WOOD FUEL SUPPLY CHAIN IN THE UNITED KINGDOM*

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ABSTRACT

Recent developments in the provision of subsidies for large-scale electricity generation in the United Kingdom have created annual markets for some 400 000 oven-dry tonnes of wood fuel from the year 2000. However, wood fuel supply costs are only on the very edge of economic viability. There will have to be major technological advances in the supply chain to contain costs, and to ensure an adequate profit element for harvesting contractors to encourage capital investment in wood fuel harvesting equipment.

A number of harvesting systems are likely to be adopted in the United Kingdom. Trials into residue compaction systems linked to large-scale comminution at the generation plants are currently ongoing and, subject to results, are likely to form one of the supply systems to be adopted. Compaction trials of the Swedish Bala Press baling system were carried out in the United Kingdom in 1996 and 1997. Results of the trials indicated greater productivity was needed to reduce costs. Trials in 1999 are concentrating on the Swedish Fibrepac compaction equipment that is being introduced into a number of harvesting systems. Investigations are also ongoing into road and rail transport of the compacted residues.

Keywords: harvesting systems; supply chain; residue compression systems; second-pass residue harvesting; one-pass systems; integration; transport.

INTRODUCTION

The use of biomass as an energy source is on the edge of economic viability, and dependent in many countries on some form of market support or production subsidy. Such a subsidy for wood fuel in Great Britain has resulted from Government legislation for subsidised electricity generation from renewable sources under the fourth round of the Non Fossil Fuel Obligation (NFFO4) 1996, and the Scottish Renewables Order (SRO) 1996. Seven electricity generation plants with a generating capacity of 67 MW were approved in the 1996 round of NFFO, 52 MW in England and 15.25 MW in Wales, with a further 2 MW in Scotland under the SRO. The first of the electricity generation plants is now under construction and, in total, there is a potential market for some 400 000 oven-dry tonnes of wood fuel per year from the year 2000. The location of the plants was political rather than

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a reflection of the location of the available resource. As a result, there will need to be a movement of a major element of the supply over some considerable distance to the approved generation plants.

WOOD FUEL HARVESTING SYSTEMS

With the exception of wood fuel from specialist energy crops, either short-rotation coppice or single trees grown specifically as an energy crop, it is most likely that in Great Britain wood fuel will be a co-product along with other conventional wood products from forest or woodland in clearfell operations. As such, wood fuel harvesting will, by necessity, as part of the overall harvesting process, become part of an integrated harvesting operation along with the conventional sawlogs and small roundwood products.

There are five elements in any wood fuel harvesting system:

- Felling
  (cutting the tree from its stump)
- Separation (unless whole-tree chipping, e.g., early thinnings)
  (separation of the multiple products—felling, delimbing, and cross cutting into logs, small roundwood, and separation of the energy element)
- Extraction
  (from the stump to the forest road)
- Transport
  (from the forest to the end user plant)
- Comminution *
  (the breaking down of the wood fuel into a homogeneous fraction suitable for the conversion process)
- Storage *
  (storage of the wood fuel in the forest, at a buffer plant or at the end product user)

Thinning operations in the United Kingdom concentrate on the removal of the poorer quality trees from within the crop whilst opening up the canopy to allow the remaining trees to put on additional increment. Clearfelling is concerned with 100% removal of the tree crop.

The harvesting system adopted can be defined by the number of passes that are required from the forest road to the stump to extract the multiple products, these products are the sawlog, small roundwood (chip/pulp wood), and the wood fuel element:

One-pass Systems

The whole tree is felled and then the multiple products are extracted as the whole tree moves in a single pass, to the forest road, landing, or central processing plant where the tree is processed and the conventional roundwood and energy products are separated. This operation is used only within clearfell operations.

One-pass systems are in use throughout Europe and North America where they operate commercially producing an energy product in addition to conventional roundwood products.

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* Not necessarily in this order

The most common system in use in North America is chain flail delimbing/debarking and in-woods chipper, with the white wood chip used in pulping and the residues for hog fuel (Watson & Twaddle 1990). This harvesting system is in use on a limited scale in the United Kingdom with white wood chip used in the production of Medium Density Fibreboard (MDF), but at the present time no market exists for the residues as wood fuel (Hudson 1997).

One-pass harvesting systems can take a number of forms and utilise equipment in a variety of combinations. They are systems that require high levels of mechanisation, needing a minimal investment in excess of £275,000 (Mitchell *et al.* 1990). In an operation (producing wood fuel) that initially may have a relatively insecure market, this carries a high risk. One such system that is in use at the present time, and is increasing, is that of extraction of the whole tree by cable crane. In this operation the whole trees are felled and extracted to the roadside where they are processed into conventional roundwood assortments. This results in large bins of residues being left at the roadside; these have a high potential for wood fuel.

Two-pass Systems

British forestry harvesting operations currently concentrate on the recovery of stemwood for use in the production of sawn timber, and small roundwood for the production of wood-based panels and pulp for paper and carton board; there is little or no recovery of wood fuel. After conventional shortwood harvesting in which the trees are felled, delimbed, and cross-cut into different assortments at the stump, the residues are left on site; if the system is mechanised then the residues will be left in windrows.

The introduction of a wood fuel harvesting element utilising available residues takes place as a second-pass operation after the extraction of the tradtional timber assortments.

Options are:

(1) Terrain comminution using a forwarder-mounted chipper and integral chip bin

(2) Extraction of loose residues for later comminution

(3) Extraction of compacted residues or compressed residues for later comminution

Integration

In any harvesting system, regardless of the point of separation of the products, or the point of comminution, the introduction of the wood fuel element **MUST** be integrated with the harvesting of the conventional products. Any wood fuel must be received at the end-user plant free of contamination. The harvesting Contractor must, at the outset of the harvesting operation, decide the means and methods as to how this can be achieved and must organise the harvesting equipment movements to harvest a contamination-free wood fuel product. Invariably, given ground conditions on many forest sites, a proportion of the residue material will be used as a brash mat for support of the harvesting equipment over wet soils. Harvesting routes and separation of the products at the point of delimbing must be considered at the outset of the operations and the potential wood fuel element separated at this point in the process. Extraction routes have to be planned to avoid moving over the wood fuel product. In addition, consideration will be needed at the planning stage to the type and amount of wood fuel that will be removed. This decision will be influenced by the demand for the smaller dimension timber products, and there will always be the option for the top diameter to be varied and the potential for whole tops to be retained as a single wood fuel element with the remaining branches and twigs used in the brash mats.

Residue Compression Systems

"A major cost in the supply of wood fuel is the transport from the point of production to the end user plant" (Forestry Contracting Association 1997). In traditional wood fuel harvesting systems, the comminution element of the harvesting operation has taken place at the forest. Costs of comminution at this point are high because of the scale of the operation and the need for the specialist comminution equipment to be mobile and serviceable in the forest. A further problem with this system is that it requires high capital investment in the harvesting sector. Comminution at the end-user plant offers economies of scale giving a lower cost for wood fuel, and also means less capital investment required in the harvesting system. The problem with comminution at the end-user plant is that, due to their high volume to weight ratio, the transport of residues in unprocessed form meant that economic payloads could not be obtained with the transport system.

Recent trials carried out in Britain and Sweden (Andersson & Hudson 1997; Hudson 1997) indicated that a substantial reduction in the transport costs of forest residues can be achieved by compressing the residue by the use of baling techniques prior to transport. A combination of compression to reduce transport costs, allied to large-scale comminution at the end-user plant, offers considerable potential for cost savings in the supply of wood fuel. The opportunity to store wood fuel in bale form prior to comminution could minimise dry matter losses, and ventilation through the bale could encourage quicker and even drying.

The compression of residues offers the following advantages over existing wood fuel harvesting systems:

- Maximising of load density of residue
- Harvesting system becomes "colder"—less interdependence between elements within the system
- Comminution at end-user-scale opportunities leading to reduced costs
- Less capital investment required
- Opportunity to integrate into existing shortwood and whole-tree harvesting systems.

Bala Press

A first stage in the development of residue compression systems was a joint development by Bala Press (manufacturers of compression equipment for the waste industry) and Trad-Energi Vast (a commercial wood fuel supply company) in Sweden of a machine capable of compressing forest residues into cylindrical "bales" of 1.2 m diameter, weighing from 435 to 569 kg (Forestry Contracting Association 1996). The individual weight of the bales is dependent on tree species and moisture content at time of baling. It was found that economic payloads could be met when transporting on flatbed articulated lorry trailers (Forestry Contracting Association 1996). Baling costs ranged from £3.95 to £4.75 per bale (£6.94–£10.91 per green tonne) (Forestry Contracting Association 1996).

Although the baling of the forest residues offers several advantages over conventional wood fuel harvesting systems, the following areas require improvement:

- The baling element results in a high production cost, making the system on the edge of economic viability;
- The shape and size of the bale do not offer the ability to utilise existing extraction and transport machinery;
- The material used to tie the formed bales represents a high proportion of the production cost—this needs to be reduced.

The Bala Press was developed for use in the municipal waste industry, to bale and wrap waste to meet summer and winter fuel demands. Therefore, the technology was not invented specifically for forestry and to date there are only three Forest Bala Presses in commercial operation.

Fiberpac

The high purchase cost and high production costs of the Bala Press have led to the development of a new machine for compressing forest residues. The Fiberpac machine is mounted on a forwarder with its own integral loader and grapple. The residues are loaded on to the feed table; the Fibre-pack unit is able to slew, allowing a multi-directional feed. The residues are fed into the compression chamber via feed rollers. The first compression chamber is fixed and pivoted from the top, the secondary compression chamber is on a stroke arm and pivoted from the bottom. Both chambers are fully synchronised and automated, the operator simply has to feed the material. As the residue log emerges from the machine it is tied with fine polypropylene twine, four wraps at either end of the log and two wraps in-between at 0.5-m intervals. Once the log is at the required length, it is cut to size with a hydraulically driven chainsaw blade. The weight of the Fiberpac machine is approximately 6.5 tonnes. Average size of the fibre log is 70 cm diameter with a length of 3.1–3.6 m. Average fibre log weight is approximately 500 kg in residue material of approximately 45% moisture content. The Fiberpac machine offers the following advantages:

(1) High productivity due to "continuous flow process"
(2) Lower overall weight
(3) Cost reduction with twine tying system
(4) Size and shape of fibre log offers ability to utilise existing equipment without modification (forwarders and timber lorries)
(5) Size and shape of fibre log offers cost savings in future handling within central processing yard.

Forest Residue Due Diligence Assessment, Proving and Transport Trials

The FCA along with several industry partners is currently conducting a Department of Trade and Industry-funded project. The project "Forest Residue Due Diligence Assessment, Proving and Transport Trials" has looked at the available compression technology, purchased a Fiberpac compression machine, and is currently conducting harvesting, transport, and storage trials on a variety of sites throughout Scotland and England.

The harvesting trial runs for a period of 3 months—August to October 1999. The trial concentrates on compressing material from both one- and two-pass harvesting systems. The first month of the trial has focused on recovering wood fuel from two-pass harvesting systems—shortwood harvesting sites. The shortwood system has to be altered both to avoid contamination of the wood fuel element, and so as not to directly affect the productivity of the harvesting equipment whilst at the same time minimising the effect of the system on the environment. Two methods have been adopted in order to facilitate this:

- Alternate brash mat method
- Long tops and mat minimisation method.

Wood fuel recovery systems in clearfell operations

Alternate brash mat method: This method has been adopted on the wetter sites where a considerable quantity of residue is necessary to support harvesting and extraction equipment used to harvest the conventional roundwood products. The harvester will fell and delimb a normal drift width (approximately 12 m), all roundwood is placed to the left of the machine at right angles to the direction of travel. All residue is placed in front of the harvester; the residue mat formed by the 12-m drift becomes the main extraction route for the roundwood and wood fuel products. The next drift harvested is narrower (approximately 9 m) which enables the roundwood to be placed closer to the main extraction residue mat to facilitate loading by forwarder. Once all roundwood is extracted the Fiberpac travels between the residue mats utilising wood fuel from the 9-m residue mat. This residue mat has only been travelled on once by the harvester, therefore minimal contamination of the wood fuel element has occurred. The Fiberpac has been adapted to United Kingdom conditions with the fitting of 700-mm-wide tyres and band tracks all round to ensure maximum flotation whilst travelling between brash mats. Residue yields with this method have been in the region of 40–50 green tonnes per hectare (GT/ha).

Long tops and mat minimisation method: This method is restricted to the mineral soil areas or summer working on more marginal sites. As the harvester fells and delimbs, all roundwood is placed to the left of the machine, with the minimum quantity of brash being placed in front of the machine. After the last roundwood product has been cut (top diameter of approximately 7 cm) the wood fuel element/long top (length approximately 2–6 m) is placed to the right of the machine at 45 degrees to the brash mat. Once roundwood is extracted the Fiberpac will travel down each brash mat collecting and compressing the wood fuel ready for subsequent extraction by forwarder. Residue yields are in the region of 80–100 GT/ha; this system offers maximum residue yield with zero contamination. The available yield will be affected by the minimum top diameter required by small roundwood processors driven by small roundwood market conditions.

Machine productivity

Two operators were given full training by the Fiberpac manufacturers over a period of 5 working days, it must be noted that in the first month of the harvesting trial the operator is still on a sharp learning curve. Despite this fact, initial productivity figures, taking other factors into account, were positive. The following machine productivity figures are based on the data obtained from second-pass harvesting using the alternate brash mat method. The data were obtained over the intial trial period of 14 working days.

Methodology: All machine productivity data—shift length, machine hours, downtime (maintenance, mechanical Fiberpac, mechanical forwarder, other), and number of Fiberlogs produced per shift were recorded electronically by the machine operator.

Results: Availability for the first trial period has been low at 56% due to technical problems with the cutting mechanism; engineering modifications aim to solve this problem. Fiberlogs per productive machine hour have been in the range of 4.7–17.3/h, an average of 9.6 Fiberlogs/h. Fiberlog weight was found to be in the range 338–784 kg, an average weight of 564 kg. All Fiberlogs are 3.6 m in length with a diameter of 70 cm. This gives a productivity of 2.6–9.7 GT/h, an average productivity of 5.4 GT/h. Productivity data are given in Fig. 1.

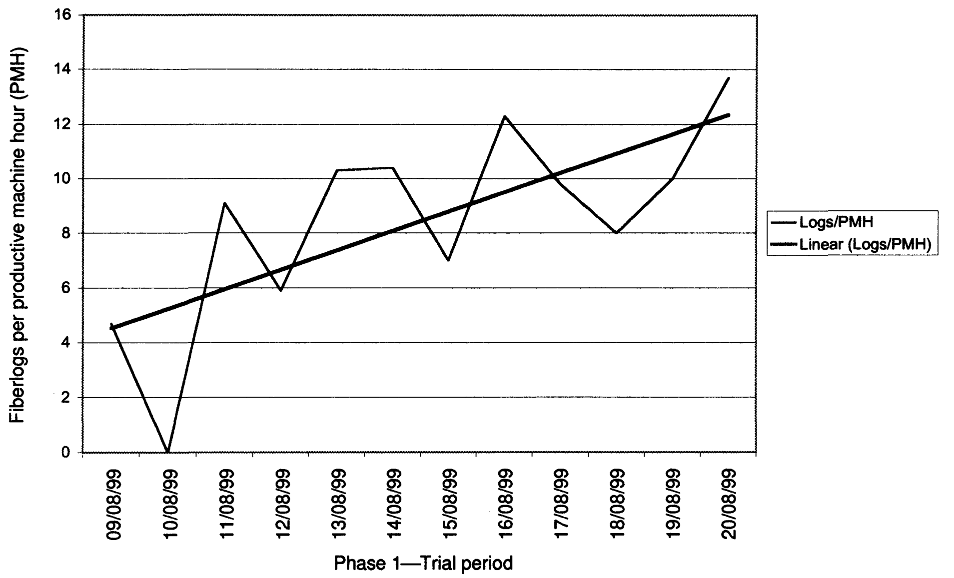

Fig. 1–Fiberpac productivity—Phase 1 trial period

Fiberlog extraction: With any terrain-based second-pass harvesting system the movement of the wood fuel product from the stump to roadside carries a cost. Fiberlogs were extracted on a Timberjack 1210B (12 tonne) forwarder. The bunk length of the Timberjack 1210B allows only one bay of 3.6-m Fiberlogs to be carried; therefore a total of 11 Fiberlogs can be carried in one load, a load weight of 6.2 tonnes. The forwarder is loaded to only 52% of its capacity. The short extraction distance on the site (maximum of 200 m) and the short loading and unloading time gave productivity of 90 GT/shift. This gives a stump to roadside cost of £4.06/GT (*see* Appendix 2). This cost can be reduced further by using a larger forwarder on the dryer sites or, if necessary, by minor engineering modifications to the forwarder bunk. This will be necessary on sites with a longer extraction distance.

Fiberpac costs including extraction to roadside: Costs for compression of the wood fuel element have been calculated with the Forestry Contracting Associations Machine Cost System (*see* Appendix 1). Costs ranged from £9.79 to £36.35/GT, with an average cost of

£16.96/GT. From samples taken from the compressed material the moisture content was 37.2%. This gives a average compression cost of £27.01/oven dry tonne (ODT). With an extraction cost of the Fiberlogs to roadside of £4.06 /GT this gives an average roadside cost of £21.02/GT (£33.47/ODT). To enable the wood fuel to be delivered at an economic cost, productivity will have to increase to allow a sufficient reduction in the cost of the production and extraction of Fiberlogs from stump to roadside (*see* Fig. 2).

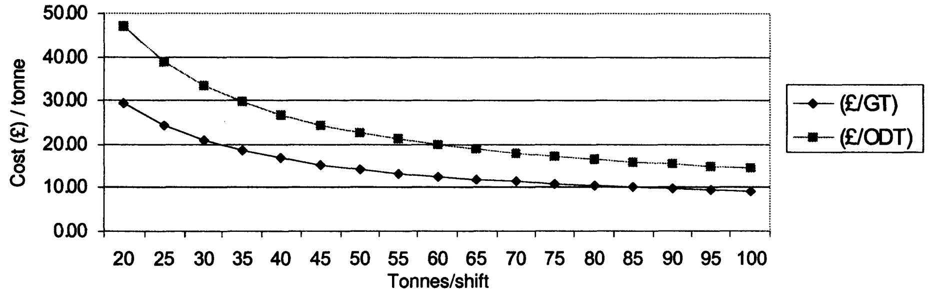

Fig. 2–Sensitivity analysis – Fiberpac compression costs

Phase 1 of the harvesting trial has seen an average of 9.6 Fibrelogs (5.4 green tonnes) per productive machine hour. This is despite the following factors:

- Learning curve for machine operator
- Technical problems with the cutting mechanism which lowered productivity.

From studies conducted in Sweden in September 1999 when the Fiberpac unit was being assessed for use in United Kingdom conditions, productivity in the region of 15 Fibrelogs per productive machine hour (PMH) (8.4 GT/PMH) was attained. When the engineering modifications on the cutting mechanism have been completed an increase in the level of productivity is envisaged.

Systems cost analysis

Compressing residue bears costs which cannot be viewed in isolation; it is as transport distances increase that benefits can be obtained from the increased load that can be carried. The cost of the total system is directly related to transport distance. Fiberpac costs must be considered as part of an integrated supply system maximising the logistical and practical benefits that the system can offer in relation to transport distances of the compressed residues. Fiberpac costs are based on a productivity of 15 Fiberlogs/PMH (8.4 GT/PMH).

A series of comparative system costs has been calculated over a one-way distance of 100 km (Table 1) and 200 km (Table 2).

Three systems have been compared:

(a) **Residue compression and comminute at the end user plant**
Maximising the increased load density of the baled residue, and benefiting from the reduced costs of comminution by the scale opportunities that are offered at the end user plant.

(b) **Extraction of residues, chip at the forest landing, and transport of chips**
The "conventional system".

TABLE 1–System costs including extraction, 100 km one-way transport distance

System	Fiberpac (£/GT)	Extraction (£/GT)	Comminution (£/GT)	Transport (£/GT)	Total (£/GT)	Total (£/ODT)
(a) Fiberpac	11.31	4.06	1.20	3.83	20.40	32.48
(b) Chip	0.00	9.12	4.22	4.33	17.68	28.15
(c) Loose residue	0.00	9.12	1.20	7.67	17.99	28.65

TABLE 2–System costs including extraction, 200 km one-way transport distance

System	Fiberpac (£/GT)	Extraction (£/GT)	Comminution (£/GT)	Transport (£/GT)	Total (£/GT)	Total (£/ODT)
(a) Fiberpac	11.31	4.06	1.20	6.50	23.06	36.73
(b) Chip	0.00	9.12	4.22	7.00	20.34	32.40
(c) Loose residue	0.00	9.12	1.20	13.00	23.32	37.14

(c) **Extraction of uncomminuted and uncompressed residues with chip at the end user plant.**
Avoids the need for compression and benefits from the reduced costs of comminution by the scale opportunities that are offered at the end user plant; however, economic payloads in the transport element are difficult to obtain.

At 100 km transport distance, System (b) is the most cost-effective with a delivered-in price of £28.15/ODT compared with £32.48/ODT for the Fibrepac System (a). As transport distance increases, the benefit of compressing the residue becomes apparent in direct comparison to System (c). In this systems analysis the Fiberpac compression system remains uncompetitive with System (b) at a transport distance of 200 km.

The compression of residues offers the following advantages over existing wood fuel harvesting systems:
- Maximising load density of residue
- Comminution at end user-scale opportunities leading to reduced costs
- Less capital investment required
- Opportunity to integrate into existing shortwood and whole-tree harvesting systems.

Despite the advantages shown above, there is still a need to improve Fiberpac productivity to give savings in the delivered price of the wood fuel at a transport distance of 200 km. The productivity and production cost (including extraction) required are shown in Fig. 3.

Productivity needs to increase by 33% to 60 tonnes per shift for the Fiberpac system to give a delivered wood fuel price of £20.24/GT to be competitive with System (b) (in-forest chipper) which gives a delivered wood fuel price of £20.51/GT.

Transport

The transport element within the supply chain of forest products can represent up to 30% of the total supply chain cost when transporting lower value products such as small roundwood (Jaakko Poyry 1998). The cost of 4 hours' transport can be equal to that of 17 years of growing a pine tree (Gardner 1996).

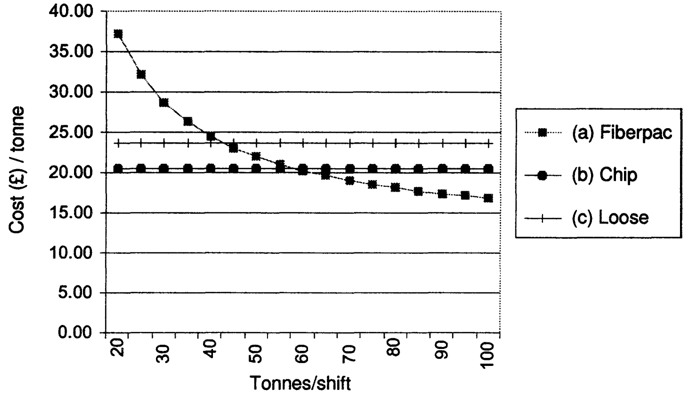

Fig. 3–Systems analysis – Required Fibrepac productivity

To fully utilise the haulage element of the supply chain the optimum length for the Fiberlogs is 3.6 m; this allows three bays of Fiberlogs, a total of 46 logs at 564 kg/Fiberlog. This allows a load of approximately 26 tonnes—+100% utilisation.

The shape and size of the Fiberlog offers the following advantages:

(1) Economic payloads can be obtained on conventional flat beds and more importantly specialist timber trailers

(2) If drying is to take place prior to comminution in the forest, economic payloads can still be obtained by using mixed loads of conventional roundwood products and Fiberlogs.

The introduction of the wood fuel element into the supply chain offers an opportunity to further improve efficiencies through the use of an integrated transport system.

With the wood fuel element coming into the system the transport price will be dependent on the following criteria:

- The moisture content of the material prior to transport
- Storage of the wood fuel in the forest prior to transport to the end user plant.

CONCLUSION

Large-scale use of wood fuel in Britain is proceeding only as a result of Government incentives. Given satisfactory construction and completion of the generation capacity currently approved, the result will be a market of 400,000 ODT/yr from the turn of the century.

The geographical location of the generation plants will necessitate lengthy supply chains. For economic transport of the wood fuel from forest residues there is a possibility of densifying the residues for transport. This would involve the introduction of compaction technology which offers many advantages over existing wood fuel harvesting systems. As the transport distance increases, the introduction of residue compaction will offer further savings in the wood fuel supply chain.

In any harvesting system, regardless of the point of separation of the products, or the point of comminution, the introduction of the wood fuel element must be integrated with the harvesting of the conventional products. Any wood fuel must be received at the end user plant free of contamination. Invariably, given ground conditions on many forest sites, a proportion of the residue material will be used as a brash mat for support of the harvesting equipment over wet soils. Harvesting routes and separation of the products at the point of delimbing must be considered at the outset of the operations and the potential wood fuel element separated at this point in the process. Extraction routes have to be planned to avoid moving over the wood fuel product. In addition, consideration will be needed at the planning stage as to the type and amount of wood fuel that will be removed.

The concept of compressing residues to minimise disruption to harvesting operations, reduce moisture content, and increase the density of transport and reduce transport costs, would appear to offer considerable potential given that productivity increases to a level at which supply chain costs become economically viable.

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APPENDIX 1

MACHINE COSTING—FIBREPAC COMPRESSION MACHINE

FORESTRY CONTRACTING ASSOCIATION
Machine cost system (cash flow basis)

Ownership cost			
Machine cost (£)	246,116	Depreciated value	50,000
Risk/profit (% of machine cost)	8	Risk/profit	19,689.28
Availability (%)	90	Equipment life (years)	11
Shifts/day	1	Monthly payment (£/month)	3,145.87
Available days per year	230	Annual payment (£/year)	37,750.41
Equipment life (hours)	14,000	Licence and insurance (£/year)	2,461.16
Interest (%)	6.5	Annual ownership cost (£/year)	59,900.85
Licence, Insurance (%) or	1	Equipment hours/year	1,242.00
Licence, Insurance (£/year)	0	**Ownership (£/hour)**	**48.23**

Operating cost					
Maintenance (% capital cost over life) or	100				
Maintenance (£/year)					
Fuel consumption (l/hour)	30				
Fuel cost (£/l)	0.14				
Oil consumption (l/hour)	1				
Oil cost (£/l)	1				
Consumables	Number	Hours	£/unit	Total £	£/hour
	10	1	0.06	0.6	0.60

		Maintenance (£/year)	21,834.00514
Twine		Maintenance (£/hour)	17.58
Turns per log =	25	Fuel (£/hour)	4.20
Length twine per turn =	2.2	Oil (£/hour)	1.00
Twine price per metre =	0.0011	Consumable (£/hour)	0.60
Price per log =	0.06	**Operating (£/hour)**	**23.38**

Labour cost			
Operator (£/shift)	75		
Operators	1		
Fringe benefits (% wage)	0	Direct labour (£/hour)	13.89
Paid hours/shift	10	Fringe benefits (£/hour)	0.00
		Labour (£/hour)	**13.89**
Idle time analysis			
Maintenance (min/shift)	90	Idle time per shift (hours)	4.00
Rest (% shift)	15	Machine hours per shift	5.40
Utilisation (%)	90	Machine hours/day	5.40
		Total cost (£/hour)	**85.50**
Overheads			
Number of machines	1		
Category	£/year		
Communications	500		
Public and Employers liability	400		
Office (stationery, rent, etc.)	200		
Marketing	0		
Bank charges and interest	500		
Professional fees	250		
Machine transport	6,000		
Vehicles	3,000		
Salaries and wages	0	Total overheads (£/year)	10,850.00
Other overheads		Total per machine (£/year)	10,850.00
		Total overheads (£/hour)	**8.74**
Productivity information			
Productivity (tonnes/shift)	45	Production (tonnes/hour)	8.33
Fiberlogs/h	10	Production (tonnes/year)	10,350
Fiberlog weight (kg)	564	Production cost (£/year)	117,038
Fiberlog moisture content (%)	37.2	**Production cost (£/GT)**	**11.31**
		Production cost (£/Fiberlog)	**6.38**
		Production cost (£/ODT)	**18.01**

N.B. Maintenance and rest allowance covered in productivity figures.

APPENDIX 2

MACHINE COSTING—FORWARDER EXTRACTING FIBRELOGS

FORESTRY CONTRACTING ASSOCIATION
Machine cost system (cash flow basis)

Ownership cost						
Machine cost (£)	140,000		Depreciated value			50,000
Risk/profit (% of machine cost)	8		Risk/profit			11,200
Availability (%)	90		Equipment life (years)			10
Shifts/day	1		Monthly payment (£/month)			2,157.41
Available days per year	230		Annual payment (£/year)			25,888.94
Equipment life (hours)	12,000		Licence and insurance (£/year)			1,400.00
Interest (%)	6.5		Annual ownership cost (£/year)			38,488.94
Licence, Insurance (%) or	1		Equipment hours/year			1,242.00
Licence, Insurance (£/year)	0		**Ownership (£/hour)**			**30.99**
Operating cost						
Maintenance (% capital cost over life) or	100					
Maintenance (£/year)						
Fuel consumption (l/hour)	20					
Fuel cost (£/l)	0.14					
Oil consumption (l/hour)	1					
Oil cost (£/l)	1					
Consumables	Number	Hours	£/unit	Total £	£/hour	
				0	0.00	
				0	0.00	
				0	0.00	
				0	0.00	
			Maintenance (£/year)			14,490
			Maintenance (£/hour)			11.67
			Fuel (£/hour)			2.80
			Oil (£/hour)			1.00
			Consumable (£/hour)			0.00
			Operating (£/hour)			**15.47**
Labour cost						
Operator (£/shift)	80					
Operators	1					
Fringe benefits (% wage)	0		Direct labour (£/hour)			14.81
Paid hours/shift	10		Fringe benefits (£/hour)			0.00
			Labour (£/hour)			**14.81**
Idle time analysis						
Maintenance (min/shift)	90		Idle time per shift (hours)			4.00
Rest (% shift)	15		Machine hours per shift			5.40
Utilisation (%)	90		Machine hours/day			5.40
			Total cost (£/hour)			**61.27**
Overheads						
Number of machines	1					
Category	£/year					
Communications	500					
Public and Employers liability	400					
Office (stationery, rent, etc.)	200					
Marketing	0					
Bank charges and interest	500					
Professional fees	250					
Machine transport	3,000					
Vehicles	3,000					
Salaries and wages	0		Total overheads (£/year)			7,850.00
Other overheads			Total per machine (£/year)			7,850.00
			Total overheads (£/hour)			**6.32**
Productivity information						
Productivity (tonnes/shift)	90		Production (tonnes/hour)			16.67
			Production (tonnes/year)			20,700
			Production cost (£/year)			83,949
			Production cost (£/tonne)			**4.06**

N.B. Maintenance and rest allowance covered in productivity figures.

APPENDIX 3

MACHINE COSTING—FORWARDER EXTRACTING LOOSE RESIDUE

FORESTRY CONTRACTING ASSOCIATION
Machine cost system (cash flow basis)

Ownership cost						
Machine cost (£)	140,000		Depreciated value			50,000
Risk/profit (% of machine cost)	8		Risk/profit			11,200
Availability (%)	90		Equipment life (years)			10
Shifts/day	1		Monthly payment (£/month)			2,157.41
Available days per year	230		Annual payment (£/year)			25,888.94
Equipment life (hours)	12,000		Licence and insurance (£/year)			1,400.00
Interest (%)	6.5		Annual ownership cost (£/year)			38,488.94
Licence, Insurance (%) or	1		Equipment hours/year			1,242.00
Licence, Insurance (£/year)	0		**Ownership (£/hour)**			**30.99**
Operating cost						
Maintenance (% capital cost over life) or	100					
Maintenance (£/year)						
Fuel consumption (l/hour)	20					
Fuel cost (£/l)	0.14					
Oil consumption (l/hour)	1					
Oil cost (£/l)	1					
Consumables	Number	Hours	£/unit	Total £	£/hour	
				0	0.00	
				0	0.00	
				0	0.00	
				0	0.00	
			Maintenance (£/year)			14,490
			Maintenance (£/hour)			11.67
			Fuel (£/hour)			2.80
			Oil (£/hour)			1.00
			Consumable (£/hour)			0.00
			Operating (£/hour)			**15.47**
Labour cost						
Operator (£/shift)	80					
Operators	1					
Fringe benefits (% wage)	0		Direct labour (£/hour)			14.81
Paid hours/shift	10		Fringe benefits (£/hour)			0.00
			Labour (£/hour)			**14.81**
Idle time analysis						
Maintenance (min/shift)	90		Idle time per shift (hours)			4.00
Rest (% shift)	15		Machine hours per shift			5.40
Utilisation (%)	90		Machine hours/day			5.40
			Total cost (£/hour)			**61.27**
Overheads						
Number of machines	1					
Category	£/year					
Communications	500					
Public and Employers liability	400					
Office (stationery, rent, etc.)	200					
Marketing	0					
Bank charges and interest	500					
Professional fees	250					
Machine transport	3,000					
Vehicles	3,000					
Salaries and wages	0		Total overheads (£/year)			7,850.00
Other overheads			Total per machine (£/year)			7,850.00
			Total overheads (£/hour)			**6.32**
Productivity information						
Productivity (tonnes/shift)	40		Production (tonnes/hour)			7.41
			Production (tonnes/year)			9,200
			Production cost (£/year)			83,949
			Production cost (£/tonne)			**9.12**

N.B. Maintenance and rest allowance covered in productivity figures.