

## **Biomass Power for Utility Applications**

### **--- *Southern Company's Experience* ---**

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**Summary.** In the Southeast renewable energy resources for large-scale power generation (i.e., 20 to 100 MW) are limited primarily to biomass. Biomass resources are relatively plentiful in our region compared to other areas of the U.S. due to the high degree of forestation and the large presence of pulp, paper, and wood products industries. However, most of the relatively inexpensive residues from wood processing and harvesting are currently utilized in existing industry boilers and in other wood waste markets. In the future low value and underutilized standing timber may represent a significant new source of biomass fuels. This may help to relieve some of the upward pricing pressures that would be experienced from commercial implementation of several relatively large-scale biomass power plants. Poultry litter could also be used as a resource to produce renewable power, but there are significant issues related to increased contaminant levels.

There are two basic methods for generating power from biomass: (1) biomass co-firing in existing power plants and (2) biomass-only utilization in dedicated plants. Biomass co-firing includes co-milling with coal, direct injection through separate burners, and direct injection by a spreader grate. Dedicated biomass power plants include currently commercial technologies such as spreader grate boilers, fluidized-bed boilers, and circulating bed boilers coupled to traditional steam power cycles.

One of the lowest cost options for biomass involves co-firing in an existing pulverized coal unit. It is a low capital investment approach to biomass combustion. Over the past decade several methods of biomass co-firing using a variety of fuels have been tested and evaluated by Southern Company with some successes. The following options for biomass co-firing are ranked in order of preference from highest to lowest priority based on preliminary estimates of the additional cost of electricity (COE): (1) Co-milling of Wood Residues, (2) Pneumatic Direct Injection of Wood Residues Through New Burners, and (3) Pneumatic Direct Injection of Switchgrass Through New Burners.

Traditional forms of biomass power plants, such as the spreader grate boiler, are usually not very efficient, but they are fairly reliable, accept a wide variety of fuels, and have a considerable experience base. Their low efficiency and large capital investment make the renewable energy from these plants relatively expensive. The following options for dedicated biomass power plants are ranked in order of preference from highest to lowest priority based on preliminary estimates of the cost of electricity (COE): (1) Wood Residues on a Retrofitted Spreader Grate at a Retired Pulverized Coal Unit, (2) Wood Residues in a New Spreader Grate Boiler or New Fluidized Bed Boiler at a Retired Pulverized Coal Unit, (3) Wood Residues in a New Spreader Grate Power Plant or New Fluidized Bed Power Plant at an Existing Site, and (4) Wood Residues in a New Spreader Grate Power Plant or New Fluidized Bed Power Plant at a Greenfield Site.

In the future pressurized (i.e., 500 psi) biomass gasification may be a comparatively low-cost renewable option. Successful use of the bio-gas in high efficiency combustion turbine systems could reduce costs of renewable energy. It is anticipated that biomass gasification combined cycle could produce power at efficiencies of about 40% as compared to the current combustion-based biomass efficiencies in the 20% to 30% range. However, biomass feeding under pressure,

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<sup>1</sup> [Forthcoming]

gas clean-up, and turbine compatibility with exhaust gases are still subjects of research. The technology is not expected to be commercially available until well beyond 2015.

**Keywords.** [Forthcoming]

## **Introduction**

Increasingly, consumer and environmental groups along with state governments are placing demands on electric utilities to replace conventional fossil-fuel generation with renewable resources. Moreover, the environment is becoming more important to customers and shareholders. The potential requirement for utilities to meet state or federal Renewable Portfolio Standards (RPS), together with various incentives or opportunities to sell green or renewable power at premium prices, all suggest a need for low-cost renewable energy options. Most states currently have voluntary green pricing programs, and about 30 states have gone even further by mandating renewables through RPS legislation.

The cost of renewable generation options in a particular region of the country depends, in part, on the amount of renewable resource in that region. Solar energy, which is already a high-cost option, becomes even less cost effective in regions that regularly experience cloudy and overcast days such as the Southeast. Limited wind resources are available in the region and may be found on isolated ridge tops and possibly off the Atlantic coast of Georgia. Other factors which affect the cost of renewable energy include capital, fuel (if any), efficiency, reliability, capacity factor, backup generation required, and energy storage. In the Southeast renewable energy resources for large-scale power generation (i.e., 20 to 100 MW) are limited primarily to biomass.

In the near term a market exists based upon the aggregated renewable energy needs of large commercial and industrial customers. Because of increased consumer sensitivity to environmental and sustainability issues, a number of these customers are making a push to brand their products as green. Several large companies have aggregated their purchasing power to jointly procure renewable energy. These blocks of renewable energy are relatively large (as much as 50 to 100 MW) compared to quantities sold in the current green pricing programs to mostly residential customers. Even though the price premium charged for renewable energy sold to these aggregated customers would be less than the premium charged to residential customers in the green pricing programs, the market risk would likely be reduced for the aggregated customer group since they would probably sign long-term contracts for the renewable energy (perhaps 5 to 10 year terms).

## **Biomass Resources**

Biomass resources are relatively plentiful in our region compared to other areas of the U.S. due to the high degree of forestation and the large presence of pulp, paper, and wood products industries.

Biomass fuels exhibit certain fundamental differences from other fossil fuels. Typically, biomass fuels are either gathered up or harvested from diffuse sources and concentrated at a given location. Biomass materials are also much lower in energy content per unit volume than fossil fuels. Consequently, there are practical limitations on the quantities that can be collected and transported without experiencing significant cost pressures. As a general rule, biomass materials can be economically transported no more than 50 to 100 miles.

Woody biomass materials currently used as fuels are, almost exclusively, residues from other processes. They may be wood processing residues such as hog fuel, bark, sawdust, and black

liquor. They may also be wood harvesting residues and forest thinnings. In some cases these commodities have both material and energy value. Wood waste markets, for example, can include mulch for urban areas, bedding for livestock and poultry, and feedstocks for materials such as particleboard. As a result, fuel pricing can be highly sensitive to locale and the competitive pressures of local and regional economies.

In the future low value and underutilized standing timber may represent a significant new source of biomass fuels. This may help to relieve some of the upward pricing pressures that would be experienced from commercial implementation of several relatively large-scale (i.e., 20 to 100 MW) biomass power plants. For example, a 20 MW plant would need about 200,000 green tons per year of biomass; whereas, a 100 MW plant would require 1 million green tons per year.

Significant efforts have also been made to develop short-rotation agricultural crops such as switchgrass to be used exclusively as fuel or energy feedstocks. To date these have not produced priced fuels that are cost-competitive with woody biomass residues.

The Southeast broiler industry produces significant quantities of poultry litter. Poultry litter is a mixture of broiler manure and partially decomposed bedding material (commonly wood shavings). Poultry litter is applied mainly on pastures used for grazing beef cattle. This practice has resulted in a buildup of soil phosphorus levels and increased concern about water quality problems. Phosphorus runoff into surface waters can cause excess algae growth, ecological problems, and odor and taste problems in drinking water. The economics of the poultry industry are being threatened by water quality concerns associated with regional phosphorus surpluses. Practical solutions to the regional phosphorus surplus problem are needed to assure the environmental sustainability of the broiler industry in the region.

Poultry litter could be used as a resource to produce renewable power, but there are significant issues related to increased contaminant levels. Nitrogen and sulfur contents are about ten times higher in than wood. This increases the potential for fuel  $\text{NO}_x$  and  $\text{SO}_2$  emissions and requires special measures for their reduction. Chloride and alkali (sodium and potassium) levels are higher in poultry litter than in wood. High chloride levels, in conjunction with high alkali levels, increase the potential for particulate emissions, corrosion problems, and acid gas emissions. Ash levels are higher compared to wood, requiring higher-volume ash-handling equipment and attention to particulate removal, slagging, and fouling.

A recent EPRI study on production of renewable power from poultry litter (March 2006) conducted by TVA concluded the following:

“Producing process heat from poultry litter is projected to be more profitable than producing electric power. Commercial efforts to recover renewable energy and nutrients from poultry litter in the TVA region should focus on providing process heat that displaces high-priced natural gas rather than producing renewable electric power. Producing electric power from poultry litter would require substantial financial incentives to be profitable, and these incentives do not appear to be forthcoming in the TVA region.”

### **Biomass Power Overview**

The combustion of biomass such as wood, grasses, and agricultural residues to produce renewable energy is typically considered  $\text{CO}_2$  neutral. Carbon released in burning biomass is the

same carbon that was absorbed from the air when the tree or grass was growing, producing essentially no net CO<sub>2</sub> contribution.

Biomass power plants have an important advantage over direct solar and wind energy in that biomass power can be dispatched. The energy is stored in the fuel and therefore backup generation or energy storage is not required. However, because combustion of a fuel is involved, biomass has higher emissions than solar or wind. Criteria pollutant emissions with clean biomass are typically lower than or equal to those for coal. Biomass has low sulfur, mercury, and ash content, while NO<sub>x</sub> emissions will usually be equal to or lower than those with coal. Current biomass generation is “small” (largest facilities are about 50 to 80 MW), which makes competition with 500 MW coal plants difficult due to economies of scale.

There are two basic methods for generating power from biomass: (1) biomass co-firing in existing power plants and (2) biomass-only utilization in dedicated plants. Biomass co-firing includes co-milling with coal and direct injection through separate burners. Dedicated biomass power plants include spreader grate boilers, fluidized-bed boilers, and gasification technologies coupled to traditional steam power cycles or to combined cycles.

One of the lowest cost options for biomass involves co-firing in an existing pulverized coal unit. It is a low capital investment approach to biomass combustion. Because biomass properties are very different from coal, the amount that can be burned with coal is generally between 1% and 15% of the plant energy input. Biomass ash properties can affect other balance of plant processes (e.g., ash sales, degradation of Selective Catalytic Reduction catalyst) and will restrict the number of plants to which biomass co-firing can be applied. Over the past decade several methods of biomass co-firing using a variety of fuels have been tested and evaluated by Southern Company with some successes.

Traditional forms of biomass power plants, such as the spreader grate boiler, are usually not very efficient, but they are fairly reliable, accept a wide variety of fuels, and have a considerable experience base. Their low efficiency and large capital investment make the renewable energy from these plants relatively expensive.

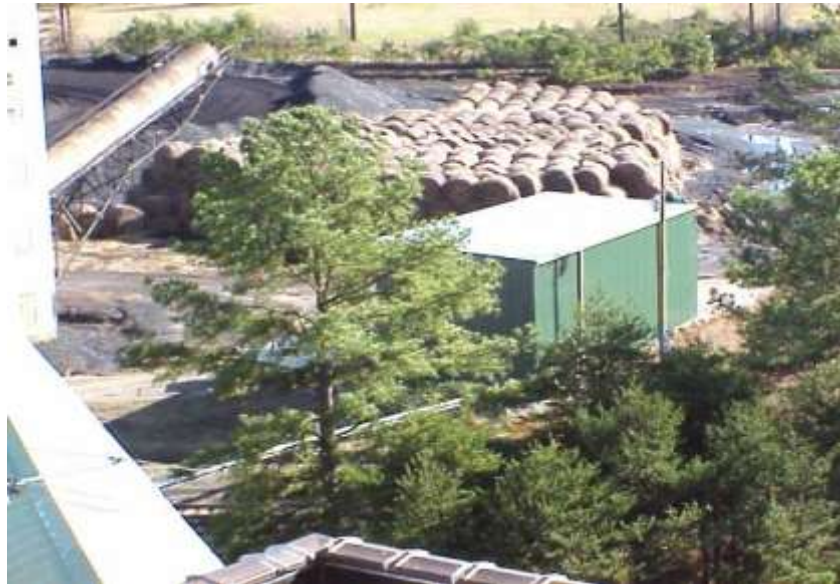
Another approach to biomass is gasification, which may eventually offer a comparatively low-cost renewable option. Gasification produces a gaseous fuel from biomass through partial combustion. The gas is composed primarily of CO and H<sub>2</sub>, and has heating value between 10% and 40% that of natural gas. Successful use of the bio-gas in high efficiency combustion turbine systems could reduce costs of renewable energy. It is anticipated that biomass gasification combined cycle could produce power at efficiencies of about 40% as compared to the current combustion-based biomass efficiencies in the 20% to 30% range. The gas might also be co-fired in existing combined cycle natural gas-fired systems. However, biomass feeding under pressure (500 psi), gas clean-up, and turbine compatibility with exhaust gases are still subjects of research.

### **Biomass Co-firing**

In general, there are three forms of co-firing biomass with coal. Co-milling involves treating the biomass as if it were coal, mixing the material with the coal, and passing it through the coal handling system and coal burners. Another technology is direct injection, in which the biomass is processed to a fine material and blown directly into the furnace through its own dedicated burners.

Co-milling requires less capital but is limited to only low percentages of biomass. Its success depends on the individual power plant design, on the form of biomass as fuel, and on the percentage co-fired. The maximum co-milling energy percentage will typically be about 3% by energy input. As much as 5% has been achieved, but the unit experienced reduced efficiency and lower load. Sawdust and sander dust worked fairly well, as did finely chipped tree trimming waste. Southern Company was not as successful with co-milling large (i.e. 1 – 2 inches fiber length and larger) wood chips due to their fibrous nature. Fibers collected in the coal pulverizer and also plugged the outlet piping of the pulverizer leading to the burner.

Direct injection by pneumatically conveying material into the furnace is generally capable of co-firing higher percentages of biomass. Tests up to 10% by energy input have been successfully performed. Capital equipment is required, and the wood or grass must be reduced to a small size, which can add to costs (e.g., grinders, fan, conveyors, ductwork). However, fairly promising results have been obtained in power plant tests conducted on direct injection of switchgrass and ground-up pallets. Energy from the switchgrass direct injection system provides the basis for Alabama Power's renewable power offering to its customers. In the picture below, switchgrass is stored near the coal pile at Alabama Power's Plant Gadsden. The green building houses the switchgrass grinding (tub grinder) and pneumatic transport systems.



In addition to the biomass handling, feeding, and capital cost issues mentioned previously, there are other key technical hurdles that must be overcome before biomass could be co-fired on significant scale. Biomass materials have concentrations of certain minerals that are potentially adverse to operation of pollution control equipment (i.e., Selective Catalytic Reduction Units used to reduce NO<sub>x</sub> emissions) located at several of our larger power plants. Southern Company is currently pursuing R&D to better define the potentially detrimental effects of these minerals. Also, many plants sell rather than store their fly ash for use in the concrete industry; however, the ASTM specifications for fly ash in cement do not currently recognize anything but fly ash from coal. As a result, there are concerns about the ability to sell wood-based fly ash in the near term. Southern Company also has a project to test the cementitious properties of mixed fly ash from co-firing.

Work continues in Southern Company to develop effective ways to co-fire larger amounts and different types of biomass in an existing boiler. Other tests include evaluation of seasonal

switchgrass varieties and “small” wood chips (i.e., fiber length of ½ inches and under) at Alabama Power’s Plant Gadsden in an on-going in an effort to improve the environmental performance and cost effectiveness of biomass co-firing. Initial co-firing tests of “small” wood chips at two Alabama Power units have been successful (see the following picture of “small” wood chips).



The following options for biomass co-firing at existing facilities are ranked in order of preference from highest to lowest priority based on preliminary estimates of the additional cost of electricity (COE). Typical utility financial parameters were used in developing the COE numbers. Any applicable tax credits were not considered in the financial analysis. The capital costs below are useful for scoping and conceptual evaluations, but are not substitutes for detailed bid proposals.

1. Co-milling Wood Residues with Coal at Existing Pulverized Coal Units

- a. Technology status – Available now
- b. Co-firing range – 1 to 5% of total energy input to boiler
- c. Typical feedstocks – Small size biomass materials such as sawdust and forest thinnings/harvest residues that have been ground to a fine, dust-like consistency. Small wood chips (i.e., less than ½ inches) may be acceptable. Large wood chips (1 to 2 inches) are not acceptable. Poultry litter is not acceptable due to the potential for boiler fouling. (Co-milling of switchgrass cubes is not acceptable based on feed system problems experienced during tests at a Georgia Power pulverized coal unit).
- d. Southern Company experience – Testing at Plant Gadsden and other system power plants
- e. Capital cost – \$75/kW of co-fired capacity

2. Pneumatic Direct Injection of Wood Residues Through Separate Burners at Existing Pulverized Coal Units

- a. Technology status – Available now
- b. Co-firing range – Up to 15% of total energy input to boiler

- c. Typical feedstocks – Sawdust and other ground biomass materials that can be pneumatically conveyed to and injected in the boiler through separate burners. Poultry litter is not acceptable due to the potential for boiler fouling.
- d. Southern Company experience – Limited. Ground-up pallets.
- e. Capital cost – \$300/kW of co-fired capacity

3. *Pneumatic Direct Injection of Switchgrass Through Separate Burners at Existing Pulverized Coal Units*

- a. Technology status – Available now
- b. Co-firing range – Up to 15% of total energy input to boiler
- c. Typical feedstocks – Chopped switchgrass (1 inch and smaller) that can be pneumatically conveyed to and injected in the boiler through separate burners.
- d. Southern Company experience – Testing at Plant Gadsden since 2001
- e. Capital cost – \$300/kW of co-fired capacity

### **Dedicated Biomass Plants**

The dominant technology for producing power from biomass is currently the spreader grate boiler. Spreader grate boilers have long been used in the forest products and pulp & paper industries to generate process steam and to co-generate both electricity and process steam.

Some electric utilities have also constructed biomass spreader grate boilers to generate electricity as their sole product. Large units have been constructed by Washington Water Power at Kettle Falls, Washington; Burlington Electric at the McNeil Generating Station in Burlington, Vermont; Schiller Station in Portsmouth, New Hampshire; and at other locations around the country.

Several options for dedicated biomass power have been evaluated including retrofitting a spreader grate in a retired coal boiler, replacing a retired pulverized coal boiler with a new spreader grate boiler, and constructing a new biomass power plant at an existing site.

Although the technology is still in the R&D stage, an option for a dedicated biomass gasification combined cycle plant has also been studied. However, biomass feeding under pressure (500 psi), gas clean-up, and turbine compatibility with exhaust gases are still subjects of research. Southern Company is investigating biomass gasification through bench- and pilot-scale research at two universities. The technology is not expected to be commercially available until well beyond 2015.

Southern Company recently completed a study of Georgia Power's Plant Mitchell to examine the technical and economic feasibility of generating electricity from 100 percent biomass, in contrast to co-firing. The project, in partnership with the Electric Power Research Institute, defined capital costs, operating and maintenance requirements, and commercially available options for converting the existing pulverized coal unit to 100 percent biomass. Plant Mitchell, in southwest Georgia, is near harvestable forests, making it an especially good site for the project.

The evaluation indicated that the conversion to 100% biomass using a retrofitted spreader grate would be cost effective. The existing pulverized coal unit now rated at 155 megawatts, would produce about 96 megawatts using biomass. If the project goes forward, the converted biomass unit would startup in mid-2012. An artist's rendition of the biomass storage piles at Plant Mitchell is shown below.





Highlights of the Mitchell biomass conversion are listed below.

- Georgia is rich with forestry resources and has a plentiful supply of surplus woody biomass and wood fuel to support Plant Mitchell.
- Within a 100-mile radius of Plant Mitchell, there are 8 million acres of forest and timberlands, and 12 million tons/year of surplus supply wood fuel.
- At 96 megawatts, Plant Mitchell would be one of the largest biomass projects of its kind in the country.
- Most of the wood fuel that would be used in the plant is considered unusable by timber companies and therefore would not compete with their needed wood supply.
- Approximately 1 million tons of the 12 million ton wood fuel supply per year would be needed to operate the plant.
- Woody biomass-fueled electricity results in less sulfur dioxide and nitrogen oxide emissions than coal-fueled electricity.
- Because the converted unit will be considered a “carbon-neutral” source (one that relies on a fuel source that absorbed CO<sub>2</sub> from the atmosphere), the conversion will result in a net reduction in CO<sub>2</sub> emissions.
- Woody biomass is a renewable form of energy.
- The biomass conversion would have lower fuel and operating costs when compared to continued operation using coal, thereby making the plant more cost-effective for ratepayers.
- Adding wood fuel to Georgia Power’s fuel supply mix would improve the company’s fuel diversity and lessen its dependence on fossil fuel sources.
- The project would bring wood fuel suppliers to the local community and create 50 – 75 new jobs in Southwest Georgia.
- Georgia Power plans to seek procurement certification from the Sustainable Forest Initiative (SFI) organization.

As a result of the positive outcome of the Mitchell study, Southern Company is also pursuing feasibility studies at other small coal unit sites to determine the technical and economic viability of converting them to 100% biomass.

Summaries of the dedicated biomass power options are presented below and are ranked in order from highest to lowest priority based on preliminary estimates of the cost of electricity (COE).



Typical utility financial parameters were used in developing the COE numbers. Any applicable tax credits were not considered in the financial analysis. The costs below are useful for scoping and conceptual evaluations, but are not substitutes for detailed bid proposals.

1. Wood Residues on a Retrofitted Spreader Grate at a Retired Pulverized Coal Unit
  - a. Technology status – Available now
  - b. Typical feedstocks – Wood chips
  - c. Estimated capital cost – \$1,000/kW to \$1,300/kW
2. Wood Residues in a New Spreader Grate Boiler or New Fluidized Bed Boiler at a Retired Pulverized Coal Unit
  - a. Technology status – Available now
  - b. Typical feedstocks – Wood chips
  - c. Estimated capital cost – \$1,500/kW to \$2,000/kW
3. Wood Residues in a New Spreader Grate Power Plant or New Fluidized Bed Power Plant at an Existing Site
  - a. Technology status – Available now
  - b. Typical feedstocks – Wood chips
  - c. Estimated capital cost – \$2,600/kW
4. Wood Residues in a New Spreader Grate Power Plant or New Fluidized Bed Power Plant at a Greenfield Site
  - a. Technology status – Available now
  - b. Typical feedstocks – Wood chips
  - c. Estimated capital cost – \$3,000/kW to \$4,000/kW