ABSTRACT

CARTER, JAVON MARCELL. North Carolina Biomass Inventory and Utilization and Pellet Production from Mixed Biomass. (Under the direction of Sudipta Dasmohapatra, Lucian A. Lucia, Glenn P. Catts, Kimberly Weems and Joe Denig.)

The *Analysis of a Renewable Portfolio Standard for the State of North Carolina* (La Capra Associates, 2006) proposes three targets for biomass utilization and fossil fuel displacement. North Carolina should displace 10% of its gasoline and diesel fuel consumption, and 7% of its predicted power consumption by 2017 using in-state biomass resources while incorporating energy efficiency measures. North Carolina is also mandated to become a leader in bio-products research and development by 2017. This research investigates two paths of the biomass and bioenergy sector and highlights North Carolina's potential to become one of the country's leaders in green energy and technology.

The purpose of this study was to explore the woody biomass inventory, availability, and current product utilization in North Carolina. The results of the study may allow an understanding of the existing and future competition in the use of biomass with the rising focus on bioenergy industry and assessment of suitable locations for ethanol bio-refineries in the state. GIS maps were generated that show the current availability and inventory of green tons of wood by counties in North Carolina. The Haywood, Jackson, Transylvania, Columbus, and Martin counties of NC have the largest base of woody biomass according to the 2007 Timber Products Output data. Based on the current utilization and inventory of woody biomass, the western North Carolina region is the most suitable location for bio-

ethanol refineries in North Carolina because the region holds an abundance of forest land and the least amount of roundwood products are produced in the region. However, biomass inventories in western North Carolina will not be able to be removed because of land ownership issues, accessibility due to the Great Smoky and Blue Ridge Mountains, and strict environmental air quality regulations and permits in the region. The second most favored area is the Piedmont and Coastal Plain regions with Montgomery, Warren, Moore, Beaufort, Halifax, and Bertie being the counties that show the most promise.

Results of data collected from 75 firms that currently utilize roundwood for conversion into various wood products (representing 26% of all roundwood utilizing firms in NC) show that 26% of the timber is converted to lumber in sawmills, 7% to pulp and paper, 6% to veneer and 8% plywood and OSB, 18% of the roundwood to chips and bark, 4% to pallet and crate mills. About 16% of the roundwood is converted to shavings and residues and the “other” category represents 14% which includes: timber and poles, cants, paneling, cross ties, boxes, tobacco barrels, slabs, cabin logs, musical instruments, furniture, tongue and grove siding, wooden rockers, turnings, and decking. These representative mills sell 19% of their products produced to wholesalers and dealers, 14% go to furniture and cabinetry, 13% to pulp and paper mills, 9% each to pallet and crate firms, and retailers. The rest of the primary customers are sawmills (7% of products), composite mills such as MDF, particleboard (6%), veneer mills (3%), plywood and OSB mills (2%), Pellet mills (2%) and others (16%).

The United States forest products industry faces many challenges that threaten its global competitiveness as it enters the 21st century such as the emergence of Asian imports especially for secondary wood products, increased demands for non-wood alternatives and environmental pressures and constraints. Such pressures clearly show the need for innovative products and processes that satisfy the needs of today's global market. A major wildfire safety concern, and potential opportunity, is the abundance of underutilized pocosin mixed biomass forest resources in North Carolina. Currently there is no commercial value to landowners and industry stake holders to harvest such material and process it. Creating value for this material through new products and processes has the potential to improve profitability of local industry supply chains in North Carolina. One potential value creating opportunity is the conversion of these to wood pellets for energy.

An economic and technical analysis of mixed biomass in the understory of forests in NC was developed to assess their feasibility of conversion to energy pellets. Pocosin mixed biomass is defined as all non-merchantable biomass unsuitable for high-value wood products, such as plywood, sawtimber, etc. The mixed biomass was first successfully converted to pellets using standard pellet equipment in the laboratory. Technical analysis included calculation of energy value, ash content and chloride content. The technical analysis showed that the manufactured pellets had an energy value of 8,222 Btu/lb, ash content of 1.28% and chloride content of 128 ppm. These values compare favorably with the premium pellet standards available in the marketplace with heat of combustion values between 7,750-9,000 Btu/lb, ash contents less than 1%, and chloride contents no more than

300 ppm. Financial indices such as net present value (NPV), internal return rate (IRR) and year-to-positive cash flow are calculated to investigate the economics of the pellet production and the technology transfer.

North Carolina Biomass Availability and Pellet Production from Mixed Forest Understory for Bioenergy Industry

by
Javon Marcell Carter

A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Forest Biomaterials Science

Raleigh, North Carolina

2010

APPROVED BY:

Lucian A. Lucia	Glenn P. Catts	Kimberly Weems

Joe Denig	Sudipta Dasmohapatra Chair of Advisory Committee

DEDICATION

This thesis is dedicated to my wife, Shamecia, and two children Jaqai and Jaylynn. The three of you have been extremely supportive of me and continue to encourage me to accomplish my aspirations. Shamecia, you are a magnificent wife and I am happy we made a concise decision to work hard, love one another, and raise our children to become improved versions of ourselves.

I love you all very much.

BIOGRAPHY

Javon Marcell Carter, son of Scott Eugene Carter and Albertha Elizabeth Thompson, was born in Fort Walton Beach, FL on November 19, 1984. While growing up in his hometown of Willingboro, NJ, he was an intelligent and gifted child whose passion was playing football. In 2002, he graduated from Willingboro High School and chose to stay home to work and attend Burlington County Community College. After a two year attempt of deciding what he wanted to do with the remainder of his life, he was offered a chance of a lifetime to join some of his best friends in attending a Historically Black College and University (H.B.C.U.) at Winston Salem State University, Winston Salem, North Carolina. In 2008, he graduated Magna Cum Laude from Winston Salem State University where he earned a Bachelor of Science degree in Mathematics with a minor in Chemistry. Motivated by many research opportunities presented in undergraduate studies and the great academic prestige, Mr. Carter continued his education at N. C. State and will earn a Master of Science degree in Forest Biomaterials with a minor in statistics in the fall of 2010.

ACKNOWLEDGEMENTS

I would like to begin by thanking my advisor Dr. Sudipta Dasmohapatra. I really appreciate you accepting me as a member of your team and allowing me to work with you on our projects, of many. I thank you for your loyalty, friendship, guidance, and patience throughout this project.

A special thanks to my mentor and friend Dr. Lucian A. Lucia for believing in me and doing everything in your power to assist me in being accepted and completing my Master of Science degree in Forest Biomaterials Science. You are an amazingly smart and fun person and I am truly blessed to have had you as a mentor along this journey.

Dr. Glenn Catts, I have always valued the impact you have made on my life as a person and student. You will be greatly missed as a teacher, thinker, and motivator because you are one of the best, thank you. To the other members of my committee, Dr. Joe Denig and Dr. Kim Weems, thank you very much for your support and advice over the last two years.

I have many friends and family who have supported me through the years that I would also like to acknowledge. To my parents, siblings, friends and family members, although 100’s of miles separate us, I always hold on to the memories we share.

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1.1 North Carolina Bioenergy Sector

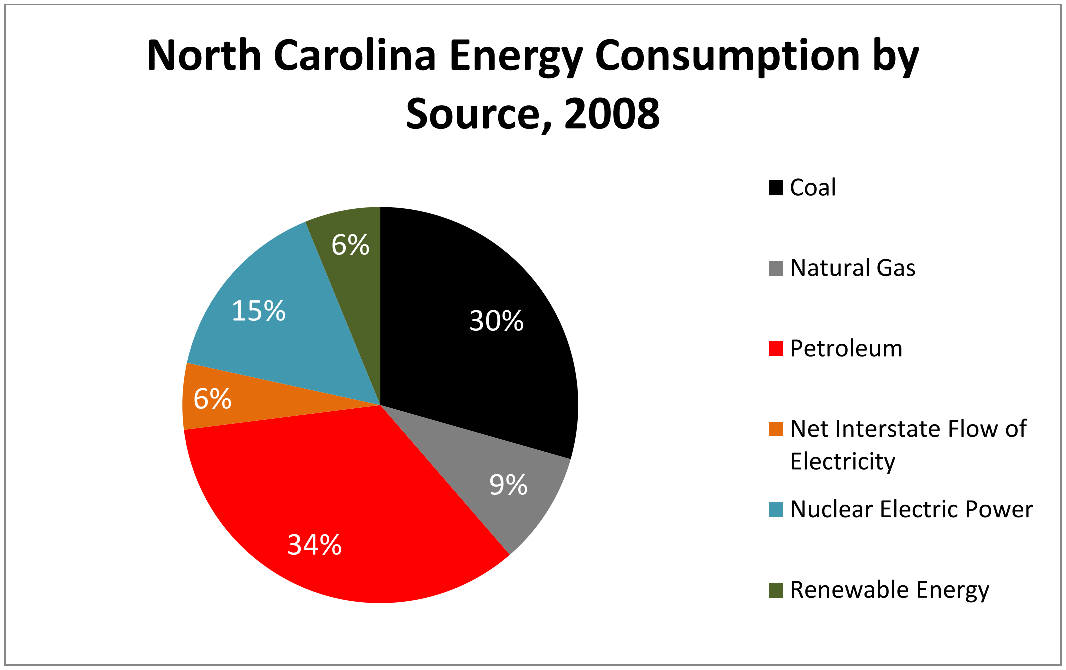

Figure 1.1 North Carolina Energy Consumption in 2008 (U. S. Energy Information Administration, 2010)

In 2008, North Carolina consumed an estimated 2,702 trillion BTUs (791.9 billion kWh) of energy (U. S. Energy Information Administration (b), 2010). The state's energy consumption ranks 37th nationally. As shown in **Figure 1.1,** petroleum accounted for 34 percent of total consumption, with coal providing another 30 percent of the energy within the state. Other major energy sources were nuclear and natural gas, which accounted for approximately 15 and 9 percent of the state's total energy consumption, respectively (U. S. Energy Information Administration (b), 2010). Renewable energy, which includes conventional hydroelectric power, biomass (wood and biomass waste, fuel ethanol, and losses and co-products from fuel ethanol production), geothermal, solar thermal and photovoltaic, and wind energy supplied over 167.2 trillion Btu (49 billion KWh), or about 6% of North Carolina's total consumption (U. S. Energy Information Administration (b), 2010). The state ranks 12th nationwide for amount of energy consumption derived from biomass resources (U.S. Department of Energy (c), 2010). Total energy consumption in North Carolina increased by 1,875.3 trillion Btu (549.6 billion kWh) between 1980 and 2008. Electricity consumption rose by 1,050.2 trillion Btu (307.8 billion kWh) during the same period (U. S. Energy Information Administration (a), 2010). Per capita petroleum use for transportation was estimated to be 21 thousand barrels for 2010, an increase of 6.7 thousand barrels since 1980 (U. S. Energy Information Administration (d), 2010).

North Carolina's electricity consumption is among the highest in the Nation. As is typical in the South, more than one-half of North Carolina households use electricity as their main energy source for home heating and cooling. North Carolina possesses about 5 percent of the Nation's net summer capacity for wood energy production and ranks among the top 10 States with the highest net summer capacity for wind power. The net summer capacity is the maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, as demonstrated by a multi-hour test, at the time of summer peak demand (period of June 1 through September 30.) This output reflects a reduction in capacity due to electricity use for station service or auxiliaries. In August 2007, North Carolina adopted a renewable energy and energy efficiency portfolio standard requiring electric utilities meet 12.5 percent of retail electricity demand through renewable energy or energy efficiency measures by 2021 (U. S. Energy Information Administration (d), 2010).

In 2009, the Obama Administration awarded $ 30.4 million in Recovery Act funding to support energy efficiency and renewable energy projects in government, commercial, and residential buildings under North Carolina's State Energy Program (U.S. Department of Energy (a), 2009). The state of North Carolina provides an array of personal and corporate tax credits and an energy loan improvement program to promote the use of biomass. Under the Renewable Energy Corporate Tax Credit a corporation can take a tax credit up to 34% (up to $2,500,000) of the cost of construction of any facility that will be used to produce an energy related product from a renewable resource. For private properties, such as residences, the credit limit is $10,500 for biomass related energy production projects. Other tax credits are available to individuals utilizing renewable energies and technologies (North Carolina Incentives for Renewable Energy, 2006). One such renewable feedstock is biomass (as indicated on page 1) generated from forestlands in North Carolina to produce bioenergy.

North Carolina has over 18.6 million acres of forestland (Southern Research Station Timber Products Output, 2007). It is estimated that logging residues in the state could provide 2.3 million dry tons of biomass each year. Mill residues can add over 5.2 million dry tons more to the supply. This translates into 6.5 trillion and 22.2 trillion Btu (1.9 billion and 6.5 billion kWh) per year in potential energy production (North Carolina State Energy Office, January 2005). Today, wood and wood waste account for 11% of North Carolina's industrial energy needs (North Carolina State Energy Office, January 2005). Urban wood residues could contribute another 833,000 dry tons of biomass annually (Milbrandt, 2005). Currently North Carolina has 0 ethanol plants and 10 biodiesel plants with a biofuel production capacity of 30 million gallons (U.S. Department of Energy (d), 2010).

The purpose of this research is to investigate two individual areas within the North Carolina bioenergy and biomass sector. This thesis is developed as two separate potential peer-reviewed journal articles:

1. Examination and review of the inventory, availability and current utilization of the woody biomass resources in North Carolina (that may affect the bioenergy industry and its location).
2. Technical and economical feasibility analysis of using mixed biomass and forest residues for wood pellet manufacturing in North Carolina.

The first article will examine the biomass availability, current utilization, and competition within North Carolina and how these particular issues can affect the future access of biomass for the bioenergy industry and the location of Bioethanol refineries. The second article details the production of wood pellets from mixed biomass and also provides a pro forma income statement for a 100,000 ton per year wood pellet manufacturing plant in New Bern County, NC. The wood pellet manufacturing plant was chosen to be located in New Bern County, NC as it is at the intersection of main traffic routes and is accessible to the forestland where the resources are available.

2 Biomass Availability and Current Utilization Affecting the Bioenergy Industry in North Carolina

2.1 Introduction

The large-scale production of fuel ethanol from lignocellulosic materials is now a major commercial objective in North Carolina. This interest arises from three perspectives: 1) an economic and job creation benefits, 2) independence and security from foreign sources of energy, and 3) the production of a renewable and environmentally friendly fuel that is inherently cleaner than gasoline. With the recent passage of a Renewable Portfolio Standard (RPS) in the state of North Carolina (2007 NC Sess. Law 2007-397) and increased attention to federal renewable energy and climate change policies, forests are increasingly turned to as a source of energy (Galik, Abt, & Wu, 2009). Almost 5.6 billion gallons of petroleum-based liquid fuels are consumed by North Carolinians every year of which none is produced in North Carolina.

The goal of the North Carolina's Strategic Plan for Biofuels Leadership, is that by 2017, 10% of liquid fuels sold in North Carolina - or about 600 million gallons - will come from biofuels locally grown and produced (Biofuels Center of North Carolina, 2010). There are currently twenty-one biofuels related (biodiesel, waste oil collection, ethanol from corn, advanced biofuels, etc.) companies in North Carolina using a variety of feedstocks. Although bioethanol has primarily been made from corn and other agricultural products, forest resources show the greatest potential for development of the biofuels industry in North

Carolina (Biofuels Center of North Carolina, 2010). These forest resources consist of standing timber from government as well as private forestlands and includes natural as well as plantation forest timber. There are 17.6 million acres of timberland in North Carolina and a limited market for the large inventory of standing timber. Annual growing stock of all timber on North Carolina lands is approximately 15,929,259 tons (Southern Research Station Timber Products Output, 2007). Each year, 247,000 acres of timberland are harvested and retained as timberlands.

For over five years, annual growth of the timber inventory has exceeded the annual timber usage (Southern Research Station Timber Products Output, 2007). This has further affected stump and delivered prices for large-scale woody biomass, which in North Carolina were already among the lowest in the southern United States (Harris, 1999-2010). Also, North Carolina continues to build greater standing inventory of woody biomass growing stock. Around the peak of timber demand for the construction and housing markets in 2006, nearly 45 million tons of wood was harvested in North Carolina for all markets, according to the U.S. Forest Service 2007 Forest Inventory Analysis (FIA) data. Despite peak demand, North Carolina still increased its standing inventory in 2006 and grew nearly 54 million tons of timber – 20% more than was harvested.

The utilization of the woody biomass and standing timber in NC is mostly in the existing traditional wood industries such as lumber, veneer, pulp and secondary wood industries. Currently, demand for timber in North Carolina is dominated by the traditional forest products industries: the pulp and paper industry utilizes pulpwood, construction markets utilize saw timber, and lumber and veneer are utilized in various secondary applications (e.g., furniture and cabinets, flooring, moulding and millwork, etc.). Based on current forest products demand, pulpwood resembles the general species flexibility and physical properties acceptable for thermochemical biofuels production. North Carolina currently has five pulp and paper mills using pulpwood as feedstock; four of these mills are located in the state's coastal plains, and one is located in the mountains. The U.S. demand for paper and paper products has declined, and a worldwide shift in paper production has impacted North Carolina's mills (Cook, Deking, Rudder, & Battista, 2004).

The construction market has seen a major slump in the past couple of years due to the economic downturn. Consequently, the demand for wood in the secondary markets such as furniture and flooring have also been affected due to the slump in the construction market. Although the demand for standing timber has declined in southeastern traditional markets in the past few years and especially in the last two years (2008 and 2009), the growing bioenergy industry and the potential utilization of forest biomass for energy will likely create a competition for the available biomass in North Carolina. The North Carolina Solar Center reported that North Carolina has a significant amount of lignocellulosic biomass (plant fibers containing lignin and cellulose) and studies indicate that they could be utilized to produce energy (Perez-Verdin, Grebner, Munn, Sun, & Grado, 2008).

2.2 North Carolina Forest Biomass Resource

Table 2.1 lists the distribution of North Carolina's annual biomass resources according to their available energy content for their most likely energy conversion (Rich, 2007). Using the most recent data available at the time of publication, biomass-derived gas provided feedstock for nearly 10.8 billion gal of ethanol in 2007 (U. S. Energy Information Administration (e), 2010), nationwide. Although forest biomass is a renewable resource, the availability of forest biomass is limited over short time periods by both the amount of land in forests and the rate of forest growth. Therefore, an increased use of forest biomass for bioenergy, biofuels, or wood and paper products will likely impact all other users of the forest resource (Galik et al., 2009).

Table 2.1 Distribution of North Carolina's annual biomass resources by energy content for their most likely energy conversion in 2007 *Construction and Demolition (C&D) **Municipal and Solid Waste (MSW) (Rich, 2007)

Forest Resources: 57%		Agricultural Resources: 16%		"Waste" Resources: 27%	
Softwood	12%	Wheat Straw	0.5%	Yellow Grease	0.5%
Hardwood	14%	Corn Stover	5.5%	Animal Renderings	2%
Pulpwood	31%	Corn Grain	6%	C&D Wood Waste	6%
		Sweet Potato	1%	MSW Wood Waste	5%
		Soybean Oil	3%	Poultry Litter	4%
				Hog Waste	4%
				Landfill Gas	5.5%

Figure 2.1 below shows the price trend of roundwood (softwood and hardwood) in North Carolina over the past 10 years. The stumpage prices for pulpwood remains steady over the ten year period. While the prices for sawtimber, ply-logs, and chip-n-saw remained constant for the first six years they have begun to decline over the last four years. When consumers increase the quantity demanded at a given price by competing for the same

supply an increase in equilibrium price will occur for sawtimber, chip-n-saw, ply logs, and pulp wood. The goal of this study is to evaluate the available biomass in North Carolina by county and examine the current markets and the locations that are suitable for sources of biomass for energy purposes. The implications will be important not only for the current bioenergy industry in terms of available feedstock but also for the traditional wood industries to look into areas considering the current competition in surrounding locations.

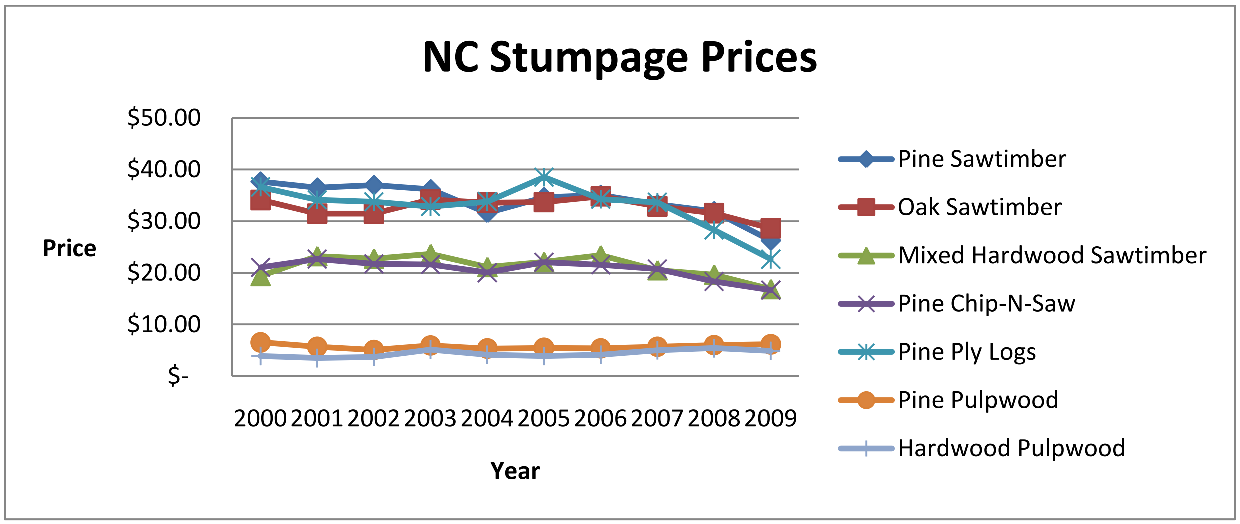

Figure 2.1 Stumpage Price Trend for Roundwood based on its Utilization in NC (Harris, 1999-2010)

2.3 Utilization of Forest Biomass Resources

The likelihood of interactions and competition between different uses of the forest biomass resource has not been unnoticed in the literature and other relevant work in the area. Industrial uses of wood for wood products constitute “the major competitor” to fuel uses of forest biomass (Sedjo, 1997). This study explored the relationship between prices for fuelwood, wood products, and other forms of energy such as coal. A recent study by Galik et al. (2009) proposes that should the demand for woody biomass in North Carolina exceed the supply of forest residues all users of forest resources will be affected by the resulting spike in resource pricing and therefore, wood consumers in existing markets will be displaced. Research in other countries point out that although the economic potential use of roundwood in energy generation is possible, promoting increased use of forest-based biomass in the energy mix will put upward pressure on the price and intensify the competition for roundwood when the energy sector starts to infringe on the existing and future supply (Lundmark, 2006).

Another school of thought suggests that the use of forest sawtimber for energy purposes is not sustainable because it will be difficult to economically justify the utilization against the high value wood use and returns in traditional wood industries (Hazel, D., 2006). This competition for forest-based biomass will be statewide and national in scope, however the greatest effect will be seen locally and regionally on the location of a new facility, availability of biomass and price. Langholtz (2006) and Langholtz et al. (2010) discuss various strategies that determine availability or total delivered price for a given quantity of woody biomass in select counties of the Southern United States. This assessment takes into account biomass type, distance, and transportation infrastructure for producing fuels from the woody biomass. The study utilized ArcGIS Network Analyst for the assessment (Langholtz, Carter, Marsik, & Schroeder, 2010).

Generally, the best facility location for any product is conceived as the place which significantly reduces production costs (i.e., a site close to feedstocks) (Perez-Verdin et al., 2008). Similarly, another study proposes that new energy-generating facilities should be situated in locations where there in not much overlap of delivery radii or competition for supply because an increase in use will increases prices (LA CAPRA ASSOCIATES, 2006). This study will assess the availability, competition and location of forest-based energy facilities in North Carolina.

2.4 Objectives

The primary objective of our work is to explore the woody biomass inventory, utilization, and availability in North Carolina. A secondary objective is to identify suitable locations for ethanol bio-refineries in North Carolina based on the current utilization and inventory of woody biomass. The specific objectives of the study are:

1. Examine the availability of wood based forest biomass in North Carolina by county;
2. Better understand the current competition and traditional markets for forest biomass;
3. Examine the location based strategies for energy firms (bio-refineries) based on the availability and current competition.

2.5 Methodology

During the first phase of the study, data for woody biomass availability and inventory were collected from several secondary sources. These secondary sources include journal articles, Forest Inventory and Analysis (FIA) and Timber Product Output (TPO) data that are jointly administered in North Carolina by the USDA Forest Service and the Southern

Group of State Foresters. The USDA Forest Service Inventory and Analysis (FIA) is a program of research that records a wide range of attributes of our nation's forests including inventories and analyses of the status and trends in resource conditions, use, productivity, and sustainability. In addition to the FIA program, the USDA complies an assessment of the Nation's renewable resources as called for in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) and subsequent amendments. The Timber Product Output Database (TPO) was established to supplement the RPA. The information reported in the TPO considers eleven variables relative to the production of wood products, including amounts of roundwood products harvested, logging residues produced and mill residues produced.

County-level data was compiled in this first phase from the FIA and TPO databases regarding the annual level of biomass removals, amount of primary timber products produced, volume or mill residues that are produced, and pricing trends within the industry. Current estimates of roundwood and primary wood products pricing was collected from the North Carolina Timber Mart South publication (2000-2009). The data accessed from US Forest Service Timber Products Output (TPO) concerning current removals and residue quantities by county was converted into vector point shapefiles and projected into NAD 83 State Plane ft coordinate system using ARC-GIS to produce woody resource inventory maps.

2.5.1 Primary Data Collection

To study the current competition and markets, in addition to literature review, primary data was collected from sawtimber and roundwood using mills in North Carolina in the second phase of the study. Different sources were used to develop a NC database that was used as sample frame for the primary data collection. These sources include the North Carolina Buyers Guide 2007, Southern Research Station's U.S. Mill locations 2005, and the Internet and company websites. The initial database consisted of 525 contacts. Duplicate mills in the aforementioned sources were removed but the sources helped to identify most if not all of the mills utilizing roundwood in North Carolina. This resulted in 342 contacts in the database. Using the internet and news releases as well as personal contact with the NC Division of Forest Resources and faculty and researchers in North Carolina, mills that were not under operation or had closed between 2007 and 2009 were removed from the database. The database contained the following information for all mills: company name, company type, email, address, contact name, product sold, type of product purchased. Data about the production volume (% volume hardwood, % volume softwood produced), and species used by the mill was available for only 45% of the mills. The cleaned database consisted of 291 primary roundwood utilizing mills (sawmills, veneer mills, pulp and paper mills , plywood mills, OSB mills, etc.).

A short questionnaire was developed to survey the mills in the aforementioned database about their raw material use (roundwood volume, % softwood and hardwood of roundwood), and products produced. In July 2009, the initial questionnaire was sent electronically (with a cover letter) to the overall sample frame of 291 companies via Surveymonkey. Two weeks after the first mailing only 5 responses were received. A reminder email was sent to the non-respondent companies where the cover letter was modified to stress the importance of the study and to remind participants that their input was crucial to the success of the study. Concerns regarding the low response rate prompted a withdrawal of some questions and modification of the remaining questions to shorten the questionnaire. Two weeks after the second mailing, an updated questionnaire and a reminder email was sent to those companies that failed to respond to the original survey. Even after the second mailing, only 9 surveys were received from the electronic survey.

Past studies on data collected from lumber companies and other wood products firms have showed a range of response rates from 2% to 50% depending on the type of data collected, objectives of the survey, survey method (electronic, mail or telephone survey), validity of email lists and who collects the data. Most of the surveys in the past in the wood industry were mail surveys, thus to generate responses, in September 2009 a mail survey was sent to the 283 non-respondents to collect data from them on the aforementioned topics. The basic strategy to increase the response included: personalized cover letters, prepaid return postage for the questionnaire, guaranteed anonymity and confidentiality, questionnaire of one page, and a raffle to win an award as a token for completing the questionnaire. The contacts were also asked to complete the questionnaire electronically, if mailing was difficult. Approximately 36 questionnaires were received after two weeks of the data collection. A reminder letter was sent after two weeks at the end of which 70 surveys were received from the second phase of data collection (mail survey strategy) bringing the total number of returned responses to 79. Of the 79 responses, 23 respondents completed the questionnaire electronically (14 electronic surveys were received after the mail questionnaire and cover letter was sent) and 56 returned surveys were from the mail questionnaire. Of the 79, four surveys were discarded because of incomplete information. Seventy five questionnaires were considered for the data analysis representing a 25.76% response rate (**Table 2.2**).

Table 2.2 Study Response Rate

Questionnaire Profile	
Initial Contacts in the Database	525
Initial Population	342
Final Population	291
Completed Responses	75
Response Rate	25.76%

2.5.2 Non-Response Bias

Data collected from the mail survey was tested for non-response bias analysis between early and late respondents (Note that because of the small response rate from the electronic survey, the 9 completed questionnaires were not included in the non-response bias analysis). Non-response bias was measured to compare differences in responses between early respondents (n=36) and late respondents (n=34) at 0.05 significance level (using independent sample t-test). Early respondents were categorized as those who responded after the initial mail, and late respondents included those who responded after the first reminder (Armstrong & Overton, 1977). Variables such as volume of roundwood use and types of markets were compared for the two groups for the non-response bias analysis. Results of the t-test (significance level or alpha = 0.05) revealed no statistically significant differences between the early and the late respondents across the aforementioned variables.

2.5.3 Data Analysis

The questionnaire provided several types of variables that were cataloged and coded for appropriate data analysis. MS-Excel® was used for storing and handling data. Data was checked for errors, and facilitated for further analysis. Excel also was used to summarize data, generate descriptive statistics, and for generating charts and tables.

2.5.4 GIS Mapping

The final population of mills developed within the database was placed in a map using their GIS coordinates to identify their locations and understand the competition and potential locations for a new energy company (based on these locations).

Several companies within the original database contained latitude and longitude coordinates. For those companies without latitude and longitude coordinates Google© Map and Garmin© 60 CSx were used to retrieve the coordinates. The GPS device is connected to the PC via USB cable. In Google Maps the company name and address was entered into the "Search Maps" box. After identifying the destination the "send" link in the destination map window will allow the destination to be sent to an e-mail, phone, car, or

GPS. Upon selecting Garmin GPS a new browser window will open and start a special locate page on the Garmin Web site. Once the Garmin page successfully locates the GPS, it will allow the coordinates to be sent to the device. After all the companies have been uploaded onto the device Minnesota Department of Natural Resources Garmin software was used to retrieve and convert to text all the coordinates. The coordinates were then input from text into the original database.

All geospatial processing for this project was done using ESRI ArcGIS 9.3.1 geographic information systems software. The database was converted into vector point shapefiles using ArcGIS based on XY coordinate data provided in the text file. This vector layer was then projected into NAD 83 State Plane ft coordinate system. A county boundary vector layer of North Carolina was projected in conjunction with the company database and TPO data to show all the wood producing mills with the volume of timber removals for each county across North Carolina.

2.6 Results and Discussion

2.6.1 Analysis of Forest Biomass Inventory and Availability

2.6.1.1 Timberland Inventory and Biomass Availability

The USDA TPO and the FIA database shows the timberland inventory in different counties of NC. Timberland is described as forestland that is producing or is capable of producing crops of industrial wood (20 cubic feet per acre per year) and not withdrawn from timber utilization by statute or administrative regulation. Inaccessible and inoperable areas are included. The distribution of timberland acres across the state of North Carolina is presented in **Figure 2.2**.

Figure 2.2 shows a widely varied distribution of forestland acres classified as timberland across the different counties in NC. The dark blue areas show maximum coverage (includes 364,033-420,001 acres) in counties such as Brunswick, Pender, Bladen, Columbus, and Moore. The yellowish green areas show the lowest coverage of forest biomass inventory (30,810–64,012 acres) in counties such as Camden, Perquimans, Pasquotank, and Mecklenburg.

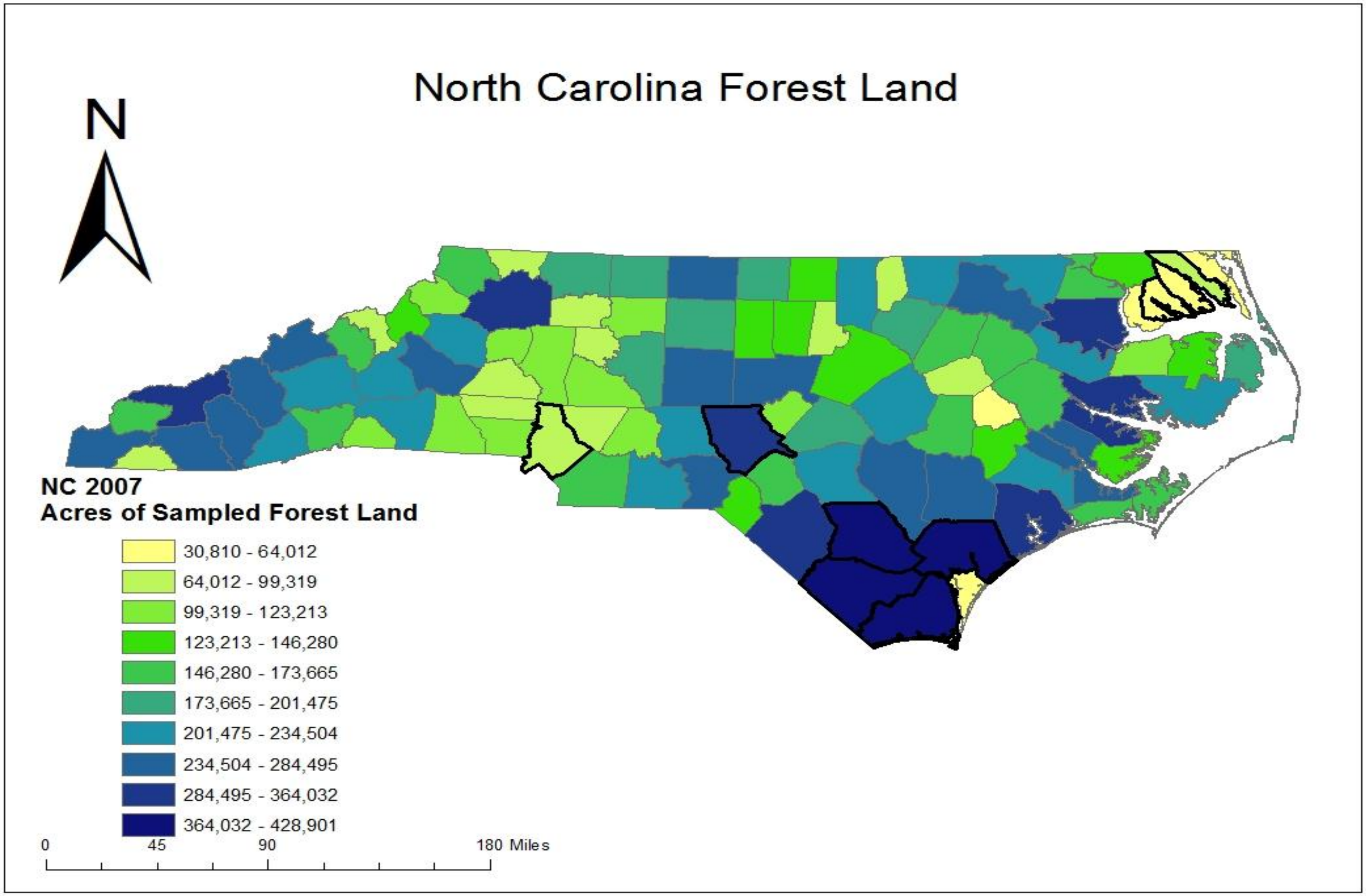

Figure 2.2 North Carolina Forest Land Distribution (in acres) by County (2007)

Within the timberland acres, the total net living tree volume is estimated to be 1.3 billion green tons across the state. **Figure 2.3** shows the volume of living trees in NC by county. As shown in **Figure 2.3**, counties such as Haywood, Jackson, Transylvania, Columbus, and Martin show the largest amount of green tons in NC in 2007. The light green colored counties (e.g., Yadkin, Greene, New Hanover, Currituck) represent the lowest green tons available for utilization.

The available amount of biomass in North Carolina is presented as the total removals, which includes the roundwood that is utilized by the various wood industries and the volume of residuals available from products being produced. The volume of timber removals including growing stock and non-growing stock for all sources (roundwood products-27.8 million green tons, logging residues-12.1 million green tons, and other removals-11.5 million green tons) totals 51 million green tons for the state in 2007 (**Figure 2.4**). **Figure 2.4** shows the distribution of roundwood removals including all sources by county. The counties represented with dark blue colors have the largest volume of removals in green tons (1,287,850-2,333,613 green tons) and those represented with light blue areas have the smallest volume of removals (16,795-123,674 green tons) in 2007.

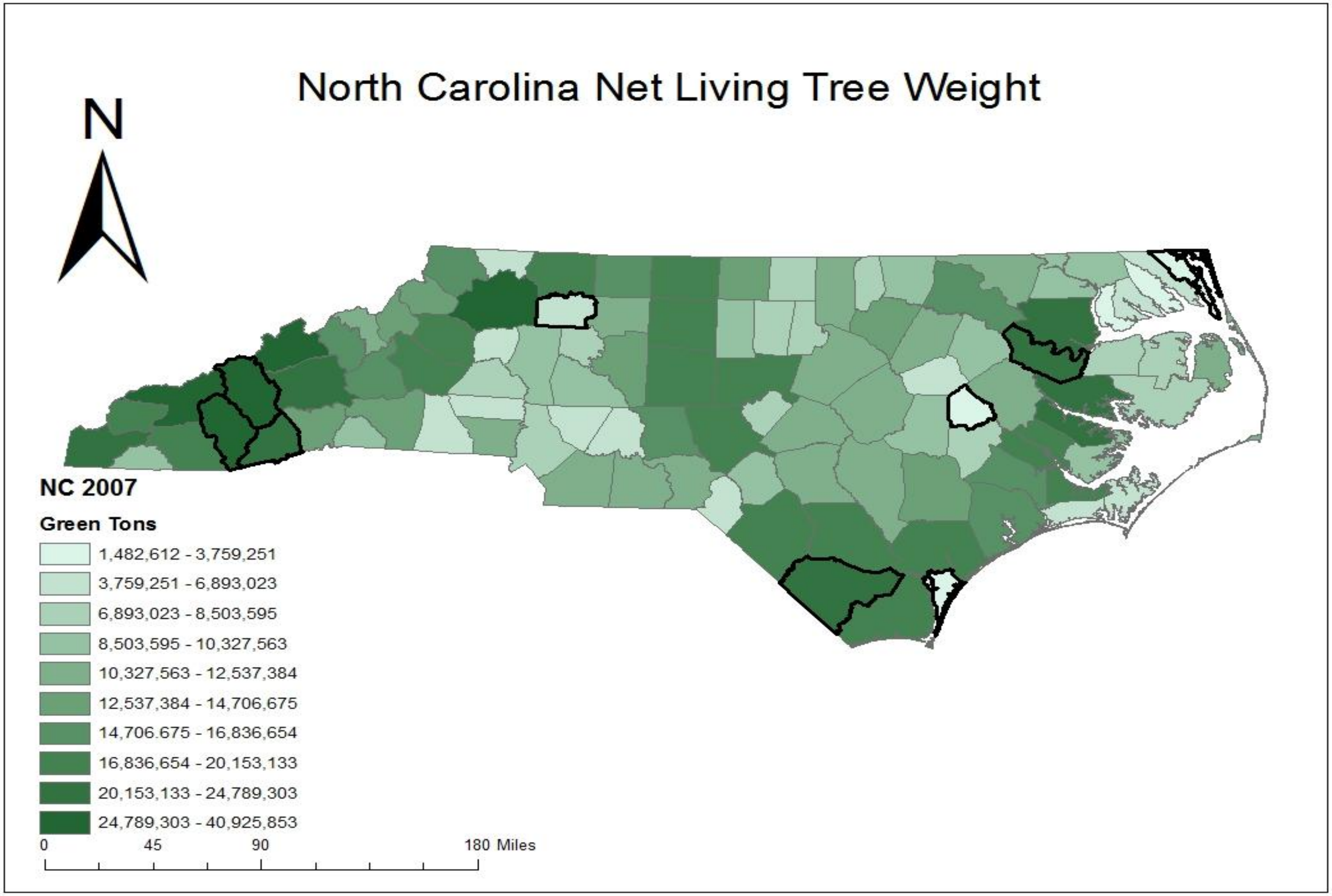

Figure 2.3 Weight of Living Trees Distribution by County in Green Tons (2007)

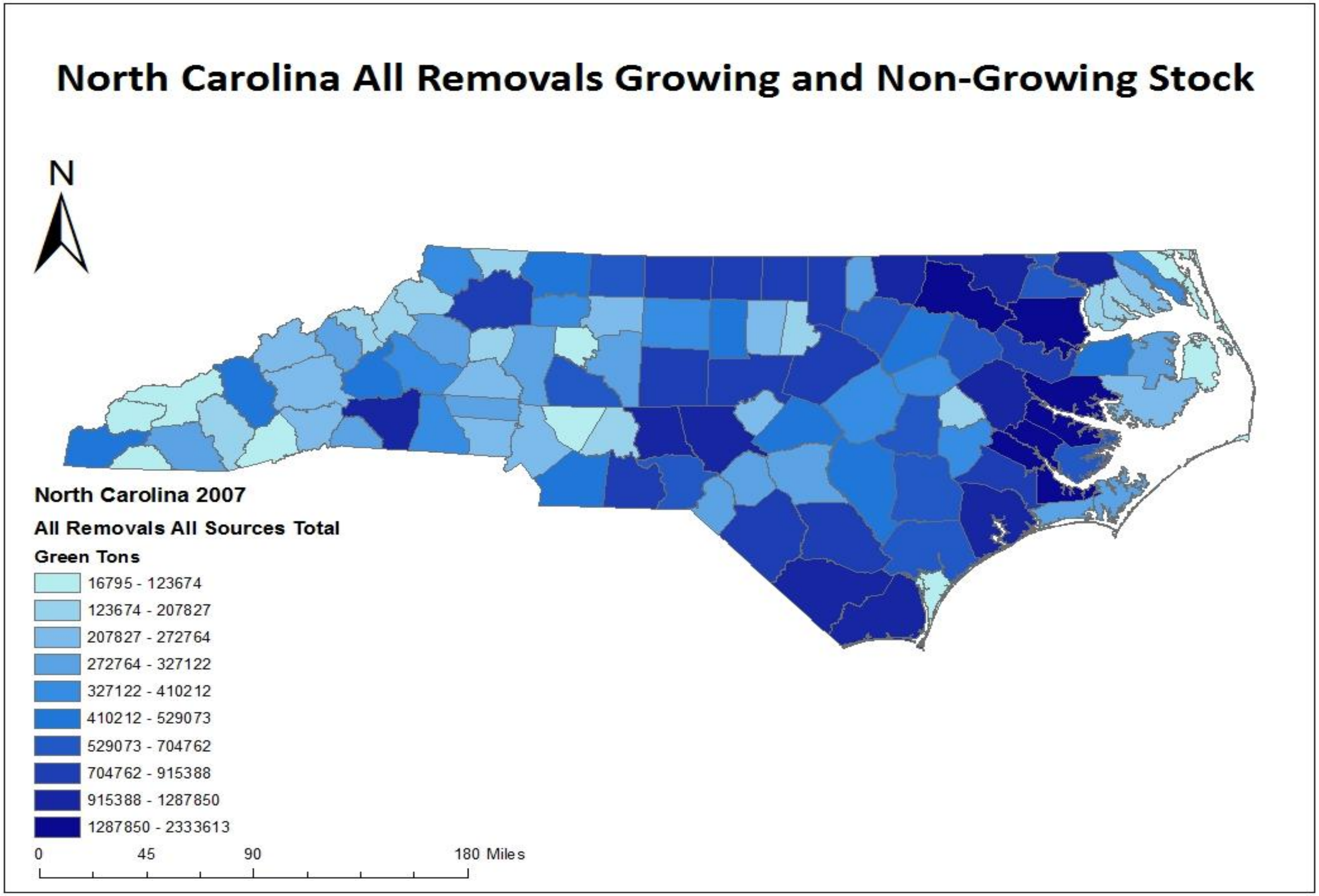

Figure 2.4 North Carolina Removals (All Sources) Distribution by County in 2007

2.6.1.2 Roundwood Products in North Carolina

Based on the history/culture and the nature of land, North Carolina is divided into three distinct regions – western North Carolina, Piedmont, and Coastal Plains. The majority of roundwood products (including saw logs, veneer logs, pulpwood, composite products, fuelwood, post-poles-pillings, and other) are produced in the Coastal Plain region of NC accounting for 14.9 million green tons of roundwood utilized in 2007 (**Figure 2.6**). This region produces mostly softwood sawlogs with the softwood products accounting for 60% of all products produced.

Table 2.3 Roundwood Products in Green Tons and Top Counties in 2007

Primary Roundwood Industry	Total Green Tons	Top Counties
Sawlogs	12,266,523	Beaufort, Craven, Moore, Columbus, Bertie
Venner Logs	1,773,359	Columbus, Brunswick, Duplin, Onslow, Wayne
Pulpwood	10,015,972	Beaufort, Bertie, Northampton, Onslow, Craven
Composite Products	1,588,063	Person, Caswell, Granville, Halifax, Chatham
Fuelwood	2,033,002	Halifax, Rutherford, Montgomery, Beaufort, Warren
Post-Poles-Pillings	56,232	Columbus, Chatham, Granville, Lee, Harnett
Other	62,850	Warren, Greene, Franklin, Stokes, Rockingham
All Products Total	27,796,001	Beaufort, Bertie, Craven, Halifax, Columbus

The western North Carolina region produces 12% of all roundwood products in NC and the Piedmont region produces 34% of all roundwood products in NC. The western North Carolina region produces mostly Hardwood roundwood products (74% of all products produced). The vast majority of products being produced across the state are saw logs and pulpwood which account for 80% of the total production (TPO 2007). The majority of roundwood products produced in the state are produced in Beaufort, Bertie, Craven, Halifax, and Columbus counties which account for 16.5% of the total production (**Table 2.3**). **Figure 2.7** shows the distribution of the major roundwood utilizing products (sawlogs, veneer logs, and pulpwood) across the counties overlaid on the biomass availability (in green tons) by county. As shown, on average, the volume of biomass is proportional to the amount of products produced in a county. In terms of residues, there are 10.3 million green tons of residues that come from mills within North Carolina during the conversion of roundwood to primary wood products. The Coastal Plains region accounts for almost 50% of all residues in North Carolina followed by the Piedmont region (37%) and the western North Carolina region (15%.)

Timber Mart-South for the past 20 years has produced a brief quarterly report of the price of primary forest products in 11 southern states. From the reports, over each quarter, the data is sorted and tabulated to arrive at a grouping of price ranges, low and high of each roundwood product. From the groupings a simple average is obtained for each state, area, and product. For grouping in North Carolina the state is split in half down the middle to represent to regions (1-west, 2-east). The stumpage prices for the state over the last decade shows an unpredictable trend with the last years showing a steady decline in prices (**Figure 2.1 page 9**).

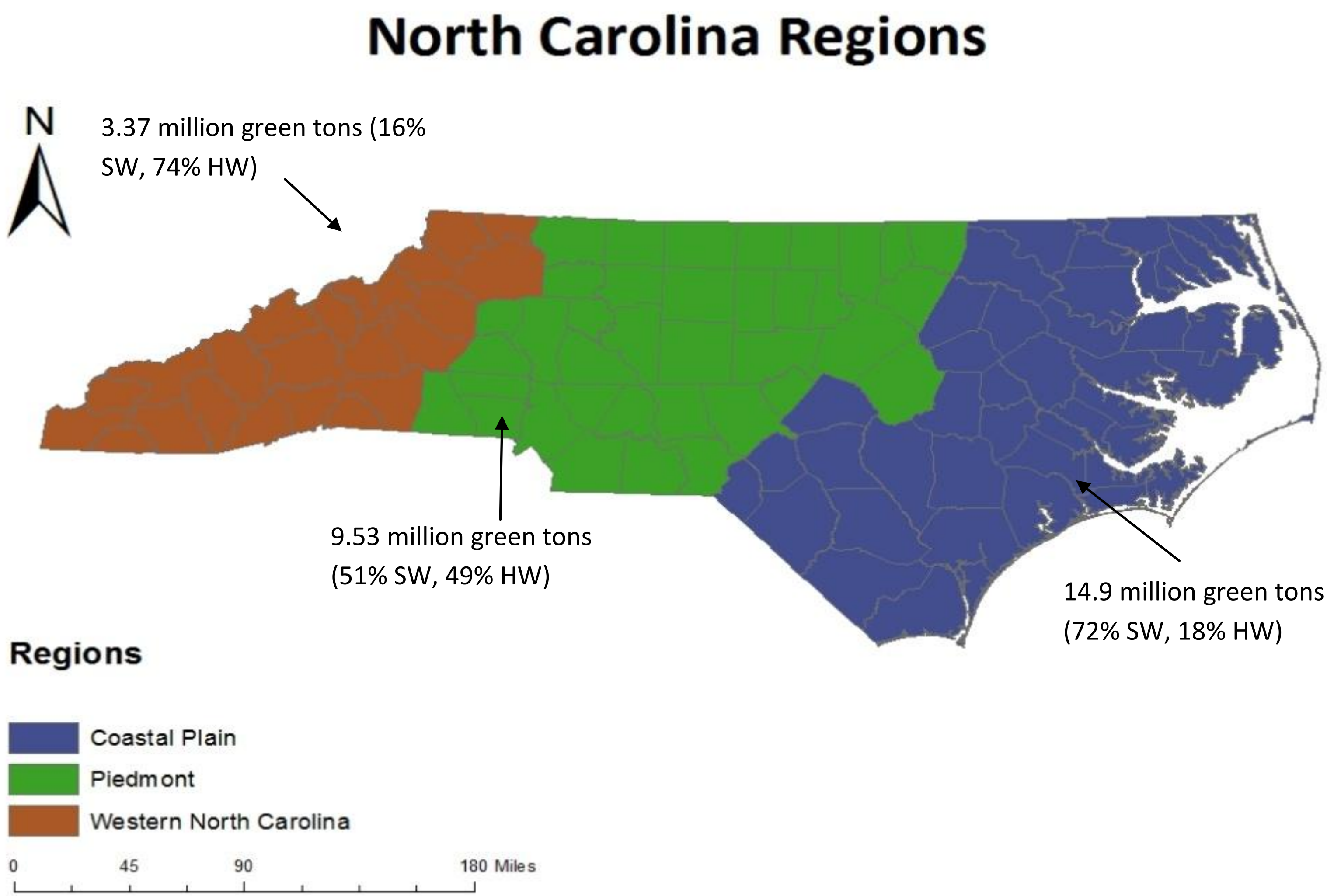

Figure 2.5 North Carolina Regions and Roundwood Utilization (Hardwood and Softwood) % in 2008

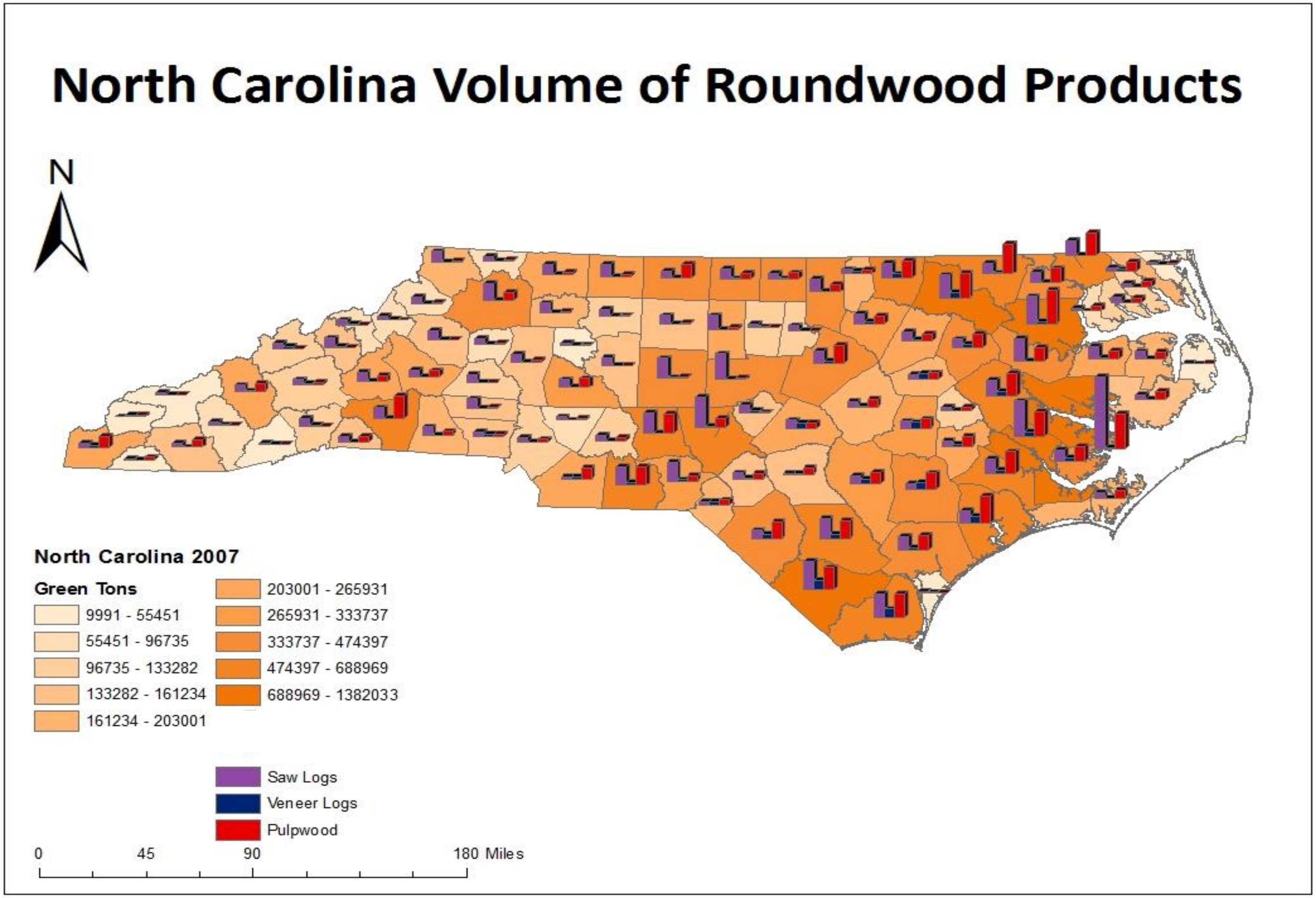

Figure 2.6 Volume of Roundwood Products Distribution by County and Bar Graphs showing Major Product Types (2007)

2.6.2 Primary Survey Results: Profile of Roundwood Utilization in North Carolina

2.6.2.1 Respondent Profile

Approximately, 49% of mills that responded to the survey (n=75) were from the Piedmont region, 18% from the coastal region and 33% from the Appalachian mountain region. The 75 respondents to the survey utilized approximately 12.14 million green tons of roundwood in the year 2008. This volume accounts for about 24% of all timber removals in 2007 (since data for 2008 removals does not exist in literature, TPO data only has data until 2007). The proportion of roundwood green tons will be much greater because the 12.14 million green tons does not include logging residues which total 10.3 million green tons.

The 75 respondents included most, if not all of the largest mills in NC including all of the pulp and paper mills in NC as well as the top 10 sawmills (in terms of volume of production in 2008). Since 2007, the volume of roundwood utilized by the sawmills and pulp mills, and therefore, the timber removals may have reduced because of the reduced demand for lumber and other affiliated wood products from the housing industry slump. Also, the depressed economy may have had a negative effect on the demand of sawtimber for primary and secondary products. The percent of hardwood roundwood and softwood roundwood consumed by the respondent mills in NC was reported to be 51% and 49%, respectively.

2.6.2.2 Primary Products and Customers

Of the total products generated by the respondents (**Figure 2.8**), 26% was lumber, 6% was veneer, 8% included plywood and OSB, 5% was pulp and paper, 20% each to chips, bark, and shavings, and residues accounted for 16% of the products produced. In addition, pallets, crates, and pellets accounted 5% of the products produced from roundwood. The 14% other products included timber and poles, cants, paneling, cross ties, boxes, tobacco barrels, slabs, cabin logs, musical instruments, furniture, tongue and grove siding, wooden rockers, turnings, and decking (**Figure 2.8**). Respondents were also asked to provide information about their immediate customers in terms of the percentage of products that are purchased by these customers. As shown in **Figure 2.9**, respondent mills sold 19% of their products to dealers and wholesalers, and 14% of products were sold to furniture and cabinet firms and 13% to pulp and paper mills.

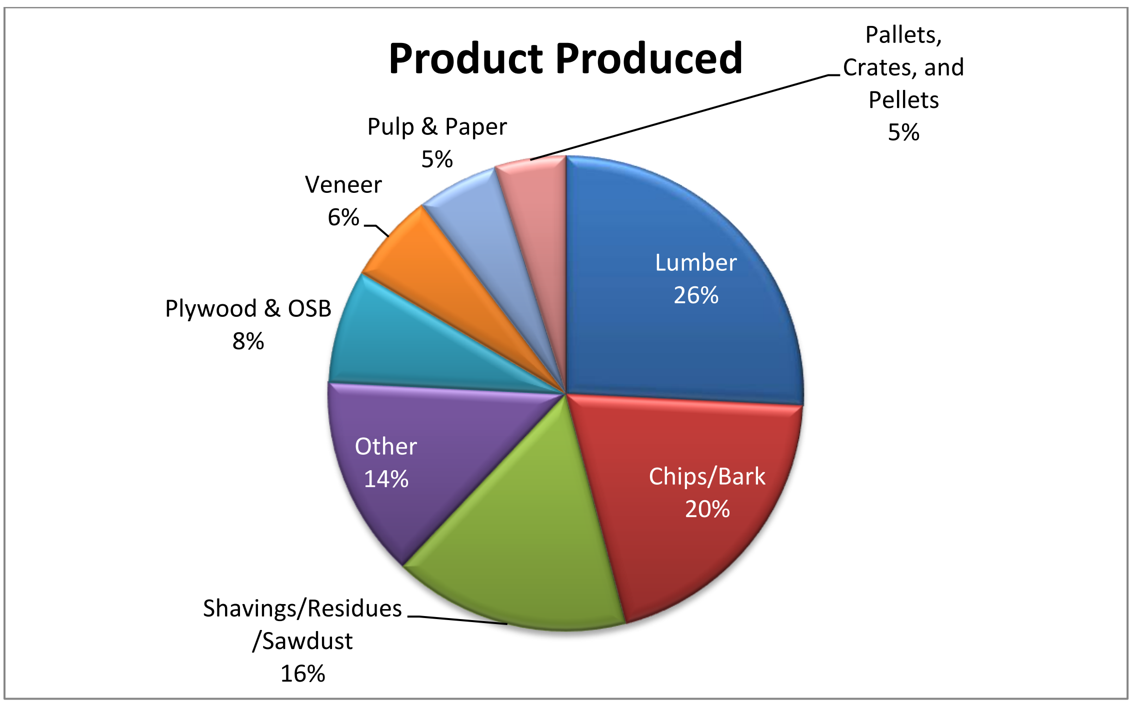

Figure 2.7 Products Produced by Respondents

About 9% (each) of the products were sold to retailers and pallet and crate firms. Approximately 10% to sawmills, planer mills and veneer mills, 6% to wood composite mills

(MDF, particleboard, etc.), and 2% each to plywood/OSB mills and pellet mills. The other category includes exports, flooring, timber frames, decking, and musical instruments .

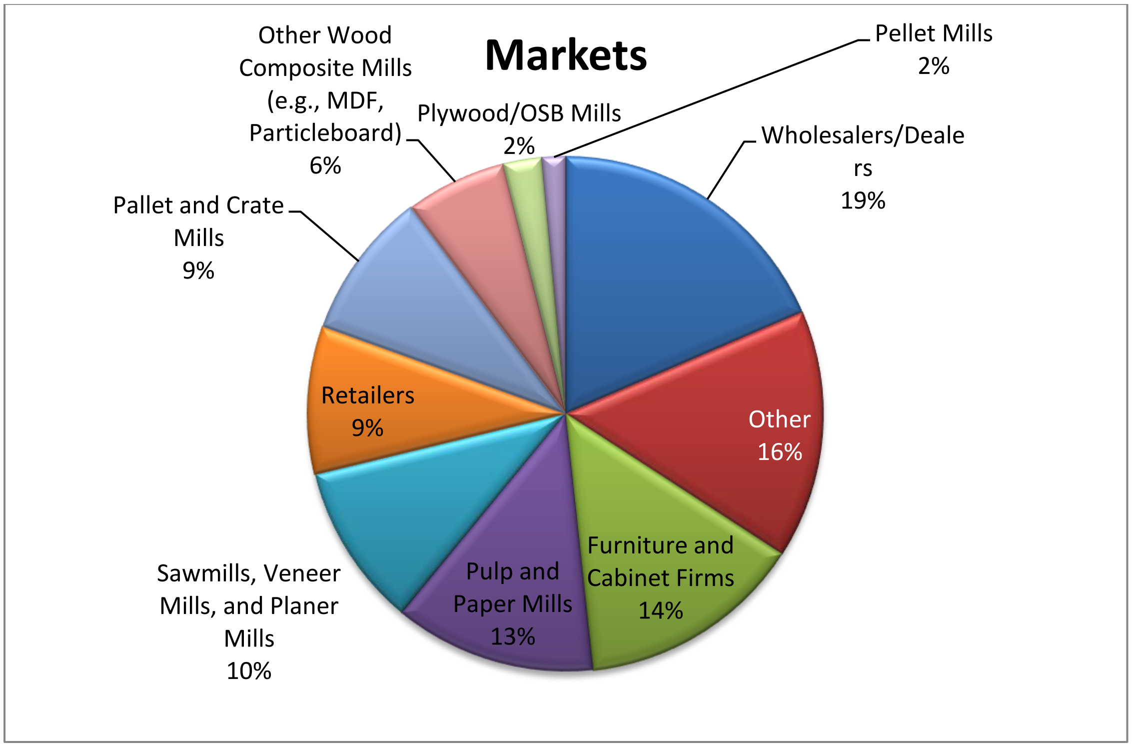

Figure 2.8 Customer Markets by Respondents

2.6.2.3 Preferable locations for Ethanol Bio-refineries

All the 291 contacts from the database that were used to generate the 75 respondents are plotted in a NC map by county (**Figure 2.10)**. This map shows where the locations of all the roundwood utilizing mills are. Note that some mills (n= 17) are located outside of North Carolina but are adjacent counties and generate some resources from North Carolina forests. Judging from the TPO, FIA, and Timber Mart-South data and the primary locations of the mills, data suggests that the western North Carolina region is a recommendable location for a Bio-Ethanol Refinery in North Carolina. Although the western

North Carolina region holds a large portion of the amount of wood products utilizing companies presented by the analysis the companies are not major contributors to the removal of roundwood in the region in spite of the region containing 30% of the net living trees at least 5 inches diameter breast height (d.b.h.)/diameter root collar (d.r.c) in NC.

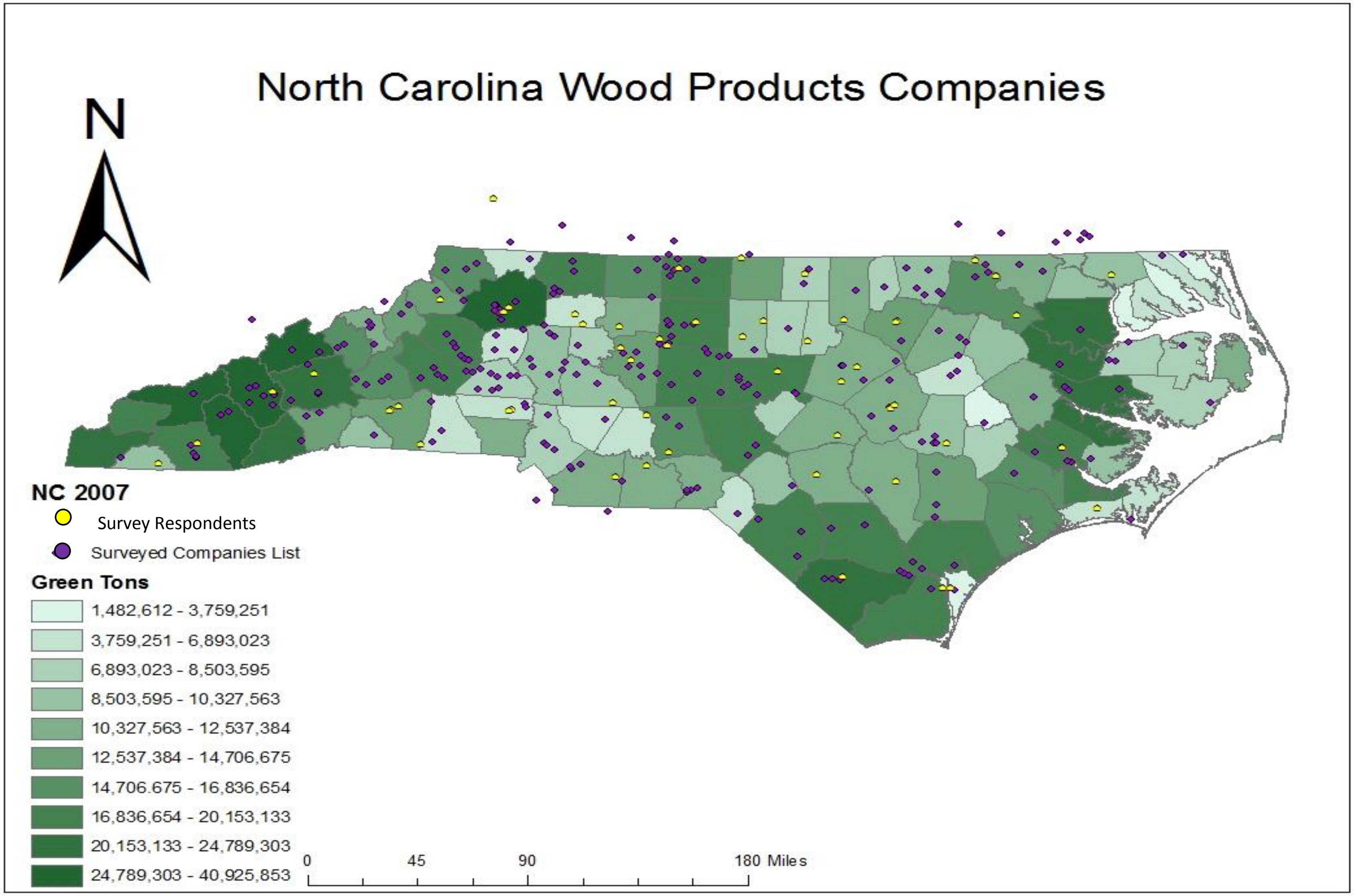

Figure 2.9 Roundwood Using Mills in North Carolina and County Borders (n = 291)

Table 2.4 shows the net living tree weight, the roundwood removal, and difference between the net living tree weight and roundwood removal in green tons for the top 20 counties in 2007. The western North Carolina region holds the top 8 counties for net living tree weight in green tons and removes far less roundwood than the Coastal Plains and Piedmont regions.

Table 2.4 North Carolina Net Living Tree Weight (NLTW), Removals (R), and Difference Between NLTW-R in green tons for the Top 20 Counties in 2007 (Southern Research Station Timber Products Output, (2007))

County	Region	Net Living Tree Weight Total (GT)	All Removals All Sources Total (GT)	Net Living Tree Weight-Removals Difference
Swain	WNC	40,925,853	70,761	40,855,092
Madison	WNC	30,441,057	252,654	30,188,403
Haywood	WNC	29,765,582	461,288	29,304,294
Wilkes	WNC	29,470,542	745,899	28,724,643
Jackson	WNC	28,368,877	154,917	28,213,960
Transylvania	WNC	24,633,663	21,922	24,611,741
Buncombe	WNC	24,789,303	238,450	24,550,853
Cherokee	WNC	24,452,555	449,040	24,003,515
Martin	Coastal Plain	22,778,231	807,197	21,971,034
Bertie	Coastal Plain	22,970,380	1,471,049	21,499,331
Columbus	Coastal Plain	21,706,605	1,287,850	20,418,755
Caldwell	WNC	20,153,133	280,633	19,872,500
Beaufort	Coastal Plain	21,804,903	2,333,613	19,471,290
Moore	Piedmont	19,924,608	972,469	18,952,139
Craven	Coastal Plain	19,942,368	1,391,160	18,551,208
Graham	WNC	18,480,131	107,512	18,372,619
Burke	WNC	18,765,660	410,212	18,355,448
Guilford	Piedmont	18,540,939	342,394	18,198,545
Macon	WNC	18,463,416	316,703	18,146,713
Rockingham	Piedmont	18,603,324	777,675	17,825,649
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All Counties	All Regions	1,321,707,179	51,317,612	1,270,389,567

The western North Carolina region also produces less roundwood products and consists of counties such as Mitchell, Yancey, McDowell, Henderson, and Transylvania where the competition for the roundwood is not as much as other places. A comparison of the stumpage prices in the Eastern and Western part of the state (the timber mart south divides prices in NC based on east and west) shows lower stumpage prices overall for the western part of the state depending on the product in 2009.

The mills and the wood using companies in that region produce 1.5 million green tons of residues that could also be utilized as feedstock in the ethanol production. Therefore, quantitatively the western North Carolina region gives the impression that it would be the most advantageous location however there are substantial reasons that the region will not be suitable. There are strict air pollution and quality regulations that must be followed in the western North Carolina region. There are 82 mountain peaks between 5000 to 6000 feet in elevation in western North Carolina, and 43 peaks rise to over 6000 feet which makes harvesting roundwood in the region more complicated. Lastly, western North Carolina regions rich culture and history which reduces the likelihood of a refinery being developed in the region.

Based on the above, the regions that show the most expedience of location are the Piedmont and Coastal Plains with Montgomery, Warren, and Moore in the Piedmont and Beaufort, Halifax, and Bertie in the Coastal Plains being the most admissible areas. **Tables 2.5 and 2.6** highlight these counties by showing the roundwood removals, roundwood products, and the difference of roundwood removals and products and the mill by-products (residues) for the top 20 counties in North Carolina, respectively.

Table 2.5 North Carolina Removals (R), Products (P), and Difference Between R-P for the Top 20 Counties in 2007 (Southern Research Station Timber Products Output, (2007))

County	Region	All Removals All Sources Total (GT)	All Products * Total (GT)	Removals-Products Difference
Beaufort	Coastal Plain	2,333,613	1,382,033	951,580
Halifax	Coastal Plain	1,453,856	779,773	674,083
Bertie	Coastal Plain	1,471,049	838,537	632,512
Craven	Coastal Plain	1,391,160	823,715	567,445
Montgomery	Piedmont	1,109,067	552,779	556,288
Rutherford	WNC	1,010,078	482,178	527,900
Columbus	Coastal Plain	1,287,850	761,716	526,134
Northampton	Coastal Plain	1,096,675	585,591	511,084
Warren	Piedmont	1,059,411	553,882	505,529
Pitt	Coastal Plain	1,017,531	558,318	459,213
Brunswick	Coastal Plain	1,121,806	688,969	432,837
Moore	Piedmont	972,469	541,194	431,275
Gates	Coastal Plain	947,346	517,654	429,692
Wake	Piedmont	872,628	464,339	408,289
Rockingham	Piedmont	777,675	378,534	399,141
Randolph	Piedmont	755,140	359,194	395,946
Wilkes	WNC	745,899	356,395	389,504
Onslow	Coastal Plain	964,132	576,319	387,813
Bladen	Coastal Plain	915,388	537,397	377,991
Granville	Piedmont	819,077	441,995	377,082
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All Counties	All Regions	51,317,612	27,796,001	23,521,611

*** Includes products produced in primary mills**

Table 2.6 North Carolina Mill By-Products for the Top 20 Counties in 2007 (Southern Research Station Timber Products Output, (2007))

County	Region	All By-Products Total
Columbus	Coastal Plain	1,244,136
Montgomery	Piedmont	1,144,228
Craven	Coastal Plain	1,028,458
Washington	Coastal Plain	930,679
Wayne	Coastal Plain	686,978
Halifax	Coastal Plain	656,943
Alamance	Piedmont	414,309
Surry	Piedmont	394,277
Rutherford	WNC	380,294
Haywood	WNC	377,734
Johnston	Piedmont	362,373
Franklin	Piedmont	333,913
Wilkes	WNC	303,672
McDowell	WNC	269,885
Chatham	Piedmont	229,952
Union	Piedmont	170,234
Gates	Coastal Plain	150,190
Warren	Piedmont	129,289
Catawba	Piedmont	124,923
Randolph	Piedmont	123,248
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All Counties	All Regions	10,347,915

2.7 Conclusion

This research investigated the woody biomass inventory, utilization, and availability in North Carolina as well as identified suitable locations for ethanol bio-refineries within the state. The results indicate that the Piedmont and Coastal Plains region typically represent 88% of the products being produced in the state (of all the products being produced).The western North Carolina region produces less roundwood products and contains 34% of the net living trees in North Carolina. This result quantitatively suggests that the western North Carolina region would be the recommended area for a bio-ethanol refinery in North Carolina because it has the feedstock and the competition for roundwood is much lower in the region resulting in lower stumpage prices. However, circumstance regarding air pollution and regulations, topography, and culture and history will dissuade any real discussion of constructing a bio-ethanol refinery in the region. Therefore the most suitable location for a bio-ethanol refinery is in the Piedmont and Coastal Plain regions with Montgomery, Warren, Moore, Beaufort, Halifax, and Bertie being the primary counties to examine further for an exact location. The purpose and objectives of this research limit the evaluation of the precise location of a bio-ethanol refinery in North Carolina. Initial results are preliminary but future research may reveal more information and opportunities for such an enterprise.

2.7.1 Limitations

The information in this paper is limited to those companies who provided information in questionnaire and those who divulged information in previous studies. Future studies may collect data from all wood products mills in North Carolina and centralize bio-refinery locations into the most suitable areas. Detailed information regarding products produced and volumes of raw material for all wood utilizing companies in North Carolina is difficult to obtain due to companies withholding sensitive information. USDA's FIA and TPO data is from the 2007 study and the 2009-2010 data is yet to be produced. Technical challenges for bioenergy production and implementation still presents issues to developers. Depending on the time and resources, future focus should be on obtaining direct information from wood utilizing companies.

3 Economic and Technical Feasibility of Using Mixed Biomass and Logging Residues for Pellet Production: An Exploratory Study

3.1 Introduction

The need to find innovative products and new markets for underutilized forest resources is the top research priority among the forest products industries and its research communities (Shepley, Wiedenbeck, & Smith, 2004). Underutilized forest resources, for the purpose of this research, are identified as shrubs, small-diameter roundwood, and forestry residues. During pre-commercial thinning of young stands, trees are often undersized for industrial utilization and are therefore left intact at the site as silvicultural residues. In commercial harvesting operations, low-quality stems and other tree components, such as the crown and stump-root system, are left at the site as logging residues. Silvicultural residues and logging residues together are called forest residues.

A 2002 USDA Forest Service's Timber Product Output survey showed that North Carolina held an estimated 2,995,000 dry tones of forest residues (Milbrandt, 2005). A recent USDA Forest Service's Timber Product Output survey conducted in 2007 shows the forest residues for the state nearly doubled in volume to 5,173,958 dry tones (Southern Research Station Timber Products Output, 2007). With the increase in energy demand nationally and in the state, one of the most value added uses of these forest residues has been indicated in earlier studies as energy-based products, primarily, pellets (Granada et al., 2006; Marinescu & Bush, 2009; Richardson, 2006). The recent increases in oil and gas prices, as well as a focus on climate change and carbon sequestration, and use of renewable materials have boosted the demand for wood pellets as an alternative to fossil fuels.

Currently, fire-suppressed pocosin vegetation blankets significant acres in eastern North Carolina. Pocosins are freshwater wetlands with fire-adapted evergreen shrubs and trees such as Swamp Bay and Pond Pine. Dense shrubbery vegetation is the result of years of wildfire suppression activity which has resulted in indiscriminate ecosystem conversion of natural plant communities into fire suppressed plant associations. Pocosins are formed on highly organic soils that have developed in poorly drained areas of the Coastal Plains. The name is an Algonquin word that means “swamp on a hill” (Patterson, 2000). Pocosins trap large amounts of rain as surface water in peat deposits. Water then slowly evaporates, seeps out as surface runoff, or percolates to groundwater (**Figure 3.1**).

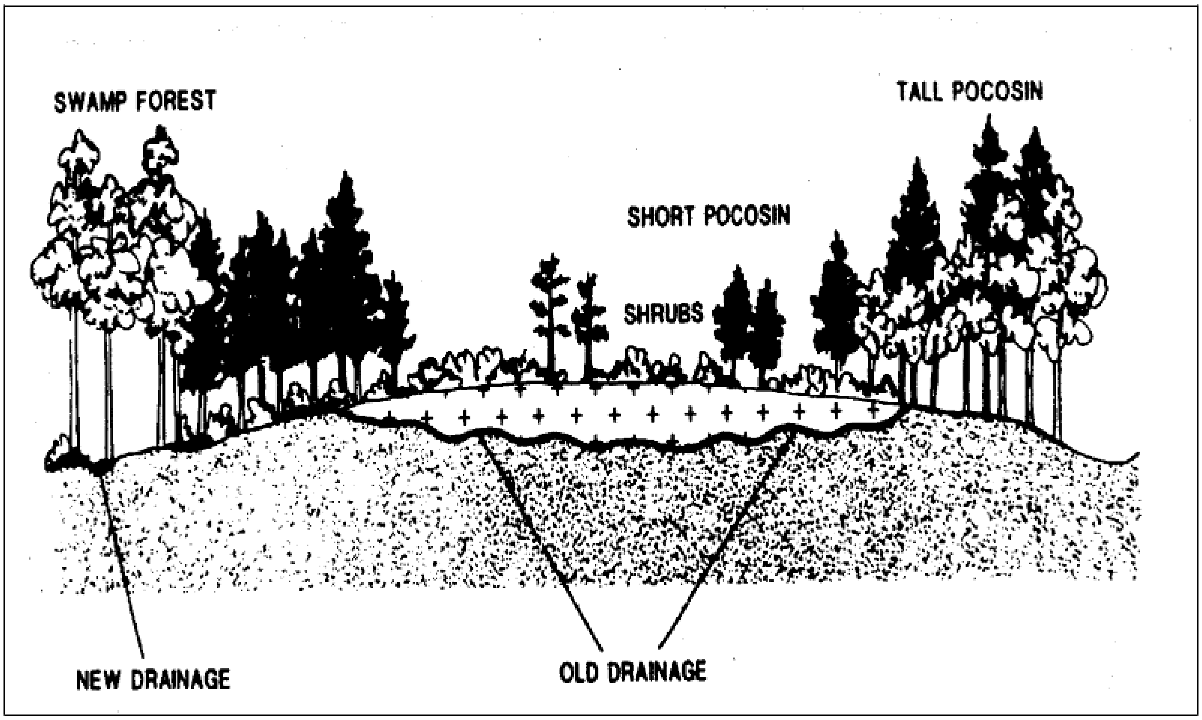

Figure 3.1 Pocosin Ecosystem Cross-Section (Robertson, 1998)

The vegetation attributed to pocosin ecosystems is also recognized as a significant public safety hazard due to the large build up of wildfire fuels. In the summer of 2008, North Carolina experienced one of the largest wildfires, caused by a lightning strike, in the United States for that year. About 450 firefighters battled a 40,000-acre (16,000-hectare) blaze in northeastern North Carolina that burned for months (Drye, 2008). The potential wildfire hazard caused by excessive pocosin biomass becomes a source of expense to the forest manager because of necessary removal and is rarely utilized commercially.

The overall goal of this project is to determine if wood energy pellets can be an alternative commercial use for pocosin biomass, particularly shrubs and small diameter trees, that might offset removal costs during activities designed to reduce wildfire risk. The objectives of this work include developing a comprehensive technical investigation of producing pellets from pocosin shrub biomass and an economic and sensitivity analysis for the feasible development of a mixed biomass wood pellet manufacturing plant in North Carolina.

3.1.1 Forest Residues to Energy: Prior Studies

There is very little information regarding the development of a technical feasibility for utilizing harvesting residues and forest understory as a feedstock alternative for wood pellets. A recent study alludes to the fact that forest understory biomass could be used as a renewable resource for conversion to a variety of fuels and energy applications, including wood pellets but no research has been published in this area currently (Marinescu & Bush, 2009). Economic feasibility studies of producing wood pellets are more abundant with researchers looking at the issue of the effect of various burner fuel options on the cost of pellet production (Mani, Sokhansanj, Bi, & Turhollow, 2006).

In Europe a comparison between Austrian and Swedish pellet production costs showed that the Swedish pellet production costs are considerably lower due to larger plant capacities, the combination of pellet production and biomass district heating plants and the implementation of technologies which allow an efficient heat recovery from the dryers (Thek & Obernberger, 2004). Another study proposed a techno-economic assessment of wood pellet production and applications in some areas of China with the consideration of technology transfer from Sweden by examining their market competitiveness with coal in the selected areas (Wang & Yan, 2005).

3.1.2 The Wood Pellet Industry

Wood pellets are a renewable fuel produced from compressed wood waste. The entire North American pellet market is estimated at 1.5 million tons per year (Pellet Fuels Institute, 2010). In the last two years, an additional 1 million tons of production has come on-line with another 500,000 under construction (Pellet Fuels Institute, 2010). Much of this new capacity is on the United States East Coast (Bihn, 2007). In the short-term, pellet manufacturing capacity within the US is expected to saturate existing markets regionally and nationally driving prices down. This fuel is manufactured in an established production process with global production figures in the range of 12 million tons per year (Loon, 2010). The majority of this fuel within the US is consumed in home heating stoves but there is a growing world market for other uses such as large scale electricity generation in Europe. The EU aims to boost the use of renewable energy to 20 percent of the region’s total by 2020 causing the production of pellets to increase by multiples over the next decade (Loon, 2010).

Lignocellulosic biomass (biomass from plants), in its original form usually has a low bulk density of 30 kg/m^3 and a moisture content ranging from 10% to 70% (wb) (Mani et al., 2006). Pelleting increases the specific density (gravity) of biomass to more than 1000 kg/m^3 (Lehtikangas, 2001; Mani, Tabil, & Sokhansanj, 2004). Pellet biomass is low and uniform in moisture content. The pellets themselves have a cylindrical form-6 to 8 mm (1/4 to 5/16 inch) in diameter and 25 to 38 mm (1 to 1 1/2 inch) in length. Wood pellets also take up much less space in storage than other biomass fuels because they have higher energy content by weight (roughly 7,750 Btu/lb to 9,800 Btu/lb at six percent moisture content). While wood pellets are typically not differentiated between softwood and hardwood sources, there are three grades based on the amount of ash produced when they are burned: Premium, Standard, and Industrial (**Table 3.1 with breakdown of grades characteristics**).

Table 3.1 Wood Pellet Grade Standards (Pellet Fuels Institute, 2010)

Characteristics	Premium Grade Fuel	Standard Grade Fuel	Industrial Grade Fuel
Bulk Density (lb/ft^3)	40.0-46.0	38.0-46.0	38.0-46.0
Diameter (inches)	0.250-0.285	0.250-0.285	0.250-0.285
Fines (%)	≥ 0.50	≥ 0.50	≥ 0.50
Chloride (ppm)	≤ 300	≤ 300	≤ 300
Pellet durability index	≥ 97.5	≥ 95	≥ 95
Length (% > 1.50 inches)	≤ 1.00	≤ 1.00	≤ 1.00
Ash Content	< 1	1 - 2	≥ 3
Heat of Combustion (BTU/lb)	7,750 – 9,000	7,750 – 9,000	7,750 – 9,000

Premium and standard grade pellets are suitable for any wood pellet boiler with automatic ash removal, including most institutional- or commercial-scale applications. Industrial grade pellets, or those with ash content greater than three percent should be avoided due to the high volume of ash produced (Biomass Energy Resource Center, 2007).

3.1.3 Pellet Process Description

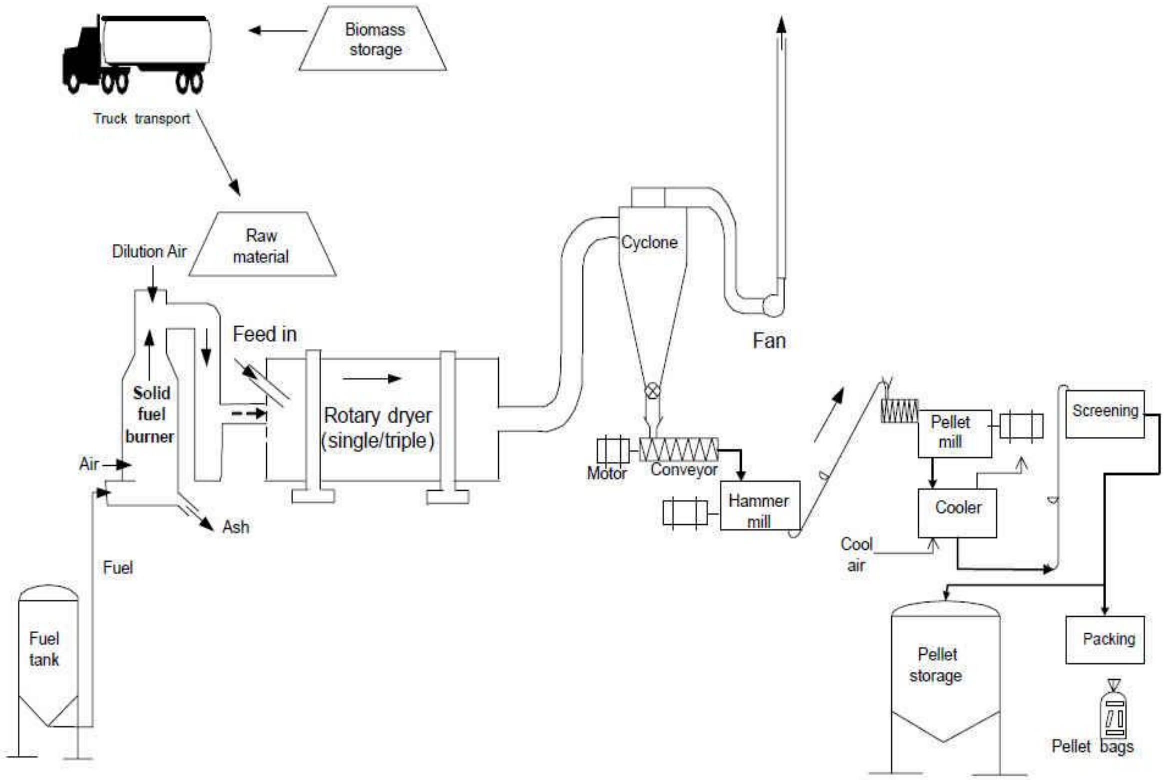

Figure 3.2 General Wood Pellet Flow Diagram (Mani et al., 2006)

Figure 3.2 shows the unit operations and the flow of biomass in a typical biomass pelleting operation that consists of several unit operations, drying, size reduction (grinding), and densification (pelleting), cooling, screening, and packaging/storage. In the US, the most common drying process for pellet production is the single pass drum dryer. Wet material is fed via a rotary valve into the rotating drum. Heat is transferred mainly through convection into the material Most of the dried material leaves the drum by gravity through a discharge box. In the gas stream suspended fine particles are conveyed to the dust collection plant.

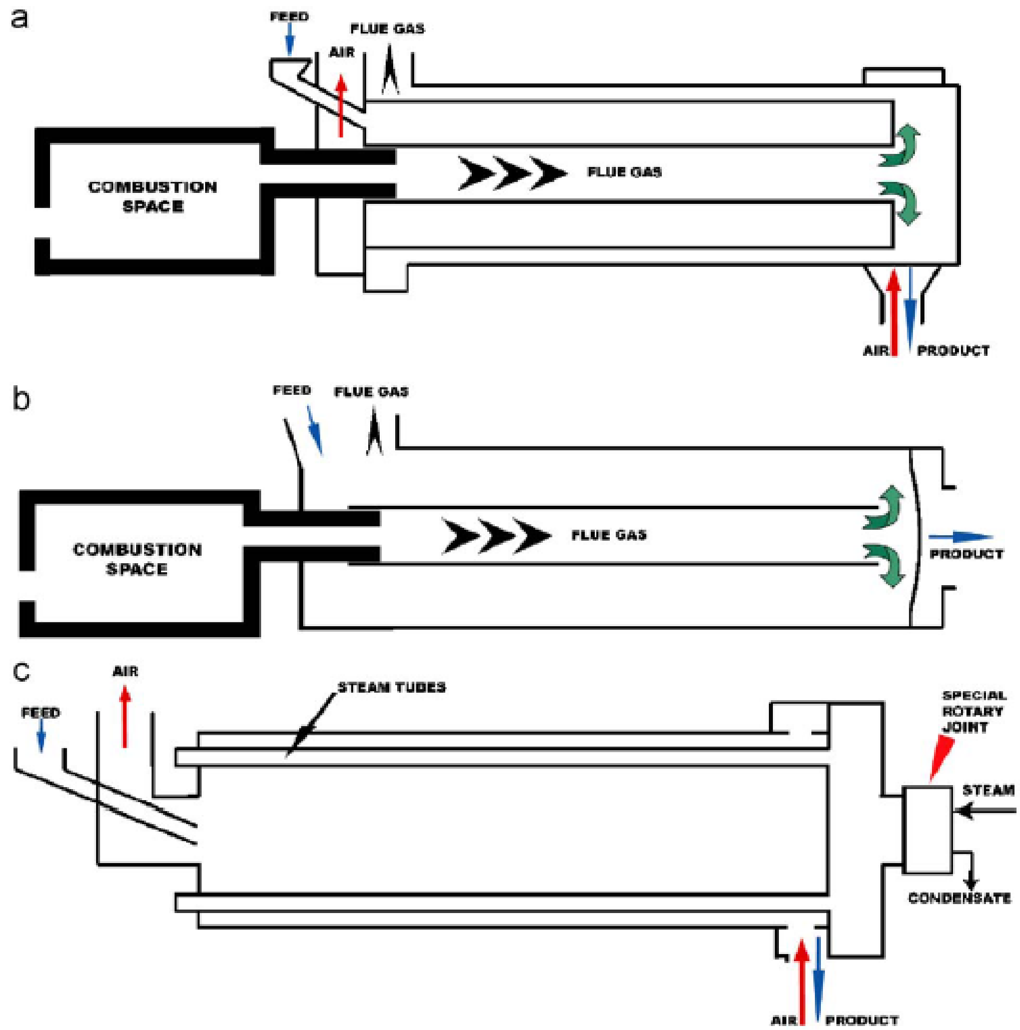

Figure 3.3 Examples of Rotary Driers

Figure 3.3 schematically shows different kinds (direct heat, countercurrent flow; direct heat, parallel flow; indirect heat, countercurrent flow; direct-indirect) of readily available rotary drum driers along with the way of working of each. The target moisture content after drying is 9-15% depending on the feedstock being utilized. The inlet temperature is about 900 to 1000^{o}F. The temperature should not be too high to avoid charring of the chips so it is controlled by recycling the outlet gases after the dryer to the inlet. The temperature profile is important and controlled by the flow. The outlet temperature is approximately 240 to 260^{o}F and sometimes lower resulting in less volatiles being driven off.

After drying, a hammer mill operating as single units or in two stages grind the material to the desired particle size (3 to 6 mm) depending on the incoming chip characteristics. The grinding will evaporate some water resulting in a decrease in moisture content of 1%. The ground material is transferred to the pellet mills for pressing into pellets. The feed to the pellet mill will be supplied from a feeder into the steaming vessel. The steaming vessel will add moisture and heat to the biomass before extrusion in the pellet mill. Superheated steam at around 100^{o}C and 25 psi will be used to achieve this goal. The added heat will allow for greater bonding of biomass as it is processed in the pellet mill.

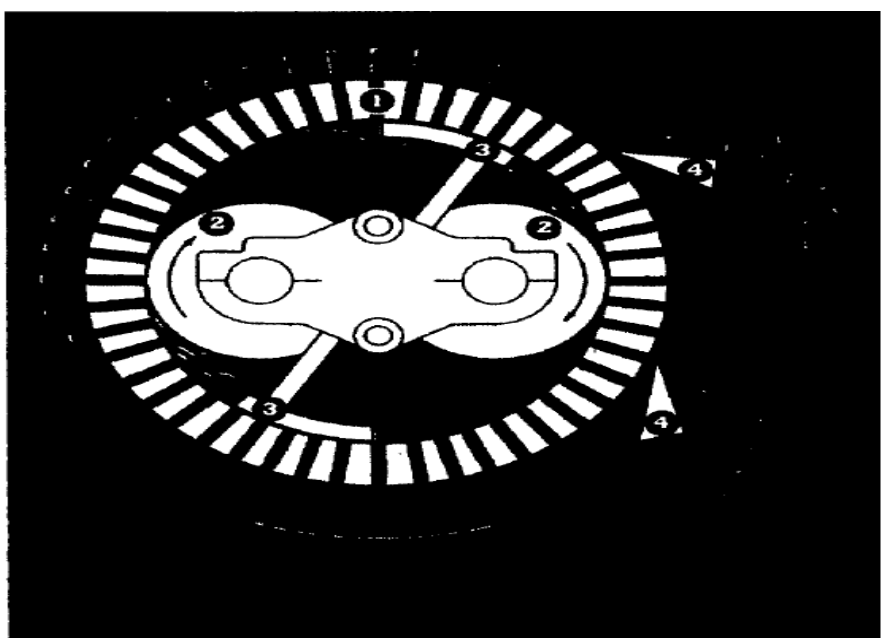

Figure 3.4 Interior functioning of a Pellet Mill (Leaver, R. H., 2000)

Biomass will leave the steam vessel into a feed spout leading to the pelleting die (**Figure 3.4 Item 1**). Distributor blades will spread the biomass across the die face (**Figure 3.4 Item 3**), and friction driven rolls (**Figure 3.4 Item 2**) will push the biomass through small holes in the die as the die revolves. Knives (**Figure 3.4 Item 4**) will be on the swing cover to cut the pellets when they reach the appropriate length. The pellets will exit the mill through an opening in the swing door. The individual pellet density ranges from 1000 to 1200 kg/m^3 (62.4 to 74.9 lbs/ft^3). The bulk density of pellets ranges from 550 to 700 kg/m^3 (34.3 to 43.7 lbs/ft^3) depending on size of pellets. Pellet density and durability are influenced by physical and chemical properties of the feedstock, temperature and applied pressure during the pelleting process (Mani, Tabil, & Sokhansanj, 2003).

In some operations, binders or stabilizing agents are used to reduce the pellet springiness and to increase the pellet density and durability. Most widely used binders for pelleting of animal feeds are calcium hydroxide (Pfost, 1964; Tabil Jr. & Sokhansanj, 1996) and soybean. Biomass from woody plants contains higher percentages of resins and lignin compared to agricultural crop residues (straw and stover). When lignin-rich biomass is compacted under high pressure and temperature, lignin becomes soft exhibiting thermosetting properties (van Dam et al., 2006). The softened lignin acts as glue so dependent on the feedstock there may or may not be a need for binders.

The temperature of pellets coming out of the pellet mill ranges from 220 to 250^{o}F and are cooled to within 41^{o}F of the ambient temperature in coolers. Cool air is normally used for the cooling in counter coolers with retention of about 20 to 30 minutes. The hardened cooled pellets are conveyed from the cooler to storage areas using an overhead hopper and mechanical or pneumatic conveying systems. Pellets may be passed over a screen to have fines removed and are weighed before being stored in enclosed storage areas. Pellets are typically sold by the bag (40 lb), by the ton (50 bags), and by the skid (60 bags). The bags should be clearly labeled with the type of pellet, their grade (i.e., premium, standard, or industrial), and their heat of combustion.

3.1.4 Objective of the Study

The objective of this study is to examine the technical and financial (economic) feasibility of converting the pocosin biomass to energy pellets. The specific objectives of the study are to:

1. Explore whether pocosin biomass has the potential to be converted into pellets for commercial/residential applications:
2. Examine the technical characteristics of the developed pellets that are important in the use of the pellets as fuel sources such as energy content, ash content and moisture content;
3. Examine the rate of return for a small scale pellet mill that may be able to produce pocosin biomass pellets.

3.2 Methodology

3.2.1 Technical Analysis

In this study, the industrial pellet production process was evaluated on a small scale exploratory experimental basis utilizing pocosin shrubs biomass as the pellet feedstock. The pocosin mixed biomass (PMB) represents the harvesting operation of the forest understory within that particular ecosystem. The PMB was collected from the Hofmann Forest, a contiguous 80,000 acre forest managed by the North Carolina State Natural Resources Foundation, Incorporated, which is located in the coastal region of North Carolina. Sixty-five green/lbs of biomass with an initial moisture content of 49.2% was collected manually. The retrieved biomass **Figure 3.6-I**, consisted of randomly selected trees and shrubs analogous to a harvesting operation utilizing Fecon Inc.'s FTX440, the harvesting equipment currently being researched to collect the biomass on a larger scale (Hannum, 2009). **Table 3.2** lists the plant scientific and common names utilized in the study. The PMB utilized in this study from the Hofmann Forest is representative of vast quantities of understory shrub biomass found in the Eastern part of the state. A wood chipper was used to chip the small diameter woody biomass.

Table 3.2 Plant Common and Scientific Names

Common Name	Scientific Name
Fetterbush Lyonia	*Lyonia Lucida*
Laurel Greenbrier	*Smilax laurifolia*
Large Gallberry	*Ilex coriacea*
Swamp Titi	*Cyrilla racemiflora*
Carolina Laurel	*Kalmia carolina*
Loblolly Bay	*Gordonia Lasianthus*
Yaupon	*Ilex vomitoria*
Coastal Sweetpepperbush	*Clethra alnifolia*
Swamp Bay	*Persea palustris*
Pond Pine	*Pinus serotina*
Dahoon	*Ilex cassine*
Wax Myrtle	*Myrica cerifera*

The biomass was fed into a hopper (**see Figure 3.6-II**)**,** on the top of the unit and the chips were discharged out the side of the equipment for collection. A Wiley mill **Figure 3.5 and 3.6-IV**, equipped with four adjustable hard tool steel knives bolted to a removable motor was used to grind the ambient moistened biomass to 4mm diameter particle size. These knives work against six stationary knives bolted into the frame. The shearing action in the process needed constant maintenance due to the high moisture content of the biomass which caused the material to become lodged into the knives crevice. Approximately 50 lbs of biomass was ground using the Wiley mill (**see Figure 3.6-III)**. The material was then taken to the College of Agricultural and Life Sciences at the North Carolina State University Feed Mill where two attempts were made at producing pellets using a pellet mill (Model

PM1112-2, California Pellet Mill Co., Crawfordsville, IN) equipped with a 4.4 mm x 35 mm die (11/64 in x 1 3/8 in).

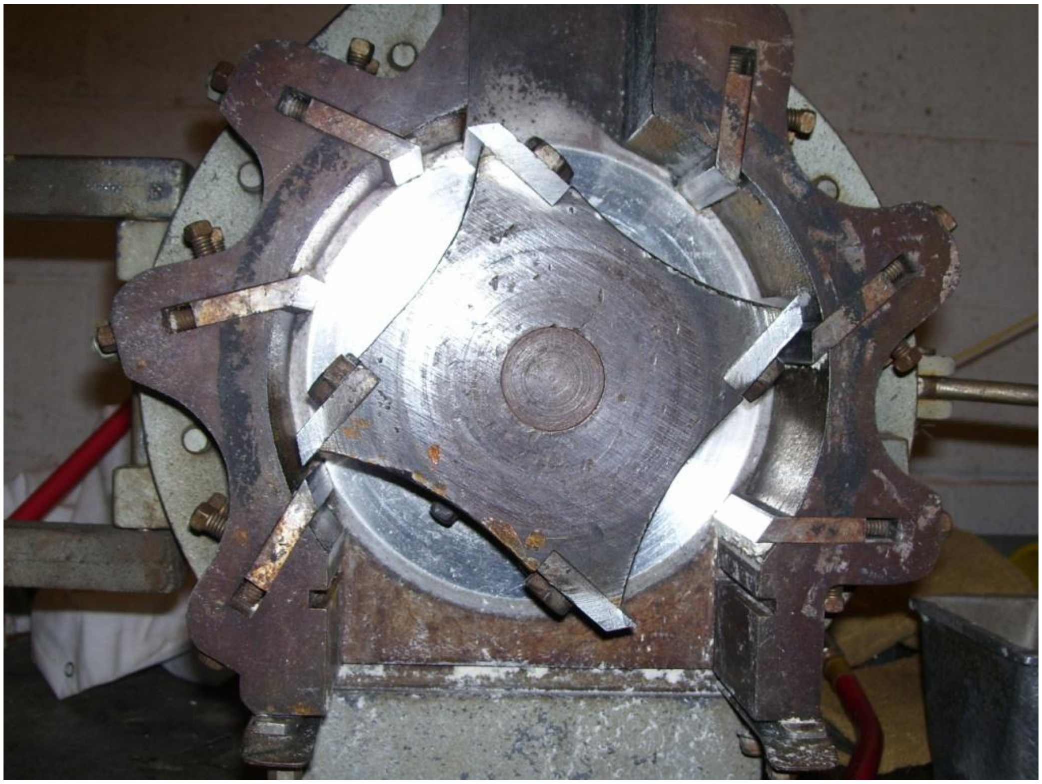

Figure 3.5 Wiley Mill equipped with 4 adjustable steel knives

At each attempt the biomass was fed into the pellet mill manually. In the first attempt a biomass feedstock moisture content of 49.2% was utilized and all of the material was rejected. To reduce the moisture content an air-drying procedure was used. The biomass was evenly spread in a 3 ½ ft x 30 ft row on the floor and allowed four days to air dry. Pellets were formed during the second attempt with a biomass feedstock moisture content of 18%. A complete flow chart of the pellet production process is given in **Figure 3.6-I through VI**.

Figure 3.6 A complete flow chart of the pellet production process

3.2.1.1 Laboratory Testing Oxygen Bomb Calorimetry and Lab Testing

The heat of combustion testing for the pocosin mixed biomass pellets was performed using Parr 1341 Oxygen Bomb Calorimeter equipped with the Parr 1108 Oxygen Combustion Bomb. Samples of premium hardwood pellets from the industry were also tested in the technical analysis for comparison. Operating procedures Parr No. 204M and 205M were used to prepare the samples, charge the oxygen bomb, and calculate the heat of combustion. 10 total samples, 5-pocosin mixed biomass and 5-premium hardwood pellets (control) were tested and heat of combustion results were recorded for each sample. Two types of statistical analyses were performed to test for a significant difference between the samples; a parametric T-test and a non-parametric Wilcoxon-Mann-Whitney Test. The T-test assumes that the two populations being compared follow a normal distribution. The Wilcoxon-Mann-Whitney test does not make an assumption on the type of distribution, but does assume that all the observations from both groups are independent of each other. Under the null hypothesis the distributions of both groups are the same, and under the alternative hypothesis the probability of an observation from one population (*X*) exceeding an observation from the second population (*Y*) is not equal to 0.5. The tests were performed to determine if a significant difference exists at the $\alpha = 0.05$ level. The null and alternative hypotheses for the T-test were:

$$H_0\text{: Hardwood } \mu_h = \text{PMB } \mu_p \text{ vs. } H_a\text{: Hardwood } \mu_h \neq \text{PMB } \mu_p$$

The Wilcoxon-Mann-Whitney Test is a distribution-free nonparametric test that combines the data and ranks the data overall. The original samples are separated, with each rank being attached to the corresponding observation. The null hypothesis is that the two samples are from identical populations. The alternative hypothesis is that the population distributions differ only in the median.

H_0: the population medians are identical vs. *H_α: one sample is from a population with greater median*

If one fails to reject H_0, then it is assumed there is no significant heat of combustion difference between the two compared pellet types (Premium hardwood pellets vs. PMB). Conclusions were made using a 95 percent level of significance ($\alpha = 0.05$).

Testing for chloride content and ash content of the samples were performed at Galbraith Laboratories, Incorporated in Knoxville, Tennessee. Galbraith Laboratories also provided the test results for ash content, chloride content, and heat of combustion for two additional samples: softwood residues and softwood residue/pocosin mixed biomass mixture.

3.2.2 Economic Analysis

For the economic analysis, we assumed that the total capital required for the pellet mill at startup is to be $10,143,950 (U.S.). Included in this total are fixed (capital) cost, operating costs, manufacturing, and equipment cost. Assumptions were made that financing for the project will come in the form of working capital (20%) and 80% financed bank loan. The purchase cost of all equipment was collected from the Buhler Group, Plymouth, MN (Data provided through personal communication in May 2010). The Buhler Group provided a budget estimate for each piece of equipment utilized in a pellet mill with a capacity of 100,000 tons per year (13.3 tons/hr). Installation cost of the equipment was 45% of the purchase cost. The capital cost includes land cost, purchase of equipment, installation and maintenance, office building construction cost, civil and electrical equipment supply cost, and costs of dump trucks, forklifts, front-end loaders, company vehicles, and forklifts.

For a more realistic scenario, we assumed that land was purchased for the plant and operation in New Bern, NC where the cost of land is the average of what can be found across NC and the estimates could be modified based on any other location within the state. The proposed land and site development cost were available from Onslow County Tax Parcels GIS Mapping System (Onslow County, 2010). The cost of 41.3 acres of land in New Bern, NC was $33,000 (U.S.) Cost estimates of company vehicles were based on estimates typical of used cars. Cost analysis of front-end loaders and forklifts were obtained from Caterpillar. The cost of the dump truck tipper was based on estimates received from an operating pellet mill (Data provided through personal communication in January 2009) .

Due to the location of the pellet mill and the annual amount of PMB available around the state, we assumed that the addition of softwood residue raw material would be beneficial for the biomass feedstock to meet the goal of 100,000 tons of pellets per year and was used in calculating the delivered raw material cost. We also assumed that construction of the facility will begin immediately upon receipt of the first $4 million. Construction is expected to last 16 months. During construction, the pellet mill will seek alternative sources of raw materials and begin preparing current material for production. We assumed a long term interest rate of 8% and a short term interest rate of 7%. The maintenance of equipment and building was assumed to be 4% of the capital cost. The 4% maintenance cost accounted for the high repair and maintenance of the pellet and hammer mills due to the wear and tear of the equipment. The operating cost includes the cost of raw material, electricity cost, motor fuel cost, bagging cost, die and roller cost and personnel costs. Personnel costs were included along with benefits and overtime assuming 20 employees: 1-Manager, 3-Shift Supervisors, 6-Production Employees, and 10-Helpers.

Using information from the technical analysis the raw material moisture content (*RMMC*) of 49.2% and finished material moisture content (*FMMC*) of 12% was used in the raw material conversion calculation. In order to obtain the fuel required for the dryer, we employed the following assumptions and calculations. The weight in tons of dry sawdust produced per ton of wet PMB (*A*) is:

$$A = \frac{1}{(1+RMMC)} x(1 + FMMC) \qquad (1)$$

The pounds of water (*W*) that needed to be evaporated was estimated from equation 2:

$$W = (1 - A)\ x\ 2000 \qquad (2)$$

The BTU's needed for evaporation (*EV*) at 1000 BTU/lb is calculated using equation 3:

$$EV = W\ x\ 1000 \qquad (3)$$

Estimation for the lbs of green sawdust (*GS*) needed to evaporate water was calculated assuming that the dry green sawdust had a value of 4000 BTU/lb and a efficiency value of 0.65 in equation 4:

$$GS = \frac{EV\ x\ 0.65}{4000} \qquad (4)$$

Estimation of green sawdust needed to dry burner fuel (*DBF*) was calculated by:

$$DBF = \left(\frac{\left(GS - \frac{GS}{(1+RMMC)}\ x\ (1+FMMC)\right) x\ 1000}{4000}\ x\ 0.65\right) \qquad (5)$$

The ton of green raw material (*GWM*) is calculated by equation 6:

$$GWM = \frac{(2000+GS+DBF)}{2000} \qquad (6)$$

We assumed that the yield based on dust loss was 90%. The dry sawdust produced at 90% yield is given by:

$$NA = A\ x\ .90 \qquad (7)$$

A ratio of wet tons (*RWT)* needed per dry ton of material is:

$$RWT = \frac{GWM}{NA} \tag{8}$$

The annual amount of raw material required for production of pellets with portions of the raw material being utilized as a dryer fuel is given by equation 9:

$$RMR = AP * RWT \tag{9}$$

where *AP* is the annual production of the mill in tons and *RWT* is the ratio of wet tons needed per dry ton of raw material.

In order to produce wood pellets, no steam conditioning or external binder were used. This is because lignin in the sawdust acts a natural binder during pelletization; as a result the cost of steam or binders was not included in the economic analysis. The capital investment analysis was calculated for the base case scenario of 13.3 tons/hour wood pellet plant. The base case pellet cost estimation was used to investigate the effect of capital cost, pellet selling price, raw material cost, and pellet production yield.

3.3 Results and Discussion

3.3.1 Technical Analysis

In the first experiment, the raw material to be converted into pellets included only PMB. Pellets were not able to be produced on a pure wet basis of 49.2% moisture content. The material runs directly through the pellet mill causing 100% rejects. After drying the material to 18% moisture content, the pellets were able to be compressed and extruded through the pellet mill. The pellet mill required 100 amps of electrical current to create the pellets which is higher than the normal 60-80 amp range. This suggests that 18% moisture content is too dry to create wood pellets using pocosin mixed biomass. Therefore, very likely, moisture content between 20-30% for the PMB would be most ideal for producing pellets. **Figure 3.7** shows the dark color and shiny coat of the pellets produced.

Figure 3.7 Pocosin Mixed Biomass wood pellets

Due to the feed mill being used to produce the pellets, we obtained a length of 1 3/8 in. and a diameter of 11/64 in. which is smaller than the commercial size being utilized in the wood pellet industry. Nevertheless, we believe pellets standard size can be obtained with the PMB material if a traditional pellet mill die is utilized. **Table 3.3** shows all heat of combustion results and descriptive statistics for premium hardwood pellets and PMB pellets. Using t-test and Wilcoxon-Mann-Whitney tests, both p-values were found to be less than 0.05, indicating that the null hypothesis can be rejected at the 95 percent-level of significance. For the t-test the data give strong evidence ($P < 0.0001$) that there is a difference in means for the two populations. Similarly the W-M-W test without making assumptions on the distribution of the populations provides fairly strong evidence against the H_0 ($P < 0.01$). Using the Wilcoxon-Mann-Whitney test confidence interval we are 95% confident that the median heat of combustion value of premium hardwood pellets is between 545.9 and 388.5 British thermal units per pound less than the median heat of combustion value of PMB pellets. The laboratory Oxygen Bomb results (**Table 3.3**) found that the manufactured PMB pellets had an average heat of combustion value of 8,222 BTU/lb. This is significantly higher (6%) compared to the 7,766 BTU/lb heat of combustion value for the premium Hardwood pellets available in the marketplace.

Table 3.3 Oxygen Bomb Calorimeter Results

Oxygen Bomb Calorimeter		
	Hardwood Pellet	PMB Pellet
Runs	………..……..(Btu/lb)	……..………….
1	7721.09392	8204.629
2	7816.10463	8309.242
3	7813.89295	8152.633
4	7763.28987	8231.214
5	7714.41194	8215.719
Mean	7765.75866	8222.687
Max.	7816.10463	8309.242
Min.	7714.41194	8152.633
Std. dev.	48.7061232	56.67181
T-test p-value *	< 0.0001	
W-M-W test p-value *	0.007937	

*** Mean difference between Hardwood pellet and PMB pellet. BTU/lb are significant at 0.05 level of significance.**

The results suggest that the pocosin mixed biomass pellets are suitable from an energy standpoint to produce a higher heat of combustion than that of premium hardwood pellets currently produced in the wood pellet market. Therefore, for the same heating or energy value, less pocosin mixed biomass pellets can be used in a heating stove/boiler at one time. **Table 3.4** also compares the ash content, chloride content, and heat of combustion for the PMB pellets, premium hardwood pellets, softwood residue, and pocosin mixed biomass/softwood residue mixture. The PMB pellets have an ash content of 1.28% and a chloride content of 128 ppm. The high ash content suggest that PMB pellets may not be used in residential applications and are sufficiently different from premium pellet grades. However, PMB pellets meet the requirements for standard or industrial grade pellets.

Table 3.4 Gailbraith Laboratory Test Results

Characteristic	Premium Hardwood Pellet	Pocosin Mixed Biomass Pellet	Softwood Residue	Softwood Residue/PMB (1:1)
Ash Content (%)	0.6341	1.28	0.2126	0.4798
Chloride (ppm)	21	128	< 9	38
Heat of Combustion (Btu/lb)	Not Tested	8,232	8,824	9,130

The second experiment included using softwood residues as feedstocks for pellets as well as a combination of softwood residues and PMB. The technical results for the softwood residues and softwood residues/PMB pellets show a heat of combustion value of 8,824 BTU/lb and 9130 BTU/lb, respectively. Commonly, softwoods contain higher lignin values than softwoods. The higher heating value for the softwood residue and softwood residue/PMB mixture compared to the premium hardwood pellet is directly related to the elemental composition of the wood. The ash content was 0.213% and the chloride content was less than 9 ppm which is below the premium grade standard of 1.00% ash and chloride content of 300 ppm. These results are only preliminary and would need to be interpreted with caution. Cautionary measures need to be employed for interpretation because the residue material used during testing was collected 6-8 months before being grinded in the hammer mill and sent off for testing.

3.3.2 Economic Analysis

The base case pellet manufacturing plant is assumed to have a production capacity of 13.3 tons of pellets/hour with the annual production of 100,000 tons. The mill operates 24 hour for 306 days annually (includes semi-annual downtime for maintenance). In this analysis, the delivered cost of raw material to the pellet operation facility was included for PMB-$27 per Green Ton and softwood residues-$17 per Green Ton (Hannum, 2009; Harris, 1999-2010). We also assumed that the land purchased was located within 3 to 8 miles of the biomass source. For the base case, we assume that the plant will utilize 50% of its capital during the first year of construction and 50% during the second year. The startup year for the mill was assumed to be 2012 and is not expected to reach full capacity until the start of the second year of operation. There is an assumed 1% annual productivity factor increase each year. All revenue will be generated through the sales of the wood pellets. The base case price for the wood pellet was assumed to be $175.00 per ton. The costs of the raw material and electricity were the largest among the annual operating costs constituting 27% and 17% of the total costs, respectively. **Table 3.5** lists the operating cost per ton for the pellet mill.

Table 3.5 Operating Cost and Percent Cost

Cost Type	Total Cost ($/ton)	Percent of Overall Cost
Direct Costs		
Raw Material	$ 32.79	26.59%
Electricity	$ 21.49	17.43%
Motor Fuel	$ 2.00	1.62%
Bagging (Includes pallets and bags)	$ 15.00	12.16%
Die and Rollers	$ 4.00	3.24%
Annual Loan Payment	$ 12.27	9.95%
Maintenance	$ 4.75	3.85%
Sub-Total Direct Costs	$ 92.30	74.85%
Indirect Costs		
Total Labor	$ 9.30	7.54%
Repair	$ 2.81	2.27%
Operating Materials	$ 1.87	1.52%
Other Fixed Costs	$ 3.74	3.03%
Insurance	$ 3.00	2.43%
Depreciation	$ 10.29	8.35%
Sub-Total Indirect Costs	$ 31.01	25.15%
Total Cost	$ 123.32	100.00%

The projected pro forma income statement with annual cash flows and the balance sheet for years 1 through 10 is shown in **Table 3.6**. The purpose of this statement is to evaluate the profitability of introducing the pellet mill into target markets. Throughout the financial statement, several assumptions are used to develop the necessary line items. The assumptions for the statement are followed by the actual statement itself.

Assumptions:

1. Production begins during month 16.
2. Production in startup year will be 75% of the capacity.
3. Net sales based on the average price of $175.00 per ton.
4. Assume total market consumption of capacity.
5. Land valued at $33,000 and does not depreciate.
6. Total plant and equipment value equals $9,978,950 depreciation is calculated using 7 years-Modified Accelerated Cost Recovery System (MACRS).
7. Startup costs total $10,143,950 – 80 percent ($8,115,160) through financing and 20 percent ($2,028,790) through issuance of stock (owner's equity), grants.
8. Payments towards long-term borrowing are calculated from the annual $1,209,398 payment minus total interest paid for the year.
    a. $8,115,160, 10-year loan at a fixed 8.00% interest rate
9. Terminal Value is the "Free Cash Flow" in final year 10, calculated by earnings before interest, tax, depreciation, and amortization (EBITDA) multiple of year 10-1.
10. Buildings (Supply and Installation), Civil Materials (Supply), and Miscellaneous costs were assumed using capital investment analyses (Voulgaraki, Balafoutis, & Papadakis, 2008).

Table 3.6 Income Statement, Base Case 100,000 Tons per Year

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Tons per Year	65,931	87,908	87,908	87,908	87,908	87,908	87,908	87,908	87,908	87,908	87,908
Price per Ton	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00	$ 175.00
Annual Revenue	$ 11,537,883	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844	$ 15,383,844
DIRECT COSTS											
Wood	$ 2,162,051	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734	$ 2,882,734
Electricity ($/KWh)	$ 1,444,302	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736	$ 1,925,736
Motor Fuel	$ 131,862	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815	$ 175,815
Bagging (Includes pallets and bags)	$ 988,961	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615	$ 1,318,615
Die and Rollers	$ 263,723	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631	$ 351,631
Annual Loan Payment	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ -
Maintenance	$ 313,171	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561	$ 417,561
Sub - Total Direct Costs	$ 6,513,468	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 8,281,492	$ 7,072,094
INDIRECT COSTS											
Total Labor	$ 792,675	$ 800,602	$ 808,608	$ 816,694	$ 824,861	$ 833,109	$ 841,440	$ 849,855	$ 858,353	$ 866,937	$ 875,606
Repair	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369
Operating Materials	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579
Other Fixed Costs	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158
Insurance	$ 197,792	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723	$ 263,723
Depreciation	$ 1,242,608	$ 2,122,927	$ 1,599,254	$ 1,232,833	$ 952,979	$ 951,474	$ 950,388	$ 582,366	$ 203,341	$ 171,864	$ 135,414
Sub - Total Indirect Costs	$ 2,987,181	$ 3,941,357	$ 3,425,691	$ 3,067,355	$ 2,795,668	$ 2,802,412	$ 2,809,657	$ 2,450,049	$ 2,079,523	$ 2,056,629	$ 2,028,849
Total Cost	$ 9,500,649	$ 12,222,849	$ 11,707,182	$ 11,348,847	$ 11,077,160	$ 11,083,904	$ 11,091,149	$ 10,731,541	$ 10,361,015	$ 10,338,121	$ 9,100,943

Table 3.6 Continued

EBIT			$ 2,037,234	$ 3,160,995	$ 3,676,662	$ 4,034,997	$ 4,306,684	$ 4,299,940	$ 4,292,695	$ 4,652,303	$ 5,022,829	$ 5,045,723	$ 6,282,901
EBITDA			$ 3,279,842	$ 5,283,922	$ 5,275,916	$ 5,267,830	$ 5,259,663	$ 5,251,414	$ 5,243,083	$ 5,234,669	$ 5,226,170	$ 5,217,587	$ 6,418,316
Calculated State Tax	5%		$ 101,862	$ 158,050	$ 183,833	$ 201,750	$ 215,334	$ 214,997	$ 214,635	$ 232,615	$ 251,141	$ 252,286	$ 314,145
Accumulated State Tax Loss			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Actual State Tax			$ 101,862	$ 158,050	$ 183,833	$ 201,750	$ 215,334	$ 214,997	$ 214,635	$ 232,615	$ 251,141	$ 252,286	$ 314,145
Calculatated Federal Tax	35%		$ 713,032	$ 1,106,348	$ 1,286,832	$ 1,412,249	$ 1,507,340	$ 1,504,979	$ 1,502,443	$ 1,628,306	$ 1,757,990	$ 1,766,003	$ 2,199,015
Accumulated Tax Loss			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Actual Federal Tax			$ 713,032	$ 1,106,348	$ 1,286,832	$ 1,412,249	$ 1,507,340	$ 1,504,979	$ 1,502,443	$ 1,628,306	$ 1,757,990	$ 1,766,003	$ 2,199,015
Total Tax			$ 814,893	$ 1,264,398	$ 1,470,665	$ 1,613,999	$ 1,722,674	$ 1,719,976	$ 1,717,078	$ 1,860,921	$ 2,009,132	$ 2,018,289	$ 2,513,161
Net Income			$ 1,222,340	$ 1,896,597	$ 2,205,997	$ 2,420,998	$ 2,584,011	$ 2,579,964	$ 2,575,617	$ 2,791,382	$ 3,013,698	$ 3,027,434	$ 3,769,741
Cash Flow			$ 2,464,948	$ 4,019,524	$ 3,805,251	$ 3,653,831	$ 3,536,989	$ 3,531,438	$ 3,526,005	$ 3,373,748	$ 3,217,039	$ 3,199,298	$ 3,905,155
Project Year		-1	0	1	2	3	4	5	6	7	8	9	10
Free Cash Flow		$ (4,271,975)	$ (3,049,635)	$ 1,716,994	$ 1,894,346	$ 2,187,898	$ 2,405,874	$ 2,443,806	$ 2,439,685	$ 2,655,612	$ 2,933,131	$ 3,003,721	$ 3,750,750
Free Cash Flow with TV		$ (4,271,975)	$ (3,049,635)	$ 1,716,994	$ 1,894,346	$ 2,187,898	$ 2,405,874	$ 2,443,806	$ 2,439,685	$ 2,655,612	$ 2,933,131	$ 3,003,721	$ 26,087,934
Discount Rate		12%											
NPV		$ 10,193,416											
IRR		29%											

3.3.2.1 Net Present Value

For analyzing economic feasibility, the net present value was utilized. Net present value (NPV) is a popular and appropriate metric used to measure the value added-or-lost through an investment. NPV is calculated by comparing the present value of future cash flows to the cost of the initial investment. The projected cash flows and free cash flows for the pellet mill are listed in **Table 3.7**. These values represent best estimates in income and expenses over the initial 10-year planning period. The net present value (NPV) estimates for an investment in the manufacturing of wood pellets were calculated using the net free cash flows with a terminal value of 5 X Earnings Before Interest, Taxes, Depreciation, and Amortization (EBITDA) of project year 10 (**Table 3.7)** over a range of discount rates (3 to 20 percent, **Table 3.8)**.

The terminal value is the value of the asset at the end of the project life. It is most often used in multi-stage discounted cash flow analysis and allows for the limitation of cash flow projections to a several-year period. The discount rate is the presumed targeted rate of return one would expect on an investment. In the base case we assumed a discount rate of 12% which provided a net present value of $10,193,416 over a 10-year project lifetime. In equation 10, NPV was calculated as the sum of all present values (PV):

$$NPV = \sum_{t=0}^{T} \frac{R_t}{(1+i)^t} \tag{10}$$

where,

t--the time of the cash flow

i –the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)

R_t—the net cash flow (the amount of cash, inflow minus outflow) at time t.

Table 3.7 Projected Cash Flows and Free Cash Flows for the 10-Year Planning Period

			Year			
	-1	0	1	2	3	4
Initial Cost	$ (4,271,975)	$ (4,271,975)				
Net Cash Flow		$ 2,464,948	$ 4,019,524	$ 3,805,251	$ 3,653,831	$ 3,536,989
Free Cash Flow	$ (4,271,975)	$ (3,049,635)	$ 1,716,994	$ 1,894,346	$ 2,187,898	$ 2,405,874
			Year			
	5	6	7	8	9	10
Initial Cost						
Net Cash Flow	$ 3,531,438	$ 3,526,005	$ 3,373,748	$ 3,217,039	$ 3,199,298	$ 3,905,155
Free Cash Flow	$ 2,443,806	$ 2,439,685	$ 2,655,612	$ 2,933,131	$ 3,003,721	$ 3,750,750

Table 3.8 The net present value for an investment in a wood pellet mill with estimated net cash flows adjusted for discount rates 3%-20%

Project Year	Free Cash Flow with Terminal Value	Present Values @ 12%	Discount Rate	Net Present Value	Discount Rate	Net Present Value
-1	$ (4,271,975)	$ (3,814,263)	**3%**	$ 28,732,738	**15%**	$ 7,037,047
0	$ (3,049,635)	$ (2,431,150)	**4%**	$ 25,650,828	**16%**	$ 6,180,159
1	$ 1,716,994	$ 1,222,123	**5%**	$ 22,900,120	**17%**	$ 5,404,139
2	$ 1,894,346	$ 1,203,891	**6%**	$ 20,441,647	**18%**	$ 4,700,638
3	$ 2,187,898	$ 1,241,472	**7%**	$ 18,241,406	**19%**	$ 4,062,252
4	$ 2,405,874	$ 1,218,891	**8%**	$ 16,269,679	**20%**	$ 3,482,401
5	$ 2,443,806	$ 1,105,454	**9%**	$ 14,500,458		
6	$ 2,439,685	$ 985,348	**10%**	$ 12,910,944		
7	$ 2,655,612	$ 957,640	**11%**	$ 11,481,126		
8	$ 2,933,131	$ 944,390	**12%**	$ 10,193,416		
9	$ 3,003,721	$ 863,498	**13%**	$ 9,032,330		
10	$ 26,087,934	$ 6,696,123	**14%**	$ 7,984,222		

3.3.2.2 Return on Investment

The return of an investment (ROI) measures the benefits of the project as a function of the total assets required. Benefits in this context refer to net income and are taken from the 10 year income statement. Total assets are a measure of the total dollar value of the assets and taken from the 10 year balance sheet. There are several ways to measure ROI, the formula used to calculate ROI for this proposal shown in equation 11:

$$\text{ROI} = \text{Net Income} / \text{Fixed Asset Value} \qquad (11)$$

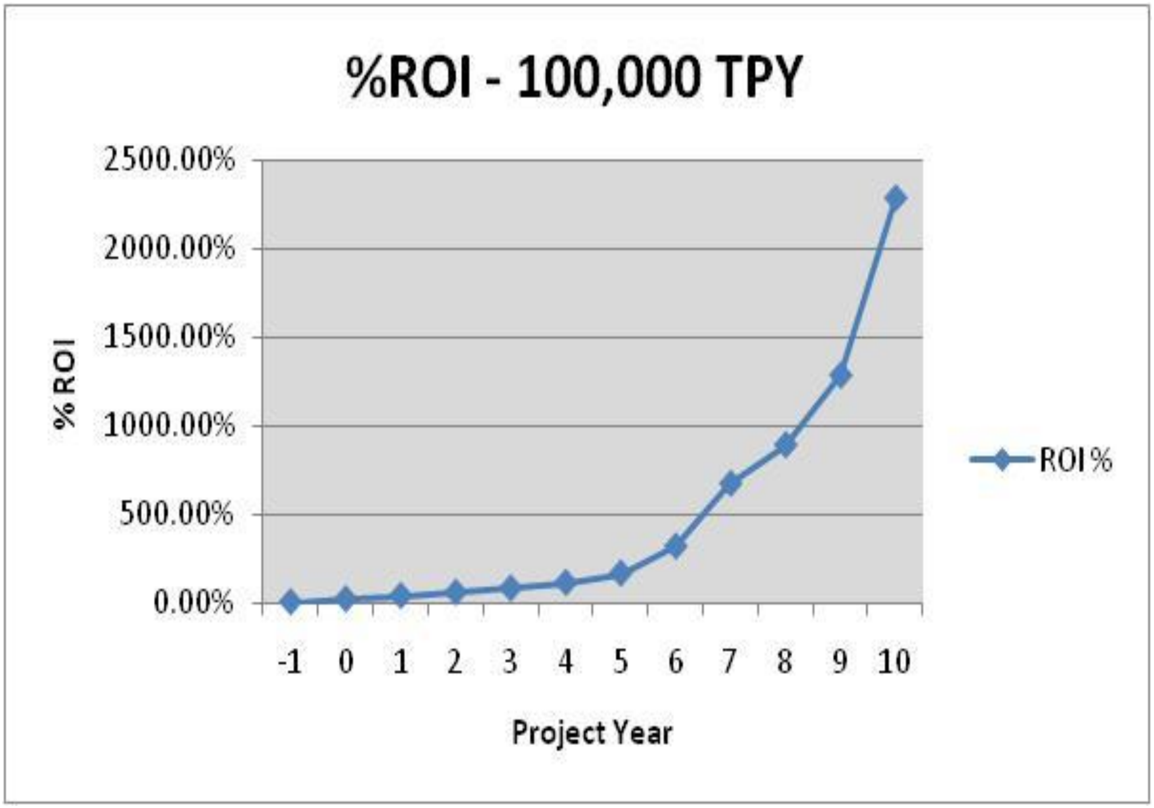

Figure 3.8 % Return on Investment for the 100,000 tons per year base case

3.3.2.3 Internal Rate of Return

The internal rate of return on an investment or project is the *annualized effective compounded return rate* or discount rate that makes the net present value of all cash flows (both positive and negative) from a particular investment equal to zero. In more specific terms, the IRR of an investment is the interest rate at which the net present value of costs (negative cash flows) of the investment equal the net present value of the benefits (positive cash flows) of the investment. Internal rates of return are commonly used to evaluate the desirability of investments or projects. The higher a project's internal rate of return, the more desirable it is to undertake the project. A 29% internal rate of return was obtained for the base case of this analysis. Given the (period, cash flow) pairs (n, C_n) where n is a positive integer, the total number of periods N, and the net present value NPV, the internal rate of return is given by ***r*** in equation 12:

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad (12)$$

Sensitivities are given for the following cases:

- Capital cost estimates of -50% and +50%
- Pellet selling price of -50% and +50%
- Pellet yield amount -50% and +50%
- Raw material biomass cost -50% and +50%

The sensitivity study determines a -/+ 50% change in capital cost, pellet selling price, pellet yield amount, and raw material cost. For example the base case pellet selling price is $ 175.00 per ton. When the selling price of pellets is reduced 50% from the base case the selling price is $87.50 and the net present value at 12% discount rate is -$27,977,849. This study shows that the wood pellet selling prices and/or the wood pellet yield amounts have the greatest effect on the investment project (**Figure 3.9)**.

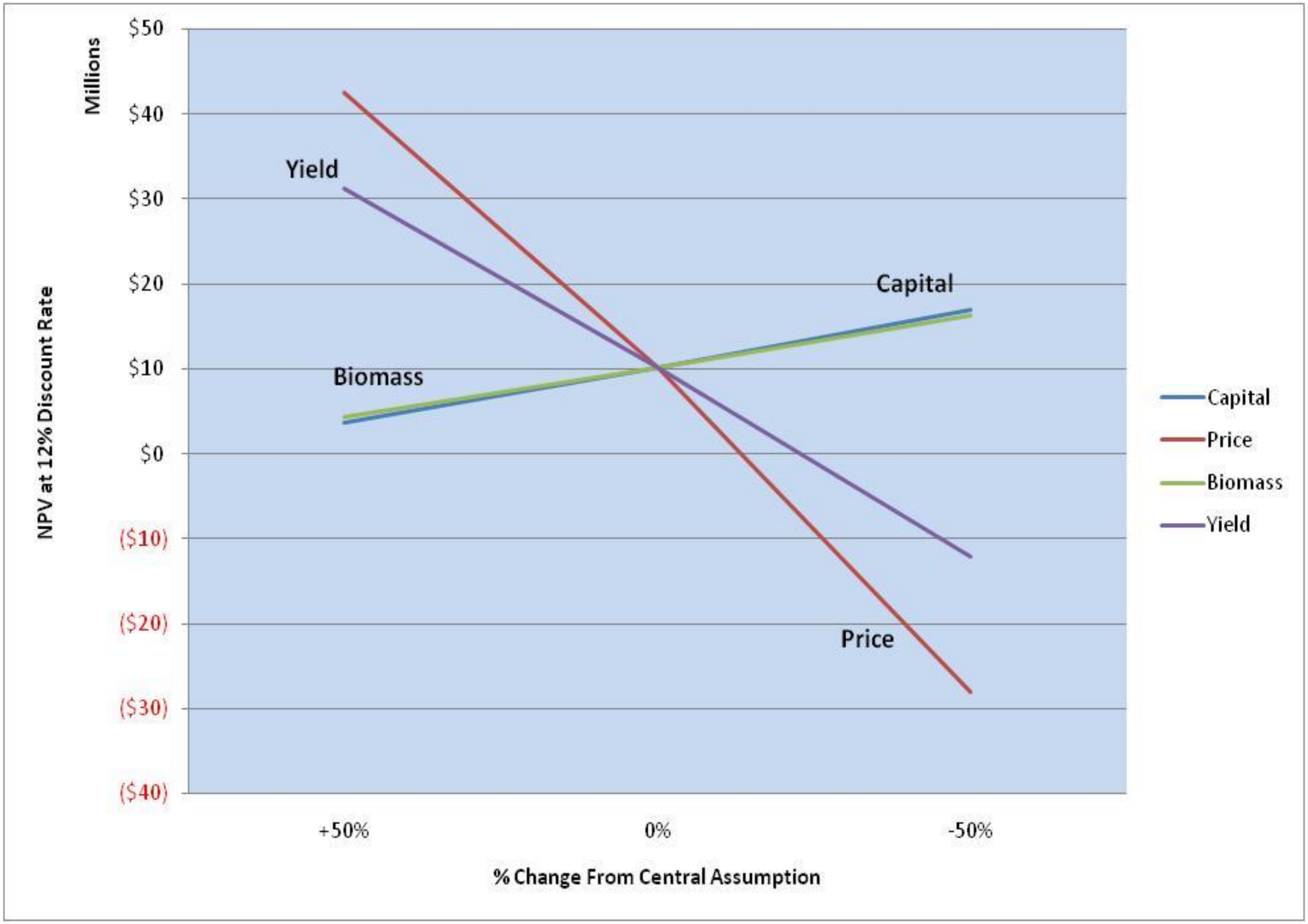

Figure 3.9 +/- 50% Change from the Central Assumption

3.4 Conclusions

Pocosin mixed biomass pellets using pocosin shrubs and trees can be technically produced and demonstrate feasible characteristics pertaining to heat of combustion values, chloride value, and ash content.. A heat of combustion value of 8,200 BTU/lb, ash content value of 1.28%, and chloride value of 128 ppm confirm that MBP would be considered standard grade pellets. A combination of PMB and softwood residues would increase the heat of combustion value; produce less ash and chlorides making wood pellets created from these raw materials suitable for premium grades. Caution should be used when making this determination because the PMB and softwood residues were not combined to create pellets in this study. Therefore the ground combination of the two raw materials may have caused error in the testing methods. Biomass pellets, PMB and softwood residues, can be economically produced with a net present value of 10.2 million and an internal rate of return of 29%, assuming drying biomass from 49.2% to 12% moisture using the raw material as fuel.

Raw material cost and electricity costs are the major cost factors on the pellet production cost followed by bagging costs. A decrease in pellet price and/or decrease in the pellet yield substantially decreases the internal rate of return of the project. An increase in capital costs or raw material cost would have a negative effect on the project as well. From a technical standpoint utilizing pocosin mixed biomass in conjunction with or without softwood residues appears to be a beneficial alternative for investors looking to invest in wood pellets. However, further technical analysis needs to be conducted regarding the production of wood pellets utilizing PMB and softwood residues, including the finished moisture content of the pellets, and testing for heat of combustion, ash content, chloride content, density, durability and fines, and the chemical composition of the pellets. The PMB pellets were created with a moisture content of 18% which required a large amount of energy from the pellet mill to produce and therefore an increase in moisture content may be needed and should be tested in future research. The economic analysis shows profitability under the proposed conditions and assumptions made. The NPV for a 10 year project lifetime was found to be $10,193,416 and the IRR at the current market condition and proposed assumption was found to be 29%.

Assumptions are used throughout this research because relevant information was not readily available. However, under the scope of this research, several bold assumptions had to be made. In particular, the assumptions are made that the market will accept the product proposed and consume 100 percent of the manufacturing capacity. Improving today's forests to the ideal ecological conditions for growing quality timber calls for the removal of large portions of fire-hazardous small-diameter trees and shrubs with limited economic value. The industry as well as the research community's responsibility will be to find efficient methods of using this material while satisfying consumer demands. Wood pellets are just one of the many opportunities available to the industry that improves the value and utilization of the resource from the forests to the consumer. Future research and ideas are necessary to develop the opportunities that will provide the cornerstone for tomorrow’s wood energy industry. All stakeholders in the forest products industry will depend on past, present, and future knowledge to ensure the competitiveness of the domestic forest products industry.

4 Conclusions

4.1 Research Perspective

North Carolina has established several programs to increase renewable energy projects and energy efficiency in government, commercial, and residential buildings under its State Energy Program. There has been considerable amount of research concerning various innovative products and process for underutilized forest resources over the past 30 years. The past research mainly presented quantitative data on yields and availability but often neglected the economic consequences of using these underutilized resources in the manufacturing process.

The research presented in this thesis is intended to investigate North Carolina’s biomass and bioenergy sectors with a review of factors that affect the location of bio-ethanol refineries as well as investigating the economic and technical feasibility of manufacturing wood pellets from underutilized resources. The scientific portion for both studies focused on using:

- Statistical methods to estimate the availability and utilization of forest resources in North Carolina.

- Laboratory data to determine the characteristics and feasibility of wood pellets created from pocosin mixed biomass.

The estimates from the availability and utilization of forest resources provided the starting point for determining the most suitable regions for acquiring resources for bio-energy production. The laboratory results confirmed that mixed biomass pellets are technically feasible. The basic cost structure for the proposed wood pellet manufacturing plant provides estimates for the economic feasibility of the venture. The analysis included the necessary capital investments for manufacturing wood pellets from underutilized PMB resources.

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6 APPENDICES

6.1 Appendix A

Table 6.1 Forest Inventory and Analysis and Timber Products Output Data Headings

COUNTY	COUNTY
SAWL_SW	SAW LOGS SOFTWOOD
VENL_SW	VENEER LOGS SOFTWOOD
PULP_SW	PULPWOOD SOFTWOOD
CP_SW	COMPOSITE PRODUCTS SOFTWOOD
FUEL_SW	FUELWOOD SOFTWOOD
PPP_SW	POST-POLES-PILLINGS SOFTWOOD
OTHER_SW	OTHER SOFTWOOD
ALLP_SW	ALL PRODUCTS SOFTWOOD
SAWL_HW	SAW LOGS HARDWOOD
VENL_HW	VENEER LOGS HARDWOOD
PULP_HW	PULPWOOD HARDWOOD
CP_HW	COMPOSITE PRODUCTS HARDWOOD
FUEL_HW	FUELWOOD HARDWOOD
PPP_HW	POST-POLES-PILLINGS HARDWOOD
OTHER_HW	OTHER HARDWOOD
ALLP_HW	ALL PRODUCTS HARDWOOD
SAWL_T	SAW LOGS TOTAL
VENL_T	VENEER LOGS TOTAL
PULP_T	PULPWOOD TOTAL
CP_T	COMPOSITE PRODUCTS TOTAL
FUEL_T	FUELWOOD TOTAL
PPP_T	POST-POLES-PILLINGS TOTAL
OTHER_T	OTHER TOTAL
ALLP_T	ALL PRODUCTS TOTAL
ARGS_SW	ALL REMOVALS GROWING STOCK SOFTWOOD
ARNGS_SW	ALL REMOVALS NON-GROWING STOCK SOFTWOOD
ARAS_SW	ALL REMOVALS ALL SOURCES SOFTWOOD
ARGS_HW	ALL REMOVALS GROWING STOCK HARDWOOD
ARNGS_HW	ALL REMOVALS NON-GROWING STOCK HARDWOOD
ARAS_HW	ALL REMOVALS ALL SOURCES HARDWOOD
ARGS_T	ALL REMOVALS GROWING STOCK TOTAL
ARNGS_T	ALL REMOVALS NON-GROWING STOCK TOTAL
ARAS_T	ALL REMOVALS ALL SOURCES TOTAL
AFL	ACRES OF SAMPLED FOREST LAND TOTAL

Table 6.1 Continued

NTVT	NET TREE VOLUME CUBIC FEET TOTAL
RAT	RESIDUES PER ACRE OF TIMBERLAND (CU FT)
FBP_SW	FIBER BY-PRODUCT SOFTWOOD
FUBP_SW	FUEL BY-PRODUCT SOFTWOOD
MBP_SW	MISC BY-PRODUCT SOFTWOOD
NUBP_SW	NOT USED BY-PRODUCT SOFTWOOD
ABP_SW	ALL BY-PRODUCT SOFTWOOD
FBP_HW	FIBER BY-PRODUCT HARDWOOD
FUBP_HW	FUEL BY-PRODUCT HARDWOOD
MBP_HW	MISC BY-PRODUCT HARDWOOD
NUBP_HW	NOT USED BY-PRODUCT HARDWOOD
ABP_HW	ALL BY-PRODUCT HARDWOOD
FBP_T	FIBER BY-PRODUCT TOTAL
FUBP_T	FUEL BY-PRODUCT TOTAL
MBP_T	MISC BY-PRODUCT TOTAL
NUBP_T	NOT USED BY-PRODUCT TOTAL
ABP_T	ALL BY-PRODUCT TOTAL

6.2 Appendix B

North Carolina State University
College of Natural Resources
Campus Box 8005
Raleigh, NC 27695-8005
919.515.5728
919.513.3496 (fax)

Please take a moment to help us assess the total roundwood use in North Carolina. When you're done, please use the pre-paid postage envelope to mail us the response.

Would you like to be entered into a raffle for I-POD Shuffle? (two will be given out for completing this survey)

YES NO ENTER PHONE: ____________________
OR EMAIL: ____________________

Production and Markets

1. Which of the following products did you produce in your mill in 2008? **PLEASE CHECK ALL THAT APPLY**

- ☐ Lumber
- ☐ Veneer Board
- ☐ Plywood
- ☐ OSB
- ☐ Pulp
- ☐ Paper
- ☐ Pallets and Crates
- ☐ Pellets
- ☐ Chips
- ☐ Shavings/Residues
- ☐ Other
  Please Specify
  ____
  ____

2. What types of immediate markets or customers did you sell your products to in 2008? **PLEASE CHECK ALL THAT APPLY**

- ☐ Sawmills
- ☐ Veneer Mills
- ☐ Wholesalers/Dealers
- ☐ Furniture and Cabinet Firms
- ☐ Retailers
- ☐ Plywood/OSB Mills
- ☐ Pallet and Crate Mills
- ☐ Pulp and Paper Mills
- ☐ Pellet Mills
- ☐ Other Wood Composite Mills (e.g., MDF, Particleboard)
- ☐ Other
  (Please Specify)
  ____
  ____

3. Of the aforementioned customers, who are your top three customers? **Considering sales in 2008**

Customer/Product 1 ____________________
Customer/Product 2 ____________________
Customer/Product 3 ____________________

4. Of your total sales/revenue in 2008, what **percent** is accounted for by your top three customers? **BEST ESTIMATE FOR 2008**

Customer/Product 1 (%): ____________________
Customer/Product 2 (%): ____________________
Customer/Product 3 (%): ____________________

Raw Material

5. Please provide your best estimate of the volume of raw material that you purchased for your mill in 2008. IN TERMS OF TONS.

Roundwood logs ____________________
Veneer ____________________
Chips ____________________
Pulp (if purchased) ____________________
Shavings/Sawdust/Bark ____________________
Any Other (please specify) ____________________
____

6. Please specify what **percentage** of your raw material in 2008 was Hardwood vs. Softwood.

	Hardwood (%)	Softwood (%)
Roundwood logs		
Veneer		
Chips		
Pulp (if purchased)		
Shavings/Sawdust/Bark		
Any other(please specify)		

Additional Comments

____
____
____
____
____

About You

Zip Code: ____________________

Thank you for your participation!

Figure 6.1 Mail-Merge Questionnaire

North Carolina State University is a land-Grant university and a constituent institution of The University of North Carolina

Department of Wood and Paper Science

NC STATE UNIVERSITY

College of Natural Resources
Campus Box 8005
Raleigh, NC 27695-8005
919.515.5728
919.513.3496 (fax)

Paper Science & Engineering 919.515.2888
Wood Products 919.515.3181
WP Extension 919.515.5637
Graduate & Distance Studies 919.515-3181

Date: September 25, 2009

Dear Primary Wood Products Manufacturers,

NC State University is conducting a short survey about the state of the wood products industry in NC. This short survey is a part of a graduate research that will help with providing information to the industry and professionals about the types of mill output and the total roundwood use in NC.

With only 7 questions, this survey will take only about 5 minutes to complete. The responses will remain confidential and will be used for educational purposes only.

Each response is critical for the success of this study. We request that you complete this questionnaire and send it in the return prepaid enveloped provided with the survey.

As a token of our appreciation for taking the time out to complete our survey, we are raffling two 2009 Apple I-Pod 2-GB shuffle's. Once the survey is closed, we will let you all know about the winners of the raffle. You will also receive a summary of the survey results as soon as the analysis is complete (by December 2009).

Thank you so much in advance. Please let me know if you have any questions.

PLEASE HELP A MASTER'S STUDENT GRADUATE!

Sincerely,

Javon Carter
MS Graduate Student, NC State University
jmcarte3@ncsu.edu

Sudipta Dasmohapatra
Assistant Professor (Marketing)
Department of Wood and Paper Science
North Carolina State University
Campus Box 8005, Raleigh, NC 27695
Phone: 919-515-5728
Email: sdasmoh@ncsu.edu

Figure 6.2 Mail-Merge Cover Letter

6.3 Appendix C

Table 6.2 Hardwood Pellets and PMB Pellets Oxygen Bomb Calorimeter Raw Data

Assembly of Data		
Variables		**Definition**
1st Test		
5.0000	**a**	*Time of firing*
6.1260	**b**	*time (to the nearest 0.1 min.) when the temperature reaches 60 percent of the total rise*
13.0000	**c**	*time at beginning of period (after the temperature rise) in which the rate of temp change has become constant*
21.6260	**ta**	*temperature at time of firing*
22.0760	**tc**	*temperature at time c*
0.0006	**r1**	*rate (temp units per min.) at which the temp was rising during the 5-min. period before firing*
0.0000	**r2**	*rate (temp units per min.) at which the temp was rising during the 5-min. period afer time c. If the temp was falling instead of rising a*
1.1000	**c1**	*milliliters of standard alkali solution used in the acid titration*
0.0000	**c2**	*percentage of sulfur in the sample*
3.8000	**c3**	*centimeters of fuse wire consumed in firing*
2414.9100	**W**	*energy equivalent of the calorimeter, determined under standardization*
0.2505	**m**	*mass of sampe in grams*
0.4493	**t**	*Temperature Rise. Net corrected temperature rise, t.*
		Thermochemical Corrections.
1.1000	**e1**	*e1 = correction in calroies for heat of formation of nitric acid = c1 if 0.0709N alkali was used for titration*
0.0000	**e2**	*e2 = correction in calories for heat of formation of sulfuric acid = (13.7)(c2)(m)*
8.7400	**e3**	*e3 = correction in calories for heat of combustion of fuse wire = (2.3)(c3) when using Parr 45C10 nickel chromium fuse wire*
4292.3672	**Hg**	*Gross Heat of Combustion. Hg, in calories per gram. Calories/gram*
7721.0939	**Hg**	*Convert calories/gram to Btu/lb*

2nd Test	**Void**	**3rd Test**		**4th Test**		**5th Test**		**6th Test**	
5.0000	a	5.0000	a	5.0000	a	5.0000	a	5.0000	a
6.0750	b	6.1250	b	6.0750	b	6.0780	b	6.0980	b
12.0000	c	14.0000	c	14.0000	c	14.0000	c	13.0000	c
21.8170	ta	19.8600	ta	20.6980	ta	21.2940	ta	21.9010	ta
22.7860	tc	20.4620	tc	21.2790	tc	22.0340	tc	22.5550	tc
-0.0004	r1	0.0032	r1	0.0040	r1	0.0020	r1	-0.0002	r1
-0.0012	r2	0.0022	r2	0.0010	r2	-0.0002	r2	-0.0010	r2
2.0000	c1	0.9000	c1	0.9000	c1	1.3000	c1	1.3000	c1
0.0000	c2	0.0000	c2	0.0000	c2	0.0000	c2	0.0000	c2
1.8000	c3	2.9000	c3	4.7000	c3	5.9000	c3	3.3000	c3
2414.9100	W	2414.9100	W	2414.9100	W	2414.9100	W	2414.9100	W
0.6619	m	0.3212	m	0.3135	m	0.4103	m	0.3702	m
0.9765	t	0.5811	t	0.5688	t	0.7394	t	0.6611	t
2.0000	e1	0.9000	e1	0.9000	e1	1.3000	e1	1.3000	e1
0.0000	e2	0.0000	e2	0.0000	e2	0.0000	e2	0.0000	e2
4.1400	e3	6.6700	e3	10.8100	e3	13.5700	e3	7.5900	e3
3553.5824	Hg	4345.1863	Hg	4343.9567	Hg	4315.8251	Hg	4288.6525	Hg
6392.1706	Hg	7816.1046	Hg	7813.8929	Hg	7763.2899	Hg	7714.4119	Hg

Table 6.2 continued

Assembly of Data

Variables		Definition
Test 1		
5	**a**	*Time of firing*
6.14	**b**	*time (to the nearest 0.1 min.) when the temperature reaches 60 percent of the total rise*
12	**c**	*time at beginning of period (after the temperature rise) in which the rate of temp change has b*
21.58	**ta**	*temperature at time of firing*
22.036	**tc**	*temperature at time c*
0.0002	**r1**	*rate (temp units per min.) at which the temp was rising during the 5-min. period before firing*
-0.0002	**r2**	*rate (temp units per min.) at which the temp was rising during the 5-min. period afer time c. If t*
0.6	**c1**	*milliliters of standard alkali solution used in the acid titration*
0	**c2**	*percentage of sulfur in the sample*
1.9	**c3**	*centimeters of fuse wire consumed in firing*
2414.91	**W**	*energy equivalent of the calorimeter, determined under standardization*
0.241	**m**	*mass of sampe in grams*
0.456944	**t**	*Temperature Rise. Net corrected temperature rise, t.*
		Thermochemical Corrections.
0.6	**e1**	*e1 = correction in calroies for heat of formation of nitric acid = c1 if 0.0709N alkali was used for t*
0	**e2**	*e2 = correction in calories for heat of formation of sulfuric acid = (13.7)(c2)(m)*
4.37	**e3**	*e3 = correction in calories for heat of combustion of fuse wire = (2.3)(c3) when using Parr 45C10*
4558.127116	**Hg**	*Gross Heat of Combustion. Hg, in calories per gram. Calories/gram*
8204.628809	**Hg**	*Convert calories/gram to Btu/lb*

Test 2		**Test 3**		**Test 4**		**Test 5**	
5	**a**	5	**a**	5	**a**	5	**a**
6.13	**b**	6.105	**b**	6.14	**b**	6.12	**b**
13	**c**	12	**c**	12	**c**	12	**c**
21.794	**ta**	22.02	**ta**	22.274	**ta**	22.446	**ta**
22.238	**tc**	22.528	**tc**	22.762	**tc**	22.998	**tc**
-0.0002	**r1**	-0.0002	**r1**	-0.0012	**r1**	-0.0014	**r1**
-0.0004	**r2**	-0.0006	**r2**	-0.0012	**r2**	-0.0012	**r2**
0.6	**c1**	0.8	**c1**	0.6	**c1**	0.7	**c1**
0	**c2**	0	**c2**	0	**c2**	0	**c2**
1.8	**c3**	4.3	**c3**	4.6	**c3**	4.1	**c3**
2414.91	**W**	2414.91	**W**	2414.91	**W**	2414.91	**W**
0.2328	**m**	0.2705	**m**	0.2597	**m**	0.2944	**m**
0.446974	**t**	0.511758	**t**	0.4964	**t**	0.560624	**t**
0.6	**e1**	0.8	**e1**	0.6	**e1**	0.7	**e1**
0	**e2**	0	**e2**	0	**e2**	0	**e2**
4.14	**e3**	9.89	**e3**	10.58	**e3**	9.43	**e3**
4616.245629	**Hg**	4529.24	**Hg**	4572.897	**Hg**	4564.288	**Hg**
8309.242131	**Hg**	8152.633	**Hg**	8231.214	**Hg**	8215.719	**Hg**

6.4 Appendix D

Table 6.3 Economic Analysis Inputs

Pellet Mill Economic Analysis		
Production per hour (tons)	13.3	
Annual number of production hours	7,344	
Annual Operating Days	306	
Operating efficiency	90%	
Raw Material Working Capital (of Annual Wood Cost)	12%	
Product Storage Working Capital (of Annual Product Value)	10%	
Capital Spending Schedule	50%	of TIC in 2011
	50%	of TIC in 2012
Ramp Up Schedule	2012	Startup
	75%	of Nominal Capacity in 2012
	100%	of Nominal Capacity in 2013
Depreciation Schedule	7 Year MACRS	
Project Life	10	Years After Statrtup
Terminal Value	5	x EBITDA of Year 9
State Tax	5%	
Federal Tax	35%	
Annual Production (Tons)	87,908	
Annual tons of green raw material	143,792	
Product Selling Price	$ 175	
Revenue per year	$ 15,383,844	
RAW MATERIAL COST		
Annual raw material cost	$ 2,882,734	
Annual production (tons)	87,908	
Delivered price (Pocosin) ($/ton)	$27.16	
Delivered price (Softwood residuals/chips) ($/ton)	$17	
Percent (Pocosin)	30.00%	
Percent (Softwood residuals/chips)	70.00%	
Annual raw material requirements (tons)	143,792	
Raw Material Conversion		
Raw Material Moisture Content (Wet Basis)	32.98%	
Raw Material Moisture Content (Dry Basis)	49.20%	
Finished Material Moisture Content (Wet Basis)	10.71%	
Finished Material Moisture Content (Dry Basis)	12.00%	
Weight (tons) OD dry sawdust produced per ton of wet	0.751	
Pounds of water that has to be evaborated	499	

Table 6.3 Continued

Btu's need for evaporation (@1000btu's per pound)	498,660	
BTU value of 1 pound od green sawdust	4,000	
Pounds green sawdust needed to evaporate water	192	
Pounds of green sawdust needed to dry burner fuel	18	
Yield (based on dust loss, etc)	90%	
Green raw material	1.105	
Dry sawdust produced	0.676	
Ratio wet tons needed per dry ton	1.64	
PAYROLL INFORMATION		
% of Payroll Tax to Salaries	5.00%	
% of Retirement Tax to Salaries	15.00%	
% of Employee INS Tax to Salaries	10.00%	
Benefits as % of Salaries	30.00%	
Wage Inflation	1.00%	
Direct Cost		
Electricity ($/KWh)	$ 0.095	per hour
Motor Fuel	$ 2.000	per FT
Bagging (Includes pallets and bags)	$ 15.000	per FT
Die and Rollers	$ 4.000	per FT
Maintenance	$ 4.750	per FT
Indirect Costs		
Repair	3%	of Original Capital Investment
Operating Materials	2%	of Original Capital Investment
Other Fixed Costs	4%	of Original Capital Investment
Insurance	$ 3.00	per FT
Fixed Asset Investment	0.15	x Depreciation
EXPENSE INFORMATION		
Percent Financed	80.00%	
Long Term Interest Rate	8.00%	
Loan Term	10	
Total Plant Property & Equipment	$ 8,378,950	
Loan Amount	$ 6,703,160	
Working Capital	$ 1,524,118	
Short Term Interest Rate	7.00%	
Sensitivity		
+50% Capital	50%	
-50% Capital	-50%	
+50% Pellet Price	50%	
-50% Pellet Price	-50%	
+50% Pellet Yield	50%	
-50% Pellet Yield	-50%	
+50% Biomass Cost	50%	
-50% Biomass Cost	-50%	

Table 6.4 Economic Analysis Loan Amortization

Loan Amoritization										
Total Investment	$ 10,143,950									
Long Term Interest Rate	8.00%									
Percent Financed	80.00%									
Loan Amount	$ 8,115,160	$ 4,057,580								
Loan Term	10									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Beginning Balance	$ 8,115,160	$ 7,554,975	$ 6,949,974	$ 6,296,574	$ 5,590,902	$ 4,828,776	$ 4,005,680	$ 3,116,736	$ 2,156,677	$ 1,119,813
Interest Rate	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
Interest	$ 649,213	$ 604,398	$ 555,998	$ 503,726	$ 447,272	$ 386,302	$ 320,454	$ 249,339	$ 172,534	$ 89,585
Annual Payment	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398	$1,209,398
Principal	$560,185	$605,000	$653,400	$705,672	$762,126	$823,096	$888,944	$960,059	$1,036,864	$1,119,813
Ending Balance	$7,554,975	$6,949,974	$6,296,574	$5,590,902	$4,828,776	$4,005,680	$3,116,736	$2,156,677	$1,119,813	$0
Working Capital	$ 1,524,117.60									
Short Term Interest Rate	7.00%									
Interest Amount	$ 106,688.23									
Total Interest Expense	$ 755,901	$ 711,086	$ 662,686	$ 610,414	$ 553,960	$ 492,990	$ 427,143	$ 356,027	$ 279,222	$ 196,273

Table 6.5 Economic Analysis Personnel Costs

Personnel Expenses						
Occupation	Cost per Unit	Salary	Benefits	Overtime%	Overtime	Total
Manager	1	$ 60,000.00	$ 18,000.00	0.00%	$ -	$ 78,000.00
Shift supervisor	3	$ 45,000.00	$ 13,500.00	0.00%	$ -	$ 175,500.00
Production Employees	6	$ 32,500.00	$ 9,750.00	5.00%	$ 2,112.50	$ 266,175.00
Helpers	10	$ 20,000.00	$ 6,000.00	5.00%	$ 1,300.00	$ 273,000.00
Total Personnel Costs	20	$ 157,500.00	$ 47,250.00		$ 3,412.50	$ 792,675.00

Table 6.6 Economic Analysis Capital Costs

Pellet Plant - Budget Estimate			
Capacity: 100,000 TPY (13.3 tons/hour)			
Category/ Area	**Description**	**Pricing (USD) Individual**	**Pricing (USD) Area Subtotals**
A. Equipment (Supply)			
WOODYARD			
1. Unloading	by others	$0.00	
2. Debarking	by others	$0.00	
3. Chipping	by others	$0.00	
4. Chip Handling	by others	$0.00	
5. Bark Handling	by others	$0.00	
DRYING			
6. Dryer Burner System	(1) Suspension Burner	$566,650.00	
7. Dryers Equipment	(1) Rotary Dryer	$1,600,000.00	
8. Fan, Ducting, Cyclones	Fan, Ducting, Recycle	$353,300.00	
9. Pollution Control	by others	$0.00	
GRINDING/PELLETING			
10. Dry Material Storage Equipm	10,000 ft3 Silo w/screw discharge	$576,000.00	
11. Dry Hammermill Equipment	(2) DFZC-600 Horizontal	$545,000.00	
12. Pelleting Systems	(3) RWPR-900	$1,110,000.00	
13. Pellet Cooling Equipment	(1) Counterflow Cooler	$179,000.00	
14. Pellet Screening Equipment	(1) Reciprocating Screen	$40,000.00	
15. Pellet Storage/ Load Out Equ	(1) Storage Bin, 1 Bagging Line	$513,450.00	
16. Conveyors (Dry Storage/Ham	misc	$333,500.00	
17. Conveyors (Cooling/Screenir	misc	$85,000.00	
18. Aspiration System(s) for Han	misc	$166,700.00	
19. Other Required Equipment	none	$0.00	
TOTAL EQUIPMENT……………………………………………………			**$6,068,600.00**
B. Electrical Equipment (Supply)	**for ABOVE ITEMS**		
1. MCC's		$295,000.00	
2. PLC/PC/Ops Controls		$270,000.00	
3. Devices, Instruments, Components, etc.		$95,000.00	
4. Lighting	by others	$0.00	
5. Conduits/Cabling	by others	$0.00	
6. Fire Protection (For Process ONLY)		$365,000.00	
TOTAL ELECTRICAL EQUIPMENT……………………………………………………			**$1,025,000.00**
C. Installation			
1. Mechanical Installation (Equip	by others	$100,000.00	
2. Electrical Installation (Equipm	by others	$100,000.00	
3. Mechanical Installation & Star	8 weeks	$81,600.00	
4. Electrical Installation & Startu	8 weeks	$98,750.00	
OTAL INSTALLATION AND ASSISTANCE……………………………………………………			**$380,350.00**

Table 6.6 Continued

D. Engineering			
1. Mechanical Engineering		$285,000.00	
2. Electrical Engineering and Programming		$198,000.00	
TOTAL ENGINEERING……………………………………………………….			**$483,000.00**
E. Land			
1. Land Cost	**43 acres**	$33,000.00	
2. Land Development		$132,000.00	
TOTAL LAND COST……………………………………………………….			**$165,000.00**
F. Buildings (Supply and Installation)			
1. Hammermill Building	by others	$0.00	
2. Pellet Production Building	by others	$0.00	
3. Hammermill MCC Room	by others	$0.00	
4. Pellet Production MCC Room	by others	$0.00	
5. Process Control Room (Interio	by others	$0.00	
Buildings Estimate……………………………………………………….		$800,000.00	
G. Civil Materials (Supply)			
1. Concrete/Foundations/Paving	by others	$0.00	
2.Structural, Catwalks, Handrails	by others	$0.00	
3. Chuteworl/Plating	by others	$0.00	
4. Process Air Piping	by others	$0.00	
5. Process Water Piping	by others	$0.00	
6. Process Hydraulic Piping	by others	$0.00	
7. Potable Water Piping	by others	$0.00	
8. Switchgear	by others	$0.00	
Civil Materials Estimate……………………………………………………….		$800,000.00	
TOTAL BUILDING AND CIVIL ESTIMATE……………………………………………………			**$1,600,000.00**
H. Miscellaneous			
1. Project/Construction Manage	by others	$0.00	
2. Project Safety Management	by others	$0.00	
3. Lubricants/Fluids	by others	$0.00	
4. Spare Parts (Critical for 1st 6-n	to be determined	$0.00	
5. Operator Training/Production	included in C3&4	$0.00	
6. Taxes	Excluded	$0.00	
TOTAL MISC ESTIMATE……………………………………………………….			**$200,000.00**
I. Light Trucks and Vehicles			
1. Delivery Truck		$15,000.00	
2. Company Car	**Chevy Malibu/Ford Taurus**	$10,000.00	
3. Front end Loader	**Caterpillar 930G 2005**	$75,000.00	
4. Semi-Truck Tipper	**Semi**	$100,000.00	
5. Fork Lift	**5,000 lbs internal combustion**	$22,000.00	
TOTAL TRUCK AND VEHICLE ESTIMATE……………………………………………………			**$222,000.00**
SUBTOTAL of ABOVE………………………			**$8,378,950.00**
APPROXIMATE SCHEDULE			
Mill Building Construction		8-16 weeks	
Preliminary Engineering Documents (Layout, Flow, etc.) from Order Date		4 weeks	
Equipment Delivery from Order Date		16 weeks	
Installation and Wiring from Equipment Delivery Date		8 -12 weeks	
Startup from Installed and Wired Date		4-8 weeks	

Table 6.7 Economic Analysis Depreciation Schedule

Depreciation

Total Capital =	$ 10,143,950											
Capacity =	97,675	Project Year ->										
Fixed Asset =	$ 8,378,950	-1	0	1	2	3	4	5	6	7	8	
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
	Fixed Asset Investment	$ 4,189,475	$ 4,189,475	$ 179,603	$ 311,651	$ 233,100	$ 178,136	$ 136,158	$ 135,933	$ 135,770	$ 80,566	
		Depreciation Factors ->	14.29%	24.49%	17.49%	12.49%	8.93%	8.92%	8.93%	4.46%		

	Fixed Assest Value	New Fixed Capital	Accumulated Depreciation	2012	2013	2014	2015	2016	2017	2018	2019	2020
2012	$ 7,181,598	$ 8,378,950	$ 1,197,352	$ 1,197,352	$ 2,052,005	$ 1,465,478	$ 1,046,531	$ 748,240	$ 747,402	$ 748,240	$ 373,701	$ -
2013	$ 5,283,531	$ 179,603	$ 2,077,670		$ 25,665	$ 43,985	$ 31,413	$ 22,432	$ 16,039	$ 16,021	$ 16,039	$ 8,010
2014	$ 4,041,183	$ 311,651	$ 1,553,998			$ 44,535	$ 76,323	$ 54,508	$ 38,925	$ 27,830	$ 27,799	$ 27,830
2015	$ 3,086,706	$ 233,100	$ 1,187,577				$ 33,310	$ 57,086	$ 40,769	$ 29,114	$ 20,816	$ 20,792
2016	$ 2,357,121	$ 178,136	$ 907,722					$ 25,456	$ 43,626	$ 31,156	$ 22,249	$ 15,908
2017	$ 1,587,061	$ 136,158	$ 906,218						$ 19,457	$ 33,345	$ 23,814	$ 17,006
2018	$ 817,863	$ 135,933	$ 905,131							$ 19,425	$ 33,290	$ 23,775
2019	$ 416,523	$ 135,770	$ 537,109								$ 19,401	$ 33,250
2020	$ 339,005	$ 80,566	$ 158,084									$ 11,513
2021	$ 236,110	$ 23,713	$ 126,607									
2022	$ 164,943	$ 18,991	$ 90,158									
				$ 1,197,352	$ 2,077,670	$ 1,553,998	$ 1,187,577	$ 907,722	$ 906,218	$ 905,131	$ 537,109	$ 158,084

Land and Buildings											
Cost	$ 1,765,000										
Life	39										
Salvage	0										
Period	39										
Depreciation per year for 39 years	$ 45,256		$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256
		Depreciation Total	$ 1,242,608	$ 2,122,927	$ 1,599,254	$ 1,232,833	$ 952,979	$ 951,474	$ 950,388	$ 582,366	$ 203,341

Table 6.7 Continued

9	10	11	12	13	14	15	16	17	18	19
2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
$ 23,713	$ 18,991									
2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
$ -										
$ 13,900	$ -									
$ 20,816	$ 10,396	$ -								
$ 15,890	$ 15,908	$ 7,945	$ -							
$ 12,159	$ 12,145	$ 12,159	$ 6,073	$ -						
$ 16,978	$ 12,139	$ 12,125	$ 12,139	$ 6,063	$ -					
$ 23,746	$ 16,958	$ 12,124	$ 12,111	$ 12,124	$ 6,055	$ -				
$ 19,731	$ 14,091	$ 10,063	$ 7,195	$ 7,187	$ 7,195	$ 3,593	$ -			
$ 3,389	$ 5,807	$ 4,147	$ 2,962	$ 2,118	$ 2,115	$ 2,118	$ 1,058	$ -		
	$ 2,714	$ 4,651	$ 3,322	$ 2,372	$ 1,696	$ 1,694	$ 1,696	$ 847	$ -	
$ 126,607	$ 90,158	$ 63,214	$ 43,800	$ 29,863	$ 17,061	$ 7,405	$ 2,753	$ 847	$ -	$ -
$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256	$ 45,256
$ 171,864	$ 135,414	$ 108,471	$ 89,056	$ 75,119	$ 62,317	$ 52,661	$ 48,010	$ 46,103	$ 45,256	$ 45,256

Table 6.8 Economic Analysis Operation Costs

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
DIRECT COSTS												
Wood	$ 2,162,051	$ 2,882,734	$ 2,911,562	$ 2,940,677	$ 2,970,084	$ 2,999,785	$ 3,029,783	$ 3,060,081	$ 3,090,682	$ 3,121,588	$ 3,152,804	**$ 32,321,832**
Electricity ($/KWh)	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	$ 3,695,332	**$ 40,648,651**
Motor Fuel	$ 131,862	$ 175,815	$ 177,574	$ 179,349	$ 181,143	$ 182,954	$ 184,784	$ 186,632	$ 188,498	$ 190,383	$ 192,287	**$ 1,971,279**
Bagging (Includes pallets and bags)	$ 988,961	$ 1,318,615	$ 1,331,801	$ 1,345,119	$ 1,358,571	$ 1,372,156	$ 1,385,878	$ 1,399,737	$ 1,413,734	$ 1,427,871	$ 1,442,150	**$ 14,784,594**
Die and Rollers	$ 263,723	$ 351,631	$ 355,147	$ 358,698	$ 362,285	$ 365,908	$ 369,567	$ 373,263	$ 376,996	$ 380,766	$ 384,573	**$ 3,942,558**
Annual Loan Payment	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ 1,209,398	$ -	**$ 12,093,981**
Maintenance	$ 313,171	$ 417,561	$ 421,737	$ 425,954	$ 430,214	$ 434,516	$ 438,861	$ 443,250	$ 447,682	$ 452,159	$ 456,681	**$ 4,681,788**
Sub - Total Direct Costs	$ 8,764,498	$ 10,051,087	$ 10,102,551	$ 10,154,529	$ 10,207,027	$ 10,260,050	$ 10,313,603	$ 10,367,692	$ 10,422,322	$ 10,477,497	$ 9,323,827	**$ 110,444,683**
INDIRECT COSTS												
Total Labor	$ 792,675	$ 800,602	$ 808,608	$ 816,694	$ 824,861	$ 833,109	$ 841,440	$ 849,855	$ 858,353	$ 866,937	$ 875,606	**$ 9,168,741**
Repair	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	$ 251,369	**$ 2,765,054**
Operating Materials	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	$ 167,579	**$ 1,843,369**
Other Fixed Costs	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	$ 335,158	**$ 3,686,738**
Insurance	$ 197,792	$ 263,723	$ 266,360	$ 269,024	$ 271,714	$ 274,431	$ 277,176	$ 279,947	$ 282,747	$ 285,574	$ 288,430	**$ 2,956,919**
Depreciation	$ 1,242,608	$ 2,122,927	$ 1,599,254	$ 1,232,833	$ 952,979	$ 951,474	$ 950,388	$ 582,366	$ 203,341	$ 171,864	$ 135,414	**$ 10,145,447**
Sub - Total Indirect Costs	$ 2,987,181	$ 3,941,357	$ 3,428,328	$ 3,072,656	$ 2,803,659	$ 2,813,120	$ 2,823,109	$ 2,466,274	$ 2,098,547	$ 2,078,481	$ 2,053,556	**$ 30,566,267**