Economic Availability of Alternative Biomass Sources for Gainesville, Florida

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Biomass Resource Assessment Part I: Availability and Cost Analysis of Woody Biomass for Gainesville Regional Utilities

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

Btu	British thermal unit
BBtu	Billion Btu
C&D	Construction and demolition debris
FIA	Forest Inventory and Analysis
GIS	Geographical Information System
GRU	Gainesville Regional Utilities
JEA	Jacksonville Electric Authority
kWh	Kilowatt hour
LR	Logging residues
Mg	Megagram, or metric ton
Min	Minute
MMBtu	Million Btu
MSW	Municipal solid waste
MW	Megawatt
MWh	Megawatt hour
PW	Pulpwood
RDF	Refuse derived fuel
SFRC	School of Forest Resources and Conservation
SRS	Southern Research Station
SFRA	Southern Forest Resource Assessment
TAL	Tallahassee
TBtu	Trillion Btu
TMS	Timber Mart South
TPO	Timber Product Output
TWh	Terawatt hour
UF	University of Florida
USDA	US Department of Agriculture
US EPA	US Environmental Protection Agency
UW	Urban wood

LIST OF CONVERSIONS

hectare	equals	2.471 acre	
acre	equals	0.4047 hectare	
kilogram	equals	2.2046 pounds	
pound	equals	0.4536 kilogram	
TBtu/yr	equals	124,400 wet tons/year woody biomass	
TBtu/yr	equals	62,200 dry tons/year woody biomass	
TBtu/yr	equals	125,000 wet tons/year municipal solid waste	
TBtu/yr	equals	100,000 dry tons/year municipal solid waste	
To convert tons per year	to	tons per day of woody biomass divide by 210	
To convert tons per year	to	tons per day of municipal solid waste divide by 310	
To convert Btu/dry lb	to	Btu/wet lb multiply by (1 minus percent moisture content)	
MM	equals	$1 * 10^6$	Mechanical & Civil Engineering
M = Mega	equals	$1 * 10^6$	Electrical Engineering
Tera	equals	$1 * 10^{12}$	International System of Units (SI)

1. INTRODUCTION

1.1. Project Background and Scope

Biomass has been identified as a potential feedstock to meet some of Gainesville's future energy demand, which is projected to increase as the community grows. An in-depth analysis of biomass-related issues is warranted as Gainesville Regional Utilities (GRU) and the City of Gainesville evaluate the potential to use biomass to generate electricity.

The most abundant biomass resource in north Florida is biomass from trees. Specific sources include urban wood waste, logging debris, and wood from forest thinnings and forest plantations. Faculty at the School of Forest Resources and Conservation (SFRC) at the University of Florida work in various aspects of forestry and bioenergy, and have a history of research and extension projects related to biomass and bioenergy in Gainesville and the southeastern US.

GRU has contracted further study of the availability of biomass by the SFRC and the Department of Environmental Engineering Sciences of the University of Florida. This document details the work carried out by Dr. Carter's group at the SFRC, covering information related to forest resources including urban wood waste, logging residues, forest thinnings, and small-diameter plantation-grown biomass. This project will deliver a companion document, "Availability and Cost Analysis of Using Municipal Solid Waste Components as Alternative Fuel Sources for Power Generation", produced by Dr. Tim Townsend and Dr. Brajesh Dubey of the University of Florida Department of Environmental Engineering Sciences. Waste resources identified in their report are combined with the forest resources identified in this report to assess overall resource availability in Section 6: "Combined resource availability."

1.2. Tasks

Four tasks were outlined for the woody biomass portion of the project proposal as follows:

<u>**Task-1**</u>**: Woodshed delineation and supply/market analysis for GRU, JEA, and TAL**. We have assessed the current economic availability of urban wood waste, logging residues, and commercial pulpwood for GRU as reported in "The Economic Availability of Woody Biomass: Gainesville Regional Utility's Deerhaven Facility". Our previous results are within the range of those described by Post and Cunillio (2003), Black and Veach (2004), and ICF (2006). However, if other utilities in north central Florida create additional markets for biomass,

competition for biomass resources will increase in the region. The location and scale of competing demand and the transportation infrastructure will affect the availability of woody biomass for GRU. To account for competing demand from other facilities, we will delineate woodsheds for GRU, JEA, and TAL based on road infrastructure around probable delivery locations. These delineations will be used to provide geographic boundaries for assessing quantities and prices of current urban wood waste, logging residues, and pulpwood resources within the three woodsheds. Potential additional biomass from forest thinnings will also be estimated. Costs will include procurement, harvest, process, and transportation costs. Quantities and prices of wood waste from C&D debris, refuse derived fuel from MSW, agriculture wastes, etc. (see report Part II) will be quantified and combined with woody biomass resources to prepare a total biomass resource supply curve for each of GRU, JEA, and TAL, showing the marginal cost (delivered, $/million Btu) per quantity of each resource (trillion Btu). Stumpage price impacts on pulpwood due to competing demands by all three facilities will also be assessed, as well as economic impacts (job creation and salaries) of 20 and 40 MW generation scenarios for the three woodsheds. Biomass resources will also be tabulated showing acreage, heat content, percent water, yield per year, and ash percentage.

Task-2: Long-term sustainability impacts from land-use change. The population of Florida is expected to double in the next 50 years, reaching 36 million by 2060. Population growth will cause land-use change, which will affect the availability of biomass resources. For example, urban sprawl will increase the availability of low-cost urban wood waste from both land clearing and urban tree cover, while the total timberland area will probably decline (unless forestland lost to urban sprawl is replaced elsewhere). Similarly, if the pulp and paper industry declines, forested land may be converted to other land uses making logging residues from conventional forestry less available, and/or wood resources may become more available for biomass production. We will provide an estimate of the acreage needed to sustain a 20 MW and a 40 MW steam turbine/generator with a heat rate of 13,500 Btu/kWh[1], and report tonnage of production/acre, and heat content of biomass produced/acre. We will then report how future land-use change might influence available acres of different types of biomass production and the quantities of biomass available annually from each resource.

[1] The original proposal assumed a heat rate of 12,000 Btu/kWh. However, under follow-up discussions with GRU, the heat rate was increased to a more conservative value. The following formula was followed to assume 3.55 TBtu/MW: (8,760 hours)*(.75 pu)*(13,500 Btu/kWh)*(k/1,000)*(40 MW)*(1,000,000/M)*(T/1,000,000,000,000).

Task-3: Transportation. Transportation options for biomass delivery will influence total delivered costs of biomass feedstocks. Intermodal freight options may be designed to alleviate traffic and potentially to store off-site biomass supplies at satellite receiving points. We will assess the potential effects of intermodal freight moves on resource quantity and cost. Scenarios will include biomass a) delivered to remote site by truck, processed at site, and transported to Deerhaven by truck; b) delivered to remote site by truck, processed, and transported to Deerhaven by rail; and c) trucked to Deerhaven, processed and used. We will tabulate our assumptions so GRU can conduct a separate analysis to include local rail freight costs.

Task-4: CO_2 emissions from harvest, process, and transportation of woody biomass. The combustion of sustainably produced biomass is CO_2 neutral, because biomass burned is equal to the amount of biomass regrown over time. However, the overall use of biomass for energy is not CO_2 neutral because, as with conventional energy, fossil fuel is used in the production of the feedstock. Research to date generally suggests that net energy ratios, and thus CO_2 intensity, of biomass is competitive with other energy sources. We will a) conduct a literature review to assess the CO_2 intensity of the production of biomass for energy, and b) estimate CO_2 emissions that would be generated from the production, harvest, processing, and transportation of urban wood waste, logging residues, and forest products. Given this is a short-term project, this study will not include field measurements or a full life cycle analysis, but rather will make calculations based on available literature and familiarity with fuel (diesel) use in biomass production and delivery operations.

1.3. Organization of the Report

Part I of this report is divided into seven main chapters. Chapter 1 presents the introduction and background to this study. Chapters 2 through 5 are dedicated to Tasks 1 through 4, respectively. Chapter 2 presents the background, methods, scenarios, and results for Task 1: Woodshed delineation and supply/market analysis for GRU, JEA, and TAL. This chapter presents results of the base case scenarios, which are expanded on in subsequent chapters. For example, Chapter 3 is dedicated to Task 2: Sustainability impacts from land-use change, which extends the methodology and results from Chapter 2 to make future projections. Similarly, Chapter 4 expands the analysis to focus on Task 3: Transportation impacts for Deerhaven. Chapter 5 is a review of literature to evaluate Task 4: CO_2 emissions from the harvest, process, and transportation of woody biomass. In Chapter 6, the results from different scenarios are combined with MSW resources identified in comparable scenarios from Part II of this report to construct combined resource supply curves. Summary, conclusions, and recommendations are presented in Chapter 7. The bibliography and appendices follow in Chapters 8 and 9, respectively.

2. TASK 1: WOODSHED DELINEATION AND SUPPLY/MARKET ANALYSIS FOR GRU, JEA, AND TAL

2.1. Background

An evaluation of the feasibility of bioenergy generation requires an assessment of not only physical availability, but also the economic availability of woody biomass resources. A comprehensive economic assessment of multiple woody biomass resources takes into account that delivered costs vary with 1) biomass type and 2) distance or travel time, which impacts transportation costs. We have assessed the current economic availability of urban wood waste, logging residues, and commercial pulpwood for GRU as reported in "The Economic Availability of Woody Biomass: Gainesville Regional Utility's Deerhaven Facility". Our previous results are within the range of those described by Post and Cunillio (2003), Black and Veach (2004), and ICF (2006) shown in Figure 1.

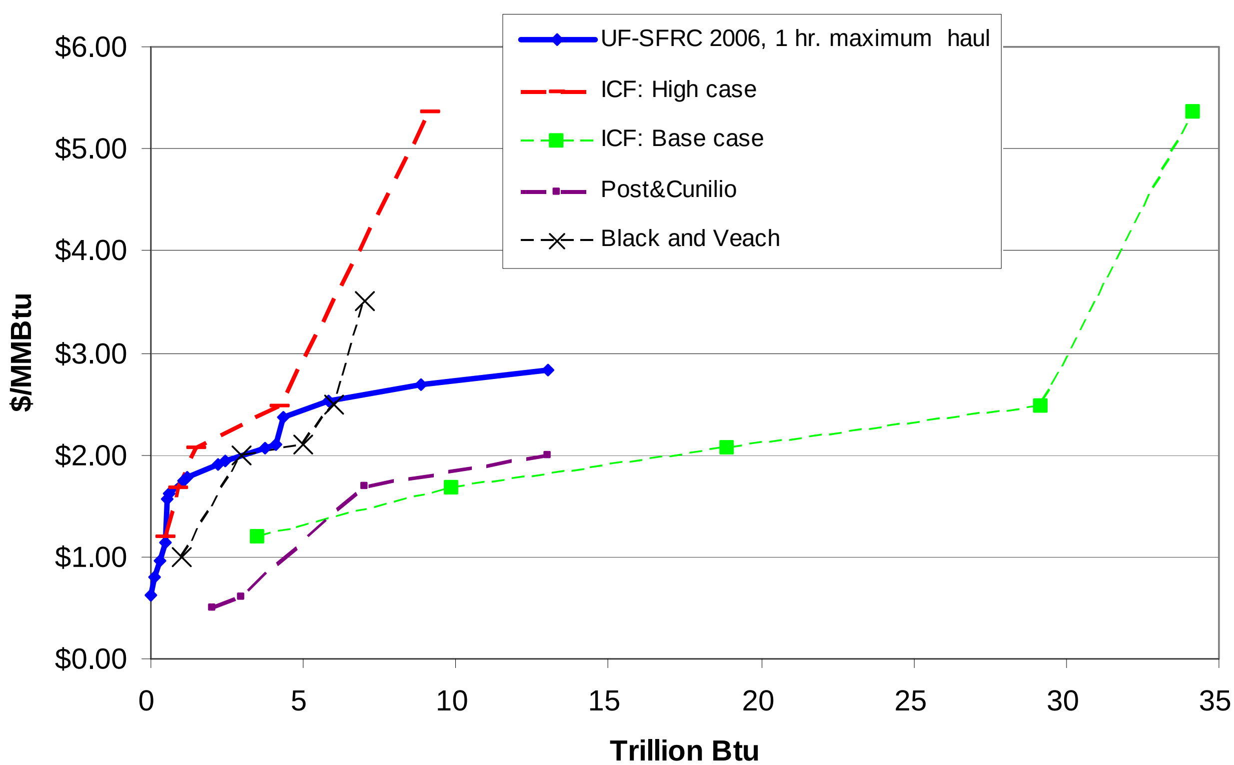

Figure 1. Compilation of biomass resource supply curves previously developed for the Deerhaven facility (Cunillio and Post 2003; Black and Veach 2004; ICF Consulting 2006; 2007).

Though these previous studies suggest there are adequate supplies of biomass to support some bioenergy generation at GRU, the development of additional bioenergy projects, for example at the Hopkins (TAL) or Brandy Branch (JEA) facilities, would increase demand for biomass resources in the region. Factors affecting the availability of biomass resources for GRU include where competing demand is located, the transportation infrastructure around these locations, and how much biomass will be used at each location. Here we construct local woody biomass resource supply curves to assess delivered costs to current GRU, JEA, and TAL generation facilities, both with and without competing demand from the adjacent facilities.

2.2. Methods

Developing localized woody biomass supply curves requires information about production costs and the physical availability of woody biomass resources in the area of interest. Here we describe our cost assumptions, the data used to estimate available woody biomass quantities, and methods to account for the spatial distribution of woody biomass resources. Resources evaluated include urban wood waste, logging residues, forest thinnings (from overstocked natural stands, overstocked plantations, and longleaf pine (*Pinus palustris*) ecosystem restoration), and commercial pulpwood. Availability and cost assumptions for these resources are detailed below.

2.2.1. Description and physical availability of resources

1. *Urban wood waste*. Trees grow in urban areas, producing urban wood waste. The resource identified here is comprised of large-diameter urban wood typically handled by tree servicing companies, rather than yard waste and leaves. Based on Wiltsee (1998) we assume an average of 0.203 green tons (40% moisture content) per person per year. This estimate excludes an additional 0.103 green tons capita^{-1} year^{-1} Wiltsee reported from industrial wood (e.g. cabinet and pallet production) and construction and demolition debris. Wiltsee's study of thirty metropolitan areas across the US showed relative consistency per capita nation wide; values tended to be higher in southern states. To exclude urban wood waste that may be too dirty or already allocated to commercial uses, we assume an availability of 60%. We multiply this average annual per capita yield by county level 2005 US Census population estimates (www.census.gov/popest/counties/) to estimate total annual yield of urban wood waste per county. On a per capita basis, these

calculations for urban wood waste are lower than those found by Post and Cunillio (2003), which may be explained in part by the large amount of biomass produced by land clearing in Alachua County. Assumptions of availability, wood densities, and energy content for all included woody biomass sources are shown in Appendix A. We then use the method described in Section 2.2.3 to estimate what portion of these county-level resources are within each resource/haul time category for GRU, JEA, and TAL. Sawmill wastes were excluded from this study, because they are already widely used for bioenergy. However, some sawmill wastes may be available and would increase the supply.

2. *Logging residues*[2]. Logging operations leave residues following timber harvests. Logging residues are typically piled and often burned on site for disposal and to allow for replanting. Logging residues have recently been identified as having the potential to produce 67.5TWh of electricity annually, with much of the resource in the southeastern US (Gan and Smith 2006). To estimate woody biomass quantities from logging residues, we accessed Timber Product Output (TPO) reports (http://srsfia2.fs.fed.us/php/tpo2/tpo.php) maintained by the Forest Inventory and Analysis (FIA) work unit of the USDA Forest Service, Southern Research Station (SRS). This database provides forest inventory and harvest information, including annual yields of logging residues and pulpwood at the county level. The SRS derives these values by updating FIA harvest data with more frequent regional harvest information based on mill surveys (Tony Johnson, pers. com., January 2006). To account for increased harvesting efficiencies and utilization, we assume current logging residues are 60% available. Stumps were excluded from this analysis, and represent an additional 435,000 dry tons (6.5 TBtu) per year within the three-facility woodshed defined below.
3. *Thinnings*. Forest growth exceeds forest harvests in Florida by about 35% (Figure 2). This combined with fire suppression results in high-density forests. 2005 FIA

[2] There is debate in the environmental community about the sustainability of harvesting logging residues. Based on Gresham (2002) removing all above-ground tree biomass would increase removals of biomass, nitrogen, and phosphorus by 23%, 164%, and 118% respectively over harvest of pole wood alone, once every 20 years. On an annual basis, this represents about 1/10th of the nutrient removal associated with agricultural row crop production. Quantities of logging residues reported here from TPO data exclude leaves, which contain 4% of the above-ground biomass and 31% of the nutrients in the above-ground biomass, and would be left on site.

data for Florida reports about 8% of timberland acres in Florida are classified as "overstocked" (Figure 3). Overstocked stands are fairly evenly distributed across age classes in Florida (Figure 4). Removing small diameter trees from overstocked stands can improve forest health and productivity; reduce the likelihood, intensity and costs of forest fires, reduce likelihood of southern pine beetle attack; and help forest landowners meet various forest management objectives (e.g. Perlack, Wright et al. 2005; Condon and Putz 2007). In this analysis we include three scenarios of forest thinnings: a) pre-commercial thinning of 36% of all standing biomass from 1/5th of overstocked *plantations* aged 5-15 years old annually[3], b) an annual pre-commercial thinning of 36% of all standing biomass from 1/5th of overstocked *natural stands* aged 5-15 years old, and c) removing 20 dry tons of invasive hardwoods per acre from 1/40th of longleaf pine forest acreages annually. Pre-commercial thinnings were restricted to young stands to avoid competition for larger diameter and higher-value commercial timber.

4. *Pulpwood*. Pulpwood refers to small diameter trees, typically 3.6 to 6.5 inches diameter at breast height (4.5 feet above the ground), that are usually harvested for manufacturing paper products. Pulpwood is a major industrial forest product in Florida. Harvesting methods include clearcutting, typically from forest plantations on private lands, and to a lesser extent commercial thinnings, in both plantations and natural stands on public and private ownerships. Unlike pre-commercial thinnings, commercial thinnings provide a profit to the forest landowner. In conditions of low pulpwood stumpage prices and high biomass demand, some portion of this pulpwood supply could be allocated to bioenergy production (Perlack, Wright et al. 2005). Annual pulpwood harvests are also derived from the FIA TPO database. We assume that all current pulpwood commercial harvests are available for use in energy production in the supply assessment. Care should be taken not to interpret these results to suggest that all

[3] This 36% of the biomass is based on harvesting every 5th row of trees (20%) plus a selective thinning of 20% of the remaining 80% of the stand (20%*80%=16%), removing a total of 36% of the stand (20%+16%). The harvesting frequency is based on two pre-commercial thinnings, one between 5-10 years of age, and one between 11-15 years of age."

the current pulpwood harvests are available at current pulpwood prices for bioenergy. However, if the less expensive resources in this analysis are used before pulpwood, it is expected that little if any pulpwood will be required to meet demand for the three potential 40 MW facilities. Our results suggest that 3.93, 3.42, and 2.96 TBtu/year from urban wood waste, logging residues, and thinnings are probably available for GRU, JEA, and TAL at prices lower than the closest available pulpwood. In other words, while commercial timber harvests comprise most of the current biomass yields in north Florida, they probably comprise a very small proportion, if any, of the least-cost feedstock mix needed to supply the three 40 MW facilities in the area, assuming each plant requires 3.55 TBtu/year[4] (Figure 2).

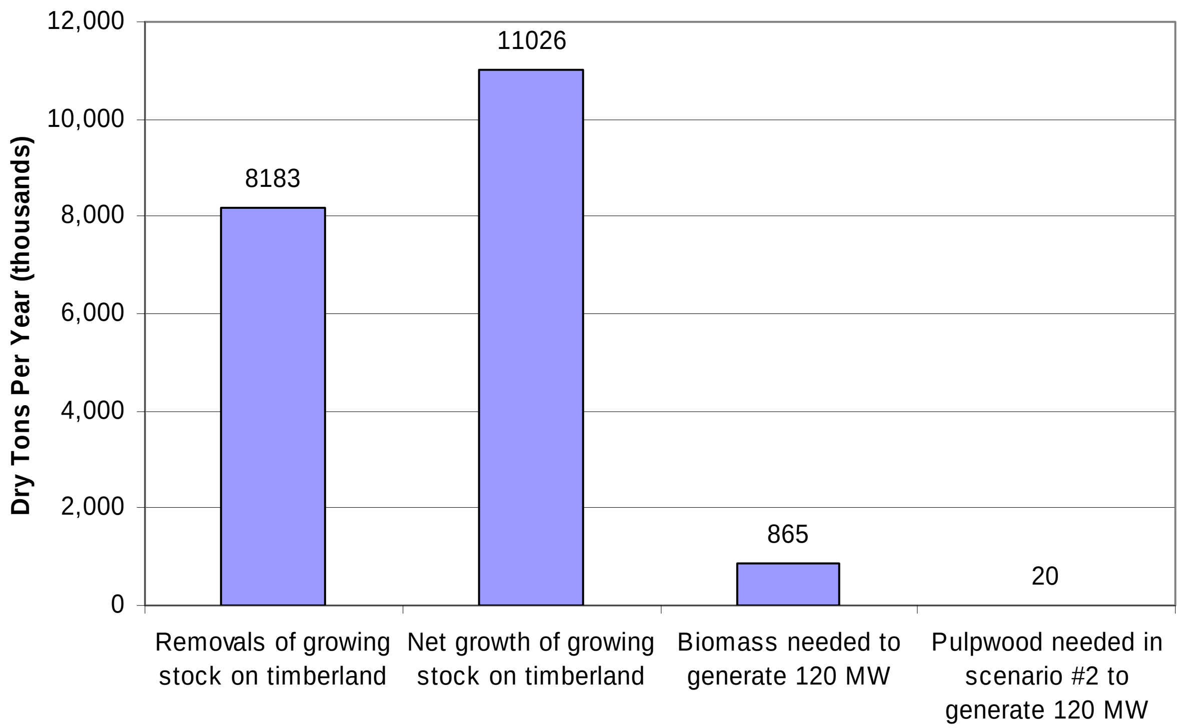

Figure 2. Removals, net growth (growth minus mortality) of commercial growing stock on timberlands in Florida, the total amount of biomass needed to generate 120 MW, and the amount of commercial pulpwood required to generate 120 MW in scenario #2 (described below) for GRU, JEA, and TAL.

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[4] The following Btu calculation for 40 MW was provided by GRU: (8,760 hours)*(.75 pu)*(13,500 Btu/kWh)*(k/1,000)*(40 MW)*(1,000,000/M)*(T/1,000,000,000,000) = 3.55 TBtu.

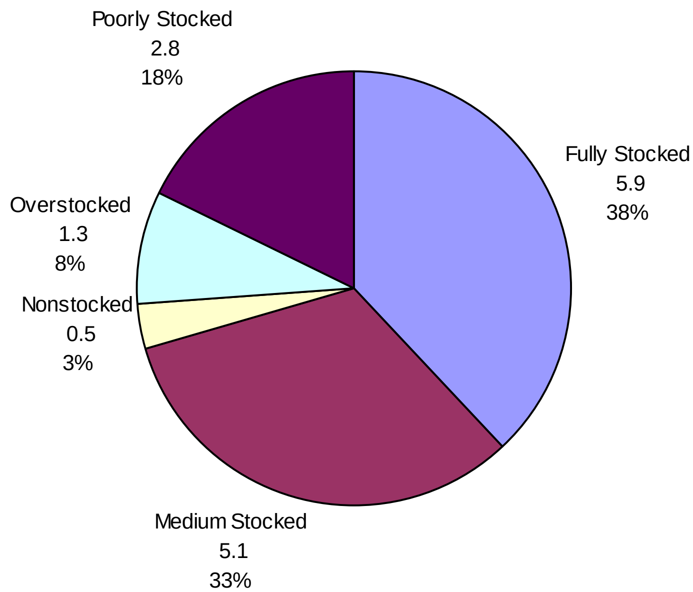


Figure 3. Timberland acres (in percent and million acres) in Florida by stocking class.

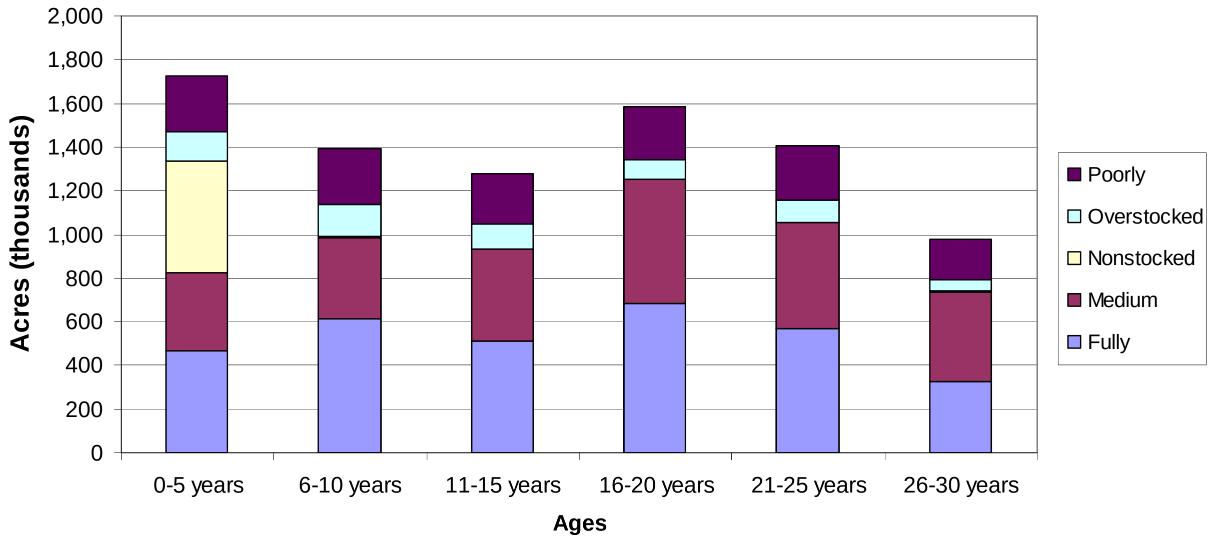


Figure 4. Florida timberland stocking condition by stand age class.

2.2.2. Cost assumptions

In addition to physical availability, information about the resource costs is required to construct supply curves. The delivered cost of woody biomass, as with conventional forest products, can be defined as a sum of procurement, harvest, transportation, and miscellaneous management costs. The cost assumptions described below are summarized in Table 1. These costs are assumed relevant for the 1st Quarter of 2007, when diesel prices are quoted at \$2.12 and \$2.49 per gallon for off-road and highway, respectively.

Procurement cost

"Procurement cost" is the amount paid to gain ownership of a biomass resource. Procurement cost is equivalent to the term "stumpage price" in the forest industry, i.e. the price paid to a timber owner for the right to harvest.

1. *Urban wood wastes*. Urban wood waste handlers in the southeastern US typically pay a "tipping fee" or disposal fee. Tipping fees for urban wood in north Florida are typically about \$20-\$25 green ton^{-1} delivered to a receiving area. This tipping fee translates into a negative procurement cost. However, tipping fees may need to be lowered to ensure that adequate supply is achieved. For this reason, we assume a lower, more

conservative tipping fee of -\$25 dry ton^{-1} (i.e., a cost of negative \$25 dry ton^{-1}), which is equivalent to -\$15 green ton^{-1}.

2. *Logging residues*. Forest plantation owners pay post-harvest site preparation costs of about \$462 ha^{-1} (\$186 acre^{-1}), including raking and piling of logging residues (Smidt, Silveira Folegatti et al. 2005). Removal of logging residues reduces these site preparation costs for replanting plantations (Watson and Stokes 1989). Therefore, logging residues also represent a liability to the resource owner and are currently available at no or low cost (Watson, Ragan et al. 1986). However, some small procurement cost may be required to draw logging residue resources. Therefore, we assume procurement costs of \$3 dry ton^{-1} (\$1.89 green ton^{-1} at 37% moisture content).
3. *Thinnings*. By definition, pre-commercial thinnings are forest thinnings done at a cost to the forest landowner as a stand treatment, rather than as a profitable harvest. However, to ensure the economic availability of forest thinnings, we assume a stumpage price of \$6 dry ton^{-1} (\$3.18 green ton^{-1}), about half that of current stumpage prices.
4. *Pulpwood*. Pulpwood is a more expensive woody biomass resource that can be employed to meet demand beyond that available from waste resources. In an initial analysis, we used south-wide averages of softwood pulpwood stumpage for the 4th Quarter of 2006 of \$13.00 dry ton^{-1}. In this analysis we have increased prices to \$15.21 dry ton^{-1} (\$8.06 green ton^{-1}) as reported by Timber Mart-South for Florida in the 1st Quarter of 2007. This price is at the higher end of the range of stumpage prices seen over the past several years.

Harvest and processing cost

1. *Urban wood wastes*. The cost of processing urban wood waste ranges from \$6.45-\$27.50 green ton^{-1} in a 2006 bid request in Florida (Osceola County Board of County Commissioners 2006). We assume that urban wood waste can be received, screened, and chipped for \$30 dry ton^{-1} (\$18.90 green ton^{-1}).
2. *Logging residues, thinnings, and pulpwood harvests*. To estimate chipping costs, we use Timber-Mart South 1st Q 2007 delivered pulp chip prices (\$30.00 green ton^{-1}) and subtracted average stumpage (\$8.06 green ton^{-1}), harvest (\$11.64 green ton^{-1}), and delivery costs (\$4.65 green ton^{-1}) yielding \$5.74 green ton^{-1}. Adding chipping costs (\$5.74 green ton^{-1}) and reported harvest costs (\$11.64 green ton^{-1}) yields \$33.00 dry

ton^{-1} (\$17.38 green ton^{-1}) for total harvest and processing costs. Harvesting and processing costs would increase on a per-ton basis for low-density stands or for widely dispersed logging residues, or may be less where logging residues are handled and piled along with conventional harvesting operations.

Transportation cost

To calculate transportation cost as a function of road conditions (see Haul Time Calculation below) we estimate transportation cost as a function of transportation time rather than distance. Based on the operational assumptions for each resource shown in Appendix A, we assume one-way transportation costs to be \$3.41, \$3.26, \$2.68 and \$3.00 green ton^{-1} hour^{-1} for urban wood waste, logging residues, pulpwood, and thinnings, respectively. We then double these values to account for return trips with empty loads, and add \$0.86-\$1.25 green ton^{-1} to account for loading and unloading. These values are conservative compared to the hauling rate of \$0.12 green ton^{-1} loaded mile^{-1} reported by Timber Mart-South for the 1th Quarter of 2007. During this period, diesel prices are quoted at \$2.12 and \$2.49 per gallon for off-road and highway, respectively. In Section 2.3.6 Scenario #6 we simulate doubling diesel costs.

See Table 1 for a summary of procurement, harvest and processing, and transportation cost assumptions for the three woody biomass resources included in this study.

Table 1. Summary of cost assumptions for four woody biomass resources. Details used in calculating the costs are shown in the appendix.

	Urban Wood Waste	*Logging Residue*	*Thinnings*	*Pulpwood*
	(\$ dry ton^{-1})			
Procurement cost[a]	-25.00	3.00	6.00	15.21
Harvest and process	30.00	33.00	33.00	33.00
Load and unload	1.98	1.80	1.92	1.72
Two-way haul (per hour)	11.86	10.78	11.54	10.30
Example total delivered cost of a 1 hour haul[b]	18.84	48.58	52.46	60.23

[a]Negative costs for urban wood waste reflect disposal costs, known as “tipping fees”.
[b]Equals the sum of the four cost categories.

Total cost by resource-haul time category

Based on the above cost assumptions, we calculate the delivered cost of each woody biomass resource within a given haul time at fifteen minute increments. We feel this approach most accurately reflects site-specific variation in road networks, speed limits, and geographical constraints. By ranking these resources from lowest cost to highest cost, we estimate the progression of most to least economically available woody biomass resources, accounting for travel time from the point of delivery. Table 2 illustrates how, under these cost assumptions, urban wood waste requiring a one-way haul up to two hours is cheaper than other woody biomass resources with shorter haul times. Transportation costs comprise 10-85% of total delivered costs, depending on the resource type and travel time (Figure 5).

Table 2. The ten least expensive woody biomass resource-haul time categories within a two-hour haul travel time ranked from least to most expensive (costs account for ash content). Costs per unit of energy are derived by dividing price in column three by energy contents (MMBtu/dry ton) shown in the appendix.

Resource	*Haul time Category (minutes)*	*$/dry ton*	*$/MMBtu*
Urban wood waste	0-15	9.94	0.62
Urban wood waste	15-30	12.91	0.81
Urban wood waste	30-45	15.87	0.99
Urban wood waste	45-60	18.83	1.18
Urban wood waste	60-75	21.80	1.36
Urban wood waste	75-90	24.76	1.55
Urban wood waste	90-105	27.73	1.73
Urban wood waste	105-120	30.69	1.92
Logging residues	0-15	40.49	2.60
Thinnings	0-15	43.81	2.71

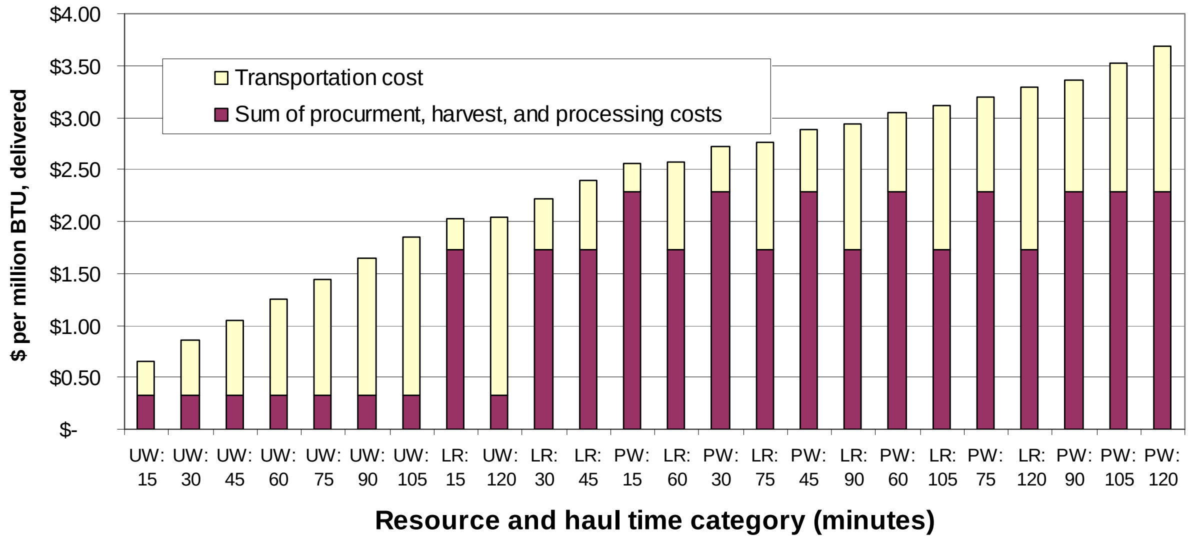


Figure 5. Transportation costs and sum of procurement, harvest, and processing costs of urban wood waste (UW), logging residues (LR), and pulpwood (PW) within a two-hour haul travel time at fifteen minute intervals. Transportation costs include loading and unloading costs.

2.2.3. Haul time calculations and woodshed delineation

When transportation costs are taken into account, more costly resources in close proximity may be economically competitive with cheaper resources further away, and vice versa. As generation capacity and demand for woody biomass intensifies, increasingly expensive and/or distant resources may need to be purchased. We use GIS to calculate travel costs based on existing road infrastructure for each community and to assess the proportion of each county within a given haul time category. We assign speed limits to roads features and divide road lengths by speed limits to estimate travel time. We increase haul time by 25 percent to account for operational delays and rerouting for bridges with gross vehicle weights less than 36 Mg (40 tons), use ArcGIS© Network Analyst to calculate service areas based on travel time, and calculate the proportion of each county in each haul time category in 15 minute intervals. See Langholtz et al. (2006) for more information about the use of ArcGIS© Network Analyst in this analysis.

Woodsheds were delineated for GRU, JEA, and TAL under two different demand conditions. Under one condition, woodsheds were defined as areas within a maximum two-hour one-way haul to each facility, ignoring competing demand among facilities. This allows for the largest woodsheds for each facility, and simulates conditions where only one of the three facilities draws on biomass resources. These woodsheds were used in the development of scenario #1: "Without competing demand", described below. Under a second demand condition, overlapping woodsheds are eliminated, and resources are allocated only to the facility with the shortest haul time. In this scenario woodsheds are smaller, simulating conditions where all three facilities equally draw on surrounding biomass resources. This scenario is used in the development of scenario #2: "With competing demand", and in subsequent scenarios, described below.

2.2.4. Price impacts on pulpwood

Increasing demand for pulpwood will increase pulpwood prices in the short run, depending on how much additional demand is generated. Our original results suggested that, after using urban wood waste (excluding C&D and industrial wood and assumed 60% available) and logging residues (excluding stumps and assumed 60% available) some quantity of pulpwood within a 15-minute haul would be used to meet demand for three 40 MW plants. This increased PW demand was estimated to be about 3.6% of the total pulpwood harvested annually within a two-hour haul of the three plants. However, after including quantities of pre-commercial thinnings for longleaf pine restoration and overstocked stands 5-15 years old (see resource descriptions above), and after using improved generation efficiency assumptions of 3.55 TBtus/year required for each 40 MW plant (rather than our previous assumptions of 4.65 TBtu/year per plant), the amount of pulpwood required to meet demand for three 40 MW plants was reduced to 0.4% of current annual pulpwood harvests within a two-hour haul of the three plants. Assuming an supply elasticity of 0.3 based on the literature, the formula for assessing price increases on the pulpwood market is:

$$\left(1+\left[\frac{\Delta\%}{0.3}\right]\right)*P \tag{1.1}$$

where Δ% is the percent change is pulpwood use and *P* is the stumpage price of pulpwood. Assuming a 0.4% increase in demand in the region, stumpage prices may increase marginally from an average of $15.21 to $15.41 per dry ton. We refer to this scenario #3 as "With price competition". In another scenario of increased price competition, we assume that 25% of the

10.65 TBtu/year required to meet demand for the three 40 MW plants would come from pulpwood. This represents an increase to 2.66 TBtu per year from pulpwood, which is a 3.7% increase in the demand for pulpwood in the region. Using equation (1.1) with this 3.7% demand increase raises stumpage prices to $20.69 per dry ton. We refer to this scenario #4 as “With price competition, 25% PW”.

2.2.5. Other competing demands

The pulpwood resources shown in this report are based on actual harvests, and should not be interpreted as entirely available at current prices due to competition. Similarly, some urban wood waste and logging residues are already dedicated to bioenergy use. Existing users of biomass resources in or near the GRU, JEA, and TAL woodsheds are identified in Table 3. Three of these facilities are identified as “Bioenergy facilities”. Of these three, Ridge Generating Station is probably too far south to draw on resources identified in this analysis, Monticello is currently idle, and Telogia uses a mix of other biomass waste resources not included in this analysis. The extent to which these facilities draw on resources identified in this analysis is not certain and needs further research. However, it is clear that most of the wood waste resources quantified here are not currently being used at these facilities.

Table 3. Existing pulpwood mills and bioenergy plants in and around north central Florida.

Facility	*Woodshed*	*Type*	*Resource consumption*
Ridge Generating Station (40 MW)	(central FL, south of woodsheds)	Bioenergy facility	None, out of woodsheds
Telogia Power Facility (12 MW)	TAL	Bioenergy facility	0-1.0 TBtu/year wood waste
Monticello (idle)	TAL	Bioenergy facility	(idle)
Georgia Pacific (Koch Brunswick Mill)	JEA	Pulpwood mill	Pulpwood
Rayonier Pulp Mill Jesup	(north of JEA)	Pulpwood mill	Pulpwood
P&G Paper Mill, Albany GA	(north of TAL)	Pulpwood mill	Pulpwood
Georgia Pacific, Clyattville GA	TAL/GRU	Pulpwood mill	Pulpwood
Buckeye Florida LLC Cellulose	TAL/GRU	Pulpwood mill	Pulpwood and logging residues
Georgia Pacific, Palatka Pulp Mill	JEA/GRU	Pulpwood mill	Pulpwood
Rayonier Fernandina Beach	JEA	Pulpwood mill	Pulpwood and logging residues
Smurfit Stone, Fernandina	JEA	Pulpwood mill	Pulpwood

The greatest competition for logging residues is likely to be from whole tree harvesting of softwood pulpwood, and the use of tree tops for boiler fuel at pulpmills.   Two of the pulpwood mill facilities identified in Table 3, Buckeye Florida LLC Cellulose and Rayonier Fernandina Beach, are believed to use some portion of logging residues in addition to mill wastes to generate electricity. Thus, we reduced our assumptions of availability of current logging residues from 90% to 60%. These values exclude stumps, leaves, and bark.

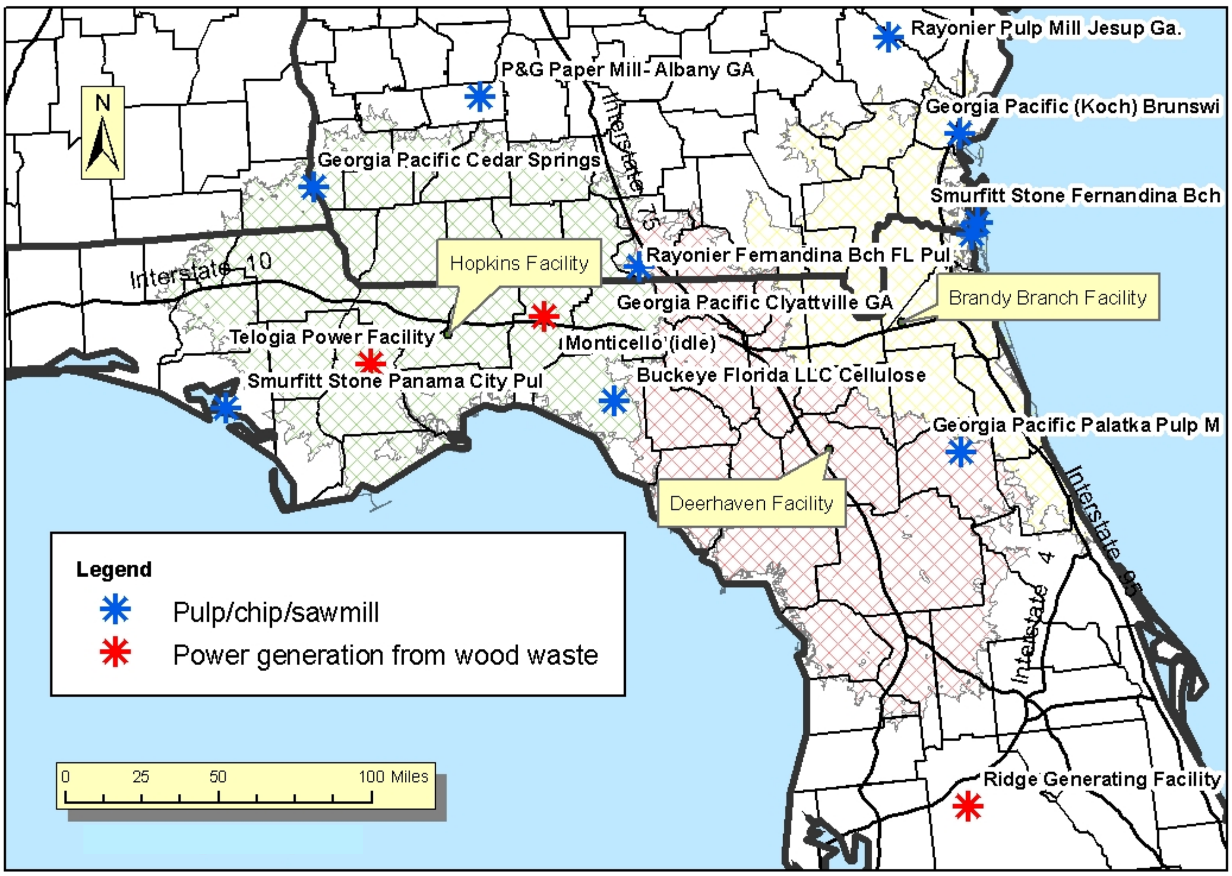


Figure 6. Geographic location of biomass using facilities identified in Table 3.

2.2.6. Supply curve construction

We constructed supply curves using the above information regarding quantities, distribution, and total costs for each woody biomass resource. Assuming homogeneous distribution of woody biomass resources within each county (a necessary assumption given the FIA and US Census source data), we calculate the amount of woody biomass in each haul time category in each county, and then summarize quantities available from each resource-haul time category for all scenarios for each facility. We then assign total delivered costs for each resource-haul time category for the various scenarios, and sort from least to most expensive (see Table 2). Supply curves are then plotted where the x axis is the cumulative total amount of woody biomass with each additional resource-haul time category, and the y axis is delivered price.

2.3. SCENARIOS

The following six scenarios were evaluated for GRU, JEA, and TAL:

2.3.1. Scenario #1: "*Without* competing demand"

In the scenario "*Without* competing demand", woodsheds were defined as areas within a maximum two-hour one-way haul to each facility, ignoring competing demand among facilities. This scenario allows for the largest woodsheds for each facility, and simulates conditions where only one of the three facilities draws on biomass resources. Base case prices are assumed. Two-hour woodsheds for the three facilities without competing demand are shown in Figures 7-9.

2.3.2. Scenario #2: "*With* competing demand"

In the scenario "*With* competing demand", overlapping woodsheds are eliminated, and areas producing biomass are allocated only to the facility with the shortest haul time. In this scenario woodsheds are smaller, simulating conditions where all three facilities compete with each other for resources, and all biomass resources are assumed to go to the facility that provides the lowest transportation cost. Base case prices are assumed. This scenario is used as the baseline for all subsequent scenarios. Two-hour woodsheds for the three facilities with competing demand are shown in Figures 7-10.

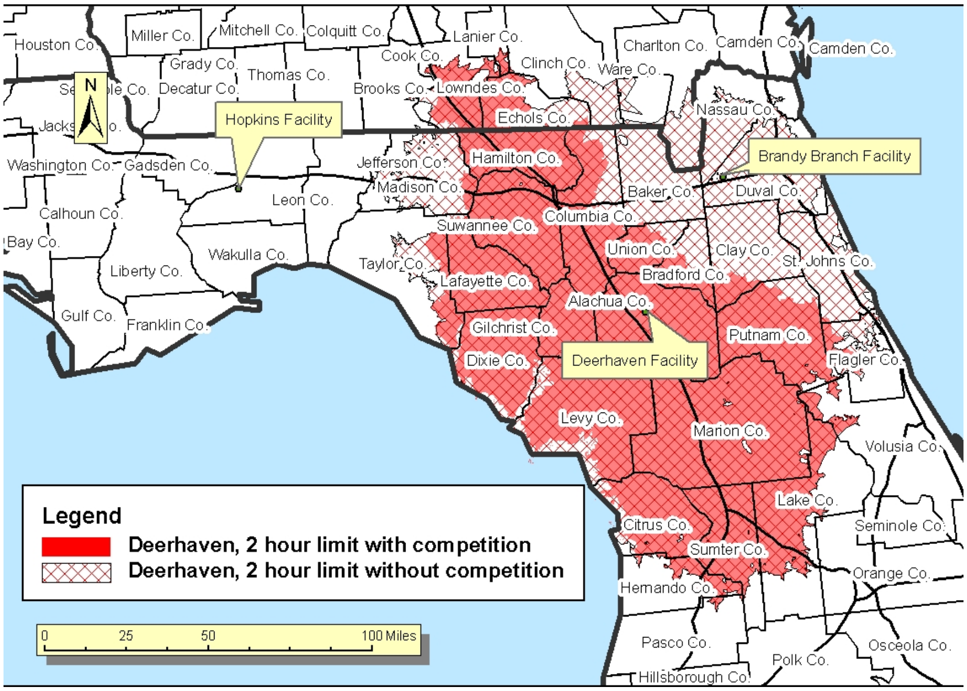


Figure 7. GRU Deerhaven two-hour one-way haul woodsheds with and without competing demand from adjacent facilities.

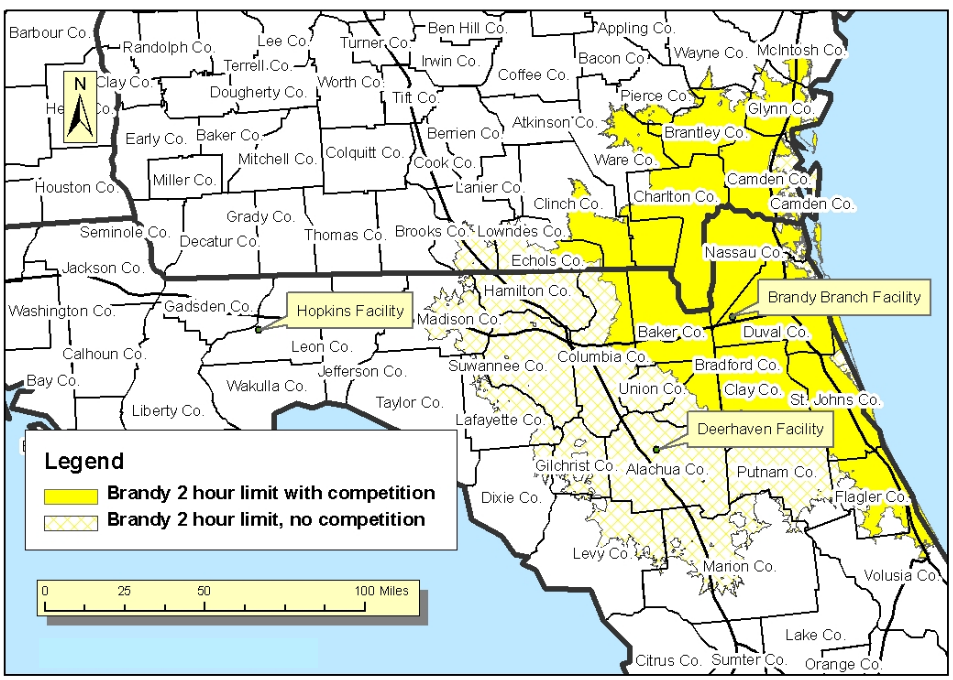


Figure 8. JEA Brandy Branch two-hour one-way haul woodsheds with and without competing demand from adjacent facilities.

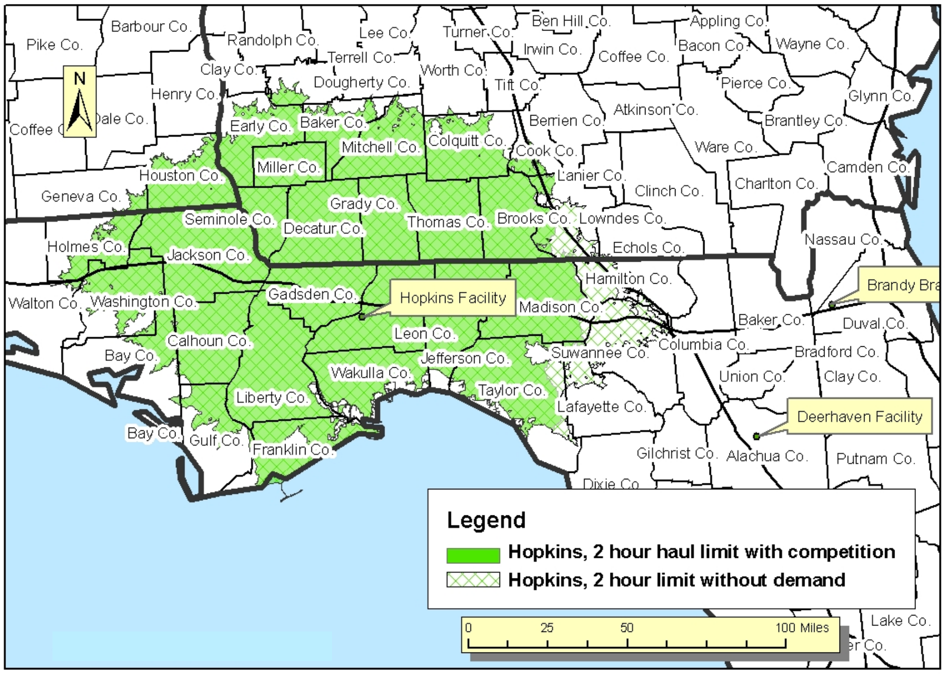


Figure 9. TAL Hopkins two-hour one-way haul woodsheds with and without competing demand from adjacent facilities.

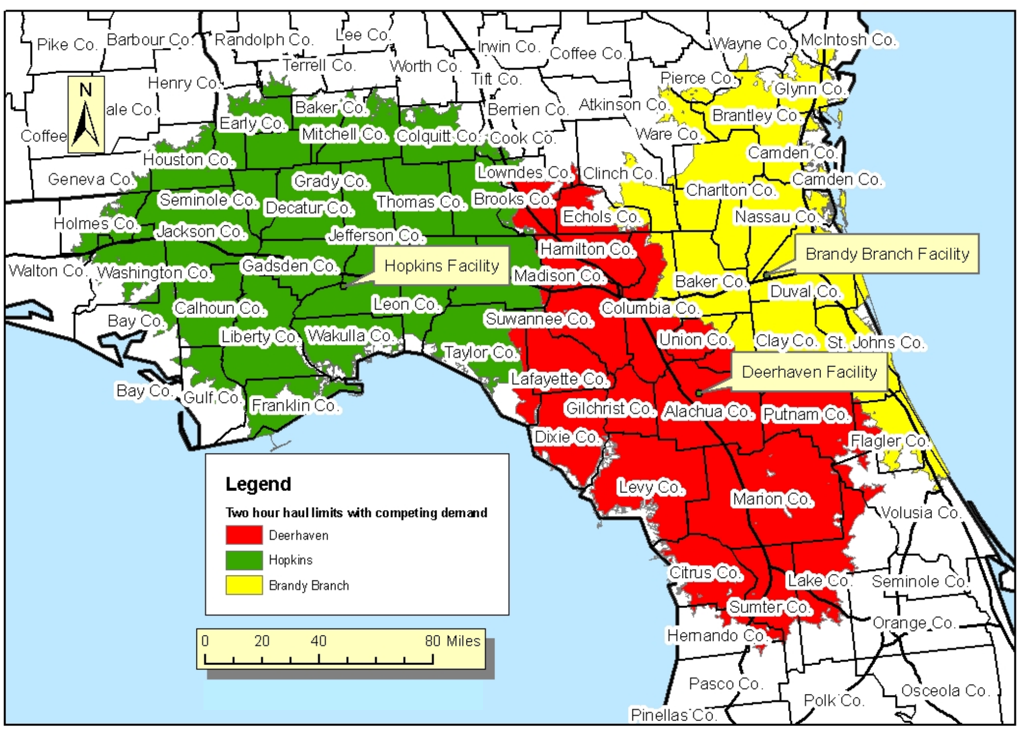


Figure 10. GRU, JEA, and TAL two-hour one-way haul woodsheds with competing demand from adjacent facilities.

2.3.3. Scenario #3: "With price competition"

Building on scenario #2: "With competing demand", the amount of pulpwood included in the least-cost supply needed to achieve 10.65 TBtu per year (for three 40 MW facilities) is used to recalculate higher pulpwood prices. This price impact is generally very low, because 97% of the least cost supply needed to generate 10.65 TBtu per year is comprised of urban wood waste and logging residues, and there is only 0.4% increase in pulpwood demand in the three woodsheds. As described above, in this scenario pulpwood stumpage prices are increased from $15.21 to $15.41 per dry ton.

2.3.4. Scenario #4: "With price competition, 25% pulpwood"

Also building on scenario #2: "With competing demand", this scenario assumes that 25% of the 10.65 TBtu/year required to meet demand for the three 40 MW plants comes from pulpwood. This represents an increase to 2.66 TBtu per year from pulpwood, which is a 3.7% increase in the production of pulpwood in the three woodsheds. Using equation (1.1), this increases stumpage prices to $20.69 per dry ton. This scenario is simulated by excluding less expensive resources until pulpwood is required to provide at least 25% of the 3.55 TBtu per year at each facility.

2.3.5. Scenario #5: "One-hour haul radius with price competition"

Again building on scenario #2: "With competing demand", this scenario additionally constrains resources to those within a one-hour one-way haul time radius. Because the woodsheds are smaller, the least-cost biomass resources are fewer, as urban wood waste and logging residues beyond a one-hour haul are excluded. Under this constraint, the amount of pulpwood used to generate three 40 MW facilities is increased to 12% of the required 10.65 TBtu/year, equivalent to 1.8% of current pulpwood harvests in the three woodsheds. As with scenario #3: "With price competition", pulpwood prices are increased to account for increased pulpwood demand in this scenario. Equation (1.1) is used to project a stumpage price increase to $17.34 per dry ton. The one-hour one-way haul radius woodsheds can be compared with the two-hour one-way haul radius woodsheds in Figure 11.

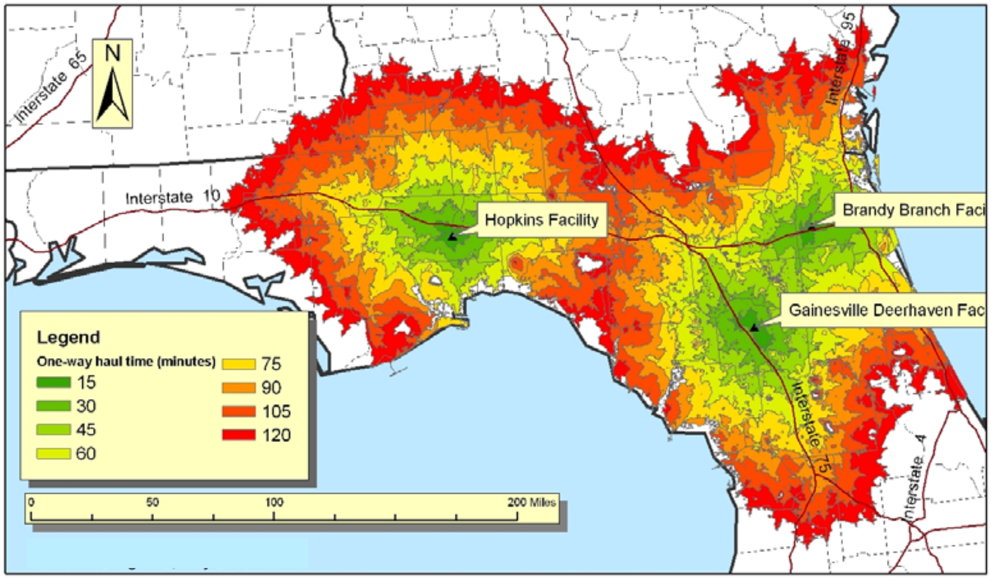


Figure 11. GRU, JEA, and TAL woodsheds with competing demand from adjacent facilities showing one-way haul times in fifteen minute increments.

2.3.6. Scenario #6: "With competing demand, doubling diesel costs"

This scenario is the same a Scenario #2: "With competing demand" with the addition that diesel fuel costs are doubled. The diesel fuel costs are assumed to be 30% of harvest and processing costs, load and unload costs, and transportation costs. Thus, by increasing these three costs 30% we simulate a scenario in which the price of diesel is doubled.

2.4. Results of the five scenarios

Results of the analysis for each of the five scenarios for the three facilities follows:

2.4.1. GRU Deerhaven facility

Table 4. Results for scenario #1, "Without competing demand" for the GRU Deerhaven facility.

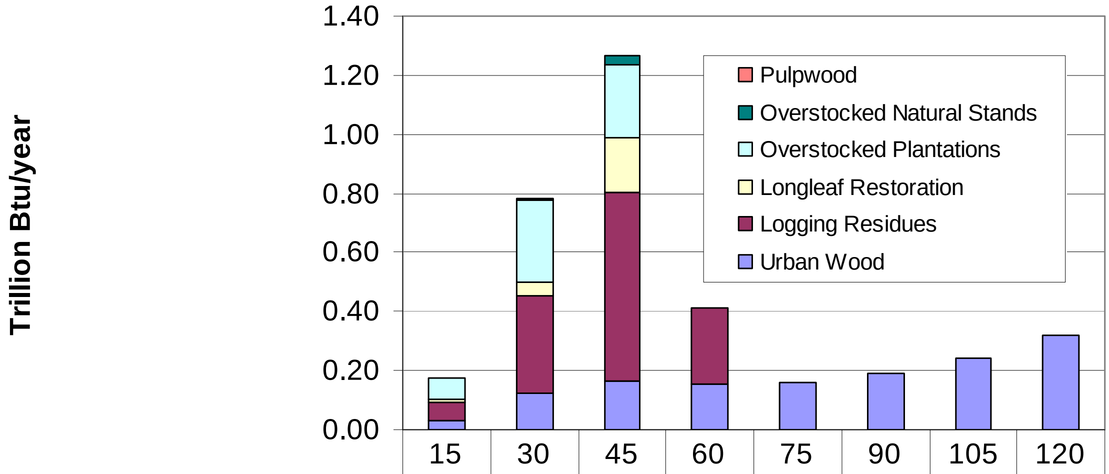
Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,940	245	0.03	0.03	0.62
Urban wood, 15-30 min.	8,234	1,040	0.12	0.15	0.81
Urban wood, 30-45 min.	10,989	1,387	0.16	0.32	0.99
Urban wood, 45-60 min.	12,563	1,586	0.19	0.50	1.18
Urban wood, 60-75 min.	18,550	2,342	0.28	0.78	1.36
Urban wood, 75-90 min.	30,171	3,809	0.45	1.23	1.55
Urban wood, 90-105 min.	49,735	6,280	0.74	1.97	1.73
Urban wood, 105-120 min.	48,581	6,134	0.73	2.70	1.92
Logging residues, 0-15 min.	4,234	325	0.07	2.76	2.60
Longleaf restoration, 0-15 min.	554	42	0.01	2.77	2.71
Overstocked natural, 0-15 min.	0	0	0.00	2.77	2.71
Overstocked plantation, 0-15 min.	4,650	351	0.07	2.84	2.71
Logging residues, 15-30 min.	21,092	1,617	0.33	3.17	2.77
Longleaf restoration, 15-30 min.	3,157	238	0.05	3.22	2.89
Overstocked natural, 15-30 min.	488	37	0.01	3.23	2.89
Overstocked plantation, 15-30 min.	18,621	1,405	0.28	3.50	2.89
Logging residues, 30-45 min.	41,858	3,210	0.65	4.16	2.94
Longleaf restoration, 30-45 min.	12,599	951	0.19	4.35	3.07
Overstocked natural, 30-45 min.	2,244	169	0.03	4.38	3.07
Overstocked plantation, 30-45 min.	16,227	1,225	0.24	4.62	3.07
Logging residues, 45-60 min.	54,362	4,169	0.85	5.47	3.12
Pulpwood, 0-15 min.	17,344	1,169	0.28	5.75	3.23
Longleaf restoration, 45-60 min.	22,662	1,710	0.34	6.09	3.25
Overstocked natural, 45-60 min.	3,582	270	0.05	6.14	3.25
Overstocked plantation, 45-60 min.	8,354	631	0.13	6.27	3.25
Logging residues, 60-75 min.	66,525	5,101	1.04	7.31	3.29
Pulpwood, 15-30 min.	89,876	6,056	1.45	8.76	3.39
Longleaf restoration, 60-75 min.	24,090	1,818	0.36	9.12	3.43
Overstocked natural, 60-75 min.	2,586	195	0.04	9.16	3.43
Overstocked plantation, 60-75 min.	12,011	907	0.18	9.34	3.43
Logging residues, 75-90 min.	85,595	6,564	1.33	10.67	3.46
Pulpwood, 30-45 min.	189,327	12,758	3.06	13.73	3.55
Longleaf restoration, 75-90 min.	31,238	2,358	0.47	14.20	3.60
Overstocked natural, 75-90 min.	3,054	230	0.05	14.24	3.60
Overstocked plantation, 75-90 min.	17,050	1,287	0.26	14.50	3.60
Logging residues, 90-105 min.	109,715	8,413	1.71	16.21	3.64
Pulpwood, 45-60 min.	258,096	17,392	4.17	20.38	3.71
Longleaf restoration, 90-105 min.	38,341	2,894	0.58	20.95	3.78
Overstocked natural, 90-105 min.	2,644	200	0.04	20.99	3.78
Overstocked plantation, 90-105	17,843	1,347	0.27	21.26	3.78

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
min.					
Logging residues, 105-120 min.	119,649	9,175	1.86	23.12	3.81
Pulpwood, 60-75 min.	318,336	21,451	5.14	28.27	3.87
Longleaf restoration, 105-120 min.	36,308	2,740	0.54	28.81	3.96
Overstocked natural, 105-120 min.	3,109	235	0.05	28.86	3.96
Overstocked plantation, 105-120 min.	12,674	957	0.19	29.05	3.96
Pulpwood, 75-90 min.	399,572	26,925	6.45	35.50	4.03
Pulpwood, 90-105 min.	463,063	31,204	7.48	42.98	4.19
Pulpwood, 105-120 min.	489,745	33,002	7.91	50.89	4.34

Table 5. Results for scenario #2, "With competing demand" for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,934	244	0.03	0.03	0.62
Urban wood, 15-30 min.	8,214	1,037	0.12	0.15	0.81
Urban wood, 30-45 min.	10,881	1,374	0.16	0.31	0.99
Urban wood, 45-60 min.	10,310	1,302	0.15	0.47	1.18
Urban wood, 60-75 min.	10,623	1,341	0.16	0.63	1.36
Urban wood, 75-90 min.	12,922	1,632	0.19	0.82	1.55
Urban wood, 90-105 min.	16,054	2,027	0.24	1.06	1.73
Urban wood, 105-120 min.	21,471	2,711	0.32	1.38	1.92
Logging residues, 0-15 min.	4,222	324	0.07	1.44	2.60
Longleaf restoration, 0-15 min.	552	42	0.01	1.45	2.71
Overstocked natural, 0-15 min.	0	0	0.00	1.45	2.71
Overstocked plantation, 0-15 min.	4,637	350	0.07	1.52	2.71
Logging residues, 15-30 min.	21,111	1,619	0.33	1.85	2.77
Longleaf restoration, 15-30 min.	3,166	239	0.05	1.90	2.89
Overstocked natural, 15-30 min.	498	38	0.01	1.91	2.89
Overstocked plantation, 15-30 min.	18,555	1,400	0.28	2.18	2.89
Logging residues, 30-45 min.	41,033	3,146	0.64	2.82	2.94
Longleaf restoration, 30-45 min.	12,567	948	0.19	3.01	3.07
Overstocked natural, 30-45 min.	2,245	169	0.03	3.05	3.07
Overstocked plantation, 30-45 min.	16,288	1,229	0.24	3.29	3.07
Logging residues, 45-60 min.	41,327	3,169	0.64	3.93	3.12
Pulpwood, 0-15 min.	17,294	1,165	0.28	4.21	3.23
Longleaf restoration, 45-60 min.	20,690	1,562	0.31	4.52	3.25
Overstocked natural, 45-60 min.	3,158	238	0.05	4.57	3.25
Overstocked plantation, 45-60 min.	8,032	606	0.12	4.69	3.25
Logging residues, 60-75 min.	46,367	3,555	0.72	5.41	3.29
Pulpwood, 15-30 min.	90,025	6,066	1.45	6.87	3.39
Longleaf restoration, 60-75 min.	18,472	1,394	0.28	7.15	3.43
Overstocked natural, 60-75 min.	2,086	157	0.03	7.18	3.43
Overstocked plantation, 60-75 min.	11,330	855	0.17	7.35	3.43
Logging residues, 75-90 min.	58,186	4,462	0.91	8.25	3.46
Pulpwood, 30-45 min.	185,973	12,532	3.00	11.26	3.55
Longleaf restoration, 75-90 min.	23,188	1,750	0.35	11.61	3.60
Overstocked natural, 75-90 min.	2,347	177	0.04	11.64	3.60
Overstocked plantation, 75-90 min.	16,093	1,215	0.24	11.88	3.60
Logging residues, 90-105 min.	56,461	4,329	0.88	12.76	3.64
Pulpwood, 45-60 min.	195,505	13,174	3.16	15.92	3.71
Longleaf restoration, 90-105 min.	28,733	2,169	0.43	16.35	3.78
Overstocked natural, 90-105 min.	1,719	130	0.03	16.38	3.78
Overstocked plantation, 90-105 min.	15,078	1,138	0.23	16.60	3.78
Logging residues, 105-120 min.	34,098	2,615	0.53	17.13	3.81
Pulpwood, 60-75 min.	210,978	14,217	3.41	20.54	3.87
Longleaf restoration, 105-120 min.	27,653	2,087	0.41	20.96	3.96
Overstocked natural, 105-120 min.	1,769	134	0.03	20.98	3.96
Overstocked plantation, 105-120	6,549	494	0.10	21.08	3.96

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
min.					
Pulpwood, 75-90 min.	266,829	17,980	4.31	25.39	4.03
Pulpwood, 90-105 min.	234,913	15,830	3.79	29.19	4.19
Pulpwood, 105-120 min.	126,116	8,498	2.04	31.22	4.34



	15	30	45	60	75	90	105	120
Pulpwood								
Overstocked Natural Stands	0.00	0.01	0.03					
Overstocked Plantations	0.07	0.28	0.24					
Longleaf Restoration	0.01	0.05	0.19					
Logging Residues	0.07	0.33	0.64	0.3				
Urban Wood	0.03	0.12	0.16	0.15	0.16	0.19	0.24	0.32

Figure 12. Biomass use profile up to 3.55 TBtu/year (40 MW) for the GRU Deerhaven facility under scenario #2, “With competing demand”.

Table 6. Results for scenario #3, "With price competition" for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,934	244	0.03	0.03	0.62
Urban wood, 15-30 min.	8,214	1,037	0.12	0.15	0.81
Urban wood, 30-45 min.	10,881	1,374	0.16	0.31	0.99
Urban wood, 45-60 min.	10,310	1,302	0.15	0.47	1.18
Urban wood, 60-75 min.	10,623	1,341	0.16	0.63	1.36
Urban wood, 75-90 min.	12,922	1,632	0.19	0.82	1.55
Urban wood, 90-105 min.	16,054	2,027	0.24	1.06	1.73
Urban wood, 105-120 min.	21,471	2,711	0.32	1.38	1.92
Logging residues, 0-15 min.	4,222	324	0.07	1.44	2.60
Longleaf restoration, 0-15 min.	552	42	0.01	1.45	2.71
Overstocked natural, 0-15 min.	0	0	0.00	1.45	2.71
Overstocked plantation, 0-15 min.	4,637	350	0.07	1.52	2.71
Logging residues, 15-30 min.	21,111	1,619	0.33	1.85	2.77
Longleaf restoration, 15-30 min.	3,166	239	0.05	1.90	2.89
Overstocked natural, 15-30 min.	498	38	0.01	1.91	2.89
Overstocked plantation, 15-30 min.	18,555	1,400	0.28	2.18	2.89
Logging residues, 30-45 min.	1,033	3,146	0.64	2.82	2.94
Longleaf restoration, 30-45 min.	12,567	948	0.19	3.01	3.07
Overstocked natural, 30-45 min.	2,245	169	0.03	3.05	3.07
Overstocked plantation, 30-45 min.	16,288	1,229	0.24	3.29	3.07
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Longleaf restoration, 45-60 min.	20,690	1,562	0.31	4.52	3.25
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Overstocked plantation, 45-60 min.	8,032	606	0.12	4.69	3.25
Logging residues, 60-75 min.	46,367	3,555	0.72	5.41	3.29
Pulpwood, 15-30 min.	90,025	6,066	1.45	6.87	3.40
Longleaf restoration, 60-75 min.	18,472	1,394	0.28	7.15	3.43
Overstocked natural, 60-75 min.	2,086	157	0.03	7.18	3.43
Overstocked plantation, 60-75 min.	11,330	855	0.17	7.35	3.43
Logging residues, 75-90 min.	58,186	4,462	0.91	8.25	3.46
Pulpwood, 30-45 min.	185,973	12,532	3.00	11.26	3.56
Longleaf restoration, 75-90 min.	23,188	1,750	0.35	11.61	3.60
Overstocked natural, 75-90 min.	2,347	177	0.04	11.64	3.60
Overstocked plantation, 75-90 min.	16,093	1,215	0.24	11.88	3.60
Logging residues, 90-105 min.	56,461	4,329	0.88	12.76	3.64
Pulpwood, 45-60 min.	195,505	13,174	3.16	15.92	3.72
Longleaf restoration, 90-105 min.	28,733	2,169	0.43	16.35	3.78
Overstocked natural, 90-105 min.	1,719	130	0.03	16.38	3.78
Overstocked plantation, 90-105 min.	15,078	1,138	0.23	16.60	3.78
Logging residues, 105-120 min.	34,098	2,615	0.53	17.13	3.81
Pulpwood, 60-75 min.	210,978	14,217	3.41	20.54	3.88
Longleaf restoration, 105-120 min.	27,653	2,087	0.41	20.96	3.96
Overstocked natural, 105-120 min.	1,769	134	0.03	20.98	3.96
Overstocked plantation, 105-120 min.	6,549	494	0.10	21.08	3.96

Resource/haul time category	Dry tons recoverable	Truckloads	TBtu/year recoverable	Cumulative TBtu/year recoverable	Price ($/MMBtu)
Pulpwood, 75-90 min.	266,829	17,980	4.31	25.39	4.04
Pulpwood, 90-105 min.	234,913	15,830	3.79	29.19	4.20
Pulpwood, 105-120 min.	126,116	8,498	2.04	31.22	4.36

Table 7. Results for scenario #4, "With price competition, 25% pulpwood" for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,934	244	0.03	0.03	0.62
Urban wood, 15-30 min.	8,214	1,037	0.12	0.15	0.81
Urban wood, 30-45 min.	10,881	1,374	0.16	0.31	0.99
Urban wood, 45-60 min.	10,310	1,302	0.15	0.47	1.18
Urban wood, 60-75 min.	10,623	1,341	0.16	0.63	1.36
Urban wood, 75-90 min.	12,922	1,632	0.19	0.82	1.55
Urban wood, 90-105 min.	16,054	2,027	0.24	1.06	1.73
Urban wood, 105-120 min.	21,471	2,711	0.32	1.38	1.92
Logging residues, 0-15 min.	4,222	324	0.07	1.44	2.60
Longleaf restoration, 0-15 min.	552	42	0.01	1.45	2.71
Overstocked plantation, 0-15 min.	4,637	350	0.07	1.52	2.71
Overstocked natural, 0-15 min.	0	0	0.00	1.52	2.71
Logging residues, 15-30 min.	21,111	1,619	0.33	1.85	2.77
Longleaf restoration, 15-30 min.	3,166	239	0.05	1.90	2.89
Overstocked plantation, 15-30 min.	18,555	1,400	0.28	2.18	2.89
Overstocked natural, 15-30 min.	498	38	0.01	2.18	2.89
Pulpwood, 0-15 min.	17,294	1,165	0.28	2.46	3.57
Pulpwood, 15-30 min.	90,025	6,066	1.45	3.92	3.73
Longleaf restoration, 90-105 min.	28,733	2,169	0.43	4.35	3.78
Overstocked plantation, 90-105 min.	15,078	1,138	0.23	4.58	3.78
Overstocked natural, 90-105 min.	1,719	130	0.03	4.60	3.78
Logging residues, 105-120 min.	34,098	2,615	0.53	5.13	3.81
Pulpwood, 30-45 min.	185,973	12,532	3.00	8.14	3.89
Longleaf restoration, 105-120 min.	27,653	2,087	0.41	8.55	3.96
Overstocked plantation, 105-120 min.	6,549	494	0.10	8.65	3.96
Overstocked natural, 105-120 min.	1,769	134	0.03	8.68	3.96
Pulpwood, 45-60 min.	195,505	13,174	3.16	11.83	4.05
Pulpwood, 60-75 min.	210,978	14,217	3.41	15.24	4.21
Pulpwood, 75-90 min.	266,829	17,980	4.31	19.55	4.36
Pulpwood, 90-105 min.	234,913	15,830	3.79	23.35	4.52
Pulpwood, 105-120 min.	126,116	8,498	2.04	25.39	4.68

Table 8. Results for scenario #5, "One-hour haul radius with price competition" for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,934	244	0.03	0.03	0.62
Urban wood, 15-30 min.	8,214	1,037	0.12	0.15	0.81
Urban wood, 30-45 min.	10,881	1,374	0.16	0.31	0.99
Urban wood, 45-60 min.	10,310	1,302	0.15	0.47	1.18
Logging residues, 0-15 min.	4,222	324	0.07	0.53	2.60
Longleaf restoration, 0-15 min.	552	42	0.01	0.54	2.71
Overstocked natural, 0-15 min.	0	0	0.00	0.54	2.71
Overstocked plantation, 0-15 min.	4,637	350	0.07	0.61	2.71
Logging residues, 15-30 min.	21,111	1,619	0.33	0.94	2.77
Longleaf restoration, 15-30 min.	3,166	239	0.05	0.99	2.89
Overstocked natural, 15-30 min.	498	38	0.01	1.00	2.89
Overstocked plantation, 15-30 min.	18,555	1,400	0.28	1.27	2.89
Logging residues, 30-45 min.	41,033	3,146	0.64	1.91	2.94
Longleaf restoration, 30-45 min.	12,567	948	0.19	2.10	3.07
Overstocked natural, 30-45 min.	2,245	169	0.03	2.13	3.07
Overstocked plantation, 30-45 min.	16,288	1,229	0.24	2.38	3.07
Logging residues, 45-60 min.	41,327	3,169	0.64	3.02	3.12
Longleaf restoration, 45-60 min.	20,690	1,562	0.31	3.33	3.25
Overstocked natural, 45-60 min.	3,158	238	0.05	3.38	3.25
Overstocked plantation, 45-60 min.	8,032	606	0.12	3.50	3.25
Pulpwood, 0-15 min.	17,294	1,165	0.28	3.78	3.36
Pulpwood, 15-30 min.	90,025	6,066	1.45	5.24	3.52
Pulpwood, 30-45 min.	185,973	12,532	3.00	8.24	3.68
Pulpwood, 45-60 min.	195,505	13,174	3.16	11.40	3.84

Table 9. Results for scenario #6, "With competing demand, doubling diesel costs" for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,934	244	0.03	0.03	1.28
Urban wood, 15-30 min.	8,214	1,037	0.12	0.15	1.52
Urban wood, 30-45 min.	10,881	1,374	0.16	0.31	1.76
Urban wood, 45-60 min.	10,310	1,302	0.15	0.47	2.00
Urban wood, 60-75 min.	10,623	1,341	0.16	0.63	2.24
Urban wood, 75-90 min.	12,922	1,632	0.19	0.82	2.48
Urban wood, 90-105 min.	16,054	2,027	0.24	1.06	2.72
Urban wood, 105-120 min.	21,471	2,711	0.32	1.38	2.96
Logging residues, 0-15 min.	4,222	324	0.07	1.44	3.32
Overstocked natural, 0-15 min.	0	0	0.00	1.44	3.32
Overstocked plantation, 0-15 min.	4,637	350	0.07	1.51	3.32
Overstocked natural, 15-30 min.	498	38	0.01	1.52	3.50
Overstocked plantation, 15-30 min.	18,555	1,400	0.28	1.80	3.50
Logging residues, 15-30 min.	21,111	1,619	0.33	2.13	3.55
Longleaf restoration, 0-15 min.	552	42	0.01	2.14	3.62
Overstocked natural, 30-45 min.	2,245	169	0.03	2.17	3.68
Overstocked plantation, 30-45 min.	16,288	1,229	0.24	2.42	3.68
Logging residues, 30-45 min.	41,033	3,146	0.64	3.05	3.77
Overstocked natural, 45-60 min.	3,158	238	0.05	3.10	3.86
Overstocked plantation, 45-60 min.	8,032	606	0.12	3.22	3.86
Pulpwood, 0-15 min.	17,294	1,165	0.28	3.50	3.92
Longleaf restoration, 15-30 min.	3,166	239	0.05	3.55	3.98
Logging residues, 45-60 min.	41,327	3,169	0.64	4.19	4.00
Overstocked natural, 60-75 min.	2,086	157	0.03	4.22	4.04
Overstocked plantation, 60-75 min.	11,330	855	0.17	4.39	4.04
Pulpwood, 15-30 min.	90,025	6,066	1.45	5.85	4.13
Overstocked natural, 75-90 min.	2,347	177	0.04	5.88	4.22
Overstocked plantation, 75-90 min.	16,093	1,215	0.24	6.13	4.22
Logging residues, 60-75 min.	46,367	3,555	0.72	6.85	4.22
Pulpwood, 30-45 min.	185,973	12,532	3.00	9.85	4.34
Longleaf restoration, 30-45 min.	12,567	948	0.19	10.04	4.34
Overstocked natural, 90-105 min.	1,719	130	0.03	10.07	4.40
Overstocked plantation, 90-105 min.	15,078	1,138	0.23	10.29	4.40
Logging residues, 75-90 min.	58,186	4,462	0.91	11.20	4.45
Pulpwood, 45-60 min.	195,505	13,174	3.16	14.36	4.54
Overstocked natural, 105-120 min.	1,769	134	0.03	14.38	4.57
Overstocked plantation, 105-120 min.	6,549	494	0.10	14.48	4.57
Logging residues, 90-105 min.	56,461	4,329	0.88	15.36	4.67
Longleaf restoration, 45-60 min.	20,690	1,562	0.31	15.67	4.69
Pulpwood, 60-75 min.	210,978	14,217	3.41	19.08	4.75
Logging residues, 105-120 min.	34,098	2,615	0.53	19.61	4.89
Pulpwood, 75-90 min.	266,829	17,980	4.31	23.92	4.95
Longleaf restoration, 60-75 min.	18,472	1,394	0.28	24.20	5.05

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Pulpwood, 90-105 min.	234,913	15,830	3.79	27.99	5.16
Pulpwood, 105-120 min.	126,116	8,498	2.04	30.03	5.37
Longleaf restoration, 75-90 min.	23,188	1,750	0.35	30.38	5.41
Longleaf restoration, 90-105 min.	28,733	2,169	0.43	30.81	5.77
Longleaf restoration, 105-120 min.	27,653	2,087	0.41	31.22	6.12

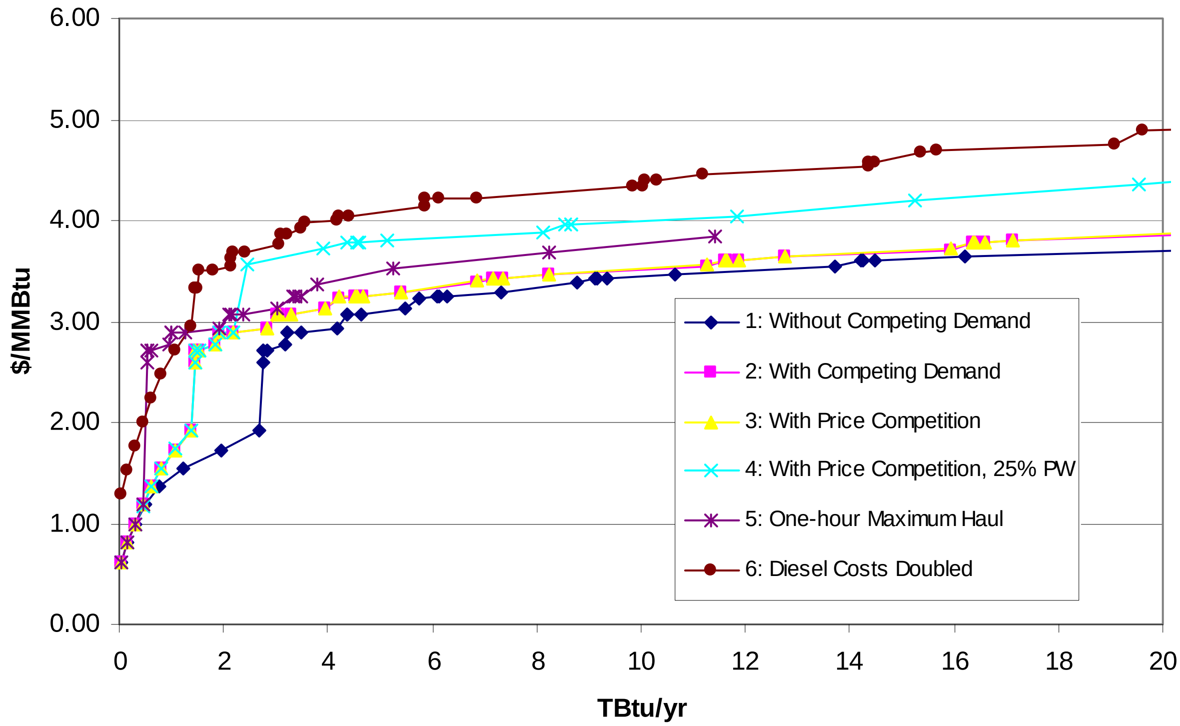


Figure 13. Results of the six scenarios for the GRU Deerhaven facility.

2.4.2. JEA Brandy Branch facility

Table 10. Results for scenario #1, "Without competing demand" for the JEA Brandy Branch facility.

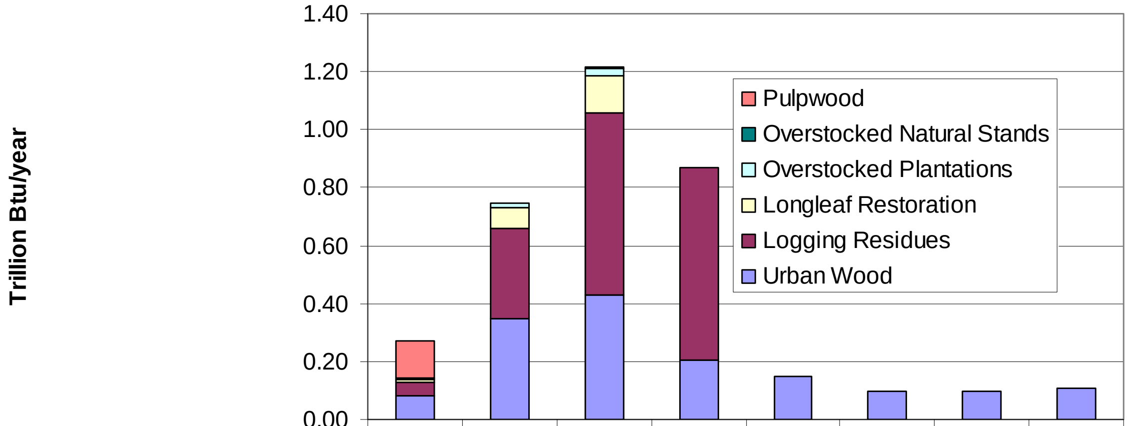
Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,621	710	0.08	0.08	0.62
Urban wood, 15-30 min.	23,481	2,965	0.35	0.43	0.81
Urban wood, 30-45 min.	30,887	3,900	0.46	0.90	0.99
Urban wood, 45-60 min.	19,436	2,454	0.29	1.19	1.18
Urban wood, 60-75 min.	19,939	2,518	0.30	1.48	1.36
Urban wood, 75-90 min.	17,539	2,215	0.26	1.74	1.55
Urban wood, 90-105 min.	18,765	2,369	0.28	2.02	1.73
Urban wood, 105-120 min.	18,460	2,331	0.28	2.30	1.92
Logging residues, 0-15 min.	2,913	223	0.05	2.35	2.60
Longleaf restoration, 0-15 min.	708	53	0.01	2.36	2.71
Overstocked natural, 0-15 min.	0	0	0.00	2.36	2.71
Overstocked plantation, 0-15 min.	131	10	0.00	2.36	2.71
Logging residues, 15-30 min.	20,645	1,583	0.32	2.68	2.77
Longleaf restoration, 15-30 min.	4,655	351	0.07	2.75	2.89
Overstocked natural, 15-30 min.	22	2	0.00	2.75	2.89
Overstocked plantation, 15-30 min.	1,174	89	0.02	2.77	2.89
Logging residues, 30-45 min.	43,286	3,319	0.67	3.44	2.94
Longleaf restoration, 30-45 min.	8,761	661	0.13	3.57	3.07
Overstocked natural, 30-45 min.	203	15	0.00	3.58	3.07
Overstocked plantation, 30-45 min.	2,065	156	0.03	3.61	3.07
Logging residues, 45-60 min.	63,573	4,875	0.99	4.60	3.12
Pulpwood, 0-15 min.	10,863	732	0.18	4.77	3.23
Longleaf restoration, 45-60 min.	10,026	757	0.15	4.92	3.25
Overstocked natural, 45-60 min.	1,733	131	0.03	4.95	3.25
Overstocked plantation, 45-60 min.	7,089	535	0.11	5.06	3.25
Logging residues, 60-75 min.	72,249	5,540	1.13	6.18	3.29
Pulpwood, 15-30 min.	88,515	5,965	1.43	7.61	3.39
Longleaf restoration, 60-75 min.	13,918	1,050	0.21	7.82	3.43
Overstocked natural, 60-75 min.	5,275	398	0.08	7.90	3.43
Overstocked plantation, 60-75 min.	16,414	1,239	0.25	8.15	3.43
Logging residues, 75-90 min.	81,146	6,222	1.26	9.41	3.46
Pulpwood, 30-45 min.	194,454	13,103	3.14	12.55	3.55
Longleaf restoration, 75-90 min.	16,654	1,257	0.25	12.80	3.60
Overstocked natural, 75-90 min.	8,018	605	0.12	12.92	3.60
Overstocked plantation, 75-90 min.	24,747	1,868	0.37	13.29	3.60
Logging residues, 90-105 min.	109,042	8,361	1.70	14.99	3.64
Pulpwood, 45-60 min.	285,914	19,266	4.62	19.61	3.71
Longleaf restoration, 90-105 min.	24,286	1,833	0.36	19.97	3.78
Overstocked natural, 90-105 min.	5,485	414	0.08	20.06	3.78
Overstocked plantation, 90-105 min.	24,792	1,871	0.37	20.43	3.78
Logging residues, 105-120 min.	115,450	8,853	1.80	22.23	3.81
Pulpwood, 60-75 min.	332,864	22,430	5.38	27.60	3.87
Longleaf restoration, 105-120 min.	31,232	2,357	0.47	28.07	3.96

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Overstocked natural, 105-120 min.	2,364	178	0.04	28.11	3.96
Overstocked plantation, 105-120 min.	14,842	1,120	0.22	28.33	3.96
Pulpwood, 75-90 min.	382,602	25,782	6.18	34.51	4.03
Pulpwood, 90-105 min.	505,145	34,039	8.16	42.67	4.19
Pulpwood, 105-120 min.	500,092	33,699	8.08	50.75	4.34

Table 11. Results for scenario #2, "With competing demand" for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,617	709	0.08	0.08	0.62
Urban wood, 15-30 min.	23,421	2,957	0.35	0.43	0.81
Urban wood, 30-45 min.	28,870	3,645	0.43	0.86	0.99
Urban wood, 45-60 min.	13,697	1,729	0.20	1.07	1.18
Urban wood, 60-75 min.	10,096	1,275	0.15	1.22	1.36
Urban wood, 75-90 min.	6,536	825	0.10	1.32	1.55
Urban wood, 90-105 min.	6,407	809	0.10	1.41	1.73
Urban wood, 105-120 min.	7,026	887	0.10	1.52	1.92
Logging residues, 0-15 min.	2,855	219	0.04	1.56	2.60
Longleaf restoration, 0-15 min.	695	52	0.01	1.57	2.71
Overstocked natural, 0-15 min.	0	0	0.00	1.57	2.71
Overstocked plantation, 0-15 min.	130	10	0.00	1.57	2.71
Logging residues, 15-30 min.	19,972	1,532	0.31	1.89	2.77
Longleaf restoration, 15-30 min.	4,505	340	0.07	1.95	2.89
Overstocked natural, 15-30 min.	17	1	0.00	1.95	2.89
Overstocked plantation, 15-30 min.	1,160	88	0.02	1.97	2.89
Logging residues, 30-45 min.	40,363	3,095	0.63	2.60	2.94
Longleaf restoration, 30-45 min.	8,277	625	0.12	2.72	3.07
Overstocked natural, 30-45 min.	176	13	0.00	2.73	3.07
Overstocked plantation, 30-45 min.	1,944	147	0.03	2.76	3.07
Logging residues, 45-60 min.	42,788	3,281	0.67	3.42	3.12
Pulpwood, 0-15 min.	10,545	711	0.17	3.59	3.23
Longleaf restoration, 45-60 min.	7,780	587	0.12	3.71	3.25
Overstocked natural, 45-60 min.	982	74	0.01	3.72	3.25
Overstocked plantation, 45-60 min.	4,213	318	0.06	3.79	3.25
Logging residues, 60-75 min.	37,594	2,883	0.59	4.37	3.29
Pulpwood, 15-30 min.	84,998	5,728	1.37	5.75	3.39
Longleaf restoration, 60-75 min.	6,784	512	0.10	5.85	3.43
Overstocked natural, 60-75 min.	1,910	144	0.03	5.88	3.43
Overstocked plantation, 60-75 min.	2,782	210	0.04	5.92	3.43
Logging residues, 75-90 min.	34,152	2,619	0.53	6.45	3.46
Pulpwood, 30-45 min.	181,780	12,249	2.94	9.39	3.55
Longleaf restoration, 75-90 min.	6,728	508	0.10	9.49	3.60
Overstocked natural, 75-90 min.	3,281	248	0.05	9.54	3.60
Overstocked plantation, 75-90 min.	1,206	91	0.02	9.55	3.60
Logging residues, 90-105 min.	50,948	3,907	0.79	10.35	3.64
Pulpwood, 45-60 min.	195,478	13,172	3.16	13.51	3.71
Longleaf restoration, 90-105 min.	7,853	593	0.12	13.62	3.78
Overstocked natural, 90-105 min.	2,109	159	0.03	13.66	3.78

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Overstocked plantation, 90-105 min.	1,630	123	0.02	13.68	3.78
Logging residues, 105-120 min.	51,108	3,919	0.80	14.48	3.81
Pulpwood, 60-75 min.	165,121	11,127	2.67	17.14	3.87
Longleaf restoration, 105-120 min.	8,305	627	0.12	17.27	3.96
Overstocked natural, 105-120 min.	527	40	0.01	17.28	3.96
Overstocked plantation, 105-120 min.	1,075	81	0.02	17.29	3.96
Pulpwood, 75-90 min.	147,268	9,924	2.38	19.67	4.03
Pulpwood, 90-105 min.	221,766	14,944	3.58	23.25	4.19
Pulpwood, 105-120 min.	220,596	14,865	3.56	26.82	4.34



	15	30	45	60	75	90	105	120
Pulpwood	0.13							
Overstocked Natural Stands	0.00	0.00	0.00					
Overstocked Plantations	0.00	0.02	0.03					
Longleaf Restoration	0.01	0.07	0.12					
Logging Residues	0.04	0.31	0.63	0.67				
Urban Wood	0.08	0.35	0.43	0.20	0.15	0.10	0.10	0.10

One-way haul (minutes)

Figure 14. Biomass use profile up to 3.55 TBtu/year (40 MW) for the JEA Brandy Branch facility under scenario #2, "With competing demand".

Table 12. Results for scenario #3, "With price competition" for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,617	709	0.08	0.08	0.62
Urban wood, 15-30 min.	23,421	2,957	0.35	0.43	0.81
Urban wood, 30-45 min.	28,870	3,645	0.43	0.86	0.99
Urban wood, 45-60 min.	13,697	1,729	0.20	1.07	1.18
Urban wood, 60-75 min.	10,096	1,275	0.15	1.22	1.36
Urban wood, 75-90 min.	6,536	825	0.10	1.32	1.55
Urban wood, 90-105 min.	6,407	809	0.10	1.41	1.73
Urban wood, 105-120 min.	7,026	887	0.10	1.52	1.92
Logging residues, 0-15 min.	2,855	219	0.04	1.56	2.60
Longleaf restoration, 0-15 min.	695	52	0.01	1.57	2.71
Overstocked natural, 0-15 min.	130	10	0.00	1.57	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	1.57	2.71
Logging residues, 15-30 min.	19,972	1,532	0.31	1.89	2.77
Longleaf restoration, 15-30 min.	4,505	340	0.07	1.95	2.89
Overstocked natural, 15-30 min.	1,160	88	0.02	1.97	2.89
Overstocked plantation, 15-30 min.	17	1	0.00	1.97	2.89
Logging residues, 30-45 min.	40,363	3,095	0.63	2.60	2.94
Longleaf restoration, 30-45 min.	8,277	625	0.12	2.72	3.07
Overstocked natural, 30-45 min.	1,944	147	0.03	2.75	3.07
Overstocked plantation, 30-45 min.	176	13	0.00	2.76	3.07
Logging residues, 45-60 min.	42,788	3,281	0.67	3.42	3.12
Pulpwood, 0-15 min.	10,545	711	0.17	3.59	3.25
Longleaf restoration, 45-60 min.	7,780	587	0.12	3.71	3.25
Overstocked natural, 45-60 min.	4,213	318	0.06	3.77	3.25
Overstocked plantation, 45-60 min.	982	74	0.01	3.79	3.25
Logging residues, 60-75 min.	37,594	2,883	0.59	4.37	3.29
Pulpwood, 15-30 min.	84,998	5,728	1.37	5.75	3.40
Longleaf restoration, 60-75 min.	6,784	512	0.10	5.85	3.43
Overstocked natural, 60-75 min.	2,782	210	0.04	5.89	3.43
Overstocked plantation, 60-75 min.	1,910	144	0.03	5.92	3.43
Logging residues, 75-90 min.	34,152	2,619	0.53	6.45	3.46
Pulpwood, 30-45 min.	181,780	12,249	2.94	9.39	3.56
Longleaf restoration, 75-90 min.	6,728	508	0.10	9.49	3.60
Overstocked natural, 75-90 min.	1,206	91	0.02	9.51	3.60
Overstocked plantation, 75-90 min.	3,281	248	0.05	9.55	3.60
Logging residues, 90-105 min.	50,948	3,907	0.79	10.35	3.64
Pulpwood, 45-60 min.	195,478	13,172	3.16	13.51	3.72
Longleaf restoration, 90-105 min.	7,853	593	0.12	13.62	3.78
Overstocked natural, 90-105 min.	1,630	123	0.02	13.65	3.78
Overstocked plantation, 90-105 min.	2,109	159	0.03	13.68	3.78

Resource/haul time category	Dry tons recoverable	Truckloads	TBtu/year recoverable	Cumulative TBtu/year recoverable	Price ($/MMBtu)
Logging residues, 105-120 min.	51,108	3,919	0.80	14.48	3.81
Pulpwood, 60-75 min.	165,121	11,127	2.67	17.14	3.88
Longleaf restoration, 105-120 min.	8,305	627	0.12	17.27	3.96
Overstocked natural, 105-120 min.	1,075	81	0.02	17.28	3.96
Overstocked plantation, 105-120 min.	527	40	0.01	17.29	3.96
Pulpwood, 75-90 min.	147,268	9,924	2.38	19.67	4.04
Pulpwood, 90-105 min.	221,766	14,944	3.58	23.25	4.20
Pulpwood, 105-120 min.	220,596	14,865	3.56	26.82	4.36

Table 13. Results for scenario #4, "With price competition, 25% pulpwood" for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,617	709	0.08	0.08	0.62
Urban wood, 15-30 min.	23,421	2,957	0.35	0.43	0.81
Urban wood, 30-45 min.	28,870	3,645	0.43	0.86	0.99
Urban wood, 45-60 min.	13,697	1,729	0.20	1.07	1.18
Urban wood, 60-75 min.	10,096	1,275	0.15	1.22	1.36
Urban wood, 75-90 min.	6,536	825	0.10	1.32	1.55
Urban wood, 90-105 min.	6,407	809	0.10	1.41	1.73
Urban wood, 105-120 min.	7,026	887	0.10	1.52	1.92
Logging residues, 0-15 min.	2,855	219	0.04	1.56	2.60
Longleaf restoration, 0-15 min.	695	52	0.01	1.57	2.71
Overstocked plantation, 0-15 min.	130	10	0.00	1.57	2.71
Overstocked natural, 0-15 min.	0	0	0.00	1.57	2.71
Logging residues, 15-30 min.	19,972	1,532	0.31	1.89	2.77
Longleaf restoration, 15-30 min.	4,505	340	0.07	1.95	2.89
Overstocked plantation, 15-30 min.	1,160	88	0.02	1.97	2.89
Overstocked natural, 15-30 min.	17	1	0.00	1.97	2.89
Logging residues, 30-45 min.	40,363	3,095	0.63	2.60	2.94
Pulpwood, 0-15 min.	10,545	711	0.17	2.77	3.57
Pulpwood, 15-30 min.	84,998	5,728	1.37	4.14	3.73
Longleaf restoration, 90-105 min.	7,853	593	0.12	4.26	3.78
Overstocked plantation, 90-105 min.	1,630	123	0.02	4.29	3.78
Overstocked natural, 90-105 min.	2,109	159	0.03	4.32	3.78
Logging residues, 105-120 min.	51,108	3,919	0.80	5.11	3.81
Pulpwood, 30-45 min.	181,780	12,249	2.94	8.05	3.89
Longleaf restoration, 105-120 min.	8,305	627	0.12	8.17	3.96
Overstocked plantation, 105-120 min.	1,075	81	0.02	8.19	3.96
Overstocked natural, 105-120 min.	527	40	0.01	8.20	3.96
Pulpwood, 45-60 min.	195,478	13,172	3.16	11.36	4.05
Pulpwood, 60-75 min.	165,121	11,127	2.67	14.02	4.21
Pulpwood, 75-90 min.	147,268	9,924	2.38	16.40	4.36
Pulpwood, 90-105 min.	221,766	14,944	3.58	19.98	4.52
Pulpwood, 105-120 min.	220,596	14,865	3.56	23.55	4.68

Table 14. Results for scenario #5, "One-hour haul radius with price competition" for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,617	709	0.08	0.08	0.62
Urban wood, 15-30 min.	23,421	2,957	0.35	0.43	0.81
Urban wood, 30-45 min.	28,870	3,645	0.43	0.86	0.99
Urban wood, 45-60 min.	13,697	1,729	0.20	1.07	1.18
Logging residues, 0-15 min.	2,855	219	0.04	1.11	2.60
Longleaf restoration, 0-15 min.	695	52	0.01	1.12	2.71
Overstocked natural, 0-15 min.	130	10	0.00	1.13	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	1.13	2.71
Logging residues, 15-30 min.	19,972	1,532	0.31	1.44	2.77
Longleaf restoration, 15-30 min.	4,505	340	0.07	1.50	2.89
Overstocked natural, 15-30 min.	1,160	88	0.02	1.52	2.89
Overstocked plantation, 15-30 min.	17	1	0.00	1.52	2.89
Logging residues, 30-45 min.	40,363	3,095	0.63	2.15	2.94
Longleaf restoration, 30-45 min.	8,277	625	0.12	2.27	3.07
Overstocked natural, 30-45 min.	1,944	147	0.03	2.30	3.07
Overstocked plantation, 30-45 min.	176	13	0.00	2.31	3.07
Logging residues, 45-60 min.	42,788	3,281	0.67	2.97	3.12
Longleaf restoration, 45-60 min.	7,780	587	0.12	3.09	3.25
Overstocked natural, 45-60 min.	4,213	318	0.06	3.15	3.25
Overstocked plantation, 45-60 min.	982	74	0.01	3.17	3.25
Pulpwood, 0-15 min.	10,545	711	0.17	3.34	3.36
Pulpwood, 15-30 min.	84,998	5,728	1.37	4.71	3.52
Pulpwood, 30-45 min.	181,780	12,249	2.94	7.65	3.68
Pulpwood, 45-60 min.	195,478	13,172	3.16	10.81	3.84

Table 15. Results for scenario #6, "With competing demand, doubling diesel costs" for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	5,617	709	0.08	0.08	1.28
Urban wood, 15-30 min.	23,421	2,957	0.35	0.43	1.52
Urban wood, 30-45 min.	28,870	3,645	0.43	0.86	1.76
Urban wood, 45-60 min.	13,697	1,729	0.20	1.07	2.00
Urban wood, 60-75 min.	10,096	1,275	0.15	1.22	2.24
Urban wood, 75-90 min.	6,536	825	0.10	1.32	2.48
Urban wood, 90-105 min.	6,407	809	0.10	1.41	2.72
Urban wood, 105-120 min.	7,026	887	0.10	1.52	2.96
Logging residues, 0-15 min.	2,855	219	0.04	1.56	3.32
Overstocked natural, 0-15 min.	0	0	0.00	1.56	3.32
Overstocked plantation, 0-15 min.	130	10	0.00	1.56	3.32
Overstocked natural, 15-30 min.	17	1	0.00	1.56	3.50
Overstocked plantation, 15-30 min.	1,160	88	0.02	1.58	3.50
Logging residues, 15-30 min.	19,972	1,532	0.31	1.89	3.55
Longleaf restoration, 0-15 min.	695	52	0.01	1.90	3.62
Overstocked natural, 30-45 min.	176	13	0.00	1.91	3.68
Overstocked plantation, 30-45 min.	1,944	147	0.03	1.93	3.68
Logging residues, 30-45 min.	40,363	3,095	0.63	2.56	3.77
Overstocked natural, 45-60 min.	982	74	0.01	2.58	3.86
Overstocked plantation, 45-60 min.	4,213	318	0.06	2.64	3.86
Pulpwood, 0-15 min.	10,545	711	0.17	2.81	3.92
Longleaf restoration, 15-30 min.	4,505	340	0.07	2.88	3.98
Logging residues, 45-60 min.	42,788	3,281	0.67	3.55	4.00
Overstocked natural, 60-75 min.	1,910	144	0.03	3.57	4.04
Overstocked plantation, 60-75 min.	2,782	210	0.04	3.62	4.04
Pulpwood, 15-30 min.	84,998	5,728	1.37	4.99	4.13
Overstocked natural, 75-90 min.	3,281	248	0.05	5.04	4.22
Overstocked plantation, 75-90 min.	1,206	91	0.02	5.06	4.22
Logging residues, 60-75 min.	37,594	2,883	0.59	5.64	4.22
Pulpwood, 30-45 min.	181,780	12,249	2.94	8.58	4.34
Longleaf restoration, 30-45 min.	8,277	625	0.12	8.70	4.34
Overstocked natural, 90-105 min.	2,109	159	0.03	8.73	4.40
Overstocked plantation, 90-105 min.	1,630	123	0.02	8.76	4.40
Logging residues, 75-90 min.	34,152	2,619	0.53	9.29	4.45
Pulpwood, 45-60 min.	195,478	13,172	3.16	12.45	4.54
Overstocked natural, 105-120 min.	527	40	0.01	12.46	4.57
Overstocked plantation, 105-120 min.	1,075	81	0.02	12.47	4.57
Logging residues, 90-105 min.	50,948	3,907	0.79	13.27	4.67
Longleaf restoration, 45-60 min.	7,780	587	0.12	13.38	4.69
Pulpwood, 60-75 min.	165,121	11,127	2.67	16.05	4.75
Logging residues, 105-120 min.	51,108	3,919	0.80	16.85	4.89
Pulpwood, 75-90 min.	147,268	9,924	2.38	19.23	4.95
Longleaf restoration, 60-75 min.	6,784	512	0.10	19.33	5.05

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Pulpwood, 90-105 min.	221,766	14,944	3.58	22.91	5.16
Pulpwood, 105-120 min.	220,596	14,865	3.56	26.47	5.37
Longleaf restoration, 75-90 min.	6,728	508	0.10	26.57	5.41
Longleaf restoration, 90-105 min.	7,853	593	0.12	26.69	5.77
Longleaf restoration, 105-120 min.	8,305	627	0.12	26.82	6.12

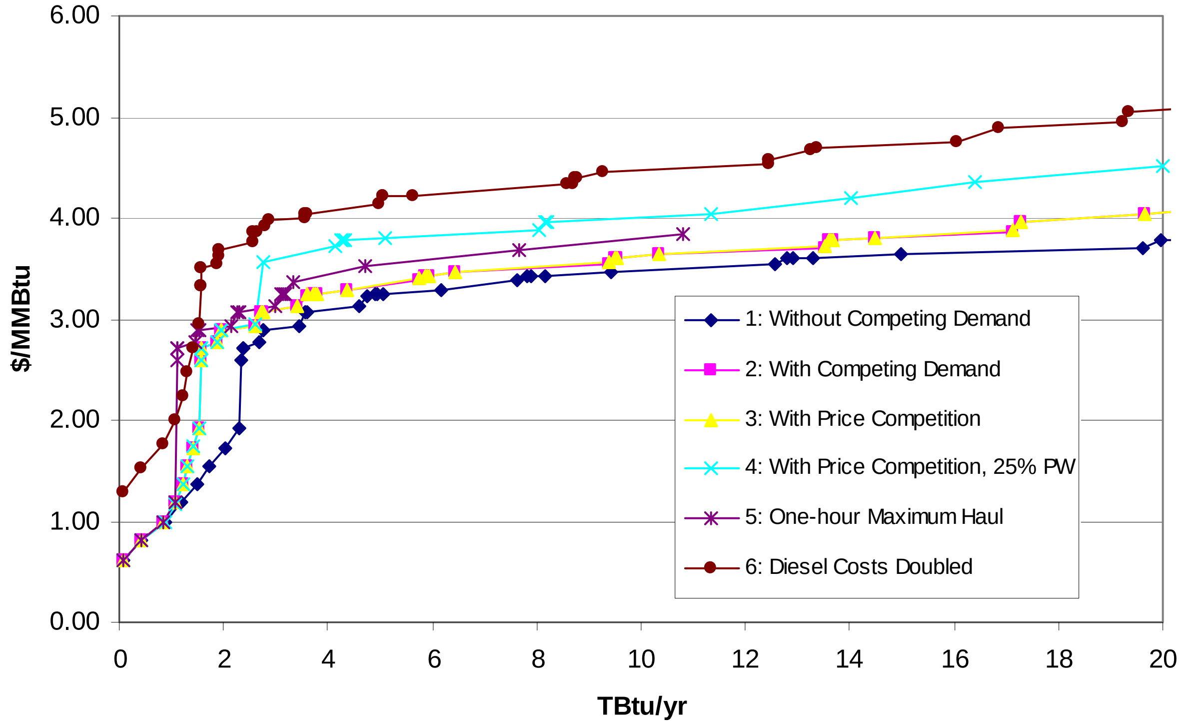


Figure 15. Results of the six scenarios for the JEA Brandy Branch facility.

2.4.3. TAL Hopkins facility

Table 16. Results for scenario #1, "Without competing demand" for the TAL Hopkins facility.

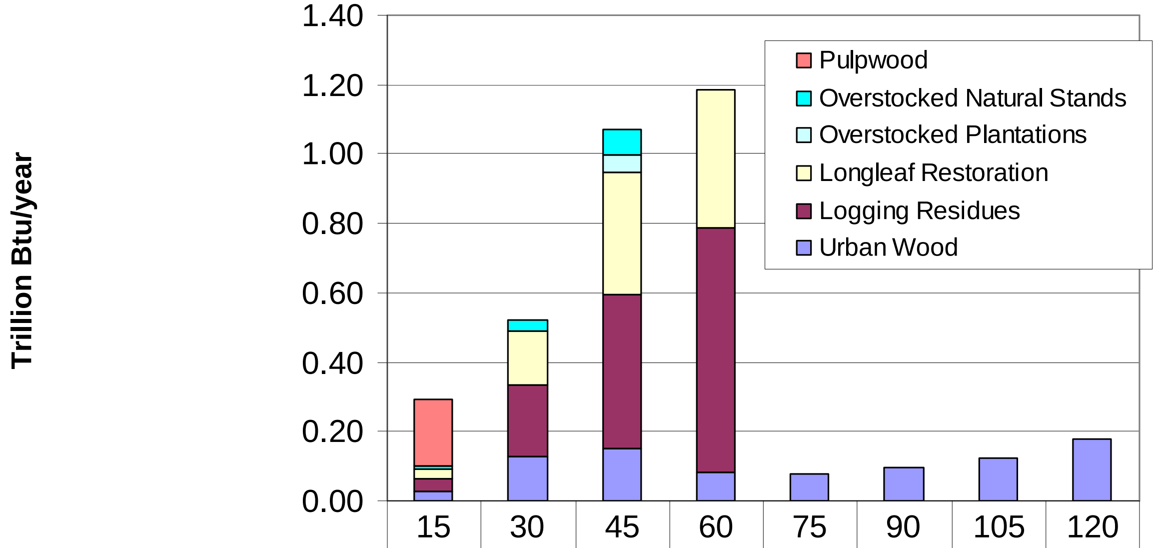
Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,778	224	0.03	0.03	0.62
Urban wood, 15-30 min.	8,452	1,067	0.13	0.15	0.81
Urban wood, 30-45 min.	10,057	1,270	0.15	0.30	0.99
Urban wood, 45-60 min.	5,430	686	0.08	0.38	1.18
Urban wood, 60-75 min.	5,324	672	0.08	0.46	1.36
Urban wood, 75-90 min.	6,523	824	0.10	0.56	1.55
Urban wood, 90-105 min.	8,813	1,113	0.13	0.69	1.73
Urban wood, 105-120 min.	15,947	2,014	0.24	0.93	1.92
Logging residues, 0-15 min.	2,408	185	0.04	0.97	2.60
Longleaf restoration, 0-15 min.	1,952	147	0.03	1.00	2.71
Overstocked natural, 0-15 min.	352	27	0.01	1.00	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	1.00	2.71
Logging residues, 15-30 min.	13,279	1,018	0.21	1.21	2.77
Longleaf restoration, 15-30 min.	10,274	775	0.15	1.36	2.89
Overstocked natural, 15-30 min.	2,194	166	0.03	1.40	2.89
Overstocked plantation, 15-30 min.	6	0	0.00	1.40	2.89
Logging residues, 30-45 min.	28,628	2,195	0.45	1.84	2.94
Longleaf restoration, 30-45 min.	23,419	1,767	0.35	2.19	3.07
Overstocked natural, 30-45 min.	4,958	374	0.07	2.27	3.07
Overstocked plantation, 30-45 min.	3,389	256	0.05	2.32	3.07
Logging residues, 45-60 min.	45,244	3,469	0.70	3.02	3.12
Pulpwood, 0-15 min.	12,010	809	0.19	3.22	3.23
Longleaf restoration, 45-60 min.	34,914	2,635	0.52	3.74	3.25
Overstocked natural, 45-60 min.	6,006	453	0.09	3.83	3.25
Overstocked plantation, 45-60 min.	7,592	573	0.11	3.95	3.25
Logging residues, 60-75 min.	70,437	5,401	1.10	5.04	3.29
Pulpwood, 15-30 min.	64,328	4,335	1.04	6.08	3.39
Longleaf restoration, 60-75 min.	33,176	2,504	0.50	6.58	3.43
Overstocked natural, 60-75 min.	10,007	755	0.15	6.73	3.43
Overstocked plantation, 60-75 min.	10,016	756	0.15	6.88	3.43
Logging residues, 75-90 min.	91,333	7,004	1.42	8.30	3.46
Pulpwood, 30-45 min.	127,047	8,561	2.05	10.36	3.55
Longleaf restoration, 75-90 min.	27,844	2,101	0.42	10.77	3.60
Overstocked natural, 75-90 min.	10,343	781	0.16	10.93	3.60
Overstocked plantation, 75-90 min.	9,665	729	0.14	11.07	3.60
Logging residues, 90-105 min.	99,374	7,620	1.55	12.62	3.64
Pulpwood, 45-60 min.	183,571	12,370	2.97	15.59	3.71
Longleaf restoration, 90-105 min.	27,069	2,043	0.41	15.99	3.78
Overstocked natural, 90-105 min.	9,640	728	0.14	16.14	3.78
Overstocked plantation, 90-105 min.	21,979	1,659	0.33	16.47	3.78
Logging residues, 105-120 min.	110,738	8,491	1.73	18.19	3.81
Pulpwood, 60-75 min.	297,265	20,031	4.80	22.99	3.87
Longleaf restoration, 105-120 min.	33,583	2,535	0.50	23.50	3.96

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Overstocked natural, 105-120 min.	5,760	435	0.09	23.58	3.96
Overstocked plantation, 105-120 min.	34,417	2,598	0.52	24.10	3.96
Pulpwood, 75-90 min.	408,392	27,520	6.60	30.70	4.03
Pulpwood, 90-105 min.	461,662	31,109	7.46	38.16	4.19
Pulpwood, 105-120 min.	506,120	34,105	8.18	46.33	4.34

Table 17. Results for scenario #2, "With competing demand" for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,777	224	0.03	0.03	0.62
Urban wood, 15-30 min.	8,459	1,068	0.13	0.15	0.81
Urban wood, 30-45 min.	10,046	1,268	0.15	0.30	0.99
Urban wood, 45-60 min.	5,435	686	0.08	0.38	1.18
Urban wood, 60-75 min.	5,329	673	0.08	0.46	1.36
Urban wood, 75-90 min.	6,524	824	0.10	0.56	1.55
Urban wood, 90-105 min.	8,280	1,045	0.12	0.68	1.73
Urban wood, 105-120 min.	12,010	1,516	0.18	0.86	1.92
Logging residues, 0-15 min.	2,408	185	0.04	0.90	2.60
Longleaf restoration, 0-15 min.	1,950	147	0.03	0.93	2.71
Overstocked natural, 0-15 min.	352	27	0.01	0.94	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	0.94	2.71
Logging residues, 15-30 min.	13,284	1,019	0.21	1.14	2.77
Longleaf restoration, 15-30 min.	10,281	776	0.15	1.30	2.89
Overstocked natural, 15-30 min.	2,194	166	0.03	1.33	2.89
Overstocked plantation, 15-30 min.	6	0	0.00	1.33	2.89
Logging residues, 30-45 min.	28,621	2,195	0.45	1.78	2.94
Longleaf restoration, 30-45 min.	23,409	1,767	0.35	2.13	3.07
Overstocked natural, 30-45 min.	4,958	374	0.07	2.20	3.07
Overstocked plantation, 30-45 min.	3,388	256	0.05	2.25	3.07
Logging residues, 45-60 min.	45,242	3,469	0.70	2.96	3.12
Pulpwood, 0-15 min.	12,006	809	0.19	3.15	3.23
Longleaf restoration, 45-60 min.	34,917	2,635	0.52	3.67	3.25
Overstocked natural, 45-60 min.	6,006	453	0.09	3.76	3.25
Overstocked plantation, 45-60 min.	7,593	573	0.11	3.88	3.25
Logging residues, 60-75 min.	70,465	5,403	1.10	4.98	3.29
Pulpwood, 15-30 min.	64,356	4,337	1.04	6.02	3.39
Longleaf restoration, 60-75 min.	33,289	2,512	0.50	6.52	3.43
Overstocked natural, 60-75 min.	10,005	755	0.15	6.67	3.43
Overstocked plantation, 60-75 min.	10,018	756	0.15	6.82	3.43
Logging residues, 75-90 min.	91,263	6,998	1.42	8.24	3.46
Pulpwood, 30-45 min.	127,007	8,558	2.05	10.29	3.55
Longleaf restoration, 75-90 min.	27,918	2,107	0.42	10.71	3.60
Overstocked natural, 75-90 min.	10,355	782	0.16	10.86	3.60
Overstocked plantation, 75-90 min.	9,665	729	0.14	11.01	3.60
Logging residues, 90-105 min.	92,653	7,105	1.44	12.45	3.64
Pulpwood, 45-60 min.	183,562	12,369	2.97	15.42	3.71
Longleaf restoration, 90-105 min.	26,874	2,028	0.40	15.82	3.78
Overstocked natural, 90-105 min.	9,577	723	0.14	15.96	3.78
Overstocked plantation, 90-105 min.	19,803	1,495	0.30	16.26	3.78
Logging residues, 105-120 min.	83,753	6,422	1.30	17.57	3.81
Pulpwood, 60-75 min.	297,376	20,039	4.80	22.37	3.87
Longleaf restoration, 105-120 min.	29,934	2,259	0.45	22.82	3.96
Overstocked natural, 105-120 min.	4,726	357	0.07	22.89	3.96
Overstocked plantation, 105-120 min.	24,424	1,843	0.37	23.26	3.96

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Pulpwood, 75-90 min.	408,036	27,496	6.59	29.85	4.03
Pulpwood, 90-105 min.	427,414	28,801	6.90	36.75	4.19
Pulpwood, 105-120 min.	378,360	25,496	6.11	42.86	4.34



	15	30	45	60	75	90	105	120
Pulpwood	0.19							
Overstocked Natural Stands	0.01	0.03	0.07					
Overstocked Plantations	0.00	0.00	0.05					
Longleaf Restoration	0.03	0.15	0.35	0.4				
Logging Residues	0.04	0.21	0.45	0.70				
Urban Wood	0.03	0.13	0.15	0.08	0.08	0.10	0.12	0.18

One-way haul time (minutes)

Figure 16. Biomass use profile up to 3.55 TBtu/year (40 MW) for the TAL Hopkins facility under scenario #2, "With competing demand".

Table 18. Results for scenario #3, "With price competition" for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,777	224	0.03	0.03	0.62
Urban wood, 15-30 min.	8,459	1,068	0.13	0.15	0.81
Urban wood, 30-45 min.	10,046	1,268	0.15	0.30	0.99
Urban wood, 45-60 min.	5,435	686	0.08	0.38	1.18
Urban wood, 60-75 min.	5,329	673	0.08	0.46	1.36
Urban wood, 75-90 min.	6,524	824	0.10	0.56	1.55
Urban wood, 90-105 min.	8,280	1,045	0.12	0.68	1.73
Urban wood, 105-120 min.	12,010	1,516	0.18	0.86	1.92
Logging residues, 0-15 min.	2,408	185	0.04	0.90	2.60
Longleaf restoration, 0-15 min.	1,950	147	0.03	0.93	2.71
Overstocked natural, 0-15 min.	352	27	0.01	0.94	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	0.94	2.71
Logging residues, 15-30 min.	13,284	1,019	0.21	1.14	2.77
Longleaf restoration, 15-30 min.	10,281	776	0.15	1.30	2.89
Overstocked natural, 15-30 min.	2,194	166	0.03	1.33	2.89
Overstocked plantation, 15-30 min.	6	0	0.00	1.33	2.89
Logging residues, 30-45 min.	28,621	2,195	0.45	1.78	2.94
Longleaf restoration, 30-45 min.	23,409	1,767	0.35	2.13	3.07
Overstocked natural, 30-45 min.	4,958	374	0.07	2.20	3.07
Overstocked plantation, 30-45 min.	3,388	256	0.05	2.25	3.07
Logging residues, 45-60 min.	45,242	3,469	0.70	2.96	3.12
Pulpwood, 0-15 min.	12,006	809	0.19	3.15	3.25
Longleaf restoration, 45-60 min.	34,917	2,635	0.52	3.67	3.25
Overstocked natural, 45-60 min.	6,006	453	0.09	3.76	3.25
Overstocked plantation, 45-60 min.	7,593	573	0.11	3.88	3.25
Logging residues, 60-75 min.	70,465	5,403	1.10	4.98	3.29
Pulpwood, 15-30 min.	64,356	4,337	1.04	6.02	3.40
Longleaf restoration, 60-75 min.	33,289	2,512	0.50	6.52	3.43
Overstocked natural, 60-75 min.	10,005	755	0.15	6.67	3.43
Overstocked plantation, 60-75 min.	10,018	756	0.15	6.82	3.43
Logging residues, 75-90 min.	91,263	6,998	1.42	8.24	3.46
Pulpwood, 30-45 min.	127,007	8,558	2.05	10.29	3.56
Longleaf restoration, 75-90 min.	27,918	2,107	0.42	10.71	3.60
Overstocked natural, 75-90 min.	10,355	782	0.16	10.86	3.60
Overstocked plantation, 75-90 min.	9,665	729	0.14	11.01	3.60
Logging residues, 90-105 min.	92,653	7,105	1.44	12.45	3.64
Pulpwood, 45-60 min.	183,562	12,369	2.97	15.42	3.72
Longleaf restoration, 90-105 min.	26,874	2,028	0.40	15.82	3.78
Overstocked natural, 90-105 min.	9,577	723	0.14	15.96	3.78
Overstocked plantation, 90-105 min.	19,803	1,495	0.30	16.26	3.78
Logging residues, 105-120 min.	83,753	6,422	1.30	17.57	3.81
Pulpwood, 60-75 min.	297,376	20,039	4.80	22.37	3.88
Longleaf restoration, 105-120 min.	29,934	2,259	0.45	22.82	3.96
Overstocked natural, 105-120 min.	4,726	357	0.07	22.89	3.96
Overstocked plantation, 105-120 min.	24,424	1,843	0.37	23.26	3.96

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Pulpwood, 75-90 min.	408,036	27,496	6.59	29.85	4.04
Pulpwood, 90-105 min.	427,414	28,801	6.90	36.75	4.20
Pulpwood, 105-120 min.	378,360	25,496	6.11	42.86	4.36

Table 19. Results for scenario #4, "With price competition, 25% pulpwood" for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,777	224	0.03	0.03	0.62
Urban wood, 15-30 min.	8,459	1,068	0.13	0.15	0.81
Urban wood, 30-45 min.	10,046	1,268	0.15	0.30	0.99
Urban wood, 45-60 min.	5,435	686	0.08	0.38	1.18
Urban wood, 60-75 min.	5,329	673	0.08	0.46	1.36
Urban wood, 75-90 min.	6,524	824	0.10	0.56	1.55
Urban wood, 90-105 min.	8,280	1,045	0.12	0.68	1.73
Urban wood, 105-120 min.	12,010	1,516	0.18	0.86	1.92
Logging residues, 0-15 min.	2,408	185	0.04	0.90	2.60
Longleaf restoration, 0-15 min.	1,950	147	0.03	0.93	2.71
Overstocked plantation, 0-15 min.	0	0	0.00	0.93	2.71
Overstocked natural, 0-15 min.	352	27	0.01	0.94	2.71
Logging residues, 15-30 min.	13,284	1,019	0.21	1.14	2.77
Longleaf restoration, 15-30 min.	10,281	776	0.15	1.30	2.89
Overstocked plantation, 15-30 min.	6	0	0.00	1.30	2.89
Overstocked natural, 15-30 min.	2,194	166	0.03	1.33	2.89
Logging residues, 30-45 min.	28,621	2,195	0.45	1.78	2.94
Longleaf restoration, 30-45 min.	23,409	1,767	0.35	2.13	3.07
Overstocked plantation, 30-45 min.	3,388	256	0.05	2.18	3.07
Overstocked natural, 30-45 min.	4,958	374	0.07	2.25	3.07
Pulpwood, 0-15 min.	12,006	809	0.19	2.45	3.57
Pulpwood, 15-30 min.	64,356	4,337	1.04	3.49	3.73
Pulpwood, 30-45 min.	127,007	8,558	2.05	5.54	3.89
Longleaf restoration, 105-120 min.	29,934	2,259	0.45	5.99	3.96
Overstocked plantation, 105-120 min.	24,424	1,843	0.37	6.35	3.96
Overstocked natural, 105-120 min.	4,726	357	0.07	6.42	3.96
Pulpwood, 45-60 min.	183,562	12,369	2.97	9.39	4.05
Pulpwood, 60-75 min.	297,376	20,039	4.80	14.19	4.21
Pulpwood, 75-90 min.	408,036	27,496	6.59	20.78	4.36
Pulpwood, 90-105 min.	427,414	28,801	6.90	27.69	4.52
Pulpwood, 105-120 min.	378,360	25,496	6.11	33.80	4.68

Table 20. Results for scenario #5, "One-hour haul radius with price competition" for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,777	224	0.03	0.03	0.62
Urban wood, 15-30 min.	8,459	1,068	0.13	0.15	0.81
Urban wood, 30-45 min.	10,046	1,268	0.15	0.30	0.99
Urban wood, 45-60 min.	5,435	686	0.08	0.38	1.18
Logging residues, 0-15 min.	2,408	185	0.04	0.42	2.60
Longleaf restoration, 0-15 min.	1,950	147	0.03	0.45	2.71
Overstocked natural, 0-15 min.	0	0	0.00	0.45	2.71
Overstocked plantation, 0-15 min.	352	27	0.01	0.46	2.71
Logging residues, 15-30 min.	13,284	1,019	0.21	0.66	2.77
Longleaf restoration, 15-30 min.	10,281	776	0.15	0.82	2.89
Overstocked natural, 15-30 min.	6	0	0.00	0.82	2.89
Overstocked plantation, 15-30 min.	2,194	166	0.03	0.85	2.89
Logging residues, 30-45 min.	28,621	2,195	0.45	1.30	2.94
Longleaf restoration, 30-45 min.	23,409	1,767	0.35	1.65	3.07
Overstocked natural, 30-45 min.	3,388	256	0.05	1.70	3.07
Overstocked plantation, 30-45 min.	4,958	374	0.07	1.77	3.07
Logging residues, 45-60 min.	45,242	3,469	0.70	2.48	3.12
Longleaf restoration, 45-60 min.	34,917	2,635	0.52	3.00	3.25
Overstocked natural, 45-60 min.	7,593	573	0.11	3.11	3.25
Overstocked plantation, 45-60 min.	6,006	453	0.09	3.20	3.25
Pulpwood, 0-15 min.	12,006	809	0.19	3.40	3.36
Pulpwood, 15-30 min.	64,356	4,337	1.04	4.44	3.52
Pulpwood, 30-45 min.	127,007	8,558	2.05	6.49	3.68
Pulpwood, 45-60 min.	183,562	12,369	2.97	9.46	3.84

Table 21. Results for scenario #6, "With competing demand, doubling diesel costs" for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	1,777	224	0.03	0.03	1.28
Urban wood, 15-30 min.	8,459	1,068	0.13	0.15	1.52
Urban wood, 30-45 min.	10,046	1,268	0.15	0.30	1.76
Urban wood, 45-60 min.	5,435	686	0.08	0.38	2.00
Urban wood, 60-75 min.	5,329	673	0.08	0.46	2.24
Urban wood, 75-90 min.	6,524	824	0.10	0.56	2.48
Urban wood, 90-105 min.	8,280	1,045	0.12	0.68	2.72
Urban wood, 105-120 min.	12,010	1,516	0.18	0.86	2.96
Logging residues, 0-15 min.	2,408	185	0.04	0.90	3.32
Overstocked natural, 0-15 min.	352	27	0.01	0.91	3.32
Overstocked plantation, 0-15 min.	0	0	0.00	0.91	3.32
Overstocked natural, 15-30 min.	2,194	166	0.03	0.94	3.50
Overstocked plantation, 15-30 min.	6	0	0.00	0.94	3.50
Logging residues, 15-30 min.	13,284	1,019	0.21	1.15	3.55
Longleaf restoration, 0-15 min.	1,950	147	0.03	1.18	3.62
Overstocked natural, 30-45 min.	4,958	374	0.07	1.25	3.68
Overstocked plantation, 30-45 min.	3,388	256	0.05	1.30	3.68
Logging residues, 30-45 min.	28,621	2,195	0.45	1.75	3.77
Overstocked natural, 45-60 min.	6,006	453	0.09	1.84	3.86
Overstocked plantation, 45-60 min.	7,593	573	0.11	1.95	3.86
Pulpwood, 0-15 min.	12,006	809	0.19	2.14	3.92
Longleaf restoration, 15-30 min.	10,281	776	0.15	2.30	3.98
Logging residues, 45-60 min.	45,242	3,469	0.70	3.00	4.00
Overstocked natural, 60-75 min.	10,005	755	0.15	3.15	4.04
Overstocked plantation, 60-75 min.	10,018	756	0.15	3.30	4.04
Pulpwood, 15-30 min.	64,356	4,337	1.04	4.34	4.13
Overstocked natural, 75-90 min.	10,355	782	0.16	4.50	4.22
Overstocked plantation, 75-90 min.	9,665	729	0.14	4.64	4.22
Logging residues, 60-75 min.	70,465	5,403	1.10	5.74	4.22
Pulpwood, 30-45 min.	127,007	8,558	2.05	7.79	4.34
Longleaf restoration, 30-45 min.	23,409	1,767	0.35	8.14	4.34
Overstocked natural, 90-105 min.	9,577	723	0.14	8.29	4.40
Overstocked plantation, 90-105 min.	19,803	1,495	0.30	8.59	4.40
Logging residues, 75-90 min.	91,263	6,998	1.42	10.01	4.45
Pulpwood, 45-60 min.	183,562	12,369	2.97	12.97	4.54
Overstocked natural, 105-120 min.	4,726	357	0.07	13.04	4.57
Overstocked plantation, 105-120 min.	24,424	1,843	0.37	13.41	4.57
Logging residues, 90-105 min.	92,653	7,105	1.44	14.85	4.67
Longleaf restoration, 45-60 min.	34,917	2,635	0.52	15.38	4.69
Pulpwood, 60-75 min.	297,376	20,039	4.80	20.18	4.75
Logging residues, 105-120 min.	83,753	6,422	1.30	21.49	4.89
Pulpwood, 75-90 min.	408,036	27,496	6.59	28.08	4.95
Longleaf restoration, 60-75 min.	33,289	2,512	0.50	28.58	5.05

Resource/haul time category	*Dry tons recoverable*	*Truckloads*	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Pulpwood, 90-105 min.	427,414	28,801	6.90	35.48	5.16
Pulpwood, 105-120 min.	378,360	25,496	6.11	41.59	5.37
Longleaf restoration, 75-90 min.	27,918	2,107	0.42	42.01	5.41
Longleaf restoration, 90-105 min.	26,874	2,028	0.40	42.41	5.77
Longleaf restoration, 105-120 min.	29,934	2,259	0.45	42.86	6.12

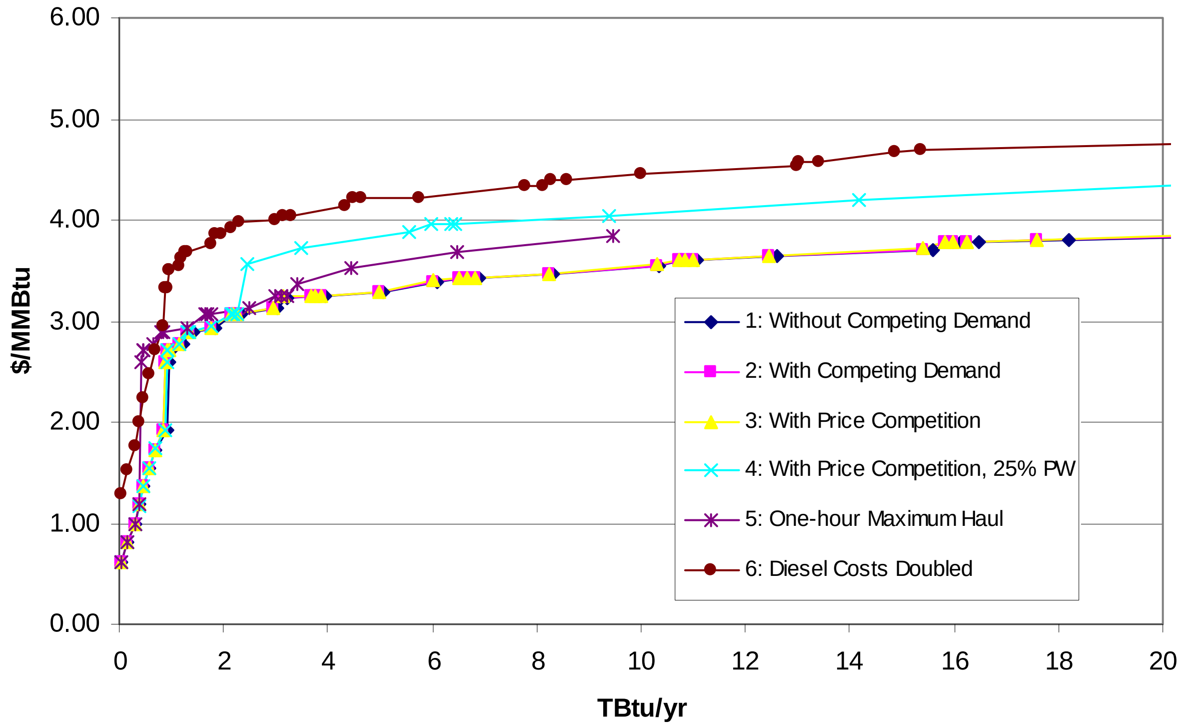


Figure 17. Results of the six scenarios for the TAL Hopkins facility.

2.4.4. General results

It is difficult to predict exactly what quantities of biomass resources will be available at what price for a specific location. However, the least-cost biomass resources needed to provide 10.65 TBtu/year (enough to generate three 40 MW facilities) in scenarios #2 and #3 would be comprised of about 35% urban wood waste, 42% logging residues, and about 20% from thinnings of natural stands and plantations. About 3% of this least-cost supply of 10.65 TBtu/year would be met with nearby pulpwood (Figure 18). The quantities of resources included in these scenarios are about 100%, 28%, 27%, 25%, 15%, and 0.4% of annually available urban wood waste, logging resides, thinnings from longleaf pine restoration, thinnings from overstocked plantations, thinnings from overstocked natural stands, and pulpwood, respectively, within the two-hour one-way woodsheds, excluding overlap of adjacent woodsheds (Figure 19).

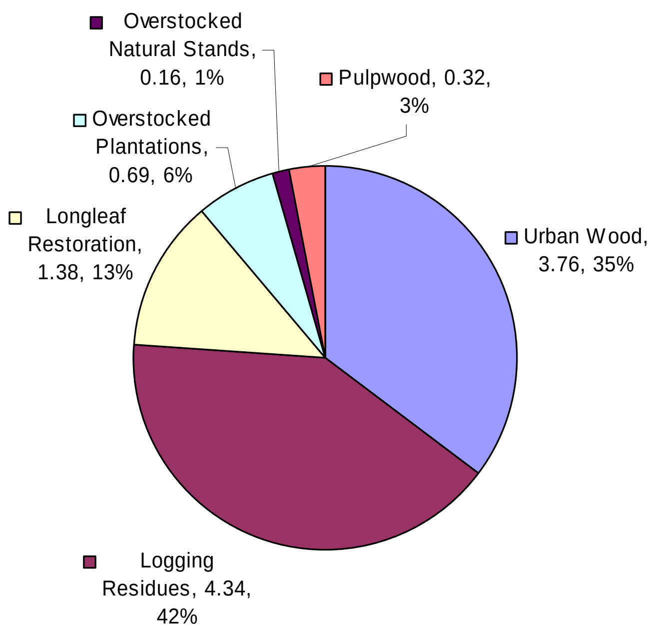


Figure 18. Total woody biomass resource composition to produce 10.65 TBtu/year for three (GRU, JEA, and TAL) 40 MW facilities under scenarios #2: "With competing demand" and #3: "With price competition". Values shown are TBtu/year, followed by percent of the 10.65 TBtu/year supply.

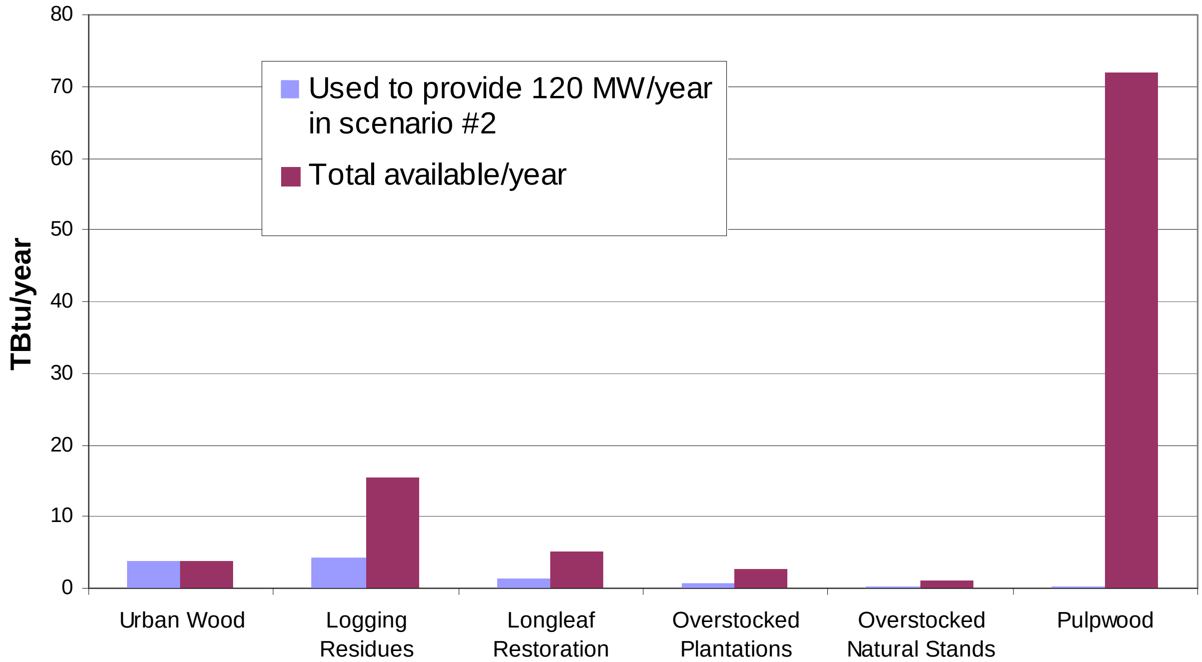


Figure 19. A comparison of A) least-cost resources used to provide 10.65 TBtu/year (e.g, three 40 MW facilities) under scenarios #2: "With competing demand" and #3: "With price competition", and B) total availability of these resources within the three two-hour woodsheds, excluding overlap of adjacent woodsheds.

Though the data used in this report were provided in tons per county, rather than acreages per county, estimates of yields and a range of possible acreages needed to provide the resources identified in Figure 18 are shown in Table 22. It is difficult to say how many acres are required to support a 20 or 40 MW plant, because most of the resources used, urban wood waste and logging residues, require no additional land for production. However, based on scenario #2, it is estimated that about 155,000 to 310,000 acres of might be accessed for 1.45 TBtu/year of logging residues for a 40 MW plant, and 77,000 to 155,000 acres might be used to produce 0.72 TBtu/year of logging residues for a 20 MW plant. An additional 13,000 to 26,000 acres could be used to produce 0.85 TBtu/year from forest thinnings or pulpwood for a 40 MW plant, or 7,000 to 13,000 acres could be used to produce 0.425 TBtu/year for a 20 MW plant. The remaining 1.25 TBtu/year for a 40 MW plant, or 0.63 TBtu/year for a 20 MW plant, would likely be derived from urban wood waste, requiring no additional land.

Table 22. Yield, acreage required, available acreage, heat content, % water, and % ash for biomass resources.

Biomass Resource	Yield per year	Acreage required for three 40 MW plants	Acreage available	Heat content (Btu/dry lb)	Percent water	% ash (dry weight basis)
Urban wood	0.122 green tons/person	N/A	N/A	8,200	40%	5%
Logging residues	0.3-0.6 dry tons/acre	460,000-930,000 acres[a]	11,387,469[b]	8,200	37%	5%
Thinnings and pulpwood	2.0-4.0 dry tons/acre	39,000-79,000 acres[c]	11,387,469[b]	8,200	47%	2%

[a]Estimated acres required to produce 4.34 TBtu/year of logging residues identified in Figure 18.
[b]Reported privately owned timberland in Florida, USDA FS Mapmaker, September 2007.
[c]Estimated acreage required to produce 2.55 TBtu/year of thinning and pulpwood identified in Figure 18.

2.5. Economic impacts (by Drs. Alan Hodges and Mohammad Rahmani)

Developing bioenergy facilities will impact local economies through the construction of facilities, purchasing locally available biomass, and operation and maintenance expenditures. The construction impacts of the project would be a one-time event that is assumed to occur within a year, while the impacts of plant operations continue each year. Fuel costs were calculated from the supply analysis results for GRU, JEA, and TAL from scenario #2: "With competing demand", and economic impacts were estimated using a software program called IMPLAN together with regional databases for Alachua, Duval, and Leon Counties. Results include *outputs* (the total revenue generated by an industry, including sales, plus changes in business inventories), *jobs* generated by sector, and *value-added* impacts (total personal and business net income). Capital construction impacts for 20 MW and 40 MW facilities are shown in Table 23. Annual (first year) impacts for 20 MW and 40 MW facilities are show in Table 24. Capital construction output impacts by industry for 20 MW and 40 MW plants are shown in

Table 25 and Table 26, respectively. All of the impact analysis results are for a single 20 or 40 MW plant built in each county. Each project is considered independently, and it was assumed that there is no constraint on supply of construction labor or professional services to accomplish these projects, even if they were done simultaneously.

Regarding the impacts of capital construction (Table 22), the impacts in Duval county are much larger than for Alachua and Leon Counties because the Jacksonville area has a significantly more well developed industrial infrastructure and manufacturing base that is capable of providing key equipment such as boilers and turbines. It was assumed that this equipment would be purchased locally if available. A few other counties in our analysis, such as Santa Rosa (Pensacola), also had similar magnitude of greater capital impacts for this reason. For Alachua and Leon counties, these items must be purchased from outside the counties, thus representing a leakage of money from the local economy.

Table 23. Capital construction total impacts from 20 MW and 40 MW facilities in Alachua, Duval, and Leon Counties, including output, employment, and value-added generation.

	ALACHUA COUNTY	DUVAL COUNTY	LEON COUNTY
Output, 20 MW Plant ($)	7,827,716	51,802,373	7,442,908
Employment, 20 MW Plant (Jobs)	76	321	66
Value-added, 20 MW Plant ($)	4,030,846	23,101,574	3,896,926
Output, 40 MW Plant ($)	10,427,833	89,886,686	10,154,594
Employment, 40 MW Plant (Jobs)	98	545	87
Value-added, 40 MW Plant ($)	5,048,256	39,442,061	5,047,405

Table 24. Operating expenditure total impacts (first year) from 20 MW and 40 MW facilities in Alachua, Duval, and Leon Counties, including output, employment, and value-added generation.

	ALACHUA COUNTY	DUVAL COUNTY	LEON COUNTY
Output, 20 MW Plant ($)	13,336,340	13,143,123	13,067,940
Employment, 20 MW Plant (Jobs)	156	150	139
Value-added, 20 MW Plant ($)	7,741,232	7,547,302	7,398,046
Output, 40 MW Plant ($)	25,437,424	25,937,143	24,131,245
Employment, 40 MW Plant (Jobs	300	311	257
Value-added, 40 MW Plant ($)	14,653,770	14,668,627	13,554,570
Fuel Costs, 20 MW Plant ($)	1,906,901	1,579,580	2,289,998
Fuel Costs, 40 MW Plant ($)	4,192,177	3,896,102	4,691,268

Table 25. Capital construction output impacts for 20 MW plants, by industry.

Industry	ALACHUA COUNTY	DUVAL COUNTY	LEON COUNTY
11 Ag, Forestry, Fish & Hunting	7,033	8,918	984
21 Mining	3,430	17,439	64
22 Utilities	34,536	245,150	6,240
23 Construction	1,124,835	3,235,462	1,009,202
31-33 Manufacturing	60,606	24,930,690	27,347
42 Wholesale Trade	137,526	1,798,179	100,832
44-45 Retail trade	279,074	1,453,730	237,174
48-49 Transportation & Warehousing	390,709	1,322,470	388,213
51 Information	114,364	741,263	131,042
52 Finance & insurance	1,924,597	4,034,789	2,156,702
53 Real estate & rental	1,222,540	2,159,424	1,204,149
54 Professional- scientific & technical services	817,494	2,631,828	845,889
55 Management of companies	23,870	900,482	55,440
56 Administrative & waste services	150,774	830,444	125,465
61 Educational svcs	16,146	123,896	11,789
62 Health & social services	292,957	1,523,683	224,323
71 Arts- entertainment & recreation	19,420	168,729	18,162
72 Accomodation & food services	142,404	792,819	121,726
81 Other services	136,982	843,636	102,869
92 Government & non NAICs	928,421	4,039,345	675,295
Grand Total	7,827,716	51,802,373	7,442,908

Table 26. Operating output impacts for 20 MW plants, by industry.

Industry	ALACHUA COUNTY	DUVAL COUNTY	LEON COUNTY
11 Ag, Forestry, Fish & Hunting	4,328,093	3,275,310	5,185,716
21 Mining	10,765	14,018	714
22 Utilities	195,993	253,666	161,225
23 Construction	357,048	646,204	183,409
31-33 Manufacturing	112,306	327,686	50,983
42 Wholesale Trade	341,895	404,788	268,171
44-45 Retail trade	627,705	632,857	552,822
48-49 Transportation & Warehousing	112,080	220,853	101,704
51 Information	222,049	240,179	258,025
52 Finance & insurance	613,829	738,173	680,013
53 Real estate & rental	452,051	509,021	410,604
54 Professional- scientific & technical services	1,696,592	1,810,684	1,722,275
55 Management of companies	118,548	185,184	144,542
56 Administrative & waste services	372,942	467,279	332,417
61 Educational svcs	41,955	58,275	30,458
62 Health & social services	752,519	724,044	599,386
71 Arts- entertainment & recreation	45,034	71,286	44,865
72 Accomodation & food services	336,844	315,540	288,880
81 Other services	301,127	310,571	233,712
92 Government & non NAICs	2,296,964	1,937,506	1,818,018
Grand Total	13,336,340	13,143,123	13,067,940

3. TASK 2: SUSTAINABILITY IMPACTS FROM LAND-USE CHANGE

3.1. Background

A significant concern is the future availability and sustainability of the woody biomass resource base. The population in Florida is expected to grow 59% by 2030. The amount of increased development associated with this growth will likely reduce the forestland base from which thinnings and logging debris are derived. However, the trend in Florida and throughout the southeast is an increase in forest plantations and annual growth rates which increases biomass availability. Increasing population and development also increases the amount of urban wood waste available. In this analysis, we use projections of population, pulpwood stumpage prices, and forestland use change in Florida from the USDA Forest Service's Southern Forest Resource Assessment (SFRA, Wear and Greis 2002). The baseline year for the FIA data used in the report was 1995. This study represents the most comprehensive and detailed analysis of forest resource uses and trends in the US South. An update document to the 2000 Assessment is Wear et al. (2007), which describes market conditions in the forest sector since 2000. Starting around that year, there was a dramatic decline in stumpage prices, for pulpwood specifically, due to declining paper production capacity combined with increasing timber inventories in the South. Stumpage prices declined some 50% from their highs in the late 1990's. Considering the results of this report, the findings in the 2000 Assessment are probably somewhat overestimated with respect to the overall strength of the southern pulpwood timber market. Importantly, the report found that there was no indication that domestic demand for southern pulpwood, nor stumpage prices for pulpwood, were expected to increase significantly in the near term.

3.2. Scenarios

The 2000 Assessment makes projections to 2040 of total timberland, timberland by management type, timber removals for softwoods and hardwoods, and stumpage prices in each of the southern states to 2040. Stumpage price changes are in real (excluding inflation) terms. The 2000 Assessment includes a base case scenario and what we will call a conservative scenario. The base case scenario projects more land being converted to pine plantations

3.2.1. Base case scenario to 2040

The SFRA base case scenario represents the best estimate (at the time of publication) of timberland use changes given various demand and supply assumptions. Of all the southern states, Florida is projected to have the largest decline in overall timberland on a percentage basis. In this scenario, the area of private timberland in northern and central Florida is projected to decline 13.4%, from 11.4 MM or million acres in 1995 to 9.8 MM acres in 2040 (Figure 20). The actual 2005 FIA data for northern and central Florida show total private timberland area to be 10.8 MM acres vs. the scenario projection of 11.1 MM acres in 2005. Also in this scenario, the area in pine plantations is expected to increase 61% from 4.3 MM acres in 1995 to 6.9 MM acres by 2040. The recent 2005 FIA data indicate pine plantations on private lands to be 4.5 MM acres vs. the scenario projection of 4.6 MM acres in 2005. It should be noted that FIA data are collected over several years and there is a delay between data collection and reporting. Therefore, these comparisons should be interpreted with this in mind.

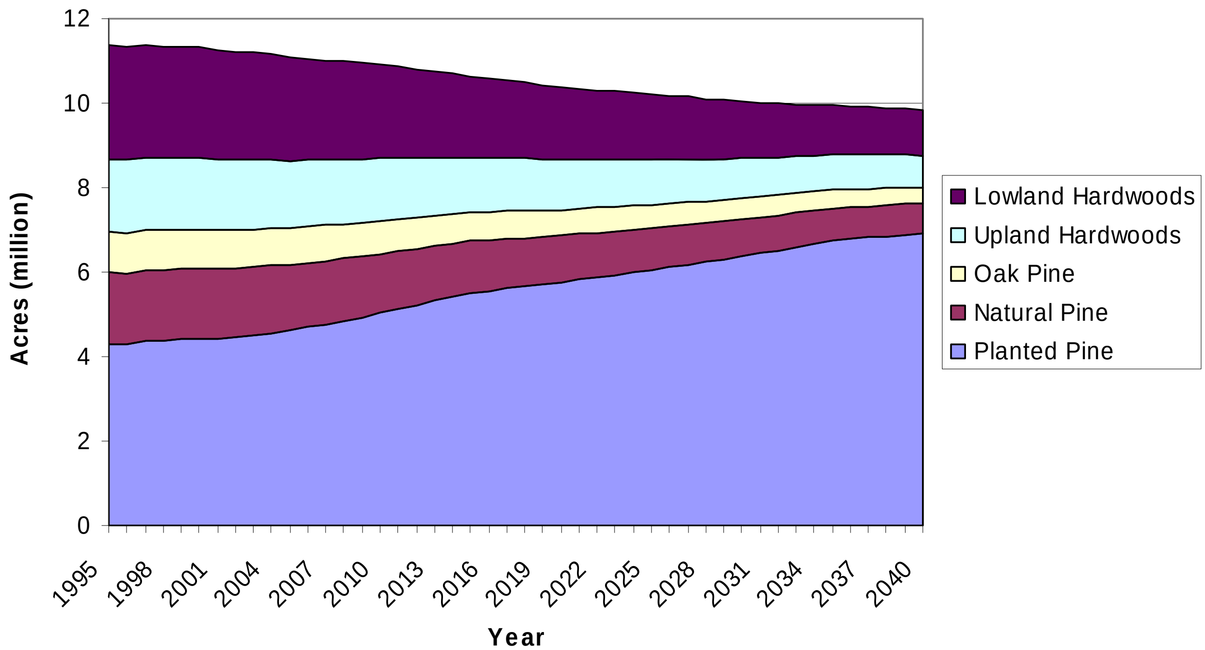


Figure 20. Projected area of private timberland in northern and central Florida by management type under the base case SFRA scenario to 2040.

Because pine plantations are more commercially productive than other forest land uses, coupled with expectations of improved growth rates on plantations, the estimates of removals in Florida under this scenario are expected to rise significantly over the projection period (Figure 21), even though the total area of timberland has declined. These removal projections are for all softwoods or hardwoods, and do not distinguish between product time (e.g., pulpwood vs. sawtimber). Softwood removals are projected to increase 130% from 1995 to 2040. Hardwood removals are projected to increase 62.8%. Projections on the availability of logging residues are assumed proportional to the removal projection data. Note that growth exceeds removals for softwoods through 2040, and to 2020 for hardwoods, indicating increasing softwood and hardwood timber inventories. Hardwood inventories begin to decline for hardwoods after 2020.

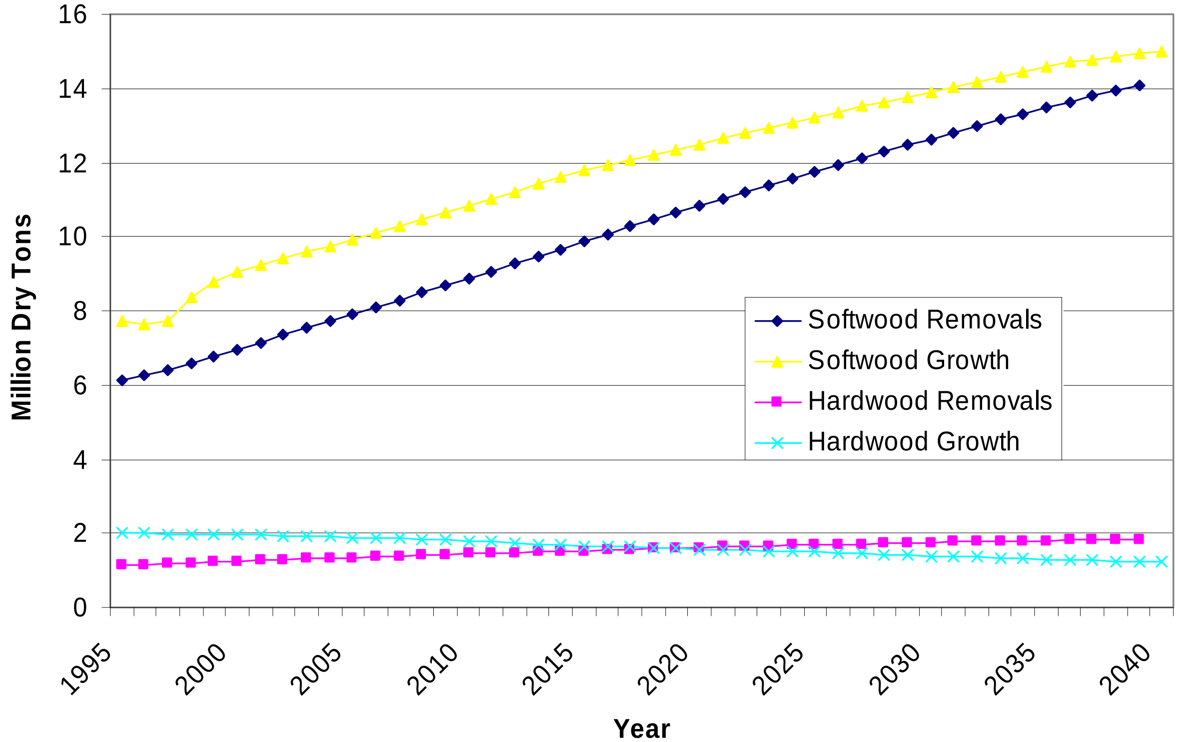


Figure 21. Projected softwood and hardwood growth and removals on private land under the base case SFRA scenario to 2040.

Finally, the SFRA makes price projections under both scenarios (Figure 22). Prices are projected to increase significantly in real terms under the base case scenario (the conservative case is discussed below). The SFRA does not distinguish between different timber products, other than by softwoods or hardwoods. The price is a composite product price. Prices are projected to rise 1.16% per year for softwoods and 1.38% per year for hardwoods. The removal and price projection data are used in our analysis, along with population growth projections, to develop the supply curves for this task.

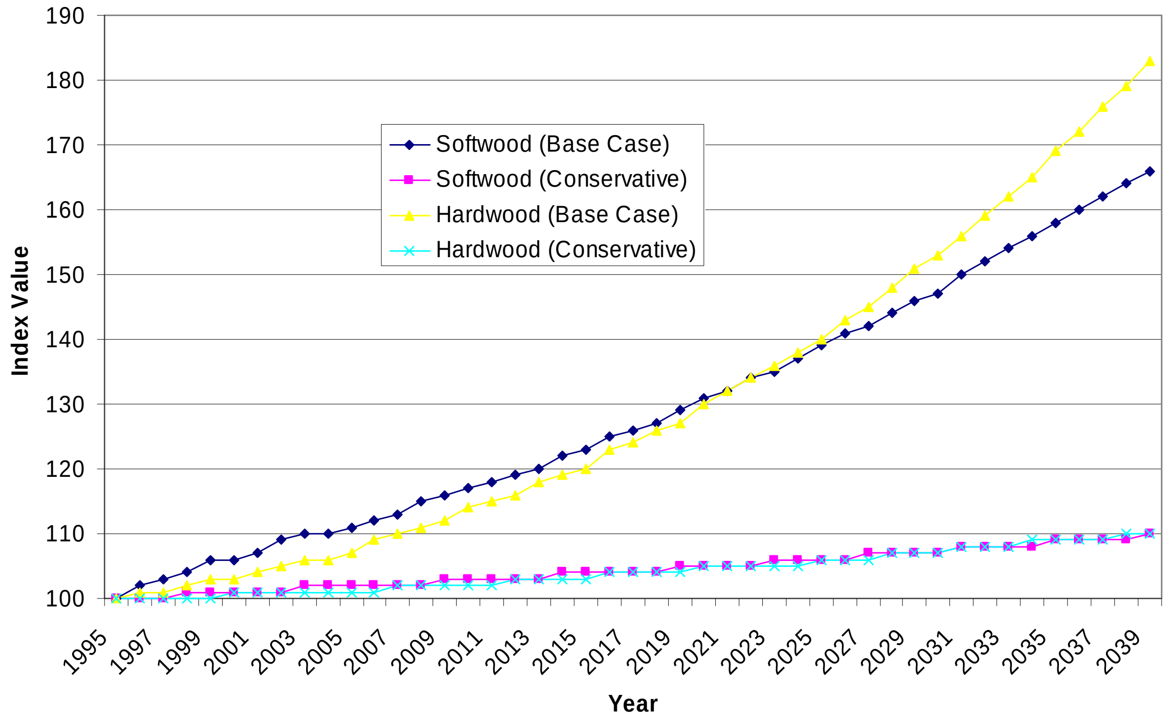


Figure 22. Projected softwood and hardwood price indices under both base case and conservative SFRA scenarios.

3.2.2. Conservative case scenario to 2040

The more conservative case is indicative of a weaker timber market. Less land is put into pine plantations, while more total timberland area is lost to alternative land uses (Figure 23). In this scenario, the area of timberland is projected to decline 25.7%, from 11.4 MM or million acres in 1995 to 8.5 MM acres in 2040. The area in plantations however still is projected to increase 26%, from 4.3 MM acres in 1995 to 5.4 MM acres in 2040. Currently, the scenario's projections are more in line with current 2005 FIA data with respect to total private timberland area and area in pine plantations.

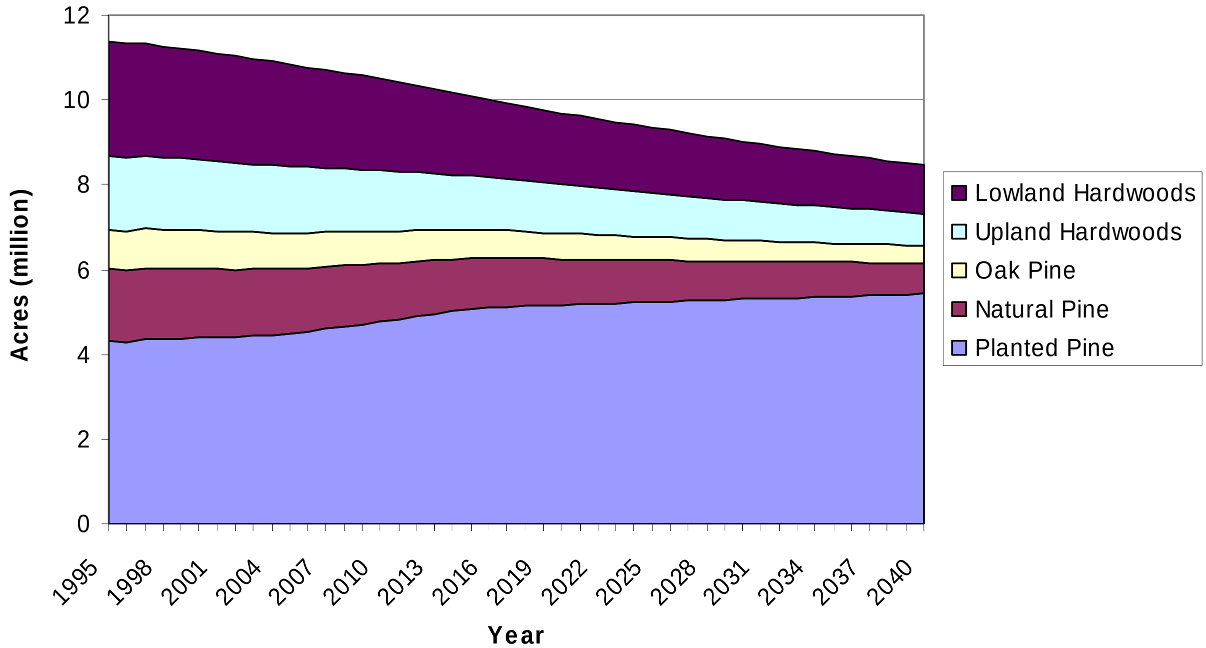


Figure 23. Projected area of private timberland in northern and central Florida by management type under the conservative case SFRA scenario to 2040.

For the conservative case, removals are also expected to increase for both hardwoods and softwoods, but at a slower rate than the base case scenario (Figure 24). Softwood removals are expected to increase 80.6% from 1995 to 2040. Hardwood removals are projected to increase 37.2%. Once again, growth is projected to exceed removals for softwoods throughout the projection period, and till 2020 for hardwoods, indicating increasing inventories.

Prices are not expected to increase nearly as sharply in the conservative case (Figure 22). For both softwoods and hardwoods, real prices are projected to increase only 0.22% per year in real terms.

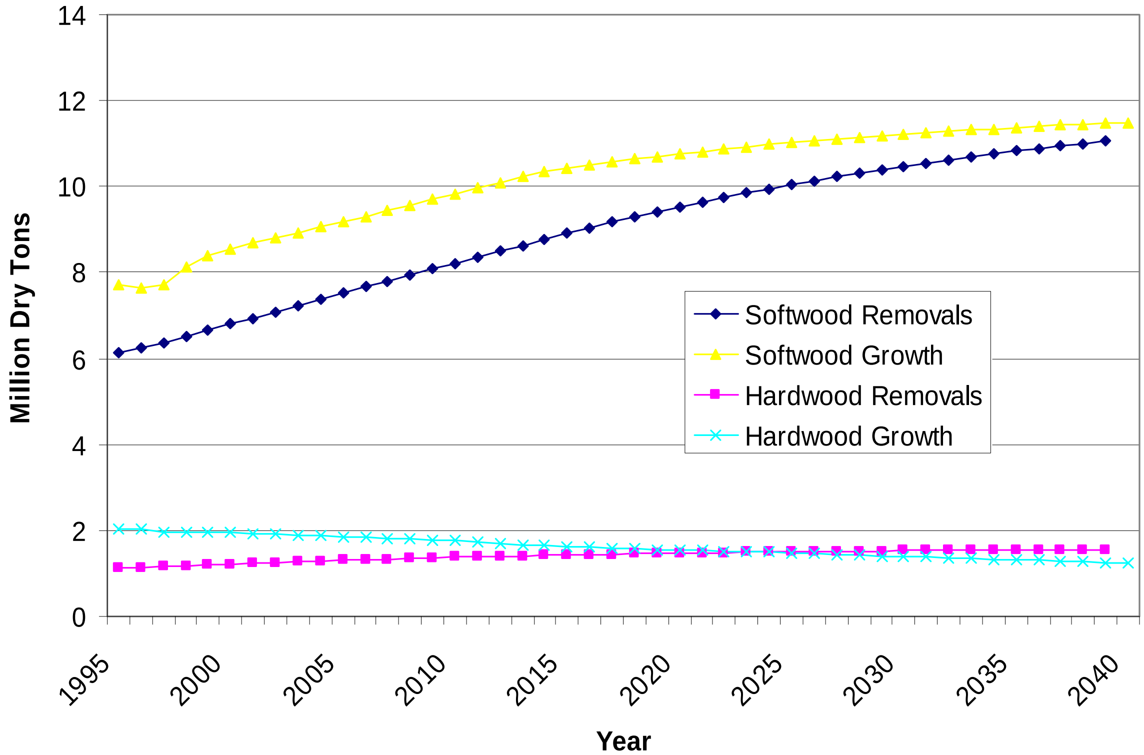


Figure 24. Projected softwood and hardwood growth and removals on private land under the base case SFRA scenario to 2040.

3.3. RESULTS

3.3.1. GRU

Table 27. Results for the base case projection to 2040 for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	3,067	0.05	0.05	0.62
Urban wood, 15-30 min.	13,026	0.19	0.24	0.81
Urban wood, 30-45 min.	17,255	0.26	0.50	0.99
Urban wood, 45-60 min.	16,350	0.24	0.74	1.18
Urban wood, 60-75 min.	16,846	0.25	0.99	1.36
Urban wood, 75-90 min.	20,491	0.31	1.30	1.55
Urban wood, 90-105 min.	25,458	0.38	1.68	1.73
Urban wood, 105-120 min.	34,048	0.51	2.19	1.92
Logging residues, 0-15 min.	6,805	0.11	2.29	2.60
Longleaf restoration, 0-15 min.	552	0.01	2.30	2.71
Logging residues, 15-30 min.	34,704	0.54	2.84	2.77
Longleaf restoration, 15-30 min.	3,166	0.05	2.89	2.89
Logging residues, 30-45 min.	69,801	1.09	3.98	2.94
Longleaf restoration, 30-45 min.	12,567	0.19	4.17	3.07
Logging residues, 45-60 min.	70,577	1.10	5.27	3.12
Longleaf restoration, 45-60 min.	20,690	0.31	5.58	3.25
Logging residues, 60-75 min.	78,783	1.23	6.80	3.29
Longleaf restoration, 60-75 min.	18,472	0.28	7.08	3.43
Logging residues, 75-90 min.	98,913	1.54	8.62	3.46
Longleaf restoration, 75-90 min.	23,188	0.35	8.97	3.60
Logging residues, 90-105 min.	95,664	1.49	10.46	3.64
Pulpwood, 0-15 min.	28,363	0.46	10.92	3.72
Longleaf restoration, 90-105 min.	28,733	0.43	11.35	3.78
Logging residues, 105-120 min.	57,858	0.90	12.25	3.81
Pulpwood, 15-30 min.	150,515	2.43	14.68	3.88
Longleaf restoration, 105-120 min.	27,653	0.41	15.10	3.96
Pulpwood, 30-45 min.	320,862	5.18	20.28	4.04
Pulpwood, 45-60 min.	339,864	5.49	25.77	4.20
Pulpwood, 60-75 min.	365,944	5.91	31.68	4.35
Pulpwood, 75-90 min.	463,563	7.49	39.17	4.51
Pulpwood, 90-105 min.	407,265	6.58	45.75	4.67
Pulpwood, 105-120 min.	219,575	3.55	49.30	4.83

Table 28. Results for the conservative case projection to 2040 for the GRU Deerhaven facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	3,067	0.05	0.05	0.62
Urban wood, 15-30 min.	13,026	0.19	0.24	0.81
Urban wood, 30-45 min.	17,255	0.26	0.50	0.99
Urban wood, 45-60 min.	16,350	0.24	0.74	1.18
Urban wood, 60-75 min.	16,846	0.25	0.99	1.36
Urban wood, 75-90 min.	20,491	0.31	1.30	1.55
Urban wood, 90-105 min.	25,458	0.38	1.68	1.73
Urban wood, 105-120 min.	34,048	0.51	2.19	1.92
Logging residues, 0-15 min.	5,472	0.09	2.27	2.60
Longleaf restoration, 0-15 min.	552	0.01	2.28	2.71
Logging residues, 15-30 min.	27,661	0.43	2.71	2.77
Longleaf restoration, 15-30 min.	3,166	0.05	2.76	2.89
Logging residues, 30-45 min.	54,793	0.85	3.61	2.94
Longleaf restoration, 30-45 min.	12,567	0.19	3.80	3.07
Logging residues, 45-60 min.	55,307	0.86	4.66	3.12
Longleaf restoration, 45-60 min.	20,690	0.31	4.97	3.25
Logging residues, 60-75 min.	61,876	0.96	5.94	3.29
Pulpwood, 0-15 min.	22,630	0.37	6.30	3.31
Longleaf restoration, 60-75 min.	18,472	0.28	6.58	3.43
Logging residues, 75-90 min.	77,670	1.21	7.79	3.46
Pulpwood, 15-30 min.	119,063	1.92	9.71	3.47
Longleaf restoration, 75-90 min.	23,188	0.35	10.06	3.60
Pulpwood, 30-45 min.	250,318	4.04	14.10	3.63
Logging residues, 90-105 min.	75,228	1.17	15.28	3.64
Longleaf restoration, 90-105 min.	28,733	0.43	15.71	3.78
Pulpwood, 45-60 min.	264,271	4.27	19.98	3.78
Logging residues, 105-120 min.	45,469	0.71	20.69	3.81
Pulpwood, 60-75 min.	284,826	4.60	25.29	3.94
Longleaf restoration, 105-120 min.	27,653	0.41	25.70	3.96
Pulpwood, 75-90 min.	360,554	5.82	31.53	4.10
Pulpwood, 90-105 min.	317,054	5.12	36.65	4.26
Pulpwood, 105-120 min.	170,623	2.76	39.40	4.42

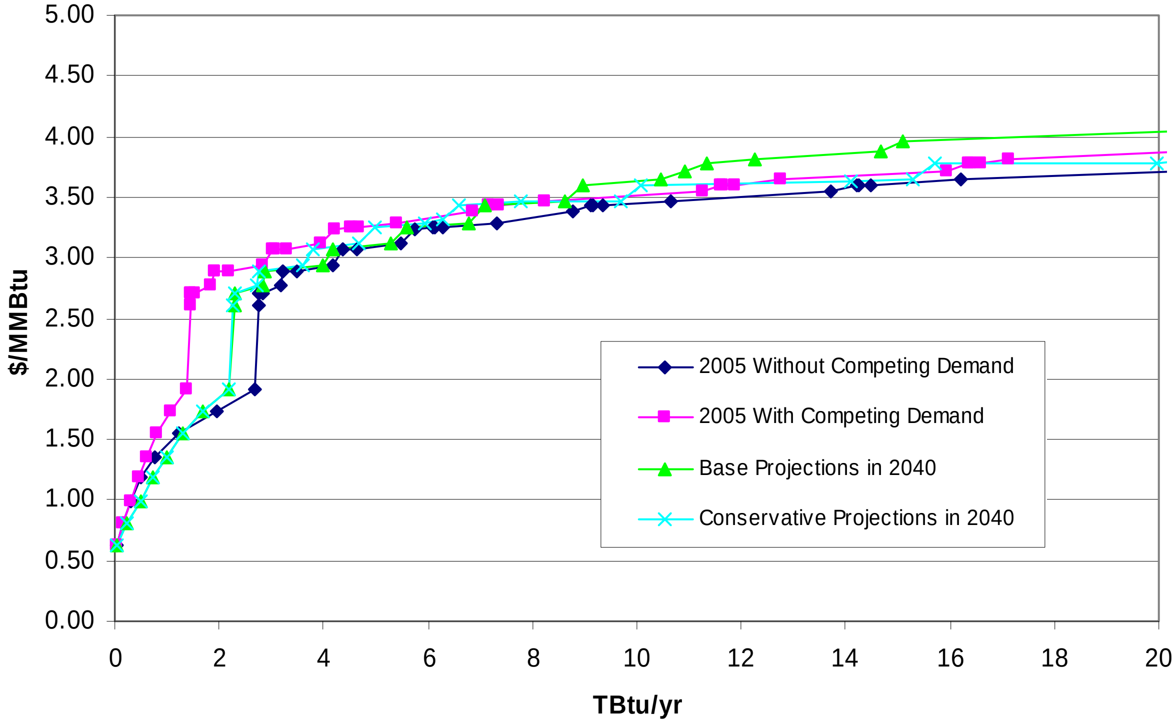


Figure 25. Comparison of scenario #1: "Without competing demand", scenario #2: "With competing demand" and base case and conservative case projections to 2040 for the GRU Deerhaven facility.

3.3.2. JEA

Table 29. Results for the base case projection to 2040 for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	8,907	0.13	0.13	0.62
Urban wood, 15-30 min.	37,139	0.55	0.69	0.81
Urban wood, 30-45 min.	45,780	0.68	1.37	0.99
Urban wood, 45-60 min.	21,720	0.32	1.69	1.18
Urban wood, 60-75 min.	16,009	0.24	1.93	1.36
Urban wood, 75-90 min.	10,365	0.15	2.09	1.55
Urban wood, 90-105 min.	10,160	0.15	2.24	1.73
Urban wood, 105-120 min.	11,141	0.17	2.41	1.92
Logging residues, 0-15 min.	4,970	0.08	2.48	2.60
Longleaf restoration, 0-15 min.	695	0.01	2.49	2.71
Logging residues, 15-30 min.	34,885	0.54	3.04	2.77
Longleaf restoration, 15-30 min.	4,505	0.07	3.11	2.89
Logging residues, 30-45 min.	70,783	1.10	4.21	2.94
Longleaf restoration, 30-45 min.	8,277	0.12	4.33	3.07
Logging residues, 45-60 min.	75,157	1.17	5.50	3.12
Longleaf restoration, 45-60 min.	7,780	0.12	5.62	3.25
Logging residues, 60-75 min.	65,916	1.03	6.65	3.29
Longleaf restoration, 60-75 min.	6,784	0.10	6.75	3.43
Logging residues, 75-90 min.	59,621	0.93	7.68	3.46
Longleaf restoration, 75-90 min.	6,728	0.10	7.78	3.60
Logging residues, 90-105 min.	88,692	1.38	9.16	3.64
Pulpwood, 0-15 min.	18,461	0.30	9.46	3.72
Longleaf restoration, 90-105 min.	7,853	0.12	9.58	3.78
Logging residues, 105-120 min.	88,368	1.38	10.95	3.81
Pulpwood, 15-30 min.	149,402	2.41	13.37	3.88
Longleaf restoration, 105-120 min.	8,305	0.12	13.49	3.96
Pulpwood, 30-45 min.	320,424	5.18	18.67	4.04
Pulpwood, 45-60 min.	345,222	5.58	24.24	4.20
Pulpwood, 60-75 min.	291,220	4.70	28.95	4.35
Pulpwood, 75-90 min.	259,194	4.19	33.14	4.51
Pulpwood, 90-105 min.	390,814	6.31	39.45	4.67
Pulpwood, 105-120 min.	387,518	6.26	45.71	4.83

Table 30. Results for the conservative case projection to 2040 for the JEA Brandy Branch facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	8,907	0.13	0.13	0.62
Urban wood, 15-30 min.	37,139	0.55	0.69	0.81
Urban wood, 30-45 min.	45,780	0.68	1.37	0.99
Urban wood, 45-60 min.	21,720	0.32	1.69	1.18
Urban wood, 60-75 min.	16,009	0.24	1.93	1.36
Urban wood, 75-90 min.	10,365	0.15	2.09	1.55
Urban wood, 90-105 min.	10,160	0.15	2.24	1.73
Urban wood, 105-120 min.	11,141	0.17	2.41	1.92
Logging residues, 0-15 min.	3,862	0.06	2.47	2.60
Longleaf restoration, 0-15 min.	695	0.01	2.48	2.71
Logging residues, 15-30 min.	27,070	0.42	2.90	2.77
Longleaf restoration, 15-30 min.	4,505	0.07	2.97	2.89
Logging residues, 30-45 min.	54,830	0.85	3.82	2.94
Longleaf restoration, 30-45 min.	8,277	0.12	3.94	3.07
Logging residues, 45-60 min.	58,178	0.91	4.85	3.12
Longleaf restoration, 45-60 min.	7,780	0.12	4.97	3.25
Logging residues, 60-75 min.	51,064	0.80	5.76	3.29
Pulpwood, 0-15 min.	14,311	0.23	5.99	3.31
Longleaf restoration, 60-75 min.	6,784	0.10	6.10	3.43
Logging residues, 75-90 min.	46,274	0.72	6.82	3.46
Pulpwood, 15-30 min.	115,616	1.87	8.68	3.47
Longleaf restoration, 75-90 min.	6,728	0.10	8.79	3.60
Pulpwood, 30-45 min.	247,658	4.00	12.79	3.63
Logging residues, 90-105 min.	68,922	1.07	13.86	3.64
Longleaf restoration, 90-105 min.	7,853	0.12	13.98	3.78
Pulpwood, 45-60 min.	266,607	4.31	18.28	3.78
Logging residues, 105-120 min.	68,875	1.07	19.36	3.81
Pulpwood, 60-75 min.	225,033	3.64	22.99	3.94
Longleaf restoration, 105-120 min.	8,305	0.12	23.12	3.96
Pulpwood, 75-90 min.	200,465	3.24	26.36	4.10
Pulpwood, 90-105 min.	302,094	4.88	31.24	4.26
Pulpwood, 105-120 min.	299,959	4.85	36.08	4.42

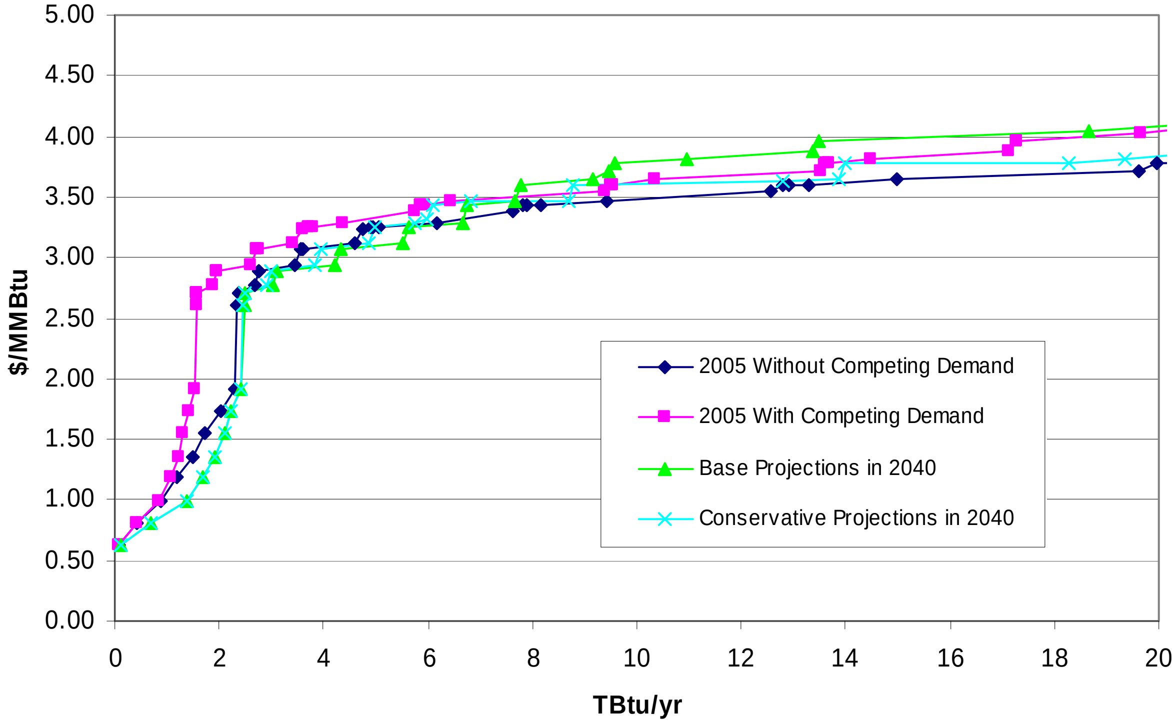


Figure 26. Comparison of scenario #1: "Without competing demand", scenario #2: "With competing demand" and base case and conservative case projections to 2040 for the JEA Brandy Branch facility.

3.3.3. TAL Hopkins facility

Table 31. Results for the base case projection to 2040 for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	2,817	0.04	0.04	0.62
Urban wood, 15-30 min.	13,413	0.20	0.24	0.81
Urban wood, 30-45 min.	15,930	0.24	0.48	0.99
Urban wood, 45-60 min.	8,618	0.13	0.61	1.18
Urban wood, 60-75 min.	8,450	0.13	0.73	1.36
Urban wood, 75-90 min.	10,346	0.15	0.89	1.55
Urban wood, 90-105 min.	13,130	0.20	1.09	1.73
Urban wood, 105-120 min.	19,044	0.28	1.37	1.92
Logging residues, 0-15 min.	3,994	0.06	1.43	2.60
Longleaf restoration, 0-15 min.	1,950	0.03	1.46	2.71
Logging residues, 15-30 min.	22,037	0.34	1.80	2.77
Longleaf restoration, 15-30 min.	10,281	0.15	1.96	2.89
Logging residues, 30-45 min.	47,079	0.73	2.69	2.94
Longleaf restoration, 30-45 min.	23,409	0.35	3.04	3.07
Logging residues, 45-60 min.	73,693	1.15	4.19	3.12
Longleaf restoration, 45-60 min.	34,917	0.52	4.71	3.25
Logging residues, 60-75 min.	116,108	1.81	6.52	3.29
Longleaf restoration, 60-75 min.	33,289	0.50	7.02	3.43
Logging residues, 75-90 min.	151,878	2.37	9.39	3.46
Longleaf restoration, 75-90 min.	27,918	0.42	9.81	3.60
Logging residues, 90-105 min.	154,269	2.40	12.21	3.64
Pulpwood, 0-15 min.	20,591	0.33	12.54	3.72
Longleaf restoration, 90-105 min.	26,874	0.40	12.95	3.78
Logging residues, 105-120 min.	139,314	2.17	15.12	3.81
Pulpwood, 15-30 min.	110,239	1.78	16.90	3.88
Longleaf restoration, 105-120 min.	29,934	0.45	17.35	3.96
Pulpwood, 30-45 min.	216,063	3.49	20.84	4.04
Pulpwood, 45-60 min.	311,023	5.02	25.86	4.20
Pulpwood, 60-75 min.	508,936	8.22	34.08	4.35
Pulpwood, 75-90 min.	705,438	11.40	45.48	4.51
Pulpwood, 90-105 min.	739,429	11.94	57.42	4.67
Pulpwood, 105-120 min.	651,425	10.52	67.95	4.83

Table 32. Results for the conservative case projection to 2040 for the TAL Hopkins facility.

Resource/haul time category	*Dry tons recoverable*	*TBtu/year Recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	2,817	0.04	0.04	0.62
Urban wood, 15-30 min.	13,413	0.20	0.24	0.81
Urban wood, 30-45 min.	15,930	0.24	0.48	0.99
Urban wood, 45-60 min.	8,618	0.13	0.61	1.18
Urban wood, 60-75 min.	8,450	0.13	0.73	1.36
Urban wood, 75-90 min.	10,346	0.15	0.89	1.55
Urban wood, 90-105 min.	13,130	0.20	1.09	1.73
Urban wood, 105-120 min.	19,044	0.28	1.37	1.92
Logging residues, 0-15 min.	3,170	0.05	1.42	2.60
Longleaf restoration, 0-15 min.	1,950	0.03	1.45	2.71
Logging residues, 15-30 min.	17,493	0.27	1.72	2.77
Longleaf restoration, 15-30 min.	10,281	0.15	1.87	2.89
Logging residues, 30-45 min.	37,513	0.58	2.46	2.94
Longleaf restoration, 30-45 min.	23,409	0.35	2.81	3.07
Logging residues, 45-60 min.	58,980	0.92	3.73	3.12
Longleaf restoration, 45-60 min.	34,917	0.52	4.25	3.25
Logging residues, 60-75 min.	92,445	1.44	5.69	3.29
Pulpwood, 0-15 min.	16,106	0.26	5.95	3.31
Longleaf restoration, 60-75 min.	33,289	0.50	6.45	3.43
Logging residues, 75-90 min.	120,390	1.88	8.33	3.46
Pulpwood, 15-30 min.	86,273	1.39	9.72	3.47
Longleaf restoration, 75-90 min.	27,918	0.42	10.14	3.60
Pulpwood, 30-45 min.	169,606	2.74	12.88	3.63
Logging residues, 90-105 min.	122,258	1.90	14.79	3.64
Longleaf restoration, 90-105 min.	26,874	0.40	15.19	3.78
Pulpwood, 45-60 min.	244,579	3.95	19.14	3.78
Logging residues, 105-120 min.	110,454	1.72	20.86	3.81
Pulpwood, 60-75 min.	398,452	6.44	27.30	3.94
Longleaf restoration, 105-120 min.	29,934	0.45	27.75	3.96
Pulpwood, 75-90 min.	549,848	8.88	36.63	4.10
Pulpwood, 90-105 min.	576,176	9.31	45.94	4.26
Pulpwood, 105-120 min.	508,670	8.22	54.15	4.42

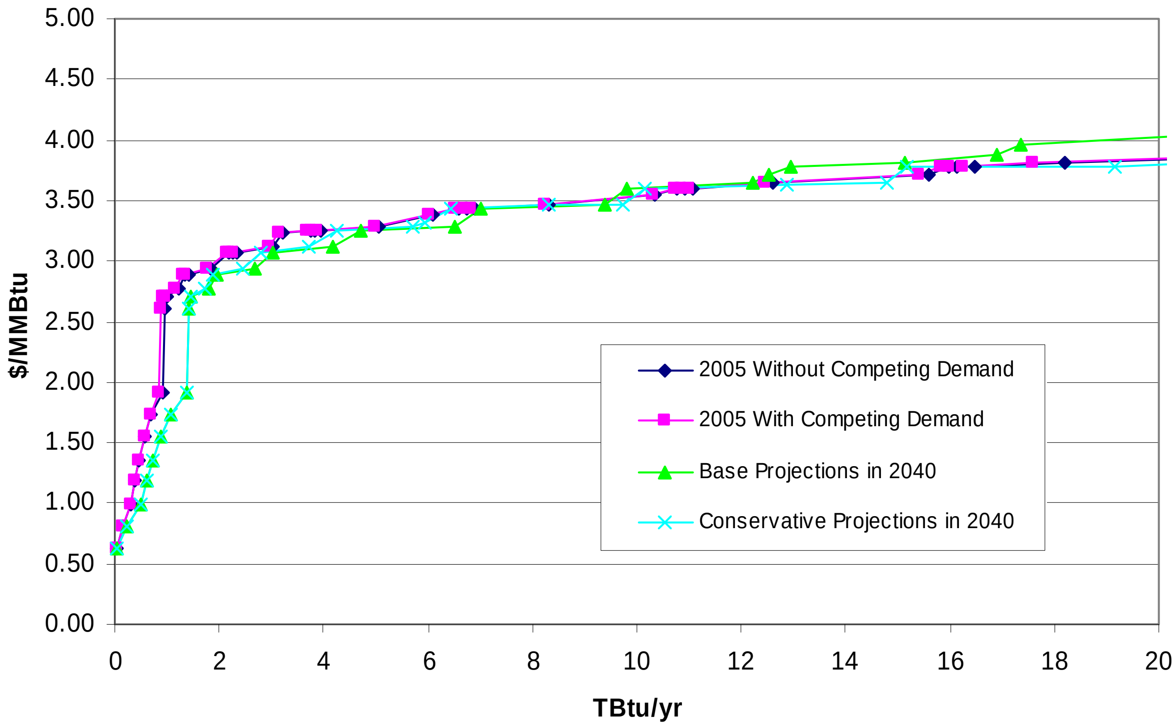


Figure 27. Comparison of scenario #1: "Without competing demand", scenario #2: "With competing demand" and base case and conservative case projections to 2040 for the TAL Hopkins facility.

3.4. Conclusions

The results of these scenarios reflect projections of increased supply due to both increased urban wood waste streams from expansion of urban areas as well as expanded production of forest products. However, at this stage we are unable to project how competing demand for biomass for energy may affect future prices. This will probably be largely influenced by future government policies regarding renewable energy and bioenergy technologies. Still the results suggest that even though projections indicate a reduction in timberland area during the next several decades, increases in per acre productivity will largely offset any losses in area. Indeed, the results from the projections are not widely different from other scenarios.

4. TASK 3: TRANSPORTATION IMPACTS FOR DEERHAVEN

4.1. Background

The establishment of a 40MW biomass power facility at the GRU Deerhaven facility will require the transport of significant volumes of biomass. In this section the impact of utilizing different scenarios for these deliveries is examined

As part of this study we analyzed three scenarios of delivery for the required biomass:

a) delivered to remote site by truck, processed, and transported to Deerhaven by truck;
b) delivered to remote site by truck, processed at site, and delivered to Deerhaven by rail; and
c) directly delivered to Deerhaven by truck.

All of these scenarios require the use of trucks to some degree. In addition, scenario b) requires intermodal rail transport. Each is discussed below.

4.2. Scenario A: Delivered to remote site by truck, processed, and transported to Deerhaven by truck

Some biomass industries, such as pulp mills and sugar mills, utilize off-site locations as intermediary receiving points, referred to as concentration yards. Concentration yards are usually implemented for the following reasons:

1. Because of harvesting conditions the biomass is harvested and placed in off-road transport equipment. This equipment cannot travel long distances on many public highways;
2. Harvesting transport equipment has limited carrying capacity, and for longer distances the material needs to be in larger vehicles to be cost-effective.
3. The facility is located in an area that prevents sufficient road access, or truck traffic is hindered by two-lane roads or school zones.
4. The required area of supply is very large, and intermediate concentration yards allow the supply area to be expanded.
5. Processing functions prior to delivery are required that are difficult to perform at the harvesting site. Examples of this are debarking and making clean pulp-grade chips.
6. Multiple products are delivered by harvesting operations (e.g. harvesting both pulpwood and sawlogs) in the same loads;
7. Quality control and rejection of non-conforming material is required to be away from the facility.
8. Insufficient storage space is available at the facility, and concentrations yards can serve as additional storage capacity. This is especially important when logging activity is very seasonal and intermittent.

For GRU most of these do not apply; the reasons for operating concentration yards may be to minimize truck impact and to increase the supply area (reasons 3 and 4 above). The potential impact of delivering all required material for a 40MW facility directly by truck is discussed in detail under scenario c). Also, potentially concentration yards could be developed in order to reduce transportation cost. However, it does not appear that concentration yards are required for Deerhaven for any of the other reasons. Generally, in Florida harvested material (or processed wood waste or agricultural products) is loaded into highway vehicles and hauled directly to the facility.

In both scenarios a) and b), the cost of operating a concentration yard will be added to the overall expense of delivery. Estimating these costs, on a dry ton basis, will help in comparing it to benefits. These costs are dependent upon the volume capacity of the yards and operating expenses.

For purposes of analyzing transport routes and assessing the use of concentration yards, the biomass supply area was divided into corridors. These corridors can be analogous to slices in a round pie; each takes a quadrant, and from the total volume contained as a percentage of the total supply and assessment of roads or natural obstacles, a projected volume by quadrant is determined. The map is shown in Figure 28.

From Figure 28 it can be seen that, in the case of a diffuse supply such as biomass, only so much volume can be concentrated in any given direction without greatly increasing the total distance. For example, a concentration yard located in the middle of Quadrant A is probably not going to be able to bring biomass located in Quadrants B,C,or D; it's probably less of a distance to ship the material directly to Deerhaven. Also, the material in Quadrant A between the concentration yard and Deerhaven will probably not go to the concentration yard unless directed, as it increasing the total miles required to be hauled.

For the purpose of this analysis, it is assumed that concentration yards will neither add nor decrease the trucking cost of material versus directly delivered to Deerhaven. This is because it is assumed that the material coming to the concentration yard can be diverted and then reshipped as economically as sending the material directly. While this may actually under estimate the impact of concentration yards, it is a starting point for this analysis.
The other dynamic is the economy of scale. One truck unloading mechanism, one scale, one truck or rail reloading system is going to be able to handle about one truck per 15 minutes. If

each truck contains about 25 tons, this is a throughput capacity of 100 tons per hour or about 800 green tons in an 8-9 hour shift. If we use an availability factor of 250 days per year then the concentration yard could theoretically handle about 300,000 green tons per year.

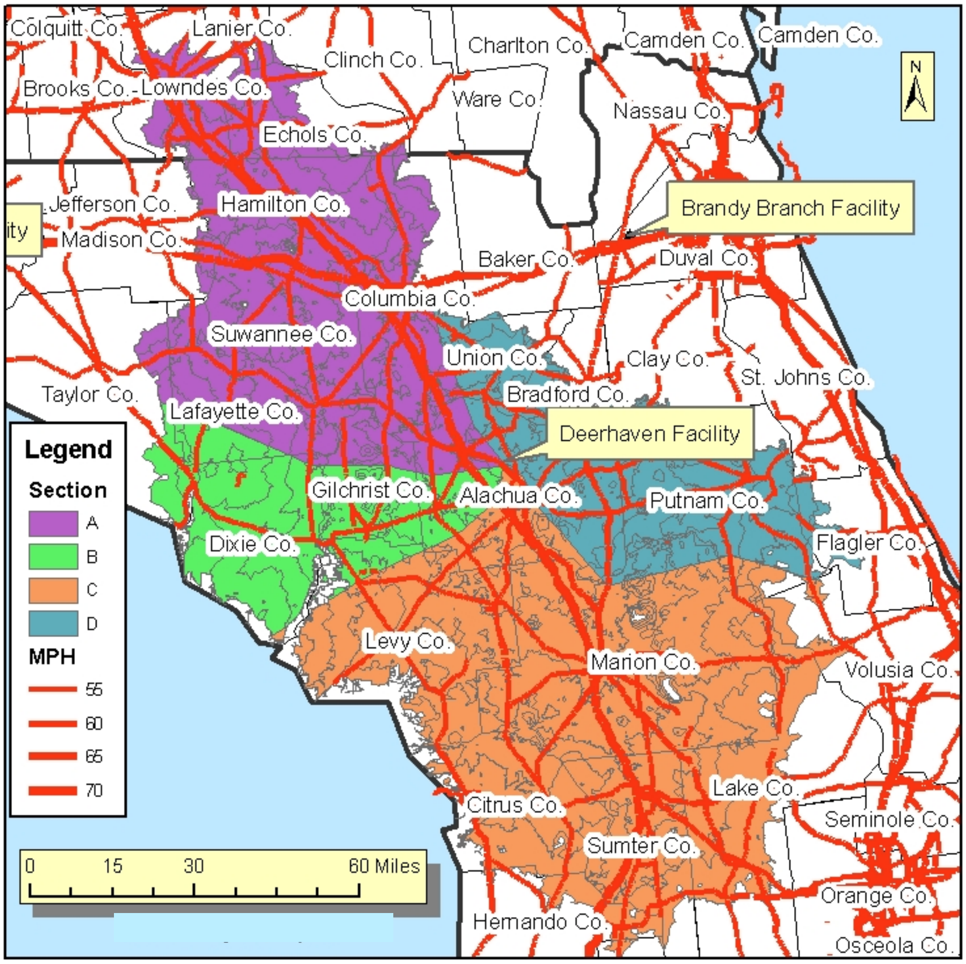


Figure 28. Identification of primary road entryways to the GRU Deerhaven facility.

Table 33. Concentration yard costs.

	Cost per Year
Production Expenses	
Purchase of Wood/Tipping Fees	$0
Fuel	$81,754
Equipment R & M	$37,200
Equipment Rental	$0
Equipment Depreciation	$136,286
Payroll	$150,610
Payroll Taxes	$14,082
Employee Benefits incl. WC ins.	$30,923
Contract Trucking	$0
Waste Disposal	$15,000
Crew Travel	$0
Miscellaneous	$0
TOTAL PRODUCTION EXPENSES	$465,854
SITE EXPENSES	
Telephone	$4,000
Bldg./Site Maintenance	$3,000
Utilities	$5,000
Outside Services	
Property Taxes	$14,616
Sote Rent-15 acres	$1,000
office Equipment Depreciation	$500
Bonding	
Permits and Licenses	$300
Fuel Testing	
Miscellaneous	
TOTAL DIRECT EXPENSES	$28,416
TOTAL EXPENSES	$494,270

Budgets were developed on the total operating cost of a concentration yard. These budgets use the estimate of four employees, 12 hours per day operation, 5 days per week, located on 15 acres of rented land zoned agricultural, and the ability to handle 300,000 green tons per year. Table 33 shows estimated expenses for operating this concentration yard.

The total expenses are estimated to be about $500,000 per year to operate this concentration yard. To estimate the impact in cost per ton, some assumption of total tons must be assumed.

Table 34. Yard cost per dry ton handled.

Dry tons per year	$/dry ton	$/MMBTU
50,000	$9.89	$0.62
100,000	$4.94	$0.31
150,000	$3.30	$0.21
200,000	$2.47	$0.15

Very few concentration yards that transfer from truck to truck are in existence today. The total volume they handle is dependent upon the surrounding biomass supply, and if local supplies dwindle or the needs of the mill change, they become cost-prohibitive. By assuming different levels of volume actually received and handled, some estimate of the cost per dry ton can be estimated. Table 34 illustrates the impact of volume on the cost per dry ton of operating a concentration yard. The table shows that if a concentration yard can be optimized to handle a maximum volume (in this example 200,000 dry tons or 400,000 green tons per year), then the cost per dry ton is $2.47 per dry ton. However, if actual volume handled is much less, then the per-ton cost could be $9.89 per dry ton. This cost is approximately equal to $.62 per MMBtu. In reality, if volume is significantly below capacity some savings may be achieved by reducing pay hours and fuel consumption, but the overall implications of volume dictating the per-ton cost of operating a concentration yard are still significant.

4.3. Scenario B: Biomass delivered to remote site by truck, processed at site, and delivered to Deerhaven by rail.

The discussion of economic impact of remote sites under Scenario a) applies generally whether the material is shipped out by truck or rail. In normal industry shipment out by rail is more common, and this may allow collection of wood from farther distances and decrease truck traffic.

Rail transport is often evaluated in the development of biomass projects, especially for heavily urbanized locations. For GRU, rail access is available, so it must at least be considered.

Rail involves an extra handling step in the delivery of all biomass. For almost all parts of the country rail cars cannot be directly loaded from the field (one exception is dedicated short-line railroads owned or controlled by the biomass user). If the biomass is derived from forest thinnings or logging residues, the material will have to be placed in a truck to remove it from the harvesting operation in the woods. This means that to use rail, the material will have to be delivered to a rail siding by truck, unloaded, and then re-loaded into a rail car. Depending on the location of the rail siding and the forest land, the truck distance may be nearly the same to the rail yard as to the facility.

Figure 29 shows the active rail lines within the vicinity of Deerhaven, and two potential rail concentration yard locations based upon rail availability. Rail transport of biomass to Deerhaven is restricted because no active rail connections are available going east or south. One access route, going north adjacent to US 441, means that the biomass collected from the supply area east and south east of Deerhaven will probably not be feasible to ship by rail.

For the two proposed rail locations, it is estimated that the freight expense to haul the biomass by truck from these locations to Deerhaven is approximately $5.00 per green ton (perhaps $8.50 per dry ton). As directed, this study did not assess the expense to haul material from these sites by rail to compare, but GRU indicated this data is available to them and this can be compared to the truck transport expense to determine the economic advantage, if any, of using rail.

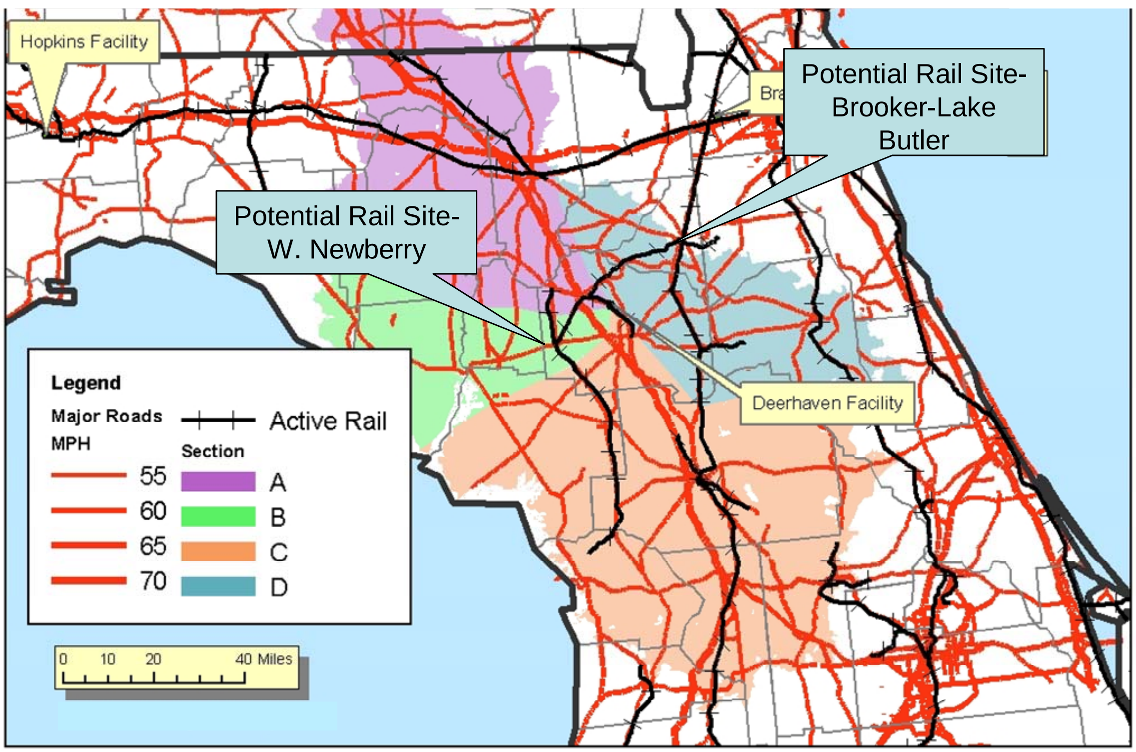


Figure 29. Potential rail concentration yard sites.

4.4. Scenario C: Biomass directly delivered to Deerhaven by truck.

Using the total biomass supply analysis provided above, and established estimates of average truck capacities for different types of biomass, an estimated 27,412 truckloads per year will be needed to supply a 40MW facility. Most wood suppliers are used to delivering material to pulp mills five or six days per week, and because of changes in daylight, weather, and machinery availability they need flexibility to deliver during as many hours as possible. Limitations in delivery times will increase the cost of delivered biomass.

Biomass is a unique form of solid fuel in that it is often delivered from all directions. Obstacles such as bridges, roadless areas, and urban areas with truck limitations are all factors in considering the impact. Based upon the current activities and the total site controlled by GRU, there are three major routes by which biomass can be transported into a 40 MW facility located on the site:

US 441 from the north;
US 441 from the South;

The use of the 43rd Street extension will probably not be viable or desirable due to the school zone for Talbot Elementary School and the congestion associated with 53rd and 39th Avenues. Using truck routes identified by the Florida Department of Transportation, the following major routes will probably be used:

- US 441 N to Alachua area
- US 441 S to SR 121; N on SR 121
- US 441 S to SR 121; S on 121 to SR 222; then west to I-75;
- US 441 S to NW 53rd Street, then east on 53rd Street to SR 26

A potential additional access could be a new entrance road directly north from the site linking to SR 121. For purposes of this discussion this road will be considered but discussed separately.

The biomass supply anticipated for the facility was divided into approximate areas served by each of the major access routes, in order to approximate the amount of traffic impact on each of the routes. Figure 28 showed the delineation of the biomass supply area into four delivery quadrants, and from this analysis an estimate of the amount of biomass arriving from each is determined. Approximate amounts of the total of each quadrant served by each of the routes identified above were estimated. This estimate, in number of trucks per day based upon 300 delivery days per year, was then compared to current traffic counts for some of the roads being discussed, to get an idea of the proportion of traffic change that these roads may see with the development of the project.

Table 35. Traffic impact, 40 MW biomass plant, GRU Deerhaven facility.

Transport Routes	**(1)** Supply Quadrant(s)	**(2)** Total Truckloads per year	**(3)** Total trucks-round trip	**(4)** Average Trucks per day	**(5)** Current Traffic per day-average	**(6)** Roadway Traffic Impact (% increase)
Total Transport Traffic	**A,B,C,D**	**27,412**	**54,824**	**183**		
US 441 from the North	A,B, 30% of D	10,792	21,585	72	19,200	0.37%
US 441 from the South	C, 70% of D	16,621	33,241	111	19,200	0.58%
US 441 S to SR 121; N on SR 121	30% of D	2,619	5,239	17	7,271	0.24%
US 441 S to SR 121; S on 121 to SR 222; then west to I-75	C	10,509	21,018	70	10,000	0.70%
US 441 S to NW 53rd Street, then east on 53rd Street to SR 26	40% of D	3,492	6,985	23	10,396	0.22%

Notes:
(1) Refers to areas in Figure One.
(2) Truck count based upon quadrants served, biomass data in supply analysis
(3) Truck trips including return= twice the number of inbound trucks
(4) Based upon 300 delivery days per year
(5) Based upon Traffic Counts as of 10/1/2006. When multiple count stations were located along route, the station showing the lowest traffic count was used.
(6) Percent of traffic increase due to delivery to 40 MW biomass plant.

Table 35 provides the results of this study, showing the number of trucks for each major route, the existing daily traffic for each route (if data was available), and the new total assuming the facility is developed and the biomass was delivered from the areas as estimated in this study.

The above analysis shows that less than 1% traffic impact is seen on any of the major roadways being considered for delivery. As the distance from the facility increases, the roadways become smaller and some increase in impact may be seen, but the volume from any given point also decreases.

This analysis also shows the impact if all deliveries occur via US 441. An additional access route could be constructed, connecting the site to SR 121. If this route were constructed the traffic impact to US 441 would be further reduced. However, the cost of the roadway and the impact at its intersection of SR 121 would need to be considered.

5. TASK 4: CO_2 EMISSIONS FROM HARVEST, PROCESS, AND TRANSPORTATION OF WOODY BIOMASS

5.1. Background

In this section we review previous studies that have quantified CO_2 emissions from harvesting and processing woody biomass.

As with other types of renewable energy, bioenergy is considered “carbon neutral”. Although carbon within biomass produces CO_2 when it is converted to energy, carbon is re-sequestered when biomass is regrown, thus producing no net emissions. In the case of wood waste, no “additional” CO_2 emissions are produced if the wood was destined to be burned for disposal purposes. If any land use practice decreases levels of soil organic carbon, this carbon pool can become a source of CO_2 emissions. However, sustainable forestry effectively infuses the forest floor with tree root systems during each harvest. While typically only about 5% of above-ground decaying wood is eventually converted to below-ground soil organic carbon, about 50% of decaying root systems are converted to below-ground soil organic carbon. Thus, removing sustainable yields of above-ground woody biomass has not been shown to reduce soil organic carbon. Rather, lands under sustainable forest management sequester and maintain high levels of above- and below-ground carbon (Markewitz 2006), and markets exist to compensate forest landowners for benefits of carbon sequestration in forest soils, tree biomass, and in durable wood products.

For the above reasons, bioenergy is considered “carbon neutral”. However, fossil fuels are used in machinery needed to produce any energy, including wind, solar, or fossil fuels. In the case of bioenergy, fossil fuels are used in the production, harvest, processing, and delivery of biomass resources. One approach to evaluating the efficiency of energy options is to calculate the “net energy ratio”, or the energy yielded divided by the energy consumed in the production of the energy. Correlated with this attribute is the carbon intensity of an energy source, expressed as percent carbon closure, net carbon offset, or as CO_2 emissions per unit of energy generated. More efficient energy options have higher net energy ratios, yielding high amounts of energy for each unit of energy input, and tend to be less carbon intensive, producing lower CO_2 emissions for each unit of energy produced. Renewable energy sources are less carbon intensive than fossil fuel energy, which produces emissions both from the production of the fuel and the use of the fuel itself. Net energy ratios of some generation options are shown in Figure 30.

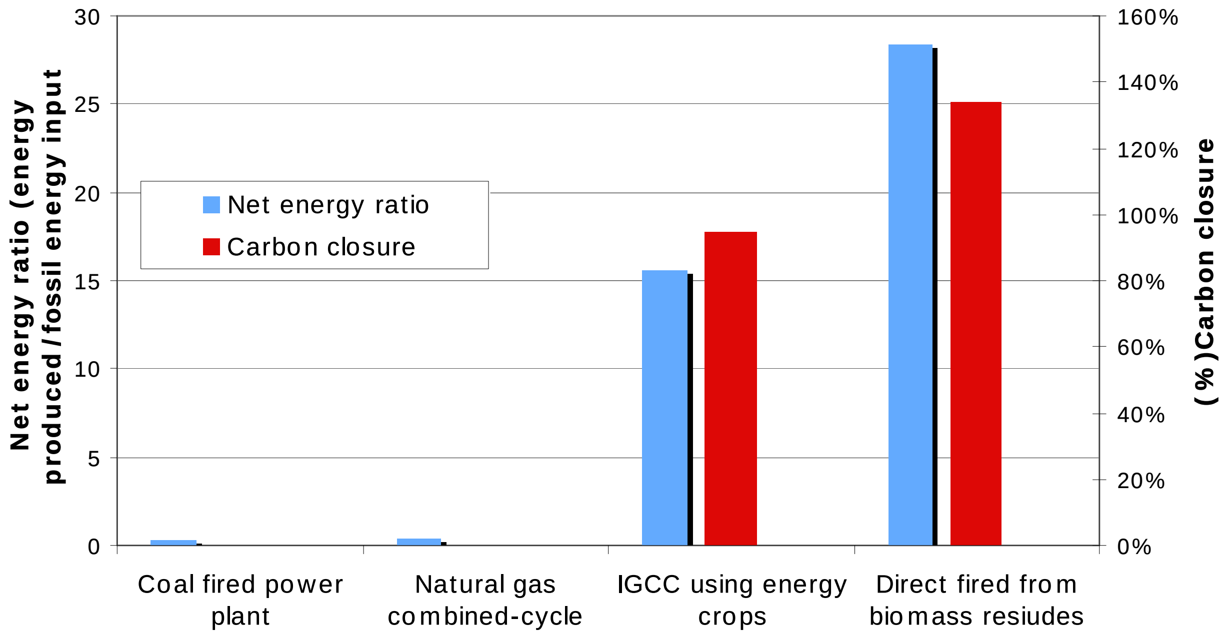


Figure 30. Net energy ratio (energy output/fossil fuel energy) and percent carbon closure of four generation technologies (adapted from Mann and Spath, 2002).

5.2. Literature review

Yoshioka *et al.* (2006) evaluated the CO_2 emissions associated with harvesting, transporting, and chipping logging residues from forest plantations in Japan. The system evaluated included 1) whole-tree yarding/skidding from 100 to 1,000 meters, 2) processor limbing and bucking at the landing of the logging site, 3) forwarder hauling of debris from the landing to the road, 4) transport of slash and chips by a 4-ton truck from 20 to 80 km, and 5) energy-conversion. Depending on the operation, CO_2 emissions ranged from 17 to 87 kg CO_2 dry Mg^{-1}, or about 4 to 6 kg CO_2 MWh^{-1}, within the range of emissions shown from a similar study in Finland. These emissions are lower that the estimated emissions of 341 and 304 kg CO_2 MWh^{-1} from coal and oil respectively.

Closer to Alachua County, Condon and Putz (2007) evaluated emissions produced from harvesting, transporting, and chipping hardwoods during longleaf pine ecosystem restoration projects. They calculated the net carbon balance as the difference between the carbon harvested in fuel chips and the carbon in fuel combusted during its harvest and transport. Equipment evaluated in the fuel chip harvesting operation included the Tigercat726B 240 HP feller, the Tigercat 630C and 630B 240 HP grapple skidder, the Tigercat 240B 190 HP knuckleboom loader, the Morbark NCL 30 Chipper, both 850, and 1,000 HP, and the Kenworth 425 HP tractor with 46 foot trailer. Harvest yields and diesel consumption rates of four projects evaluated by Condon and Putz are show in Table 36. When CO_2 emissions from harvest and transportation are divided by potential energy generation, total CO_2 emissions from production yields 38 to 44 kg CO_2 MWh^{-1}, higher than the 4 to 6 kg CO_2 MWh^{-1} reported by Yoshioka *et al.* (2006). Higher emissions are expected as more energy is required to thin natural stands than to collect logging residues from plantation harvests. Still, the emissions are less than the 341 and 304 kg CO_2 MWh^{-1} reported above from coal and oil respectively.

Table 36. Biomass yield, carbon content of biomass, fuel consumption, and carbon content of fuel of four hardwood removal projects in north Florida reported by Condon and Putz (2007).

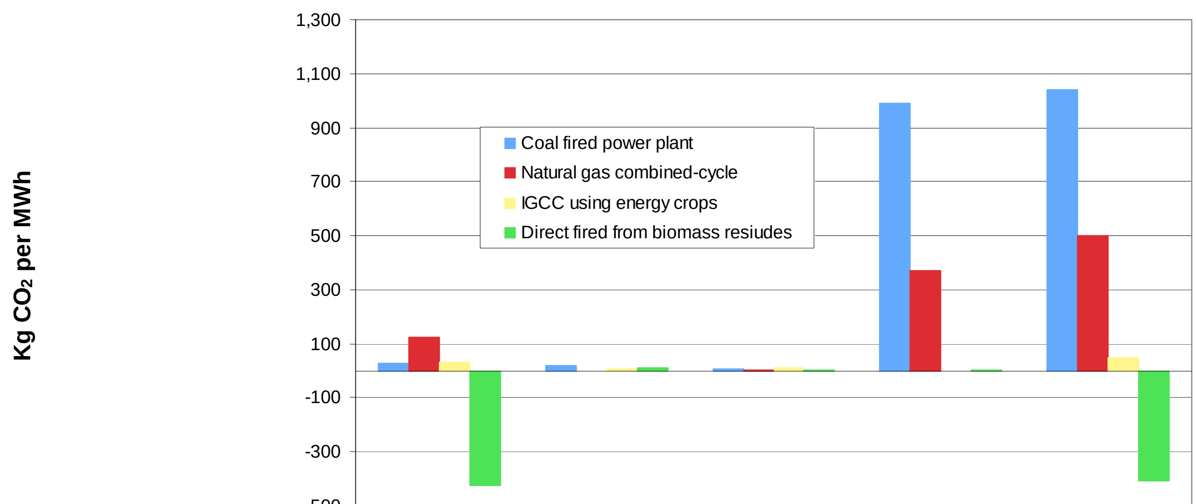
Project	Harvested chips	Carbon in harvested chips	Diesel consumed		Carbon in diesel consumed	
			Harvest	Transport	Harvest	Transport
	(Dry Mg)	(Mg)	(liters)		(Mg)	
A	2,875	1,351	27,005	16,133	19.7	11.8
B	1,683	791	15,986	13,306	11.7	9.7
C	1,047	492	11,031	7,400	8.1	5.4
D	983	462	8,517	6,825	6.2	5

Table 37. CO_2 analysis of yields and inputs reported by Condon and Putz (2007) shown in Table 36.

Project	Harvested chips (Dry Mg)	Carbon in harvested chips (Mg)	Total CO_2 emitted in production (Mg)[a]	CO_2 emissions reductions (Mg)[b]	Potential generation from harvested chips (MWh)[c]	CO_2 Emissions from production (kg CO_2/MWh)
A	2,875	1,351	116	4,954	3,070	38
B	1,683	791	78	2,900	1,797	44
C	1,047	492	50	1,804	1,118	44
D	983	462	41	1,694	1,050	39

[a]Calculated as carbon in diesel consumed in harvest plus carbon in diesel consumed in transport times 3.67 to convert carbon to CO_2.
[b]Estimated as carbon in harvested chips times 3.67 to convert carbon to CO_2.
[c]Calculated as dry Mg chips*0.901 tons/Mg*16 million Btu/dry ton* 1 MWh/13.5 million Btu.

Studies by Mann and Spath (1997; 2002) and Spath *et al.* (1999) at the National Renewable Energy Laboratory have evaluated CO_2 emissions and energy efficiencies of producing, handling, processing and converting energy resources, including fossil fuels and biomass. Mann and Spath presented comparisons of a representative coal fired power plant, a natural gas combined cycle power plant, a biomass integrated gasification combined cycle power plant, and a direct fired power plant from biomass residues (Figure 31). Emissions from cultivation, harvesting, processing, and transportation of biomass from *energy crops* are reported to be 37 kg CO_2 MWh^{-1}, close to the 46 kg CO_2 MWh^{-1} reported for mining, processing, and transporting coal. However, because the fuel for bioenergy is carbon neutral, total net CO_2 emissions from IGCC using energy crops are reported to be about 1/20th the total net CO_2 emissions from an average coal fired power plant. Furthermore, if biomass feedstocks are derived from waste streams, there are no additional emissions from the production of the feedstock, and in some situations the use of waste biomass for energy can actually result in negative CO_2 emissions.



	Production	Transport	Plant construction	Power plant operation	Total net emissions
Coal fired power plant	29	18	5	991	1,042
Natural gas combined-cycle	125	-	2	372	499
IGCC using energy crops	31	6	12	-	49
Direct fired from biomass resiudes	-423	10	3	3	-407

Figure 31. Comparisons of CO_2 emissions from production of fuels, transportation, plant construction and power plant operation of 1) a representative coal fired power plant, 2) a natural gas combined cycle power plant, 3) a biomass integrated gasification combined cycle power plant, and 4) a direct fired power plant from biomass residues. “Production” refers to mining in the case of coal and natural gas, and cultivation in the case of biomass crops. In the case of biomass residues, the negative value is attributed to avoided carbon emissions from biomass decay.

5.3. Summary

CO_2 emissions from the production, harvest, process, and transportation of biomass fuels in the examples above range from -413 to 44 kg CO_2 MWh^{-1}. CO_2 emissions from the production, processing, and transportation of fossil fuels in the examples above range from 47 to 125 kg CO_2 MWh^{-1}. Because biomass fuels are carbon neutral, total net CO_2 emissions per MWh are an order of magnitude less than total net CO_2 emissions from electricity from fossil fuels, depending largely on the conversion technology.

6. COMBINED RESOURCE AVAILABILITY

Part 1 of this document includes urban wood waste from tree servicing debris and woody biomass from forests. Part 2 of this document focuses on MSW resources, including C&D wood waste, refuse derived fuels, tires, and yard waste. This chapter combines resources identified in both Parts of this analysis in tabular form, ranked from cheapest to most expensive on an energy basis. The objective of this approach is to assess total quantities and costs of feedstock supply that may be available if resources from both Part 1 and Part 2 are used for energy generation. We combine resources for each utility (GRU, JEA, and TAL) under Scenario #2: "With competing demand", which includes resources within two hours of each facility, but assumes that all three facilities operate, and that resources are allocated only to the closest facility. As with the tables of results presented in Chapter 2, GRU has the option of including or excluding any particular row (resource) identified in the following tables.

Table 38. Combined resources (resources identified in both Part I and Part II) for GRU assuming Scenario #2: "With competing demand", ranked from least to most expensive.

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	0.029	0.029	0.62
Urban wood, 15-30 min.	0.123	0.151	0.81
Urban wood, 30-45 min.	0.162	0.314	0.99
Urban wood, 45-60 min.	0.154	0.468	1.18
Urban wood, 60-75 min.	0.159	0.626	1.36
Urban wood, 75-90 min.	0.193	0.819	1.55
Urban wood, 90-105 min.	0.240	1.059	1.73
Alachua Co. C&D Wood	0.165	1.224	1.80
Alachua Co. Tires	0.137	1.361	1.82
Urban wood, 105-120 min.	0.320	1.681	1.92
Gilchrist Co. Tires	0.005	1.686	1.92
Dixie Co. Tires	0.005	1.690	1.96
Putnam Co. Tires	0.023	1.713	2.01
Marion Co. Tires	0.092	1.805	2.01
Lafayette Co. Tires	0.004	1.809	2.02
Gilchrist Co. C&D Wood	0.002	1.811	2.04
Suwannee Co. Tires	0.015	1.826	2.05
Hamilton Co. Tires	0.002	1.828	2.05
Citrus Co. Tires	0.076	1.904	2.10
Sumter Co. Tires	0.039	1.943	2.10
Dixie Co. C&D Wood	0.025	1.968	2.12
Levy Co. C&D Wood	0.010	1.978	2.16
Lake Co. Tires	0.203	2.181	2.17
Lanier Co. Tires	0.008	2.189	2.17
Lowndes Co. Tires	0.096	2.285	2.18
Hernando Co. Tires	0.066	2.351	2.21
Putnam Co. C&D Wood	0.031	2.381	2.24
Marion Co. C&D Wood	0.146	2.527	2.25
Cook Co. Tires	0.016	2.543	2.26
Lafayette Co. C&D Wood	0.001	2.544	2.27
Suwannee Co. C&D Wood	0.010	2.554	2.33
Hamilton Co. C&D Wood	0.004	2.558	2.34
Citrus Co. C&D Wood	0.222	2.780	2.45
Sumter Co. C&D Wood	0.038	2.818	2.46
Alachua Co. Yard trash	0.246	3.063	2.50
Logging residues, 0-15 min.	0.066	3.129	2.60
Lake Co. C&D Wood	0.450	3.579	2.64
Lanier Co. C&D Wood	0.002	3.581	2.64
Lowndes Co. C&D Wood	0.024	3.605	2.65
Overstocked plantation, 0-15 min.	0.070	3.675	2.71
Overstocked natural, 0-15 min.	0.000	3.675	2.71
Longleaf restoration, 0-15 min.	0.008	3.683	2.71
Hernando Co. C&D Wood	0.175	3.858	2.73
Logging residues, 15-30 min.	0.329	4.187	2.77
Gilchrist Co. Yard trash	0.001	4.188	2.84

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Cook Co. C&D Wood	0.004	4.192	2.85
Overstocked plantation, 15-30 min.	0.278	4.471	2.89
Overstocked natural, 15-30 min.	0.007	4.478	2.89
Longleaf restoration, 15-30 min.	0.047	4.526	2.89
Logging residues, 30-45 min.	0.639	5.165	2.94
Dixie Co. Yard trash	0.007	5.172	2.96
Overstocked plantation, 30-45 min.	0.244	5.416	3.07
Overstocked natural, 30-45 min.	0.034	5.450	3.07
Longleaf restoration, 30-45 min.	0.189	5.638	3.07
Putnam Co. Yard trash	0.103	5.741	3.11
Logging residues, 45-60 min.	0.644	6.385	3.12
Marion Co. Yard trash	0.331	6.716	3.14
Lafayette Co. Yard trash	0.001	6.717	3.17
Pulpwood, 0-15 min.	0.279	6.996	3.23
Suwannee Co. Yard trash	0.023	7.019	3.25
Overstocked plantation, 45-60 min.	0.120	7.139	3.25
Overstocked natural, 45-60 min.	0.047	7.187	3.25
Longleaf restoration, 45-60 min.	0.310	7.497	3.25
Hamilton Co. Yard trash	0.010	7.507	3.26
Logging residues, 60-75 min.	0.722	8.229	3.29
Pulpwood, 15-30 min.	1.454	9.683	3.39
Citrus Co. Yard trash	0.363	10.047	3.42
Overstocked plantation, 60-75 min.	0.170	10.217	3.43
Overstocked natural, 60-75 min.	0.031	10.248	3.43
Longleaf restoration, 60-75 min.	0.277	10.525	3.43
Sumter Co. Yard trash	0.053	10.578	3.43
Logging residues, 75-90 min.	0.907	11.484	3.46
Pulpwood, 30-45 min.	3.004	14.488	3.55
Overstocked plantation, 75-90 min.	0.241	14.730	3.60
Overstocked natural, 75-90 min.	0.035	14.765	3.60
Longleaf restoration, 75-90 min.	0.348	15.113	3.60
Logging residues, 90-105 min.	0.880	15.993	3.64
Lake Co. Yard trash	0.274	16.267	3.68
Lanier Co. Yard trash	0.015	16.281	3.68
Lowndes Co. Yard trash	0.173	16.454	3.69
Pulpwood, 45-60 min.	3.158	19.612	3.71
Overstocked plantation, 90-105 min.	0.226	19.838	3.78
Overstocked natural, 90-105 min.	0.026	19.864	3.78
Longleaf restoration, 90-105 min.	0.431	20.295	3.78
Hernando Co. Yard trash	0.197	20.492	3.81
Logging residues, 105-120 min.	0.531	21.023	3.81
Pulpwood, 60-75 min.	3.408	24.431	3.87
Overstocked plantation, 105-120 min.	0.098	24.529	3.96
Overstocked natural, 105-120 min.	0.027	24.556	3.96
Longleaf restoration, 105-120 min.	0.415	24.971	3.96
Cook Co. Yard trash	0.029	25.000	3.97
Pulpwood, 75-90 min.	4.310	29.310	4.03

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Alachua Co. MSW	1.097	30.407	4.10
Pulpwood, 90-105 min.	3.795	34.202	4.19
Pulpwood, 105-120 min.	2.037	36.239	4.34
Gilchrist Co. MSW	0.048	36.287	4.39
Dixie Co. MSW	0.036	36.323	4.48
Putnam Co. MSW	0.270	36.593	4.62
Marion Co. MSW	1.346	37.939	4.64
Lafayette Co. MSW	0.017	37.956	4.66
Suwannee Co. MSW	0.129	38.085	4.73
Hamilton Co. MSW	0.046	38.131	4.74
Citrus Co. MSW	0.974	39.105	4.87
Sumter Co. MSW	0.342	39.447	4.88
Lake Co. MSW	1.016	40.463	5.09
Lanier Co. MSW	0.105	40.568	5.09
Lowndes Co. MSW	1.251	41.819	5.10
Hernando Co. MSW	0.843	42.662	5.20
Cook Co. MSW	0.208	42.870	5.33

Table 39. Combined resources (resources identified in both Part I and Part II) for JEA assuming Scenario #2: "With competing demand", ranked from least to most expensive.

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	0.084	0.084	0.62
Urban wood, 15-30 min.	0.350	0.433	0.81
Urban wood, 30-45 min.	0.431	0.864	0.99
Urban wood, 45-60 min.	0.204	1.069	1.18
Urban wood, 60-75 min.	0.151	1.219	1.36
Duval Co. Yard trash	1.265	2.484	1.49
Urban wood, 75-90 min.	0.098	2.582	1.55
Baker Co. Yard trash	0.031	2.613	1.61
Nassau Co. Yard trash	0.005	2.618	1.63
Union Co. Yard trash	0.018	2.636	1.65
Bradford Co. Yard trash	0.039	2.675	1.68
Urban wood, 90-105 min.	0.096	2.770	1.73
Clay Co. Yard trash	0.176	2.946	1.77
Duval Co. C&D Wood	0.961	3.907	1.78
Columbia Co. Yard trash	0.022	3.929	1.81
Duval Co. Tires	0.383	4.313	1.82
Charlton Co. Yard trash	0.019	4.332	1.82
Ware Co. Yard trash	0.057	4.389	1.82
Baker Co. Tires	0.011	4.400	1.88
Nassau Co. Tires	0.035	4.436	1.88
Union Co. Tires	0.007	4.442	1.90
Camden Co. Yard trash	0.096	4.538	1.90
Bradford Co. Tires	0.007	4.545	1.91
Urban wood, 105-120 min.	0.105	4.650	1.92
Baker Co. C&D Wood	0.002	4.652	1.93
St. Johns Co. Yard trash	0.232	4.884	1.94
Nassau Co. C&D Wood	0.036	4.919	1.94
Clay Co. Tires	0.098	5.017	1.96
Union Co. C&D Wood	0.001	5.018	1.97
Columbia Co. Tires	0.049	5.068	1.97
Charlton Co. Tires	0.011	5.078	1.98
Ware Co. Tires	0.032	5.110	1.98
Brantley Co. Yard trash	0.030	5.140	1.99
Bradford Co. C&D Wood	0.004	5.143	2.01
Camden Co. Tires	0.053	5.197	2.02
St. Johns Co. Tires	0.119	5.316	2.04
Echols Co. Yard trash	0.009	5.325	2.04
Brantley Co. Tires	0.016	5.341	2.06
Echols Co. Tires	0.005	5.346	2.09
Flagler Co. Yard trash	0.176	5.523	2.11
Clinch Co. Yard trash	0.012	5.535	2.12
Clay Co. C&D Wood	0.049	5.584	2.12
Flagler Co. Tires	0.118	5.701	2.13
Clinch Co. Tires	0.007	5.708	2.13

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Glynn Co. Tires	0.064	5.772	2.14
Glynn Co. Yard trash	0.116	5.888	2.14
Pierce Co. Tires	0.016	5.904	2.15
Wayne Co. Tires	0.027	5.931	2.15
Pierce Co. Yard trash	0.029	5.960	2.15
Columbia Co. C&D Wood	0.027	5.987	2.16
Charlton Co. C&D Wood	0.003	5.989	2.18
Ware Co. C&D Wood	0.008	5.997	2.18
McIntosh Co. Tires	0.012	6.009	2.21
Volusia Co. Tires	0.559	6.568	2.23
Camden Co. C&D Wood	0.013	6.581	2.27
McIntosh Co. Yard trash	0.021	6.602	2.28
Volusia Co. Yard trash	1.173	7.775	2.31
St. Johns Co. C&D Wood	0.119	7.894	2.32
Worth Co. Tires	0.021	7.915	2.36
Brantley Co. C&D Wood	0.004	7.920	2.38
Echols Co. C&D Wood	0.001	7.921	2.44
Flagler Co. C&D Wood	0.251	8.171	2.53
Clinch Co. C&D Wood	0.002	8.173	2.54
Glynn Co. C&D Wood	0.016	8.189	2.56
Pierce Co. C&D Wood	0.004	8.193	2.57
Logging residues, 0-15 min.	0.044	8.238	2.60
Longleaf restoration, 0-15 min.	0.010	8.248	2.71
Overstocked natural, 0-15 min.	0.000	8.248	2.71
Overstocked plantation, 0-15 min.	0.002	8.250	2.71
McIntosh Co. C&D Wood	0.003	8.253	2.72
Volusia Co. C&D Wood	0.957	9.210	2.76
Logging residues, 15-30 min.	0.311	9.521	2.77
Longleaf restoration, 15-30 min.	0.068	9.589	2.89
Overstocked natural, 15-30 min.	0.000	9.589	2.89
Overstocked plantation, 15-30 min.	0.017	9.606	2.89
Logging residues, 30-45 min.	0.629	10.235	2.94
Longleaf restoration, 30-45 min.	0.124	10.359	3.07
Overstocked natural, 30-45 min.	0.003	10.362	3.07
Overstocked plantation, 30-45 min.	0.029	10.391	3.07
Logging residues, 45-60 min.	0.667	11.058	3.12
Pulpwood, 0-15 min.	0.170	11.228	3.23
Longleaf restoration, 45-60 min.	0.117	11.345	3.25
Overstocked natural, 45-60 min.	0.015	11.360	3.25
Overstocked plantation, 45-60 min.	0.063	11.423	3.25
Logging residues, 60-75 min.	0.586	12.009	3.29
Pulpwood, 15-30 min.	1.373	13.382	3.39
Longleaf restoration, 60-75 min.	0.102	13.483	3.43
Overstocked natural, 60-75 min.	0.029	13.512	3.43
Overstocked plantation, 60-75 min.	0.042	13.554	3.43
Logging residues, 75-90 min.	0.532	14.086	3.46
Pulpwood, 30-45 min.	2.936	17.022	3.55
Longleaf restoration, 75-90 min.	0.101	17.123	3.60

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Overstocked natural, 75-90 min.	0.049	17.172	3.60
Overstocked plantation, 75-90 min.	0.018	17.191	3.60
Logging residues, 90-105 min.	0.794	17.984	3.64
Pulpwood, 45-60 min.	3.158	21.142	3.71
Longleaf restoration, 90-105 min.	0.118	21.260	3.78
Overstocked natural, 90-105 min.	0.032	21.291	3.78
Overstocked plantation, 90-105 min.	0.024	21.316	3.78
Logging residues, 105-120 min.	0.796	22.112	3.81
Pulpwood, 60-75 min.	2.667	24.780	3.87
Longleaf restoration, 105-120 min.	0.125	24.904	3.96
Overstocked natural, 105-120 min.	0.008	24.912	3.96
Overstocked plantation, 105-120 min.	0.016	24.928	3.96
Pulpwood, 75-90 min.	2.379	27.307	4.03
Duval Co. MSW	4.928	32.235	4.09
Pulpwood, 90-105 min.	3.582	35.818	4.19
Baker Co. MSW	0.103	35.921	4.25
Nassau Co. MSW	0.240	36.161	4.28
Union Co. MSW	0.069	36.230	4.31
Pulpwood, 105-120 min.	3.564	39.793	4.34
Bradford Co. MSW	0.106	39.899	4.35
Clay Co. MSW	1.029	40.928	4.48
Columbia Co. MSW	0.397	41.325	4.53
Charlton Co. MSW	0.139	41.464	4.55
Ware Co. MSW	0.416	41.880	4.55
Camden Co. MSW	0.695	42.575	4.66
St. Johns Co. MSW	0.933	43.508	4.72
Brantley Co. MSW	0.214	43.722	4.78
Echols Co. MSW	0.067	43.789	4.86
Flagler Co. MSW	0.525	44.314	4.96
Clinch Co. MSW	0.087	44.401	4.97
Glynn Co. MSW	0.838	45.239	5.00
Pierce Co. MSW	0.207	45.446	5.01
McIntosh Co. MSW	0.152	45.598	5.19
Volusia Co. MSW	3.392	48.990	5.23

Table 40. Combined resources (resources identified in both Part I and Part II) for TAL assuming Scenario #2: "With competing demand", ranked from least to most expensive.

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Urban wood, 0-15 min.	0.027	0.027	0.62
Urban wood, 15-30 min.	0.126	0.153	0.81
Urban wood, 30-45 min.	0.150	0.303	0.99
Urban wood, 45-60 min.	0.081	0.384	1.18
Urban wood, 60-75 min.	0.080	0.463	1.36
Urban wood, 75-90 min.	0.097	0.561	1.55
Urban wood, 90-105 min.	0.124	0.684	1.73
Calhoun Co. C&D Wood	0.001	0.685	1.75
Calhoun Co. Tires	0.016	0.701	1.80
Leon Co. C&D Wood	0.588	1.289	1.81
Leon Co. Tires	0.251	1.540	1.83
Gadsden Co. Tires	0.013	1.554	1.88
Wakulla Co. Tires	0.018	1.571	1.88
Grady Co. Tires	0.024	1.595	1.91
Liberty Co. Tires	0.001	1.596	1.92
Urban wood, 105-120 min.	0.179	1.775	1.92
Gadsden Co. C&D Wood	0.010	1.786	1.94
Wakulla Co. C&D Wood	0.006	1.791	1.94
Thomas Co. Tires	0.041	1.832	1.95
Decatur Co. Tires	0.027	1.860	1.95
Jefferson Co. Tires	0.007	1.867	1.99
Madison Co. Tires	0.010	1.878	1.99
Grady Co. C&D Wood	0.006	1.884	2.01
Liberty Co. C&D Wood	0.001	1.885	2.02
Mitchell Co. Tires	0.024	1.909	2.03
Worth Co. Tires	0.021	1.931	2.04
Colquitt Co. Tires	0.042	1.973	2.05
Brooks Co. Tires	0.016	1.988	2.05
Miller Co. Tires	0.006	1.994	2.05
Seminole Co. Tires	0.009	2.003	2.05
Taylor Co. Tires	0.006	2.009	2.06
Houston Co. Tires	0.007	2.016	2.06
Franklin Co. Tires	0.004	2.019	2.07
Baker Co. Tires	0.004	2.023	2.08
Thomas Co. C&D Wood	0.010	2.034	2.09
Early Co. Tires	0.011	2.045	2.10
Decatur Co. C&D Wood	0.007	2.052	2.10
Jackson Co. Tires	0.033	2.084	2.12
Washington Co. Tires	0.005	2.089	2.12
Holmes Co. Tires	0.009	2.098	2.14
Jefferson Co. C&D Wood	0.003	2.100	2.21
Madison Co. C&D Wood	0.005	2.106	2.21
Geneva Co. Tires	0.038	2.143	2.22
Henry Co. Tires	0.006	2.149	2.23

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Walton Co. Tires	0.089	2.238	2.27
Mitchell Co. C&D Wood	0.006	2.244	2.30
Worth Co. C&D Wood	0.005	2.250	2.32
Colquitt Co. C&D Wood	0.011	2.260	2.33
Brooks Co. C&D Wood	0.004	2.264	2.34
Miller Co. C&D Wood	0.002	2.266	2.34
Seminole Co. C&D Wood	0.002	2.268	2.34
Taylor Co. C&D Wood	0.002	2.270	2.38
Houston Co. C&D Wood	0.002	2.272	2.38
Franklin Co. C&D Wood	0.007	2.278	2.39
Baker Co. C&D Wood	0.001	2.279	2.41
Calhoun Co. Yard trash	0.003	2.282	2.43
Early Co. C&D Wood	0.003	2.285	2.47
Jackson Co. C&D Wood	0.003	2.288	2.52
Washington Co. C&D Wood	0.002	2.290	2.52
Leon Co. Yard trash	0.151	2.441	2.53
Holmes Co. C&D Wood	0.001	2.442	2.56
Logging residues, 0-15 min.	0.038	2.479	2.60
Gadsden Co. Yard trash	0.044	2.524	2.70
Wakulla Co. Yard trash	0.001	2.525	2.70
Longleaf restoration, 0-15 min.	0.029	2.554	2.71
Overstocked natural, 0-15 min.	0.005	2.559	2.71
Overstocked plantation, 0-15 min.	0.000	2.559	2.71
Geneva Co. C&D Wood	0.009	2.569	2.74
Henry Co. C&D Wood	0.002	2.570	2.76
Logging residues, 15-30 min.	0.207	2.777	2.77
Grady Co. Yard trash	0.043	2.820	2.80
Liberty Co. Yard trash	0.001	2.822	2.81
Walton Co. C&D Wood	0.220	3.041	2.88
Longleaf restoration, 15-30 min.	0.154	3.196	2.89
Overstocked natural, 15-30 min.	0.033	3.229	2.89
Overstocked plantation, 15-30 min.	0.000	3.229	2.89
Thomas Co. Yard trash	0.074	3.303	2.92
Decatur Co. Yard trash	0.049	3.352	2.93
Logging residues, 30-45 min.	0.446	3.798	2.94
Longleaf restoration, 30-45 min.	0.351	4.149	3.07
Overstocked natural, 30-45 min.	0.074	4.223	3.07
Overstocked plantation, 30-45 min.	0.051	4.274	3.07
Jefferson Co. Yard trash	0.008	4.282	3.08
Madison Co. Yard trash	0.014	4.296	3.08
Logging residues, 45-60 min.	0.705	5.001	3.12
Mitchell Co. Yard trash	0.044	5.045	3.21
Worth Co. Yard trash	0.038	5.083	3.23
Pulpwood, 0-15 min.	0.194	5.277	3.23
Colquitt Co. Yard trash	0.075	5.353	3.25
Longleaf restoration, 45-60 min.	0.524	5.876	3.25
Overstocked natural, 45-60 min.	0.090	5.966	3.25
Overstocked plantation, 45-60 min.	0.114	6.080	3.25

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Brooks Co. Yard trash	0.028	6.108	3.26
Miller Co. Yard trash	0.010	6.119	3.26
Seminole Co. Yard trash	0.016	6.134	3.26
Logging residues, 60-75 min.	1.098	7.232	3.29
Taylor Co. Yard trash	0.014	7.246	3.31
Houston Co. Yard trash	0.012	7.258	3.31
Franklin Co. Yard trash	0.023	7.281	3.32
Baker Co. Yard trash	0.007	7.288	3.36
Pulpwood, 15-30 min.	1.040	8.328	3.39
Longleaf restoration, 60-75 min.	0.499	8.827	3.43
Overstocked natural, 60-75 min.	0.150	8.977	3.43
Overstocked plantation, 60-75 min.	0.150	9.128	3.43
Early Co. Yard trash	0.021	9.148	3.44
Logging residues, 75-90 min.	1.422	10.570	3.46
Jackson Co. Yard trash	0.036	10.606	3.51
Washington Co. Yard trash	0.006	10.611	3.51
Pulpwood, 30-45 min.	2.052	12.663	3.55
Holmes Co. Yard trash	0.003	12.666	3.57
Longleaf restoration, 75-90 min.	0.419	13.085	3.60
Overstocked natural, 75-90 min.	0.155	13.241	3.60
Overstocked plantation, 75-90 min.	0.145	13.385	3.60
Logging residues, 90-105 min.	1.444	14.829	3.64
Pulpwood, 45-60 min.	2.965	17.794	3.71
Lafayette Co. Yard trash	0.001	17.795	3.72
Longleaf restoration, 90-105 min.	0.403	18.198	3.78
Overstocked natural, 90-105 min.	0.144	18.342	3.78
Overstocked plantation, 90-105 min.	0.297	18.639	3.78
Logging residues, 105-120 min.	1.305	19.944	3.81
Geneva Co. Yard trash	0.068	20.011	3.82
Henry Co. Yard trash	0.011	20.022	3.85
Pulpwood, 60-75 min.	4.804	24.826	3.87
Longleaf restoration, 105-120 min.	0.449	25.275	3.96
Overstocked natural, 105-120 min.	0.071	25.346	3.96
Overstocked plantation, 105-120 min.	0.366	25.712	3.96
Walton Co. Yard trash	0.013	25.725	4.00
Pulpwood, 75-90 min.	6.591	32.317	4.03
Calhoun Co. MSW	0.038	32.355	4.04
Leon Co. MSW	1.525	33.880	4.12
Pulpwood, 90-105 min.	6.904	40.784	4.19
Gadsden Co. MSW	0.149	40.933	4.26
Wakulla Co. MSW	0.074	41.007	4.26
Pulpwood, 105-120 min.	6.112	47.119	4.34
Grady Co. MSW	0.311	47.430	4.35
Liberty Co. MSW	0.021	47.451	4.36
Thomas Co. MSW	0.536	47.987	4.45
Decatur Co. MSW	0.357	48.344	4.46
Jefferson Co. MSW	0.078	48.422	4.58
Madison Co. MSW	0.098	48.520	4.58

Resource/haul time category	*TBtu/year recoverable*	*Cumulative TBtu/year recoverable*	*Price ($/MMBtu)*
Mitchell Co. MSW	0.318	48.838	4.69
Worth Co. MSW	0.279	49.117	4.72
Colquitt Co. MSW	0.546	49.663	4.73
Brooks Co. MSW	0.202	49.865	4.74
Miller Co. MSW	0.076	49.941	4.74
Seminole Co. MSW	0.113	50.054	4.74
Taylor Co. MSW	0.046	50.100	4.78
Houston Co. MSW	0.090	50.190	4.78
Franklin Co. MSW	0.057	50.247	4.79
Baker Co. MSW	0.052	50.299	4.83
Early Co. MSW	0.149	50.448	4.89
Jackson Co. MSW	0.244	50.692	4.95
Washington Co. MSW	0.094	50.786	4.95
Holmes Co. MSW	0.047	50.833	5.00
Dougherty Co. MSW	1.128	51.961	5.01
Geneva Co. MSW	0.490	52.451	5.21
Henry Co. MSW	0.076	52.527	5.23
Walton Co. MSW	0.462	52.989	5.36

7. CONCLUSIONS

It is impossible to predict exactly what amount of which type of resources would be available to each facility at some price. However, under base case scenario #2, which assumes GRU, JEA, and TAL all use the biomass resources closest to them, the total amount of woody biomass available for less than $3.00 per MMBtu delivered in the two-hour woodsheds of the three facilities is 474,500 dry tons, or 7.20 TBtu, per year. Fifty-three percent of this total is urban wood waste within a two-hour haul of the three facilities, 37% is logging residues within a 45-minute haul, and the remaining 10% is comprised of thinnings within a 30-minute haul. This total includes 2.82 TBtu/year delivered to GRU, 2.56 TBtu/year to JEA, and 1.78 TBtu/year TAL. The total consists of 11% of the wood waste, logging residues, and thinnings available within a two-hour maximum haul of the three facilities.

The least-cost biomass resources needed to provide 10.65 TBtu/year (enough to generate three 40 MW facilities) in scenario #2 would be comprised of about 35% urban wood waste, 42% logging residues, and about 20% from thinnings of natural stands and plantations. To provide 3.55 TBtu per year for each facility, the amount required to produce 40 MW, the marginal cost is expected to be $3.12, $3.23, and $3.25 per MMBtu at GRU, JEA, and TAL, respectively.

About 3% of this least-cost supply of 10.65 TBtu/year would be met with nearby pulpwood (Figure 32). Pulpwood comprises 0%, 4%, and 6% of the least-cost resources used to provide 40 MW for GRU, JEA, and TAL, respectively. The 10.65 TBtu/year needed to power these three facilities, is 11% of the 100.91 TBtus/year from urban wood waste, logging residues, thinnings, and pulpwood identified within a two-hour haul of the three facilities. The resources included in these scenarios are about 100%, 28%, 27%, 25%, 15%, and 0.4% of annually available urban wood waste, logging resides, thinnings from longleaf pine restoration, thinnings from overstocked plantations, thinnings from overstocked natural stands, and pulpwood, respectively, within the two-hour one-way woodsheds, excluding overlap of adjacent woodsheds (Figure 33).

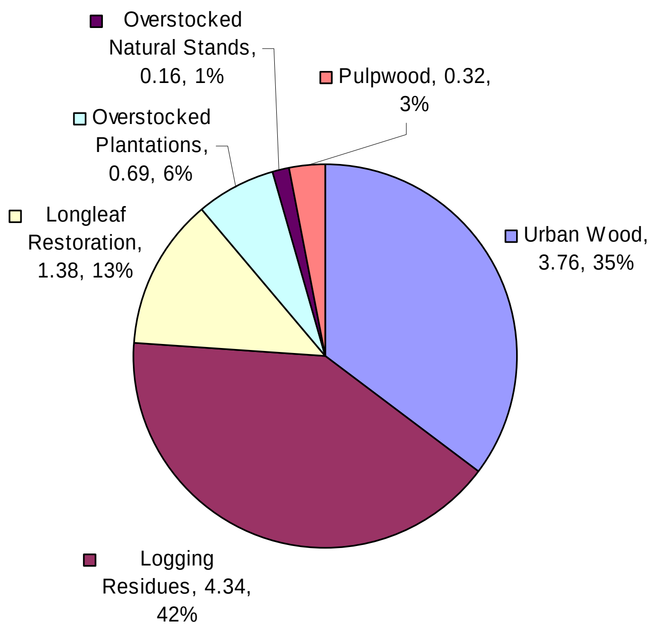


Figure 32. Total woody biomass resource composition to produce 10.65 TBtu/year for three (GRU, JEA, and TAL) 40 MW facilities under scenarios #2: "With competing demand" and #3: "With price competition". Values shown are TBtu/year, followed by percent of the 10.65 TBtu/year supply.

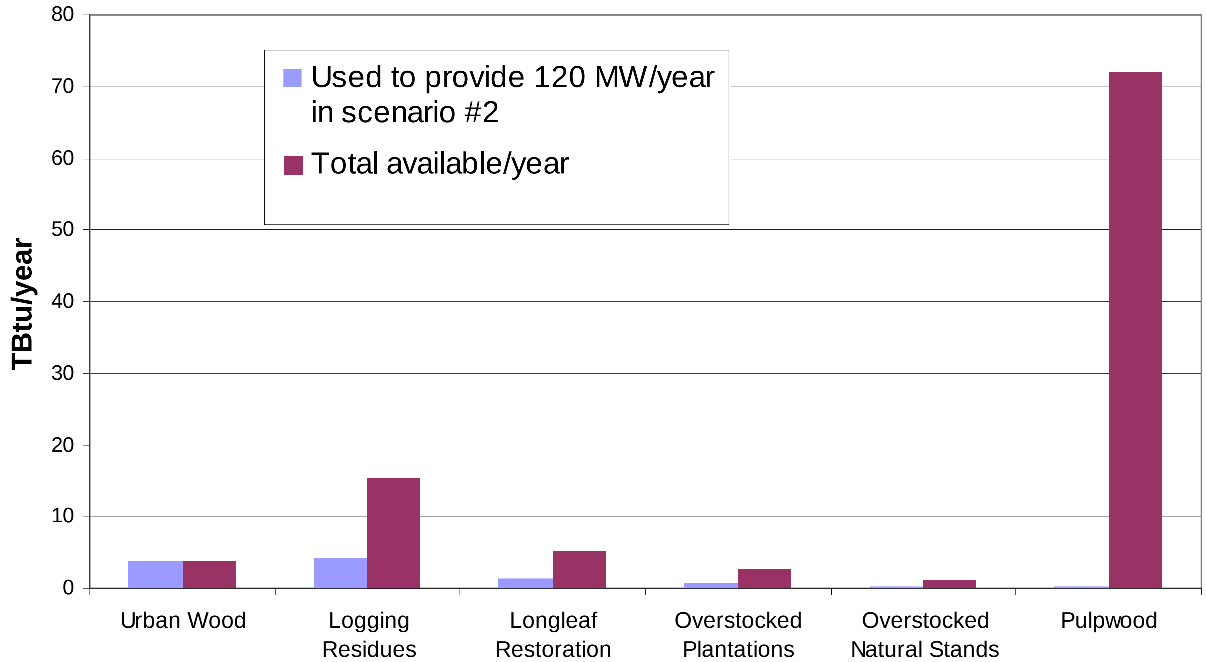


Figure 33. A comparison of A) least-cost resources used to provide 10.65 TBtu/year (three 40 MW facilities) under scenarios #2: "With competing demand" and #3: "With price competition", and B) total availability of these resources within the three two-hour woodsheds, excluding overlap of adjacent woodsheds.

There is some debate as to how much commercial pulpwood could and should be used to generate bioenergy. Clearly, the pulp and paper industry stands to lose, and tree farmers stand to gain, if the demand for pulpwood increases. Given the large amount of pulpwood compared to the other resources, at a minimum pulpwood could serve as a "backstop" to ensure that quantities of biomass are available to meet bioenergy demand based mostly on other biomass sources. Alternatively, if forest plantations are deemed more environmentally beneficial than competing land-use options, or more holistically, if social and environmental costs of using energy from forest plantations are less than from using conventional fuels, then an argument could be made for increasing the demand for pulpwood for bioenergy.

Considerable effort was made to ensure that quantities of biomass were not overestimated. A conservative, peer-reviewed per-capita value was used to calculate quantities of urban wood waste. This value excluded C&D and industrial wood waste, and further was assumed to be only 60% available. After beginning this project, we reduced assumptions of availability of current logging residues from 90% to 60% to account for whole tree harvesting by pulpwood mills. However, this loss was more than compensated by updating assumptions of Btus required to generate 40 MW from 4.65 TBtu/year to 3.55 TBtu/year based on improved generating efficiencies. While many variables in this assessment will change with time, we believe that by accounting for as many details as possible and using conservative assumptions, our results are "best available".

Two components of this analysis were challenging to assess. One was potential quantities of biomass from thinnings. While urban wood waste, logging residues, and pulpwood are currently available resources, forest thinnings which might become available if a market develops are more speculative. Furthermore, wood that may become available from thinnings could be sold to pulpwood markets rather than for bioenergy, if it meets commercial size and quality specifications. However, as described in section 2.2.1, thinnings were assumed only to come from young overstocked stands or from infrequent habitat restoration projects.

The other challenging aspect of this project was determining total delivered price for the various resources. On the one hand, stumpage prices, harvesting, and transportation costs have been well-documented for many years. However, it is difficult to predict how profit-seekers will behave as markets develop. Similarly, future environmental policies that incentivize more renewable energy, or technological developments like cellulosic ethanol that may eventually convert woody biomass to transportation fuels at competitive prices, may increase demand for biomass in the future. For these reasons, we believe a) the quantities described in these scenarios are known with reasonable certainty, b) the prices for these resources is based on the best information available, and represents a good starting point for assessing the economic feasibility of bioenergy projects, and c) long-term contracts for biomass would have to be negotiated with suppliers to validate the price assumptions presented in the report.

At the outset of the project, long-term availability was going to be evaluated by determining the impact of land-use change on biomass availability. Under this approach it might have been assumed that reduced forest area in the future will result in less woody biomass. However, after further consideration we decided to extend our current approach to quantify urban wood waste based on population data and forestry resources based on USDA Forest Service data. In short, both population and forest production is projected to increase in Florida, which, if anything, would increase future quantities of urban wood waste and logging residues, which together comprise over three quarters of currently available least-cost biomass resources. While we are confident that woody biomass waste will be at least as abundant in 2030 in Florida as it is now, projecting future prices is less certain in light of changing markets and technologies.

We have evaluated the economic availability of biomass resources based on available published data. However, we have not accounted for opportunistic biomass resources. At the broadest level, about every three to five years, there is a significant source of biomass made available in north Florida, for example from urban wood waste from hurricanes, or forest biomass from insect infestations or fire-damaged plantations. Providing a market for these episodically available resources would reduce their associated costs. Another opportunity to expand the biomass resource is from the aspect of forest management. Management practices, for example planting density, thinning scheduling and intensity, and final harvest, is responsive to changing markets and landowner objectives. We feel that possibly the greatest opportunity to increase the availability of woody biomass is to modify silvicultural practices to produce woody biomass. This could be done by increasing planting density and starting thinning at a younger age, thus increasing the profitability of tree farming, and thereby reducing the pressure to convert land to nonforest uses. Biomass thinnings could be a valuable complement to sawtimber production. A third opportunity is simply to incentivize forestry and tree production. Forest plantation establishment historically has increased with demand for forest products, and conversely, declines with decreased demand. In conclusion, while the actual composition of the biomass supply that would be employed to provide 40 MW is unknown, clearly in the long-term there are various resource options that could be used.

There are various factors to consider in the decision of how much if any “commercially available” forest biomass can or should be included in the feedstock mix for bioenergy facilities. It is a potentially politically sensitive issue to suggest increasing harvests of forest biomass for purposes of energy generation. However, our results suggested that there are significant amounts of woody biomass available from various sources, many at prices competitive with current costs of fossil fuels on a Btu basis. These quantities and prices are detailed in Section 2.3. While forest resources can be exhausted if managed irresponsibly, it is well documented that opportunities exist to use biomass wastes and forest resources that at a minimum are sustainable and renewable, and in many cases benefit the resources themselves. For these reasons, we recommend that GRU, in coordination with JEA and TAL, continue the process of evaluating the economic viability of using biomass resources to meet projected increases in electricity demand.

8. APPENDIX

Appendix A: Base case scenario assumptions of operations, costs, energy content, and availability for logging residues, urban wood waste, thinnings, and pulpwood.

Variable/attribute	*Logging residues*	*Urban Wood Waste*	*Thinnings*[a]	*Pulpwood*
Load and unload time per load (hours)	0.50	0.50	0.50	0.50
Load and unload cost per load ($)	$ 25.00	$ 25.00	$ 25.00	$ 25.00
Green tons per load	23.0	22.0	25.0	28.0
Load and unload cost per green ton ($)	$ 1.09	$ 1.14	$ 1.00	$ 0.89
Moisture content (green weight basis)	37%	40%	47%	47%
Ash content (green weight basis)	2.5%	2.5%	1.0%	1.0%
Load and unload cost per dry ton ($)	$ 1.80	$ 1.89	$ 1.93	$ 1.72
Haul cost ($/hour/load)[b]	$ 75.00	$ 75.00	$ 75.00	$ 75.00
Haul cost ($/hour/green ton)	$ 3.26	$ 3.41	$ 3.00	$ 2.68
Two-way haul cost ($/hour/dry ton)	$ 10.78	$ 11.86	$ 11.54	$ 10.30
MMBtu/dry ton	15.58	15.99	16.15	16.24
Harvest and process ($/dry ton)	$ 33.00	$ 30.00	$ 33.00	$ 33.00
Procurement cost ($/dry ton)	$ 3.00	$ -25.00	$ 6.00	$ 15.21
% of quantity assumed recoverable	60%	60%	100%	100%

[a]Includes longleaf restoration thinnings and thinnings of overstocked plantations and natural stands.
[b]Based on prices received from trucking companies accounting for varying fleet age, weight, and expenses.

Appendix B: Assumptions of wood densities by major species group.

	Pounds/dry cubic foot	Pounds/green cubic foot (50% MC)
Hardwoods	32	64
Softwoods	30	60

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