ForestEnergy Programme 2006-08

The COFORD ForestEnergy programme has the objective of securing marketable wood fuel of acceptable moisture content for sale as wood chip, firewood and other wood fuels, to support the development of the renewable wood energy sector in Ireland. The programme achieved this through commercial scale demonstrations of forest harvesting supply chains for wood energy on 15 forest sites (Figure 1). At each site the supply chain productivity, fuel quality and delivered energy cost of each system was assessed. Different storage options and seasoning schedules over one and two summer seasons were investigated. Public demonstrations of machinery and methods were held each year of the programme.

Conifer sites
1. Abbeyfeale, Co Limerick
2. Ballybofey, Co Donegal
3. Bweeng, Co Cork
4. Croaghrimcarra, Co Mayo
5. Foilagohig, Co Cork
6. Frenchpark, Co Roscommon
7. Kilbrin, Co Cork
8. Swan, Co Laois
9. Woodberry, Co Galway

Broadleaf sites
10. Dovea, Co Tipperary
11. Manseragh, Co Tipperary
12. Mullinavat, Co Kilkenny
13. Portlaw, Co Waterford
14. Stradbally, Co Laois

Cutaway peat site
15. Boora, Co Offaly

Long-term storage trial site
16. Rochfortbridge, Co Westmeath

Figure 1: Location of the ForestEnergy programme trial sites.

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FORESTENERGY PROGRAMME

Whole-tree harvesting of broadleaf first thinning for energy wood chip production

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Introduction

Harvesting wood fuel from forest thinnings differs from other types of harvested assortments in that the whole tree can be used. The branches and tree tops will produce suitable material for chipping - only the leaves are not suitable as fuel. Any wood that is to be used for energy should be seasoned (dried) before it is chipped as the energy content of wood chips is directly related to the moisture content (the lower the moisture content the greater the energy content). Seasoning whole trees in the stand, before chipping, uses the ambient climate to drive off moisture and does not require investment in dedicated storage. As the tree dries, the leaves desiccate, turn brown and drop off. A distinct advantage is that the nutrients, which are mainly found in the leaves, stay in the forest. Forest sites differ in local climate, exposure and humidity, so the time required to season timber before chipping will vary.

Wide variation in stem straightness and size is typical of young broadleaf stands, and sites also differ widely in terms of stem quality and the number of potential final crop trees. These trees should be marked before thinning is carried out, and should be avoided where possible when laying out extraction racks.

First thinning or tending should remove about one third of the total number of stems, with the objective of cutting permanent extraction racks and selectively felling trees that are most directly competing with potential final crop trees.

The small diameter of trees removed generally means that they are left *in situ* or used as firewood. In firewood production, the trees are felled, delimbed, cross-cut and forwarded or skidded to a landing to be converted into firewood. Much of the tree biomass found in the tops and branches is retained in the forest when firewood is produced, whereas whole-tree chipping utilises the total tree biomass of thinned trees.

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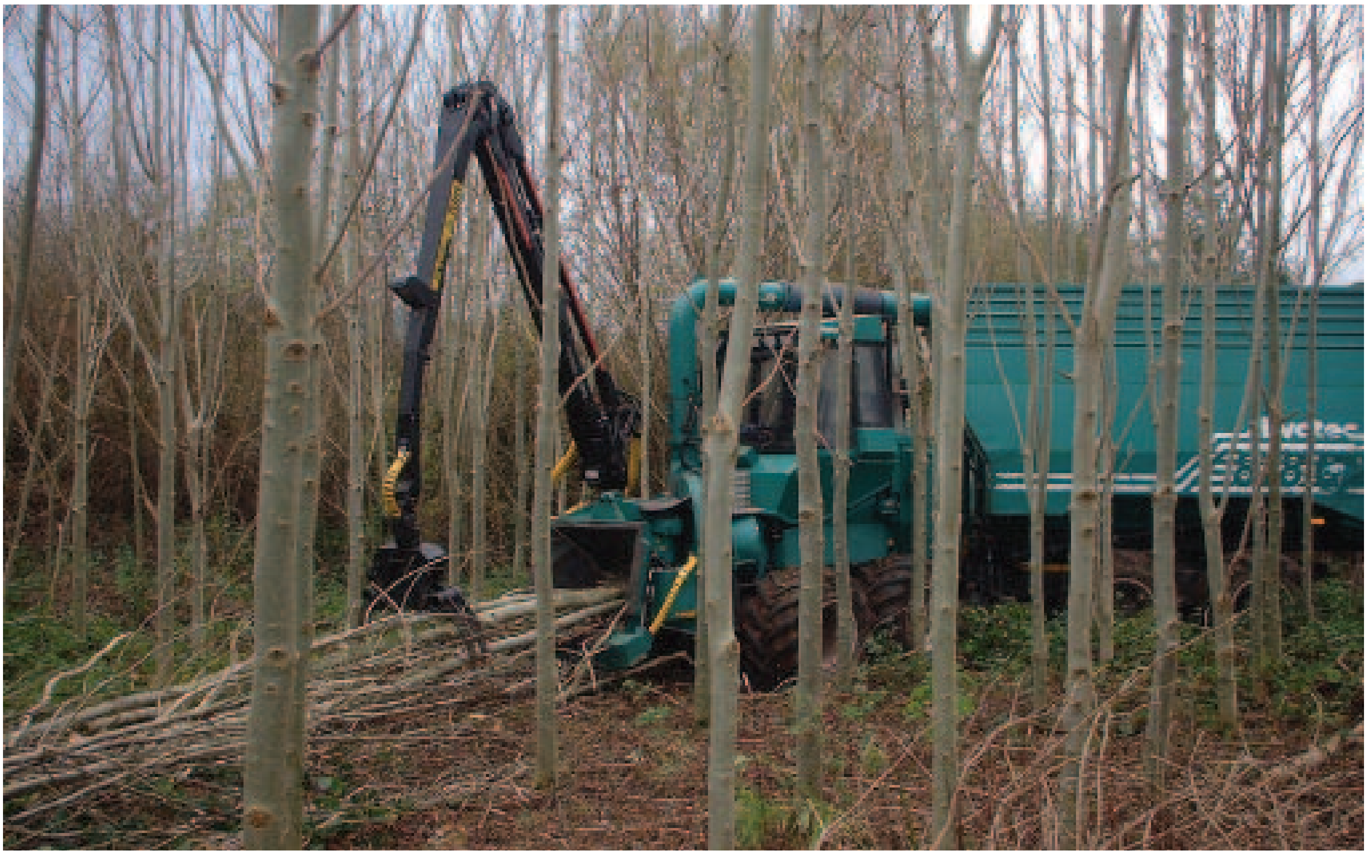
The whole-tree thinning method is usually a one stage approach in broadleaves: during the intervention, one line in seven is felled by chainsaw, with selection thinning in the rows between the extraction racks. Trees removed in selective thinning are presented with their butt ends in the rack, at an acute angle (preferably less than 30^{o}) to the direction of travel. The trees are left to dry for at least one summer and are then chipped with a terrain chipper (tested at ForestEnergy sites in 2006 and 2008).

Alternatives tested in 2006 were:

- Combined row and selection thinning by chainsaw, chipping in the stand by terrain chipper;
- Row thinning only, felling by chainsaw, chipping in the stand by terrain chipper;
- Combined line and selection thinning with a feller-buncher, chipping in the row;
- Combined row and selection thinning by feller-buncher, forwarding to the roadside, stacking and eventual chipping with a truck-mounted chipper. The roadside stack was covered with plastic to facilitate drying.

Thinning was carried out at an early stage of the development of the stand, at a height of about 8 m, some years prior to what would be the usual height at first thinning. Using this early intervention, growth is concentrated on fewer and better trees, so that subsequent thinnings will yield larger, more profitable material.

The study of the suitability of this method in Ireland was a key element of the COFORD ForestEnergy programme, as whole-tree thinning is successfully used elsewhere for wood fuel production. The advantage of the whole-tree method over standard thinning is that a substantially larger volume of wood fuel is produced, as tops and branches and small trees are chipped. This method also has a positive impact on stand quality, since the operation focuses on releasing potential final crop trees from competition, as well as creating permanent access through the stand. A disadvantage of whole-tree thinning is that there is no brash mat for the machines to operate on; however, some felled stems can be sacrificed and put under the wheels where required by machines.



Silvatec chipper in an ash thinning. Note that in this case the trees are chipped from the top, which is not the preferred method.

The machines to carry out this work were not yet available in Ireland when the trials took place, so all machines and their crews were transported from Denmark. At the time of writing one terrain going tractor-mounted chipper is now available in Ireland.

Machines

In all stands the line trees were felled by chainsaw. Different chainsaw operators were employed on different sites, so instructions had to be given and work monitored at each site. The trees were felled so that each one lay along the line in the same direction.

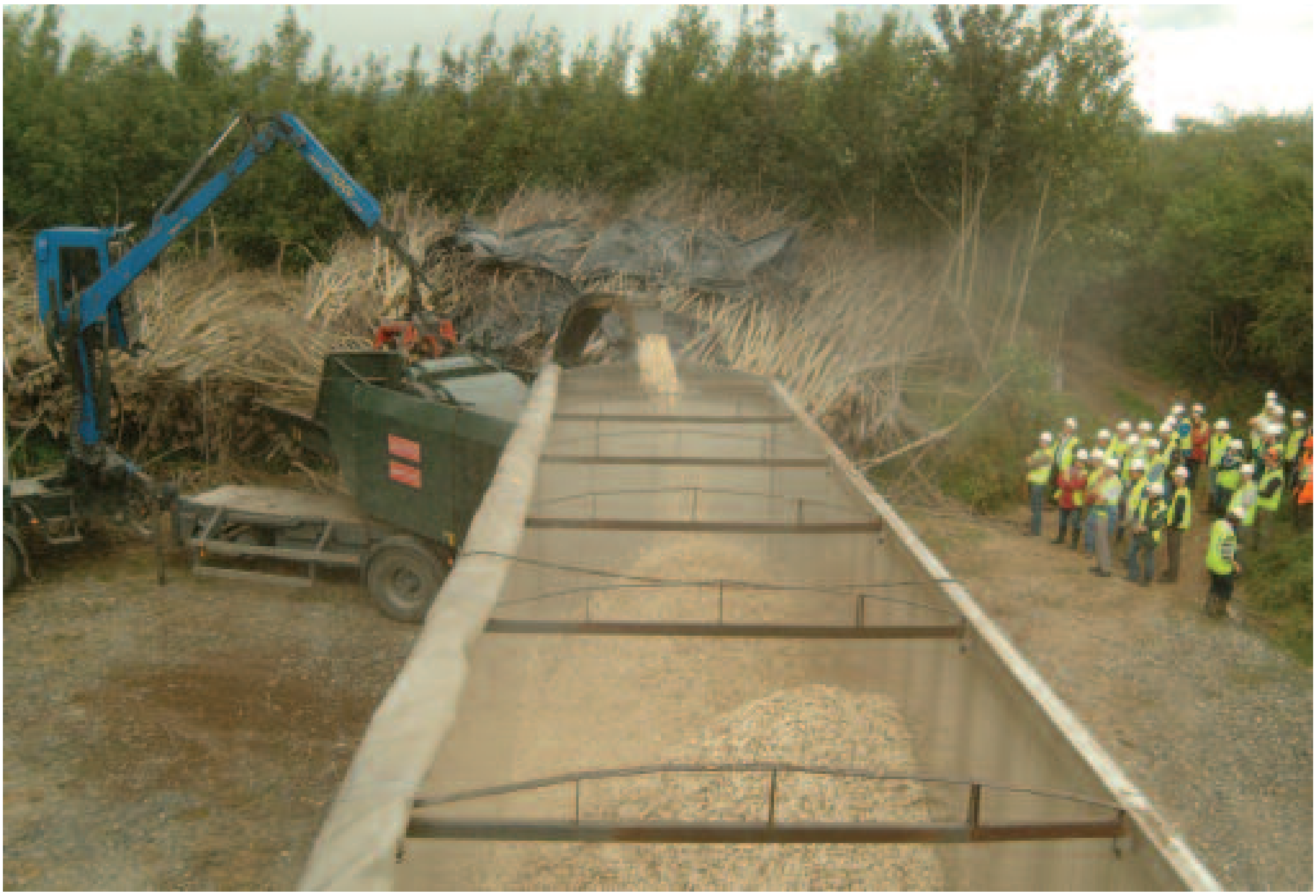
In 2006 a combined row and selection thinning was done using the feller-buncher: a three-axled Silvatec base machine, equipped with a parallelogram crane and a Silvatec felling head. The felling head has a stabilising cylinder that enables it to take trees out in a standing position. The head also has a set of accumulating arms, instead of feed rollers and delimbing knives, so that more than one tree in a cycle could be felled and lifted out to the rack.

The Silvatec chipper is a self-propelled machine, developed for chipping trees in confined spaces in the stand. In Denmark, 500 mm wide tyres are normally used, but for operations in Ireland these were replaced with wider 600 mm tyres to increase flotation. In the 2008 chipping trials, these tyres were complemented with band tracks. The front-mounted chipper can handle trees up to 35 cm in diameter. Chips are blown to the rear of the machine into a 15-17 m^3 storage tank, that can be lifted high in the air to unload the chips into a chip forwarder.

The chip forwarders were also equipped with wider tyres than are usually used in Denmark. In 2008, after a few days of trials without band tracks, it became necessary to mount tracks on the forwarder to increase flotation and traction.

The chip forwarder transports the chips from inside the stand to the roadside, where chips can be tipped into containers or other vehicles for road transport.

Tractor mounted TP 280 chipper on a Valmet tractor towing a high tipping trailer.



Jenz 700 truck mounted chipper blowing chips from the pile of whole trees into a walking-floor truck.

In 2006, a tractor-mounted, terrain-going TP280 disk chipper mounted on a large Valmet tractor, which was permanently reversed, was included in the trials. A hitch was attached to the tractor nose, so the machine could tow a high tipping trailer. Unlike the Silvatec chipper, this machine must travel to and from the stand to unload at the roadside.

In 2006, the chips were transferred to tractor-trailers or tipped onto the ground and reloaded onto walking floor trucks. In 2008, the whole-tree chip was again tipped at roadside and reloaded into walking-floor lorries.

Results

The average figures for the two years of study are reported. Further details will be presented in the final ForestEnergy project report.

Table 1 lists the average results of the operations in 2006 and 2008 for whole trees felled either by chainsaw (selection thinning) or by feller-buncher (combined row and selection thinning) and chipped either by Silvatec or TP tractor terrain chippers. One plot of whole ash trees received a line and selection thinning with the feller buncher, and the whole trees were forwarded and stacked at roadside and chipped with a Jenz 700 towed chipper. The results of this trial are presented for comparison.

The average total production cost of wood chip to roadside ranged from €26.88/$m^{3\ sb}$ to €62.38/$m^{3\ sb}$. The high costs were caused by the very small trees on the site and because the site was so small that the chipper could be reversed out of the stand and did not use the chip forwarder.

Factoring in the moisture content, the production cost per unit of wood energy ranged from €2.82/GJ to €7.09/GJ. There were large differences between the years in the total production cost per m^3 solid biomass. In 2006 the costs

System productivity

All operations were time studied, and the net productive time was recorded. Net productive time excludes all interruptions and, in order to reflect a normal working day, allowances were added to obtain work place time. Allowances include rest breaks, small repairs and other normal interruptions, but exclude events such as major breakdowns and bogging. as these are unpredicatable By adding 30% allowances for machine work, and 70% for chainsaw work, productive machine hours (pmh) was obtained.

Units

In all cases the volume of loose chips ($m^{3\ lv}$) from the chippers was converted to m^3 solid biomass ($m^{3\ sb}$) by using a conservative ratio: 1 $m^{3\ lv}$= 0.33 $m^{3\ sb.}$ All production figures and costs are expressed in $m^{3\ sb}$/pmh or €/$m^{3\ sb}$. With the measured moisture content of the chips at the time of chipping, the energy content of the chips is expressed in GJ/$m^{3\ sb}$ and the final cost is expressed in €/GJ.

were lowest due to the high productivity of both the felling and the chipping.

There was a lot of variation in the felling costs for the chainsaw operations. Differences between individual sites were even larger but have been evened out by averaging. This variation was primarily due to the additional work in presenting the selectively felled trees into the extraction rack line in 2008 compared to the line thinning of 2006. Additional factors causing variation in productivity are different levels of competence amongst chainsaw operators, the variation in mean tree size between different sites, as well as the thinning intensity.

Felling by feller-buncher was much more productive, but also more expensive due to the much higher hourly cost of the machine. Chipping was much faster after the feller-buncher, in comparison to the chainsaw-felled plots. This was because the feller-buncher could place the entire felled tree in the line, allowing the terrain chipper to continuously move forward. In the plots felled by chainsaw, the trees were presented at an angle to the chipper's direction of travel, forcing the chipper to stop/start as each tree was fed in.

Forwarding whole trees to the roadside, and chipping them after summer drying under cover resulted in a very good fuel with low moisture content, but the costs were higher

Table 1: Overview of productivity and costs of the whole-tree method with terrain chipping in broadleaves.

Year	2006	2006	2006	2006	2008
Number of sites	1	1	1	1	2
Thinning type	Line	Line	Line+selective	Line+selective	Line+selective
Thinning method	Chainsaw	Chainsaw	Feller-buncher	Feller-buncher	Chainsaw
Felling productivity (m^3/pmh)	4.24	4.24	9.13	6.3	1.47
Forwarding productivity	-	-	-	5.44	-
Chipping machine	TP280 Tractor	Silvatec	Silvatec	Jenz	Silvatec
Chipping productivity (m^3/pmh)	4.8	13.4	17.4	22.5	6.61
Chainsaw cost @ €25/pmh (€/$m^{3\ sb}$)	5.88	5.88			17.00
Feller-buncher cost @ €100/pmh (€/$m^{3\ sb}$)	-	-	10.95	15.88	-
Forwarding cost @ € 100/pmh (€/$m^{3\ sb}$)	-	-	-	16.57	-
Silvatec chipper cost @ €300/pmh (€/$m^{3\ sb}$)		21.96	19.99		45.39
TP tractor chipper cost @ €100/pmh (€/$m^{3\ sb}$)	21.00				
Jenz truck chipper cost @300/pmh (€/$m^{3\ sb}$)				11.91	
Total cost (€/$m^{3\ sb}$)	26.88	27.84	30.94	44.36	62.38
Average energy content (GJ/m^3) at chipped MC	9.5	9.8	9.2	10.9	8.8
Average energy cost to roadside (€/GJ)	2.82	2.85	3.37	4.07	7.09

than terrain chipping operations on the same site. It is important to note that trees were felled in early spring, prior to leafing, so the felled trees could be stacked at roadside. Stacking whole trees with leaves attached is not recommended as leaf decomposition promotes rot and restricts drying.

An estimate of the delivered cost of wood energy to the end user may be made by including some assumptions on the whole chain costs. If the forest owner gets €5 per m^3 solid biomass (stumpage), then the total cost at the roadside delivered in containers would be in the order of €3.37 to €7.64 per GJ. The cost of road transportation needs to be added to arrive at a delivered-in price. Depending on the distance to be covered, this could add another €1.50/GJ, giving a total delivered-in cost at the plant of €5.36 to €10.05 per GJ. In this calculation a 10% allowance for a management fee for the wood fuel trader is included. Since the trees have been felled several months prior to the chipping, an interest cost has accrued on the felling cost. The management fee also includes interest on the felling expenses.

Stumpage (€5/$m^{3\ sb}$) €/GJ	€ 0.55
Chipping operation €/GJ	€ 2.82 - € 7.09
Road transportation 50 km €/GJ	€ 1.50
Traders allowance 10% €/GJ	€ 0.49 - € 0.91
Total delivered-in cost €/GJ	€ 5.36 - € 10.05

Conclusions

The total delivered-in costs of this type of wood fuel from broadleaf thinnings at a major consumer would be in the order of €5.36- €10.05 per GJ, or roughly €50-94 (€61-115) per tonne at 45-35% moisture content. These data are based on fewer stands than the results of the softwood thinnings. More data are required, especially considering the large variation in costs.

Seasoning whole trees at the stump ensures that leaves, which contain most nutrients, have time to wither and fall off, maintaining soil fertility. Also, the wood dries efficiently at the stump as the leaves transpire water from the stem. Even after one summer, cut stems had dried sufficiently to be supplied as fuel to boilers requiring chips with a moisture content below 35%. However, harvesting operations in broadleaves are best carried out in winter when the trees are bare of leaves and the moisture content in the standing tree is naturally low – for example in ash a moisture content of 36% was recorded in February. This means trees can be felled, chipped and the fuel dispatched over a period of weeks.

The absence of a brash mat for machinery is a major concern in utilising whole-tree thinning in Ireland. Ground-bearing capacity was a problem each year, not only for the chipping operation. Better soil conditions were found in the broadleaf stands and rutting was prevented by using band tracks.

Line thinning by chainsaw was fast, and produced the lowest cost wood chip, but the benefit to the stand of line thinning only was limited.

Where line and selection thinning was carried out by chainsaw, the trees were presented in a herringbone pattern, which meant that the chipper had to wait until almost the whole tree was chipped before it could move forward again. Felling by feller-buncher increased the productivity of the terrain chipper, because the chipping machine could move forward almost continuously.

Forwarding after the feller-buncher and chipping at the roadside produced a dry fuel, but the costs were higher than for the terrain chipping.

*For information and a free on-line advisory service on the wood energy supply chain, the quality of wood fuels and internal handling visit **www.woodenergy.ie***