Systems That Convert Wood into Energy

Phillip Badger, Mohammad Rahmani, Pratap Pullammanuppallil, Alan W. Hodges, & Lauren McDonell

There are a variety of systems that can transform wood into energy for residential, commercial, and industrial uses. These systems can produce from less than 1 megawatt (MW) to more than 100 MW of power, and can use wood exclusively or in combination with other fuels, such as coal or natural gas. This energy can be used to generate electricity, heat buildings with water, steam, or air (space heat), and produce steam for industrial processes (process heat). This fact sheet provides a basic background in these technologies for people who wish to follow the technical conversation of using woody biomass.

Electricity. Typically, when wood is used to produce electricity, it is burned in a boiler, through a process called direct combustion. Alternatively, the wood may be converted into a combustible fuel through gasification or pyrolysis, and the secondary fuel is then burned in a boiler. In all of these processes, only about one-third of the energy in the wood is converted into electricity (this is also true of fossil fuel systems). The other two-thirds become waste heat in the form of hot air, hot water, or steam. When this waste heat source is captured in a combined heat and power system (also called cogeneration) more optimal energy efficiencies are reached. See the "Process Heat and Power" section of this fact sheet and the *Heat and Power Applications* fact sheet for more discussion about this topic. All of our materials can be found at http://www.interfacesouth.org/woodybiomass.

Direct Combustion. In direct combustion, wood can be burned alone or in combination with other fuels, such as coal or solid waste. In most boiler systems, wood chips, ground wood, or wood pellets are carried into the combustion chamber (also known as a firebox) on a traveling metal grate. The heat from the burning wood makes steam, which turns turbines, generating electricity.

A stoker boiler, which is typically used in smaller facilities (10-25 MW), has a traveling grate (a wide metal chain) that moves wood along the bottom of the firebox. The wood is usually carried to the grate by a conveyor system, or, in a spreader stoker system, by a high-speed rotor that throws wood into the furnace over the moving grate. Air is pulled through the fuel particles and traveling grate. The arched ceiling of the firebox directs the boiler's heat onto the fuel on the grate. At the same time that the wood travels through the firebox, the wood gradually burns up and leaves ash. The grate moves the ash to the end of the line where it drops off into a receptacle. From there, the ash can be disposed of as permitted.

Co-firing refers to burning two or more fuels simultaneously in the same boiler. There are two ways this can be accomplished. One method is to mix the wood with coal in the coal-handling equipment, pulverize both fuels together, and blow the mixed wood/coal particles into the boiler. This commingling of fuels is the easiest and least expensive; however, only 4 to 7 percent of the total fuel input can be wood because the coal pulverizing equipment is not designed for grinding or conveying wood fibers. Another method of co-firing is to grind and feed the wood and coal dust separately into the boiler.

Gasification. Wood can also be used to produce electricity through gasification, which exposes the wood to extremely high temperatures, producing a combustible gas (commonly called producer gas), char, water vapor, and ash. Producer gas contains combustible components such as carbon monoxide, methane, and hydrogen. There are several types of gasifier systems that can use wood or charcoal. Normally wood and charcoal are not gasified together as their gasification characteristics are different. Four types of gasifiers are described in Box 1. The quality of gas from commercial biomass gasification systems is as good as that from coal gasification systems. Table 1 compares the gas quality from wood and charcoal gasification systems. Gas produced from a gasification system can be used as a fuel for power generation or combined heat and power generation.

Pyrolysis. Another method for generating electricity from wood is pyrolysis, the process of heating wood (or other organic material) at a high temperature in the absence of oxygen. This distills the wood into three main

Box 1. *Basic Types of Gasifiers*

Updraft (or counter current) – This is the oldest and simplest type of gasifier. Air comes in through the bottom and the producer gas is released from the top.

Downdraft (or co-current) – In this configuration, air comes in through the bottom, and gas is removed from the bottom; it can produce low-tar gas with fewer environmental impacts.

Circulating Fluidized Bed (CFB) – Air is blown through a bed of small, heated, solid particles. Wood (or other fuel) feeds in from the bottom and is mixed with heated particles comprising the bed. Air from the combustor stack is used so that it is very low in oxygen to prevent combustion in the gasifier. The injection of air from the bottom keeps fuels suspended in the bed, allowing the fuel particles ready access to the heat. Ash is typically carried out of the gasifier with the gas and removed from the gas stream. Fluidized beds provide greater temperature control and greater fuel flexibility, but are more expensive to construct and operate.

Integrated Gasification Combined Cycle (IGCC) – This relatively new, highly advanced technology can use wood or coal to produce between 30 and 140 MW of power. IGCC is more efficient and produces lower emissions than conventional technologies. While the technology has been used successfully, it is currently not cost-effective.

Table 1. *Comparison of Composition of Gas from Commercial Wood and Charcoal Gasifiers* FAO 1986

Component	Wood gas (% volume)	Charcoal gas (% volume)
Nitrogen (N_2)	50-54	55-65
Carbon monoxide (CO)	17-22	28-32
Carbon dioxide (CO_2)	9-15	1-3
Hydrogen (H_2)	12-20	4-10
Methane (CH_4)	2-3	0-2
Gas heating value (kJ/m^3)	5000-5900	4500-5600

products: liquid oil, char (which can be converted into activated carbon), and a combustible gas. Slow pyrolysis processes operate at lower temperatures and long process times (hours or days) and are used to produce charcoal. They are not the focus of this discussion. Fast pyrolysis processes operate at higher temperatures, have process times of a few seconds, and are used to produce a light liquid product called BioOil or pyrolysis oil with charcoal as a by-product. Typically fast pyrolysis processes produce BioOil[4] (60-70 percent), charcoal (25-30 percent), and combustible gases.

The term BioOil is used by the fast pyrolysis industry to differentiate the high quality, lightweight liquid product made by fast pyrolysis processes from the thick, viscous liquids produced by slow pyrolysis processes.

BioOil has a much higher amount of energy per cubic foot than wood, making it more cost effective to transport than solid wood. Small satellite pyrolysis plants can be located close to wood sources, with trucks carrying BioOil to be burned at a main utility plant. BioOil can also be used in a process called reburning, where it is injected and burned just above the main burner in the boiler. This process converts harmful nitrogen oxides (NO_x) from the emissions into elemental nitrogen (N_2), which is not harmful and is plentiful in our atmosphere. Both the char and gaseous products can be burned to provide the heat for the pyrolysis process. The type of wood has a slight influence on the composition of resulting products. The product composition is also influenced by the temperature at which pyrolysis is carried out. Higher temperatures favor gaseous products.

Space Heat

In addition to producing electricity, wood can be used to heat homes, institutions such as schools or hospitals, or manufacturing facilities in different ways. Facilities that use wood to produce space heat can range in size from less than 1 MW to around 40 MW. Larger-scale operations often use wood to produce both space heat and process heat (heat from steam used in various industrial processes), as well as electricity. Wood-burning units consist of a boiler or stove and can be located inside or outside the living areas. In all systems that use wood for space heat, the wood is burned to heat air, hot water, or steam that is circulated through the building(s) to increase the temperature. Different systems use different forms of wood including split wood fuel (firewood), whole trees, wood chips, wood pellets, waste wood from forest products production, and briquettes. Some of the wood-burning units can use other types of feedstocks such as oil, electricity, or natural gas in combination with wood.

Wood-fired stoves often heat air that is circulated by fans, while furnaces heat air in a heat exchanger that moves air through a forced air ductwork system. These furnaces usually have a firebox with automatic draft control and optional hot-water coils that are controlled by a thermostat. See the fact sheet, *Small Heating Units*, for more information.

Another type of space heat technology utilizes hot water moving through pipes (hydronic systems). The heated pipes spread warmth through the building. These systems can be used in buildings with existing radiators or similar heating designs. Some systems include an extra heat-storage tank to store excess heat for later use.

Boilers can generate steam or hot water which can then be pumped through insulated pipes into buildings. Radiators, fan-coils, lengths of pipe, or other means are used to transfer the heat into the air at the desired delivery point. In some cases, boiler systems are connected to plumbing to provide domestic hot water. The thermal energy in steam is much higher than in hot water and the heat can be exchanged more efficiently.

Combination systems are perhaps the most versatile of the space heating systems but also the most expensive. They allow for wood to be used in combination with other fuels, such as oil or gas, when burning wood is not possible. However, this flexibility requires two combustion chambers.

Process Heat and Power

Wood is commonly used to produce heat or steam for industrial operations such as sugar mills, cabinet companies, and brick manufacturers. Since one-third of the energy produced by burning or gasifying wood can be converted to electricity and the other two-thirds is heat, industries often generate electricity and recover and use the heat, improving efficiencies by more than 35 percent. Many utilities that use wood to produce electricity also sell the heat or steam to industrial operations for process heat. Wood is an obvious fuel choice for industries that produce wood products. Many forest product industries are able to produce more than half of their own energy using waste wood. Table 2 compares the operational and cost data for a 1 MW combined heat and power generating system (Quaak et al. 1999).

Summary

There are many types of systems that can harness wood's energy for a variety of uses. The choice to use wood for electricity, heat, or power depends on the availability of a sustainable supply of wood, the cost of the wood and alternate fuels, and other variables. With existing technology, wood energy can produce electricity, space heat, or process heat in the South.

For more information about using wood to produce energy, visit http://www.interfacesouth.org/woodybiomass and read other fact sheets, community economic profiles, and case studies from this program, or http://www.forestbioenergy.net/ to access a number of other resources.

References

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Authors

Phillip Badger, Bioenergy Technical Director, Southern States Energy Board, Florence, AL; Mohammad Rahmani, Coordinator of Economic Analysis, Food and Resource Economics Department, University of Florida, Gainesville, FL; Pratap Pullammanuppallil, Assistant Professor, Agricultural and Biological Engineering, University of Florida, Gainesville, FL; Alan W. Hodges, Associate Extension Scientist, Food and Resource Economics Department, University of Florida, Gainesville, FL, and Lauren McDonell, Program Coordinator, School of Forest Resources and Conservation, University of Florida, Gainesville, FL.

Table 2. *Typical Data for 1 MW Electrical Power Generation Systems* FAO 1986

	Units	Steam Cycle System, Electricity Only	Combined Heat and Power, Steam Cycle System
Capacity	MW	1.00	1.00
Efficiency of electricity production	percent	0.14	0.11
Efficiency of biomass fueled heat only boiler	percent	0.90	0.90
Efficiency of heat production	percent	---	0.79
Heat utilization	% heat produced	---	75.00
Electricity production	MWH/year	6000.00	4,643.00
Useful heat production	MWH/year	---	25,789.00
Fuel consumption	Kg/kwh	1.84	2.37
Capital costs	$/kwh	0.08	0.10
Fuel cost	$/kwh	0.07	0.07
Maintenance	% capital cost	5.00	5.00