Chapter 2 What is Biomass?

2.0 Introduction

In exploring the topic of woody biomass production and utilization, you will need to have a fairly thorough understanding of the various types of biomass that can be used for heat, power, electricity, transportation fuels, and other bioproducts. This chapter provides a comprehensive discussion of woody biomass and a basic overview of agricultural biomass.

2.1 Biomass

Biomass is any organic matter that is renewable over time. More simply, biomass is stored energy. During photosynthesis, plants use light from the sun's energy (light energy) to convert carbon dioxide and water into simple sugars and oxygen.

Fossil fuels are hydrocarbon deposits, such as petroleum, coal, or natural gas, derived from organic matter from a previous geologic time. They are essentially fossilized biomass and differ from present-day biomass in that they come from organic matter created millions of years ago, which has been stored below ground. In other words, the key difference between biomass and fossil fuels is age!

Fossil fuels contain carbon that was removed from the atmosphere, under different environmental conditions, millions of years ago. When burned, this carbon is released back into the atmosphere. Since the carbon being released is from ancient deposits, and new fossil fuels take millions of years to form, burning fossil fuels adds more carbon to the atmosphere than is being removed.

Biomass, on the other hand, absorbs atmospheric carbon while it grows and returns it into the atmosphere when it is consumed, all in a relatively short amount of time. Because of this, biomass utilization creates a closed-loop carbon cycle. For example, you can grow a tree over the course of ten or twenty years, cut it down, burn it, release its carbon back into the atmosphere and immediately start growing another tree in its place. With certain fast-growing biomass crops such as switchgrass, this process can occur even faster.

2.2 Woody Biomass

Woody biomass is the accumulated mass, above and below ground, of the roots, wood, bark, and leaves of living and dead woody shrubs and trees. Woody biomass can be used for heat, power, and electricity generation; biofuels production; and biochemicals production (e.g., adhesives, solvents, plastics, inks, and lubricants). Wood; wood residue and byproducts; and bushes, shrubs, and fast-growing trees, grown specifically for energy, are all considered woody biomass. The principle sources for woody biomass in the United States are harvest residues; mill residues; small diameter trees; cull trees; trees damaged by or at risk of wildfire, insects, and disease; urban wood waste, short rotation woody crops, and fuelwood, *Handout 2: Woody Biomass Basics*, found in the back of this chapter, provides a condensed overview of woody biomass and may be a useful handout for your audience or clientele.

Harvesting and Other Residues

Residues from forest harvesting operations include logging residues (i.e. branches, tops, and stumps) left on-site, low-quality commercially grown trees, dead wood, and other noncommercial tree species. Other residues include wood that has been cut and burned during land conversion, precommerical thinnings, and other management techniques such as a crop tree release and timber stand improvement (TSI). Harvesting residues and other removals are routinely left behind at the harvest site because they are expensive to transport and there are few markets for the material. However, harvesting residues and other removals amount to approximately 67 million dry tons annually, and of this, approximately 41 million dry tons are economically and physically available for recovery and use, according to the United States Department of Agriculture Forest Inventory and Analysis (FIA) programs' Timber Product Output (TPO) Database Retrieval System, (U.S.DOE and USDA, 2005).

The possibility of using woody biomass for energy production and other products has the potential to create markets for these harvesting residues. As a feedstock source, harvesting residues are generally delivered in one of the following three forms: unconsolidated material, comminuted material, and bundled material. It can also be converted, in-woods, to a higher value product.

Unconsolidated

Figure 1: *Volume differences of the same weight material by different product types.* Photo courtesy of USDA Forest Service, Forest Products Laboratory.

Unconsolidated material, or woody biomass in its raw form, is what remains after the trunk of the tree has been harvested. This may include stumps, bark, leaves, needles, branches, and even the trunk itself. Historically, this material was considered unmerchantable (unsellable) and in most harvest operations was left in place on the logging site or piled up at the landing—the place where wood is delimbed, sorted, and loaded onto trucks for transport. However, advances in biomass utilization promise new opportunities for the utilization of unconsolidated woody biomass feedstock. In many cases, unconsolidated harvesting residue is used as hog fuel at wood manufacturing facilities. (Hog fuel is a combination of ground wood and wood waste used to generate power or produce on-site heat and power.) For more information on conversion to heat and power, please see chapter 3, "Products and Possibilities."

One obstacle that remains in the broader use of unconsolidated material is the cost of transportation. Bulky by nature, this material has a low bulk density, in other words, a high volume-to-mass ratio (Figure 1). Compressing the material, although not widely performed, helps increase bulk density. A more conventional method of increasing the bulk density of woody biomass is to reduce its size significantly, either by chipping, grinding, or shredding.

Comminuted

Comminution is the process of making woody material smaller. Reducing the size of logging residue usually occurs in the woods or at the landing but is sometimes delayed until the feedstock reaches the processing facility. Of the three types of reduction (chipping, grinding, and shredding) chipping is the most common (Figure 2). This is because chippers are well integrated into conventional harvesting systems. Chippers have high output, high-speed cutting knives, and in most cases the ability to throw chipped material into truck vans for hauling.

Figure 2: *Comminuted material.* Photo by Sarah Ashton, Southern Regional Extension Forestry.

Bundled

One recent innovation involves the compaction of logging residues into cylindrical bales called composite residue logs (CRL) or biomass bundles (Figure 3). Typically, these bundles have a diameter of about 2.0 to 2.5 feet and are about 10 feet long. One of the most appealing aspects is that they can be handled similarly to round logs; however, production of the logs requires specialized machinery. Unlike comminuted material, these bundles can be stored for longer periods of time without decomposing.

Although technically feasible, the current market price for wood-based fuel in the U.S. does not support the cost of bundling. And at the other end, the current price of wood-based fuel does not support the transport of unconsolidated material, especially with the fluctuation of prices for petroleum-based fuels. At this time, comminuted biomass is the most economically feasible form.

Figure 3: *Composite residue logs.* Photo courtesy of Sylvain Martin, Latin Europe at John Deere Forestry.

In-woods Conversion

In areas where the cost of transporting wood remains a challenge, portable wood-to-energy conversion units may be an option. Small-scale, portable pyrolysis (a system that turns wood directly into an oil and char) and gasification (a system that turns wood directly into a gas) units can be towed to a harvesting site and utilized to produce fuel on-site. It is important to note, however, this technology is still largely in its experimental stages. See chapter 3, "Products and Possibilities" for more details on biomass conversion processes.

Forest Health Improvement

A number of management activities aimed toward increasing the health of forests can require removal of woody biomass. Fuel load reduction, removal of dead or dying wood due to insect or disease, and ecological restoration are three management activities that can result in substantial amounts of woody biomass.

Fire

Fire, often a result of lightning strikes, is a naturally occurring, necessary agent of change in wildland ecosystems. Fire performs a "cleaning" task, keeping fuels loads down and as a catalyst, driving vital ecological processes such as the regeneration of certain tree species. However, communities during the last century have feared fire and have not understood this natural process. Because of these fears, communities have made ongoing efforts to suppress fires in natural areas.

If not properly managed or exposed to natural disturbances such as fire, forests can accumulate excessive amounts of small diameter woody biomass and other vegetation

Figure 4: *Millions of dollars are spent fighting wildfires each year; harvesting biomass can reduce the intensity and frequency of these catastrophic fires.* Photo courtesy of U.S. Forest Service, National Renewable Energy Laboratory.

that can act as fuel. Fire suppression over the past century, combined with intensive forest management and a generally warmer and wetter climate, has led to increasingly dense vegetation. When wildfires occur, this heavy accumulation of biomass often leads to larger and more severe fires. Such fires threaten public health and safety, homes, businesses, timber resources, watersheds, and wildlife habitat.

Public agencies and some private forest landowners are focusing efforts on thinning forests to reduce wildfire risks and to make forest stands more resilient to insects and disease. Fuel treatment thinnings, in addition to reducing fuel loads in overstocked forest stands, can provide large volumes of woody biomass. According to a recent study, about 8.4 billion dry tons of biomass have been identified nationally for potential treatment, yet due to inaccessibility, recovery limits, and the merchandizing of some timber for higher value, more traditional forest products, only 60 million dry tons of fuel treatment thinnings can be removed annually (U.S. DOE and USDA, 2005).

Insects

Insects are another naturally occurring agent of change. However, a series of mild winters and drought-like summers in recent years has led to North America's largest ever-recorded epidemic outbreak of mountain pine beetle. Millions of acres of trees have been killed, particularly in Colorado, Alaska, and parts of Canada. If harvested immediately, a practice commonly referred to as sanitation, the majority of wood can be used in conventional forest product markets. However, if wood is badly damaged or left to sit too long after beetle kill occurs, then traditional forest product markets may not be an option. A promising alternative market for this lower quality wood is bioenergy.

Ecological Restoration

There are a number of ecological restoration efforts occurring in the U.S. that require or will require the removal of large amounts of standing biomass. Examples of these efforts include eradication of invasive species such as melaleuca trees; reestablishment of native species such as longleaf and shortleaf pine; and reversing the effects of harmful practices such as high-grading, a practice that reduces the quality of a forest stand's genetic stock. As markets for bioenergy develop, removal of standing biomass for such projects could become more affordable.

Municipal and Construction Wastes

The two major sources of urban wood residues are the woody portion of municipal solid waste (MSW) and construction and demolition debris. Of the 62.1 million dry tons of urban wood residues generated annually, about 28.3 million dry tons are economically and physically recoverable (McKeever, 2004).

Municipal Solid Waste

Figure 5: Waste *wood can be utilized for energy instead of sent to landfills.* Photo courtesy of David Parsons, National Renewable Energy Laboratory.

The portion of MSW that is wood includes items such as discarded furniture, pallets, packaging materials, processed lumber, and yard and tree trimmings. Of the 13 million dry tons of woody MSW generated annually, approximately 8 million dry tons are available for recovery (McKeever, 2004). This material is generally recycled as mulch or compost; sent to a landfill; or burned for heat, power, and electricity.

In recent years, small, portable wood chippers and bailing units that press yard debris into "logs" similar in appearance to that of traditional firewood have emerged. Some municipalities provide large yard debris carts, which are collected weekly. Other areas work with local businesses to ensure collection options such as drop-off bins and designated collection facilities.

Landfill Gas

Landfill gas (LFG) is a natural byproduct of decomposing organic matter. It is approximately 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2). Landfills can be significant sources of greenhouse gas emissions because they contain a significant amount of organic matter, and over time the organic matter breaks down and releases its gases into the atmosphere. These emissions can be captured and used to produce heat, power, electricity, and biofuels. Approximately 400 landfill gas-to-energy projects exist in the U.S. today (Riat, et al. 2006). Fairfax County, Virginia, has been using LFG since 1989 to power three electricity generating facilities, one pollution control plant, and the on-site landfill maintenance buildings.

Construction and Demolition

Figure 6: *Unused wood from the construction of townhouses.* Photo courtesy of Kiley Barnes, Southern Regional Extension Forestry.

Residential and commercial wood frame construction and demolition generates cut-offs, scraps, and waste that constitute a relatively clean and homogeneous waste stream that can make an excellent feedstock for biomass fuel and energy production. Moreover, this particular waste is relatively easy to access. Wood waste processors can coordinate with construction contractors to designate an area for discarded wood waste or set up drop boxes on site for scraps. Of the 39.3 million dry tons of construction and demolition debris generated annually, approximately 20.3 million dry tons are available for recovery (McKeever, 2004).

It is important to note that the end-use of the feedstock determines how clean and consistent it is. Sometimes, urban and construction wood waste can contain too many contaminants to be used for certain applications. For example, air quality regulations may prevent creosote-treated telephone poles from being burned for heat and power. Another example is wood waste from demolition activities. This material can contain contaminants such as paints, plastics, and known carcinogens and may not be suitable for some applications. In other cases, the wood material may be in such poor condition that the cost of cleaning limits the economic viability of processing and reusing the material.

Figure 7: *Storm damaged trees in populated areas make waste that is traditionally hauled to a landfill and/or burned in the open.* Photo courtesy of Randy Cyr, Greentree Technologies.

Figure 8: *Hurricane damaged trees.* Photo courtesy of Peter L. Lorio, Jr., U.S. Forest Service.

Natural Disasters

Clean up operations after natural disasters, such as hurricanes and ice storms, produce large amounts of debris that have traditionally been piled up to burn or rot (Figures 7 and 8). Debris from these disasters is largely underutilized, but changes have occurred in recent years. After Hurricane Ivan blew through the Florida panhandle in 2004, Escambia County managed 6.5 million cubic yards of woody debris, 60 percent of which it exported to Italy for energy generation. A company called American Biorefining shredded millions of tons of tree debris the following year after Hurricane Rita affected thousands of acres of eastern Texas forests and destroyed a number of roofs and homes. The material was then shipped to European countries for biomass fuel (Yepsen, 2008).

Processing Residues

Residues from forest products manufacturing such as sawdust, black liquor, and bark, are commonly used to create on-site energy in the form of heat and power. Char, pellets, particleboard, nonstructural panels, and animal bedding are also derived from wood processing residues. These residues come from primary and secondary wood processing mills and pulp and paper mills. This type of biomass feedstock is highly desirable because it tends to be clean, concentrated, uniform, and low in moisture, and requires little or no transportation. Currently, about 97 percent of this resource is utilized (U.S. DOE and USDA 2005).

Sawdust

Sawdust is the wood residue created when a log is cut to make lumber. It is fairly uniform in size and shape and is commonly referred to as wood flour, which indicates the particles can pass through a 20-gauge mesh screen. Sawdust with high moisture content has relatively limited uses. It can be used for residential heating in special sawdust furnaces as well as for smoking meats. When dried, sawdust is typically either densified into pellets or directly gasified, combusted, or pyrolized (made into an oil) to generate electricity, heat, and oil.

Bark

Bark is the outermost part of woody stems and branches and makes up about 9 to 15 percent of a log's volume. Bark is used to produce tannins, dyes, resins, flavorings, and medicinal products, and other chemical extracts. Bark is also used as mulch, soil amendment, a fuel source. Approximately 10 tons of bone-dry bark is the equivalent of 7 tons of coal when used for energy. In addition, bark is used in building materials such as fiber and particleboard as well as insulation board because it conducts heat less readily than wood.

Black Liquor

Black liquor is a recycled byproduct formed during the pulping of wood in the papermaking process (Figure 9). More specifically, it is the substance that remains after cellulose fibers have been broken down and removed from the original chemical slurry (a thick mixture of solids and liquid) to form paper. It consists of lignin, water, and other chemicals used in the extraction process. It is an important liquid fuel in the pulp and paper industry, typically recovered and recycled either through combustion or gasification in on-site boilers or gasifiers. The results of these processes are heat energy, carbon dioxide, and recoverable chemicals. The steam that is generated during the black liquor recovery process contributes significantly to the energy needs of pulp and paper mills. Recovered chemicals can be recycled into white liquor, which is the original slurry of chemicals used in the pulping process, reducing the pulping process's chemical needs by almost 90 percent.

Figure 9: *Black liquor.* Photo courtesy of Keith Weller, Agricultural Research Service.

Short Rotation Woody Crops

Fast growing short rotation woody crops (SRWC), such as hybrid poplars, willows, and other species, are specifically grown to be an energy feedstock (Figure 10). The species of trees are often chosen because they sprout from a cut stump. Properly managed, SRWCs can grow rapidly and be ready for harvest in four to eight years. After harvest, the site can be replanted, or the stumps can be left to regrow. Ideally, the sprouts soon form a few dominant stems, which are then ready for harvesting again within another four to eight years. For some species, this can be repeated several times before replanting becomes necessary. Growing short-rotation energy forests can also be combined with wastewater disposal, as sewage and wastewater from food processing factories and farms can contain nutrients that can accelerate tree growth. Using wastewater to irrigate a SRWC plantation offers an opportunity to mitigate point-source pollution, which is water pollution that comes from a single source such as a pipe or culvert.

Figure 10: *A stand of hybrid poplar trees in Oregon.* Photo courtesy of Warren Gretz, National Renewable Energy Laboratory.

Short rotation woody crops have shown promise as an economically viable strategy for producing a sustainable supply of wood biomass. Fast growing species can be planted at relatively low costs and harvested in less time than traditional species. Biotechnology is expected to substantially increase energy crop yields in the future.

Fuelwood

In addition to residues, waste, and dedicated energy crops, pulp wood and commercial-grade timber can be used as an energy or bioproducts feedstock. When used this way, the fiber is called fuelwood. In 2005, approximately 35 million dry tons of fuelwood was used in the residential and commercial sectors where it was harvested and burned for space- and process-heat (U.S.DOE and USDA 2005). This may become more feasible in areas where the forest products industry is not buying or paying competitive market prices for pulp and commercial grade wood due to mill closures, market shifts, or other reasons.

2.3 Agricultural Biomass

Agricultural biomass is a relatively broad category of biomass that includes: the food-based portion of crops (corn, sugarcane, soybeans, beets, etc.), the nonfood-based portion of crops (e.g., corn stover [leaves, stalks, and cobs], orchard trimmings, rice husks, perennial grasses, animal waste, and landfill gases. Traditionally, costs for recovering most agricultural residues are high, and therefore, they have not yet been widely used as an energy source; however, they can offer a sizeable biomass resource if technology and infrastructure are developed to economically recover and deliver this type of biomass to energy facilities. It is important to note that not all agricultural biomass residuals following harvest can be utilized for energy. Some portion (often as much as 50 percent) must be left on the ground to replace soil nutrients and to protect from soil erosion. *Handout 3: Agricultural Biomass* provides an overview of agricultural biomass you may find useful as a handout when presenting this topic to an audience.

Figure 12: *Current U.S. biodiesel production is primarily from oil from soybeans such as these or from recycled restaurant cooking oil.* Photo courtesy of Warren Gretz, National Renewable Energy Laboratory.

Food-based Portion of Crops

The food-based portion of crops is the part of the plant that is either oil or simple sugars. Rapeseed (used for canola oil), sunflower, soybeans, corn, sugarcane, and sugar beets are all examples of this type of agricultural biomass (Figure 12). Corn, sugar beets, and sugarcane are commonly fermented to produce ethanol. Oilseed crops can be refined into biodiesel.

Nonfood-based Portion of Crops

The nonfood-based portion of crops is the portion of the plant that is commonly discarded during processing and consists of complex carbohydrates. This category includes materials such as corn stover, wheat, barley, and oat straw, and nutshells. Stover and straw are fermented into ethanol. Nutshells are typically refined into biodiesel or combusted for heat. Due to the important function of crop residues in erosion protection and overall soil quality, their sustainable use is accomplished through the planning and monitoring of harvest rates specific to a given site.

Figure 13: *Switchgrass in the field.* Photo courtesy of Art Wiselogel, National Renewable Energy Laboratory.

Perennial Grasses

Perennial grasses have a lifecycle of several years. Some examples include big bluestem, sweet sorghum, Miscanthus, and switchgrass (Figure 13). The advantages of perennial grasses are that they have a low-nutrient demand, a large geographical growing range, and high net energy yields (Downing et al., 1995). Perennial grasses are typically fermented into biofuels such as cellulosic ethanol, or they are densified into pellets and burned directly for heat and power. Major challenges remain in reducing the alkali, chlorine, silica, and moisture content of perennial grasses. Chlorine can cause fouling (the accumulation of unwanted material on surfaces) and corrosion in boilers. Silica affects ash formation, and moisture content, if not reduced, can affect energy value.

Animal Waste

Beef cattle, dairy cattle, hogs, and poultry all produce manure, which can be used to produce energy. Manure is typically categorized as liquid, slurry, or solid. In its solid state, manure can be burned for heating and cooking or to produce a gas for energy production. As a slurry, manure releases methane (CH_4), which can be captured to produce heat, power, electricity, and biofuels.

Figure 14: *Feedlot operations result in massive accumulations of manure which can be used to produce energy.* Photo courtesy of Brian Prechtel, Agricultural Research Service.

2.5 Summary and Conclusion

There are many different types of woody biomass and agricultural biomass available for utilization for heat, power, electricity, fuel, and other bioproducts. Availability, cost, distance to the processing facility, end-product, and other factors will determine the feasibility of using any particular type of biomass for energy or other bioproducts production.

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