# HARVESTING AND UTILIZATION
## Methods, Equipment, and Costs
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*This section explains the harvesting system selected, based upon topography, soil condition, and tree size. It is a highly mechanized, capital intensive system which includes tracked feller-bunchers to cut and bunch the trees, and tracked forwarders to transport the bunched trees to a whole tree chipper. The chips will be loaded into vans and transported to a designated site. The total capital cost, including support equipment, will be $14,104,000 and the annual operating expenditure will be $6,764,837.*

## PLANTATION AND TREE CHARACTERISTICS

The proposed energy plantation will consist of 46,750 acres divided among three locations planted in equcalyptus and leucaena. Spacing will be 6 ft x 6 ft for 1,210 trees per acre; the rotation age of the plantation stands may vary from 5 to 8 years; and the average tree size at harvest will be at least 6 inches dbh. Trees of this size are estimated to have a volume of $4.75/ft^3$ and to contain 333 lb of biomass, green weight, based on a density of 70 $lb/ft^3$ before chipping, and 21 $lb/ft^3$ after chipping. Moisture content of the green chips is 50 percent on a wet basis.

During the second and third rotations, the individual tree stems will be somewhat smaller, about 5 inches dbh, but multiple stems will sprout from the original stumps. Surviving sprouts per stump will vary, but should be near these percentages of the original size—1 stem/60 percent stump, 2 stems/30 percent stump, 3 stems/10 percent stump.

The foliage portion of harvested trees along with most of the dirt will be separated at the chipper. No attempt will be made to recover it, other than possibly spreading this foliage over the area near the chipper.

## ENERGY PRODUCTION AND EFFICIENCY

The planned plantation of 46,750 acres with an estimated growth of 20 green tons of harvestable biomass per acre per year will yield 10 bone dry tons per acre per year over the rotation period of 5 to 7 years. With a requirement of approximately 467,500 bone dry tons (935,000 green tons) per year it will be necessary to harvest about 7,790 acres of plantation per year starting with the sixth year after start of plantation establishment. The daily harvesting rate (based on 240 work days per year) will have to be 3,896 green tons per day to meet this need. The selected harvesting system will produce this quantity of chips and deliver them to the plant.

The harvesting system, including transportation of chips to the plant 35 miles away, will require approximately 1,180,000 gallons of fuel and other petroleum products per year. By equating the above values to equivalents of barrels of oil (42 gallons per barrel), calculations can be made.

Harvesting needs:

$$\frac{1,180,000 \text{ gal.}}{42 \text{ gal/bbl.}} = 28,100 \text{ barrels of oil}$$

Equivalent energy (gross) produced:

935,000 green ton wood chips x 1 bbl/bT = 935,000/barrels of oil

Energy efficiency ratio:

$$\frac{935,000}{28,100} = 33.3:1$$

This ratio appears favorable and indicates the feasibility of plantation harvesting using the proposed highly mechanized system.

## HARVESTING SYSTEMS CONSIDERATIONS

A broad range of harvesting system alternatives were available for consideration at the beginning of this study. The alternatives ranged from highly labor intensive systems based on manual felling with chainsaws and inwoods transport by rubber-tired cable skidders to the portable chipper at the landing or chipping deck, to highly mechanized systems such as mobile chippers that fell, chip, and transport the chipped material to the landing. The mobile chipping systems are the least labor intensive but are very capital intensive. They are also the least highly developed at this time and therefore the least reliable. As criteria were developed for tree species, sites (including acreage limitations), plantation yields, social factors, and plant requirements, the choice of alternatives was narrowed.

Based primarily on the major factors of total daily production requirements of 3,896 green tons per day for 240 days per year, small tree sizes of 6 inches dbh at the end of rotation, given site conditions (slopes, rocks, low bearing strength soils), high level of rainfall, and limited labor force for woods work; four mechanical systems appeared feasible:

o   The machinery used in this system are rubber-tired drive-to-tree feller-bunchers, rubber-tired grapple skidders, and portable whole tree chippers. Similar systems

have been proven capable of high production at reasonable costs. Generally, rubber-tired machines are faster and less costly (fixed and variable) than tracked machines performing the same functions. This system becomes sensitive to tree size, however, as tree size decreases below 6 inches dbh. Stand densities also influence the production capacities of the feller-bunchers. The major drawbacks to this system arise from the plantation environment. A high percentage of plantation sites contain slopes over 10 percent, and drive-to-tree feller-bunchers operate better on flatter lands. Also, during wet weather, soils have low bearing strengths, and excessive soil compaction could result. Another problem is that drive-to-tree feller-bunchers could run over the stumps, possibly damaging them and the vehicle tires.

o Machinery used here are limited area feller-bunchers, cable skyline yarder, rubber-tired or tracked grapple skidders (at landing), and a portable whole tree chipper. This system can operate under the most adverse conditions of slopes, soils, and weather, but problems with it are higher costs and required additional harvesting/planning skills. Also, the cable yarding system needs slopes of 10 percent or greater to provide suitable cable deflection for fully or partly suspended log loads for high speed yarding without damage to the plantation; some plantation areas considered have slopes less than 10 percent.

o Machinery used in this system are mobile chip harvesters and forwarders. Mobile chip harvesters appear to be the least sensitive to small stem diameters (tree volumes) and have the potential for high production rates with reduced labor requirements. Presently, all machines of this type are only in the prototype stage of development, and are restricted to relatively rock free sites with slopes less than 20 percent. Also, the present design would have to be modified to accept trees of 30 ft and greater in height, growing in dense stands of 1,200 trees or more per acre, if it were to be used for this project.

o Limited-area accumulating feller-bunchers, tracked clam bunk skidders, and a portable whole tree chipper comprise the next system considered. For the conditions of this study—biomass volume requirements, sites, and plantation size—this system is the most flexible. It is capable of working under adverse terrain and weather conditions while maintaining good production potential. It also causes little site/stand disturbance. The system is highly mechanized, keeping labor requirements low and placing a relatively moderate cost on high production. THIS IS THE SYSTEM SELECTED.

## SELECTED SYSTEM AND PRODUCTION RATES

The selected system is made up of two limited-area feller-bunchers (also known as swing-to-tree feller-bunchers), two steel tracked clam bunk skidders with knuckle boom loaders, and one portable whole tree chipper. Transportation of chips will be by standard highway truck tractors pulling vans.

The feller-buncher selected is modified from a standard commercial hydraulic excavator. The changes have been made to the outer or stick boom and additional adaptations of the accumulating feller-buncher shear or other cutting device may be required to reduce damage to the stump or butt log. The use of an accumulating shear head will help to increase production when harvesting small trees. Use of the swing machines and boom mounted shear will permit cutting a 50-ft wide swath as the machine progresses across the plantation. Production increases and site impact reduction will result from not having to drive to each tree. The tracked carrier will operate on slopes of up to 30 percent. Ground pressures will be within the 6 to 7 psi range, so the unit will be capable of working under poor soil conditions. Bunches of up to 21 trees (6 ft x 6 ft tree spacing) will be made with minimum travel. Representative machines of this type are the Drott 40 LC and John Deer 693 B.

The selection of a steel tracked clam bunk skidder was based on specific requirements dictated by the operating conditions. The skidder must be able to operate on wet poor bearing strength soils, withstand abrasive soils, and self-load bunches into full payloads without excessive, stump-damaging travel. The selected machine has high travel rates for good production. It will work also on slopes up to 40 percent, making it compatible with the feller-buncher. The basic machine is represented by the FMC 180 log skidder and will be modified by adding the clam bunk and loader similar to the FMC 200 BG skidder.

The portable whole tree chipper is to be a standard disk chipper with a conveying system and a boom loader. It will discharge chips directly into chip vans. The chipper is represented by a Morbark model 550 or Trelan DL-18.

## HARVESTING EQUIPMENT AND COSTS

The total output of a chipping operation depends upon the organization of the work. The most common practice is to fell the trees, transport them to an open area, chip into a vehicle, and transport. One line production varies according to the chipper, climate, chip van availability, and other factors; including preparation of work at the harvesting site, movement of the chipper within and between harvesting sites, and servicing and repairs. Table 7-1 shows the amount of equipment necessary for the total harvesting job based on a production goal of 467,500 BDT/year of wood chips. This production goal will require 14 operational systems, each comprised of two feller-bunchers, one bunk grapple skidder and one whole tree chipper. For some items, spare machines have been included and are planned as replacements only in cases of major equipment failures requiring more than one day to repair. Each system will have the services of a full time on-site mechanic. Two additional mechanics will work in the central shop to

handle major repairs and to provide assistance to the field mechanics. An adequate inventory of spare parts should be kept in stock to reduce repair down times.

The 14 systems are to be in operation each work period. Because each system is based on one whole tree chipper, 3 spares will be purchased as insurance. The total capital cost of a chipper is about $128,000 and the total capital investment, including spares, is $2,176,000.

Each system will operate with two feller-bunchers, therefore twenty-eight operational feller-bunchers will be used during each work period. Three spares will be used as backups in case of major failures and major maintenance needs that could take an operational feller-buncher out of service for more than a day. This is less critical, however, than having replacements for chippers or skidders, because half of the system production could be maintained with only one operational feller-buncher. If necessary, then, the three spare feller-bunchers could be deleted to reduce the capital investment. Each unit costs approximately $140,000, so omitting the spares would reduce the initial cost by $420,000, bringing the total investment from $4,340,000 to $3,920,000.

Only one tracked clam bunk skidder is required for each system. This piece of machinery, though, could be the most sensitive to weather and terrain factors (with little opportunity to correct for adverse conditions—except by shortening skid distance) and to down times caused by mechanical failures. Plans are made here for the minimum number of machines, one for each of the 14 systems plus three spare units, to be purchased at an estimated cost of $140,000 per unit, bringing the total capital investment to $2,380,000. More of these machines may be needed, however, requiring more capital investment.

Transportation of the wood chips to the loading site will require an approximate 70 mile round trip. Six 50 ft chip vans will be located at each chipping site and an equivalent 8 chip vans will be located at each site per 8-hour day. Wood chip transportation will be conducted on a 24-hour basis, about 3 round trips per 8-hour day. Therefore, 17 truck tractors (14 operational, 3 spares) and 84 chip vans are required. The estimated capital cost of these units are $986,000 and $2,352,000 respectively. The total capital cost will be $3,338,000.

Finally, at the destination of the loaded chip vans will be 2 chip van unloaders (total cost $220,000) that lift the entire truck and van to a 45° angle to unload the wood chips. This completes the total cycle of a woodchipping operation—cutting trees with feller-bunchers, forwarding the trees to the chipper, chipping the whole trees, transporting the woodchips to a destination, and unloading.

Other equipment, though, is necessary to support this type of operation. For example, 7 pickup trucks ($70,000 total) will be needed by the supervisors. Each supervisor will manage 2 of the 14 woodchipping operations to make sure that the high cost system is running as smoothly as possible. To move the work crew from various locations, 14 vans also are needed, for a total of $140,000. Each chipping site will have a maintenance truck fully equipped with a mechanic and the necessary tools for on site repairs. Two other maintenance vehicles and mechanics will be stationed at a central repair shop for major servicing. Therefore, 16 maintenance units are needed, for a total cost of $252,000. Three fuel trucks will service the whole operation (1 at each site). They will travel to each chipping operation and fill the existing fuel tanks. The three fuel trucks will cost $45,000 and 14 fuel tanks, about $56,000. A D-4 dozer type, needed at each site for preparation and maintenance of the landing, will complete the support group. Each D-4 dozer will cost $917,000.

At the central repair shop, an 8 unit chipper knife sharpener, about $128,000 will be operating continuously. Each chipper requires 15 sets of chipper blades, for a total of 210 sets, costing $42,000.

TOTAL COST

A summary of all these costs is presented in Table 7-1. The total, including 2 percent for inventory and 15 percent for contingency, is $16,501,680. The depreciated value per year is about $2,385,000 and the annual operating cost will reach $6,764,837. As expected, the high cost items in the harvesting system are the woodchippers, feller-bunchers, forwarders, and truck transportation.
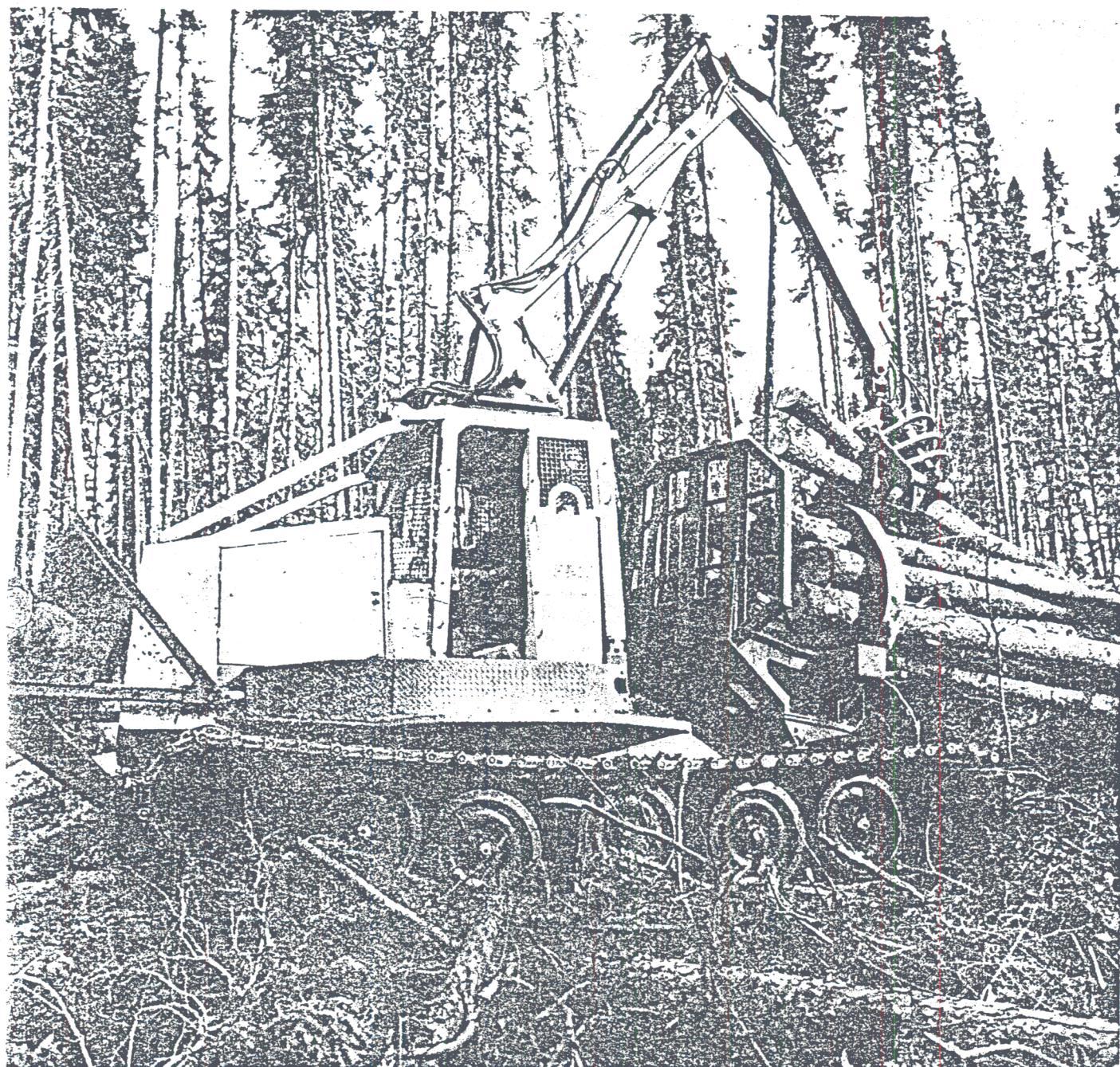
*A Clam Bunk Skidder in operation.*

TABLE 7-1: SUMMARY OF HARVESTING COST

| Equipment | Labor | Life | Units | Unit Capital Cost | Unit Salvage Values | Total Capital Cost | Annual[3] Operating | Percentage of Annual Operating Costs For Labor |
|---|---|---|---|---|---|---|---|---|
| Chipper | 28[1,4] | 5 | 17[2] | 128,000 | 25,200 | 2,176,000 | 1,184,064 | 43.1 |
| Fellerbuncher | 28[4] | 4 | 31[2] | 140,000 | 28,000 | 4,340,000 | 1,758,883 | 29.1 |
| Forwarder | 14[4] | 4 | 17[2] | 140,000 | 28,000 | 2,380,000 | 1,092,609 | 23.4 |
| Truck Tractor | 42[4] | 3 | 17[2] | 58,000 | 11,000 | 986,000 | 970,662 | 48.5 |
| Chip Vans | -- | 8 | 84 | 28,000 | 5,600 | 2,352,000 | 460,992 | -- |
| Pickup Trucks | 7 | 3 | 7 | 10,000 | 2,000 | 70,000 | 70,630 | 0.0 |
| Crew Vans | -- | 3 | 14 | 10,000 | 2,000 | 140,000 | 141,260 | -- |
| Maintenance Trucks with Tools | 16[5] | 5 | 16 | 18,000 | 3,600 | 252,000 | 497,400 | 62.8 |
| Fuel Trucks | 3[6] | 5 | 3 | 15,000 | 2,400 | 40,000 | 51,056 | 79.0 |
| Fuel Tanks | -- | 5 | 14 | 4,000 | 720 | 56,000 | 9,408 | -- |
| Chip Van Unloaders | 2[6] | 10 | 2 | 120,000 | 24,000 | 220,000 | 165,481 | 48.4 |
| Dozer (D-4) | 14[4] | 5 | 14 | 65,000 | 13,000 | 917,000 | 229,768 | 28.9 |
| Knife Grinder | 8[6] | 8 | 8 | 16,000 | 3,200 | 128,000 | 132,682 | 80.9 |
| Knives | -- | 1 | 210 sets | 200 | -- | 42,000 | -- | -- |
| Subtotal | 162 | | | | | 14,104,000 | 6,764,837 | |
| Inventory (2% of Capital) | | | | | | 282,080 | | |
| Contingency (15% of Capital) | | | | | | 2,115,600 | | |
| TOTAL | | | | | | 16,501,680 | | |

[1] includes landhand
[2] includes 3 spare units
[3] includes interest, insurance, taxes, maintenance, repairs, fuel, lubricants, and labor (units in field)
[4] labor cost $9.50/hr
[5] labor cost $10.00/hr
[6] labor cost $7.00/hr