

3. Production of Wood Fuels

The utilisation of forest chips for fuel is of great importance to forestry, since the production and sale of forest chips enable the necessary stand care and also the conversion of stands from one species to another. For heating and CHP plants, wood is an easy fuel to handle.

Production of Forest Chips

The production of forest chips typically takes place in connection with three different tasks:

- Thinning in immature softwood stands.
- Conversion of stands.
- Clearing of logging residues.

Quantitatively, the proportion of the first-mentioned task is absolutely predominant, but the proportion of logging residues is growing. The conversion of mountain pine and contorta pine to other more productive species is slowly being completed.

Thinning in Immature Softwood Stands

Thinning in immature stands is made in order to encourage the growth and thus increase the total yield of useful material from the trees that remain in the stand. Additional benefits of thinning are improved health of the stands and higher recreational value for the visiting public.

In establishing a softwood stand, a stock of 3,500-5,000 trees is planted per ha. First thinning is normally performed when the trees are approx. 8 m high. 25-50% of the trees are removed, thereby reducing the number of stems to 2,000-2,500 trees per ha. When the trees in the stand are approx. 10 m high, a second thinning is performed, often a selective thinning, thereby reducing the number of stems to approx. 1,000-1,500 trees per ha.

The trees from first thinning are so small that it is difficult to sell them as commercial timber, and chipping is therefore a widely used practice. In periods when the price of pulp is low, trees from second thinning are also chipped.

It appears from a survey made by the Danish Forest and Landscape Research Institute on behalf of the Danish

Energy Agency /ref. 10/ that in addition to the amount of 553,000 m³ solid mass of wood for energy production that was consumed already in 1994, the production can be further increased by an amount in the range of 400,000 and 720,000 m³ solid mass.

The sale of forest chips is a prerequisite of carrying out early thinnings at a low price or without any costs for the owner of the forest. Without the market outlets, thinnings would most often be postponed until the trees have attained a size where a balance can be achieved between the cost of thinning and the income from the sale of the product. Thinning in due time is a prerequisite of the production of high quality commercial timber. In other words, it is not possible to maintain a production of high quality commercial timber without at the same time producing (and selling) wood fuel.

Conversion of Stands

Today the conversion of pine wood stands (mountain pine and contorta pine) primarily takes place in order to make space for new, more productive stands, typically of spruce, Scotch pine or broad-leaved trees (primarily oak). In addition, clear-cutting of certain older pine stands is done with the purpose of restoring heath or dune landscapes.

The sale of forest chips is an absolute prerequisite of carrying through the conversion in a financially justifiable way. Without market outlets for wood chips, the owner of the forest will have to pay for both the forest clearing and restocking of the area, and thus the price is higher than

the estimated income of the new stand in the future. The sale of forest chips from a conversion can normally more or less pay for the clearing of the area so that the owner only has to pay for the restocking of the area with forest trees.

Clearing of Forest Residues

After clear-cutting of stands, large amounts of forest residues are left in the area, primarily tops from trees that have been harvested, but also branches and logs that have been cut off due to rot.

Normally it is necessary to clear the cultivation area for residues so as to facilitate restocking. Often residues are gathered and arranged in long rows. The rows can be used as skidrows along which vehicles can move later on in the life of the stand, but it takes at least 5-10 years for the rows to rot away so as to enable vehicles to pass along them.

Research has proven that tops from clear-cuttings can be profitably chipped and used for fuel. Thus chipping contributes to the benefit of the harvesting, and often makes the clearing of the area unnecessary, since chipping removes a large proportion of the residues /ref. 32/.

The annual clear-cutting in Denmark amounts to approx. 2,500 ha of old spruce. With an estimated yield of the tops of approx. 40 m³ l. vol per ha, approx. 100,000 m³ l. vol of wood chips can be produced per year by the chipping of residues left after old spruce.

Harvesting of Forest Chips

The production of forest chips can be divided into several stages /ref. 33/:



photo: the danish land development service/dorte thomsen

The feller-buncher, which is a narrow off-road machine with a crane mounted saw felling head, fells the thinning trees and arranges them in rows, so that the chipper can subsequently chip them after drying for a couple of months.



photo: søren fodgaard

Chipper in operation in a clear-cutting area in an old Norway spruce plantation at Gludsted Plantage. Residues consisting of tops are chipped. This ensures, among other things, a better passage when restocking the area with new forest trees.

- Felling for chipping.
- Chipping.
- Off-road hauling.
- Storage in the forest.
- Road transport.

Felling for Chipping

Felling for chipping is made in a way that ensures that the wood chips produced are as dry as possible. The moisture content of the trees is lowest from January-March, and the felling of trees for chipping should therefore take place in the first three months of the year. This may also limit the risk of stump infection by the decay fungus *Heterobasidion annosum* which can subsequently spread from the roots of the stumps to the remaining trees in the stand. The trees that have been felled are left in the area for the summer. This is done in order to achieve drying of the trees to a certain extent and in order to enable needles and small branches to detach before chipping. The moisture content in wood chips is thus reduced from 50-55% to approx. 35-45%, and the majority of the nutrients in the trees - actually contained in the needles and small branches - remains in the area.

By felling of the trees in the early part of the year for the purpose of chipping after the summer season, there is a certain risk of insect infestation in relation to softwood. In risk areas, the trees

should be inspected frequently. If the insect infestation is too serious, the chipper can at relatively short notice be ordered to remove the trees that have been attacked. So far, no serious insect infestation of felled trees has been noticed in Denmark, because they are normally placed in the shade of the residual stand, resulting in poor living conditions for the insects.

Felling is performed by chain saw or by a feller-buncher. The feller-buncher is a special machine equipped with a crane mounted saw felling head. During thinning, the feller-buncher requires a track in order to travel in the stand. The establishing of skid rows normally takes place by manual chain saw felling. The material is dried over the summer and chipped one season before selective thinning takes place.

During the establishing of skid rows and during felling, it must be remembered that the chipper has limited movability on soft areas, when passing ditches or operating on steep slopes. Also chippers have large turning radii and require much space for entering skid rows. The feller-buncher dumps the trees in rows, butt ends in the same direction, enabling the chipper to easily take them by the crane and feed them into the chipper, while the machine simultaneously travels slowly forward.

During clear-cutting of old spruce stands, the felling is normally performed

with chain saw or by means of harvesting machinery. During harvesting by a one grip harvester, the tops can be placed in the same direction in rows, after the processing of commercial timber, thereby making the chipping operation easier. Harvesting should also be planned, so that the greatest possible amount of tops are placed in the rows /ref. 32/. It is of great importance not to drive over the tops during the haulage of the commercial timber products, since it would result in an increased amount of broken material and an increase in the sand content.

Chipping

A chipper consists of a self-propelled basic machine with cabin, chipper and crane equipment mounted at the front part of the machine. At the rear end of the basic machine, a high-tipping container is mounted. There are both specialised machines designed for the purpose of chipping only and also large agricultural tractors equipped with a chipper and high-tipping trailer.

The chipper has an infeed opening with hydraulic rollers that push the logs into the chipper. The chippers have undergone a rapid development over the recent 20 years. Thus their productivity has been increased from approx. 80 m³ l. vol of wood chips per day in 1980 to approx. 300-400 m³ l. vol per day in 1998.

Chippers can be classified in three different categories: Disc chippers, drum chippers, and screw chippers. They differ only in their way of chipping. All chippers are equipped with a fan to blow the chips out of the chipper housing through the chute into the container. The screw chipper is not used in Denmark anymore.

The disc chipper consists of a heavy, rotating disc with rectangular holes in which chipper knives are mounted radially (Figure 6). Normally a disc chipper for fuel chips has 2-4 knives.

When rotating, the disc with the chipper knives pass the anvil, which is a fixed steel block, at short distance. The size of the wood chips can be controlled by varying the anvil and knife position from 12 to 35 mm.

The disc chipper is the most common type of chipper in Denmark. It produces a uniform quality wood chips and consumes less energy than a similar size drum chipper. The machine is suitable for

chipping whole trees and logs, but less suitable for logging residues.

The drum chipper consists of a rotating drum, in the curving of which 2-4 longitudinal holes are situated equipped with knives (Figure 7). The drum chipper knives also pass a fixed anvil. The size of the wood chips can be controlled in the same way as described under the disc chipper, i.e., from 10 to 50 mm in fibre length.

There are only few drum chippers in Denmark. These machines are suitable for comminuting whole trees, logs, and residues. A drum chipper cuts over the whole knife width and is therefore less sensitive to sand and other pollutants than the disc chipper.

Off-Road Hauling

As the chipper is a very expensive machine, the work should to a high extent be arranged so as to comply with the requirements of the machine. It is usual to have a tractor with high-tipping trailer or a specialised forwarder following the chipper, thereby enabling it to continue chipping while the forwarder carries the wood chips to the roadside.

Storage in the Forest

The storage of wood chips forms an important part of the distribution of the fuel from forest to heating plant. It is necessary to store wood chips for several reasons:

- The consumption of wood chips varies heavily with the time of the year.
- There are periods when harvesting of wood chips is not possible.

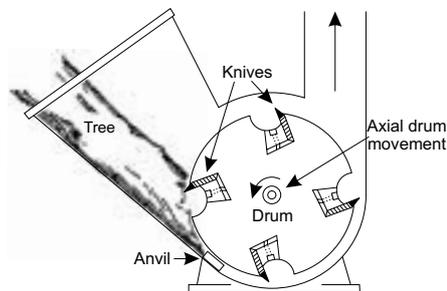


Figure 7: The drum chipper circular movements cause the knife entrance angle in relation to the tree fibre direction to change with the tree diameter. It therefore produces wood chips of a more non-uniform size than a disc chipper /ref. 34/.

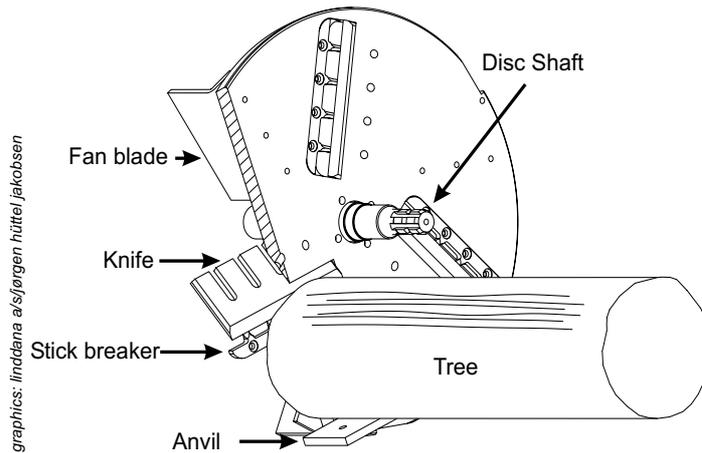


Figure 6: The disc chipper principle ensures that the wood chips are produced to a rather uniform size, since the entrance angle in relation to the fibre direction of the tree is the same irrespective of the thickness of the tree.

- During the summer more wood chips are produced than consumed.

Wood chips should preferably be produced as the need for it arises at the heating plant. However, storage cannot be avoided, as the forests have to meet larger demands for wood chips in cold periods and be capable of delivering wood chips even if stand conditions make working there impossible. Normally it is specified in the contract of supply, how large quantities of wood chips, the forest has undertaken to store during the heating season (normally 10-20% of the heating plant's annual consumption).

The storage site should be carefully selected /ref. 35/. The wood chip pile should first and foremost be placed close to an all-weather road that is capable of carrying trucks throughout the year. The road should be dry, since the pile would otherwise be splattered when vehicles pass. The pile should be located higher than the road, as water would otherwise percolate from the road into the wood chip pile. The ground under the pile should be level and free of stumps, large stones or residues. Wood chip piles should be made as large as possible, since it minimises the loss at the bottom of the pile. However, wood chip piles must not be higher than 7-8 metres, due to the risk of spontaneous combustion in piles.

Chips for storing should be as dry as possible and of the best possible quality. If the wood chips are to be stored for more than two weeks, the pile should be covered with tarpaulins. A certain drying takes place in the central part of a wood chip pile that has been covered with tarpaulins. The evaporated water condenses in the outer wood chip layers, which thereby become equally wetter.

If wood chips are stored with a view to reducing the moisture content, it should be stored under roof. Experiments have shown that storage under roof for 4-6 months may result in a reduction of the moisture content from approx. 45% to 25-30 % /ref. 36/. In the case of outdoor storage without tarpaulins, the wood chip moisture content will increase, whereas the overall moisture content of chips stored under tarpaulins remains constant.

Road Transport

Road transport of forest chips is normally performed by means of container trucks which with a container on the tractor and one on the trailer can transport approx. 80 m³ l. vol at a time. If delivered at the



photo: biopressforben skatt

The pile of wood chips releases vapour due to the natural decomposition by fungi and bacteria. The decomposition breaks down the wood into carbon dioxide, water, and heat.

time of chipping, at least two containers, preferably more, should be placed in the forest. The containers are filled as the chips are produced, and the truck carries the wood chips to the heating plant or storage site concurrently. During loading from storage, it is normal to use a wheel loader for filling the containers. With an output of 30-50 m³ l. vol per hour, a chipper can fill up two containers in 2-3 hours /ref. 37/.

Production of Wood Pellets

Wood pellets are normally produced from dry industrial wood waste, as e.g. shavings, sawdust and sander dust. Pulverised material is forced through a die under high pressure. The hole size of the die determines the diameter of the pellets and is generally between 8 and 12 mm. It is not necessary to use any agent for binding the particles together into pellets, but if an agent is added, this information must be included at sale and delivery. The pellets are cooled after pelletizing. Then they are screened in order to separate fines etc. from acceptable pellets, and finally they are stored either in bulk or in bags. Pellets are delivered by tipping trailer or by fodder wagon using a fan to load the pellets into a silo at the consumer's place.

If pellets are burnt as purify fuel-wood, it should comply with the executive order concerning bio-waste /ref. 31/. This executive order sets out that wood pellets should not contain more than max.1% glue and no paint or any other



photo: bigpress/farben skøtt

Container being loaded with wood chips by means of a tractor equipped with a high-tipping trailer. The truck picks up the container subsequently in order to transport the wood chips to the heating plant.

products for surface treatment. If the pellets contain these substances, a waste tax (1999: DKK 350/tonne) shall be paid, and the pellets should not be burnt on plants that have not been approved for waste incineration.

Production Based on Wood Waste

Large amounts of wood waste are used for energy production (see Chapter 2.1).

Wood waste may be recycled wood, e.g. demolition wood, which has been used for applications before being burnt, or it may be residues from the forest product industries in the form of by-products etc. The wood that often varies a lot in size is comminuted before burning. Wood waste falls under the provisions of the executive order on biomass waste mentioned above.