Final Report to the South Carolina Forestry Commission on

POTENTIAL FOR BIOMASS ENERGY DEVELOPMENT IN SOUTH CAROLINA

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Report Highlights

This report quantifies the amount of forestry and agricultural biomass that is available for energy production on a sustainable basis in South Carolina. It also includes an analysis of the economic impacts of transferring out-of-state costs for coal to in-state family forest landowners and biomass processors. The economic analysis focuses on stand-alone biomass plants rather than co-firing at existing coal plants due to the magnitude of biomass that is available. In summary, the biomass resource is plentiful and the technology is available to utilize it efficiently. Keeping energy dollars in state will create jobs, improve the environment, and benefit the state and local economy. The report recommends the formation of a task force to identify strategies for encouraging the development of biomass energy production in South Carolina.

The Biomass Resource

- The sources for forest biomass were quantified using the Forest Inventory and Analysis (FIA) and the Timber Product Output (TPO) programs that are jointly administered in South Carolina by the USDA Forest Service and the SC Forestry Commission.
- **Logging Residues**: 4,411,500 green tons per year are available. There is an average of 96,000 tons/county/year.
- **Precommercial Thinnings**: 8,555,796 tons/year are available. There is an average of 186,000 tons/county/year.
- **Commercial Thinning**: 5,336,000 tons/year are available. There is an average of 116,000 tons/county/year.
- **Southern Scrub Oak**: 48,792 tons/year available in 7 counties.
- **Mill Residues**: 1,712,528 tons/year available. All but 12,086 tons are being utilized currently.
- **Urban Wood Waste**: 621,000 tons/year available (based on .1655 tons/person/year in densely populated counties and .1487 tons/person/year in rural counties)
- **Forestry Biomass Totals**: 20.9 million tons/year of sustainable biomass.
- **Agricultural Biomass Totals**: 1.2 million tons/year (corn – 492,128 tons/year, wheat – 224,721 tons/year, soybean – 238,424 tons/year, cotton – 296,113 tons/year).
- **Forestry & Ag Biomass Totals**: Over 22 million tons/year of sustainable biomass. This could theoretically replace 4.8 million tons of coal in SC (1/3 of all the coal used in producing power in SC).

Conversion of Biomass to Power

- Dedicated **biomass-fueled power plants**. This is mature technology. Plants tend to be small (20-40 MW) and less efficient than coal and natural gas plants.
- Next generation **biomass-gasification plants**. These will match coal & natural gas plants in efficiency when available.

- **Co-firing biomass** with coal may be a viable option for utilizing sizable amounts of biomass for power production in South Carolina. Biomass can substitute for 15% or more of coal with little loss of efficiency. There are many environmental benefits (lower emissions of ozone causing chemicals, no mercury, no net release of carbon to atmosphere, wildfire risk reduction, RCW habitat improvement). There needs to be further study of coal-fired plants to see which ones could co-fire w/ biomass economically.

Short-term Scenario

- Short-term goal of **10 - 40 MW biomass plants** fueled w/ logging residue and some thinnings. This would offset 8% of coal and produce 3% of the electrical production in the state.
- **Job Creation**: 5,700 jobs during the year the 10 plants are built and 1060 jobs during subsequent years.
- **Wages**: Additional wages of over $200 million are expected in the year the 10 plants are built and $30-37 million in additional wages in subsequent years.
- Economic impact of 10 biomass plants would increase **net state revenue** by $14 million in the year that the plants are constructed and $2.5 million in subsequent years.
- **Local governments** would have a net benefit of between $23 and $29 million annually from 10 biomass plants.
- **Utility bills** would increase $3.44 on a $100 power bill to allow utilities to recover capital construction costs. Other options include state tax credits.
- **Green power**, that is power produced from renewable energy, commands a premium price ($1-$3/MWh higher) that can help offset the higher cost of production.
- Forestlands would be healthier & more productive.
- Reduced emission of SO2, NOx, mercury, atmospheric carbon.

Recommendations

- There needs to be further study of coal-fired plants to see which ones could co-fire w/ biomass economically. This is a cost-effective way to utilize biomass with little or no increase in consumer's utility bills.
- A task force should be developed of representatives of each utility operating in the state, representatives of state government, forest industry and other stakeholders to investigate alternatives for encouraging the development of biomass energy production in South Carolina.

POTENTIAL FOR BIOMASS ENERGY DEVELOPMENT IN SOUTH CAROLINA

Introduction

The utilization of biomass for energy in South Carolina may have many benefits, including improved forest management, increased revenue for land owners through utilization of biomass not currently utilized, lower site prep costs, environmental benefits for biomass verses coal power generation, increased revenues for farmers, fire prevention due to reduced fuel loading on forest lands, markets for pre-commercial thinnings, additional jobs and additional economic activity within the state. Goals of this study included: 1) quantify the amount of forest and agricultural biomass that can be utilized for energy in South Carolina; 2) determine the economics of utilizing the biomass that is available; 3) conduct a cost/benefit analysis taking into account the direct and indirect benefits to the state, and determine the amount of subsidy that could be justified to promote biomass energy; 4) identify other factors that should be considered before the State commits to develop a biomass energy program.

The Biomass Resource

The biomass resource considered for this study consists of forest biomass and agronomic crop residues.

Forest Biomass

The sources for biomass were quantified using the Forest Inventory and Analysis (FIA) and the Timber Product Output (TPO) programs that are jointly administered in South Carolina by the USDA Forest Service and South Carolina Forestry Commission.

The USDA Forest Service Forest Inventory and Analysis (FIA) program is a continuous forest inventory that has evolved from a periodic survey that began in 1930. FIA records a wide range of attributes of our nation's forests including species abundance, tree growth, mortality and removals by harvest. Field plot measurements are collected by the South Carolina Forestry Commission. The USDA Forest Service's Southern Research Station is responsible for quality assurance/quality control, data analysis, and reporting. The FIA program began as a periodic inventory and has evolved into an annual inventory reported every five years. The improved annual method includes new information on understory vegetation and coarse woody debris. The inventory provides information that can indicate change and trends in our nation's forests, which can be used by managers and policy makers to protect and preserve our natural resources.

FIA is derived from a three-phase process. The initial phase separates the use of land into forest and nonforest use from aerial photography. This phase established the acreage that supports forests and develops trends in land use. The second phase incorporates sample ground plots that sample one plot for every six thousand acres within the state. The sample plots that fall in forestland are measured for an array of attributes. The plots falling in nonforestland are visited and recorded to establish rates of land use change. The final phase is to collect data of forested land during the growing season, which provides measurements of vegetation inventory, coarse woody debris, and forest health.

Phase 3 consists of visiting a smaller number of plots than during phase 2; approximately one plot is inventoried for every ninety-six thousand acres. In development an annual inventory, the plots are measured each year at a rate of twenty percent per year and reported every five years.

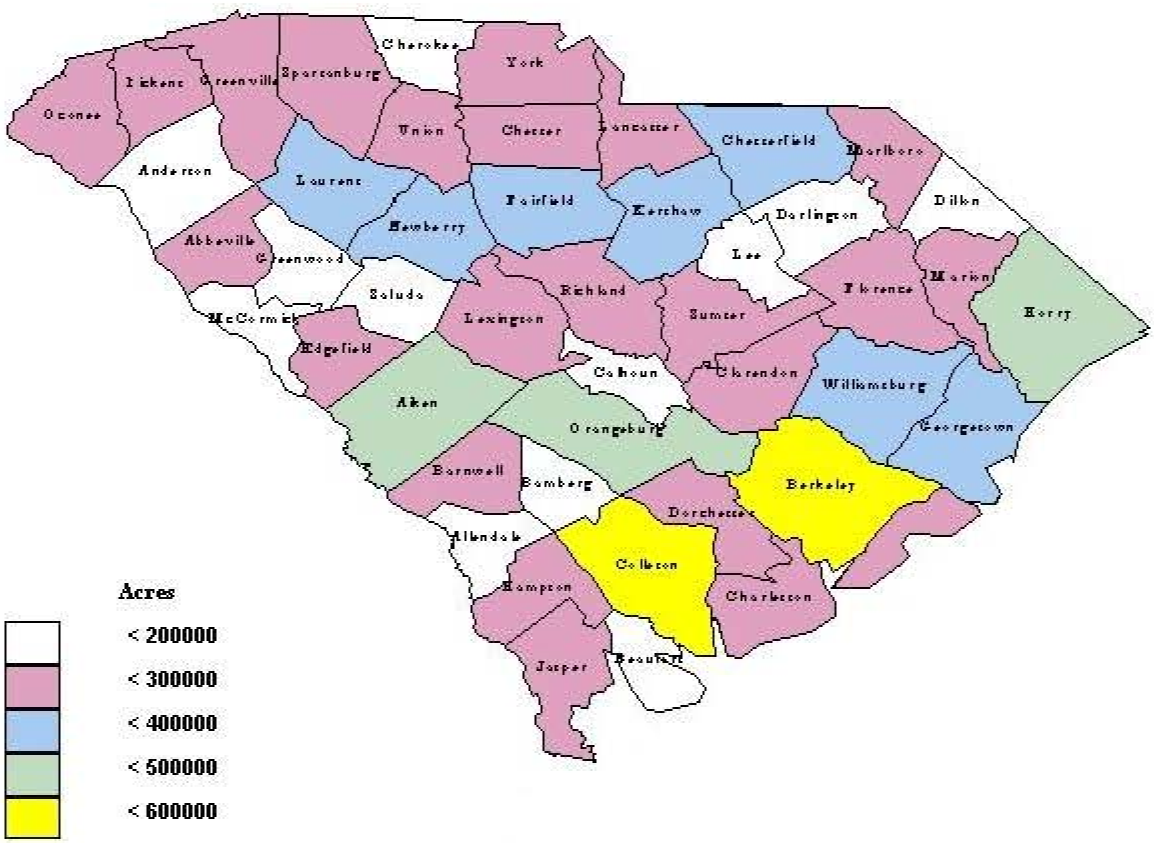
In addition to the FIA program, the USDA Forest Service compiles an assessment of the Nation's renewable resources as called for in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) and subsequent amendments. The RPA combines information from the FIA and other sources along with economic variables to predict the future demands and trends that affect our Nation's forests. To better portray amounts of wood products produced from our Nation's forests, the Timber Product Output Database (TPO) was established to supplement the RPA. The information reported in the TPO considers eleven variables relative to the production of wood products, including amounts of roundwood products harvested, logging residues produced and mill residues produced.

The quantities of woody biomass derived from logging residues, precommercial and commercial thinning, and the southern scrub oak forest type are each presented on a per timberland acre basis per county. These figures do not represent the amount of material in that form on each timberland acre but is the distribution of available material among all timberland acres. As an example, the amount of logging residues per timberland acre in Abbeville County is 0.14 green tons. This illustrates that the amount of logging residues produced within the county amount to 0.14 green tons/acre when distributed among the number of timberland acres. These figures are useful when attempting to predict the quantity of logging residues within a particular area or radius of a location.

Timberland is described as being forestland that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Inaccessible and inoperable areas are included. The distribution of timberland acres across the state of South Carolina is presented in Figure 1.

The supply of biomass within South Carolina varies by source and geographical location. The quantities are presented as the total available, the annually available, and the available per acre of timberland, with the exception of mill residues and urban wood waste, which are not affected by the number of timberland acres within the particular county. Quantities are grouped by county and subtotaled for each of the three regions within the State. The regions are displayed in a consistent order for each of the sources: Piedmont region, Northern Coastal Plain region, and Southern Coastal Plain region with the exception of southern scrub oak and mill residue materials, which are confined to particular areas or sites across the State.

Figure 1: Distribution of Timberland



Source: USDA Forest Service, Forest Inventory and Analysis 2001

Categories of Forest Residues

A. Logging Residues

Logging residues are the unused portions of growing stock trees cut or killed by logging and left in the woods. After mill residues this is the most readily available source of biomass. These residues consist largely of limbs and tops that are not collected during the harvest operation. The amount of residues left after harvesting varies among logging crews, which have different merchandising strategies and levels of effectiveness.

The feasibility of using logging residues as a source of biomass is largely dictated by the practices carried out during the harvesting operation. Often residues are dragged away from the logging deck and spread across the harvested area as a means of distributing nutrients contained in the logging residues to the site. This practice makes the collection of residues uneconomical in most situations. In hardwood stands that are selectively logged for sawtimber, an average of about 40 percent of the tree is left in the woods in the form of tops and limbs (Smith, 1982). But this amount can be much higher. For example, in the first thinning of pine plantations in Aiken County, in the Lower Coastal

Plain Region, the amount of saleable fuel material to product material can be as high as 61% (Micky Scott, Collum's Lumber Products, LLC, Personal Communication).

The quantity of logging residues produced each year is estimated by county from the number of acres harvested and then distributed among the number of timberland acres within the county. Logging residues available in the Piedmont region of South Carolina are presented in Table 1 by the acres of timberland in each county in the region.

Table 1: Piedmont Region, Annual Available Logging Residues (Green Tons)

County	Timberland Acres	Total	Residues per Acre of Timberland
Abbeville	218,714	29,970	0.14
Anderson	195,990	38,040	0.19
Cherokee	150,261	46,740	0.31
Chester	286,353	117,300	0.41
Edgefield	254,030	54,420	0.21
Fairfield	371,085	162,150	0.44
Greenville	236,256	33,270	0.14
Greenwood	185,639	127,320	0.69
Lancaster	263,633	39,810	0.15
Laurens	306,577	99,000	0.32
McCormick	199,718	112,740	0.56
Newberry	303,491	206,340	0.68
Oconee	248,290	48,000	0.19
Pickens	207,593	54,090	0.26
Saluda	178,524	93,900	0.53
Spartanburg	253,486	128,880	0.51
Union	252,281	125,400	0.50
York	258,606	83,760	0.32
Total	**4,370,527**	**1,601,130**	**0.37**[a]

*Source: USDA Forest Service, Timber Product Output 2002
[a]Annual production distributed per acre of timberland within the region

Logging residues in the Piedmont region have the capability to contribute approximately 1,600,000 tons of woody material annually. Newberry County, which has the second largest area of timberland in the region, produces the highest quantity of logging residues with approximately 206,000 tons per year. Within the Piedmont region an average of 0.37 tons are produced annually per acre of timberland.

The quantity of logging residues available within the Northern Coastal Plain is presented in Table 2. The quantities are estimated by county from the number of acres harvested and then distributed among the number of timberland acres within the county.

The Northern Coastal Plain region has the largest area of timberland in the State. With five counties having more than 350,000 acres in timberland, this region is capable of contributing the largest amount of woody material from logging residues. Logging residues average 0.35 tons per acre of timberland and total about 1,610,000 tons annually.

The largest quantity of logging residues is produced in Georgetown County with approximately 204,000 tons annually.

Table 2: Northern Coastal Plain Region, Annual Available Logging Residues (Green Tons)

County	Timberland Acres	Total	Residues per Acre of Timberland
Berkeley	536,350	105,390	0.20
Charleston	274,223	56,850	0.21
Chesterfield	370,874	38,790	0.10
Clarendon	216,380	38,790	0.18
Darlington	157,318	109,920	0.70
Dillon	147,981	99,390	0.67
Florence	279,979	100,680	0.36
Georgetown	361,291	204,150	0.57
Horry	437,026	176,040	0.40
Kershaw	341,586	119,760	0.35
Lee	107,928	44,670	0.41
Marion	204,239	120,270	0.59
Marlboro	206,019	99,570	0.48
Richland	297,470	96,270	0.32
Sumter	241,596	63,900	0.26
Williamsburg	370,692	135,390	0.37
Total	**4,550,952**	**1,609,830**	**0.35[a]**

*Source: USDA Forest Service, Timber Product Output 2002

[a]Annual production distributed per acre of timberland within the region

The quantity of logging residues produced in the Southern Coastal Plain region, by county, is shown in Table 3. The quantities are estimated by county from the number of acres harvested and then distributed among the number of timberland acres within the county.

The Southern Coastal Plain region is capable of contributing a total of approximately 1,200,000 tons of woody material in the form of logging residues annually. The largest producing county is Hampton County with 198,360 tons per year. There is an average of 0.36 tons of logging residues available annually per acre of timberland within the region. This region has the smallest area of timberland in the Sate, more than 1,000,000 acres less than the Piedmont and Northern Coastal Plain regions.

Logging residues are currently not utilized to potential. Developing a market for these materials could raise the return on timber and increase the efficiency of the forestry industry by reducing wastes. Logging residues, statewide, could provide an average of 4,411,500 tons annually to a developed woody biomass energy market.

Table 3: Southern Coastal Plain Region, Annual Available Logging Residues (Green Tons)

County	Timberland Acres	Total	Residues per Acre of Timberland
Aiken	475,503	134,610	0.28
Allendale	180,914	64,770	0.36
Bamberg	184,012	56,070	0.30
Barnwell	242,398	85,770	0.35
Beaufort	114,074	27,240	0.24
Calhoun	137,540	31,590	0.23
Colleton	508,011	168,720	0.33
Dorchester	246,746	93,090	0.38
Hampton	275,647	198,360	0.72
Jasper	297,802	112,740	0.38
Lexington	233,539	53,130	0.23
Orangeburg	403,740	174,450	0.43
Total	**3,299,926**	**1,200,540**	**0.36[a]**

*Source: USDA Forest Service, Timber Product Output 2002

[a]Annual production distributed per acre of timberland within the region

B. Intermediate Thinning

Intermediate thinning is a silvicultural operation whereby smaller and less desirable trees are removed to enhance residual trees. The main focus of intermediate thinning is to remove trees that are not desirable to enhance production of more valuable products such as sawtimber, veneer logs, and poles. Thinning allows timber growers to experience a return early in the rotation, but the majority of the return is realized with the final harvest. Thinning is the one of the few harvesting operations in which the removed stems are less valuable than the remaining stems.

Materials derived from thinned stands are primarily used for pulp and paper manufacturing. Currently there are seven pulp and paper mills in South Carolina with six more near our border (Harper, 2003). The pulp and paper market is currently oversaturated with fiber, especially softwood. This oversupply presents an opportunity to develop an energy market using intermediate thinnings as a source of biomass.

The thinning opportunities for energy biomass have been broken down into two categories: 1) unmerchantable or precommercial thinning – removal of stems less than 5.0 inches in dbh (diameter at breast height, 4.5 feet above ground), and 2) commercial-thinning which removes stems that are 5.0-8.9 inches in dbh.

C. Intermediate Thinning -- Precommercial

Precommercial thinning is one of the largest expenses in stand improvement a timber grower can encounter in the course of a rotation. A precommercial thinning involves removing a high percentage of saplings from a stand to provide room for the remaining stems to grow. The need for precommercial thinning is predominantly associated with natural regeneration in which the stand is allowed to reproduce itself by natural seeding without seedlings being imported from outside sources and with minimal management activities. Thinning may be done in pine and hardwood stands.

Precommercial thinning is expensive in that a return is not immediately realized in monetary form. The precommercially thinned stand will grow to a more valuable product class in less time with the sites' nutrients and water being divided among less stems in the future. However, the material removed is currently of no use. If a market were developed that could use this material, managers would be better able to deal with severely overstocked, young stands. In Tables 4, 5 and 6, the supply of currently unmerchantable material is presented by region and county as the amount existing on timberland and the estimated annual growth on timberland.

Table 4: Piedmont Region, Growing Stock and Estimated Annual Growth of Precommercial Biomass (<5.0 inches DBH) on Timberland (Green Tons)

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Growth	Annual Growth/Acre of Timberland
Abbeville	218,714	2,231,062	10.2	185,922	0.9
Anderson	195,990	1,600,643	8.2	133,387	0.7
Cherokee	150,261	1,523,819	10.1	126,985	0.8
Chester	286,353	1,966,218	6.9	163,852	0.6
Edgefield	254,030	1,351,791	5.3	112,649	0.4
Fairfield	371,085	3,001,552	8.1	250,129	0.7
Greenville	236,256	1,628,164	6.9	135,680	0.6
Greenwood	185,639	1,957,473	10.5	163,123	0.9
Lancaster	263,633	2,175,864	8.3	181,322	0.7
Laurens	306,577	2,542,028	8.3	211,836	0.7
McCormick	199,718	1,011,741	5.1	84,312	0.4
Newberry	303,491	2,685,707	8.8	223,809	0.7
Oconee	248,290	2,308,269	9.3	192,356	0.8
Pickens	207,593	1,720,424	8.3	143,369	0.7
Saluda	178,524	1,234,306	6.9	102,859	0.6
Spartanburg	253,486	2,114,472	8.3	176,206	0.7
Union	252,281	1,704,142	6.8	142,012	0.6
York	258,606	1,943,754	7.5	161,980	0.6
Total	**4,370,527**	**34,701,429**	**7.9[a]**	**2,891,786**	**0.7[a]**

*Source: USDA Forest Service, Forest Inventory and Analysis 2001

[a]Average distribution among timberland acres within the region

The Piedmont region is currently supporting 34,701,429 tons of unmerchantable biomass that is not being utilized. The estimated annual growth is an increase of 2,891,786 tons. Fairfield County supports the largest amount of currently unmerchantable material with 3,001,552 tons producing approximately 250,129 tons annually.

The existing and estimated annual growth of unmerchantable biomass on timberland in the Northern Coastal Plain Region is shown in Table 5. The Northern Coastal Plain region is estimated to be able to produce 3,375,610 tons of biomass annually from currently unmerchantable material. The region supports the highest amount of these materials with 40,507,315 tons. Berkeley Count has the highest annual growth with 370,101 tons.

Table 5: Northern Coastal Plain Region, Growing Stock and Estimated Annual Growth of Precommercial Biomass (<5.0 inches DBH) on Timberland (Green Tons)

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Growth	Annual Growth/Acre of Timberland
Berkeley	536,350	4,441,214	8.3	370,101	0.7
Charleston	274,223	2,799,447	10.2	233,287	0.9
Chesterfield	370,874	2,888,222	7.8	240,685	0.6
Clarendon	216,380	1,974,441	9.1	164,537	0.8
Darlington	157,318	1,676,488	10.7	139,707	0.9
Dillon	147,981	1,212,694	8.2	101,058	0.7
Florence	279,979	2,793,586	10.0	232,799	0.8
Georgetown	361,291	2,869,743	7.9	239,145	0.7
Horry	437,026	3,528,922	8.1	294,077	0.7
Kershaw	341,586	3,331,842	9.8	277,654	0.8
Lee	107,928	762,147	7.1	63,512	0.6
Marion	204,239	2,461,604	12.1	205,134	1.0
Marlboro	206,019	1,370,188	6.7	114,182	0.6
Richland	297,470	2,715,414	9.1	226,285	0.8
Sumter	241,596	2,463,538	10.2	205,295	0.8
Williamsburg	370,692	3,217,825	8.7	268,152	0.7
Total	**4,550,952**	**40,507,315**	**8.9[a]**	**3,375,610**	**0.7[a]**

*Source: USDA Forest Service, Forest Inventory and Analysis 2001

[a]Average distribution amoung timberland acres within the region

Table 6 shows the quantity of existing unmerchantable biomass and estimated annual growth for the Southern Coastal Plain Region. The Southern Coastal Plain region currently supports 27,460,803 tons of unmerchantable biomass. These materials are growing at an annual rate of 2,288,400 tons. Colleton County supports the largest quantity of unmerchantable biomass with 4,853,053 tons and an annual growth of 404,421 tons annually.

Many of the small trees in this precommercial category do not grow to merchantable size but are out-competed by more vigorous stems and die from lack of nutrients, water, and sunlight. The course of natural selection chooses the better specimens to grow; however, the superior stems are subjected to increased levels of stress during this competing stage and grow at a slower rate than if the stand was thinned for biomass to produce energy. If a method of collecting these materials in an efficient manner is developed, unmerchantable material could supply approximately 8,555,796 tons annually on a sustainable basis with a base of 102,669,000 tons.

Table 6: Southern Coastal Plain, Growing Stock and Estimated Annual Growth of Precommercial Biomass (<5.0 inches DBH) on Timberland (Green Tons)

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Growth	Annual Growth/Acre of Timberland
Aiken	475,503	3,422,106	7.2	285,176	0.6
Allendale	180,914	1,609,583	8.9	134,132	0.7
Bamberg	184,012	1,679,460	9.1	139,955	0.8
Barnwell	242,398	1,817,997	7.5	151,500	0.6
Beaufort	114,074	939,807	8.2	78,317	0.7
Calhoun	137,540	1,343,496	9.8	111,958	0.8
Colleton	508,011	4,853,053	9.6	404,421	0.8
Dorchester	246,746	2,174,299	8.8	181,192	0.7
Hampton	275,647	2,591,777	9.4	215,981	0.8
Jasper	297,802	2,112,266	7.1	176,022	0.6
Lexington	233,539	1,607,380	6.9	133,948	0.6
Orangeburg	403,740	3,309,579	8.2	275,798	0.7
Total	3,299,926	27,460,803	8.3[a]	2,288,400	0.7[a]

*Source: USDA Forest Service, Forest Inventory and Analysis 2001

[a]Average distribution among timberland acres within the region

D. Intermediate Thinning--Commercial

Currently the pulpwood market, especially for softwood, is saturated. A five year drought, southern pine beetle epidemic, increases in intensive pine management, various incentives through federal and state cost-share programs for reforestation and afforestation, and imports -- primarily from Canada have all contributed to lowering the pulpwood prices in South Carolina (Harper, 2003).

It is uncertain how much of the current supply to pulpwood markets would be available for energy production in the event of a developed market. The supply of woody biomass for an energy market from pulpwood-size timber was evaluated as 50% the current existing and annual growth for this study.

The supply of biomass from merchantable-sized pulpwood in the Piedmont region is presented in Table 7.

Table 7: Piedmont Region, 50% Growing Stock and Annual Net Growth of Growing Stock on Timberland (Green Tons) in Trees 5.0-8.9 inches DBH

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Net Growth	Annual Net Growth/Acre of Timberland
Abbeville	218,714	1,485,502	6.8	126,509	0.58
Anderson	195,990	974,227	5.0	95,831	0.49
Cherokee	150,261	691,082	4.6	58,175	0.39
Chester	286,353	1,481,839	5.2	116,551	0.41
Edgefield	254,030	815,732	3.2	48,063	0.19
Fairfield	371,085	1,517,464	4.1	135,385	0.36
Greenville	236,256	1,193,663	5.1	76,166	0.32
Greenwood	185,639	1,023,379	5.5	87,679	0.47
Lancaster	263,633	1,524,275	5.8	104,612	0.40
Laurens	306,577	1,462,321	4.8	77,511	0.25
McCormick	199,718	1,132,638	5.7	87,738	0.44
Newberry	303,491	1,601,770	5.3	128,856	0.42
Oconee	248,290	1,394,746	5.6	70,139	0.28
Pickens	207,593	746,170	3.6	62,959	0.30
Saluda	178,524	1,202,353	6.7	145,202	0.81
Spartanburg	253,486	1,135,343	4.5	84,348	0.33
Union	252,281	1,258,897	5.0	102,009	0.40
York	258,606	1,349,219	5.2	99,934	0.39
Total	**4,370,527**	**21,990,622**	**5.0[a]**	**1,707,667**	**0.39[a]**

*Source: USDA Forest Service, Forest Inventory and Analysis 2001
[a]Average distribution among timberland acres within the region

The supply of biomass to an energy market from the Piedmont region (considering half of the current pulpwood supply is available for use in producing energy) could yield 21,990,622 tons with 1,707,667 tons of net growth per year. On average there are currently 5.0 tons of biomass in the 5.0-8.9 inch diameter class per acre of timberland. The Piedmont region is capable of supplying 0.39 tons per timberland acre per year. Newberry County has the largest quantity of material in this diameter grouping with 1,601,770 tons. Saluda County has the largest net growth of this material with 145,202 tons annually.
The supply of biomass from merchantable-sized pulpwood stems in the Northern Coastal Plain region is presented in Table 8.

Assuming 50% utilization for energy wood, the Northern Coastal Plain region is currently supporting 21,506,221 tons of woody biomass in the 5.0-8.9 inch diameter class that could be used to supply an energy market. Energy wood in this size class is growing at a rate of 0.39 tons per acre of timberland or 1,783,355 tons per year for the region. Berkeley County has largest quantity of biomass in this grouping with 2,425,811 tons standing, while Kershaw County has the highest annual net growth with 205,134 tons.

Table 8: Northern Coastal Plain Region, 50% Growing Stock and Annual Net Growth of Growing Stock on Timberland (Green Tons) in Trees 5.0-8.9 inches DBH

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Net Growth	Annual Net Growth/Acre of Timberland
Berkeley	536,350	2,425,811	4.5	153,553	0.29
Charleston	274,223	1,244,416	4.5	126,632	0.46
Chesterfield	370,874	1,348,081	3.6	118,821	0.32
Clarendon	216,380	1,104,658	5.1	61,801	0.29
Darlington	157,318	793,046	5.0	113,009	0.72
Dillon	147,981	567,872	3.8	39,780	0.27
Florence	279,979	1,308,678	4.7	104,882	0.37
Georgetown	361,291	2,099,853	5.8	173,730	0.48
Horry	437,026	1,921,272	4.4	129,448	0.30
Kershaw	341,586	1,763,797	5.2	205,134	0.60
Lee	107,928	865,941	8.0	102,628	0.95
Marion	204,239	958,226	4.7	58,581	0.29
Marlboro	206,019	1,103,086	5.4	80,310	0.39
Richland	297,470	1,419,323	4.8	97,070	0.33
Sumter	241,596	1,165,968	4.8	77,560	0.32
Williamsburg	370,692	1,416,194	3.8	140,415	0.38
Total	**4,550,952**	**21,506,221**	**4.7**[a]	**1,783,355**	**0.39**[a]

Source: USDA Forest Service, Forest Inventory and Analysis 2001
[a]Average distribution among timberland acres within the region

The supply of biomass from merchantable-sized stems in the Southern Coastal Plain region is presented in Table 9. The Southern Coastal Plain region has the highest quantity of biomass within this class per acre of timberland with an average of 6.1 tons. With 50% utilization for energy wood, the region currently supports 20,033,150 tons with an annual growth of 1,834,879 tons. Colleton County has the largest quantity of material in this group with 3,455,031 tons. Dorchester County has the highest annual net growth (227,046 tons/yr.).

The supply of biomass from the pulpwood-sized stems is uncertain in that a portion will be harvested for pulp or managed into high product classes. Assuming half of the current supply of this source will be available to an energy market, South Carolina could produce about 5,336,000 tons per year on a sustainable basis with a base of approximately 63,529,000 tons. Developing an energy market for this biomass will affect the pulpwood price, but how and by how much is uncertain.

Table 9: Southern Coastal Plain Region, 50% Growing Stock and Annual Net Growth of Growing Stock on Timberland (Green Tons) in Trees 5.0-8.9 inches DBH

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre Timberland	Annual Net Growth	Annual Net Growth/Acre Timberland
Aiken	475,503	1,906,060	4.0	143,064	0.30
Allendale	180,914	880,042	4.9	71,008	0.39
Bamberg	184,012	1,464,778	8.0	148,922	0.81
Barnwell	242,398	1,629,062	6.7	213,013	0.88
Beaufort	114,074	732,598	6.4	79,658	0.70
Calhoun	137,540	602,960	4.4	84,336	0.61
Colleton	508,011	3,455,031	6.8	214,096	0.42
Dorchester	246,746	1,827,460	7.4	227,046	0.92
Hampton	275,647	1,948,025	7.1	176,208	0.64
Jasper	297,802	1,993,185	6.7	201,130	0.68
Lexington	233,539	1,105,084	4.7	77,998	0.33
Orangeburg	403,740	2,488,865	6.2	198,400	0.49
Total	**3,299,926**	**20,033,150**	**6.1**[a]	**1,834,879**	**0.56**[a]

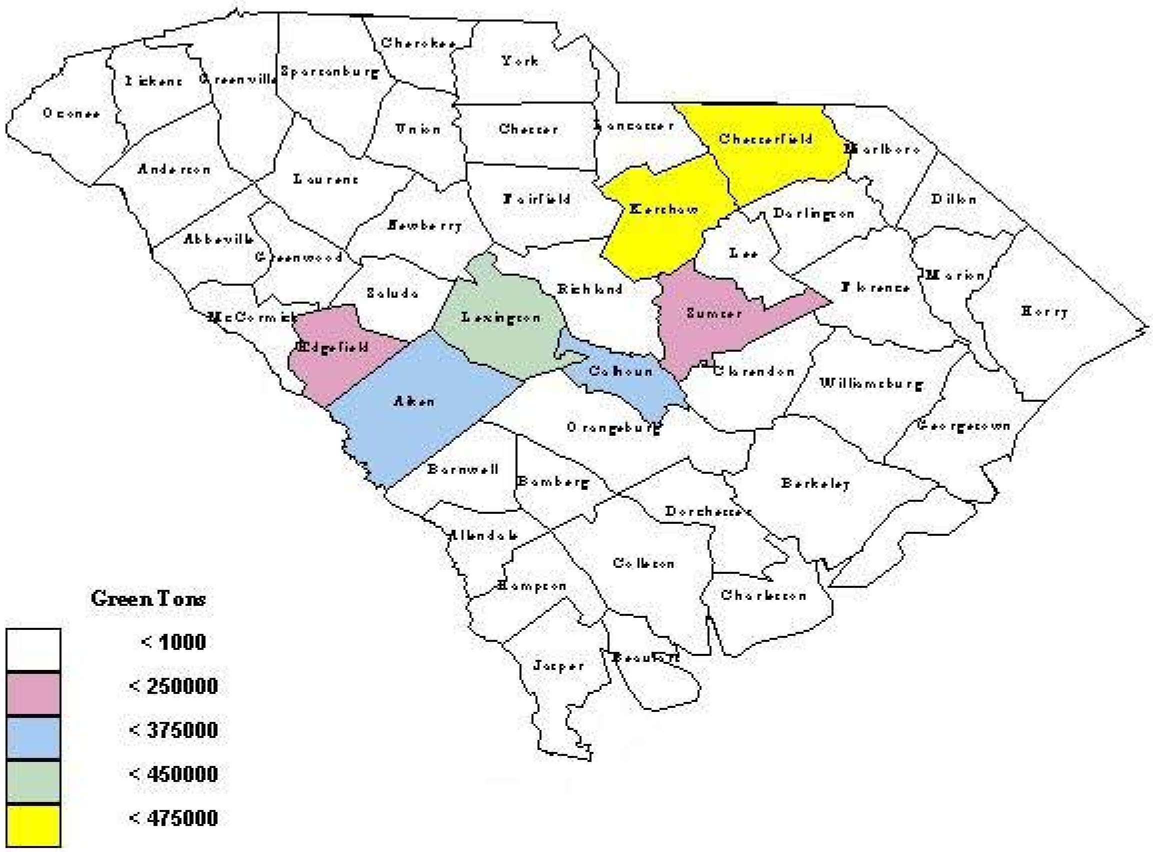
*Source: USDA Forest Service, Forest Inventory and Analysis 2001
[a]Average distribution among timberland acres within the region

E. Southern Scrub Oak

The southern scrub oak forest type occurs on xeric sites in the Southeastern Coastal Plain. It ranges from southeast Virginia to central Florida and west to southeast Louisiana on dry pinelands and sandy ridges (Little, 1976). Within South Carolina, the scrub oak forest type is concentrated in the Sandhills, which stretch along the Fall Line of the state (Meyers et al. 1986). Counties in the Sandhills area that contain more than ten acres of this forest type are Aiken, Calhoun, Chesterfield, Edgefield, Kershaw, Lexington, and Sumter, as shown in Figure 1 (Forest Inventory and Analysis Database, 2001). Richland County has stands with southern scrub oak components; however, they are not classified as timberland. (*see* glossary) Richland County is highly developed in and around the city of Columbia and sites that would support southern scrub oaks have been converted to urban uses or managed for more valuable species.

Sites that support southern scrub oak species are characterized by deep, dry sands (Meyers et al. 1986). The southern scrub oak forest type in the absence of fire is a climax community for Sandhill sites. Fire exclusion for many decades has allowed scrub oak species to replace the fire-dependant longleaf pine, which historically dominated Sandhill's sites.

Figure 2: Distribution of Southern Scrub Oak Forest Type



Source: USDA Forest Service, Forest Inventory and Analysis 2001

The scrub oak forest type is composed of low quality hardwood species (from a timber management standpoint) such as turkey oak (*Quercus laevis*). Scrub oak species are short in statue, reaching heights of 20 to 50 feet with an average diameter of about 7 inches by age 50 (Elias, 1980; Harlow, 1963). The wood of these scrub oak species is close-grained, hard and heavy, but the trees do not grow large enough, on average, to have timber value, except as excellent fuel (Burns, 1990). The existing quantity of this biomass source is presented in Table 10.

The southern scrub oak forest type currently accounts for 2,439,580 green tons of standing timber in the seven counties listed. Using these species for energy production would provide a market for this forest type. The annual allowance shown in Table 10 could be supplied on a sustainable basis if the land base currently in scrub oak were harvested at a rate of 2% annually. Using this rate would allow the land base to be used over a 50-year period. These figures do not include any additional growth that would occur on stands before the initial harvest within the first 50-year period. The scrub oak would regenerate itself following harvest by sprouting – no artificial regeneration methods would be needed.

Estimates of the quantities of energy wood presented for the southern scrub oak had a relatively high percent error that averaged 12.5% at the 67% confidence level. This implies, for example, that the amount of total existing scrub oak material in Aiken has a 67% chance of being within +/- 12.5% of the 319,209 tons given. Despite the large errors, the figures were used as an estimate of supply since the overall contribution of biomass relative to other sources was small. On average, southern scrub oak stands with an average diameter of seven inches are capable of producing approximately 15 tons per acre of fuel wood (Bryant Boyce, Canal Wood, Personal Communication).

Table 10: Southern Scrub Oak, Growing Stock and Annual Allowance on a 50-Year Rotation (Green Tons)

County	Timberland Acres	Total Growing Stock	Average Growing Stock/Acre of Timberland	Annual Allowance	Annual Allowance/Acre Timberland
Aiken	475,503	319,209	0.67	6,384	0.01
Calhoun	137,540	351,797	2.56	7,036	0.05
Chesterfield	370,874	474,617	1.28	9,492	0.03
Edgefield	254,030	225,090	0.89	4,502	0.02
Kershaw	341,586	460,554	1.35	9,211	0.03
Lexington	233,539	408,511	1.75	8,170	0.03
Sumter	241,596	199,800	0.83	3,996	0.02
Total	**2,054,668**	**2,439,580**	**1.19[a]**	**48,792**	**0.02[a]**

*Source: USDA Forest Service, Forest Inventory and Analysis 2001
[a]Average distribution among timberland acres within the region

F. Mill Residues

Mill residues refer to bark and woody material that is generated in primary wood-using mills when roundwood products are converted to other products. Primary wood using mills are defined as industries receiving roundwood or chips from roundwood for the manufacturing of products such as veneer, pulp, and lumber. Examples of mill residues are slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores, clippings, and pulp screenings. These wastes include bark and wood residues (both coarse and fine materials) but exclude logging residues (Smith et al. 2001).

Mill residues are used to produce pulp, fuel and miscellaneous products such as mulch. The use of these residues varies among mills. The quantity of these residues can be seen in Table 11, according to the county within which mills are located and how the residues are processed.

Mill residues produced an annual total of 3,293,203 tons in 2002. The quantity of fuel material produced was 1,600,442 tons annually. The product produced from mill residues is directly affected by return. If the return on selling residues for fuel is higher than for pulp than the supply of material could possibly increase from 1,600,442 to 2,946,650 tons annually. If the material that is currently unused (12,086 tons) is also used for fuel, there could be a supply of material ranging from 1,600,442 to 2,958,736 tons annually. The quantity of fuel can be expected to remain constant if mill efficiencies, outputs and quantities of miscellaneous products remain constant, meaning that residues used as fuel can not be used as pulp because of a lack of quality (dirty low-grade chips) or because of type (bark). The mill residue supply will be considered as the amount produced and currently used for fuel and the amount currently unused for a total of 1,612,528 tons annually.

Table 11: Annual Mill Residues (Tons) by County and Product

County	Pulpwood	Fuelwood	Misc products	Not Used	Total Product
Allendale	74,533	72,671	4,031	0	151,235
Bamberg	8,159	13,426	4,099	0	25,685
Berkeley	74,386	114,867	24,103	0	213,356
Chester	212,642	39,724	1,538	9,588	263,492
Chesterfield	8,390	4,003	4,757	0	17,150
Clarendon	10,846	9,642	8,735	0	29,224
Colleton	17,761	61,891	8,442	0	88,094
Darlington	76,135	159,605	1,061	0	236,800
Dorchester	54,865	80,024	11,522	106	146,518
Florence	36,567	114,971	36,297	0	187,835
Georgetown	170,782	235,035	23,225	0	429,043
Greenwood	85,763	26,379	32,828	0	144,970
Hampton	77,472	55,472	0	0	132,943
Laurens	11,237	12,825	606	257	24,925
Lexington	23,836	30,388	10,686	0	64,910
Marlboro	0	37,536	0	0	37,536
Newberry	189,492	188,380	69,899	0	447,771
Oconee	27,190	5,465	21,949	203	54,807
Orangeburg	69,211	73,332	1,845	0	144,388
Pickens	24,930	8,737	19,002	863	53,532
Richland	77,607	160,572	37,594	0	275,774
York	14,402	95,499	12,245	1,069	123,215
Total	**1,346,208**	**1,600,442**	**334,466**	**12,086**	**3,293,203**

*Source: USDA Forest Service, Timber Product Output 2002

The mill residues that make up the 1,612,528 tons annually consist of bark and wood. The quantities that are produced as these byproducts and used as fuelwood or are not used are presented in Table 12.

Mill residues produced and used as fuel or are unused annually are predominately bark. Bark residues produced annually total approximately 927,000 tons. The remaining 685,000 tons are composed of fine and course wood residues.

Table 12: Annual Mill Residues Used as Fuel and Unused by Residue Type (Tons)

County	Bark Residues	Wood Residues	Total Mill Residues
Allendale	27,413	45,257	72,671
Bamberg	4,325	9,101	13,426
Berkeley	100,729	14,138	114,867
Chester	41,490	7,822	49,312
Chesterfield	1,378	2,624	4,003
Clarendon	1,879	7,763	9,642
Colleton	24,767	37,126	61,891
Darlington	125,956	33,649	159,605
Dorchester	20,489	59,640	80,130
Florence	77,563	37,408	114,971
Georgetown	140,585	94,451	235,035
Greenwood	0	26,379	26,379
Hampton	22,708	32,764	55,472
Laurens	4,476	8,607	13,082
Lexington	12,539	17,849	30,388
Marlboro	37,536	0	37,536
Newberry	47,747	140,633	188,380
Oconee	815	4,853	5,668
Orangeburg	22,986	50,346	73,332
Pickens	604	8,996	9,600
Richland	120,206	40,367	160,572
York	91,234	5,333	96,567
Totals	**927,425**	**685,103**	**1,612,529[a]**

*Source: USDA Forest Service, Timber Product Output 2002
[a]Higher than previously stated due to rounding

G. Urban Wood Waste

Municipal wood wastes as characterized by G. Wiltsee (United States Department of Agriculture, 1998), have three major components as differentiated on the basis of the material's origin: 1) municipal solid waste, 2) industrial wood waste, and 3 clearing/demolition waste. The supply of biomass from these materials is directly correlated to the population and industrial activity of the area and can be calculated on a per person basis. The supply of biomass from this source will only increase with the increasing population, which makes the future of this source secure.

Municipal solid waste refers to the material that is discarded from individual residences and from small businesses, such as tree service companies. This source of wood waste is most stringently tied to the local population and can range in significance from 20 to 90% of an area's total urban wood waste. The median of this range is approximately 63%. Waste originating from this sector include materials such as household yard waste, household remodeling scrap, municipal and utility tree trimmings, and wooden shipping containers (other than pallets) that are disposed of by retail and grocery stores.

Industrial wood waste is the discarded material from industrial plants. The main contributors are companies that work with wood in making their products, such as pallet, cabinet, furniture and custom building companies. These operations have an abundance of waste that is usually landfilled and not utilized. The supply of this source of biomass is more directly correlated with an area's industrial activity rather than the area's population. Industrial wood waste can range from minimal to approximately two thirds of the total urban wood waste in an area, with the median being about 14%.

The third sector of urban wood waste is waste that originates from the clearing of land or the demolition of buildings. These materials are estimated to contribute from 4-40% of the total waste within some areas with the median being around 23% for most areas. Clearing and demolition wastes are most strictly correlated with the construction activities in an area. Areas with high rates of development can expect to have wastes from this sector to represent 40% of the total urban waste stream. Land clearing can contribute large amounts of waste within this sector; however, amounts are hard to predict given the variation of biomass densities on different sites.

Wiltsee (United States Department of Agriculture, 1998) found that the population of an area directly affected the quantity of total urban waste produced on a per person basis. He found that in higher population density areas such as Spartanburg and Greenville, there are higher amounts of urban waste produced per person and that in areas of lower population densities, such as Florence, the urban waste per person is lower. At high population densities, he found that total urban waste could be estimated using a per year amount of .1655 tons/person and for areas of low population densities a figure of .1487 tons per capita could be used.

In this study, the figure of .1655 tons per person per year was applied to the five most densely populated counties in the state and the figure of .1487 tons per person per year was applied to other less densely populated counties. Using these figures it is estimated that the urban waste stream of South Carolina produces approximately 621,000 tons of woody biomass that could be utilized for energy production each year. By using these materials for the production of energy, the amount of landfill space needed per year will be markedly reduced.

The amount of urban wood waste produced each year is presented by county in the Piedmont region in Table 13.

The Piedmont region of South Carolina is capable of producing 247,650 tons of urban wood waste per year, if the population within this region remains constant. However, population increases can be expected, as this is one of the fastest growing areas of the state (Ware, 2002). Greenville County is the highest populated county in the region and produces approximately 62,826 tons of wood waste annually.

Table 13: Piedmont Region, Urban Wood Waste (Tons)

County	Population	Wood landfilled/capita	Wood landfilled/year
Abbeville	26,167	0.1487	3,891
Anderson	165,740	0.1487	24,646
Cherokee	52,537	0.1487	7,812
Chester	34,068	0.1487	5,066
Edgefield	24,595	0.1487	3,657
Fairfield	23,454	0.1487	3,488
Greenville	379,616	0.1655	62,826
Greenwood	66,271	0.1487	9,854
Lancaster	61,351	0.1487	9,123
Laurens	69,567	0.1487	10,345
McCormick	9,958	0.1487	1,481
Newberry	36,108	0.1487	5,369
Oconee	66,215	0.1487	9,846
Pickens	110,757	0.1487	16,470
Saluda	19,181	0.1487	2,852
Spartanburg	253,791	0.1655	42,002
Union	29,881	0.1487	4,443
York	164,614	0.1487	24,478
Total	**1,593,871**		**247,650**

*Source: US Census Bureau, 2000 and G. Wiltsee, 1998

The quantity of urban wood waste available annually by county in the Northern Coastal Plain region is presented in Table 14.

Table 14: Northern Coastal Plain Region, Urban Wood Waste (Tons)

County	Population	Wood landfilled/capita	Wood landfilled/year
Berkeley	142,651	0.1487	21,212
Charleston	309,969	0.1655	51,300
Chesterfield	42,768	0.1487	6,360
Clarendon	32,502	0.1487	4,833
Darlington	67,394	0.1487	10,021
Dillon	30,722	0.1487	4,568
Florence	125,761	0.1487	18,701
Georgetown	55,797	0.1487	8,297
Horry	196,629	0.1487	29,239
Kershaw	52,647	0.1487	7,829
Lee	20,119	0.1487	2,992
Marion	35,466	0.1487	5,274
Marlboro	28,818	0.1487	4,285
Richland	320,677	0.1655	53,072
Sumter	104,646	0.1487	15,561
Williamsburg	37,217	0.1487	5,534
Total	**1,603,783**		**249,077**

*Source: US Census Bureau, 2000 and G. Wiltsee, 1998

The Northern Coastal Plain Region of South Carolina produces approximately 249,000 tons of urban wood waste annually. The region encompasses the state's capital and the state's largest port city, both of which produce over 50,000 tons of wood waste per year.

The quantity of urban wood waste produced per year by county in the Southern Coastal Plain region is presented in Table 15.

Table 15: Southern Coastal Plain Region, Urban Wood Waste (Tons)

County	Population	Wood landfilled/capita	Wood landfilled/year
Aiken	142,552	0.1487	21,197
Allendale	11,211	0.1487	1,667
Bamberg	16,658	0.1487	2,477
Barnwell	23,478	0.1487	3,491
Beaufort	120,937	0.1487	17,983
Calhoun	15,185	0.1487	2,258
Colleton	38,264	0.1487	5,690
Dorchester	96,413	0.1487	14,337
Hampton	21,386	0.1487	3,180
Jasper	20,678	0.1487	3,075
Lexington	216,014	0.1655	35,750
Orangeburg	91,582	0.1487	13,618
Total	**814,358**		**124,724**

Source: US Census Bureau, 2000 and G. Wiltsee, 1998

The Southern Coastal Plain region has the lowest population density in South Carolina and therefore produces the smallest amount of urban wood waste (124,724 tons annually). The most populated area within the region is Lexington County, which produces approximately 35,750 tons of wood waste annually.

The production of energy from this source will increase as the population continues to grow throughout the state at approximately 1.2% annually (US Census Bureau, 2000). If the population were to remain constant, an annual supply of approximately 621,000 tons would be available.

Costs of Collecting Woody Biomass

The cost of collecting woody biomass is viewed as a two-part cost consisting of the initial capital cost of equipment and the operational costs of harvesting and delivering the material. In most cases the economical opportunity of performing a harvesting operation for fuel biomass is directly correlated with stand size and should usually be exercised on stands larger than 20 acres in size (Bryant Boyce, Canal Wood, Personal Communication).

Processing woody biomass into a form that can be used as fuel from the discussed sources requires a capital investment in several pieces of equipment. In addition to the initial costs of the equipment, operational costs are incurred that vary with the quantity of product that is produced. Operational costs include expenditures such as operator wages, fuel, and maintenance.

The major pieces of equipment required to produce wood chips are the feller/buncher, grapple skidder, chipper with grapple boom, and a tractor and trailer. These four pieces or a combination of the four can be found in almost any forest chipping operation and are efficient in removing large volumes of material with minimal site impact.

The feller/buncher requires one operator and is designed to mechanically fell predetermined or operator selected stems. The saw head is equipped with an accumulating arm that collects the stems as they are cut and retains them in an upright position until the arm is full, as shown in Figure 3. The operator can then tilt the saw head at a forward angle, laying the bundle of stems in a pile on the ground for easy access by the skidder. A three-wheeled feller/buncher is able to navigate through small areas such as in thinning operations without excessive damage to residual stems, and can have a turning radius as small as ten feet and six inches. The capital cost for a feller/buncher is approximately $200,000.

The grapple skidder is responsible for moving the felled stems from the stand and to the logging deck. The skidder uses a grapple claw to pick up the bundle felled by the feller/buncher and drags the bundle to the logging deck. The skidder is capable of stacking the stems using the hydraulic blade mounted on the front. The skidder moves the stems within reach of the grapple boom mounted on the chipper and returns into the stand for another load. The cost of a skidder is about $180,000. A grapple skidder requires one operator.

The whole tree chipper is capable of producing chips of a predetermined size from stems fed into the infeed. The chipper then deposits the chips in a trailer or a pile on the ground through a shoot. From the cab, a single person operates the chipper by feeding the material into the infeed using the grapple boom. The chipper requires a capital cost ranging from $250,000 to $350,000 depending on available options. The chips are blown from the chipper into a trailer that is then hauled by truck to a processing facility. At the facility the truck is anchored and lifted so that the chips fall out the rear of the trailer. The trailers are capable of hauling from 20 to 25 tons of chips in a single haul. The capital cost of a hauling truck is approximately $75,000 and about $35,000 for an open top trailer.

Collecting logging residues can be accomplished economically on many sites simultaneously or shortly following a harvesting operation if residues are not distributed back over the harvested area (Micky Scott, Collum's Lumber Products, LLC, Personal Communication). Tops and limbs can be collected at the landing instead of being scattered, increasing the number of opportunities for utilizing these resources. Utilizing logging residues not only produces an additional source of return for the forest landowner but also lowers the intensity or need of site preparation in regenerating the next stand. Processing logging residues that have been collected on or near the logging deck can be accomplished using, at minimum, a grapple skidder, a chipper, two hauling trucks and four trailers. The capital cost of this equipment is around $720,000. Using a chipper to process logging residues in the form of tops and limbs can be accomplished at a cost of approximately $12 per ton inwoods cost (Micky Scott, Collum's Lumber Products, LLC, Personal Communication). Applying the freight cost of $2 per mile, a trailer load (25 tons) of chipped logging residue delivered to an energy producing facility at a distance of 50 miles would have a delivered cost of approximately $16.00 per ton.

The primary technique in South Carolina for harvesting timber is a single stem approach in which each stem is cut individually. The economics of this approach hinder the ability of operating within stands that are dominated by small diameter trees. The cost of harvesting rises rapidly as stem diameter decreases. In 1980, a sensitivity test found that a green ton of chips could be produced from 11 inch dbh stems for around $6.00 while for 1-inch dbh stems the cost was $107.00 (Kluender, 1980). The cost rose sharply around 5 inches dbh, the break-off point separating commercial thinning from unmerchantable.

The average dbh of removed stems affects the ratio of feller/bunchers to skidders that is needed for moving the material to the landing. In a working day of 10 hours, where a skidder is operating for 7 hours, approximately 42 cords (113 tons) can be moved by that skidder. Removing material with an average dbh of 4-inchs, one skidder can remove material cut from two feller/bunchers, at 5 inches two skidders are needed and at 7 inches three skidders are needed to haul the cut material without falling behind (Robertson, 1984).

A thinning operation should include, at minimum, one feller/buncher, two skidders, one chipper, three trucks and six chip trailers. The greatest disadvantage of a whole tree chipping operation is the high initial cost, around $1,245,000. The in-woods cost varies greatly as described above; however, the cost of chipping and freight for a fifty mile distance should be approximately $18/ton (Bryant Boyce, Canal Wood, Personal Communication).

Southern scrub oak stands are harvested for the production of fuel wood throughout the Sandhills region. The equipment used in these operations is the same as commercial thinning for fuel discussed above and therefore the costs should be relatively similar.

Discussion

South Carolina has 12.2 million acres of timberland that produce a significant quantity of woody material available for energy production. Logging residues, pre-commercial thinning, and commercial thinning offer the largest opportunity for an energy market considering the quantity of each source and the degree of current use in the state. Mill residues and the southern scrub oak forest type also are capable of contributing a significant supply of woody biomass to a developed energy market with mill residues being the most readily available source. However, the majority of mill residues are already being utilized.

The total number of tons of the woody biomass by source discussed is presented in Table 15. South Carolina contains approximately 175 million tons of biomass from the sources listed in Table 16. Unmerchantable and commercial thinning opportunities provide the largest potential supply to a biomass energy market with a total base of about 102 million and 64 million green tons, respectively.

Table 16: Total Available Biomass in South Carolina

Region	Biomass Source	Green Tons (Millions)
Piedmont		
	Logging Residues	1.6
	Precommercial Thinning	34.7
	Commercial Thinning	22.0
	Urban Wood Waste	0.2
Northern Coastal Plain		
	Logging Residues	1.6
	Precommercial Thinning	40.5
	Commercial Thinning	21.5
	Urban Wood Waste	0.2
Southern Coastal Plain		
	Logging Residues	1.2
	Precommercial Thinning	27.5
	Commercial Thinning	20.0
	Urban Wood Waste	0.1
All Regions		
	Mill Residues	
	Wood Residues	0.7
	Bark Residues	0.9
	Southern Scrub Oak	2.4
Total		**175.1**

*Source: Forest Inventory and Analysis 2001, Timber Product Output 2002

The number of tons of woody biomass available on an annual basis is presented in Table 17. The annual quantity of material available for energy production from woody biomass is approximate 20.9 million tons. These quantities could be used to produce energy on a sustainable basis.

Table 17: Annual Available Biomass in South Carolina

Region	Biomass Source	Green Tons (Millions)
Piedmont		
	Logging Residues	1.6
	Precommercial Thinning	2.9
	Commercial Thinning	1.7
	Urban Wood Waste	0.2
Northern Coastal Plain		
	Logging Residues	1.6
	Precommercial Thinning	3.4
	Commercial Thinning	1.8
	Urban Wood Waste	0.2
Southern Coastal Plain		
	Logging Residues	1.2
	Precommercial Thinning	2.3
	Commercial Thinning	1.8
	Urban Wood Waste	0.1
All Regions		
	Mill Residues	
	Wood Residues	0.7
	Bark Residues	0.9
	Southern Scrub Oak	0.5
Total		**20.9**

*Source: Forest Inventory and Analysis 2001, Timber Product Output 2002

Agronomic Crop Residues

Crop residues (cobs, stems, leaves, straw, and other plant matter) left in agricultural fields after harvest could potentially be used for energy production. Currently, these residues are of little economic value to producers. Most residues are either plowed into the soil, left on the soil surface to reduce erosion and improve soil quality, or burned prior to planting the next crop. Using crop residues for energy production represents a potential additional source of income for South Carolina producers.

Corn, cotton, soybean, and wheat are the four most widely produced crops in South Carolina (Tables 18 through 21, Figures 3 through 6). There are no data available for the amount of biomass produced for these crops in South Carolina, although estimates can be derived from grain production and acreage values reported for each crop by the South Carolina Agricultural Statistics Service (SC Agric. Stat. Serv., 2003). For our biomass estimates, we assumed that one bushel of grain weighed 56 lbs for corn, 60 lbs for soybean, and 60 lbs for wheat. Grain and lint yields used in the calculations were 5-year averages (1998-2002) provided by the SC Agricultural Statistic Service. Planted acres shown in Tables 18 through 21 are those reported for 2002, which was a normal year in terms of acres planted (5 year averages not available). Grain moisture was assumed to be 15.5% for corn, 13% for wheat and soybean, and 0% for cotton lint. Calculated biomass values shown in Tables 18 through 21 were converted to 0% moisture basis. In contrast to other states, crop residues are generally not used for animal feed in South Carolina and the estimates shown would be available for energy production.

Corn (Table 18) and wheat (Table 19) offer the greatest opportunity for biomass production in South Carolina, although wheat acres have declined dramatically in recent years due to low commodity prices. Statewide, about 490,000 tons of corn and 225,000 tons of wheat biomass are produced each year. Wheat is harvested for grain in late May and early June. Thus, biomass harvest would occur near this time. Soybean is generally planted immediately after wheat harvest and planting delays due to biomass collection would not be acceptable because of the significant soybean yield loss that would occur. Waiting for wheat straw to dry or for residue baling equipment to become available would cause such planting delays. Corn is harvested for grain in late August and early September in South Carolina. No crop is planted immediately after corn harvest so there is not a demand to quickly remove the corn biomass from the field, as is the case for wheat. Drying conditions for wheat and corn residues may be less than optimal due to the high humidity levels in the Southeast during those times. Corn, wheat, soybean, and cotton are all produced primarily in the Coastal Plain region of the State. Greatest production counties for these crops are located near the center of the Coastal Plain, thus any processing facilities should be located near the center of these counties.

The amount of biomass removed from crop fields would be less than the amounts shown in Tables 18 through 21 primarily because of federal recommendations pertaining to soil conservation measures. The USDA-NRCS recommends that at least 30% of the soil surface be covered by plant residues to control soil erosion and to maintain soil productivity (termed using conservation tillage). The amount of residues needed to provide 30% residue cover would vary by crop and the soil type the crop is produced upon. However, the amount of residue that must remain in the field to provide 30% residue cover would be substantial. If all crop residues are removed and surface coverage drops below 30%, producers would not be able to participate in federal government programs that provide financial incentives for using conservation tillage practices.

Due to the seasonality and low energy density of agronomic crop residues, they may not be as economically viable as forest biomass in the near future. For these reasons, the agronomic crop residues will be considered as a potential source only after the forest biomass energy industry has been established.

Table 18. Estimated Corn Residue in SC.

COUNTY	2002 Corn Acres	Dry Residue tons/acre	Dry Residue tons/county
Abbeville	--	--	--
Aiken	3,600	1.09	3,918
Allendale	13,700	1.25	17,180
Anderson	--	--	--
Bamberg	7,700	1.30	10,020
Barnwell	5,600	1.14	6,360
Beaufort	--	--	--
Berkeley	3,500	1.35	4,720
Calhoun	11,300	1.80	20,319
Charleston	--	--	--
Cherokee	--	--	--
Chester	--	--	--
Chesterfield	4,600	1.61	7,401
Clarendon	39,500	1.73	68,224
Colleton	6,700	1.32	8,877
Darlington	13,000	1.63	21,223
Dillon	7,500	1.61	12,067
Dorchester	8,900	1.40	12,424
Edgefield	--	--	--
Fairfield	--	--	--
Florence	18,000	1.47	26,405
Georgetown	2,500	1.37	3,431
Greenville	--	--	--
Greenwood	--	--	--
Hampton	10,000	1.35	13,486
Horry	16,800	1.61	27,029
Jasper	--	--	--
Kershaw	2,000	1.28	2,555
Lancaster	1,000	1.28	1,278
Laurens	--	--	--
Lee	17,000	1.54	26,144
Lexington	6,300	1.85	11,627
McCormick	--	--	--
Marion	6,200	1.59	9,828
Marlboro	3,400	1.66	5,631
Newberry	--	--	--
Oconee	600	--	--
Orangeburg	44,000	1.63	71,832
Pickens	--	--	--
Richland	5,300	1.42	7,524
Saluda	--	--	--
Spartanburg	--	--	--
Sumter	33,100	1.66	54,820
Union	--	--	--
Williamsburg	17,000	1.51	25,742
York	--	--	--
Other Counties	11,200	0.00	--
STATE	320,000	1.54	492,128

Table 19. Estimated Wheat Residues in SC.

COUNTY	2002 Wheat Acres	Dry Residue tons/acre	Dry Residue tons/county
Abbeville	--	--	--
Aiken	4,500	0.84	3,758
Allendale	15,500	0.99	15,373
Anderson	2,500	0.97	2,414
Bamberg	4,800	0.91	4,385
Barnwell	4,600	0.94	4,322
Beaufort	--	--	--
Berkeley	2,800	1.02	2,850
Calhoun	6,800	1.20	8,164
Charleston	--	--	--
Cherokee	--	--	--
Chester	--	1.10	--
Chesterfield	10,100	1.12	11,335
Clarendon	29,400	1.25	36,832
Colleton	4,500	0.91	4,111
Darlington	32,400	1.04	33,826
Dillon	38,700	1.02	39,393
Dorchester	4,800	1.02	4,886
Edgefield	--	0.97	--
Fairfield	--	--	--
Florence	52,500	0.94	49,329
Georgetown	3,800	0.99	3,769
Greenville	--	1.07	--
Greenwood	--	--	--
Hampton	7,900	0.89	7,010
Horry	47,800	0.99	47,408
Jasper	--	--	--
Kershaw	2,100	1.17	2,466
Lancaster	700	--	--
Laurens	--	0.94	--
Lee	28,000	1.20	33,617
Lexington	4,300	0.91	3,928
McCormick	--	--	--
Marion	17,700	0.86	15,245
Marlboro	24,400	1.07	26,110
Newberry	1,400	1.02	1,425
Oconee	700	1.07	749
Orangeburg	27,300	1.12	30,639
Pickens	--	--	--
Richland	4,900	1.04	5,116
Saluda	--	0.91	--
Spartanburg	--	0.94	--
Sumter	23,000	1.15	26,413
Union	--	--	--
Williamsburg	22,300	1.02	22,699
York	--	--	--
Other Counties	4,800	0.00	0
STATE	210,000	1.07	224,721

Table 20. Estimated Soybean Residue in SC.

COUNTY	2002 Soybean Acres	Dry Residue tons/acre	Dry Residue tons/Co
Abbeville	--	--	--
Aiken	4,500	0.44	1,997
Allendale	15,500	0.47	7,282
Anderson	2,500	0.44	1,109
Bamberg	4,800	0.47	2,255
Barnwell	4,600	0.52	2,401
Beaufort	--	--	--
Berkeley	2,800	0.57	1,608
Calhoun	6,800	0.55	3,727
Charleston	--	--	--
Cherokee	--	--	--
Chester	--	--	--
Chesterfield	10,100	0.52	5,272
Clarendon	29,400	0.55	16,114
Colleton	4,500	0.52	2,349
Darlington	32,400	0.55	17,758
Dillon	38,700	0.55	21,211
Dorchester	4,800	0.57	2,756
Edgefield	--	--	--
Fairfield	--	--	--
Florence	52,500	0.55	28,775
Georgetown	3,800	0.55	2,083
Greenville	--	--	--
Greenwood	--	--	--
Hampton	7,900	0.52	4,124
Horry	47,800	0.57	27,447
Jasper	--	--	--
Kershaw	2,100	0.57	1,206
Lancaster	700	0.52	365
Laurens	--	0.52	--
Lee	28,000	0.57	16,078
Lexington	4,300	0.55	2,357
McCormick	--	--	--
Marion	17,700	0.50	8,777
Marlboro	24,400	0.55	13,374
Newberry	1,400	0.57	804
Oconee	700	0.50	347
Orangeburg	27,300	0.55	14,963
Pickens	--	--	--
Richland	4,900	0.50	2,430
Saluda	--	--	--
Spartanburg	--	--	--
Sumter	23,000	0.55	12,606
Union	--	--	--
Williamsburg	22,300	0.57	12,805
York	--	--	--
Other Counties	4,800	0.00	0
STATE	435,000	0.55	238,424

Table 21. Estimated Cotton Residues in SC

COUNTY	2002 Cotton Acres	Dry Residue tons/acre	Dry Residue tons/county
Abbeville	--	--	--
Aiken	5,600	0.86	3,591
Allendale	1,800	1.02	1,375
Anderson	600	0.71	318
Bamberg	8,800	0.97	6,413
Barnwell	6,500	0.70	3,429
Beaufort	--	--	--
Berkeley	--	--	--
Calhoun	25,600	1.01	19,392
Charleston	--	--	--
Cherokee	--	--	--
Chester	--	--	--
Chesterfield	500	--	--
Clarendon	5,400	0.86	3,483
Colleton	1,600	0.74	890
Darlington	40,800	1.03	31,569
Dillon	19,500	0.93	13,553
Dorchester	8,200	0.83	5,074
Edgefield	700	0.60	315
Fairfield	--	--	--
Florence	13,700	0.82	8,391
Georgetown	1,100	--	--
Greenville	--	--	--
Greenwood	--	--	--
Hampton	7,400	0.91	5,051
Horry	500	0.82	306
Jasper	--	--	--
Kershaw	800	0.72	431
Lancaster	--	--	--
Laurens	--	--	--
Lee	25,300	0.76	14,358
Lexington	2,400	0.76	1,374
McCormick	--	--	--
Marion	6,000	0.81	3,660
Marlboro	30,400	0.90	20,596
Newberry	1,100	0.87	719
Oconee	--	--	--
Orangeburg	27,400	0.93	19,009
Pickens	--	--	--
Richland	3,200	--	--
Saluda	1,200	0.86	776
Spartanburg	--	--	--
Sumter	8,700	0.98	6,362
Union	--	--	--
Williamsburg	28,400	0.91	19,419
York	3,200	0.82	1,964
Other Counties	3,600	0.00	0
STATE	290,000	0.90	196,113

Fig. 3 Corn Biomass by County in South Carolina

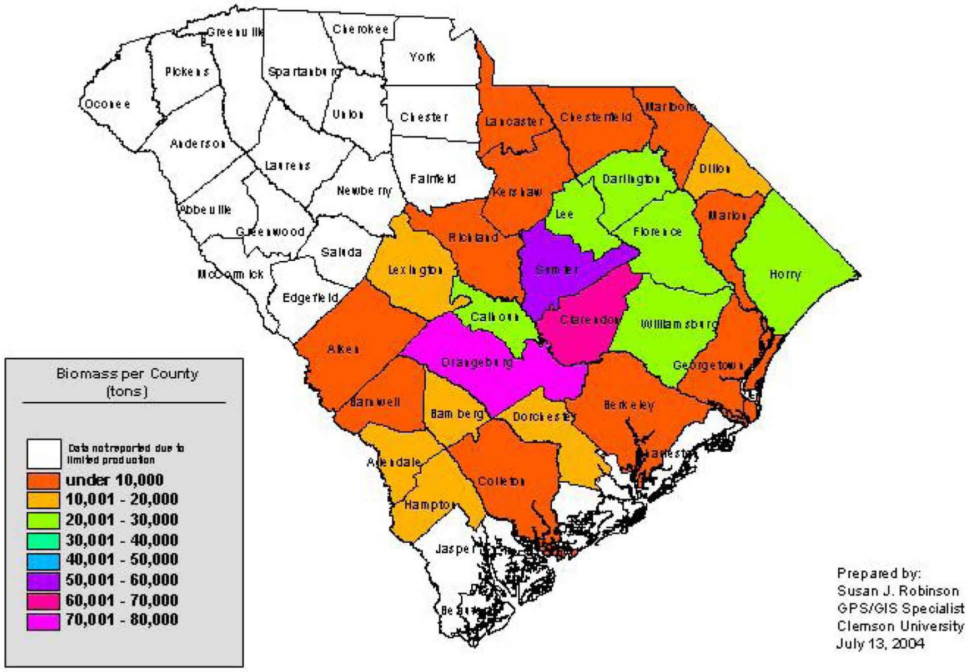


Fig. 4 Wheat Biomass by County in South Carolina

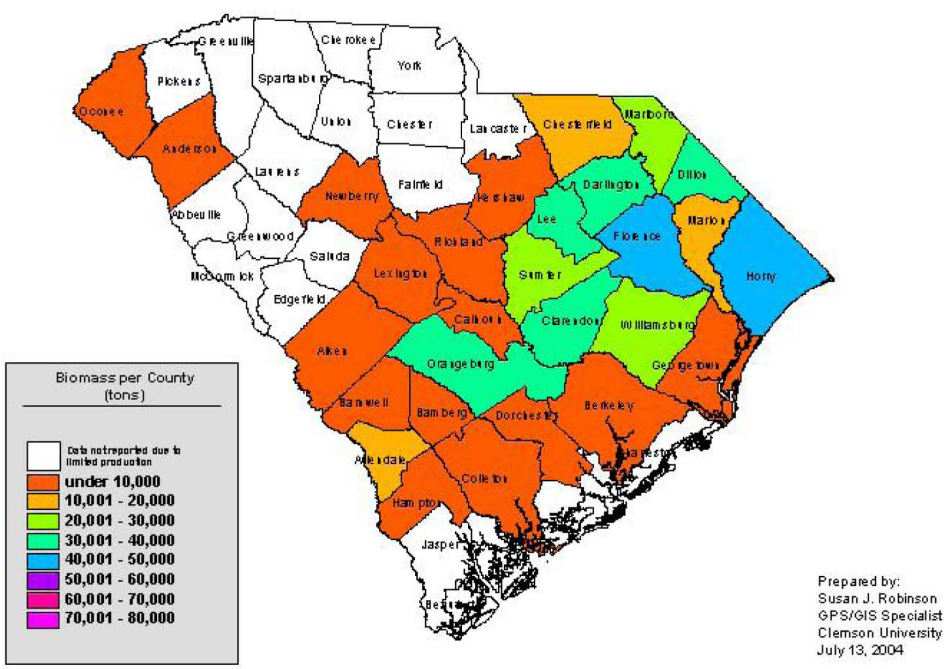


Fig. 5 Soybean Biomass by County in South Carolina

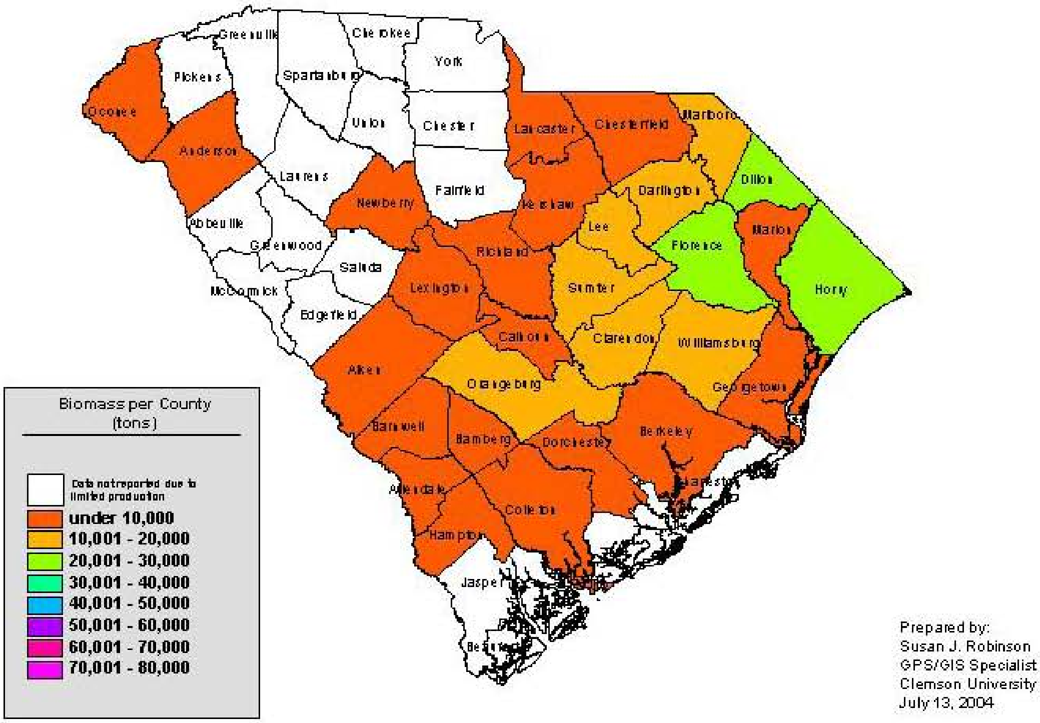
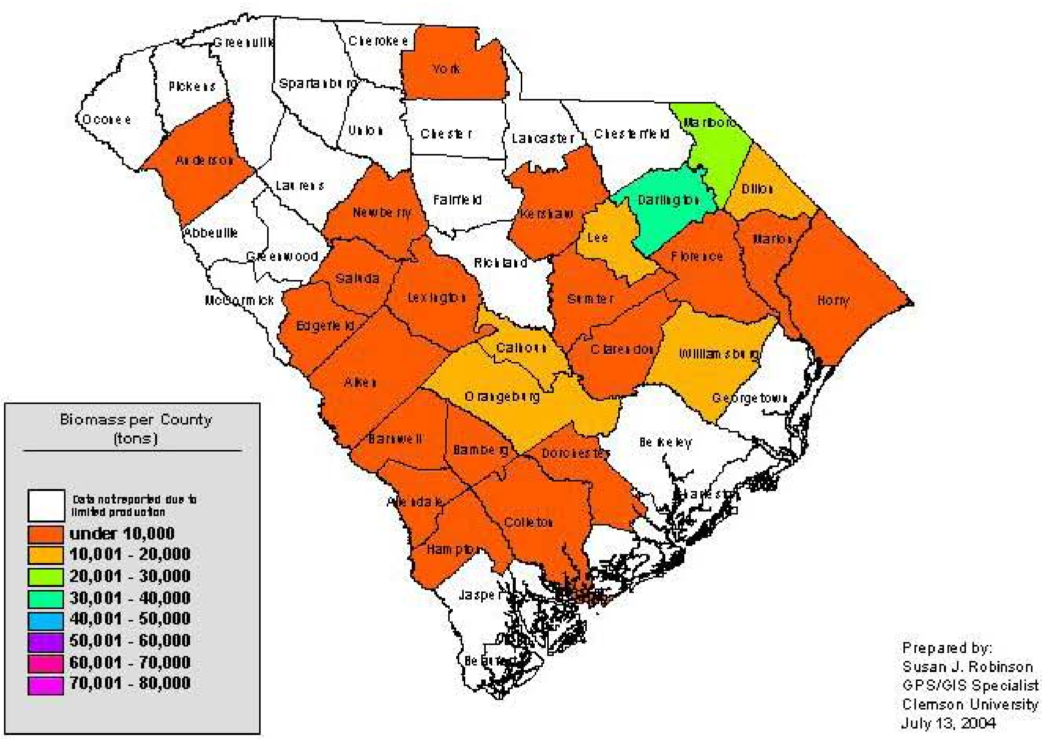


Fig. 6 Cotton Biomass by County in South Carolina



Conversion of Biomass to Power

Fossil fuels (natural gas, petroleum, and coal) are marketed by large energy firms that provide a consistent, standardized fuel that has usually under-gone considerable upgrading. Biomass fuels are typically provided "as produced", with little refinement and no nationally recognized standards. Quality may vary between sources, from one year to the next, or even between deliveries, so you must know the capabilities of the combustion system and specify and monitor the fuel supply to meet those needs. There are many types of biomass fuels, and each type has different characteristics. To further complicate the utilization of biomass, considerable variation may exist within each fuel type. It has been said that when working with biomass fuels, you must either design the combustion system to handle a wide variety of fuels, or you must process the fuels so they are suited to the combustion system available. Either approach adds costs to the overall energy production.

Most biomass fuels contain some amount of water. This can range from a small percentage up to 50% water (expressed on a wet basis). Water contributes to the cost of handling and transportation, but does not contribute any energy. The heating of the water and its conversion to steam requires energy, which is taken from the heat generated by the combustion of the biomass. Combustion systems using high moisture content fuels will have a slower response time to increased energy demand. In addition, wet fuels are subject to biological activity that can cause oxygen depletion in closed storage areas. They can also be subject to heating that can lead to spontaneous combustion. Very dry fuels create a dust hazard during handling and can pose a fire/explosion hazard.

The non-combustible inorganic (mineral) content of biomass is generally referred to as ash. It can be either inherent, that is, deposited within the biomass during plant growth, or contaminant, that is, mixed with the biomass from external sources. Inherent ash is generally low in clean wood (0.5%), higher in bark (3.5%) and significant in annual crops such as straw (6.2%), but usually consistent within a fuel type. Contaminants such as dirt, sand, metal and plaster depend on the fuel source, how it was handled and the degree of cleaning during fuel preparation. It can vary widely within a fuel type or even within a fuel load (Canadian Natural Resources). Ash does not contribute energy and represents a small energy loss if dumped hot. Major problems can occur when excessive contaminant ash softens/ melts to form lumps of slag that can block grates and cause erosion and jamming of ash augers. Combustion of fuels with high alkali levels can cause problems in the boiler tubes when vaporized alkali deposits as slag on the heat exchange surfaces.

Biomass fuels have a low energy density when compared to fossil fuels. For example, wood chips have about three times the bulk per unit of energy than does coal. Therefore, when planning a wood fuel storage facility, one must plan 3 times the volume of storage for wood fuel if one is to maintain the same number of days storage as required for a coal storage facility. Biomass is also hygroscopic, and protection from weather is a consideration. Wood chips, for example, are often stored in a shed or stacked in the open. Square straw bales, on the other hand, should be kept indoors. For a large biomass combustion facility, covered storage is often not feasible. Elaborate, automated storage and retrieval systems typically can cause more combustion outages due to disruptions in the fuel supply to the combustion unit than from problems with the combustion unit itself. As a result, most large biomass energy facilities generally employ a relatively simple storage and retrieval system. A typical system for handling and storing wood chips, sawdust and bark might consist of a hydraulic truck dump to lift up the trailer (and often the truck, too) and dump the payload onto a concrete slab where it is moved, by means of a front end loader, either into a large outdoor storage pile or directly onto a reclaim conveyor (generally a live bottom drag chain assembly). As excess fuel comes in, it is placed into storage, and as additional fuel is needed it is retrieved from storage. Rotation of the fuel pile is also necessary, with a first in, first out sequence often employed.

Most current dedicated biomass-fueled power plants use direct-combustion boilers coupled with steam turbines (Boyland). A typical biomass energy plant will consist of a primary biomass combustion chamber equipped with an air swept feeder to evenly distribute the biomass fuel over either a fixed, vibrating or traveling grate coupled with a high pressure water tube boiler equipped with a super-heater and attached to a multi-stage steam turbine. Another variation is a starved air primary chamber to gasify the biomass, after which it passes into a secondary combustion chamber for complete combustion of the gases. Often, the combustion is multi-staged to achieve a balance of temperatures and complete combustion for controlling temperatures to meet emission limit requirements. This technology is mature, readily available and reliable. Plants tend to be relatively small (20 to 40 MW) and inefficient, when compared to more traditional power generation fuels, such as coal and natural gas. This contributes to a relatively high cost of delivered electricity from biomass generating plants.

The next generation of stand-alone biomass power plants may be both less expensive and more efficient. One of the most promising near-term technological options is a combined-cycle biomass gasification system, which is the biomass equivalent to a natural gas combined-cycle system. In this case, biomass is converted to a gas, in an atmosphere of steam or air, to a medium- or low-energy-content gas. This biogas powers a combined-cycle power generation plant. However, biomass gasification combined-cycle systems are not yet commercially available, although one small plant is operating in Sweden.

A potentially lower-cost, near-term option for converting biomass to energy is to co-fire it with coal in existing power plants. Co-firing means mixing the biomass with the coal to reduce the amount of coal used. Co-firing has been practiced, tested, or evaluated for a variety of boiler technologies, including pulverized coal boilers of both wall-fired and tangentially fired designs, coal-fired cyclone boilers, fluidized-bed boilers, and spreader stokers. Demonstrations and trials have shown that biomass can effectively substitute for 15% or more of coal use. Preparation of biomass for co-firing involves well-known technologies. After tuning the boiler’s combustion output, there is little loss in total efficiency. Test results indicate that a 0.5% decrease in the boiler’s overall thermal efficiency with 10% biomass co-firing is likely. Since biomass generally has much less sulfur than coal, there are reductions in sulfur dioxide emissions and, to a lesser degree, nitrogen oxide emissions (Boyland). Co-firing of biomass may not be feasible at many coal plants, often because of the logistics associated with storage, handling and preparation of biomass fuel, and difficulty getting the biomass into the combustion chamber. In South Carolina, the authors are aware of only one coal boiler where this option has been demonstrated with very minor adaptations to the facility. (Denton, Kress, Todd). Supplementing coal with biomass in South Carolina may be a viable option for utilizing sizable amounts of biomass for power production in South Carolina. However, this will not be known without further study of existing coal fired power plants, and without an incentive for utilities to incorporate biomass co-firing during the planning stages of any new coal fired power plants.

Economics

Direct Economic Considerations

There are two parts to the direct economic considerations of utilizing biomass for energy. First, is the cost of production, and second is the sale of the energy after it has been produced.

The cost of production is a function of the capital cost to build the plant, plus the operating cost to operate the plant. The size of the power plant has a tremendous effect on the final cost of the power produced. Because of the low energy density and the corresponding high transportation cost for transporting biomass fuels, the optimum size for a biomass power plant is probably in the 40 to 50 MW range (Burchfield). A study by the University of Georgia puts the capital cost for a 4.623 MW wood-fired power plant at $2,503,569. per MW of capacity (Curtis). A biomass power plant developer has put the total capital cost for a 40 MW wood-fired power plant at $1,600,000. per MW of capacity (Burchfield). A public utility study was done that projected the capital cost for a 50 MW biomass power plant at $109,676,000. or $2,194,000. per MW (Wisconsin). Assuming $18.00 per ton of wood fuel delivered to these plants, it was estimated that these plants would produce power at a cost of $155.22 per MWh for the 4.623 MW plant, and $89.75 per MWh for the 40 MW plant, and $77.64 per MWh for the 50 MW plant (this assumes a plant that operates at an 80% load factor). The per unit capital cost of a biomass power plant is significantly higher than the capital cost of a utility size coal plant, which is approximately $1,300,000. per MW (Denton, Todd). The final power cost of electricity from biomass is also significantly higher than electricity from a new coal power plant, which has been estimated at $41.30 per MWh (Wisconsin).

At first glance, it might be assumed that the cost of the wood fuel would have a major impact on the final cost of the power, and that fluctuations in fuel cost would cause major swings in the cost of the power. However, the 40 MW plant has a sensitivity of approximately $1.40 per MWh for each $1.00 in wood fuel cost. If the wood fuel were delivered free, the cost of the power produced would still be about $64.50 per MWh, compared with a cost of $89.75 per MWh at a fuel cost of $18.00 per ton. The high cost of power produced utilizing wood for fuel is more a function of capital cost and other operating costs besides fuel cost, than the actual cost of the fuel itself. Even with free fuel, the biomass power plant cannot compete economically with the coal power plant.

Determining the cost of production for power produced utilizing biomass is relatively simple to calculate. All that is necessary is to know the capital cost, operating cost, load factor and capacity. The sale of the power is extremely complicated. It is not simply a matter of selling the power to a utility and them reselling it to their customers. The utilities are faced with an extremely complex system that has evolved over many decades to provide complete service to their customers. Among the issues that complicate the production and sale of power to a wide range of customers are: The fact that the same amount of power is not produced around the clock…there are peaking issues that must be accommodated. The power must be transmitted from the point of production to the point of use. Redundancy must be built into the system to assure power when needed. Utilities must deal with growth and declines in energy use, coupled with the corresponding installed capacity and forecasts for future use and the lead time necessary for implementation of new capacity. Then there are the dynamics of the variety of fuels, fluctuating costs of the fuels, and how that mix must be manipulated to maximize the value to the energy customer. Taking all this into account, it is easy to see that adding biomass to the mix is a complex issue. The best gauge to the value of power produced utilizing a biomass fuel from a plant with a high load factor is to look at contracts that have been negotiated during the recent power market conditions, for existing plants. The prices paid by utilities for multiyear contracts seem to fall into the range of $30.00 to $40.00 per MWh. This range is reinforced by looking at projected futures prices for energy sold without contracts through an energy broker (Table 22). One such projection places the average value of power through 2004 and 2005 at an average of $38.75 per MWh. A biomass energy plant could conceivably be built without contracts, and the power sold through a power broker. However, this increases the risk to the developer, and is not a likely scenario.

A market has been developing for "green power." Green power is basically environmentally friendly methods of generating power, including biomass power (wind and solar are other methods of producing green power). Many utilities have programs whereby their customers can voluntarily pay extra to purchase more expensive green power, effectively subsidizing the production of the green power. In addition, some states have mandated that the utilities operating in those states provide a portion of the power sold as green power. These requirements for green power are often satisfied by the utilities purchasing green power from third parties rather than the utilities generating the power themselves. A secondary market has developed and there are brokers who serve to connect the producers and the buyers of green power. One such company has placed a current value on green power at between $1.00 and $3.00 per MWh (Mainstay). This can help offset the higher cost of producing green power, although the subsidy has not reached a level required to close the gap between the cost of producing green power and power from more traditional fuels.

Table 22 Futures Curve for Power Sales

7x24					
Weighted Price		Total Wtd	Total Hours		**Month**
$	46.08	$ 34,280	744	**2004**	**Aug**
$	39.29	$ 28,290	720		**Sep**
$	34.79	$ 25,886	744		**Oct**
$	34.59	$ 24,905	720		**Nov**
$	38.46	$ 28,614	744		**Dec**
$	**38.66**	$ 141,975	3672		
$	43.62	$ 32,455	744	**2005**	**Jan**
$	42.83	$ 28,780	672		**Feb**
$	38.69	$ 28,784	744		**Mar**
$	37.94	$ 27,318	720		**Apr**
$	36.10	$ 26,856	744		**May**
$	36.42	$ 26,221	720		**Jun**
$	44.60	$ 33,185	744		**Jul**
$	45.85	$ 34,115	744		**Aug**
$	34.59	$ 24,906	720		**Sep**
$	32.43	$ 24,126	744		**Oct**
$	34.58	$ 24,900	720		**Nov**
$	38.31	$ 28,502	744		**Dec**
$	**38.83**	$ 340,149	8760		

(Davis)

Indirect Economic Considerations

In the interest of better understanding the economic and fiscal implications of potential biofuels electricity generation on the state of South Carolina, the Carl Vinson Institute of Government at the University of Georgia analyzed the overall economic and fiscal impact of a typical biofuels electric generation facility. The Carl Vinson Institute has developed a comprehensive, county level economic forecasting and economic impact model of the United States economy that is ideally suited to this analysis. The Regional Dynamics (ReDyn) model is an advanced, highly flexible, Internet-based tool for economic forecasting and for analyzing the impact of businesses, policy changes, and significant events. The model was developed precisely to help state and local governments and communities make better-informed economic and policy decisions, by explicitly estimating how an exogenous shock to a regional economy will spread out to impact other industries and other regions, and how those impacts will change dynamically over time.

For this project, the (ReDyn) model was configured to analyze economic impacts for every county in the state of South Carolina and for a total of 308 different industry types, conforming to the 4 digit North American Industry Classification System (NAICS) coding system. The forecast horizon for the economic impact analysis was annually through the year 2020. The core ReDyn model was augmented using the ReDyn Fiscal Impact Module, so the fiscal impacts of a typical biofuels electric generation facility could be estimated as well.

The optimum size for a biofuels facility was determined to be 40 megawatts. It is critical at this point to understand precisely how the biofuels facility might have a macroeconomic impact on the state. The electric generation facility itself is assumed to have no economic impact on the state whatsoever, in that a biofuels electricity generation facility would simply displace coal electricity generation. Although the operation of the facility itself is assumed to have no net economic impact on the state, the change in the type of fuel consumed can have a very significant impact on the state. Virtually all money spent in South Carolina to purchase coal immediately leaves the state. But because the state has a rich potential source of biofuels, and because economical operation of a biofuels facility effectively requires that the source of the biofuels be within 40 miles of the generation facility, money spent to purchase biofuels will almost entirely stay within the state. In a nutshell, a biofuels plant offers the opportunity for South Carolinians to employ local loggers instead of distant miners. It is the total impact of this change in the supply chain that is of particular interest for this analysis.

A 40 megawatt facility would require approximately 400,000 tons of biomass fuel per year, and would replace a total of 262,000 tons of coal. The delivered price of the biomass fuel is estimated to be $18 per ton, for a total fuel cost of $7,200,000; at a price of coal of $45 per ton, the total price of the coal that is replaced is $11,790,000. The difference in the total price of the two fuels of $4,590,000 would, presumably, be spent by the generator on other resources, be passed through to the consumer, or be rebated back to the shareholder. For this analysis, we assumed the difference in fuel costs would make its way into the income stream of South Carolinians, and be re-spent by them in the same consumption profile as their current income.

The capital cost of the biomass power plant would be $64,000,000, and this is included in the impact analysis as well. Production of the biofuels required to operate the facility would require 7 whole tree chipping operations, and a typical whole tree chipping operation will have 7 employees, for a total increase in employment of 42. The capital cost for each whole tree chipping operation is approximately $1,000,000, for a total capital expenditure of $7,000,000. Each chipping operation will also require the hauling support of 2 tractors and 3 trailers, for a capital cost of $160,000 per operation, or a total investment of $1,120,000 on the trucking operation. Each trucking operation requires 3 people, for a total employment of 21 involved in trucking the biofuels. Because all economic efficiency demands that the biofuels be produced within 40 miles of the electric generation facility, it was assumed that all whole tree chipping and shipping operations would be located in the same county as the electric generation facility.

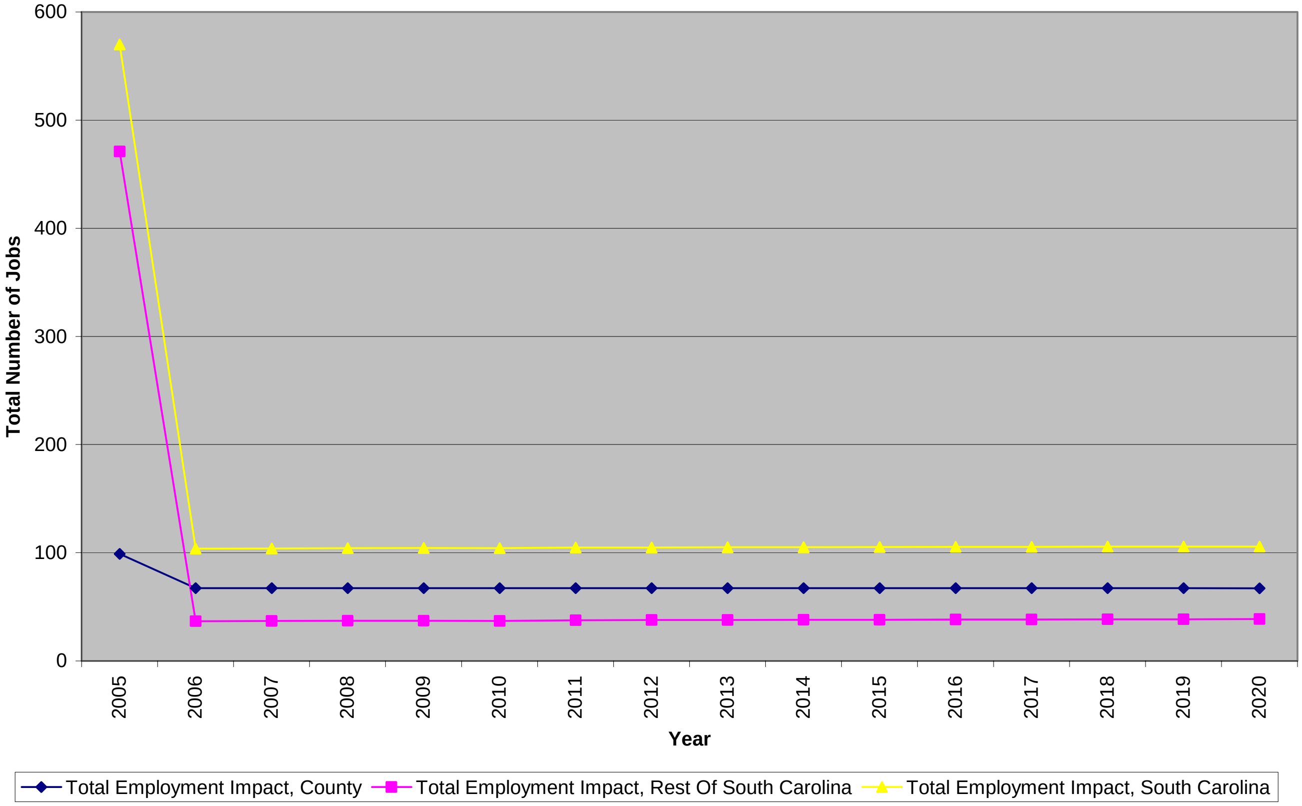
Having identified the economic “footprint” of a typical (40 megawatt) biofuels power plant, it was next necessary to estimate the location of such a facility. Because the aggregate economic impact of such an operation can very widely depending upon where the facility is located, and because there are a number of plausible potential locations within the state, it was determined that the best course of action was to run three separate economic impact scenarios, each one locating the facilities in a different plausible county within the state. For this analysis, Colleton County, Aiken County and Laurens County were identified as plausible locations that cover a wide variety of geography and forest types. For reporting purposes, we will be reporting the average estimated fiscal and economic impact from these three scenarios. It was assumed that the facility, and all necessary supply chain infrastructure would be built in the year 2005, and would be in operation from 2006 through the end of the forecast period in 2020.

Employment Impact of the Typical Electric Generation Facility

A biofuels electric generation facility would shift spending on fuels from coal imported to South Carolina to wood produced in South Carolina. As discussed above, this would directly employ people to process and ship the raw wood. The income of these workers would then be re-spent, in part in South Carolina, producing some additional South Carolina employment. These employees would, in turn re-spend some of their income in South Carolina, and so on. It is the aggregate effect of all of these rounds of re-spent income, across industries and across regions, which the Regional Dynamics model explicitly quantifies.

The year in which the facility is constructed, 2005, the typical facility is estimated to generate a total of 99 jobs in the county where the facility is located, and an additional 471 jobs elsewhere in the state of South Carolina, for a total of 570 jobs statewide. Once the facility is operational, total net employment in the county is expected to be approximately 70 employees greater than it would be in the absence of the facility. Once the facility is up and running, it is also forecast to sustain an additional 36 to 39 jobs elsewhere in the state of South Carolina, for a total employment impact over the operation years (2006-2020) of approximately 106 to 109 jobs. The annual forecast is shown in the graph below.

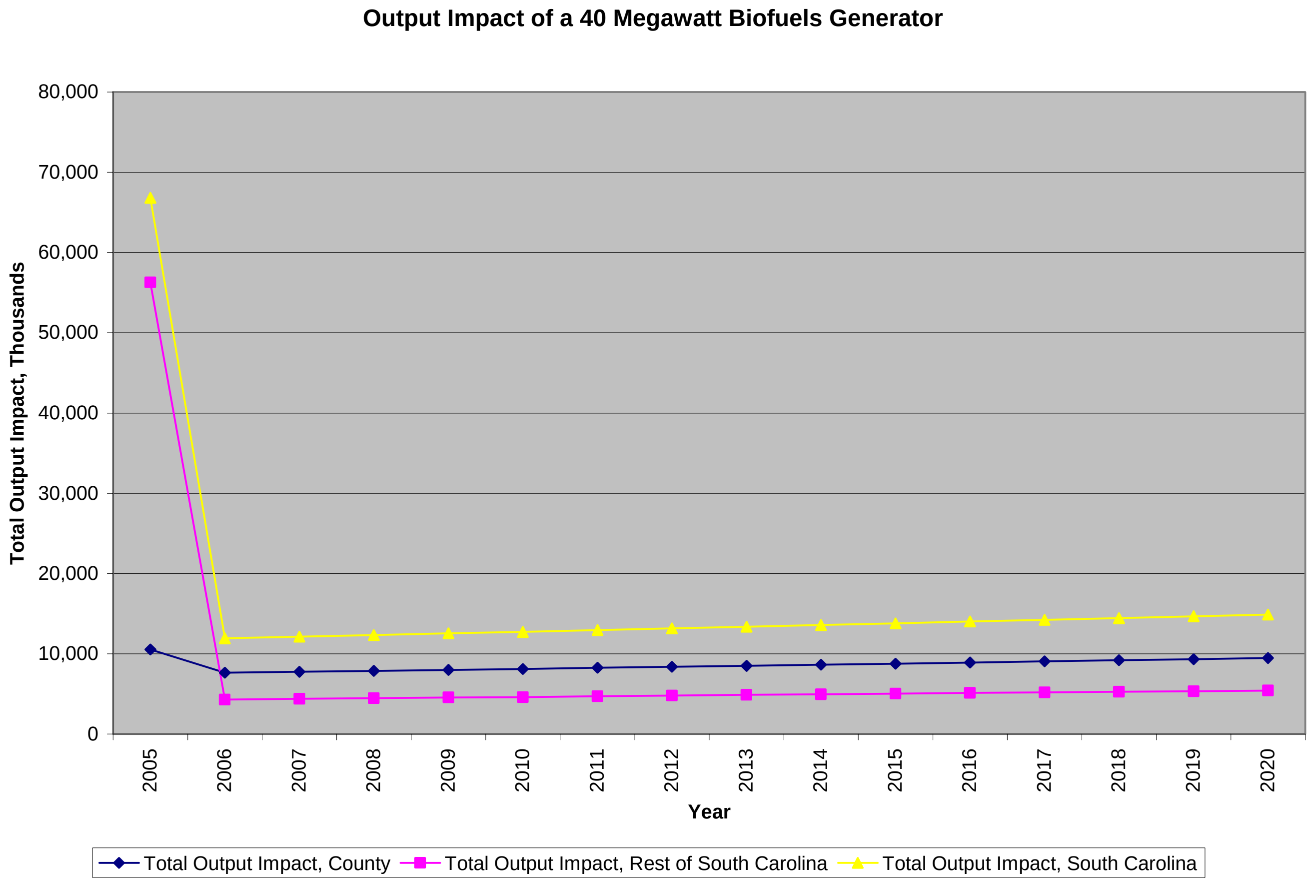
Employment Impact of a 40 Megawatt Biofuels Generator



Output Impact of the Typical Electric Generation Facility

The additional employees in the county and the state are, naturally, associated with an increase in the total amount of output (or, if you prefer, total sales) produced in the state and in the county.

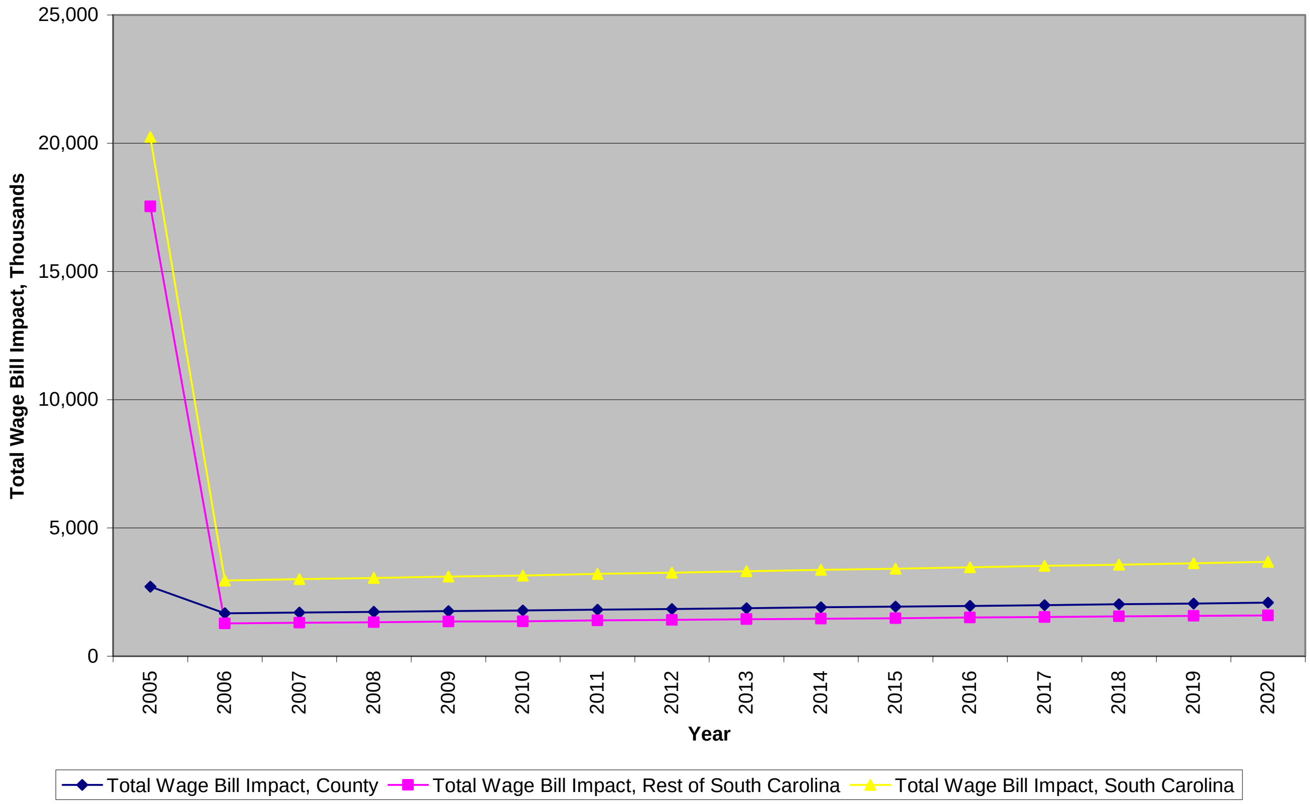
The year in which the facility is constructed, 2005, the typical facility is estimated to generate a total of over $10 million in additional output in the county where the facility is located, and over $50 million in additional output elsewhere in the state of South Carolina, for a total of approximately $60 million statewide. Once the facility is operational, total output in the county is expected to be just over $7.5 million in 2006, rising to just under $9.5 million by 2020. The total output in the rest of the state is expected to be approximately $4.3 million in 2006, rising to just under $5.5 million by 2020. The increase in output over time is a result of the forecast increase in productivity (output per worker) over the forecast period. The output impact of the facility is summarized in the graph below



Wage Bill Impact of the Typical Electric Generation Facility

The additional employees in the county are also associated with an increase in the total amount of wages paid in the county and the state. In the year in which the facility is constructed, it is estimated to generate a total of approximately $2.7 million in additional wages in the county where the facility is located, and over $17.5 million in additional wages elsewhere in the state of South Carolina, for a total of just over $20 million statewide. Once the facility is operational, total output in the county is expected to be just under $1.7 million in 2006, rising to just under $2.1 million by 2020. Total wages earned in the rest of the state are expected to be approximately $1.3 million in 2006, rising to just under $1.6 million by 2020. As with the increase in output over time, the increase in wages over time is a result of the forecast increase in productivity over the forecast period. The wage impact of the facility is summarized in the graph below

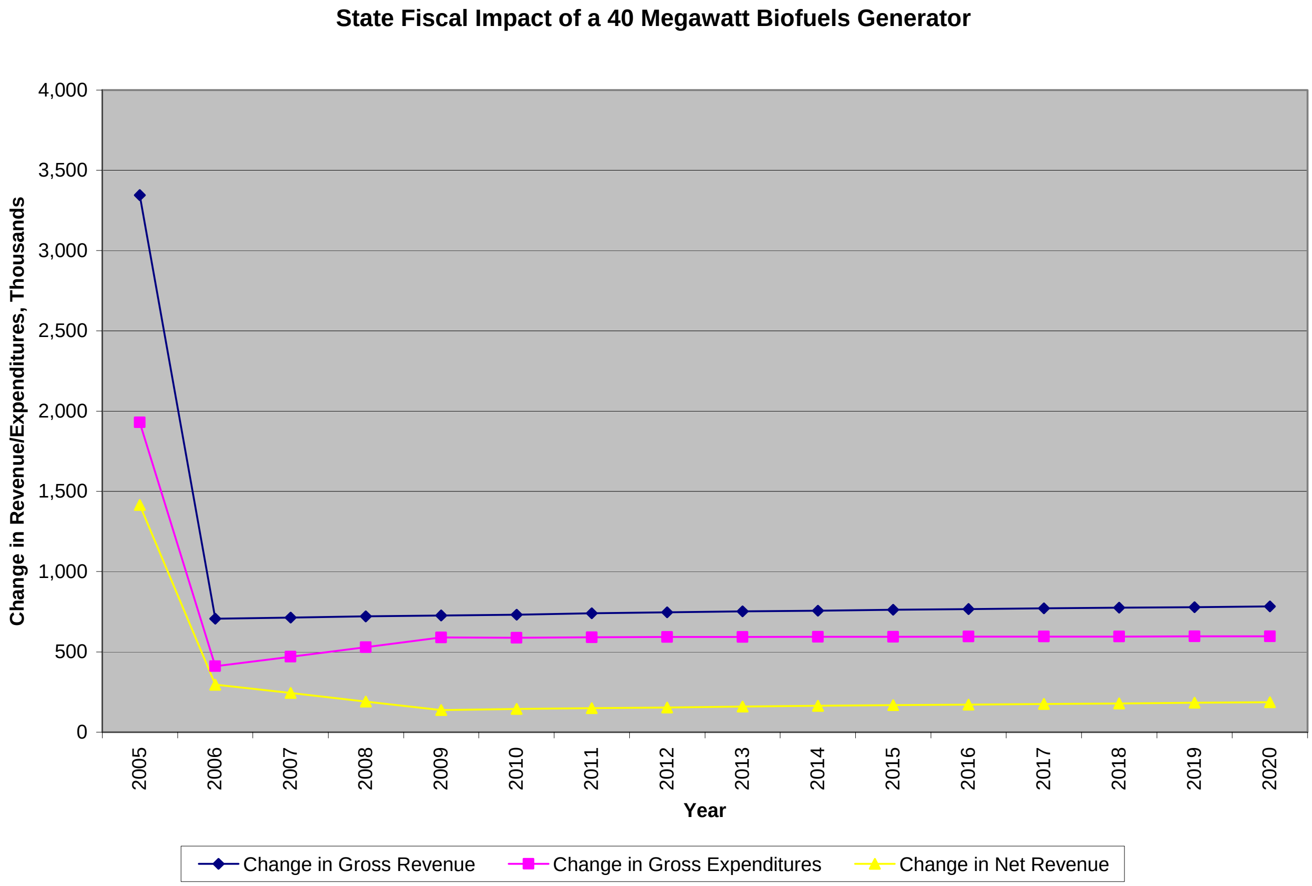
Wage Bill Impact of a 40 Megawatt Biofuels Generator



State Government Fiscal Impact of the Typical Electric Generation Facility

All of the additional economic activity generated by the electric generation facility will, naturally, have fiscal implications for both state and local government. The Regional Dynamics Fiscal Module estimates the fiscal impact of these economic changes for 22 different state government tax and expenditure line items, based upon the effective rates of taxation and effective per capital government expenditures in the state. The estimated state government gross revenue impact of our typical electric generation facility is forecast to be just over $3.3 million dollars in 2005, and during the operation phase, gross revenues are forecast to be $700,000 to $800,000 greater than they would otherwise be.

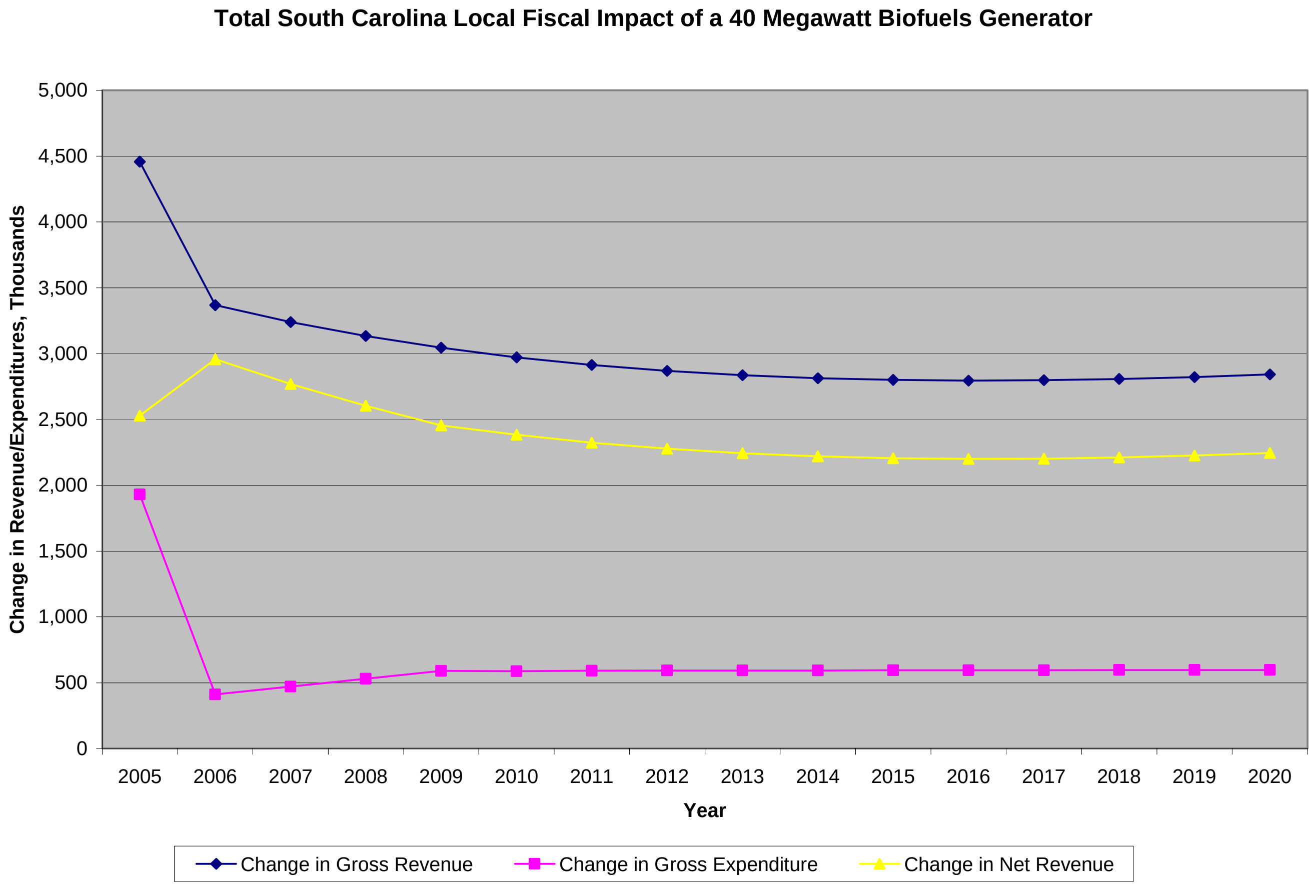
Expenditures by the state, given current expenditures per capita in South Carolina, are expected to increase by $1.4 million in 2005, and over the rest of the forecast period are forecast to fluctuate between $410,000 and $600,000. Thus, the net revenue impact for the state is expected to be positive in the amount of $1.9 million dollars in 2005, and approximately $250,000. per year throughout the forecast period. The state revenue and expenditure impact is outlined in the graph below.



Local Government Fiscal Impact of the Typical Electric Generation Facility

The Regional Dynamics Fiscal Module is also designed to estimate the fiscal impact of economic changes for 22 different local government tax and expenditure line items, again based upon the effective rates of taxation and effective per capital government expenditures in the state. The estimated state government gross revenue impact of our typical electric generation facility is forecast to be just under $4.5 million dollars in 2005, and during the operation phase, gross revenues are forecast to between $2.8 million and $3.4 million per year greater than they would otherwise be.

Total expenditures by local governments in the state of South Carolina, given current local government expenditures per capita in the state, are expected to increase by under $1.9 million in 2005, for a net benefit of approximately $2.6 million in 2005, and over the rest of the forecast period the expenditures are forecast to fluctuate in the neighborhood of $500,000 per year, for a net benefit between $2.3 million and $2.9 million. The net revenue impact for the local governments in the state are expected to be positive throughout the forecast period. These fiscal impacts are shown in the graph below.



The state and local government fiscal impact analyses were conducted assuming that there are no tax breaks or additional (unique) government expenditures, at any level of state or local government, associated with the biofuels facility. In addition, note that the local government fiscal impact quantifies the total impact of the project across all local governments in the state, and not just the economic impact of the facility on the county where it is located. It is likely that the lion's share of the local government fiscal impact is felt in the county where the facility is located, but at least some of these impacts are felt by local governments elsewhere in South Carolina.

Summary and Conclusions

There are many pieces of the puzzle that must fit together in order for a viable biomass energy industry to emerge. Among these is a reliable supply of biomass in sufficient quantities, acceptable quality, and reasonable price delivered to the point of use. You must have the technology to convert the biomass to an energy form that is accessible to the end user with acceptable environmental ramifications. And, all this must be economical when compared to alternative forms of energy.

One of the first issues that must be addressed is the form of energy that is useable. The most efficient use of biomass is conversion to heat (hot air), and the utilization of hot air.

An example of this is in the production of oriented stand board, where the hot air is used in a large dryer to dry the wood flakes that are used to make the board. The next most efficient use of biomass energy is probably in the production of steam for process heat in industrial situations. An example of this would be using steam in a lumber mill to dry lumber. Biomass has been used successfully in other applications where steam in required, such as textile finishing plants, and in the production of distilled water and sterilization of mass-produced products. However, markets for hot air and steam are limited, and the “easy” situations for using biomass in these applications have been sought out by developers and as a result, there is no broad biomass energy markets for steam and hot air available for development. The only way that a sizable biomass energy market can be developed is in the production of electricity.

The economics of electrical generation and distribution are extremely complex. It is often thought that the economics of biomass is the simple case of building a biomass power plant, base loading the plant, hooking into the power grid, and selling the power to a utility. Discussions with utility representatives quickly get to the complications, which include the fact that power is not used around the clock at the same level, there are many types of fuel, and each type of fuel lends itself to specific power generating situations. The utilities are expected to provide power at peak use times, which means that at non-peak times, there is idle generating capacity. Biomass does not lend itself to rapid up and down load situations, and it generally must compete with base load coal plants, which have similar combustion characteristics. Unfortunately for the proponents of power from biomass, a base load coal plant is the least expensive way to generate power, so this limits the value of a biomass plant to the economics of power generation from coal. These complexities and realities of biomass power production are the reason that biomass to electricity is not common throughout the southeastern US, despite the abundance of biomass available. Many states and many organizations have promoted biomass energy for the past 25 years, and still, biomass use is basically limited to broad use by the forest products industry, selected steam applications in other industry groups, and a few power generation plants that were put in during a time when high energy payments were dictated through FERC laws. The situation has basically not changed during the past 25 years. For these reason, we cannot reasonably expect the development of biomass for power generation on a broad scale without some form of incentives or subsidies.

In South Carolina, there is sufficient biomass available on a sustained basis to support a sizeable biomass energy industry. The harvesting of the biomass can be done within acceptable environmental boundaries, and in fact, the harvesting can be used as a useful forest management tool to improve the health of the State’s forest lands. If we take a very conservative approach, and look at the easiest, most economical portion of the biomass available for harvest (logging residues and merchantable thinnings), and use 50% of those that may be available on an annual basis, we find that we have over 4 million tons per year available for energy use. This would power 10 of the 40 MW biomass power plants that we have determined is in the optimal size range. From a resource standpoint, a goal of 400 MW of power production from biomass is a reasonable near-term goal for a sustainable biomass energy industry.

If we compare the average electricity futures price of $38.75 per MWh (Table 22) to the average production costs for a 40 and 50 MW biomass power plant of $83.69 per MWh, we see that biomass power production is at an economic disadvantage of approximately $44.96 per MWh of power produced. If we consider this in the context of a single 40 MW biomass power plant operating at a load factor of 80%, we can see that this plant will cost approximately $12.5 million dollars per year more to build and operate than the revenue from power sales. This is the difference that must be made up by some form of subsidy if these plants are to be built. The state government benefits from the additional economic activity by about $250,000. per year, so there is not much there that will help the economics. Local governments have gross revenue benefits of over $2. million dollars per year, but identifying where those occur and passing those to the developer of the project will be difficult. Perhaps some property tax incentives could be developed to influence citing of the plants. At best, even after taking into account the indirect benefits and assuming those could be captured and used to offset the additional cost, the 40 MW biomass power plant will have a shortfall of approximately $10. million dollars per year. The simplest way to subsidize biomass plants is to spread the increased cost of power production over the users of the power in the form of increased rates paid by the consumers of the power. To accomplish this, it would require mandates that the utilities that produce power in the state must produce a certain percentage of power produced in the state utilizing biomass fuels, and that they be allowed to pass along the additional cost of production to the power consumers in the form of higher power rates. This method would insure that there will be development of a biomass power industry, verses some form of incentive that may or may not be used, such as tax credits or grants to offset initial capital costs.

In the year 2002, power from coal generated in South Carolina totaled 36,490,769 MWh (US Department of Energy-2). Ten 40 MW biomass power plants at an 80% load factor would generate 2,784,000 MWh, which would offset approximately 7.63% of the coal used per year. The total power generated in South Carolina in 2002 was 93,689,257 MWh, and the ten 40 MW biomass plants would equal approximately 2.97% of the total electrical production in the state. If we assume that the utilities are required to purchase 2.97% of their power from biomass power plants at a cost of $83.69, and they could have purchased or produced that power at the average futures cost of $38.75, we can compute a weighted average to determine the percentage of increase in rates required to pay for the difference in business as usual verses producing 2.97% of the power from biomass.

Biomass contribution	2.97 X 83.69 =	248.56
Existing costs for remaining percentage	97.03 X 38.75 =	3759.91
Total		4008.47
Current situation without biomass	100 X 38.75 =	3875.00
Increase		133.47
Percent increase	133.47/3875 = 3.44%	

Thus, households that currently have a $100. per month power bill would have to pay an additional $3.44 on their monthly bill to support the biomass energy initiative.

There are other ways to subsidize biomass energy, but it is difficult to provide ways of subsidizing complex economic situations without creating unintended consequences and without impacting the stakeholders that are currently operating in the forest products industry in general and in the biomass wood industry specifically. Regardless of the form of the subsidy, the dollars required are the same.

The benefits of biomass power generation to the state would include an estimated creation of approximately 5,700 jobs during the year that the ten plants are built and an estimated 1060 jobs during the subsequent years. State revenues are projected to increase $2.5 million per year and county revenues are projected to increase $20. million per year. In addition, the markets for logging residues and thinnings will provide an additional forest management tool that will make the state's forest lands more productive. It will provide increased revenue for land owners through utilization of biomass not currently utilized, lower site prep costs, and fire prevention due to reduced fuel loading on forest lands. It will provide environmental benefits for biomass verses coal power generation, and it will open the possibility of diverting biomass from landfills for use in power generation. As the market develops, it may also include opportunities for increased revenue to farmers by incorporating agronomic residues into the fuel mix.

A logical next step would be to develop a task force made up of representatives of each utility operating in the state, representatives of state government, representatives of the forest industry, and other stakeholders. The economics must be refined, both in terms of the relative costs of power production and the methods of passing on the increased costs to the power consumers. A method of implementation along with a reasonable timetable must be established. A separate study should be conducted to review the existing coal plants in the state to determine if any may lend themselves to co-firing. Only after this information is available can policy makers determine if the benefits of such an endeavor is worthwhile to the residents of South Carolina.

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Glossary

Annual mortality—The average annual volume of sound wood in growing-stock trees that died from natural causes during the period between inventories.

Annual removals—The net volume of growing-stock trees removed from the inventory during a specified year by harvesting, cultural operations such as timber stand improvement, or land clearing.

Coarse materials—Wood residues suitable for chipping, such as slabs, edgings, and trimmings.

Commercial species—Tree species suitable for industrial wood products.

Cull tree—A live tree, 5.0 inches in diameter at breast height (d.b.h.) or larger, that is unmerchantable for saw logs now or prospectively because of rot, roughness, or species. (See definitions for rotten and rough trees.)

Diameter class—A classification of trees based on diameter outside bark measured at breast height (4-1/2 feet above ground). D.b.h. is the common abbreviation for "diameter at breast height." With 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches d.b.h.

Federal—An ownership class of public lands owned by the U.S. Government.

Fiber products—Products derived from wood and bark residues, such as pulp, composition board products, and wood chips for export.

Fine materials—Wood residues not suitable for chipping, such as planer shavings and sawdust.

Forest industry—An ownership class of private lands owned by companies or individuals operating wood-using plants.

Forest land—Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated.
Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest type—A classification of forest land based on the species presently forming a plurality of the live-tree stocking.

Fuelwood—Wood used for conversion to some form of energy, primarily in residential use.

Growing stock—A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, includes only trees 5.0 inches d.b.h. and larger.

Hardwood—A dicotyledonous tree, usually broad-leaved and deciduous.

Industrial wood—All commercial roundwood products except fuelwood.

Live cull—A classification that includes live, cull trees. When associated with volume, it is the net volume in live, cull trees that are 5.0 inches d.b.h. and larger.

Logging residues—The unused portions of growing-stock trees cut or killed by logging and left in the woods.

MWh—Megawatt hour.

Net annual growth—The average annual net increase in the volume of trees during the period between inventories. Components include the increment in net volume of trees at the beginning of the specific year surviving to its end, plus the net volume of trees reaching the minimum size class during the year, minus the volume of trees that died during the year, and minus the net volume of trees that became cull trees during the year.

Net volume in board feet—The gross board-foot volume of the saw log portion of live sawtimber trees less deductions for rot or other defect affecting use for lumber.

Net volume in cubic feet—The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs.

Noncommercial species—Tree species of typically small size, poor form, or inferior quality, which normally do not develop into trees suitable for industrial wood products.

Nonforest land—Land that has never supported forests and lands formerly forested where use of timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 4.5-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., must be more than 1 acre in area, to qualify as nonforest land.)

Nonindustrial private—An ownership class of private lands where the owner does not operate wood-using plants.

Other products—A miscellaneous category of roundwood products that includes such items as cooperage, pilings, poles, posts, shakes, shingles, board mills, charcoal, and export logs.

Ownership—The property owned by one ownership unit, including all parcels of land in the United States.

Ownership unit—A classification of ownership encompassing all types of legal entities having an ownership interest in land, regardless of the number of people involved. A unit may be an individual; a combination of persons; a legal entity such as a corporation, partnership, club, or trust; or a public agency. An ownership unit has control of a parcel or group of parcels of land.

Planted forest—Planted forests are areas deemed to be forest by RPA definition and made up of at least 40 percent planted trees of either native or exotic species. Planted forests may be divided into two groups: plantations and augmented forests.

Plantations—Forest stands consisting almost exclusively of planted trees, of native or exotic species, and intensively managed to maintain this composition to maturity. Management practices may include extensive site preparation prior to planting and suppression of competing vegetation.

Augmented forest—Forest stands consisting of at least 40 percent planted trees, of native or exotic species, but not intensively managed to assure dominance of these trees in the stand at maturity. Management practices may include suppression of competing vegetation at the time of planting.

Poletimber trees—Live trees at least 5.0 inches in d.b.h., but smaller than sawtimber trees.

Primary wood-using mill—A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and pulpmills that convert pulpwood into wood pulp.

Productivity class—A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

Pulpwood—Roundwood, whole-tree chips, or wood residues that are used for the production of wood pulp.

Reserved forest land—Forest land withdrawn from timber utilization through statute, administrative regulation, or designation without regard to productive status.

Residues—Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples are slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Rotten tree—A live tree of commercial species that does not contain a saw log now or prospectively primarily because of rot (that is, when rot accounts for more than 50 percent of the total cull volume).

Rough tree—(a) A live tree of commercial species that does not contain a saw log now or prospectively primarily because of roughness (that is, when sound cull due to such factors as poor form, splits, or cracks accounts for more than 50 percent of the total cull volume) or (b) a live tree of noncommercial species.

Roundwood products—Logs, bolts, and other round timber generated from harvesting trees for industrial or consumer use.

Salvable dead tree—A downed or standing dead tree that is considered currently or potentially merchantable by regional standards.

Saplings—Live trees 1.0 inch through 4.9 inches d.b.h.

Saw log—A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards.

Sawtimber—A classification of timber inventory that is composed of sawtimber trees of commercial species.

Sawtimber trees—Live trees containing at least one 12-foot saw log or two noncontiguous 8-foot logs, and meeting regional specifications for freedom from defect. Softwood trees must be at least 9.0 inches d.b.h., and hardwood trees must be at least 11.0 inches d.b.h.

Seedlings—Live trees less than 1.0 inch d.b.h. and at least 1 foot in height.

Select red oaks—A group of species in the genus *Quercus* that includes cherrybark oak, northern red oak, and Shumard oak.

Select white oaks—A group of species in the genus *Quercus* that includes white oak, swamp white oak, bur oak, swamp chestnut oak, and chinkapin oak.

Softwood—A coniferous tree, usually evergreen, having needles or scale-like leaves.

Sound dead—The net volume in salvable dead trees.

Stand size class—A classification of forest land based on the size class of all live trees in the area. The classes include: nonstocked, seedling-sapling, poletimber and sawtimber stands.

Nonstocked stands—Forest land that is stocked with less than 10 percent of full stocking with all live trees. Examples are recently cut-over areas or reverting agricultural fields.

Seedling-sapling stands—Forest land that is stocked with at least 10 percent of full stocking with all live trees with half or more of such stocking in seedlings or saplings or both.

Poletimber stands—Forest land that is stocked with at least 10 percent of full stocking with all live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of poletimber exceeds that of sawtimber.

Sawtimber stands—Forest land that is stocked with at least 10 percent of full stocking with all live trees with half or more of such stocking in poletimber or sawtimber trees or both, and in which the stocking of sawtimber is at least equal to that of poletimber.

Stocking—The degree of occupancy of land by trees, measured by basal area or number of trees by size and spacing, or both, compared to a stocking standard; that is, the basal area or number of trees, or both, required to fully utilize the growth potential of the land.

Timberland—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

Tops—The wood of a tree above the merchantable height (or above the point on the stem 4.0 inches diameter outside bark [d.o.b.]). It includes the usable material in the uppermost stem.

Unreserved forest land—Forest land that is not withdrawn from harvest by statute or administrative regulation. Includes forest lands that are not capable of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands.

Veneer log—A roundwood product from which veneer is sliced or sawn and that usually meets certain standards of minimum diameter and length and maximum defect.