5  An integrated supply system for forest biomass

Timothy L. Jenkins and John W. Sutherland

Introduction

As noted in previous chapters the U.S. has a large wealth of forest resources. The proposition of displacing petroleum through biofuels or creating renewable electricity derived from forest-based biomass resources has tremendous appeal. It offers opportunities for improved energy independence, a more favorable trade balance, job creation in rural areas, decreased demand for petroleum, and lower fossil-derived CO₂ emissions. To seize on the opportunity to use forest biomass in a manner that is economically viable, environmentally sound, and acceptable to society requires that careful consideration be given to all stages of the supply system or 'value chain'.

Forest resources can be placed into two categories: industrial wood and fuelwood (USDA Forest Service 1989). Industrial wood is all merchantable wood, also known as roundwood, which is utilized for lumber, pulp and paper, and other commercial products. Fuelwood is roundwood that is used for fuel plus forest residues. Forest residues can in turn be broken down into three groupings: slash from final fellings, slash and small trees from thinnings and cleanings, and un-merchantable wood (EUBIA 2007). Figure 5.1 shows the uses of forest resources for industrial and fuelwood purposes.

In considering the environmentally, economically, and societally sustainable use of forest resources for the creation of renewable energy and biofuels, a variety of factors must be considered. Many of these factors are discussed in greater detail in other chapters. Fundamentally, all of these factors should be simultaneously considered, in an integrated manner, to select technologies and make decisions that are the best from a life-cycle sustainability perspective. Extracting forest resources, pre-processing, storage, and movement to a processing facility are critical steps in the conversion of biomass to a useful form. These steps often have significant costs and do not add value to the biomass. Thus, the decisions associated with these steps require careful consideration.

The technology and practices for harvesting and collection of forest resources were addressed in Chapter 4. Chapter 4 also provided a brief overview of pre-processing, transportation, and storage of forest biomass.
An integrated supply system for forest biomass

This chapter builds upon those discussions by offering additional insights into the logistical (pre-processing, transportation, and storage) systems needed prior to and upon arrival of forest biomass resources at a processing facility site. Several important factors, which impact the supply chain and key activities necessary to ensure a viable and sustainable system of supply, will be identified and discussed.

Finally, a review of the specific needs of a processing facility will be discussed in order to bring together the complete forest resource supply system from the forest to the processing facility in an integrated way. Clearly, these demands will influence the size and type of storage facility, the required pre-processing steps, and the ideal mode for biomass transportation from forest to processing facility.

Pre-processing
As previously noted low-density forest residues or biomass have moisture contents around 55 per cent and are not desirable from a transportation standpoint. Densification techniques such as comminution and drying have been discussed as a means of increasing the mass of cellulosic material that can be transported per load. We will discuss three strategies for comminution.

Figure 5.1 Uses of forest resources.
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of forest residues, all of which are used in Finland and Sweden and some of which are used in the U.S. These strategies are:

- field site chipping (terrain or at a landing, generally roadside chipping);
- terminal (sometimes described as a storage facility) chipping;
- chipping at the plant.

In Sweden, the first two have been practiced since the late 1970s (EUBIA 2007), while the latter is still under testing in Sweden, although in Finland it is now well established. The most predominant comminution method is roadside chipping, where the material is brought out from the harvest site to a landing or roadside location and ground or chipped. Details associated with these strategies will now be described, followed with some thoughts on drying.

Field (forest) site chipping

There are two basic ways to transport forest materials, as whole logs or bundles, and as ground or chipped pieces. A third means of transportation, discussed in Chapter 4 and later in the section on transportation, is to bail the stems and other small wood, which is similar to bundling. From purely a transportation standpoint, grinding or chipping of forest residues is preferred over carrying bundles/bales since it allows for higher material packing density. This pre-processing can be accomplished either in the woods (terrain chipping) or at the landing or roadside (Suadicani 2003).

Terrain chipping

Comminution in the terrain, or at the source, requires a highly mobile chipper suitable for cross-country operations and possibly equipped with a tippable 15–20 m³ (20–26 yd³) chip container. If the mobile chipper and container are separate pieces of equipment then the container carrier must also be highly mobile. The chipper moves in the terrain on the paths created by felling trees or on strip roads and transfers the biomass with its grapple loader to the feeder of the chipping device (Figure 5.2). The chip load is hauled to the roadside and tipped into a larger container, which may be on the ground or on a truck trailer. One advantage of terrain chipping is that less machinery is required for harvesting, which makes the organization of the work easier. Additionally, less landing space is required for terrain chipping than for roadside chipping (Alakangas et al. 1999). One drawback to this method is that when large volumes of forest biomass are processed, terrain chipping may become difficult to manage.
A method used in Scandinavia is to employ a single chipper truck that replaces a truck-mounted chipper and separate chip truck. A chipper truck blows the chips directly into a container and then hauls the load to a processing facility. One disadvantage of this equipment is that it generally has a smaller load capacity, which tends to reduce the operation radius, thus potentially limiting the size of the energy production plant. On the other hand, as only one single unit is needed the costs tend to be lower, thus making the chipper truck suitable for small work sites and for delivering chips to smaller nearby processing facilities.
Terminal (storage) site chipping

Comminution at a terminal is a compromise between comminution at a landing and at the plant, and can be effective when the need for storage is advisable due to seasonality of forest resource availability. Biomass is hauled uncomminuted to the terminal for size reduction, and then transported to the plant as chips in large chip vans, suitable railcars or on barges. If the network of terminals is dense, the distance from the logging site to the terminal remains short. For this case, the system does not differ much from the traditional option where comminution is carried out at a landing. A terminal is a tool for controlling the procurement process and managing the flow of biomass. Biomass can be stored at the terminal uncomminuted and processed when the demand for fuel is high and working conditions at the forest end of the supply chain are difficult (Andersson et al. 2002).

Facility/Plant chipping

When comminution is performed at the plant, truck transportation of biomass takes place in the form of loose logging residues, that is, whole trees or pieces of unmerchantable wood. The low bulk density of the biomass is the
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weak link in the plant chipping system. It is therefore necessary to increase the bulk density of residues. A new system has been developed where logging residues are compressed and tied into 70 cm (2.3 ft) diameter, 3 m (10 ft) long bales or composite residue logs (CRLs) (Figure 5.4). These bales or CRLs are transported to the roadside using a conventional forwarder and on to the terminal or processing facility using a conventional timber truck.

Comminution at a plant, unlike the other two methods, eliminates the need for chip vans and makes the chipper or grinder an independent process. As a result, the technical and operating availability of the equipment increases, control of the procurement process is facilitated, demand for labor is decreased, and control of fuel quality is improved. Mobile or towed chippers can be replaced by heavy stationary crushers that are suitable for comminuting all kinds of biomass, including stump and root wood, and recycled wood. The larger the fuel flow, the more obvious become the advantages of such a stationary system. Since the investment cost is high, typically only large plants can afford a stationary chipper or grinder.

Drying

The methods for drying whole residues or chips include open (transpirational) air, thermal, and mechanical compression (Bowyer et al. 2007: 469–470). The

Figure 5.4 Terrain collection of forest residues.

simplest and cheapest method is open-air drying. Mechanical drying will not be discussed, as this method is best suited for applications where water has been added to the biomass during processing. Thermal drying is used to predry wood before combustion. This process is widely used in Scandinavian countries and has begun to see use in the U.S. (Bowyer et al. 2007). Air drying can take place in all four areas where chipping or grinding occur: in the forest, at the landing, while in storage at a terminal, and at the energy processing facility. As noted in Chapter 4 and the following two sections, reducing the moisture content of forest biomass can increase bulk density, which reduces transportation costs and improves stability during storage. Additionally, drying has a direct impact on energy costs and actually adds value to the biomass by increasing its energy density and improving its combustibility (Hakkila 2004).

Transportation

There are many ways of moving forest resource material from the harvesting site to an energy facility. At least two steps are required: 1) a mustering activity to assemble biomass in the field, and 2) a long hauling activity directed at moving the assembled biomass to the facility. Mustering options include carrying the material by hand, the use of human-powered implements like wheelbarrows or carts, and forest harvesting equipment like forwarders and skidders; as is evident, these options suggest moving materials only over short distances. For long hauling, several options are available: road, railway, water, and air. Air will not be considered since the cost, as noted in Table 5.1, is excessive. Furthermore, most commodity transportation in the U.S. is done by road, rail, and water at 78, 16, and 6 per cent, respectively (AASHTO 2003).

Figure 5.5 shows the movement of forest resources using truck, train, and barge. As shown in Figure 5.6, movement from the field location to the final end user can take several paths (Andersson et al. 2002).

Three of these pathways in the figure include movement to a terminal for storage or for additional pre-processing. Storage will be discussed later in the chapter. The other two pathways are direct transport from the field to the plant as either comminuted or uncomminuted residues. It is likely that movement from the field to the terminal will be by truck. This is due to the nature of the resource: loose, bundled, or comminuted, and the available infrastructure. From the terminal, any of three modes are possible depending on location, cost, and volume of material needed by the energy producer.

Road transport

Trucking is often the most expensive option for shipping the harvested biomass to the facility supply chain and can account for as much as half the costs (McDonald et al. 2001). Its advantages include flexibility in terms of
Table 5.1  Average freight revenue per tonne km (current $)

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KEY: U = data are not available.
a General freight common carriers, most of which are LTL (less-than-truckload) carriers.
b Total finished goods.

Figure 5.5 Transportation modes for forest resources. Photos courtesy of David Shonnard, upper left; Hakkila (2004), upper right; Timothy Jenkins, lower two.

Figure 5.6 Transportation pathways from source to energy producer.

accessibility to locations not reachable by other transportation modes, and ability to handle smaller loads in relation to competing modes. The map displayed in Figure 5.7 shows the expanse and intricacy of the U.S. highway system. Over the road (OTR) infrastructure and networks are very well established in the U.S. In assessing potential future changes to the roadway system
that could influence biomass transport, it is not likely that new systems will be developed in the short- (three to five years) or mid-term (five to 10 years) (Carter et al. 2002). Additional roadway challenges include limitations to movement (e.g. road weight restrictions) during seasonal thawing in the upper half of the U.S. and bridge/underpass restrictions established based on weight/height limits.

Most commodities hauled on roadways use semi-truck tractors and trailers. A wide variety of configurations of truck and trailer can be achieved with the best selection dependent on the intended use and cargo. Traditionally, forest resources such as roundwood have been carried on a flat bed trailer capable of carrying logs up to 2.7 m (9 ft) in length cross-wise and as long as 22.9 m (75 ft) along the length of the trailer. Generally such logs are not intended for energy production. However, such logging trailers can be used to haul bundled forest residues assuming they have been configured into CRLs using a slash bundler as described in Chapter 4 and shown in Figure 5.4 or in bales.
Alternatively, this residual material can be ground or chipped using mechanized equipment with the resulting wood particles or chips carried in a panel trailer or chip van. As described previously, these chip vans are used to carry chipped or ground biomass from the forest landing or terminal to the processing facility. The chip vans can vary in size from 40 m$^3$ (52 yd$^3$) to 113 m$^3$ (148 yd$^3$).

There are several challenges with these options, one of which is depicted in Figure 5.8 with trucks hauling unprocessed logging residues, stems and other tree sections, chips, and roundwood (logs for pulping). For each load depicted in the figure, the same amount of solid wood is being carried (Nilsson 1983).

As shown in this figure, bundling or haphazard arrangement of forest residues produces air pockets within the load (lower material density), which increases the volume of the load for a given mass. Roundwood has the highest material density, and grinding/chipping of forest residues allows this forms of biomass to begin to approach that of roundwood. In almost all cases, a higher density load is preferred from a transportation standpoint. For the cases shown on the left side of the figure, weight will not be the issue; rather, the loads will be volume constrained meaning that the trailer is not carrying as much weight as it could. In addition, it should be remembered that freshly recovered biomass contains high moisture content, up to 50 per cent water. Since this water content has no value to the energy facility, its transportation is a costly, non-value added activity. Beyond these concerns, after the truck/trailer has transported the biomass to the energy facility, it must return for

![Figure 5.8 Proportion of solids in un-commminated residues, tree sections, chips and pulpwood.](image)

*Source: Andersson et al. (2002), courtesy of Sigurd Falk.*
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another load empty; again, this represents a cost that adds no value to the supply chain.

Railway and water transport

As with road systems, railway and water transport systems are well developed and provide a significant network for movement of commodities within the U.S. Like roadways, it is not expected that additional infrastructure will be developed to accommodate any increase in demand needed by those harvesting forest residues for energy production. The maps of Figures 5.9 and 5.10 show the infrastructure of the rail and inland waterway transport systems for the U.S.

The primary asset of rail is its ability to move large quantities of material over long distances. It is also a relatively ‘green’ system, in that its consumption of energy per unit load per mile is lower than OTR modes (AASHTO 2003). One of its major disadvantages is the cost of capital improvements. Unlike highways, railway beds are owned and operated by the railroads that travel on them. Maintenance of rail beds, exchanges, and track is at the discretion of the railroad (not the government), although established guidelines are in place for safety and security. In several parts of the U.S. the rail systems are more extensive than roadways and are the preferred method for

Figure 5.9 Rail freight flows in the United States – 1999.

moving commodities. Transportation by rail is cheaper than by truck (see Table 5.1) and more gross weight can be transported over longer distances. Regarding transportation of forest residues, many energy-producing plants already have rail infrastructure in place to support deliveries of coal and other fossil fuels. Switching to or increasing the use of forest biomass and train transportation seems a logical step towards a more sustainable form of energy.

Waterborne commerce is one of the oldest forms of transportation and an important element in the movement of commodities such as grain and coal (Gibbons 1986: 74–75). Even industrial wood and forest residues are transported on water (U.S. Army Corps of Engineers 1980; Stenzel et al. 1985: 314–320). However, drawbacks to water transportation include its slowness, lack of direct routes, and sensitivity of this mode to weather factors that can cause delays. Although forest biomass can be hauled by large barges, this is
generally impractical. First, the quantities for movement would have to be substantial in order to be economical, with amounts in excess of 5,450 tonnes (6,000 tons) per load (Stenzel et al. 1985). In addition, most facilities using these materials would need to be near a port or use transhipment via truck or train to complete the trip.

The rail and inland waterway transport industries are presently stable, productive, and competitive, with enough business and profit to operate but not to update their infrastructure quickly or expand rapidly (AASHTO 2003). Several aspects of the railway and water systems will need to be improved in order to add more capacity and expand to accommodate more biomass shipments. Two such improvement areas are new carriers and improved logistics planning.

Storage

At some point during the movement of biomass from the field site to a processing facility it is likely that the biomass will be stored. The processing facility will also maintain a certain amount of storage as noted in Chapter 4 and by Wilkerson et al. (2007).

The need to store forest resources is driven by such issues as the need to keep a processing facility running year-round, seasonal availability of biomass, processing facility size, and type of energy being produced. The storage of forest resources is dependent upon several factors. These include the availability of year-round harvesting, the types and species of forest resources being harvested, and the operational requirements of the end user facilities. Balancing these supply and demand issues can be eased by storage sites (log yards) (Andersson et al. 2002). For industrial wood, a log yard can serve many purposes, as is evident from the specific descriptors often assigned to them: mill yard, reload yard, sort yard, etc. A log yard can range in size from 0.20 ha (0.5 acre) to 4 ha (10 acres) with an average size between 2 and 4 ha (5 to 10 acres); these facilities can be operated by the end user, a logging company, or a third party who operates the yard for profit (Dramm et al. 2002).

The challenge of log yards is in cost control and management. Simply building and using them for collection, storage and processing of forest residues would probably result in failure. Utilizing them in conjunction with industrial wood storage and sorting would likely improve long-term economic viability and provide outlets for any sorted forest material not considered merchantable to the industrial sector. The value added by integrating the storage and processing of forest residues with merchantable wood storage would reduce costs and provide additional outlets from other yard operations like debarking and peeling (Dramm et al. 2002).

The integrated storage and operational system described may suggest that storage of forest residues will take place only at purpose-built facilities intermediate to the forest and production facility or at the production facility
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itself. However, it is possible to store the residues at the forest or field site as well. This section will describe two methods for storage operations as well as several types of material storage.

**Storage locations – centralized and decentralized**

The size of an energy processing facility, the availability of forest biomass, and the cost to transport biomass dictates the need and size for storage locations and facilities. Storage facilities may be needed to support the required rate of biomass delivery to meet operational specifications of the energy plant. Though it is likely that there will be some storage capacity on-site at the energy processing facility to maintain operations for a minimum time period, additional storage may be needed at a centralized nearby facility or decentralized facilities closer to the source of the forest resources. Whether centralized or decentralized storage is used will be determined by several factors: location of biomass resources in relation to the plant site, seasonal availability of biomass for processing, transportation equipment requirements and costs, need for intermediate pre-processing before arrival at the plant site, and available on-site storage at the facility.

Since in many parts of the U.S. harvesting takes place year-round, the need for external storage may be unnecessary. However, this does not preclude the need for terminal sites to provide for centralized comminution of residues.

**Storage types**

Depending on the size of the energy processing facility, offsite storage may be necessary in order to maintain a sufficient and continuous supply of biomass feedstock to sustain plant operation. Several types of options are available for the storage of forest resource biomass. Badger (2002) noted that these options include open air or canopy covered, enclosed structure, and underground silo or bin (Figure 5.11). Each of these types will be described in detail and additional considerations identified for future requirements and relating storage to both pre-treatment needs and transportation.

Open air storage yards are the simplest and cheapest to build (EPA 2007). This system has a concrete or crushed rock floor and the forest residues are formed into piles or windrows. These can be made either by using a mechanical conveyor system or by using front-end loaders or similar handling equipment. The residues are unloaded from the truck using a truck tipper, walking bed trailer, or small front-end loaders (Chapter 4). Once the piles are formed they can be left exposed to the air or covered with tarps to reduce exposure to rain. Covered piles are typically lower in height in order to reduce heat buildup. If these systems are built at the processing facility site, additional equipment such as a radial screw active reclaim feeder can be used to move the residues from the piles into the plant (EPA 2007). Otherwise, the
residues can be reloaded onto trucks, rail cars, or barges for transport to the processing facility from a storage terminal.

**Enclosed structure**

This storage system, unlike the bin or silo to be described below, has a floor similar to the open-air system but also includes a large roof. It can be used to house chips as noted in Figure 5.11 and to store bundled or baled uncomminuted residues. These bundles or bales are then stacked out of the weather until needed either for delivery to the energy plant or comminuted and then transported. This storage system is the most expensive option.

**Bin or silo**

Bins or silos are smaller structures and would likely be used at the site of the processing facility (Nurmi 1999; Badger 2002). A bin, which can be used with both green and dry residues, is a rectangular shaped concrete structure buried in the ground so that the top of the structure is at ground level. The top of the bin (or bunker) may be covered or a shed constructed over it. Burial in the ground minimizes biomass-freezing problems and facilitates truck unloading directly into the bunker (GLRBEP 1986). Augers are used to move the material out of the bin and into the plant (Figure 5.11).
Silos provide ease of biomass retrieval and require minimal space. The structures are typically vertical cylinders constructed out of metal or concrete (Badger 2002). Silos, unless carefully designed, are subject to blockages caused by irregular shaped or large forest residue pieces. This is referred to as bridging (Schmidt 1991). Since most forest residue chips have poor flow characteristics, silos are usually equipped with agitators or screw augers to prevent bridging. Wet or green biomass stored in silos is subject to freezing and adhering to the silo wall. One method to minimize freezing problems is to construct the silo so that its lower six meters are within a heated building (GLRBEP 1986).

Regardless of the method used to store forest residues, there are some inherent advantages and risks (see Chapter 4). The biggest advantage is the reduced strain on harvesting and transportation systems (Andersson et al. 2002) – storage provides a biomass inventory buffer, which can be relied on if problems occur in harvesting or transportation. In addition, the material can dry while in storage, thus reducing its water content and increasing its value. The risks include the high cost of building storage structures, dry matter degradation and potential increases in moisture content (Nurmi 1999), self-heating and potential flammability (Springer 1979), and fungal and bacterial growth (Andersson et al. 2002).

Garstang et al. (2002) indicates that maintaining suitable pile heights and properly rotating and queuing biomass can mitigate many of these concerns, thus providing an option for sustainable supplies of forest residues for energy production.

Impact on transportation and pre-processing

The need for any pre-processing and the modes of transportation being used to move the biomass from the field to the energy processing plant must be considered when planning the design, size, and location of any storage facility or facilities. Storage yards will likely be multipurpose facilities that integrate storage of multiple species and grades of industrial wood, pre-processed roundwood for utility poles or log structures, and uncomminuted and chipped or ground material residues (Dramm et al. 2002). The yards can be located near multiple modes of transportation, and be used for staging and reloading to cost effective transport modes such as rail and water.

Integrated supply system

Up to this point we have provided an overview of the supply system necessary to support the emergence and viability of energy production from forest resources. In Chapter 4 the authors described the harvesting and collection of forest residues in an integrated way with logging operations and forest management. Along with operations in the forest, the remaining segments of the supply chain must be developed in an integrated fashion as well.

There are several unique challenges confronting the development of an
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integrated supply system for forest resources to produce energy products. These include the limitations associated with existing technologies for harvesting and material collection as noted previously, composition of the forest material itself, requirements from the processing facility, and economical modes of transportation and storage. Additionally, many of the following factors impact in unpredictable ways the orderly flow of biomass from field to energy conversion facility (Lindley and Backer 1994):

- low bulk density of forest biomass;
- spoilage due to high moisture content or water absorption during storage;
- variability in physical and chemical characteristics of forest biomass;
- geographical and seasonal variations in biomass;
- conflicting demands for labor and machines;
- combustible nature of biomass;
- changes in harvesting strategy based on soil fertility issues;
- local regulations on storage and transport; and
- changes in biomass demand owing to sensitivity of prices for co-products.

In combination, these factors add levels of uncertainty and complexity that need to be addressed across the entire supply system.

The uniqueness of woody biomass

The integration of fuelwood collection (e.g. forest residues) with other forest resource harvesting operations is complex, mainly due to the unique nature of forest biomass. Biomass properties can vary by species, size, age, and season (Andersson et al. 2002). Though it is unlikely that energy producers need to utilize single species or specific types, other industries do have requirements for diameter, stem length, shape, and other characteristics that might preclude harvesting in certain areas at certain times. Without an integrated effort for resource harvesting and recovery, the feasibility of collecting the fuelwood may be cost prohibitive.

The logistics system is not a simple supply chain from the forest to the energy producer. The biomass to energy supply chain must be integrated with other existing supply chains; these integrated chains provide increased efficiencies and reduced costs (Hektor 1998). Such nested supply chains form a complex network of parallel and interconnected linkages that requires careful development; during operation, such a complex system can offer cost improvements through reduced transportation and specialty equipment needs, and improved utilization of labor.

Current strategies/systems

In Chapter 4 the current harvesting techniques for roundwood and forest residues were described and how the use of integrated processes would benefit
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collection of residual forest resources. To illustrate further the use of integrated practices across the whole supply chain, Figure 5.12 links all the key functional areas: harvesting, transportation, storage, and pre-processing together with the final end user.

The integration of forest residue collection and processing along with logging operations is already a well-established practice in Scandinavia. Figure 5.12 depicts three ways to comminute residues: in the woods, at the landing, and at the energy production facility. As a means of increasing bulk density of residues for transport in lieu of onsite comminution, bundling or baling can be employed. Bundling is a promising technology for collecting residues (Chapter 4). Additionally, baling into large rectangular bales offers increased bulk density and easier handling for local and long-distance transportation (Dooley et al. 2006).

The next area where integration is critical is in storage. The merits of storing forest residues for use later by the energy processing facility have been described. However, simply storing whole residues and comminuted material alone would not be profitable (Dramm et al. 2002). One solution is to combine the storage of forest residues along with industrial wood in log yards. Such an addition gives the log yard owners another value-added operation that improves financial health and viability. Moreover, since many of these yards are located near the forest resource, transportation of uncomminuted residues is minimized. It is also typical for these storage facilities, while

![Figure 5.12 Forest chips harvesting methods integrated into wood raw material harvesting.](image)

*Source: Hakkila (2004).*
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located near the forest material source, to have additional transport modes linked to them on site, namely railroad spurs. Depending on location there may also be a river or other waterway nearby for barge hauling. The inclusion of rail or water transport at this point provides less costly means of transport with the assumption that large quantities of material need to be moved. This is dependent on the requirements of the energy production facility.

Energy facility requirements

Up to this point we have discussed the supply chain for forest resources used in energy production from an integrated perspective at the forest and in storage. It is worth noting that the user of the biomass material has certain requirements that need to be considered in order for this system to be viable. These concerns include size of the residues, quality of the material, contamination, moisture content, and whether the resource is a single or mixed species (Simpkins et al. 2006). The size of any energy processing facility will also impact the size and type of onsite storage and equipment requirements, availability of pre-processing equipment for comminuting residues, and the transport systems that can be used (Badger 2002).

Yet another consideration in terms of the needs of the energy processing facility is the likelihood that such a facility will be co-located with other forest product operations. Andersson et al. (2002) describe the integration of forest residue use or energy wood (EW) industries with other operations including solid wood (SW) industries and pulpwood (PW) industries. Thus, in addition to possible stand-alone production facilities making use of economy of size and other factors to reduce costs, combining two or more different facilities could simplify transportation planning and costs, provide for more storage options, and allow for optimization across the whole supply chain.

Production costs

While fossil fuels occur in large deposits and can therefore be recovered at hauled with relatively low handling/transportations costs, forest fuels are spatially distributed and must be collected and transported from a large number of locations. The costs of these residues depend on many steps within the logistics chain – such as harvesting, comminuting, storage, and transport – as well as the scale of operation, the biomass source, and the quality requirements placed upon the biomass.

The largest fraction of the procurement cost is associated with biomass mustering and long haul road transport. Therefore, the core of forest chip logistics is the control of transportation costs. Converting the biomass into transportable form with a chipper, crusher, bundler, or baler is also an essential part of the logistics system. Factors such as technological progress, up-scaling, refinement of procurement logistics, and learning through experience have led to significant reductions in supply costs of forest resources
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in recent decades. However, as the demand increases, the operations have to be extended to more and more difficult stand conditions and remote locations, potentially putting pressure on the supply and costs of forest resources.

Summary

A facility focused on converting forest biomass into energy resources relies heavily on a stable, predictable feedstock stream in order to be successful. This requires a reliable, well-established supply chain for delivering forest resources to the facility in a form that can be used effectively by the processes being employed. In general, the supply chain requires steps for: 1) harvesting forest resources, 2) transporting forest resources, and 3) storage and pre-processing of forest resources prior to facility usage. As has become evident, a variety of options are available for each of these steps in the supply chain. Ultimately, the choices made at each step should be jointly determined, since the decision at one step can influence the performance at other steps; thus, the supply chain must be established in an integrated manner (Ertogral et al. 1998).

The supply chain from forest to processing facility is complex and interconnected. The environmental, economical, and societally sustainable use of forest resources for the creation of renewable energy and biofuels requires the consideration of a variety of factors: biomass composition, economical transport and storage, and processing facility requirements. Biomass characteristics that impact supply chain decisions include low bulk density of forest biomass, variability in physical and chemical characteristics of forest biomass, biomass combustibility, and potential spoilage due to high moisture during storage.

The infrastructures for transporting forest fuelwood are well developed in the U.S., and many equipment systems already exist to move forest biomass from field to plant. There are issues to be aware of in order to plan and make decisions about transportation as well as storage. These include geographical and seasonal variations in biomass, local regulations on storage and transport, and the interconnected nature of forest product companies within the market that can impact wood prices.

Ultimately a facility focused on converting forest biomass into energy resources relies heavily on a reliable feedstock stream in order to be successful. This requires a dependable, well-established supply chain for delivering forest resources to the facility in a form that can be used effectively by the processes being employed. We have discussed modes of transportation, storage facilities, and pre-processing. Storage facilities, though capital intensive, may be needed to support the possible seasonality of forest harvesting and collection of residues. These intermediate facilities would provide staging areas for material during low demand periods, and opportunities for drying and pre-processing before forwarding to the energy processing facility.
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Many of the operations and technologies that have been discussed in this chapter are being tested or are currently in use in countries such as Finland and Sweden. Given the dramatic changes that appear to be underway in terms of the use of forest resources for renewable energy and biofuel production in the U.S., it appears that efforts should be directed to implementing many of the operations, technologies, and 'lessons learned' elsewhere to rapidly and successfully establishing a robust energy production industry based on forest resources.

References


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