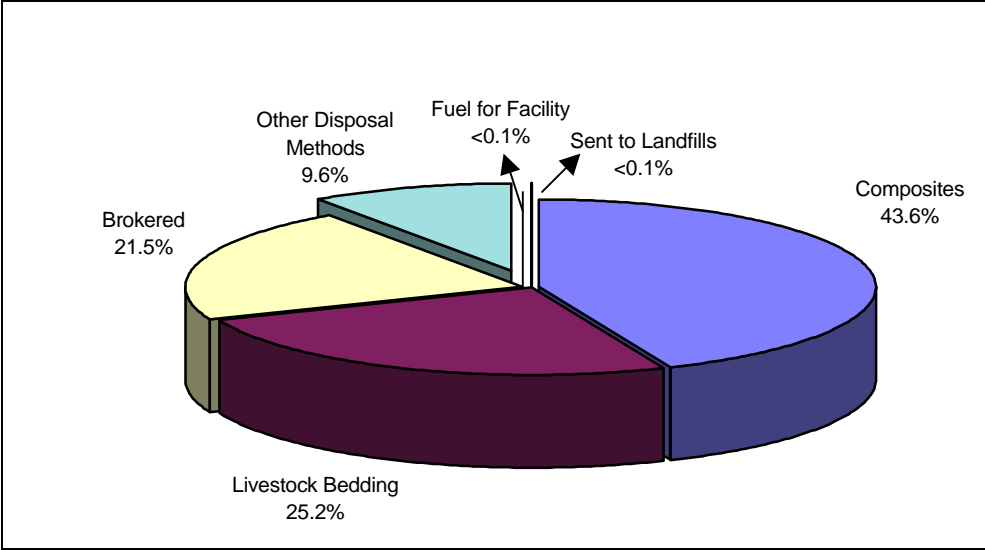


Figure 39. Current Markets and Market Share for Rough Mill Operations Planer Shavings

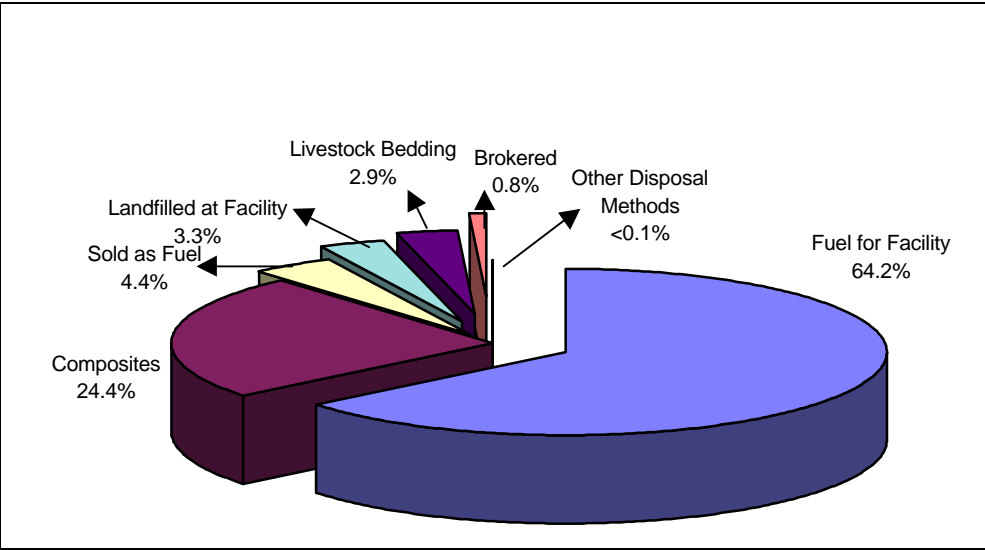


Figure 40. Current Markets and Market Share for Rough Mill Operations Coarse Residues

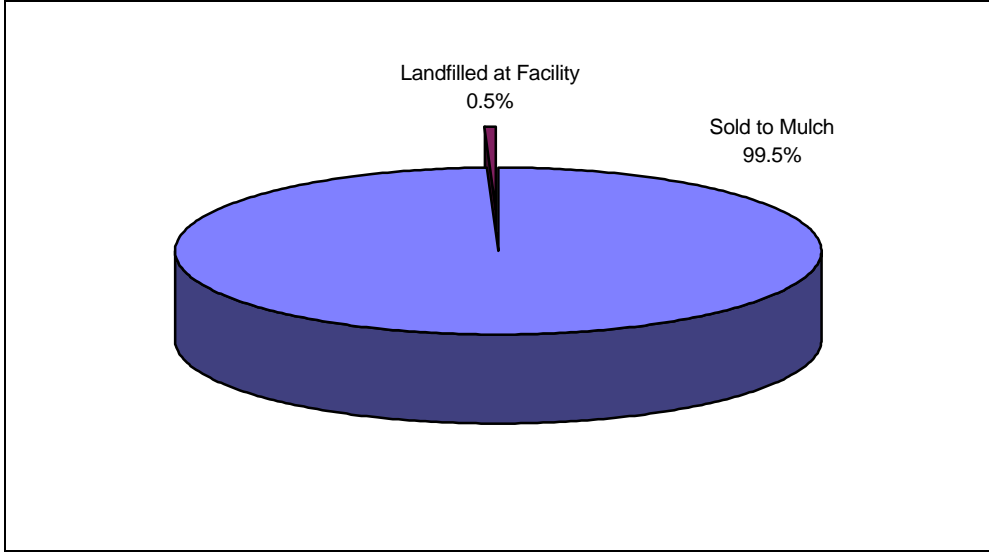


Figure 41. Current Markets and Market Share for Rough Mill Operations Bark

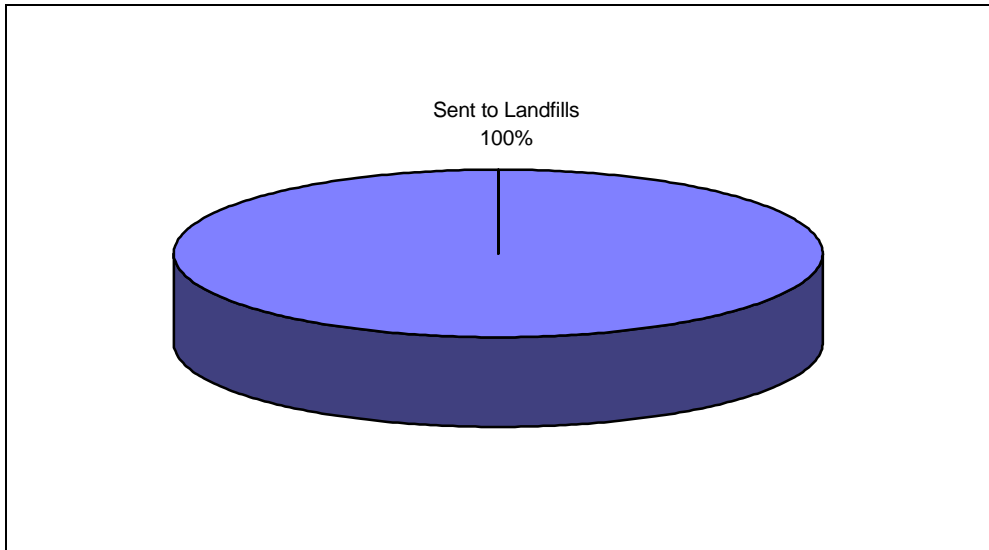


Figure 42. Current Markets and Market Share for Rough Mill Operations Other Green and Dry Residues

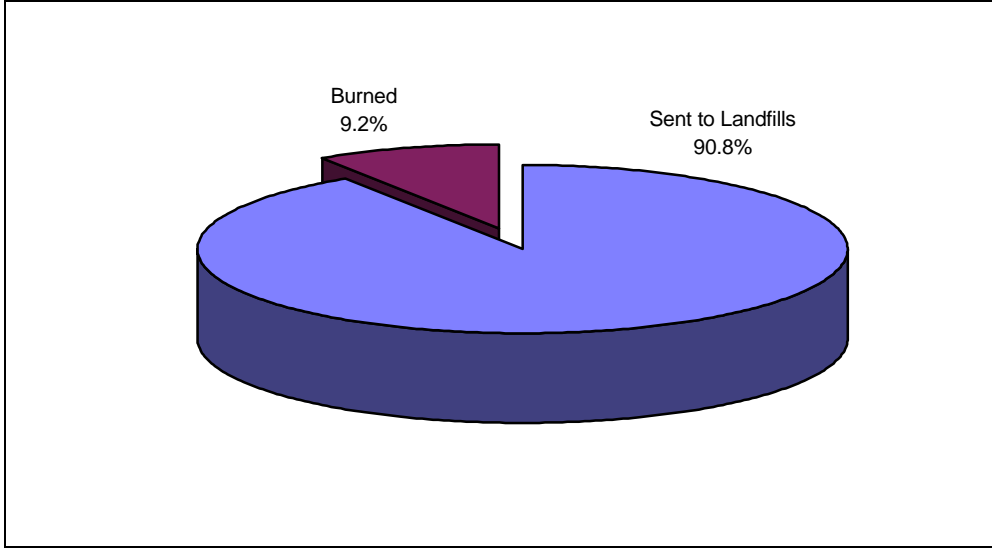


Figure 43. Current Markets and Market Share for Rough Mill Operations Scrap Pallets

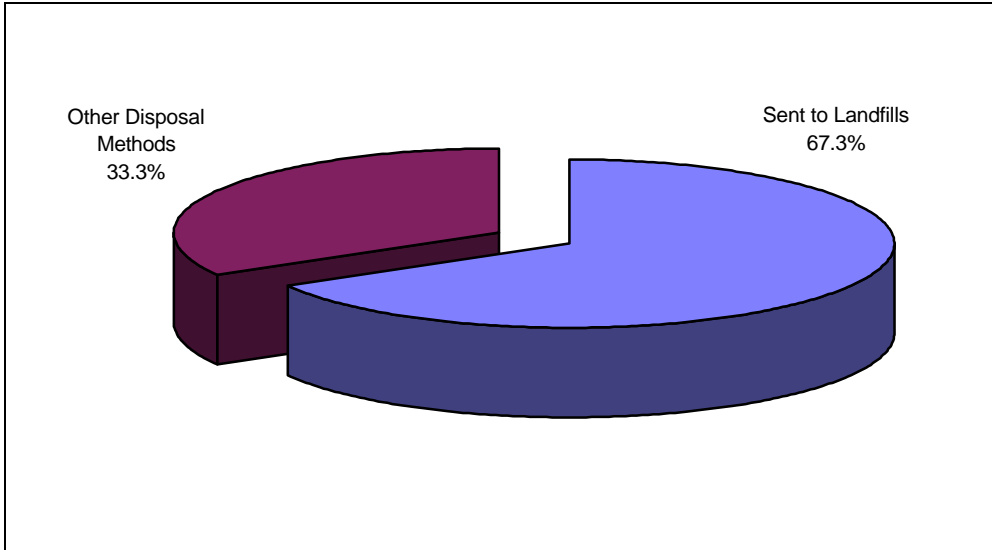


Figure 44. Current Markets and Market Share for Rough Mill Operations Sanderdust

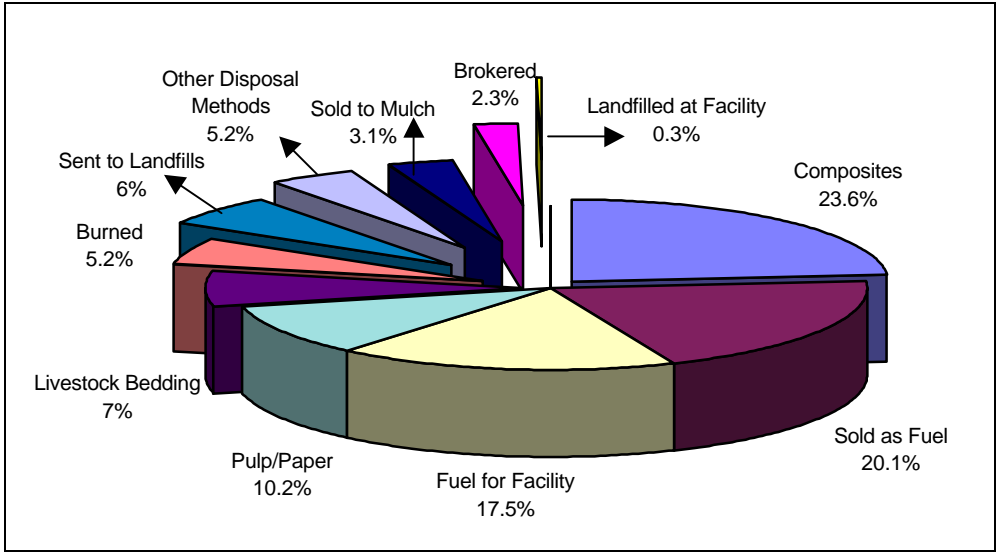


Figure 45. Current Markets and Market Share for Rough Mill Operations Wood Residues

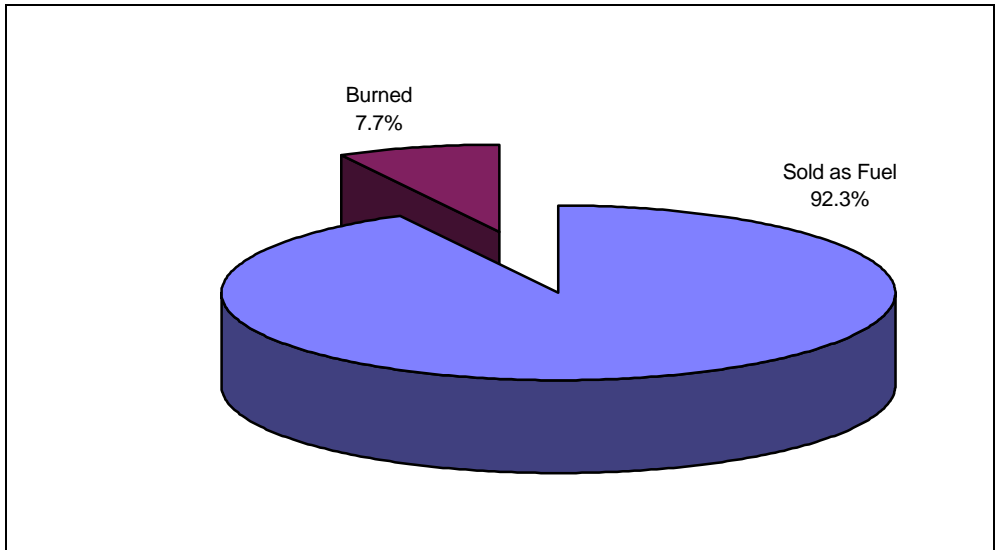


Figure 46. Current Markets and Market Share for Pallet Manufacturers Mixed Residues

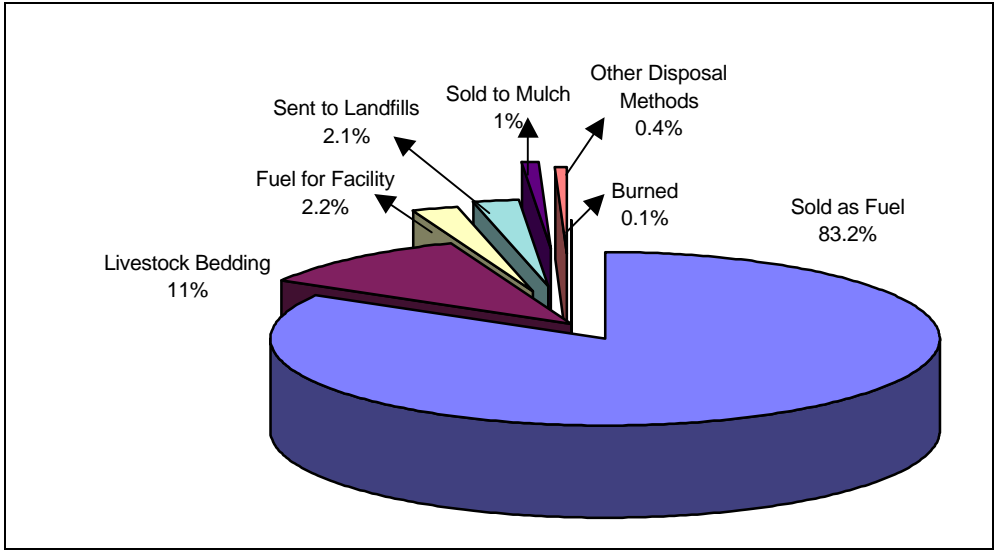


Figure 47. Current Markets and Market Share for Pallet Manufacturers Scrap Pallets

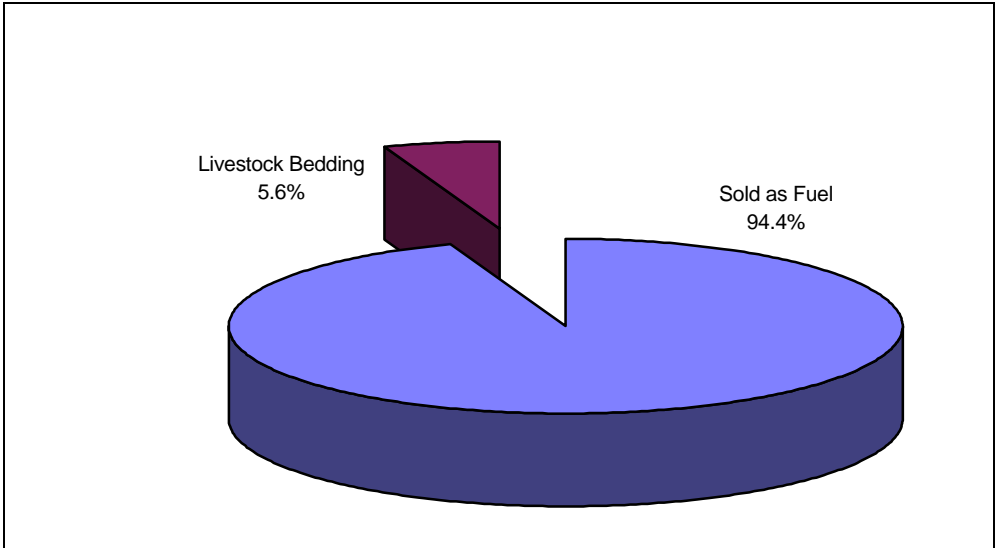


Figure 48. Current Markets and Market Share for Pallet Manufacturers Sawdust

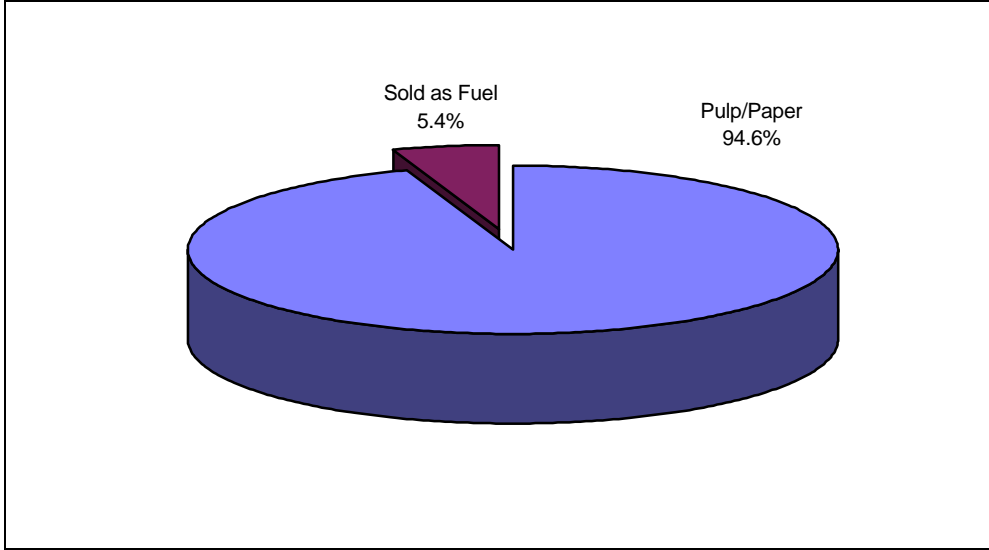


Figure 49. Current Markets and Market Share for Pallet Manufacturers Chips

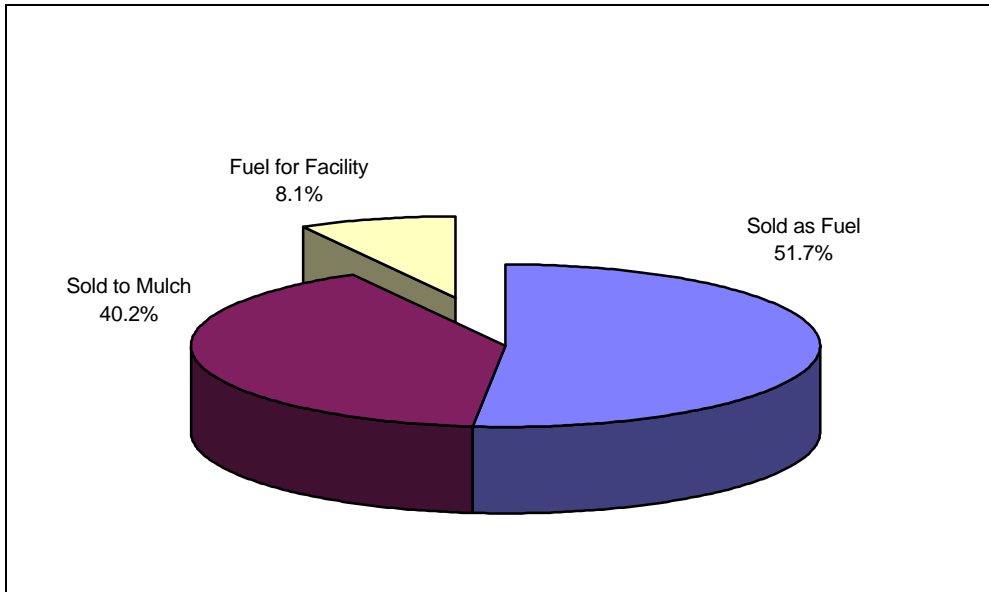


Figure 50. Current Markets and Market Share for Pallet Manufacturers Bark

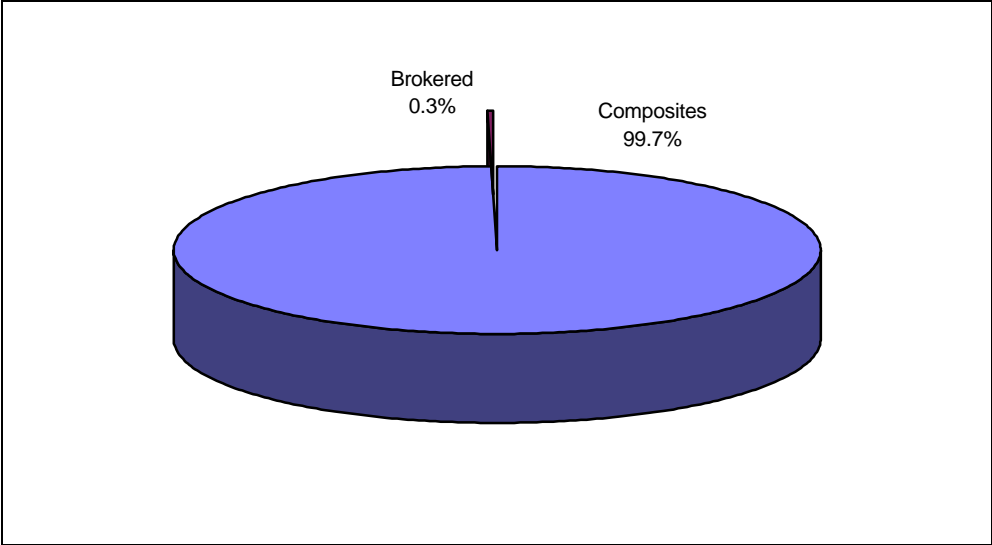


Figure 51. Current Markets and Market Share for Pallet Manufacturers Planer Shavings

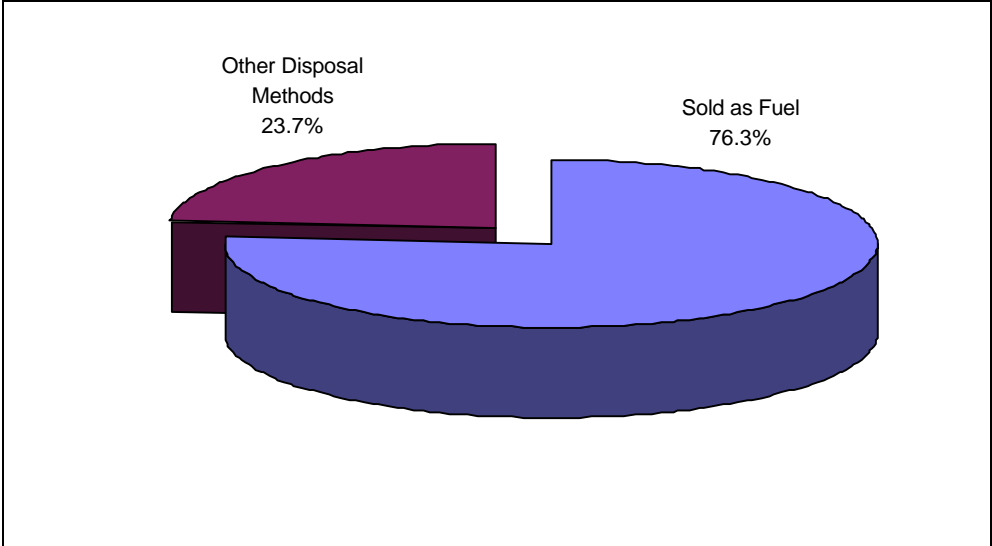


Figure 52. Current Markets and Market Share for Pallet Manufacturers Other Dry Residues

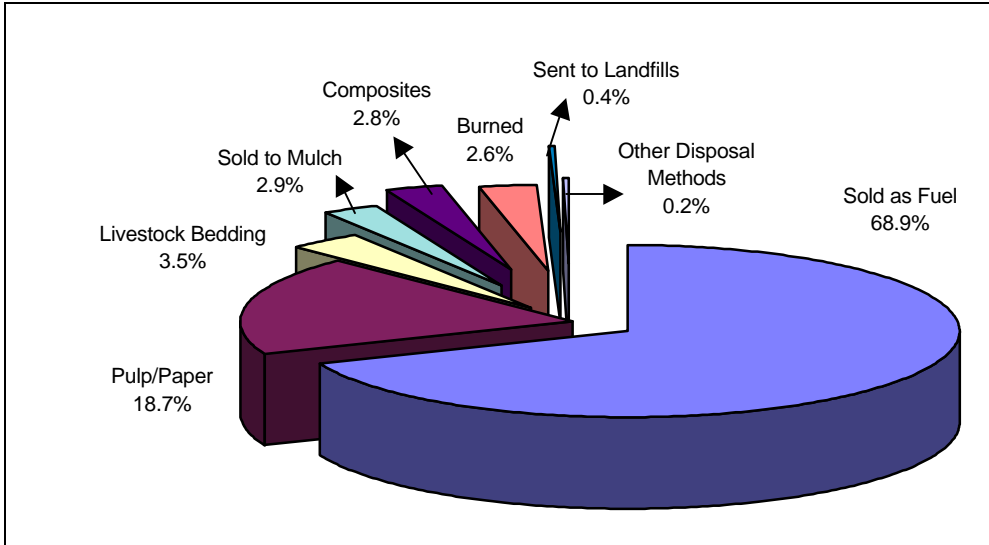


Figure 53. Current Markets and Market Share for Pallet Manufacturers Wood Residues

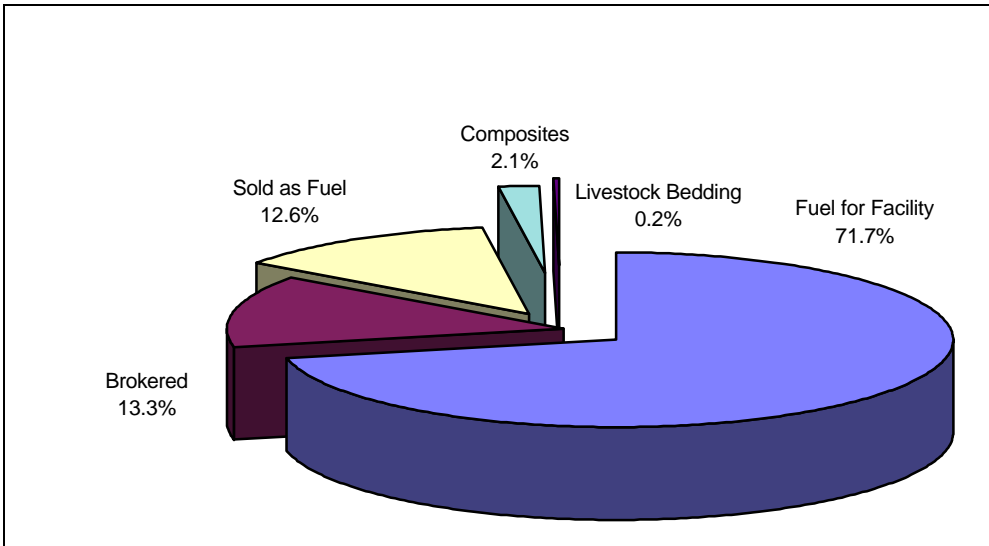


Figure 54. Current Markets and Market Share for Furniture Manufacturers Mixed Residues

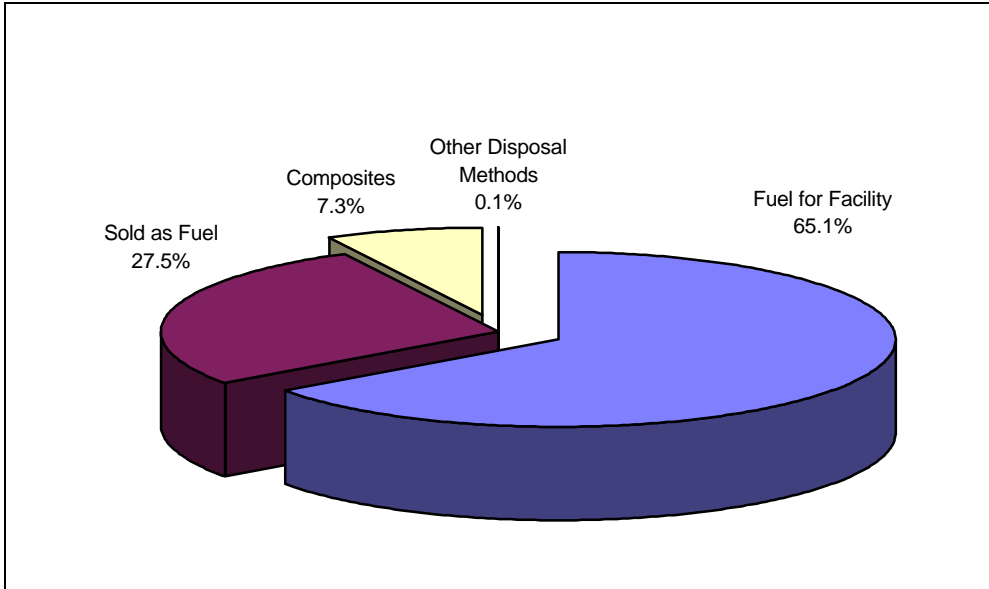


Figure 55. Current Markets and Market Share for Furniture Manufacturers Sawdust

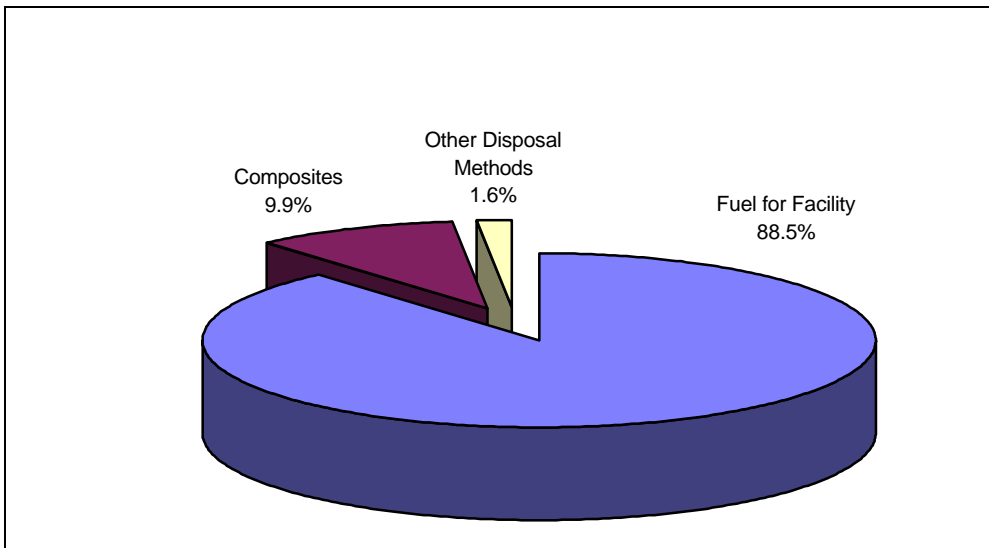


Figure 56. Current Markets and Market Share for Furniture Manufacturers Planer Shavings

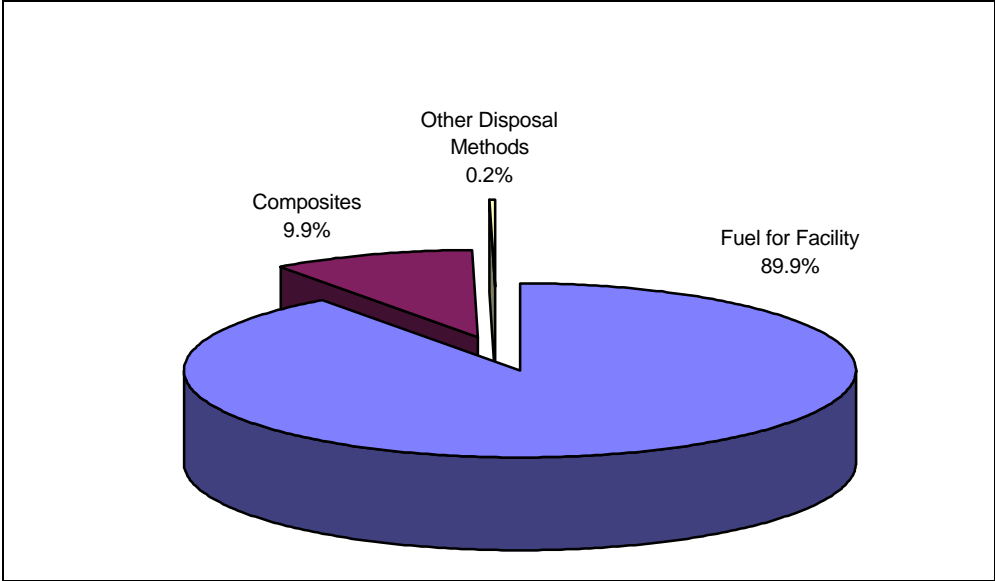


Figure 57. Current Markets and Market Share for Furniture Manufacturers Sanderdust

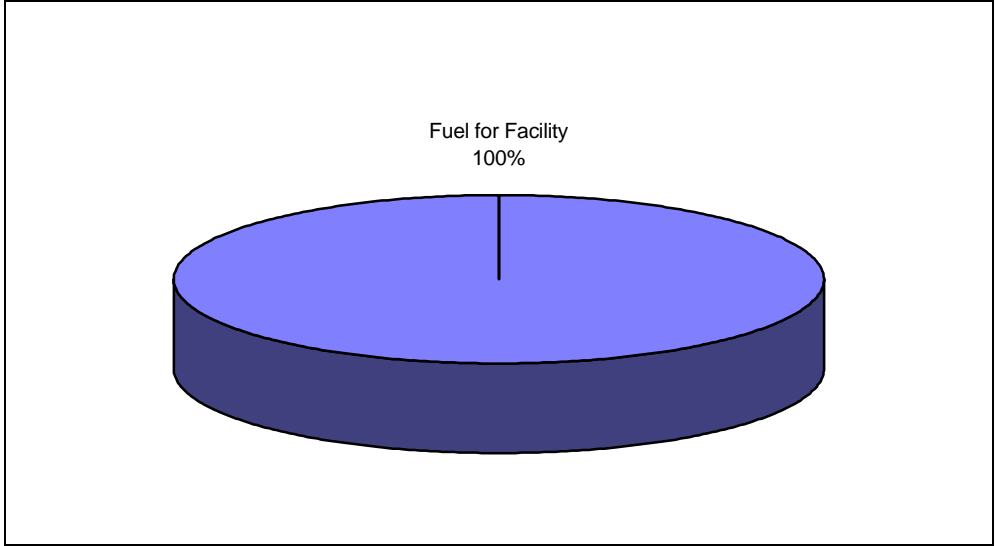


Figure 58. Current Markets and Market Share for Furniture Manufacturers Chips

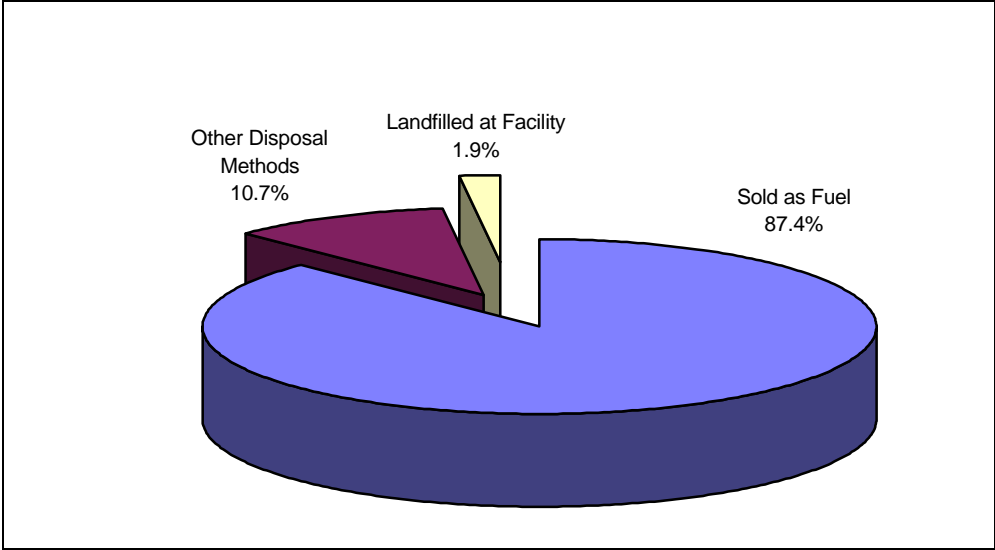


Figure 59. Current Markets and Market Share for Furniture Manufacturers Coarse Residues

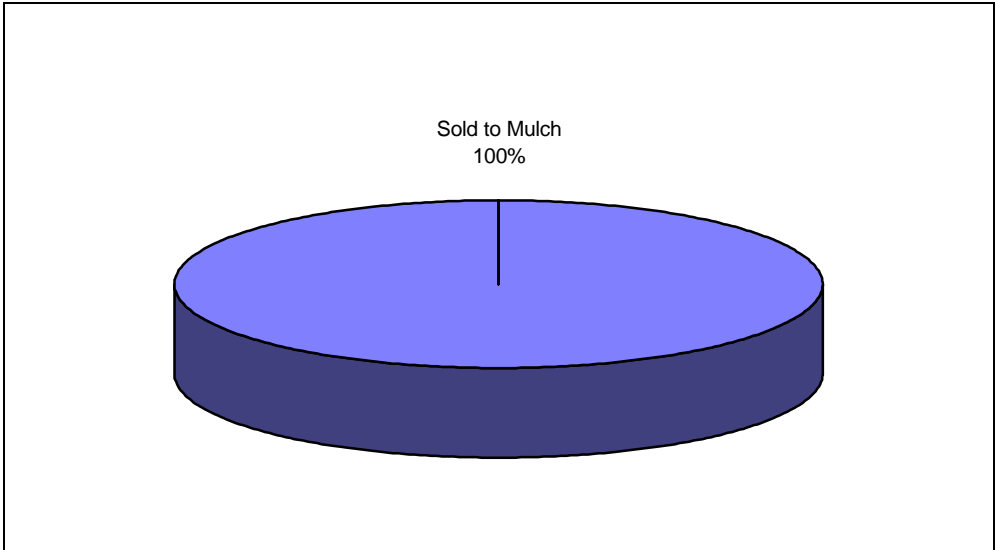


Figure 60. Current Markets and Market Share for Furniture Manufacturers Bark

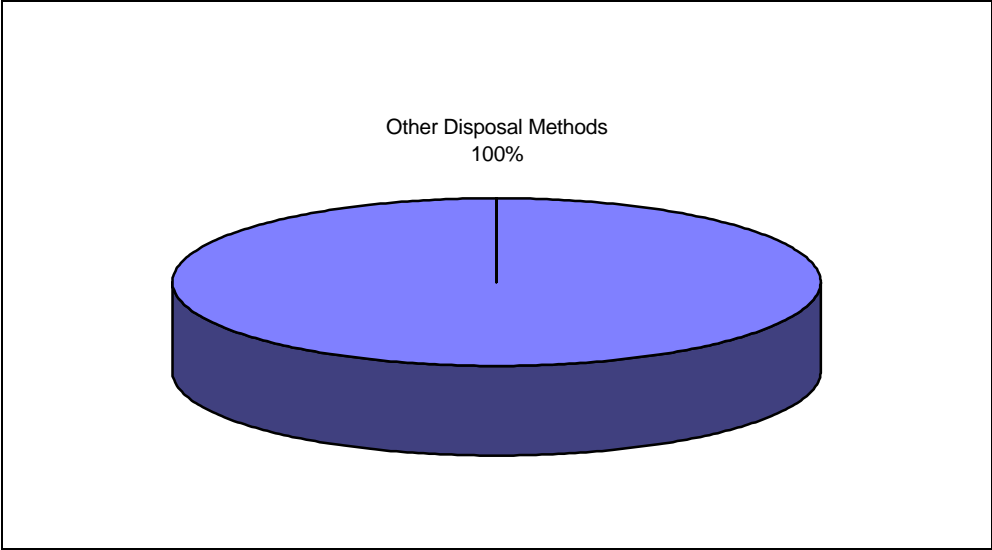


Figure 61. Current Markets and Market Share for Furniture Manufacturers Other Dry Residues

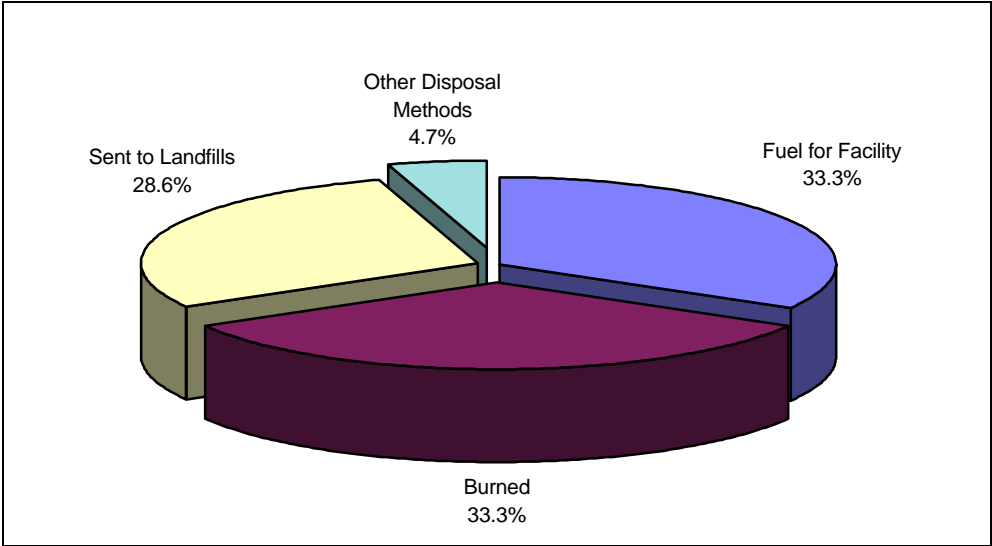


Figure 62. Current Markets and Market Share for Furniture Manufacturers Scrap Pallets

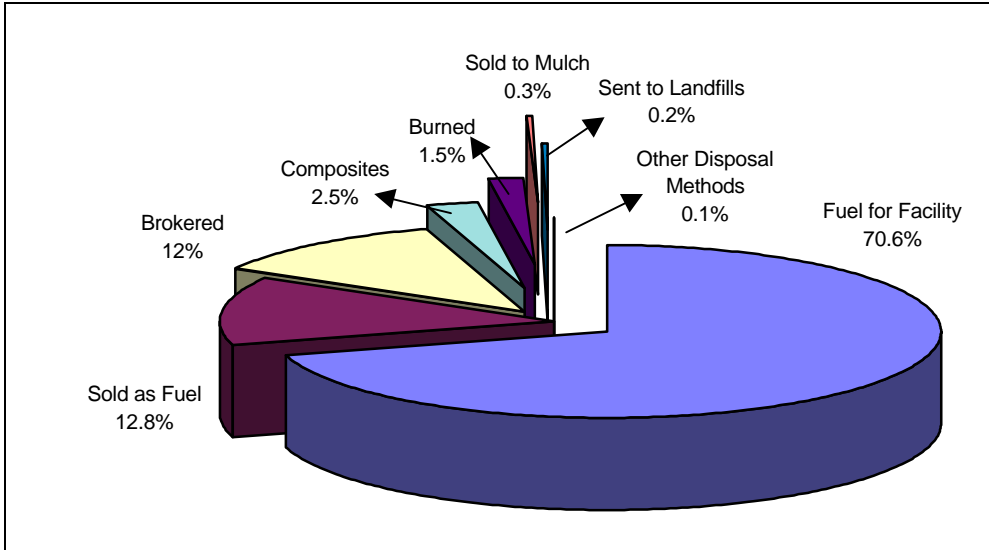


Figure 63. Current Markets and Market Share for Furniture Manufacturers Wood Residues

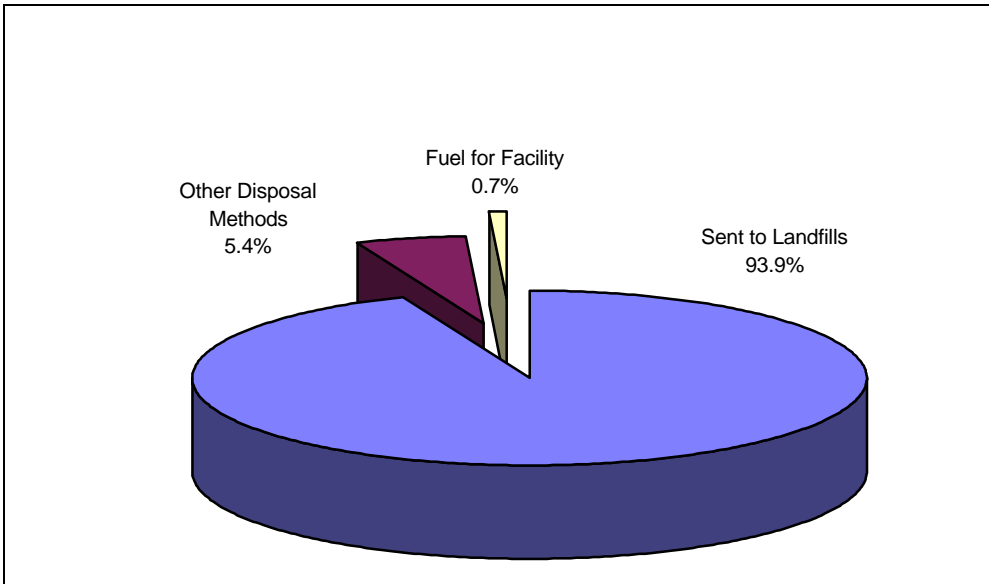


Figure 64. Current Markets and Market Share for Housing Manufacturers Other Dry Residues

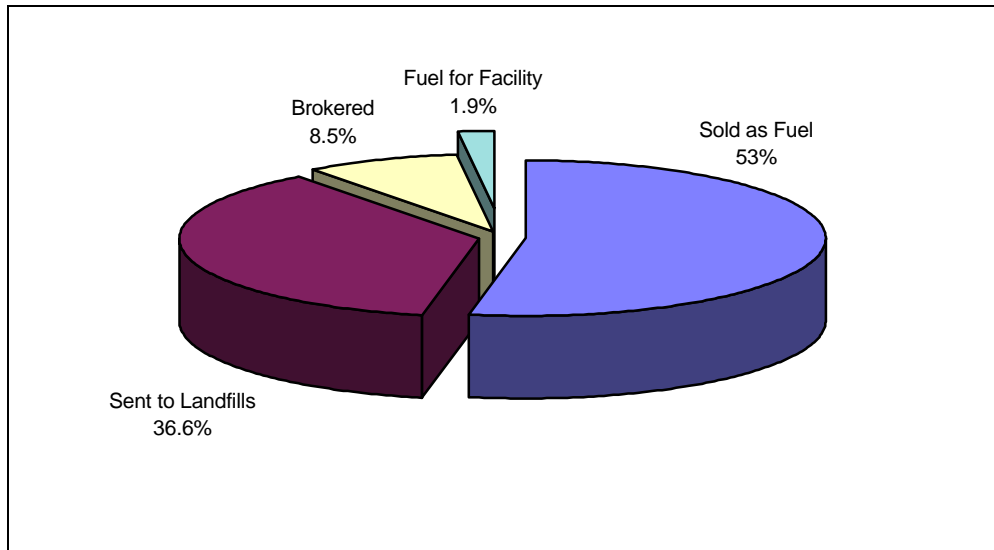


Figure 65. Current Markets and Market Share for Housing Manufacturers Chips

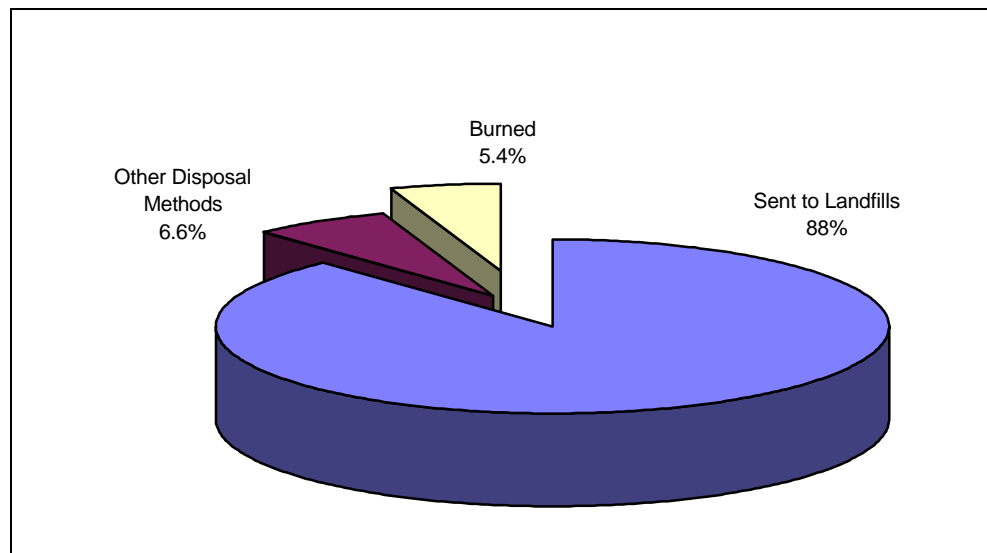


Figure 66. Current Markets and Market Share for Housing Manufacturers Mixed Residues

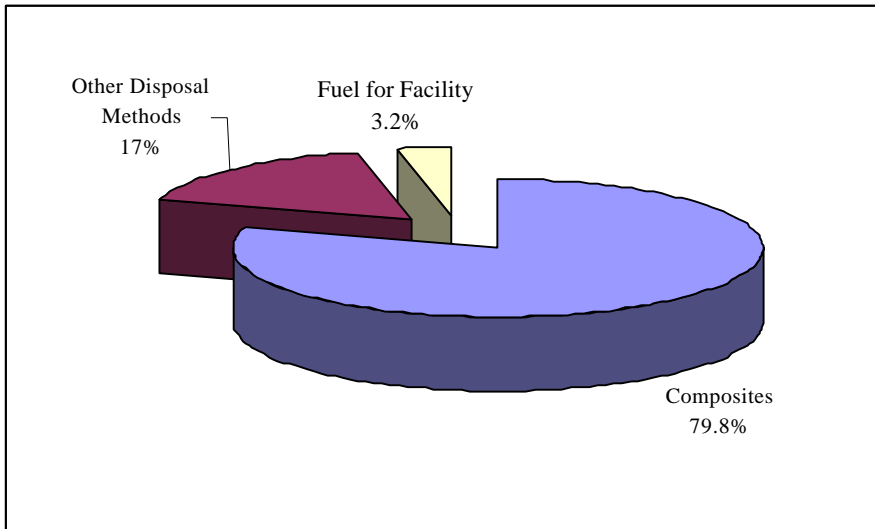


Figure 67. Current Markets and Market Share for Housing Manufacturers Coarse Residues

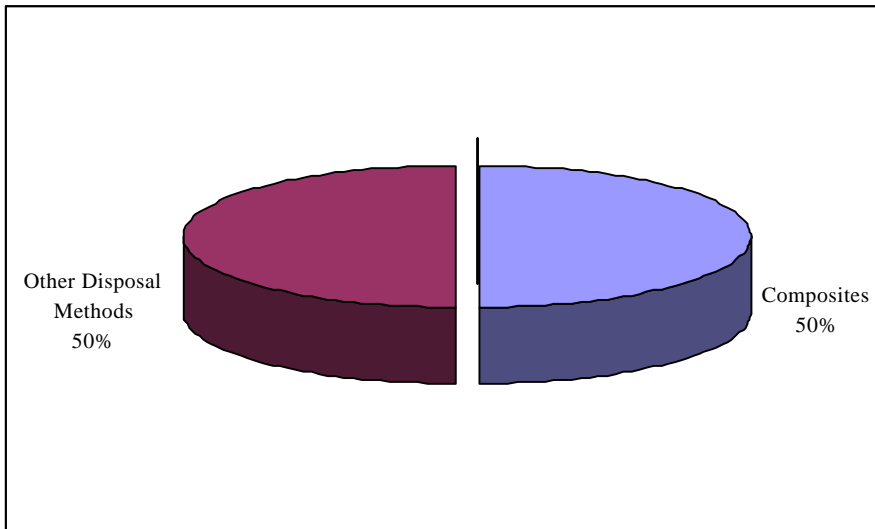


Figure 68. Current Markets and Market Share for Housing Manufacturers Planer Shavings

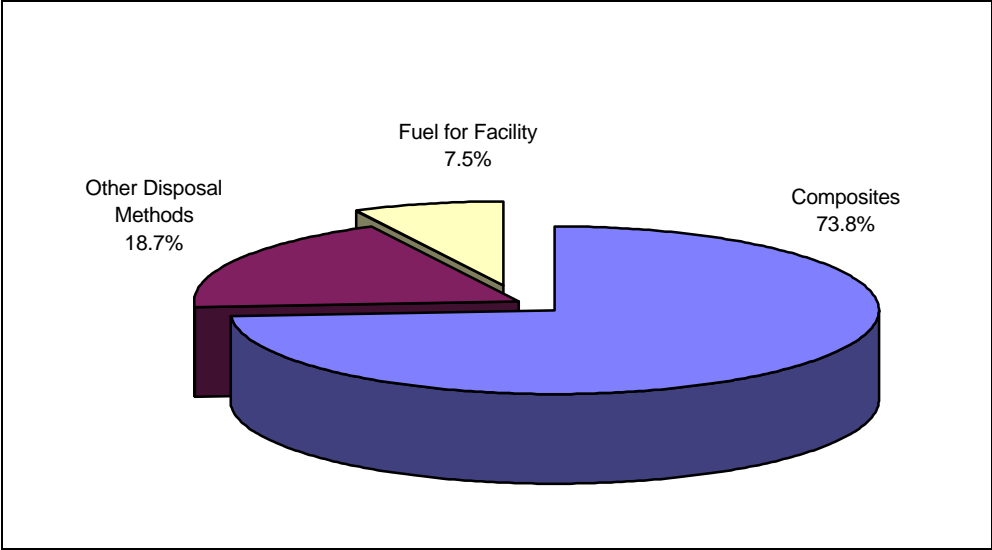


Figure 69. Current Markets and Market Share for Housing Manufacturers Sawdust

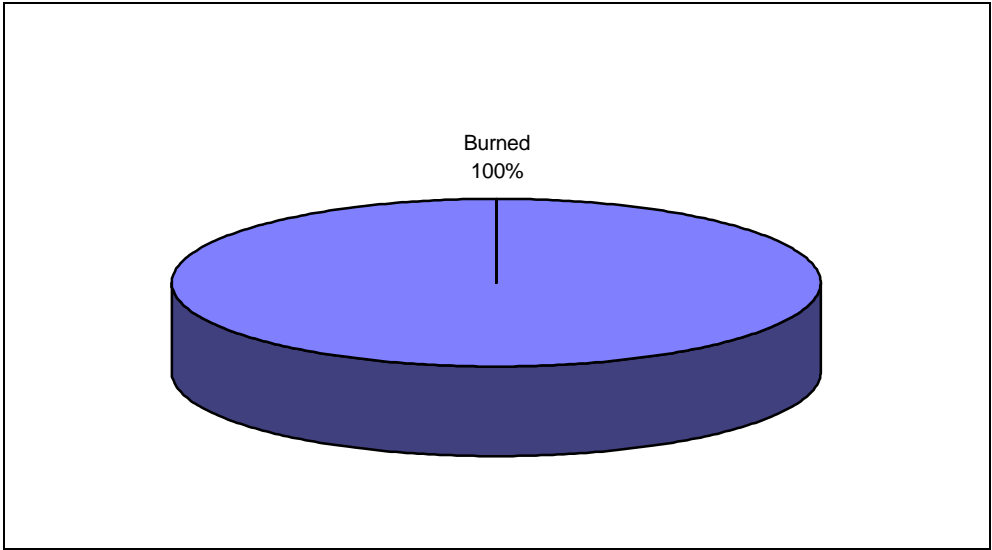


Figure 70. Current Markets and Market Share for Housing Manufacturers Sanderdust

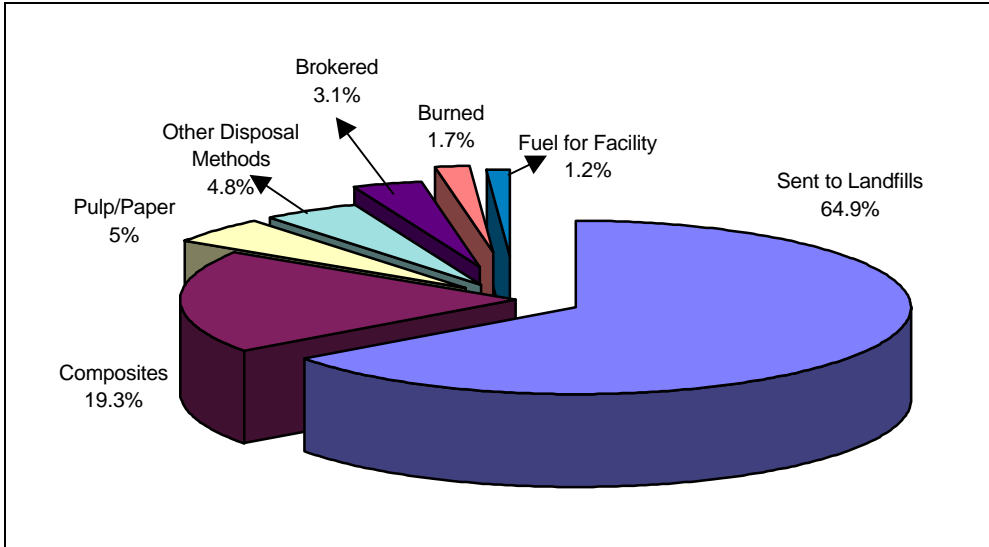


Figure 71. Current Markets and Market Share for Housing Manufacturers Wood Residues

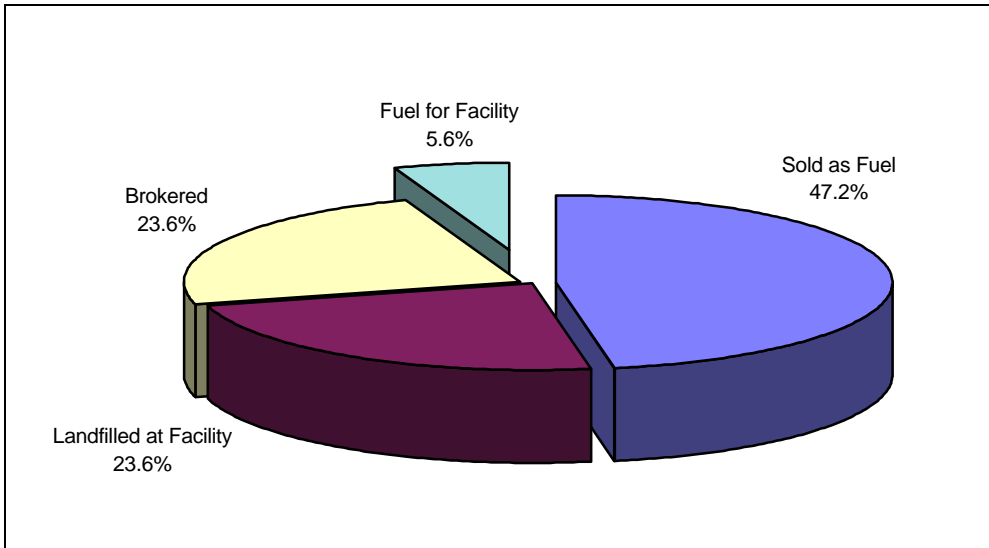


Figure 72. Current Markets and Market Share for "Other" Manufacturers Green and Dry Residues

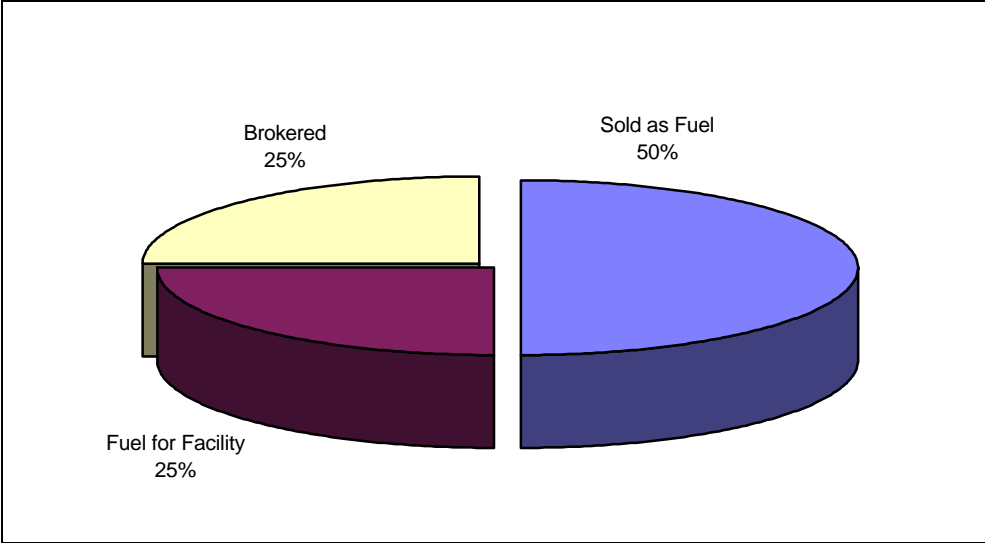


Figure 73. Current Markets and Market Share for “Other” Manufacturers Scrap Pallets

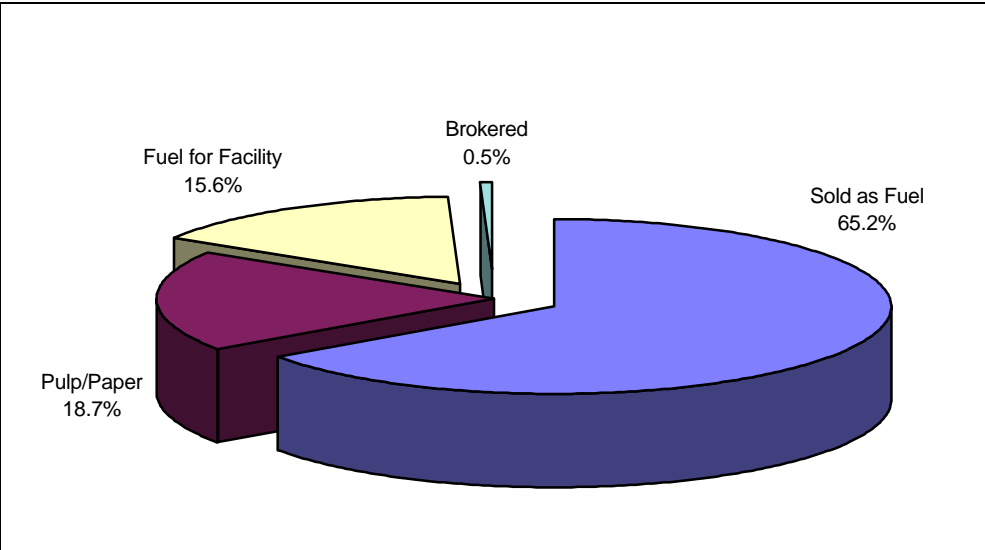


Figure 74. Current Markets and Market Share for “Other” Manufacturers Chips

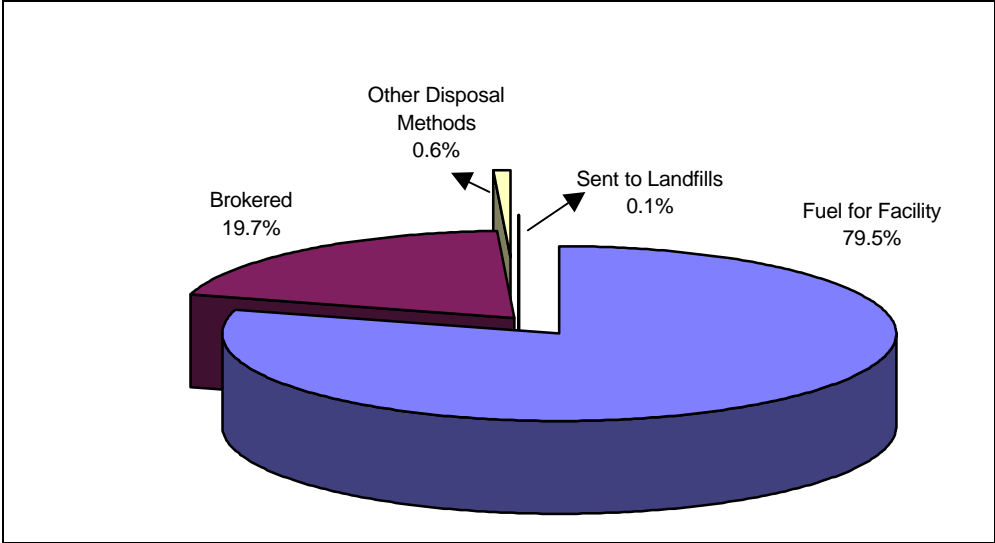


Figure 75. Current Markets and Market Share for "Other" Manufacturers Sawdust

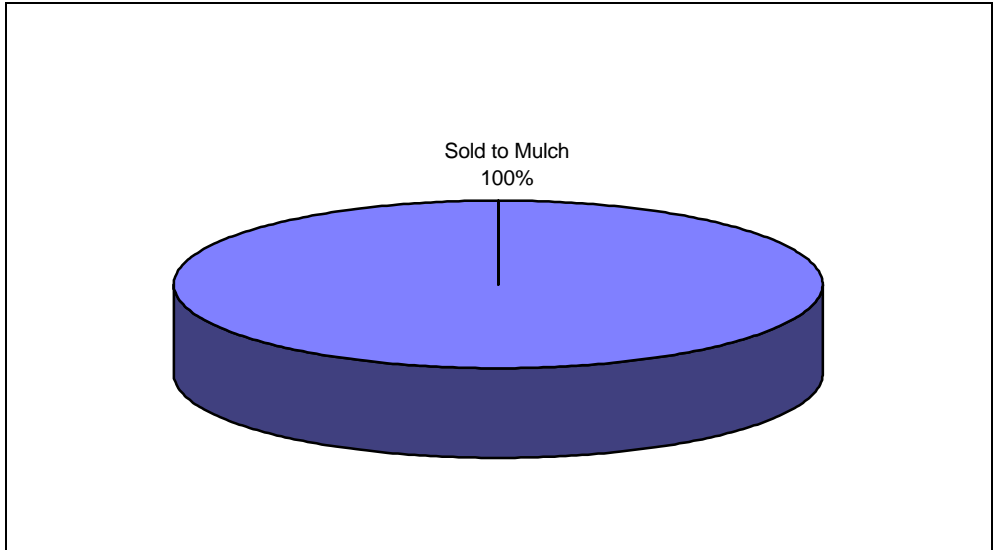


Figure 76. Current Markets and Market Share for "Other" Manufacturers Bark

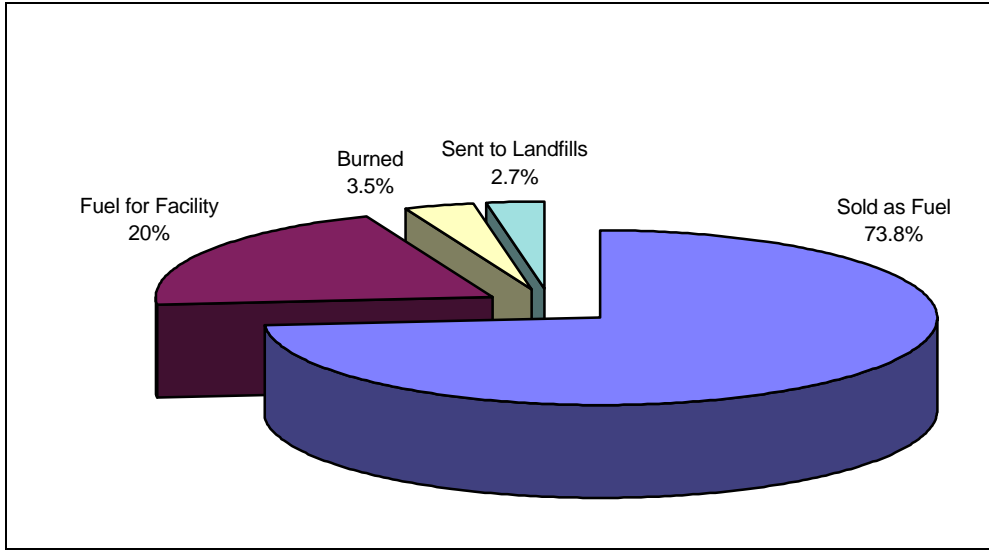


Figure 77. Current Markets and Market Share for "Other" Manufacturers Coarse Residues

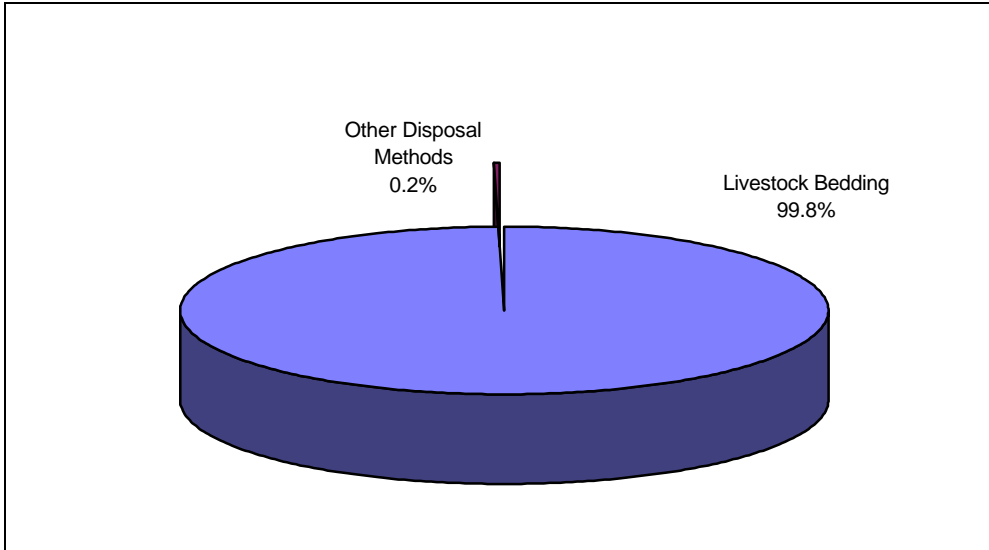


Figure 78. Current Markets and Market Share for "Other" Manufacturers Planer Shavings

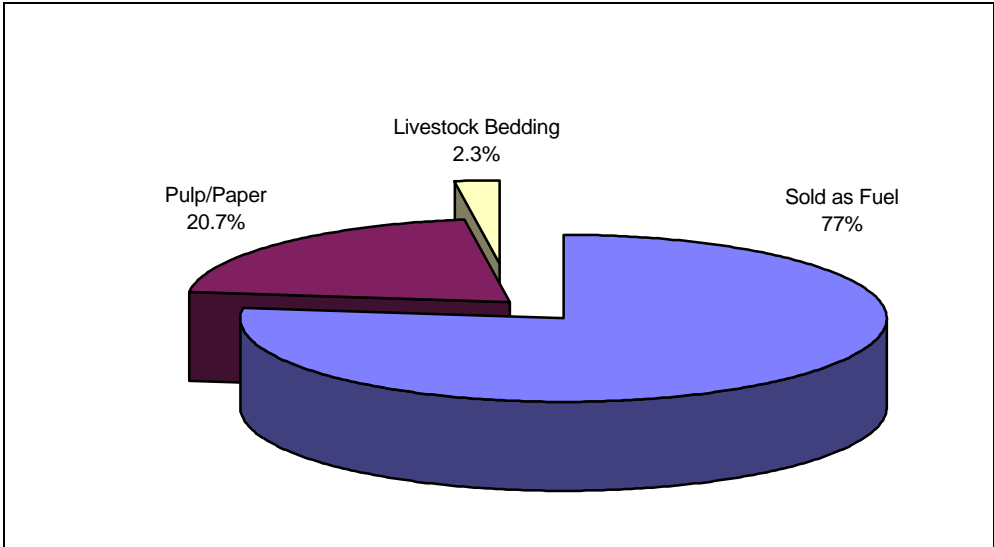


Figure 79. Current Markets and Market Share for "Other" Manufacturers Mixed Residues

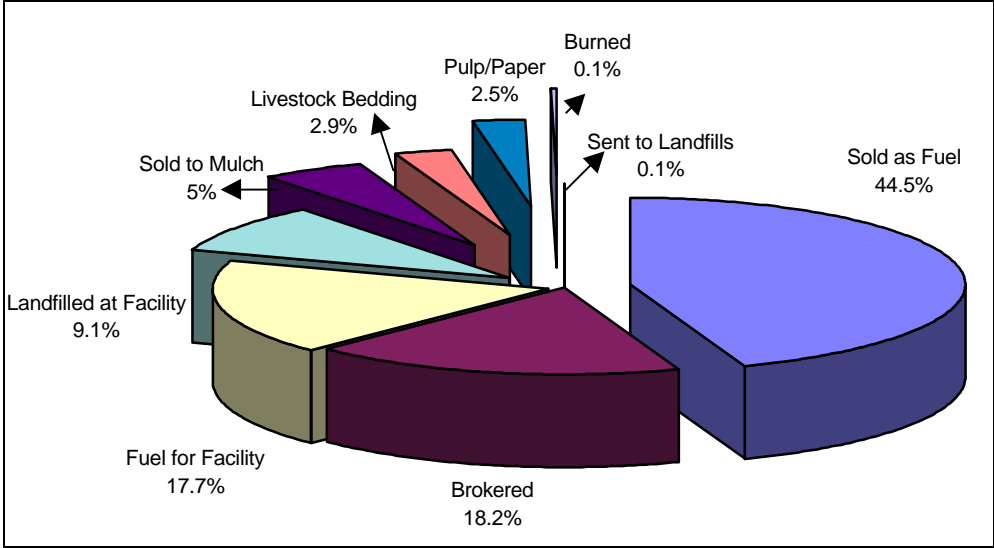


Figure 80. Current Markets and Market Share for "Other" Manufacturers Wood Residues

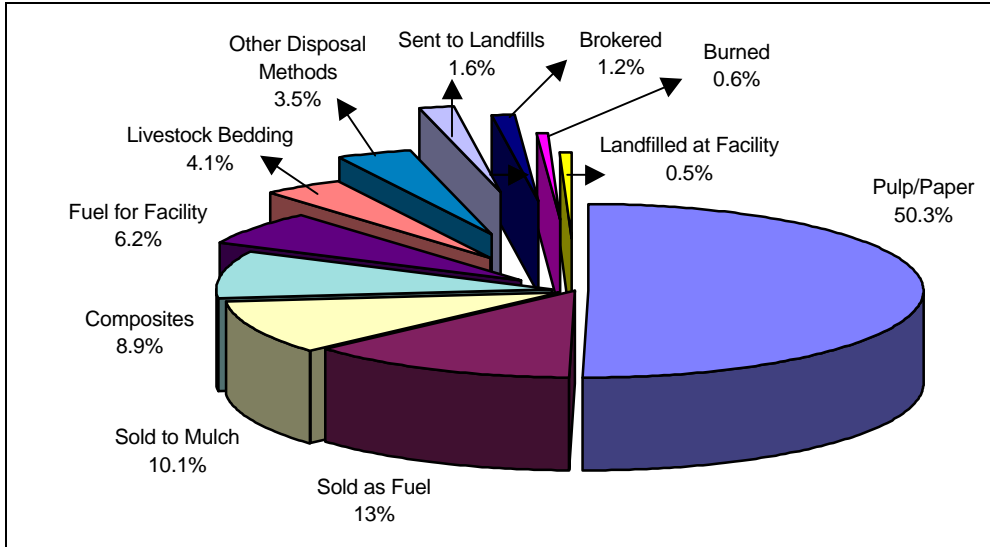


Figure 81. Current Markets and Market Share for Virginia Wood Manufacturers Wood Residues

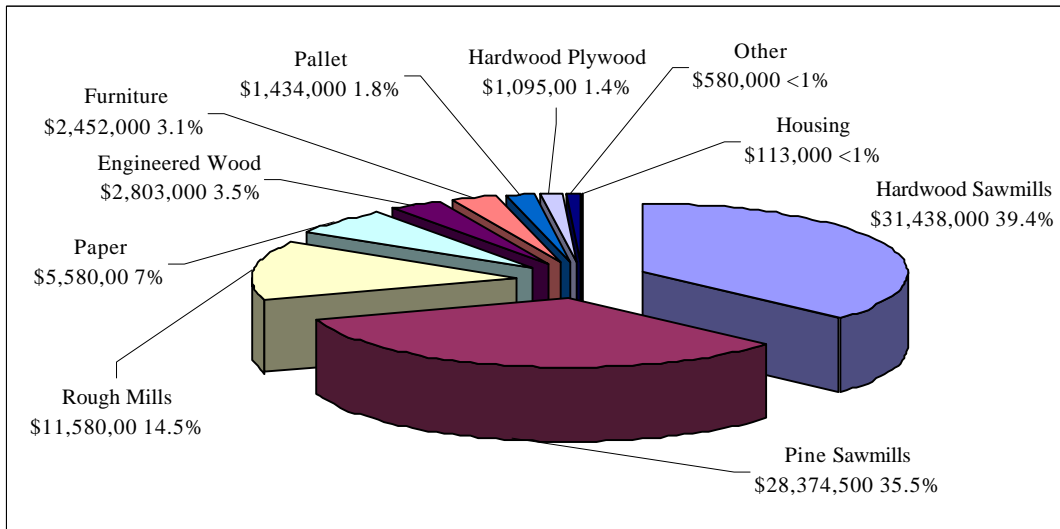


Figure 82. Estimated Value and Market Share for Virginia Wood Manufacturers Wood Residues

CHAPTER 3

SOLID WOOD WASTE DISPOSAL IN VIRGINIA

Methods

A literature search and review were conducted to ascertain if similar wood waste disposal studies have been conducted in other states. First, all municipal, construction and demolition, and “other” waste facilities in Virginia were contacted to gather relevant data regarding solid wood waste disposal in the Commonwealth.

A questionnaire, administered through the mail, was used to collect data and was directed to the facility manager or the government official in charge of the facility. The waste facilities list was obtained from a previous survey conducted by the Center for Forest Products Marketing and Management at Virginia Tech. The first section of the questionnaire used categorical questions to identify if the organization operated a landfill, type(s) and number of landfills operated, the quantity of all waste received at these facilities, tipping fees, and the quantity of solid wood received at the facility. The second section of the questionnaire used percentage scales to measure the volume and percentages of various types of solid wood received at the facility, and if the percentage of solid wood was increasing, decreasing, or remained the same. The third section of the questionnaire asked if the facilities actively marketed wood by-products, if they had the capacity to recycle wood, and if within the next three years, did they plan to begin the processing of wood by-products. The fourth section of the questionnaire requested the percentage of solid wood processed at their facility, average tipping fee, and what was the primary method of disposal. The final section of the questionnaire asked for the average selling price of wood by-products, did the facility restrict wood from being landfilled, and how the facility disposed of wood by-products if they did not recycle them (Appendix B).

Before administering the survey, the questionnaire was evaluated by knowledgeable faculty members at Virginia Tech in the Department of Wood Science and Forest Products. In addition, the questionnaire was randomly pre-tested at six landfill facilities in the state. The responses to the pretest were used to clarify question wording, order, and if additional questions needed to be asked. The questionnaire, along with a signed cover letter, was mailed in May of 1997 to 139 waste facilities in Virginia. This mailing sequence was conducted three-more times over a three-month period, with a reminder letter mailed in between (Dillman Method) (Dillman 1978).

Estimation Procedure

Waste volume and solid wood residue volumes directed to Virginia's landfills were extrapolated to estimate the total waste and solid wood volume directed to Virginia's landfills. The following steps outline the procedure used in this extrapolation:

1. The waste facilities total waste volume was divided by the number of responding landfills (of that particular landfill type). For example, MSW facilities reported receiving 5,076,926 tons of all waste in 1996. The total waste was divided by the number of responding MSW facilities, 5,076,926 divided by 46. This resulted in an average of 110,368 tons received at each responding MSW facility in 1996.
2. The average was multiplied by the number of responding facilities, in addition to the number of non-responding facilities. The average volume received, 110,368 tons was multiplied by 56 (46 plus 10 non-responding MSW facilities), resulting in an estimated 6.2 million tons of all waste received by MSW facilities in 1996.

This procedure was repeated for each landfill type in order to estimate the total solid wood volume and the volume of each residue type. This estimation procedure is similar to that used by Bush, Reddy, Bumgardner, Chamberlain, and Araman (1997) to estimate pallet production. The focus of their research was to estimate the number of pallets disposed in landfills, the wood volume contained in those pallets, and pallet recovery.

Respondents

The solid wood waste disposal questionnaire was mailed to 139 Virginia landfills in May of 1997. One hundred and seven facilities responded, 75 indicated they accepted wood residues and 32 indicated they did not accept wood residues. There were 17 bad addresses out of the 139 mailed questionnaires. The initial response rate was approximately 54 percent and the adjusted response rate was 83 percent.

Seventy-five landfill facilities responded and facility managers indicated that they operated 46 municipal solid waste (MSW), 26 “Other” waste facilities, and 18 construction and demolition (C&D) landfills, for a total coverage of 90 landfills. “Other” waste facilities included private company, fly ash, asbestos, industrial, composting and yard waste facilities, inert waste, mulching operations, drop off or transfer stations, and energy recovery facilities.

Results and Discussion

Responding Virginia landfills reported receiving approximately 8.2-million tons of all wastes in 1996. Included in this total, responding Virginia landfills reported receiving approximately 8 percent or 688,650 tons of solid wood in 1996 (Table 1).

Municipal Solid Waste Facilities

Responding MSW landfills reported receiving approximately 5.1 million tons or 62 percent of all waste directed to responding Virginia landfills in 1996. The average volume received at responding MSW facilities was approximately 110,370 tons per facility and the average tipping fee was \$34.91 per ton per facility (Table 1).

Responding MSW facilities reported receiving approximately 358,550 tons of solid wood at their facilities in 1996. The solid wood waste total was 7 percent of all wastes reported received at responding MSW facilities in 1996 (Table 1).

Approximately 43 percent of the total solid wood received by responding MSW waste facilities or 152,500 tons were yard trimmings, nearly 92,850 tons or 26 percent were construction and demolition wastes, 42,500 tons or 12 percent were scrap pallets, and 37,550 tons or 10 percent were “other” wood wastes. These four residue types comprised approximately 92 percent of the solid wood wastes received by responding MSW facilities in 1996 (Table 2). “Other” wastes included furniture and manufactured housing wood residues, solid wood mixed with C&D residues, tree trunks, and stumps.

Twenty-four or approximately 56 percent of the responding MSW facilities reported no change in the volume of solid wood collected during the past three years. Seventeen or nearly 37 percent of responding MSW facilities reported the volume of solid wood increased by an average of 13 percent over the past 3 years. Four or approximately 9 percent of the responding MSW facilities reported the volume of solid wood decreased by an average of 2 percent during the past 3 years.

Twenty-three or 50 percent responding MSW facilities reported they restricted wood, in any form, from being landfilled. Seventeen or nearly 49 percent responding MSW facilities reported burying solid wood (in the form it was received) as the principal method of solid wood waste disposal. Nine or 26 percent of responding MSW facilities reported burning solid wood, 7 or 20 percent MSW facilities reported utilizing other disposal methods and 2 or approximately 6 percent facilities reported processing solid wood and then burying the processed wood. "Other" disposal methods included open burning, wind rowing processed solid wood or bark was used to resurface internal roads at the facility.

The estimated total of all MSW wastes received was approximately 6.2 million tons. The estimated solid wood total was approximately 430,500 tons. The MSW estimated solid wood total was comprised of 185,600 tons of yard trimmings, 113,00 tons of construction and demolition wastes, 51,778 tons of scrap pallets, 45,700 tons of "other" wood residues, 17,000 tons of treated wood, 11,400 tons of bark, and 6,000 tons of sawdust (Table 3).

Construction and Demolition Facilities

Responding C&D landfills reported receiving approximately 550,600 tons or 7 percent of all wastes directed to responding Virginia landfills in 1996. The average volume received at responding C&D facilities was approximately 30,589 tons per facility and the average tipping fee was \$29.50 per ton per facility (Table 1).

Responding C&D facilities reported receiving approximately 186,600 tons of solid wood at their facilities in 1996. The solid wood waste total was nearly 34 percent of all wastes reported received at C&D facilities in 1996 (Table 1).

Approximately 69,150 tons of the total solid wood received by responding C&D facilities or 37 percent were construction and demolition wastes, nearly 46,600 tons or 23 percent were “other” wood residues, 41,700 tons or 22 percent were yard trimmings, and 21,800 tons or 12 percent were sawdust residues. These four product types comprised approximately 94 percent of the solid wood wastes received by responding C&D facilities in 1996 (Table 2). “Other” wastes included stumps and industrial wastes.

Twelve or approximately 67 percent of the responding C&D facilities reported no change in the volume of solid wood collected during the past three years. Four or nearly 22 percent of the responding C&D facilities reported the volume of solid wood increased by an average of 16.7 percent during the past three years. Two or approximately 11 percent of the responding C&D facilities reported the volume of solid wood decreased by an average of 2 percent during the past three years.

Six or 33 percent responding C&D facilities reported they restricted wood, in any form, from being landfilled. Thirteen or nearly 81 percent responding C&D facilities reported burying solid wood, in the form it was received, as the principal method of solid wood disposal. Two or nearly 12 percent responding C&D facilities reported other disposal methods, 1 or nearly 6 percent burning solid wood as the method of disposal. “Other” disposal methods included composting, open burning, and transferring wood wastes to facilities that accepted wood.

The estimated total, of all C&D wastes received, was approximately 611,800 tons. The estimated solid wood total was approximately 209,550 tons. The C&D facilities estimated solid wood total was comprised of 76,850 tons of construction and demolition wastes, 46,350 tons of yard trimmings, 51,800 tons of “other” residues, 6,350 tons of scrap pallets, 24,200 tons of sawdust, 3,750 tons of treated wood, and 270 tons of bark (Table 3).

Other Waste Facilities

“Other” waste facilities included private company, fly ash, asbestos, industrial, composting and yard waste facilities, inert waste, mulching operations, drop off or transfer stations, and energy recovery facilities.

Responding Other landfills reported receiving approximately 2.6 million tons or 31 percent of all waste directed to responding Virginia landfills in 1996. The average volume

received at responding Other facilities was approximately 98,700 tons per facility and the average tipping fee was \$27.07 per ton per facility (Table 1).

Responding Other facilities reported receiving approximately 143,500 tons of solid wood at their facilities in 1996. The solid wood waste total was approximately 5 percent of all wastes received at responding Other facilities in 1996 (Table 1).

Responding Other facilities reported receiving 70,324 tons of “other” wood residues or approximately 49 percent of the total solid wood received and 59,500 tons or 42 percent of wood residues received were bark residues in 1996. These two product types comprised nearly 91 percent of the solid wood residues received by responding Other facilities in 1996 (Table 2). “Other” wood included industrial and storm debris wood.

Four or approximately 15 percent of the responding Other facilities reported no change in the volume of solid wood collected during the past three years. Four or nearly 15 percent of the responding Other facilities reported the volume of solid wood increased by an average of 23 percent during the past three years. Three or approximately 12 percent of the responding Other facilities reported the volume of solid wood decreased by an average of less than 1 percent during the past three years.

Ten or nearly 39 percent of the responding Other facilities reported they restricted wood, in any form, from being landfilled. Eleven or nearly 55 percent of the responding Other facilities reported burying solid wood, in the form it was received, was the principal method of solid wood disposal. Five or 25 percent of the responding Other facilities reported burning solid wood and 4 or 20 percent of the responding Other facilities reported utilizing other disposal methods. “Other” disposal methods included solid wood being chipped and utilized for ground cover at the facility.

The estimated total, of all Other wastes received, was approximately 2.8 million tons. The estimated solid wood total was approximately 173,000 tons. The Other estimated solid wood total was comprised of 85,600 tons of “other” wood residues, 72,400 tons of bark, 5,050 tons of scrap pallets, 4,100 tons of yard trimmings, and 3,050 tons of construction and demolition wood wastes (Table 3).

Recycling and Marketing of Wood Residues

Virginia's responding waste-handling facilities reported recycling approximately 343,400 tons of solid wood in 1996. This included approximately 154,700 tons of yard trimmings, 81,800 tons of "other" wood residues, and 48,000 tons of bark (Table 4). Responding waste facilities reported marketing nearly 331,000 tons of solid wood in 1996. This included approximately 135,250 tons of solid wood being recycled and marketed by "other" methods, 133,100 tons were chipped and sold for fuel, and 38,300 tons were marketed as-is and given away or sold for fuel (Table 5).

Municipal Solid Waste Facilities

Seventeen or approximately 37 percent of the responding MSW facilities reported recycling nearly 160,374 tons of solid wood waste in 1996. Nearly 71 percent or 114,250 tons of solid wood processed were yard trimmings, nearly 30,000 tons or 19 percent were scrap pallets, and approximately 9,750 tons or 6 percent were construction and demolition wastes. Responding MSW facilities reported an average tipping fee of \$32.74 per ton for solid wood waste received at the processing facilities. These four residues comprised 96 percent of the recycled solid wood received at responding MSW facilities in 1996 (Table 4).

Responding MSW facilities reported marketing approximately 152,200 tons of solid wood in 1996. Nearly 133,000 tons or 87 percent were chipped and sold for fuel 11,900 tons or 8 percent were given away or sold for fuel (marketed as-is). These two methods of marketing wood residues constitute 95 percent of the recycled wood processed at responding MSW facilities (Table 5). Responding MSW facilities reported an average selling price of \$20.10 per ton for ground or chipped wood.

Twenty-four or approximately 52 percent responding MSW facilities reported they had the capability to recycle wood, reuse wood or they managed a solid wood waste processing facility. Nineteen or nearly 41 percent responding MSW facilities reported they do not have plans to begin recycling wood within the next three years. Two or approximately 4 percent responding MSW facilities reported they planned to begin recycling wood within the next three years.

Construction and Demolition Facilities

Responding C&D landfills reported recycling nearly 44,200 tons of solid wood waste in 1996. Nearly 58 percent or 25,500 tons were “other” wood, 11,325 tons or 26 percent were yard trimmings, and 4,800 tons or 11 percent were construction and demolition wastes. “Other” types of wood waste included leaves, chips, and stump grindings. These three residues comprised 95 percent of the recycled wood residues received at responding C&D facilities in 1996 (Table 4). Responding C&D facilities reported an average tipping fee of \$36.11 per ton for solid wood.

Six or 33 percent of the responding C&D facilities reported actively marketing wood residues directed to their facility. Eight or approximately 44 percent of the responding C&D facilities reported they had the capability to recycle wood, reuse wood or they managed a solid wood waste processing facility. Eight or nearly 44 percent of the responding C&D facilities reported they have plans to begin recycling wood within the next three years. Ten or approximately 56 percent of the responding C&D facilities reported that they do not have plans to begin recycling wood within the next three years.

Responding C&D landfills reported marketing 17,300 tons of solid wood in 1996. Approximately 87 percent or 15,000 tons of C&D wood waste was marketed as-is and 1,700 tons or 10 percent were marketed by “other” methods (Table 5). These two methods comprised nearly 97 percent of the recycled wood processed at C&D facilities. “Other” methods included giving away processed wood for mulch, animal bedding, and compost. Responding C&D facilities reported an average selling price of \$17.50 per ton for ground or chipped wood.

Other Waste Facilities

“Other” waste facilities included private company, fly ash, asbestos, industrial, composting and yard waste facilities, inert waste, mulching operations, drop off or transfer stations, and energy recovery facilities.

Responding Other facilities reported recycling 138,850 tons of solid wood residues in 1996. Approximately 40 percent or 55,300 tons were “other” wood residues, 44,500 tons or 32 percent were bark residues, 29,150 tons or 21 percent were yard trimmings, and 8,200 tons or 6 percent were sawdust (Table 4). These four residues comprised approximately 99 percent of the

recycled solid wood waste at responding C&D facilities in 1996. “Other” types of wood waste included leaves, chips, and stump grindings. Responding Other facilities reported an average tipping fee of \$14.67 per ton for solid wood.

Four or nearly 15 percent responding Other facilities reported actively marketing wood residues directed to their facility. Nine or approximately 36 percent responding Other facilities reported they had the capability to recycle wood, reuse wood, or they managed a solid wood waste processing facility. Fifteen or nearly 94 percent responding Other facilities reported they do not have plans to begin recycling wood within the next three years. One or approximately 6 percent responding Other facility reported they have plans to begin recycling wood within the next three years.

Responding Other facilities reported marketing 161,500 tons of wood residues in 1996. Nearly 82 percent or 132,300 tons of wood residues were marketed by “other” methods and 26,450 tons or 16 percent were marketed as-is and sold or given away for fuel. These two methods constitute approximately 98 percent of the wood residues marketed by Other facilities (Table 5). “Other” means included residues being given away or sold for mulch, animal bedding, compost, or core material for wood composite manufacturing. Responding Other facilities reported an average selling price of \$3.00 per ton for ground or chipped wood.

Conclusion

The third objective of this study was to quantify the volume and types of wood residues entering Virginia’s waste handling facilities. This research indicates that responding Virginia waste facilities received approximately 8.2 million tons of all wastes in 1996 and 688,666 tons or 8 percent of this waste was solid wood (Table 1). Yard trimmings comprised approximately 197,650 tons or 29 percent, construction and demolition wastes 164,500 tons or 24 percent, other wood 151,500 tons or 22 percent, bark 69,100 tons or 10 percent, scrap pallets 52,400 tons or 8 percent, sawdust 29,200 tons or 4 percent, and treated wood 17,300 tons or 2.5 percent of the total solid wood received at Virginia’s waste facilities in 1996 (Table 2).

Responding Virginia MSW landfills reported receiving an average of approximately 110,350 tons of all wastes and C&D landfills reported receiving 30,589 tons in 1996. Araman, Bush, and Reddy (1996) estimated MSW landfills averaged receiving approximately 103,300

tons of all wastes and C&D landfills received approximately 29,300 tons of all wastes in 1995. Responding Other facilities reported receiving an average of 98,700 tons of all wastes 1996.

The 1996 solid wood residues total accounted for 8 percent of all wastes received at responding Virginia landfills in 1996. Responding MSW landfills reported receiving 7 percent solid wood and C&D landfills reported receiving 33.9 percent solid wood in 1996. Araman et al. (1996) estimated that solid wood, as a percentage of total waste landfilled, averaged 7.3 percent nationally at MSW landfills and 37.8 percent at C&D landfills in 1995. Araman et al. (1996) estimated approximately 8 percent of the waste received at MSW facilities, in the Southern states, were wood wastes and 39 percent were wood wastes at C&D facilities. Other waste facilities reported receiving approximately 6 percent solid wood residues in 1996.

Responding MSW facilities reported recycling approximately 160,400 tons, C&D facilities 44,200 tons, and Other facilities 138,850 tons of wood residues directed to these respective facilities in 1996 (Table 4). Recycled wood was approximately 50 percent of the solid wood received by responding Virginia landfills in 1996. Approximately 345,250 tons of solid wood appeared to be available for recycling in 1996. Responding Virginia waste facilities appear to have approximately 148,750 tons of construction and demolition wastes, 69,700 tons of “other” wood, 42,850 tons of yard trimmings, 21,000 tons of sawdust, 19,400 tons of scrap pallets, 19,125 tons of bark, 15,200 tons of treated wood, and 15,200 tons of treated wood available for utilization in 1996.

Responding Virginia landfills reported marketing approximately 330,950 tons or 48 percent of the solid wood in received 1996. Approximately 384,700 tons of the solid wood received and 12,500 tons of recycled wood produced by responding Virginia landfills appeared to be available for marketing in 1996.

The trend nationally and locally is for landfills to reduce the volume or exclude wood residues from being landfilled. This trend is due in part to increasing federal and state waste reduction legislation. Several opportunities may exist for Virginia’s landfills to dispose of the solid wood directed to their facilities. It has been reported that several landfills nationally are separating construction and demolition debris for reusable timbers, lumber, siding, doors, and window frames, to name a few, and reselling these items to the public or giving them away to charitable organizations.

Virginia's landfill managers should explore markets for larger woody materials. A recognized trend is fingerjointing, where smaller pieces of lumber are processed and glued together to produce millwork and flooring products. Smaller materials, once properly processed, appear to have substantial markets relatively close at hand. Virginia has large equine, poultry, nursery, and landscaping businesses and they utilize a substantial volume of wood residues in their operations.

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Table 1. Responding Virginia Waste Facilities Summary

	MSW		C&D		Other		Total	
Number of Responding Facilities	46		18		26		90	
Average Tipping Fees	\$34.91		\$29.50		\$27.07		\$30.49	
	MSW		C&D		Other		Total	
	Tons	%	Tons	%	Tons	%	Tons	%
Total Waste Volume	5,076,926	62.0	550,609	6.7	2,566,607	31.3	8,194,142	100
Average Volume	110,368		30,589		98,716		91,046	
Solid Wood Volume	358,564	7.0	186,627	33.9	143,475	5.6	688,666	8.4

Table 2. Virginia Waste Facilities Solid Wood Residues

	MSW		C&D		Other		Total	
Residue Type	Tons	%	Tons	%	Tons	%	Tons	%
Yard Trimmings	152,473	43.1	41,722	22.5	3,388	2.4	197,583	29.0
C&D	92,857	26.3	69,156	37.3	2,519	1.8	164,532	24.1
Other Wood	37,553	10.6	46,636	23.5	70,324	49.4	151,513	22.2
Bark	9,362	2.6	240	0.1	59,498	41.8	69,100	10.1
Scrap Pallets	42,532	12	5,720	3.1	4,147	2.9	52,399	7.7
Sawdust	4,916	1.4	21,782	11.7	2,504	1.8	29,202	4.3
Treated Wood	13,933	3.9	3,371	1.8	0	0	17,304	2.5
Total	353,626		185,627		142,380		681,633	

1. Totals may not add up to reported total due to rounding.

Table 3. Virginia Waste Facilities Estimated Wood Residues Summary

	MSW-Tons	C&D-Tons	OTHER-Tons	TOTAL-Tons
Total Waste Volume	6,180,606	611,788	2,862,754	9,655,147
Estimated Solid Wood Volume	436,513	209,963	160,030	803,906
Residue Type (Tons)	MSW	C&D	OTHER	Total
Yard trimmings	185,619	46,358	4,125	236,102
C&D	113,043	76,840	3,067	192,950
Other Wood	45,717	51,818	85,612	183,146
Bark	11,397	267	72,432	84,096
Scrap Pallets	51,778	6,356	5,049	63,182
Sawdust	5,985	24,202	3,048	33,235
Treated Wood	16,962	3,746	0	20,707
TOTAL	430,501	209,586	173,332	813,419

1. Estimated totals may not add up to reported total due to rounding errors.

Table 4. Virginia Waste Facilities Recycled Wood Summary

	MSW		C&D		Other		TOTAL	
Number of Respondents	17		6		9		32	
	MSW		C&D		Other		TOTAL	
	Tons	%	Tons	%	Tons	%		
Recycled Wood Volume	160,374	39.4	62,382	15.3	183,858	45.3	406,614	
	MSW		C&D		Other		Total	
Product Type	Tons	%	Tons	%	Tons	%	Tons	%
Yard Trimmings	114,246	71.3	11,325	25.6	29,162	21.0	154,733	45.0
Other Wood	992	0.6	25,487	57.7	55,324	39.8	81,803	23.8
Bark	3,291	2	186	0.4	44,498	32.0	47,975	14.0
Scrap Pallets	29,991	18.7	2,390	5.4	413	0.3	32,974	9.6
C&D	9,744	6.1	4,781	10.8	1,253	0.9	15,778	4.6
Sawdust	0		10	<0.1	8,204	5.9	8,214	2.4
Treated Wood	2,110	1.3	0	0	4	<0.1	2,114	0.6
Total	160,374		44,179		138,858		343,411	

Table 5. Virginia Waste Facilities Wood Residues Marketing Summary

MARKETING METHOD	MSW		C&D		OTHER		TOTAL	
	Tons	%	Tons	%	Tons	%	Tons	%
Marketed as-is	2,301	1.5	15,000	86.7	2,080	1.3	19,381	5.9
Marketed as-is, given away or sold for fuel	11,862	7.8	0	0	26,441	16.4	38,303	11.6
Marketed for landfill cover	435	0.3	550	3.2	24	<0.1	1,009	0.3
Marketed & chipped for other uses	3,392	2.2	0		540	0.3	3,932	1.2
Chipped and sold for fuel	132,973	87.4	50	0.3	60	<0.1	133,083	40.2
Other	1,217	0.8	1,700	9.8	132,340	82.0	135,257	40.9
Total	152,180		17,300		161,485		330,965	

CHAPTER 4

SUMMARY AND RECOMMENDATIONS

Summary

Wood Residue Manufacturers

This study indicates that Virginia's wood product manufacturers produce a significant quantity and a wide variety of wood residues. The estimated green and dry chip residues production were 2.2 million tons or 38 percent of the total wood residues produced by primary and secondary manufacturers in 1996. The estimated bark production was 1.3 million tons or 23 percent and green and dry sawdust 1.2 million tons or 22 percent of the total wood residues produced by primary and secondary manufacturers in 1996. These three residues comprised approximately 4.7 million tons or 90 percent of the estimated wood residues produced by Virginia's wood product manufacturers in 1996 (Table 1).

Our estimates indicate hardwood and pine sawmills (primary manufacturers) produced an estimated 3.8 million tons or 66 percent of the total wood residues in 1996. Primary manufacturers also included engineered wood, hardwood plywood, and paper manufacturers, who produced nearly 708,000 tons or 14 percent of the total estimated residues. Primary manufacturers produced approximately an estimated 4.5 million tons or 80 percent of Virginia's wood residues in 1996 (Table 2).

Our study indicates secondary manufacturers, which included roughmill operations, pallet, furniture, other, and housing manufacturers produced approximately an estimated 1.1 million tons or 20 percent of Virginia's wood residues in 1996 (Table 2).

The primary markets for chips were pulp and paper manufacturers, with nearly a 90 percent share of the chip market (Figure 1). We estimate 1,671 tons or less than 0.1 percent of the chips produced in 1996 appear not to have adequate markets.

Mulch or bark companies were the primary markets for bark, approximately a 44 percent market share. Nearly 31 percent of bark residues were sold to pulp or paper manufacturers for fuel (Figure 2). We estimate approximately 118,050 tons or 9 percent of the bark produced in 1996 appears not to have adequate markets.

The primary markets for sawdust were the fuel markets, approximately 31 percent, pulp or paper manufacturers 26 percent, and composite manufacturers 17 percent, nearly a 74 percent market share (Figure 3). We estimate nearly 50,900 tons or 4 percent of the sawdust produced in 1996 appears not to have adequate markets.

Fuel markets were the primary destination for mixed residues. Nearly 27 percent of mixed residues were sold to others as fuel and 20 percent were used at the facility for fuel. Approximately 17 percent were sold to composite manufacturers, 12 percent were sent to landfills, and 10 percent were disposed of by other methods. (Figure 4). We estimate approximately 113,000 tons or 27 percent of the mixed residues produced in 1996 appear not to have adequate markets.

The primary markets for other green and dry residues were the fuel markets, nearly a 48 percent market share. Approximately 22 percent of other green and dry residues were brokered, 10 percent were sold to bark or mulch companies and 10 percent were landfilled at the facility (Figure 5). We estimate nearly 39,500 tons or 17 percent of other green and dry residues produced in 1996 appear not to have adequate markets.

Composite manufacturers were the primary markets for planer shavings, nearly a 61 percent market share. Livestock bedding had approximately a 15 percent market share and 8 percent were sold to pulp or paper manufacturers (Figure 6). We estimate approximately 4,600 tons or 2 percent of the planer shaving production in 1996 appears not to have adequate markets.

The primary markets for scrap pallets were the fuel markets 49 percent and pulp or paper manufacturers 25 percent, with approximately a 74 percent market share (Figure 7). We estimate nearly 3,600 tons or 4 percent of the scrap pallet residues produced in 1996 appear not to have adequate markets.

Coarse residues were primarily utilized at the facility for fuel. The primary markets, after own facility use, were the composite manufacturers and other fuel markets. These three markets combined have nearly a 93 percent market share (Figure 8). We estimate approximately 19,200 tons or 4 percent of the coarse residues produced in 1996 appear not to have adequate markets.

The primary markets for sanderdust were the fuel markets. Approximately 65 percent of the sanderdust residues produced were used at the facility for fuel and 29 percent was sold to others as fuel, nearly a 95 percent market share. We estimate approximately 11,000 tons or 2 percent of the sanderdust produced appears not to have adequate markets (Figure 9).

This study indicates pulp and paper manufacturers consume approximately 50 percent of Virginia's wood residues. Fuel markets 13 percent, mulch or bark companies 10 percent, composite manufacturers 9 percent, fuel for facility 6 percent, livestock bedding 4 percent, and combined disposal methods constitutes the remaining markets for Virginia's wood residues (Figure 10).

This research indicates that 6.6 percent or approximately 196,000 tons of the reported wood residue production in Virginia appears not to have adequate markets. Responding primary manufacturers report having approximately 143,000 tons of wood residues without adequate markets and responding secondary manufacturers have nearly 53,000 tons of wood residues without adequate markets. We estimate, in 1996, primary manufacturers having approximately 267,000 tons of wood residues and secondary manufacturers have nearly 127,000 tons of wood residues without adequate markets.

Responding hardwood sawmills appear to have inadequate markets for approximately 66,000 tons, pine sawmills 2,700 tons, engineered wood manufacturers 46,000 tons, and hardwood plywood manufacturers 27,000 tons. Responding primary manufacturers disposed of inadequate market residues by utilizing other disposal methods for approximately 105,400 tons, sending 30,700 tons to landfills, landfilling 5,800 tons at the facility, and burning 980 tons.

Responding rough mill operations appear to have inadequate markets for approximately 40,600 tons, pallet manufacturers 3,750 tons, furniture manufacturers 100 tons, housing manufacturers 3,700 tons, and other manufacturers 5,100 tons. Responding secondary manufacturers disposed of inadequate market residues by sending approximately 19,000 tons to landfills, burning 15,600 tons, utilizing other disposal methods for 12,900 tons, and landfilling 5,700 tons at the facility.

Virginia's wood products manufacturers disposed of inadequate market residues by utilizing "other" disposal methods for approximately 118,300 tons, sending 49,700 tons to landfills, burning 16,900 tons, and landfilling 11,500 tons at the facility.

The amount of excess wood residue's available for markets appears to have decreased during the past 25 years based on previous studies. The reduction in the availability of wood residues may be attributed to several factors:

- 1) an increase in the number of manufacturers who utilize wood residues,
- 2) increased marketing efforts by wood residue producers,
- 3) utilization of smaller saw kerfs,
- 4) increased emphasis on volumetric recovery of logs, lumber or wood-composites (achieved by installation of laser guided log or lumber scanners, computer assisted networks, and computer programs which determine sawing or cutting patterns),
- 5) many mills have installed boilers to produce steam or electricity to operate dry kilns or other plant equipment,
- 6) as a result of the current (1997-1998) increased demand for timber nationally and locally, many producers may be processing logs and/or cants into pallet material.

Several wood product manufacturers commented disposal of wood residues was a problem and growing concern. Responding companies indicated they temporarily had to store residues at their facilities due to the distance to buyers or lack of markets. Several respondents indicated they occasionally had to curtail operations due to inconsistent wood residue markets. One responding company stated wood residue disposal costs had precluded plant expansion

The Center for Forest Products Marketing and Management at Virginia Tech has available a directory of wood residue users. Contact the Center at (540) 231-5876 and ask for a copy of "1997 Directory of Virginia's Wood Residue Users".

Waste Facilities

This research indicates that Virginia's waste facilities received approximately 8.2 million tons of all wastes in 1996. Approximately 688,600 tons or 8 percent of this waste was solid wood. Yard trimmings comprised approximately 197,600 tons or 29 percent, construction and demolition wastes 164,500 tons or 24 percent, "other" wood 151,500 tons or 22 percent, scrap pallets 52,400 tons or 8 percent, bark 69,100 tons or 10 percent, sawdust 29,200 tons or 4 percent, and treated wood 17,300 tons or 3 percent of the solid wood received at Virginia's waste facilities in 1996.

MSW facilities received approximately 353,500 tons or 51 percent, C&D facilities received 185,600 tons or 27 percent, and Other facilities received 142,400 tons or 21 percent of the solid wood waste directed to Virginia's landfills in 1996.

Responding MSW facilities reported recycling approximately 160,400 tons or 47 percent, C&D facilities 44,200 tons or 13 percent, and Other facilities 138,850 tons or 40 percent of the solid wood wastes directed to these respective facilities in 1996.

Responding Virginia landfill facilities marketed approximately 331,000 tons or 48 percent of the solid wood received in 1996. Chipping solid wood and marketing wood residues by other methods constituted nearly 135,250 tons or 41 percent, 133,100 tons or 40 percent were chipped and sold for fuel, 38,300 tons or 12 percent were marketed as-is and sold or given away for fuel, and 19,400 tons or 6 percent were marketed as-is. "Other" marketing methods included residues being given away or sold for mulch, animal bedding, compost, or core material for wood composite manufacturing. These four processing methods constituted 99 percent of Virginia waste facilities marketing efforts in 1996.

Whilst Virginia's waste facilities recycled approximately 47 percent of the reported solid wood received, there remains approximately 345,250 tons available for utilization. Combining Virginia's waste facilities available wood residues 345,250 tons with Virginia's wood product manufacturers available wood residues 196,000 tons, results in approximately 541,250 tons of potentially available wood residues. Assuming that a tractor-trailer contains approximately 20 tons of wood residues, dividing the available wood residues 541,250 tons by 20 tons, it can be estimated 27,060 tractor-trailer loads of wood residues are potentially available for utilization.

Several Virginia waste facilities have initiated programs to reduce solid wood wastes from entering landfills. These programs include offering significantly reduced tipping fees for wood wastes separated from other wastes, installing chippers or grinders to process solid wood, separating solid wood and transferring it to facilities that accept wood wastes, and working directly with consumers and producers of wood products to direct their wood wastes to businesses utilizing wood in their manufacturing processes.

Recommendations

Wood product manufacturers should emphasize increasing volumetric recovery. This can be achieved by installing laser scanning systems, computer assisted networks, and computer assisted sawing or cutting programs. While this may seem to be cost prohibitive, over the long-term increased volumetric recovery and decreased residue production should make such an investment in technology based equipment financially attractive.

Virginia wood products manufacturers or the Commonwealth of Virginia should develop a clearing house for wood wastes. Producers would be able to list the residues available and consumers would have access to this information. Producers and consumers should be able to access the clearinghouse via a toll-free telephone line or an Internet access site. This initiative could tap into or be modeled after the USDA Forest Service Surplus and Scrapwood Products Exchange (this program was designed to promote and stimulate trade of high-quality wood wastes between wood product manufacturers worldwide). The Virginia initiative should encompass all wood residues and not exclusively concentrate on high-quality wood residues (as the USDA Forest Service program does). For example, one Virginia mulching operation responded that they could not procure sufficient wood residue volumes to meet market demand.

The establishment of consortiums or partnerships is another alternative. Wood residue producers who have inadequate markets or are not satisfied with prices received for their residues could invest in these partnerships. These entities could facilitate the transportation, storage, and marketing of excess/undervalued wood residues. In addition, the consortiums/partnerships should consider value-added manufacturing processes for wood residues. For example, sawdust, sanderdust, and fines could be utilized to produce pellet fuel for wood stoves, smoking pellets for cooking, industrial absorption material, wood flour, excelsior, and co-firing with existing coal utilizing electricity producers. Bark, chips, mixed residues, scrap pallets, and planer shavings could be processed for landscape, agricultural uses (e.g. soil amendments and land stabilization), poultry, equine, and animal litters. In addition, sawdust and fines are being utilized for sewerage amendments. Chips and bark can be colored for markets where aesthetics are of importance. Larger wood residues such as end trims can be processed to manufacture finger-jointing material, crafts, surveyors' and garden stakes, fence pickets, decorative and garden fencing, flower boxes, bird and dog houses, and flooring are just some of the value-added opportunities available for these types of material. Members could possibly barter wood residues among themselves (e.g. trade excess sawdust for end-trims or bark for

finished products). Members include primary and secondary wood product manufacturers, and landfill facilities, along with anyone who produces wood residues.

The Commonwealth of Virginia should consider offering investment tax credits, tax deferments, or other types of incentives to businesses that are interested in utilizing wood residues in their manufacturing or production processes. The availability of residues, combined with available residues from landfill facilities, may attract businesses to expand in or locate to Virginia if different forms of financing were available. For example, the EPA offers a guide to assist those wishing to invest in or start a recycling business. The guide offers information on access to capital, financing strategies, legal advice, and business planning.

Several manufacturers and waste facilities indicated purchasing tub grinders or chippers to process wood residues. Processed wood can be sold to local customers, landscape contractors, nurseries, poultry and equine operations, and other agricultural interests. For example, several states are exploring sawdust and agricultural waste combinations to produce high-quality composts. Other markets that appear to be available are municipal and private industry water and sewer treatment facilities. Wood residues can be combined with sewerage to produce composts and assist in the purification process.

Dollar value-added production and marketing alternatives include fingerjointing larger wood residues, to decrease excess wood residue production and increase profitability. If manufacturers are not interested in investing in the equipment necessary for production, they should explore the market for manufacturers who do produce fingerjointed material. Several manufacturers produce strips during the manufacturing/re-manufacturing process. In addition, these wood residues could be utilized to produce flooring (particularly oak flooring).

All of Virginia's waste facilities should offer reduced tipping fees for wood wastes when they are separated from other wastes. Several opportunities are available, which include offering significantly reduced tipping fees for wood wastes separated from other wastes, installing chippers or grinders to process solid wood, separating solid wood and transferring it to facilities that accept wood wastes. In addition, they can work directly with consumers and producers of wood products to direct their wood wastes to businesses utilizing wood in their manufacturing processes. Smaller sized materials, once properly processed, appear to have substantial markets relatively close at hand. Virginia has large numbers of equine, poultry, nurseries, and landscape businesses. These businesses utilize a substantial volume of wood residues in their operations. Another alternative product area is separating construction and demolition wastes for all

recyclable materials, specifically materials that could be used in remodeling or new home construction. These materials could be sold or given to organizations such as Habitat for Humanity.

The development of products that can be manufactured from wood residues is expanding. Federal, university, and private researchers are developing machinery, production techniques, as well as products that can be produced from wood residues. The regional and national trend of landfills not accepting wood waste, the closure of landfills, and recent federal and state recycling legislation to limit dumping of solid wood waste necessitates that new markets for wood residues be identified. This will encourage wood product industries located in the Commonwealth of Virginia to expand and take advantage of these available natural resources.

Conclusion

It does not appear Virginia's wood products manufacturers and waste facilities produce enough volume of wood residues in the quantities necessary to attract large, wood residue utilizing industries to the Commonwealth. However, there is sufficient wood residues volume to complement or support existing businesses or new businesses that do not require substantial volumes of wood residues for their manufacturing operations.

The disposal of Virginia's wood residues appears not to be an acute problem. The majority of wood product manufacturers have sufficient markets. Obviously, residue disposal can be a problem if you do not have adequate markets. Even with adequate markets for wood waste, many wood product manufacturers reported the prices received for their residues were not sufficient. They were just breaking even with associated transportation costs. Wood residue disposal appears to be a localized and industry specific problem.

The opportunities for adding value to wood residues are vast. A value-added product can be any product or wood residue that has the potential to increase return to the business or landfill facility. The initiative required to manufacture value-added products and develop new markets is up to the business or landfill management. The Commonwealth of Virginia offers forest product marketing assistance through the forest products program at Virginia Tech, the Economic Development Program, and the Department of Forestry. Producers of wood residues can contact Virginia Tech extension personnel for consultation and advice.

Table 1. Total Estimated Virginia Wood Residues Produced by SIC Code^{1,2}

Primary Manufacturers (SIC Code)	Estimated Production (Tons)	Percentage of All Estimated Wood Residues
Hardwood Sawmills (2421)	2,297,149	39.4%
Pine Sawmills (2421)	1,549,144	26.6%
Engineered Wood Manufacturers (2493)	226,309	3.9%
Hardwood Plywood Manufacturers (2435)	105,650	1.8%
Paper Manufacturers (2621, 2631)	507,663	8.7%
Secondary Manufacturers		
Rough Mill Operations (2431, 2434, 2426)	733,816	12.6%
Pallet Manufacturers (2448)	213,905	3.7%
Other Manufacturers (5211, 2429, 2499)	64,662	1.1%
Furniture Manufacturers (2511, 2512, 2519, 2521, 2531, 2599)	115,297	2.0%
Housing Manufacturers (2451, 2452, 2439)	19,772	0.3%
Total	5,758,622	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

Table 2. Virginia Wood Residues Estimated 1996 Production

Residue Type	Reported Tons Produced	Estimated Tons^{1,2}	Percentage of Total Estimated Wood Residues Produced
Green chips	1,136,054	2,006,763	
Dry chips	75,852	220,783	38.2%
Green bark	639,801	1,311,717	22.8%
Green sawdust	594,917	1,145,631	
Dry sawdust	44,461	126,632	21.8%
Green mixed residues	75,503	155,888	
Dry mixed residues	108,561	262,492	7.2%
Green planer shavings	52,914	89,420	
Dry planer shavings	70,239	143,041	4.0%
Other green residues ³	17,622	26,614	
Other dry residues ³	44,287	81,748	1.9%
Green coarse residues	16,301	31,886	
Dry coarse residues	23,033	63,395	1.6%
Pallets	55,180	90,785	1.6%
Green sanderdust	50	177	
Dry sanderdust	29,469	55,339	0.9%
Total	2,984,244	5,758,622	100%

1. Extrapolated using data provided by the Virginia Employment Commission by SIC code, as of 12/31/96.

2. Extrapolated by deriving a factor from Virginia Department of Forestry 1996 estimates.

3. "Other" green and dry residues included: slabs, edgings, end trims, blocks, cores, etc.

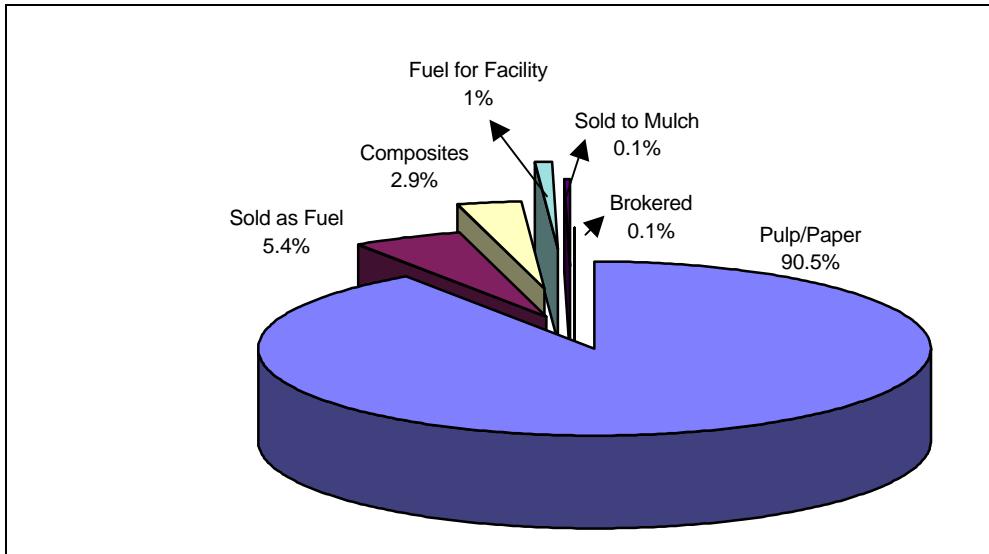


Figure 1. Current Markets and Market Share for Virginia Wood Manufacturers Chips

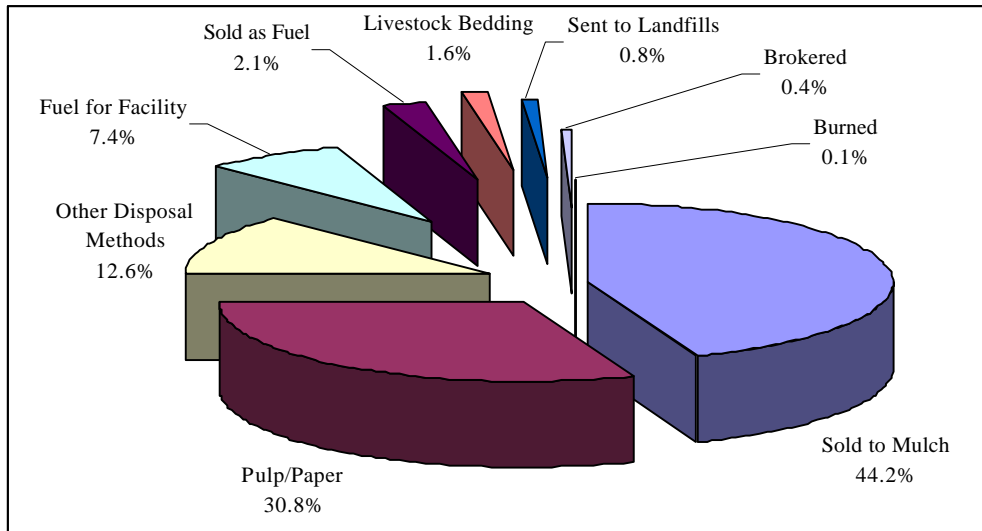


Figure 2. Current Markets and Market Share for Virginia Wood Manufacturers Bark

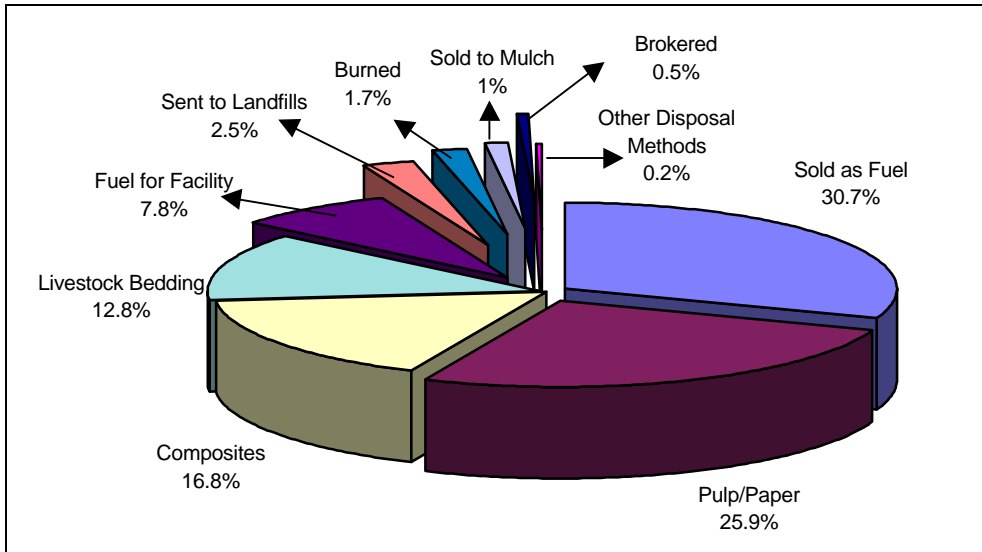


Figure 3. Current Markets and Market Share for Virginia Wood Manufacturers Sawdust

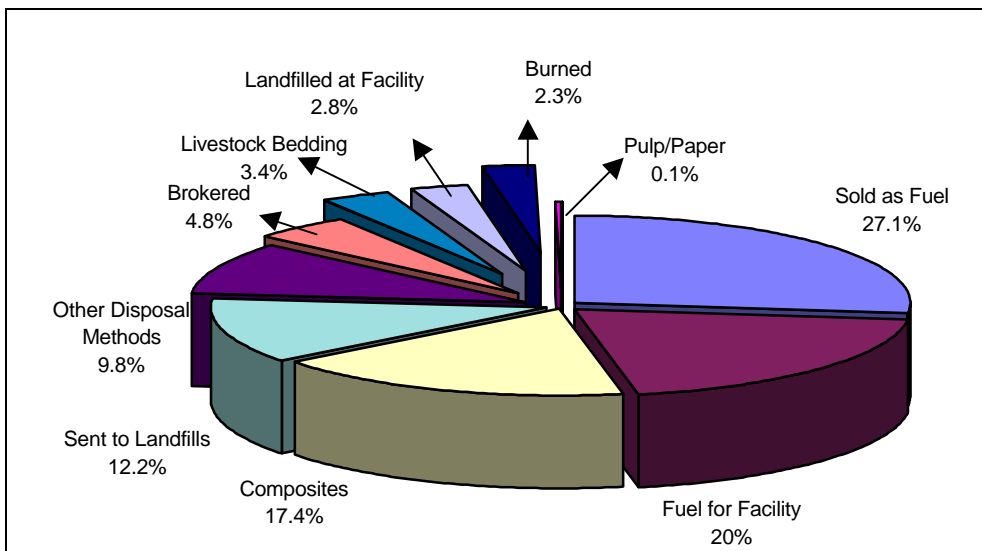


Figure 4. Current Markets and Market Share for Virginia Wood Manufacturers Mixed Residues

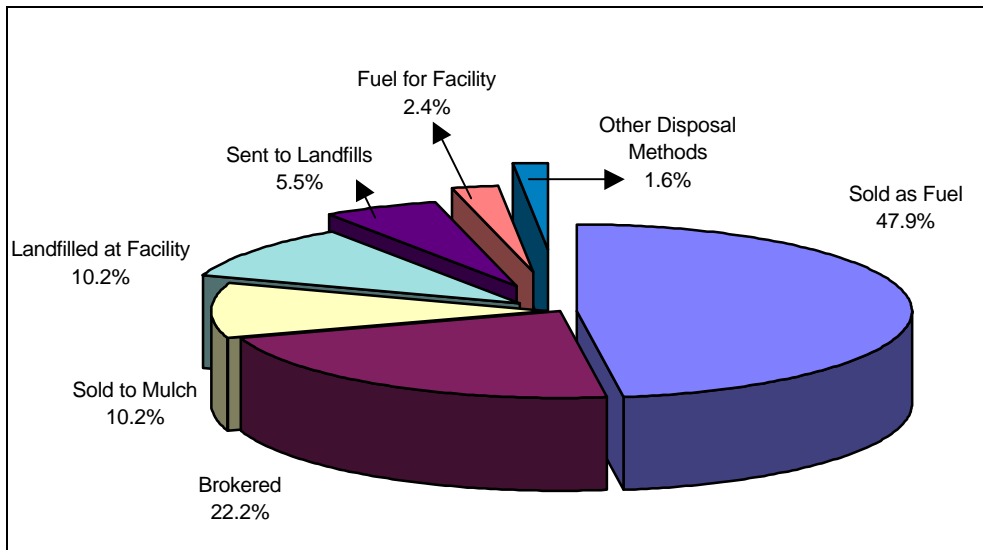


Figure 5. Current Markets and Market Share for Wood Virginia Manufacturers Other Green and Dry Residues

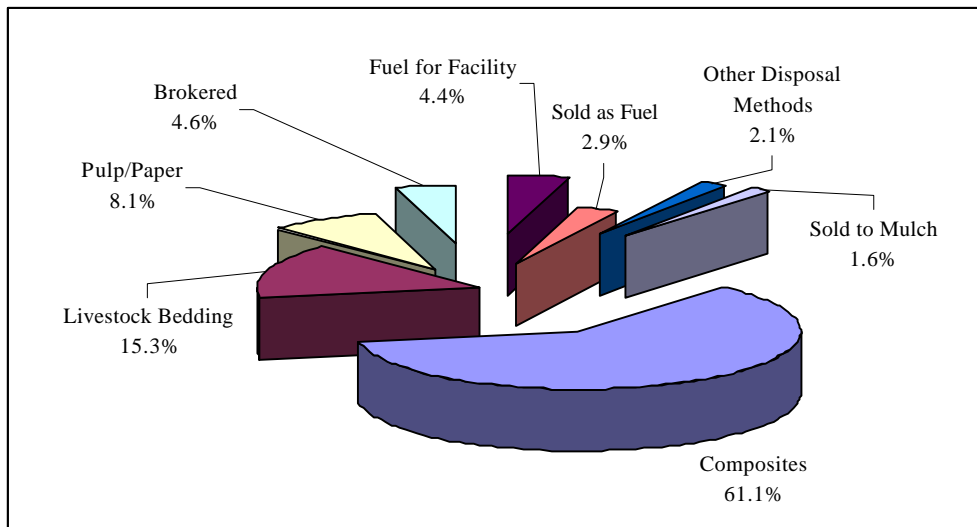


Figure 6. Current Markets and Market Share for Virginia Wood Manufacturers Planer Shavings

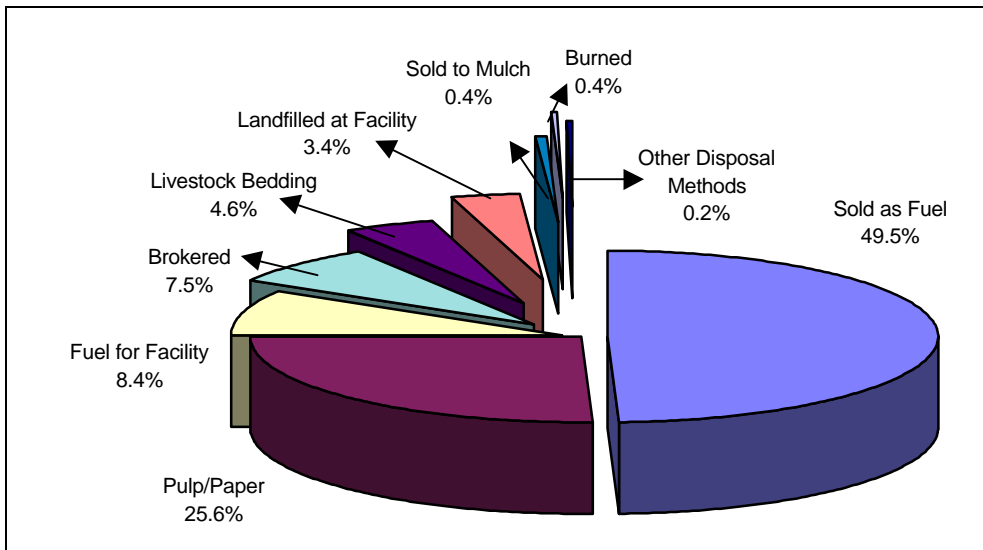


Figure 7. Current Markets and Market Share for Virginia Wood Manufacturers Scrap Pallets

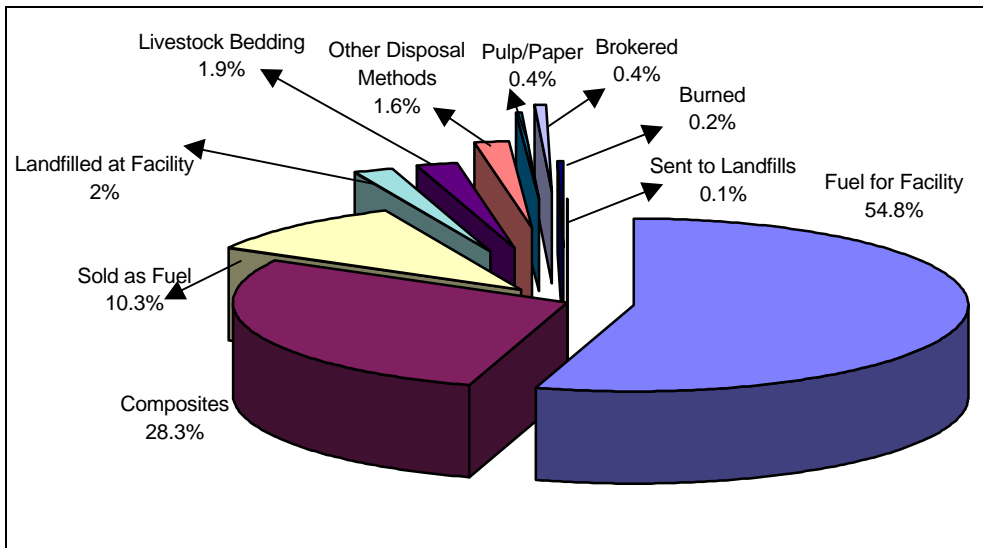


Figure 8. Current Markets and Market Share for Virginia Wood Manufacturers Coarse Residues

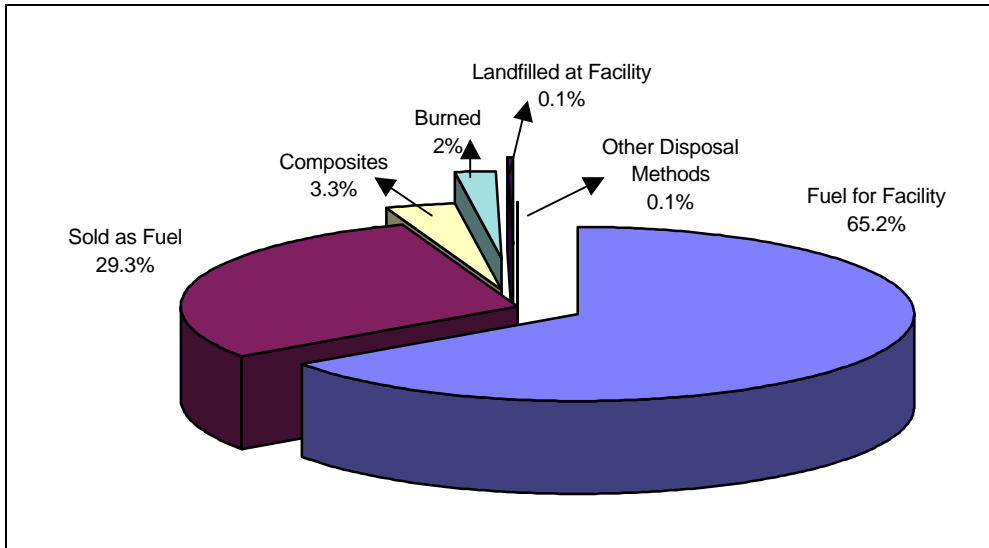


Figure 9. Current Markets and Market Share for Virginia Wood Manufacturers Sanderdust

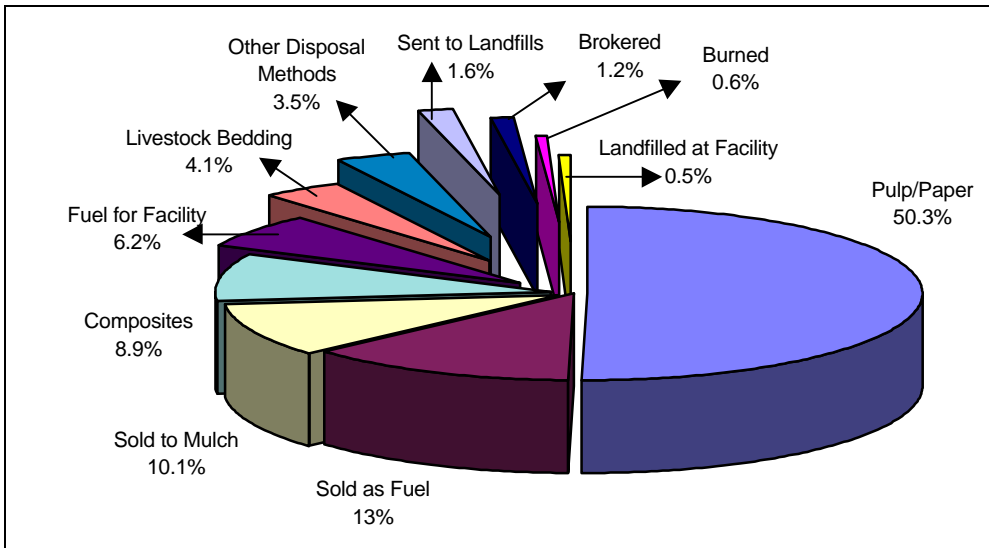
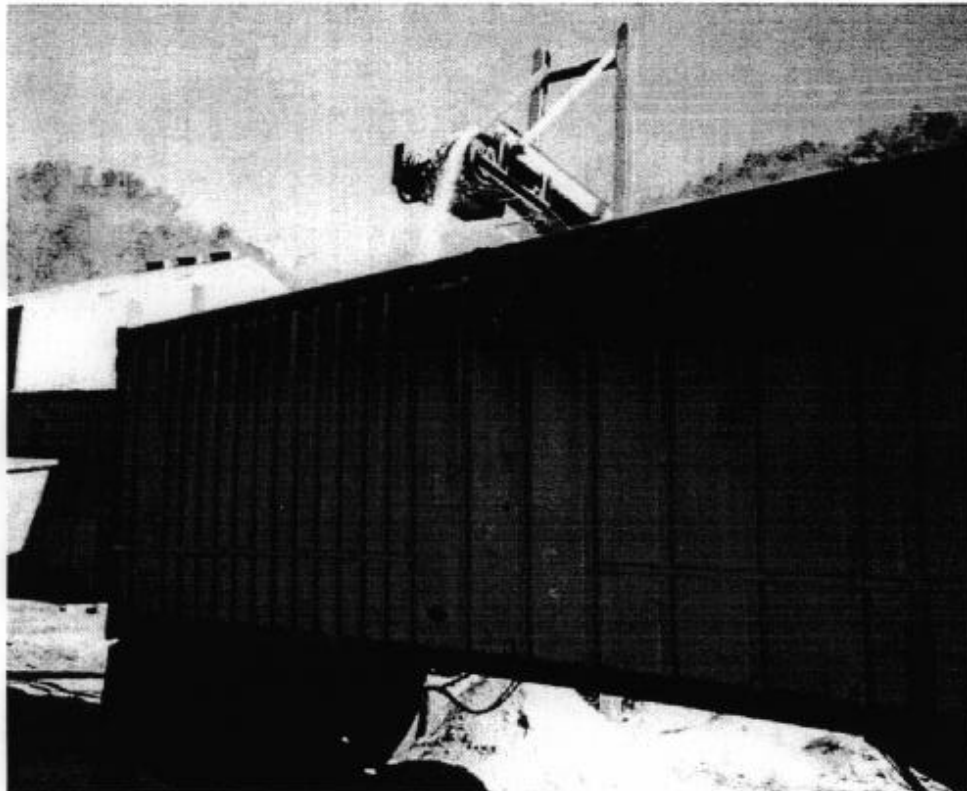


Figure 10. Current Markets and Market Share for Virginia Wood Manufacturers Wood Residues

APPENDIX A

WOOD WASTE IN VIRGINIA: ITS AVAILABILITY AND MARKETS
QUESTIONNAIRE, COVER LETTER, AND POSTCARDS

Wood Waste in Virginia: Its Availability and Markets



**Center for Forest Products Marketing
Department of Wood Science and Forest Products
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0503**

**If you have any questions, please contact
Delton Alderman
Phone: (540) 231-5876; Fax: (540) 231-8868**

The purpose of this research is to quantify the amount of wood residue generated by the wood products industry in Virginia, to identify the current uses of wood residue, and to compile a list of users of wood residues. Your response is vital for successfully completing this research work. If your company operates more than one wood products manufacturing facility, please answer the following questions as they relate to the only facility you manage. **If you manage more than one facility, please complete a separate questionnaire for each facility.** Please feel free to copy it, if you need more than one questionnaire. Thank you!

1. **Does your company generate or use wood residue?**

- No —→ Please stop here and return the questionnaire. Postage is prepaid. Thank you!
- Yes

2. **What type of facility do you operate?** (Please check only one major facility that you manage. If you operate more than one type of facility, please fill out a separate questionnaire for each.)

- Softwood sawmill
- Hardwood sawmill
- Plywood plant
- Veneer plant
- Reconstituted board plant (e.g. MDF, particleboard, OSB, LVL)
- Furniture manufacturer
- Cabinet manufacturer
- Flooring manufacturer
- Dimension manufacturer
- Pallet manufacturer
- Planer mill
- Other (Please specify.): _____

3. **At this production facility, what do you use the most?**

- Hardwoods Softwoods (e.g. pine)

4. **How many people did you employ in 1996?** (Please report all full-time employees.)

Number of full-time employees in 1996: _____

5. **In 1996, what were the major products manufactured at your facility and their production?** (Please specify the product types and report their total production and units of measure for 1996, e.g. hardwood lumber in board feet or plywood in square feet.)

Product type	1996 production quantity	Unit of measure ¹ (Bd. ft., ft. ² , mtrs ³ ., etc.)

¹ Please specify thickness if you are reporting unit of measure in sq. ft. or sq. meters.

6. **How much wood residue did your facility generate in 1996?** (Please report the *estimated* quantity of various types of wood residue generated at the facility you manage. If your facility does not keep track of quantity by wood residue type, please report the total mixed wood residue generated under the type “mixed residue.”)

Type of wood residue	Hogged (ground up)		Quantity generated	
	Yes	No	Green (tons)	Dry (tons)
Chips				
Coarse residue ¹				
Sawdust				
Planer shavings				
Bark				
Sanderdust				
Used or scrapped pallets				
Mixed residue				
Other (Please specify.) _____				

¹ Slabs, edgings, trims, cores, etc.

7. **What is your facility’s raw material to finished product recovery?** (Please report in percentage.)

The yield of our facility in 1996 was _____%

8. Please specify the **percentage** of total wood residue used in 1996 in different applications in terms of each type of residue your facility generated.

User of wood residue	Type of wood residue								
	Chips	Coarse Residue ¹	Saw-dust	Planer shavings	Bark	Sander-dust	Used or scrap-pallets	Mixed residue	Other
	%	%	%	%	%	%	%	%	%
Sold to paper/pulp manufacturers									
Sold to wood composite manufacturers									
Sold to others for fuel									
Sold as bedding for livestock									
Sold to bark and mulch companies									
Used at our facility for fuel									
Burned as waste									
Sent to landfills									
Landfilled at our facility									
Sold/given away to wholesaler/broker									
Other (Please specify.) _____									
TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%

¹. Slabs, edgings, trims, cores, etc.

9. If you sent wood residue to landfills in 1996, what was the primary reason? (Please check only one.)

- Lack of consistent markets for wood residue
- Sending residue to landfills is more economical than any other available options
- Lack of wood residue recyclers in our area
- Other (Please specify.) _____

10. **If you sent wood residue to landfills in 1996, which type of landfill did you send the majority of wood residue?** (Please check only one.)

- Municipal solid waste (MSW) landfill
- Construction and demolition (C&D) landfill
- Industrial landfill
- Your own company's landfill
- Other (Please specify.) _____

11. **Did the lack of markets for wood residue in 1996 restrict your company's production in any way?**

- Yes →
- No

How did the lack of markets restrict your company's production?
(Please check only one.)

- Reduction in the daily production
- Completely stopping the production for a few days
- Other (Please specify.): _____

12. **Did the cost of disposing wood residue in 1996 restrict your company's production in any way?**

- Yes →
- No

How did the cost of disposing restrict your company's production?
(Please check only one.)

- Reduction in the daily production
- Completely stopping the production for a few days
- Other (Please specify.): _____

13. **Please list the names and addresses of your customers for each type of wood residue.** (This information will be used to create a directory of users of wood residues.)

Company name	Contact name	Address	Telephone number	Type of Wood residue sold/given away

14. **What was the average selling price of each type of wood residue in 1996?** (If you gave it away, please report "0". If you paid someone to haul the wood residue away from your facility, report the price you paid using a negative sign in front of the price. For example, if you paid a contractor \$25/ton to haul green sawdust, please report it as -\$25 under the appropriate column.)

Wood Residue	Average sale price (\$)	
	Green (\$/ton)	Dry (\$/ton)
Chips		
Coarse residue ¹		
Sawdust		
Planer shavings		
Bark		
Sanderdust		
Used or scrapped pallets		
Mixed residue		
Other (Please specify.):		

¹ Slabs, edgings, trims, cores, etc.

15. **Please comment on any issues pertaining to wood residue that we have not already asked you or you wish to share.**

Thank you for participating in the study. If you have any questions, please direct them to Delton Alderman at (540) 231-5876. Please fold, tape, and return the completed questionnaire. The postage is prepaid.

VIRGINIA TECH
BROOKS CENTER
ATTN: DELTON ALDERMAN
P.O. BOX 850
BLACKSBURG, VA 24063-9985



VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

CENTER FOR FOREST PRODUCTS
MARKETING AND MANAGEMENT

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Phone: (540) 231-5876 Fax: (540) 231-8868
rsmith4@vt.edu <http://vtwood.forestprod.vt.edu/>

3/4/97

Guy N Rawley
Rawleys Cabinet Shop
Rt 1 Box 371
Mt Solon VA 22843

Dear Mr. Rawley:

As wood prices continue to rise, efficient conversion of raw material to finished product remains a major priority for most forest products firms. However, finding profitable markets for the by-products produced during the manufacture of wood products is another major concern for most companies. In Virginia we have recently lost major manufacturing facilities that utilize wood by-products. This study is designed to estimate the amount of wood by-products (waste ?) that are produced in this region and determine the current markets for these products. This information will provide state decision makers with information which may assist in the location of new companies that will utilize this material. This study will help you by providing a comprehensive directory of those firms who currently use wood by-products in the state.

This study is being conducted by the Department of Wood Science and Forest Products at Virginia Tech, in cooperation with the Virginia Forest Products Association, the Virginia Department of Mines, Minerals and Energy, the Powell River Project, and the Virginia Department of Forestry. Since your name was chosen at random from a list of manufacturers, your response is vital to the success of this project. Your name and response will be held in strict confidence. The questionnaire is numbered to allow me to remove your name from the mailing list after I receive your response.

Your assistance in answering the enclosed questionnaire will allow us to properly estimate the amount of wood by-products produced in the state and identify the markets that currently exist for this material. Please take a few minutes to answer the questionnaire and return it. Return postage is prepaid. Thank you very much for your help. If you have any questions or comments, please contact me at (540) 231-5876.

Sincerely,

Delton Alderman
Graduate Student

Dear Wood Products Manufacturer,

I need your help! Two weeks ago I mailed you a copy of the questionnaire titled *Wood Waste in Virginia: Its Availability and Markets*. I am contacting you to ask you to complete the questionnaire. If you have completed and returned the questionnaire, please accept my thanks! If you haven't, please take time to complete and return the questionnaire. Since your name was chosen randomly, your participation in this study is extremely important to accurately represent Wood Residue Production and Markets in Virginia.

Should you have any questions, please call me at (540) 231-5876 or fax (540) 231-8868. Thank you for your help!

Sincerely,



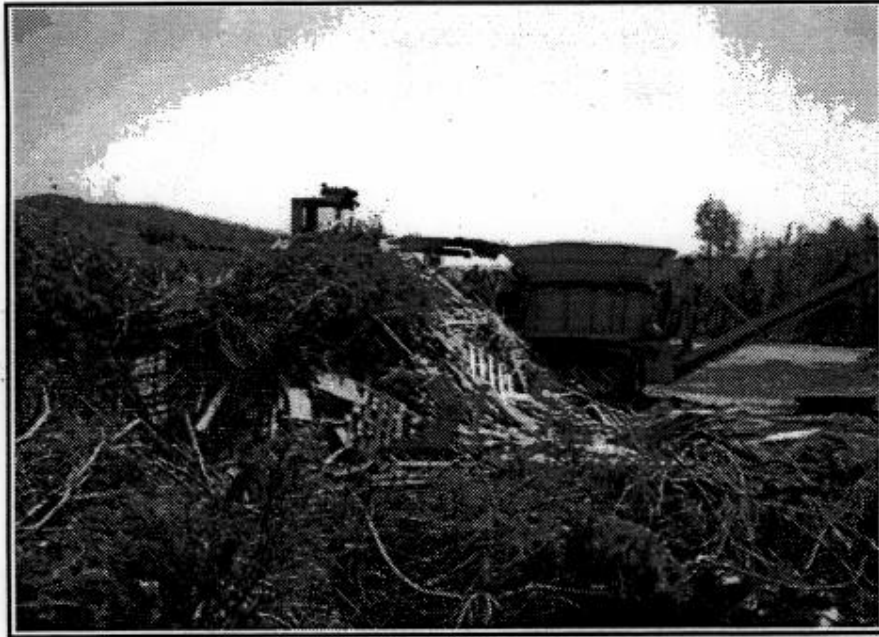
Delton Alderman
Graduate Student, Virginia Tech

APPENDIX B
STUDY OF SOLID WOOD WASTE DISPOSAL IN VIRGINIA QUESTIONNAIRE,
COVER LETTER, AND POSTCARDS



VIRGINIA POLYTECHNIC INSTITUTE
AND STATE UNIVERSITY

Study of Solid Wood Waste Disposal in Virginia



Center for Forest Products Marketing
Department of Wood Science and Forest Products
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0503

If you have any questions, please call
Delton Alderman
Phone: 540-231-5876
Fax: 540-231-8868

*This questionnaire is part of a project designed to better understand the role of wood in the waste stream. The information you provide will be used to help improve the understanding and management of wood waste. Of course, your response is confidential. If you feel that someone else in your organization is better qualified to answer these questions, please feel free to forward the questionnaire to that person. **Thank you for your help.***

1. Does your organization operate and/or manage any type of landfill?

No \longrightarrow *Please stop here and return the questionnaire. Postage is prepaid.*

Yes \longrightarrow *Please continue*

2. How many of each of the following types of landfills does your organization operate or manage? *(Please write the number next to each type)*

_____ Municipal Sanitary Waste (MSW) landfill(s)

_____ Construction and Demolition debris (C&D) landfill(s)

_____ Other (please specify) _____

3. In 1996, approximately how much waste (all types) did you receive at each type of landfill? What was the average tipping fee for mixed waste at these landfills?
(Please ignore a category if it does not apply to you)

Type of Landfill	Waste received in 1996 (tons)	Average tipping fee (\$/ton)
Municipal Sanitary Waste		
Construction and Demolition debris		
Other (please specify): _____		

4. **Approximately how much of the waste received at your landfill(s) in 1996 was wood?** (Please provide the best estimated percentage for each type of facility. Again, please ignore a category if it does not apply to you)

Type of Landfill	<u>Wood waste</u> received in 1995 (% of total waste)
Municipal Sanitary Waste	%
Construction and Demolition debris	%
Other (please specify): _____	%

5. **What percentage of solid wood that you received in 1996 was in the following categories.** (Please estimate as best you can)

<u>Type of Wood Waste</u>	<u>Estimated Percentage</u>
Sawdust:	%
Bark:	%
Wood Pallets	%
Construction Debris:	%
Yard Trimmings:	%
Preservatively Treated Wood:	%
Other (please specify): _____	_____%
	100%

6. **How has the volume of wood collected at your solid waste facility(s) changed over the past three years?** (Please check one)

- Increased \longrightarrow **By what percentage? %**
 Decreased \longrightarrow **By what percentage? %**
 No change

7. Do you actively market the wood waste products you receive into your landfill?

No

Yes → Please describe the markets available for your wood residue:

Now we would like to ask about facilities or areas set aside for processing wood/yard waste. Please answer the following questions related to this facility(s). Please answer question 8 even if your organization does not operate or manage a wood/yard waste facility.

8. Do you have the capability to recycle or reuse wood? In other words, does your organization manage or operate a wood/yard waste processing facility?

No

Do you plan to begin processing wood for recycling or reuse within the next three years?

Yes

No

Please skip to the last page (question 14)

Yes

→ Please continue

9. In 1996, how much waste did you receive at your wood/yard waste processing facility(s)? (Please include waste that was initially received at a MSW or C&D landfill but diverted to a wood/yard waste processing facility)

_____ tons

10. In 1996, approximately what percentage of the waste processed at your wood/yard waste processing facility(s) was: *(Please estimate as best you can)*

<u>Type of Wood Waste</u>	<u>Estimated Percentage</u>
Sawdust:	%
Bark:	%
Wood Pallets	%
Construction Debris:	%
Yard Trimmings:	%
Preservatively Treated Wood:	%
Other (please specify):	_____ %
	100%

11. In 1995, what was the average tipping fee for wood at your wood/yard waste processing facility(s)?

_____ \$ per ton

12. What was done with the wood you accepted in 1996 at your wood/yard waste processing facility(s)? *(Please indicate the percentage of total wood accepted)*

- _____ % Given away or sold as-is for reuse
- _____ % Given away or sold as-is for fuel
- _____ % Ground or chipped at your facility(s) for use as landfill cover
- _____ % Ground/chipped at your facility(s) and given away or sold for fuel
- _____ % Ground or chipped at your facility(s) for other uses (e.g., mulch, animal bedding, compost, soil amendment, and core material for particleboard)
- _____ % Other (please specify)

100%

13. If you grind or chip wood, what was your average selling price for this material in 1996? *(Please skip this question if you did not grind or chip wood pallets. If you did not charge for the material, please answer zero)*

_____ \$ per ton of ground or chipped pallets

14. Does your organization restrict wood of any form to be to be landfilled?

No

Yes → Please describe the restrictions:

15. Is there something we should have asked about wood at landfills but did not?
(Please comment below)

***Please fold, tape, and return the questionnaire. The postage is prepaid.
Thank you for your help!***

**VIRGINIA TECH
THOMAS M BROOKS FOREST PRODUCTS CENTER
ATTN: DELTON ALDERMAN
PO BOX 850
BLACKSBURG, VA 240601-9985**

Please return the questionnaire after folding in half and taping the ends together (*Please do not staple*). Before mailing, please make sure that the return address is visible. **The postage is prepaid.**

THANK YOU!

June 4, 1997

Carlton Dudding
Atlantic Waste Disposal Sanitary Landfill
4451 Crossings Blvd
Prince George VA 23875

Dear Mr. Dudding:

The amount and types of solid wood reaching landfills in Virginia are unknown. What is being done with solid wood once it reaches these landfills is also a question that needs to be answered. The Department of Wood Science and Forest Products at Virginia Tech, along with the Virginia Department of Mines, Minerals and Energy, the Southeastern Regional Biomass Energy Program of the TVA, and the Powell River Project at Virginia Tech are conducting a study to answer these questions. The information obtained through this study will play a vital role in assessing the availability of solid wood materials for recycling and the future planning of solid wood waste management at landfills.

As part of this study, we are contacting people in charge of waste disposal facilities in Virginia and surrounding states. Since you are one of the few randomly selected landfill managers who will receive a copy of the study questionnaire, your response is vital for the success of this work. Please take a few minutes to complete the questionnaire and return it to us. It is quite short and should not take very long to complete. The postage is prepaid.

If your organization does not operate or manage a landfill, please answer the first question and return the questionnaire. All responses are strictly confidential. The identification number on the questionnaire is used to remove your name from the list before the next mailing and to avoid bothering you with unnecessary follow-up mailings.

If you have any questions regarding the research or questionnaire, please feel free to contact me at 540-231-5876 or fax at 540-231-8868. I want to thank you in advance for your assistance.

Again, your assistance with this study is greatly appreciated.

Sincerely,



Delton Alderman
Graduate Research Assistant

Dear Landfill Manager,

I need your help! Two weeks ago I mailed you a copy of a questionnaire titled the *Study of Solid Wood Waste Disposal in Virginia*. I am contacting you to ask you to complete the questionnaire. If you have completed and returned the questionnaire, please accept my thanks. If you haven't, please take a few minutes to complete and return the questionnaire. Since your name was chosen at random, your participation in this study is extremely important to accurately measure and report the amount of solid wood going into Virginia's landfills.

Should you have any questions, please call me at (540) 231-5876 or fax (540) 231-8868. Thank you in advance for your help.

Sincerely,

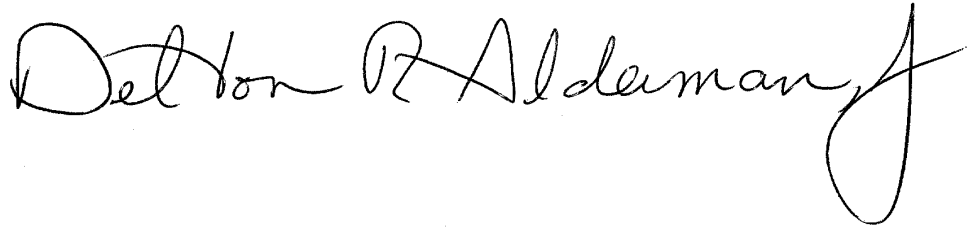


Delton Alderman
Graduate Student, Virginia Tech

APPENDIX C

VITA

Delton Ray Alderman, Junior was born in Galax, Virginia on May 31, 1958. Mr. Alderman received a B.S. in Forestry and Wildlife Management, in the option of Industrial Forestry Operations, from Virginia Polytechnic Institute and State University in 1982. Upon completion, he worked as a procurement forester, forestry consultant, and served the Nation as an AmeriCorp volunteer, specializing in the design, fabrication, and installation of wooden timber bridges. In 1996 he returned to complete requirements for a Masters in Wood Science and Forest Products.

A handwritten signature in black ink that reads "Delton R. Alderman, Jr." The signature is written in a cursive style with a large, looping initial 'D' and a long, sweeping tail on the 'J'.