



United States  
Department of  
Agriculture

Forest Service

**Southern Forest  
Experiment Station**

New Orleans,  
Louisiana

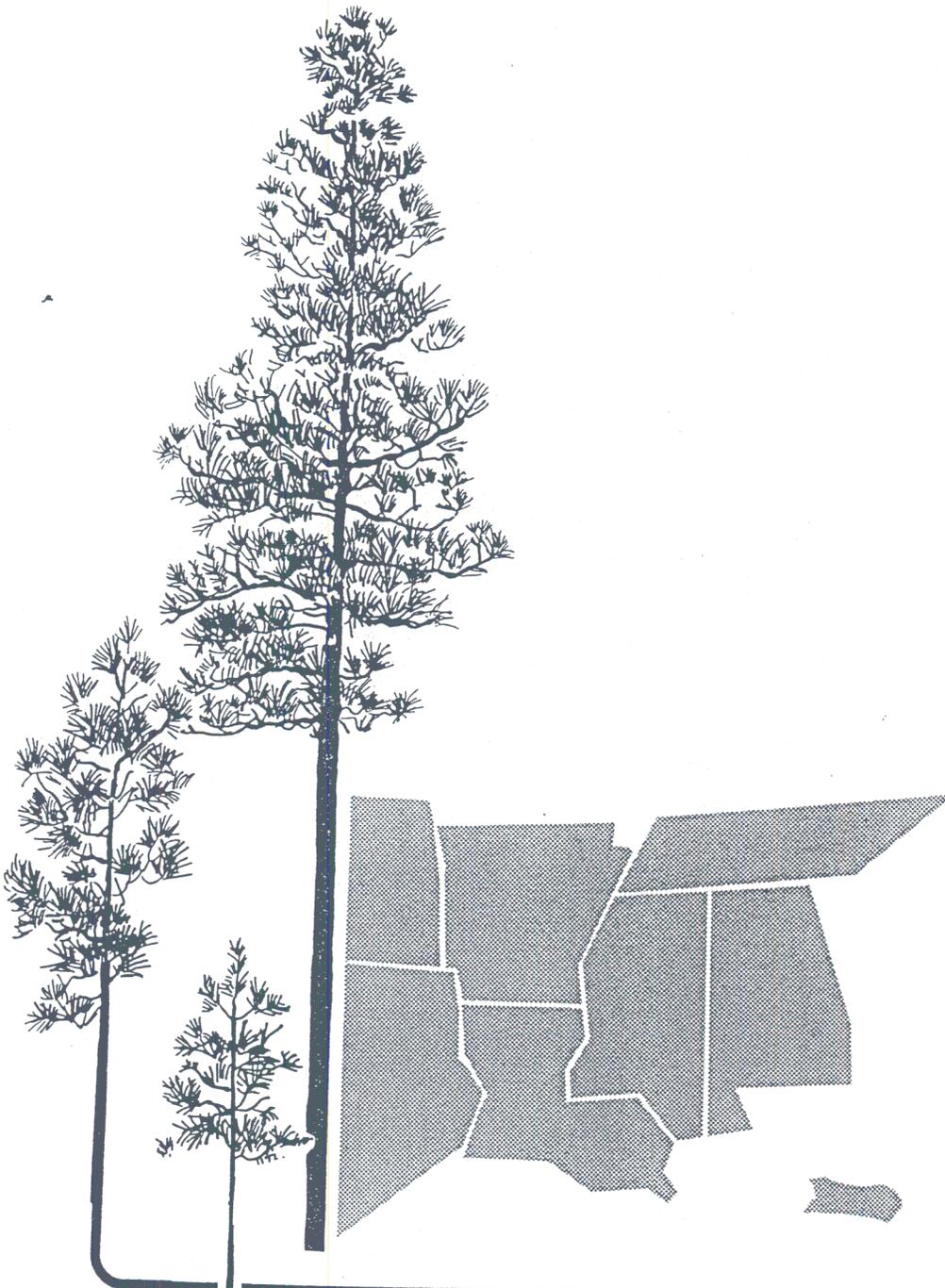
Proceedings Reprint



## HARVESTING AND HANDLING FUELWOOD

Christopherson, Nels; Stokes, Bryce;  
Wiselogel, Art; Woodfin, Sammy; Zerbe,  
John

In: Fazio, James R., comp., ed. Trees  
for fuelwood: a step toward energy  
diversity. Nebraska City, NE: The Arbor  
Day Institute: 34-44. Chapter 3.



Southern  
Forest  
Experiment  
Station

## Chapter Three

---

# Harvesting and Handling Fuelwood

### Conference Contributors to Chapter Three

- **Nels Christopherson**,  
Research Marketing Engineer  
Forestry Sciences Laboratory  
USDA Forest Service  
Houghton, Michigan
- **Art Wiselogel**,  
Senior Scientist  
National Renewable Energy Laboratory  
Golden, Colorado
- **Bryce Stokes**,  
Project Leader  
Forestry Sciences Laboratory  
USDA Forest Service  
Auburn, Alabama
- **Sammy Woodfin**,  
Forest Engineer  
Tennessee Valley Authority  
Norris, Tennessee
- **John Zerbe**,  
Program Manager  
Energy and Global Change  
USDA Forest Service  
Madison, Wisconsin

Cutting, transporting, and storing wood makes up a key link in the chain of events necessary to put trees to use for energy. It is also the weak link in the chain.

Considerable knowledge has been accumulated to help with selecting the right trees and successfully growing an energy plantation. If the land is available and the desire is there to grow fuelwood, then the planting stock and methods to do the job are there to help, too. Similarly, anyone desiring to burn wood for energy will find an array of equipment available to make it possible. But in the essential step of getting

wood "off the stump" and to the furnace, the user faces the challenge of either huge costs or Rube Goldberg inventiveness.

In this chapter are some guidelines that may be helpful in sorting out the options.

### Rotation Length

The period of time between planting and the first harvest in a fuelwood plantation, and the time between subsequent coppice cuttings of the stump sprouts, are called the rotation lengths or periods. The ideal

---

rotation length is when the trees reach their point of diminishing returns. That is, when the mean annual diameter growth begins to decrease, it is time to harvest. The closer the trees are planted, the sooner this occurs, but it will vary by site, species, and even the particular clone that was planted. In average soils with no fertilization, hybrid poplars planted on a 4' x 4' spacing may be expected to reach this point of financial maturity in 6 to 8 years. The same trees on an 8' x 8' spacing may continue increasing their annual increments to 12 years or longer. Much faster growth can be found, however. For example, selected hybrid poplars planted on good soils in the Pacific Northwest are ready to harvest in six years when planted at 8' x 8' spacing.

As will be seen in the discussion of harvesting equipment, there are tradeoffs between cutting larger quantities of small diameter trees instead of fewer but larger stems. Most people prefer to realize a return on their investment as soon as possible and to let the roots and stumps begin producing the next crop more quickly. Therefore, a look at a sampling of tree rings is a sensible guide providing an indication of when annual growth begins to decrease. Probably just as often, the need for cash or a pre-determined diameter size will be used to guide the decision.

### **Harvest Season**

In large biomass operations, harvesting may be necessary throughout the year. Under most circumstances, however, har-

vesting is a wintertime activity. There are several reasons for winter harvesting, especially in northern climes:

- Lower moisture content in wood (less weight and less subsequent drying necessary).
- More successful coppice regrowth, i.e. sprouting is more robust and food stores in the roots are available for rapid growth.
- Less chance of frost damage to new shoots.
- Leaves remain in the field for recycling nutrients and reducing possible noxious emission into the air during combustion.
- Fewer insect/disease problems and less tree mortality.
- Frozen ground protects against compaction and root damage by harvesting equipment and reduces erosion.
- Farmers have more time and laborers are more available for plantation work.

### **Selecting Harvesting Equipment**

Under ideal circumstances, someone planting an energy forest will know before planting what kind of harvesting equipment will eventually be used. Obviously, this will help determine spacing so the equipment can be accommodated. It will also help in planning service roads, loading areas and storage needs if the wood will be burned by the grower.

Sammy Woodfin, an experienced forest engineer, offers a series of questions that

can provide insights on what equipment is appropriate to different situations:

**1. Where will the plantation be located?**

Slope has an important effect on production costs. Even with hand labor, the cost of producing a cord of wood increases as slope increases.

The time required for manually felling and bucking trees goes up as slope increases.



Slope also influences the kind of machinery that can be used:

Maximum Slope	Suitable Equipment
15%	Farm Tractors
40%	Rubber-tire Skidders
60%	Crawler Tractors
60%+	Cable Systems

**2. What will be grown?**

Tree size at harvest time is another important factor in limiting the kind of equipment that can be used. In fact, this is the factor that creates the greatest dilemma for fuelwood growers. In most cases, plantation-grown fuelwood is too large for conventional agricultural equipment and too small for cost-effective use of mechanized pulpwood harvesters.

If large diameter trees (e.g. 4 inches or more diameter breast high) are grown, feller-bunchers are available for large-scale harvesting, or traditional felling and skidding can be used. Cost of this equipment varies with the size of trees it can handle, so fuelwood producers would probably be looking at the lower end of the size scale. Still, such a feller-buncher costs approximately \$70,000 - \$100,000. As Nels Christopherson has pointed out, another disadvantage of conventional forestry equipment is that in most cases it is of the "stop and go" variety, i.e. it stops, works on a single tree, then proceeds to the next.

Engineers realize that this kind of movement adds considerably to operating costs.

Equipment designed for small diameter trees has been developed by numerous individuals and organizations in the United States and Canada. Unfortunately, none of the machines have been developed beyond the prototype stage. For commercially available fuelwood harvesters, it is currently necessary to consider equipment marketed in Finland and Sweden. Models that harvest small-diameter trees have successfully gone beyond the stop and go method to a slow but continuous harvesting operation.

The multiple stems resulting from coppice growth present other harvesting challenges, particularly since the stems often vary in size. In this case, cutting and bundling for transportation loses some of its advantages to processes that convert the trees to chips, shreds, or even chunkwood right in the field. Again, chipping equipment, especially, is common in operations ranging from urban forestry waste handling to whole-tree logging operations in the pulpwood industry, but none is designed specifically for use in fuelwood plantations.

**3. What is the size of your operation?**

Basically, this question asks, "How much are you willing to invest in harvesting equipment?" This, in turn, depends largely on the volume of wood to be processed.

If you are planning a large-scale fuelwood operation or are interested in providing the harvesting function for a number of growers on a full-time basis, then it makes good sense to consider specialized harvesting equipment. Whether this means buying existing forestry equipment or foreign models of SRWC harvesters, or developing your own operational machine from a prototype, you will want an efficient machine and it can be dedicated wholly to fuelwood harvesting or harvesting and processing.

If your plans are to harvest fuelwood as a means to supplement your income, it may be wiser to consider developing equipment that attaches to a farm tractor, with the tractor remaining available for other uses.

In small plantations such as portions of a farm or even at The National Arbor Day Foundation's Lied Conference Center, the most economical harvesting method may be one that is primarily good old-fashioned manual labor! This is particularly true when high levels of production are not the

# Equipment Available for Harvesting Fuelwood

*Photos courtesy of  
USDA Forest Service,  
North Central Forest  
Experiment Station.*



1. Traditional forestry equipment—feller-buncher



2. Traditional forestry equipment—whole-tree chipper



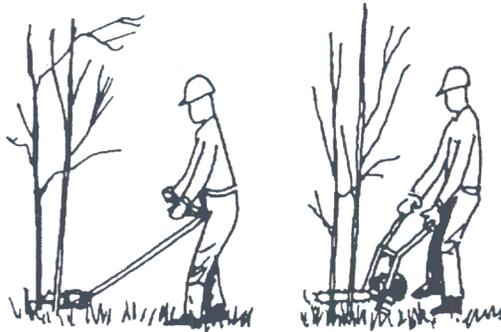
3. Canadian SRWC harvester prototype mounted on a farm tractor.



4. Commercially - available Swedish SRWC harvester for small diameter trees.

important consideration. In a study by Bryce Stokes and Bruce Hartsough, it was found that the cost of felling a ton of fuelwood from 3-inch DBH trees with a chainsaw was half as much as doing the same work with a 67 hp, 3-wheel feller-buncher or a 60 hp prototype, continuous-travel SRWC feller-buncher with saw. When combined into a complete system of felling and removing wood to roadside, the chainsaw, a small skidder (75 hp), and medium chipper (400 hp) became the most economical way to harvest 3-inch DBH trees. In plantations with 6-inch DBH trees, the chainsaw system fell behind the 3-wheel feller-buncher (combined with the same skidder and chipper). The SRWC feller-buncher, combined with the skidder and chipper, came out best at half the per ton cost as the chainsaw group.

Harvesting small diameter fuelwood may be done with a brush saw, chainsaw, or a chainsaw mounted on a felling frame. Tractor-mounted winches, skidding devices or front end loaders can forward the fuelwood to roadside for chipping or hauling.



Details of the above study are available from Stokes, but the point it best illustrates is that growing a fuelwood plantation does not need to wait for new harvesting technology to be in place. The best approach initially, at least, may be to use relatively low cost equipment that is readily available.

## Chippers

The use of wood through direct combustion is usually in the form of chips. Fortu-

nately, there is a wide variety of chipping equipment to handle this part of a fuelwood system. Which chipper is selected depends on such variables as:

- Size of trees to be processed
- Amount of wood chips required
- Rate of chip production needed
- Importance of consistent chip size



*A small, industrial-size chipper can be used in the plantation or at roadside parking areas.*

USDA Forest Service

Art Wiselogle, senior scientist with the National Renewable Energy Laboratory, provides this helpful summary of information about chippers and managing chip supplies.

The selection of chipping equipment ranges from small brush-chipping units available from local rental stores to large, stationary machines that devour large trees brought whole to a wood yard. Of more interest to most fuelwood growers are small to medium size portable chippers that operate either on their own power or from a farm tractor. These units can handle trees up to 8 inches in diameter and are fed manually.

Of the three basic chipper designs (disc, drum and vee-drum), the disc chipper is the most common. It consists of a series of radially mounted knives on a circular disc. The disc chipper is easy to maintain and produces a high percentage of quality chips. Factors influencing a chipper's performance are knife angle, knife sharpness, disc rpm, and feed rate. Other factors affecting chips are tree diameter, percent moisture, and whether the material is frozen.

## Flying Fuelwood

*Helicopters retrieve logging slash from an assembly area, transport it to a chipper at roadside, make a round trip to a second area, then back to the first — all with almost no lost motion.*

— John Zerbe USDA  
Forest Service

If a chainsaw and strong back represent one end of the harvesting spectrum, hauling by helicopter is at the other end.

Helicopters have been used successfully in California as a way to economically remove logging slash (branches and other tree parts left after a logging operation). The result is the availability of fuelwood while at the same time cost-effectively reducing a forest fire hazard, preparing the site for the next forest generation, and doing it with minimum impact on the environment.

Helicopter yarding was introduced in the Stanislaus National Forest in California after forest fires in 1987, so debris harvesting by helicopter has become an alternative to broadcast burning there. The amount of forest debris converted to fuel is typically 25 dry tons per acre. This still allows for 50 percent ground cover retention to maintain soil productivity. The availability of this alternative is especially important on the west coast where traditional slash burning is rapidly being phased out due to air quality controls.



Helicopter fuel reduction (removal) is much more economical than using a cable system. Other ground-based systems are more economical but cause greater damage to the land. The average cost for helicopter logging with the purchaser having rights to products is \$200 to \$350 per acre.

These costs are competitive with conventional broadcast burning, yet provide the least ground disturbance of all biomass or conventional slash removal methods. Contracts with no outlet for products would cost \$700 per acre, illustrating one more benefit of using trees for energy.

For the wood energy industry, chip size can affect quality through its influence on the chip pile environment. Low rpm, slow feed rate, dull knives, wide knife angle, and green wood promote the production of large chips. The opposite conditions produce small chips, pins, and fines. Both the large and small chips can cause modifications in the chip pile environment that will affect chip quality and create handling problems. Therefore, it is important to manipulate the chipper variables to compensate for the material being chipped. The quality and consistency of the chips produced by a chipper will directly affect the quality of the chips in storage and during combustion.

### Managing The Chip Pile

There is no better way to retain the quality, or fuel value, of trees than to handle and store the wood as logs. One such system used for generating electricity is discussed in Chapter 4. At the present, however, available handling and transportation systems give chipped wood a greater advantage. Somewhere in between are wood chunks, which many fuelwood plants are using as a reasonable compromise. But chips still predominate as the most common form of fuelwood for combustion, and their greatest disadvantage is that they deteriorate and lose quality fairly rapidly if not managed carefully. The following information is intended to help you understand how chips can be handled to maintain their highest possible value as fuel.

### Chip Pile Dynamics

Most wood energy facilities maintain on site a 30 to 45 working-day supply of feedstock in outside storage. This amount of

feedstock ensures the availability of wood chips when chipping equipment is broken, trees are not available, or a surge of material is required. Usually, the area required to store the desired amount of wood chips is too large to justify covered storage.

Wood chip piles are constructed using two methods: a labor-intensive method with bulldozers, and a more automated system involving gravity feed. Wood chips in piles constructed by bulldozers suffer from reduced quality caused by a pile design that is necessitated by this equipment. Wood chip piles built using gravity feed systems, such as conveyor belts and pneumatic blowers, produce conical piles. A derivation of the conical pile is the wind row pile, which is nothing more than an array of closely spaced conical piles. The conical shaped pile has been shown to maintain better wood chip quality and be more economical.

Conical piles have standard, 45 degree slopes. When piled from 10-40 feet in height, the piles have been found to have predictable patterns of behavior that facilitate storage management. The two major factors involved are temperature and moisture. These create a pile environment that, along with the ambient environment, either encourages or discourages the growth of fungi and bacteria. This, in turn, controls the deterioration of fuelwood quality.

Here are some important insights on the factors that affect chip pile quality

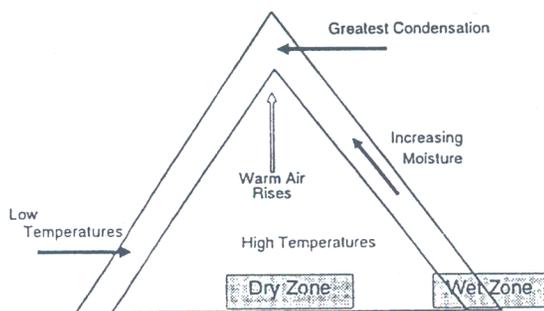
#### 1. Moisture

Soon after a wood chip pile is constructed, two distinct moisture regions develop. The exterior region of the pile is moist; the interior region of the pile is dry. The exterior region moisture comes from two

Fuelwood stored in wind row chip piles at Northwest Missouri State University



sources. One is from water in the warm air rising from the interior of the pile and condensing in the cooler exterior region of the pile; the other is from rain or snow. The interior of the pile will lose 20-25 percent of its original moisture during the first 60 days after pile construction. The moisture in the exterior of the pile will increase 50 percent or more during the same period. The exterior of the pile actually protects the interior from increasing moisture during precipitation. When the exterior layer becomes saturated, water will run off the pile. Over time, moisture will eventually percolate into the pile as the pile interior cools.



### Chip pile moisture and temperature dynamics.

Source: The Effects of Outside Storage on the Fuel Potential of Green Hardwood Residues by M. L. Curtis, M.S. Thesis, Virginia Polytechnic Institute, 1980.

## 2. Pile Temperature

The temperature in a chip pile follows in a predictable pattern under normal circumstances. The exterior, moist-layer temperature lags behind the ambient air temperature by 8 to 24 hours. The interior of the pile has high temperatures. There is a rapid increase in interior pile temperature because of the respiration of living cells in the wood chips. These initial temperatures range from 40-60 degrees C. Piles built with clean chips are cooler than whole tree chip piles because the living cells in the cambium have been removed. Interior pile temperatures are maintained by the respiration of bacteria and fungi living off the free sugars and cellulose in the wood chips. If the interior temperature of the pile reaches approximately 65 degrees C, the fungi will cease to function. After the fungi and bacteria are killed by temperature or starvation, the interior wood chip pile temperature will gradually decrease. As the interior tempera-

## Spontaneous Combustion

Under some circumstances the temperature in a chip pile will increase to a level where spontaneous combustion can occur. When air does not circulate freely through the pile because of chip compaction during construction, or a layer of some kind (such as fines or ice), heat pockets will develop. In these heat pockets, acetic acid produced by the fungi and bacteria can build up. At sufficient concentrations the acetic acid will oxidize wood. Chemical oxidation will create temperatures of 80-100°C. If the wood chips are exposed to these temperatures for 60-90 days, then exposed to the oxygen in air, spontaneous combustion is likely to occur.

ture decreases additional moisture will move into the pile.

## 3. Bacteria and Fungi

Bacteria and fungi can cause loss in wood biomass and a reduction in feedstock quality. Most of the various microorganisms found in wood chip piles use free sugars and do not decay wood. Some organisms produce by-products that stain the wood and compromise quality for use in bleached pulps. Other fungi and bacteria break down the cellulose, hemicellulose, and lignin into food and nutrients to support growth. Cellulose, hemicellulose, and lignin are the macromolecules that comprise the structure of wood. These organisms cause wood decay.

There are two major groups of fungi endemic in temperate and tropical regions that cause the deterioration of wood. White rot fungi use all the macromolecules in the wood. Brown rot fungi use the cellulose and hemicellulose. These fungi grow best in temperatures from 30 to 45 degrees C. and at moisture levels from 40 to 100 percent. A general rule of thumb employed by many woodyard managers is a 1 percent per month reduction in wood biomass resulting from fungal activity. Research has shown that the rate of decay in wood chip piles varies with the season. Fungal decay averages approximately 1.5 percent in the summer and 0.5 percent in winter. The effect of bacteria that decompose wood is

inconsequential when compared to the rate and amount of woody material deteriorated by wood rot fungi.

Wood rot fungi can be controlled through several methods. The use of various fungicides and chemicals has proven effective, but these add cost and create environmental and health concerns. Other microorganisms have been found to control wood rot fungi,

temperatures remain below freezing for most of the winter, or where precipitation is rare and light, may lose the moisture in the outer layer of chips. The moist outer layer will reappear with the occurrence of precipitation. Dry chips will not support fungal growth. Thus, dry wood chip piles will have only small wood deterioration losses. The more common occurrence in temperate and

tropical climates is that frequent precipitation will cause a rapid formation of the outer moist layer. The outer layer will often reach saturation within 30 days after pile construction. In areas where frequent and intense precipitation occurs, small piles may become completely saturated. Saturation will cool the interior pile temperatures to slightly above ambient. The relatively low interior pile temperatures will not dry the interior, allowing it to become a good habitat for white and brown rot fungi.

#### GREEN CHIPS OR DRY?

The moisture content of chips does make a difference. Moisture content can be lowered by: winter harvesting of trees, covered storage, or using dry mill residues, old pallets, well-seasoned wood, demolition wood and similar material.

##### Green Fuels

(Above 50 percent moisture content)

Approximately 5,000 BTUs/lb.

Equals 5.5 cu. ft. of natural gas

##### Dry Fuels

(Below 15 percent moisture content)

Approximately 7,500 BTUs/lb.

Equals 7.5 cu.ft. of natural gas

but their effectiveness is low and their cost is high. Current methods of control involve manipulating the wood chip pile environment. By creating a hot dry environment, the wood rot fungi can be suppressed.

#### 4. Ambient Environment

Climate can affect the typical wood chip pile temperature cycle. Prolonged cold ambient temperatures can cool interior pile temperatures. As the ambient temperatures warm, so do the interior pile temperatures. Wood chip piles built during freezing conditions will have interior temperatures that remain below or near freezing. Frozen wood chip piles will thaw after prolonged ambient temperatures above freezing. After the wood chip pile thaws, it will start the typical pile temperature and moisture cycle described previously. Again, ice forming on a warm wood chip pile can restrict air movement, leading to spontaneous combustion when the ice layer melts.

The normal development of an outer moist and an interior dry region of a wood chip pile can be accelerated or voided by the intensity, type, and frequency of precipitation. Wood chip piles in areas where tem-

#### Preventing Chip Decay

The predictable dynamics of a conical wood chip pile provide useful guidelines for controlling moisture and preventing decay of the fuelwood.

##### 1. Use large chips.

Wood chip size can have an impact on pile construction, chip quality, and handling. Larger wood chips and wood chunks allow for better air flow into the pile. There is less wood area exposed to fungi and the pile dries better. Currently, many wood combustion facilities are using wood chunks and larger wood chips to improve combustion quality. Unfortunately, the tradeoff is that in rainy environments, water can percolate deeper into the pile increasing percent moisture and reducing quality.

Wood chippers have been designed to produce chips of consistent size. Consistency in chip size is important to the pulp and paper industry, thus chippers have evolved from producing quality pulp wood chips. The standard wood chip has dimensions of approximately 1 1/2 x 1/2 x 1/4 inches plus

or minus 30 percent. As of yet, no such standardization has occurred for wood chunkers. Wood chunks vary greatly in size, from 2 to 5 1/2 inches long. Research on drying rates indicates that chunks in that size range dry at comparable rates. Chunks generally dry twice as fast as wood chips for the first 60 days of storage. Eventually, both wood chunks and wood chips reach a moisture equilibrium. Disadvantages of using wood chunks are that they require a 33 percent larger area for storage than the same weight in wood chips, and they can not be stacked in piles with sides as steep as wood chip piles.

## 2. Construct the pile carefully.

Wood chip piles should be constructed on clean, well-drained hard surfaces. All old wood chips should be removed before a new pile is started. Old wood chips can serve as an inoculum for wood rot fungi. If wood chip piles are built on poorly drained sites, they will serve as a "wick" for the standing water. This will increase the moisture content of the wood chip pile, creating a suitable environment for wood rot fungi. Placing the pile on concrete not only facilitates good drainage, it helps keep a higher percentage of the base free of dirt, gravel, and other contaminants. After concrete, the best surfaces to use are asphalt, compacted soil and gravel, in that order.

During wood chip pile construction, precautions should be taken to prevent situations that can result in spontaneous combustion or promote wood rot fungal growth. All metals should be removed from the wood chips because metals conduct heat and contribute to spontaneous combustion. Layers of fines, ice, and bark should not be allowed to develop and restrict air movement. Sections of the pile containing large amounts of bark and fine material will also create pockets of fungal activity. Fungus is often introduced into the interior of the pile on the bark. The bark and the fines tend to hold moisture and provide an ideal environment for the beginning of fungal growth.

Piles constructed with gravity feed systems will tend to be of a conical shape. Conical piles 40 feet and less in height are less prone to spontaneous combustion than taller piles and piles constructed by bulldozers. Piles constructed by bulldozers have broad flat tops that collect moisture and promote the growth of fungi. Bulldozers also compact the pile, causing restrictions in air movement that can result in spontaneous

combustion. The large conical pile and the wind row derivation maximize the volume of chips located in the hot dry interior portion of the pile where fungal activity is lowest. The dry wood chips have higher available energy than green wood chips, making them of better quality for combustion.

Finally, the chip pile should be built close to the facility that will burn the chips. Systems that move wood chips from the storage area can become expensive if the wood chips need to be transported over much distance. However, the wood chip piles should be built away from sources of fly ash, dust, and sand which will lower quality.

## 3. Limit the length of storage.

To optimize the beneficial effects of storage, wood chips should not remain in the pile longer than 30-60 days, depending on the pile environment. Under freezing conditions chips can remain in the pile much longer. Most wood energy facilities maintain a 30 to 45 working day supply of chips in storage.

The most popular storage operating system is first in/first out. The first in/first out method uses the oldest wood chip piles first. Under normal circumstances the wood chips would be stored from 6-8 weeks. This duration of storage is long enough to facilitate drying but not long enough to allow significant biomass losses.

Another approach to storage is the standby pile. A standby pile is built and maintained for a long period while the wood energy facility requirements are met by fresh material. When fresh wood chips are not available or a surge of wood chips are required, chips are reclaimed from the standby pile. In some instances the standby pile is small enough to be kept under covered storage which allows chip quality to be maintained. In general, the standby pile is in the open and the wood chips are low quality. In theory, the low quality chips are to be used only until the normal flow of fresh wood chips is resumed.

## Keys To The Future

The successful introduction of fuelwood systems in the United States will depend on the successful implementation of its many components. It begins with the right trees on the right land, but it also depends heavily on harvesting in the right way. What is "right," in turn, depends on many factors, some of which were discussed in this chap-

ter. It also means doing the job safely and making it pay. Unfortunately, individuals interested in this are quite on their own, with sources of advice and assistance scattered and certainly not formalized as they are with more traditional farming systems. Just as imposing is the problem of not having a local dealership from which to select the right equipment for the job.

With time, this situation may change, but for now the inventiveness and determination of those who pioneer in fuelwood harvesting technology will be put to the test.

With chip handling the picture is brighter. There is a long history of material handling grounded in agricultural crop processing, the pulp and paper industry and

others where wood chips or chip-like products have been transported, stored, and processed for decades. Nonetheless, the challenges are here — especially in handling chips at minimum cost and maintaining their quality to provide the highest heat value as a fuel. For wood to meet its potential among diversified energy supplies, more research is needed to provide more answers and more guidance. Just as importantly, investment is needed to convert prototype machinery into commercial products, and to develop dependable delivery systems to link fuelwood growers with users. Clearly, the harvesting and handling of fuelwood is essential to the future success of using trees for energy.

### Recommended for More Information

*Environmental Impacts of Harvesting Wood for Energy* by J. E. Johnson, P. E. Pope, G. D. Mroz and N.F. Payne. 1987.

“Wood Harvesting and Handling” in *Short-Rotation Intensive Culture of Woody Crops for Energy*

Both available from:

The Council of Great Lakes Governors  
35 E. Wacker Dr., Suite 1850  
Chicago, IL 60601