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Small-scale Systems for Harvesting Woodfuel Products

TECHNICAL NOTE

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SUMMARY

Small woodlands in Great Britain are a potential source of woodfuel for local heating, but there are difficulties identifying efficient harvesting systems. This Technical Note provides guidance on the selection of appropriate systems for small-scale harvesting operations. It considers four factors that influence the overall selection: i) woodland type and woodfuel product(s); ii) site and management constraints; iii) harvesting system options and iv) extraction machinery options. The guidance is based on a comprehensive series of case studies undertaken by Forest Research. A summary of the woodfuel production costs for the woodland types studied and a comparative summary of harvesting options are provided as tables.

INTRODUCTION

The area of publicly and privately owned small woodlands (<10 ha) in Great Britain extends to over 0.4 million hectares. There is significant potential to produce woodfuel for local heating requirements from this resource, however it is often difficult to identify efficient harvesting systems because many of the woodlands are:

- undermanaged and often of low timber quality;
- difficult to access;
- deficient in road or track infrastructure;
- frequently remote from main markets.

This Technical Note gives guidance on the selection of harvesting systems which would be appropriate for small-scale operations, particularly those which could provide woodfuel either on its own in whole, or as part of a more diverse product mix. The guidance is based on a comprehensive series of case studies undertaken by Forest Research which are described in full in the report *Supply of wood fuel from small-scale woodlands for small-scale heating* (ETSU, 1999). The report provides more detailed information on outputs, costs and systems descriptions for the sites studied and recommended systems of work.

Many of the systems and machines described here are regularly used in forestry, and the principles to consider when selecting the most appropriate options are often those associated with normal harvesting practice. However, wood-fuel products such as whole trees, very small diameter trees, and small diameter material from crowns and branches may not be extracted during normal forestry operations.

SELECTING SYSTEMS FOR SMALL-SCALE HARVESTING

There are four key sets of factors that influence the overall selection of an effective harvesting operation:

- woodland type and woodfuel product;
- site and management constraints;
- choice of harvesting system;
- choice of extraction machinery.

The first three factors when taken together will influence the selection of appropriate extraction machinery. In the case studies felling costs are included where woodfuel production is part of the overall harvesting operation, and not where only the extraction of residues was studied.

Case studies were undertaken on systems ‘as found’. In some instances the chosen system may not have been the best to use if alternative machinery had been available. Where shortfalls in any one system were found, these were highlighted in the respective case study report.

Woodland type and woodfuel product(s)

The existing and potential woodfuel products available from different woodland types are shown in Table 1.

Site and management constraints

The factors listed below will affect choice of harvesting system and extraction machinery. Often a compromise will have to be made between ordering priorities and optimum

Table 1 Crop types with examples of classifications in the case studies.

Woodland type	Description	Product	Case study no.
Mixed broadleaf coppice[1]	Rotations of *c.* 15–50 years	Overgrown coppice (but not small sized hazel)	10, 11
Young broadleaved crops[2]	< *c.* 40 years < *c.* 20 cm dbh (diameter at 1.3 m)	Thinnings	3, 4, 5, 7
Old broadleaved crops[3]	> *c.* 40 years and >20 cm dbh	Crown, branchwood and other lower grade material.	1
Shelterwoods[3]	Even aged or uneven aged	Crown, branchwood and other lower grade material	
Mature or over mature broadleaves[3]	Group or single tree felling of >40 cm dbh	Crown, branchwood and other lower grade material	1, 8, 12
Any conifer or broadleaf crop[3]	Undersized stemwood or branchwood	Crown, branchwood and low-grade stem wood	6, 9 and 13
Amenity woodland and roadside trees	Amenity and landscape planting (often urban)	Woody shrub wastes	2

[1]Mixed broadleaved coppice; [2]early broadleaved thinnings; [3]crownwood, residue and scrub.

performance. The key factor in all of the systems described is the method of extraction. This must be considered in conjunction with the costs and other constraints.

Costs

Full costings incorporating all the following aspects are required to establish true unit costs:

- **Capital costs.** That is the direct purchase cost or lease/hire cost of machinery. This is affected by:
  - Whether it is already available (e.g. if the owner already has machinery which could be used);
  - How much it will be used (generally the higher the usage the lower the hourly cost). Jobs should therefore be planned to ensure maximum use.
- **Fixed and variable costs.** Depreciation, planned maintenance, fuel and spares.
- **Labour or contract charges, contractor and equipment availability.**
- **Product value(s).** That is where higher incomes are generated by the production of higher value products, over and above woodfuel production.
- **Marketing strategy.** Small woodland owners may find benefits in co-operative working/marketing.

Environment

Small woodlands can be particularly vulnerable to environmental damage during harvesting operations due to:

- use of machinery that is inappropriate to the site (for example, agricultural tractors or skidders);
- a lack of brash for machinery to run on;
- sites with soil types, such as clays and brown earths, that are easily disturbed during wet weather;
- bad working practices, for example, a lack of appropriate protection techniques on sites close to watercourses that may lead to water pollution;
- restrictions that mean work has to be carried out in the wetter winter months of the year;
- the use of unskilled labour.

All work should be planned to minimise environmental impacts. The need for protection of soil, vegetation, wildlife, water, and archaeology should be identified. Weather can also influence the potential for damage, for example working during wet weather can considerably increase soil disturbance and harvesting may have to be postponed or an alternative system selected.

Terrain

The following site factors can constrain machinery use:

- **Ground firmness.** Can it support the machine for the duration of the operation?
- **Roughness.** Are there obstacles (such as boulders or stumps) or uneven ground that the machinery will have to cope with?
- **Slope.** Are there steep slopes that the machinery will have to climb or descend and what are the dangers in terms of overturning or slipping? Slope will always be a major limiting factor, and will impose constraints on the type of machinery which can be used.

Weather conditions, particularly rain, can change the significance of site factors and whether the machinery can still operate effectively and safely; ground firmness can decrease considerably in wet conditions. Good planning, and the use of appropriate materials such as brash, may reduce the limitation on extraction caused by soft ground.

Access and logistical

- **Site access.** Access must be available for machinery to get to the site and for the produce from harvesting to be transported away. If hard roading (a forest road or adequate track) is not available then a suitable track may have to be constructed.
- **In-wood access.** The ground conditions in the wood may not be adequate to cope with all the machinery travel needed. In areas with heavy traffic (for example key route or extraction route convergence at forest roads) it may be necessary to construct a hard track. Such requirements will depend upon the total area to be harvested, extraction distances, load sizes and volumes to be extracted.
- **Extraction distance.** Long distances can significantly influence machinery choice and extraction cost. For example, skidding distances of 250–300 m are considered the economical break point.
- **Felled yields per hectare.** Greater yields of produce will require more in-wood travel for extraction purposes. High volumes may require a review of the extraction machinery chosen or the specification of extraction routes or tracks to ensure the ground firmness can cope with the amount of traffic.
- **Types of product.** Different product types may affect the choice of extraction machinery or system. For example, crownwood can be difficult to extract without some in-wood conversion, and long poles or whole trees cannot be extracted by some forwarders.
- **Product mix and numbers of products.** If products are similar, such as sawlogs of similar lengths, they can be taken out in mixed loads. If products are variable, for example sawlogs, stakes and crown wood, each may have to be extracted separately. Depending upon the yields per hectare, this can result in small or part loads being extracted and this affects the volume of traffic and cost of the operation.
- **Roadside conversion space.** Cross-cutting and stacking of different products requires space, particularly at roadside where they are stacked ready for haulage, and adequate provision should be planned for. At sites where space is limited and high volumes are being extracted, specific space may need to be provided by clearing a small area of ground and constructing some additional hard road access.
- **Tree protection.** Extraction systems and routes should be planned to minimise tree and ground disturbance. For example, avoid skidding long poles against standing trees and activities that may cause ground compaction as this could damage root systems.

In general terms, all of the above will be major economic considerations in any planned operation. Site and in-wood access will have a direct effect on current and future operations, therefore various road and tracking options will need to be considered and planned for.

Health and safety

Safety is only discussed in general terms for the range of different machine systems covered by this Note. For specific machine-related information, refer to the respective supplier, agent, manufacturer and the Arboriculture and Forestry Advisory Group (AFAG) guides. Consideration must be given to operator training, safe working practices and manual handling. Three main aspects need to be considered to create a safe working environment and optimal conditions for efficient work:

- a well-planned operation on a suitably organised worksite.
- the use of appropriate and well-maintained equipment;
- employing well-trained operators familiar with the machine(s) in use and the personal, protective equipment (PPE) required;

The scale and nature of some operations often requires the use of modified agricultural equipment as the most cost-effective means of harvesting woodfuel products. Such equipment must comply with all machine regulations. The main health and safety legislation covering the use of these machines is:

- The Provision and Use of Work Equipment Regulations 1998 (PUWER).
- The Management of Health and Safety at Work Regulations 1999 (MHSW).
- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER).

Site and operation risk assessments should be carried out by the site/forestry works manager to cover all planned operations. These must be communicated to all site workers. This is a requirement of the Management of Health and Safety at Work (MHSW) regulations.
The assessments should identify the action needed to eliminate or control risks, including:

- any hazards associated with the site;
- the suitability of the machine for the process or operation;
- the safe, ongoing management of operators, workers, hauliers and the public who may approach sites.

Should further guidance be required contact your local Health and Safety Executive (HSE) office (see page 12).

Choice of harvesting system

A harvesting system is made up of a number of components to fell, process and extract timber products to an in-wood loading area, roadside or other location. Each process within the system uses different work methods and equipment, which can be varied to suit particular site conditions, tree size or product types. The following systems are described with reference to the case studies:

- Tree or pole-length
- Part pole-length
- Shortwood
- Whole-tree harvesting
- Terrain chipping

Table 2 gives a summary of the case study details and woodfuel production costs for the woodland types studied. Table 3 gives machinery costs, site and management constraints, and extraction costs for each of the harvesting options. Note that the pros and cons of each system need to be considered on their relative merits—provided that health and safety and environmental requirements are met.

Tree or pole length system

Case studies 1, 3, 4, 5 and 9.

- Uses only the stem wood and results in crown and branch wood residues.
- At one time the most common system in use in the UK and still popular in certain areas and crop types.
- A three-phase operation best suited to a tree volumes greater than 0.1 m^3. The tree is felled and delimbed, normally extracted by tractor (winch skidder) or cable-crane to roadside. The pole is usually cut into various products (sawlog, pulp, fencing and woodfuel) and then sorted and stacked for collection. Some buyers may take the whole pole to the sawmill for conversion to enable a better judgement on how to convert and obtain best value for the products.

Part pole-length system

Case studies 2, 4 and 10.

- Uses parts of the stem wood and results in crown and branch wood residues.
- Commonly used in the harvesting of broadleaves, it allows a better standard of organised product presentation in certain situations.
- Sawlogs are removed from the main stem at stump, allowing easier product sorting. Load sizes may be smaller if product density is low and this can have an effect on outputs. The system is primarily suited to skidders, but forwarders or cablecranes can be used. Crown wood and other products and residues can be extracted by a variety of means as described in Shortwood systems.

Shortwood system

Case studies 7, 8, 10, 11, 12 and 13.

- Uses stem, crown and branchwood, normally down to a specific diameter size.
- A two-phase operation, generally very efficient and suitable for all tree sizes but efficiency can be limited by ground conditions or slope.
- The tree is delimbed and crosscut at stump. Extraction only deals with saleable products, including woodfuel, unusable residues being left in wood.
- The number of products should be kept to less than five. This reduces the need for product sorting, both at stump and at roadside. The preferred method of extraction is forwarder, subject to ground conditions (soil structure, wetness and localised terrain conditions will have a bearing on the load carrying capacity of the site, in relation to the number of machine passes). Although cablecranes can be used they can be expensive to set up and are therefore limited to difficult or otherwise inaccessible sites. Skidders can operate the system; subject to distance travelled (maximum 250–300 m) and ground protection requirements.

Whole-tree harvesting

Case study 6.

- Uses the whole tree and results in little or no crown and branch wood residues. It can be divided into three sub-systems:
  - whole-tree comminution: whole tree harvested and chipped to provide one product;
  - integrated harvesting: whole tree harvested, conventional roundwood products produced and residues chipped;
  - residue harvesting: conventional shortwood system used with branches and tops chipped in wood, at roadside or in any other suitable location.
- Chipping is normally incorporated as part of the process; the whole tree or any part of the tree can be chipped. Chipping takes place at stump, in rack, at roadside or in any other suitable location, subject to extraction (machine access and maneuverability are often constraining factors). Harvesting involves the recovery of nearly all the above ground parts of the tree (stem, branches, foliage) and in some crops can

almost double the yield in terms of weight. Subsequent processing can be in wood or at roadside.

- Extraction is normally by wire rope (using skidder, cablecrane, highlead or portable winch) or 'Clambunk' skidding.

Terrain chipping

Case study 12.

- Uses the whole tree and results in little or no crown and branchwood residues.
- A self-propelled chipper unit is used for wood requiring some product accumulation prior to chipping either by forwarding or skidding. Chips are normally 'blown' into a trailer or purpose built bins and forwarded to roadside for subsequent haulage.

Choice of extraction machinery

Forest machinery developments have been rapid over the last decade, with a diverse range of available machines that are highly efficient and affordable. Extraction machinery in general use includes the following generic types.

Forwarders

Purpose built or agricultural tractor-trailer units equipped with a loading crane. They come in a range sizes and extract converted products by lifting them entirely clear of the ground. Variations include All terrain vehicle (ATV) based units and mini/midi tractor variants.

Tractor cradles

A purpose made frame or box unit which mounts on an agricultural tractor 3-point linkage system. Produce is manually loaded into the cradle.

Tractor-mounted hydratongs

A tractor-based unit equipped with hydraulically operated tongs, which extracts by lifting one end of full-length trees clear of the ground and pulling them to roadside.

Skidders

Purpose built tractors, which extract by lifting one end of full-length trees clear of the ground and pulling them to roadside. Variations include All terrain vehicle (ATV) based units and mini/midi tractor variants.

Cableway systems

Ropeway systems where timber is extracted by means of moving cables, powered by a static tractor or lorry-powered winch. The timber load can be carried wholly or partially clear of the ground. Examples include Skyline and High lead systems.

Terrain chippers

Purpose built or agricultural tractor units equipped with a bulk container or trailer unit, a loading crane and chipper unit. Produce is normally processed directly into the container or trailer. They come in a range of sizes.

Wood chipping costs and indicative outputs

If the woodfuel chip production costs for each case study are compared to extraction only costs, a noteworthy difference emerges, with felling and/or chipping comprising the most significant element of the cost. This is not the case for normal forestry operations because the total cost of production per m^3 solid to 7 cm, equates to the measured volume put through the chipper. However the actual volume realised through the use of branchwood can be higher so the unit cost can be less. Where a volume to weight ratio is expressed, for example 1:1, the cost of production per tonne, at moisture content for the species being worked, stays the same. Where the aim is to produce material at a given moisture content, for example 30%, a greater volume of green timber will be required to produce 1 tonne of usable fuel. Indicative costs and outputs for various common types of chippers and these are shown in Table 4.

Winch-based systems

There is a range of systems in terms of size, which can be manual or mechanical. Timber is extracted by means of a moving cable, which is powered by a winch drum. Produce is extracted by pulling it to roadside.

Table 4 **Chipping outputs and costs** (m^3 solid wood per hr).

	Disc chipper	Drum chipper	Screw chipper	Comments
Outputs	3–4	4–5	4–5	Output dependent upon material size machine size. (Semi-professional and small home models not included.)
Costs	£10.00	£7.50–£8.50	£7.50–£8.50	Two man team at £8.00/man hr* and includes £2.00/m^3 for cross-cutting. (Machine purchase and other operational costs not included.)

*This 1998 figure relates to operations carried out at that time. It does not include on-costs or overheads.

Table 2 Case study information: wood fuel production costs (to roadside)

Case study	Material derived from	Crop type	Slope class[a]	System	Extraction machines	Product density (m^3 ha^{-1})	Woodfuel (chip) production costs £ per tonne[b]
Broadleaved thinnings							
3	Mid-rotation thin	Beech (high forest)	Level with steep 'snaps'	Pole length	Tractor skidder	68	28.50
4	Early thin	Oak (high forest)	Level	Shortwood	'Small' farm forwarder	29	24.75
				Pole length	Tractor skidder	29	24.29
5	Early thin	Mixed broadleaves (high forest)	Steep	Shortwood	Wire loader	36	39.31
				Pole length	Portable winch	36	33.60
					Tractor skidder	42	32.69
7	Early thin	Oak (high forest)	Level	Shortwood	Wire loader	32.5	39.64
					Tractor cradle	32.5	34.00
					'Large' farm forwarder	32.5	28.91
					Purpose built forwarder	32.5	28.68
8	Mid rotation thin	Oak (high forest)	Moderate	Shortwood	'Small' farm forwarder	N/A	28.68
					'Large' farm forwarder	N/A	26.87
					Mini forwarder	N/A	27.69
					Wire loader	N/A	45.09
				Pole length	Tractor skidder	N/A	27.28
Mixed broadleaved coppice							
10	Coupe felling	Mixed broadleaved coppice	Level	Shortwood	'Small' farm forwarder	160	30.66
					Mini forwarder	160	34.28
				Part pole	Tractor skidder	160	35.56
11	Coupe felling	Ash coppice	Moderate	Shortwood	Mini forwarder	90	28.91
					'Large' farm forwarder	90	30.01
					Purpose built forwarder	90	32.48
Crownwood, residues and scrub							
1	Crown wood from late thinning	Beech (high forest)	Moderate	Shortwood	Portable winch	71	49.16
				Pole length	Tractor skidder	71	27.28
8	Crown wood from mid-rotation thinning	Oak (high forest)	Moderate	Terrain chip	Tractor & trailer	N/A	94.13
12	Crown wood from overstorey felling	Beech (continuous cover forest)	Level to moderate	Shortwood	'Small' farm forwarder	24	22.62
				Terrain chip	Tractor & trailer	27	48.64
6	Scrub clearance	Scrub	Moderate	Whole-tree	Tractor skidder	16	69.79
9	Pre-commercial thinning	Mixed broadleaves (high forest)	Level	Shortwood	ATC forwarder	71	47.84
				Pole length	ATC skidder	71	52.44
13	Pre-commercial thinning	Mixed broadleaves	Level	Shortwood	Mini forwarder	30	34.08
					ATC forwarder	30	36.69
				Pole length	ATC skidder	30	44.64
2	Conifer tops from thinning	Pine (high forest)	Level	Part pole	Purpose built forwarder	Thinnings: 32 Tops: 8.8	51.38

[a] Level/gentle slope <20%; moderate slope 20–33%; steep/very steep 23%– >50%. [b] Moisture content of 30% (wet basis).

Table 3 Harvesting options: pros (✓) and cons (✗) need to be considered in light of overall performance.

	Forwarders*			
	Purpose-built forwarder	**Farm forwarder**	**Purpose built mini forwarder (carrying up to 1.5 tonne)**	**ATC based forwarder**
Cost(s)	✓ Often have lowest unit costs on large-scale operations. ✗ High capital cost. ✗ High hourly cost. ✗ High transport costs (problem on small jobs).	✓ Flexible; can be cheaper in terms of unit cost than purpose built 8–10 t machines on small jobs. ✓ Mid-range capital cost.	✓ Low unit costs for shorter extraction distances able to compete with larger purpose built machines on some sites. ✗ Relatively high capital cost, with higher unit costs than large machines on bigger jobs/longer extraction distances.	✓ ATC cost varies. ✓ Attachments low cost. ✗ Generally high unit costs.
Environment	✓ Damage generally less than that caused by skidding or cablecrane systems. ✓ Given right conditions (ground, weather, brash availability) large forwarders will require fewer passes to remove produce. ✗ May cause standing tree root damage. ✗ Route pre-organisation and maintenance requirements high on wet sites in order to avoid site damage.	✓ Damage generally less than that caused by skidding or cablecrane systems. ✗ May cause standing tree damage/root damage. ✗ Route pre-organisation and maintenance requirements high on wet sites in order to avoid site damage. ✗ Route planning to take account of forwards machine movement limitation.	✓ Very low ground impact.	✓ Potential for crop damage low. ✗ High traction force and low weight can cause ground damage if not properly used.
Site	✓ Suitable for extracting conifer residues. ✓ Slopes <50%. ✓ Suitable for all woodland types. ✓ Slopes up to 60% for whole tree Clambunk forwarder; clearfell only.	✓ Suitable for extracting conifer residues. ✓ Slopes <30%. ✓ Suitable for all woodland types. ✗ Obstacles and rough terrain can cause problems, but less for Powerdrive trailers.	✓ Slopes 30% to 50% dependent on machine design type (for example frame-steered = 50%). ✓ Suitable for all woodland types. ✓ Manoeuvrable within crops. ✗ Less ground clearance than larger machines.	✓ Manoeuvrable. ✗ Slope – ATC & trailer <25%. ✗ Roughness can cause problems. ✗ Brash/waste can cause problems.
Plan and organise	✓ Greater load capacity and capable of dealing with large programmes efficiently. ✓ Particularly suited to distances >500 m. ✗ Cost of transport to site. ✗ Ease of access. ✗ Not always suited to whole-tree or long pole systems, depends on limitations of 'bunk'.	✓ Greater load capacity. ✓ Can be used for other agricultural activities. ✓ Suited to distances >500 m ✓ Small whole tree system can be effective with simple bunk and loading technique modifications. ✗ Not suited to long pole systems.	✓ Easy access. ✓ Easy transportation. ✓ Can be used for other off-road operations. ✗ Low load capacity. ✗ Suited to distances <250 m.	✓ Easy access. ✓ Easy transportation. ✗ Low load capacity, suited only to small jobs. ✗ Suited to distances <200 m.
Health and safety	✓ Good ergonomics in comparison to farm forwarders.		✗ No OPS, FOPS or ROPS** protection on some machines.	✗ Manual handling involved. ✗ No OPS, FOPS or ROPS** protection on some machines.
Indicative extraction costs (£/t) by case study	Case study 2: £14.17 Case study 7: £6.67 Case study 11: £5.32	Case study 4: £4.23 Case study 7: £4.84 Case study 8: £3.82 (Lge) Case study 8: £5.19 (Sml) Case study 10: £2.20 (Sml) Case study 11: £3.35 (Lge) Case study 12: £2.25 (Sml)	Case study 8: £4.44 Case study 10: £4.85 Case study 11: £3.98 Case study 13: £3.14	Case study 9: £11.58 Case study 13: £4.99

* In this guide forwarder size classes are taken as large: 15–20 tonnes; medium: 8–14 tonnes; small (or midi): 5–7 tonnes; mini: < 5 tonnes.
** OPS = operator protective structure; FOPS = falling object protective structure; ROPS = rollover protective structure.

Table 3 Harvesting options: pros (✓) and cons (✗) need to be considered in light of overall performance (continued).

	Tractor cradle	Hydratongs	Wire loader
Cost(s)	✓ Low capital cost. ✗ Requires tractor unit.	✓ Low capital cost. ✓ Can achieve lower unit costs over short extraction distances. ✗ Requires tractor unit.	✓ Low capital cost. ✗ Generally high unit costs. ✗ Requires tractor unit.
Environment	✗ High potential for site damage. ✗ May cause standing tree/root damage.	✗ High potential for site damage. ✗ May cause standing tree damage/root damage. ✗ Potential for ground damage, particularly on wet sites.	✓ Moderate ground impact. ✗ May cause standing tree damage/root damage. ✗ Generally has lower flotation capacity than purpose built machines.
Site	✓ Suitable for all woodland types. ✓ Allows access to difficult sites. ✓ Manoeuvrable within crops. ✗ Slope limitations <25%.	✓ Suitable for all woodland types. ✓ Allows access to difficult sites. ✓ Manoeuvrable within crops. ✗ Slope limitations <25%.	✓ Suitable for all woodland types. ✓ Allows access to difficult sites. ✓ Able to work with very widely-spaced racks.
Plan and organise	✓ Easy access. ✓ Easy transportation. ✓ Can be used for other agricultural activities. ✗ Low load capacity, only suited to small jobs. ✗ Suited to distances <150 m. ✗ Only suitable for early thinning operations and shortwood system producing short lengths. ✗ Manual handling requirement precludes the production of large products. ✗ Not suited to whole tree or long pole systems.	✓ Easy access. ✓ Easy transportation. ✓ Can be used for other agricultural activities. ✗ Low load capacity, only suited to small jobs. ✗ Suited to distances <150 m. ✗ Only suitable for thinnings operations. ✗ Suited to whole tree or long pole systems, working downhill.	✓ Easy access. ✓ Easy transportation. ✗ Low load capacity, suited only to small jobs. ✗ Suited to distances <500 m. ✗ Limited product length for best efficiency. ✗ Detailed route planning and felling presentation essential to avoid high unit costs.
Health and safety	✗ Some manual handling involved.		✗ Some manual handling involved.
Indicative extraction costs (£/t) by case study	Case study 7: £8.69	No case study data available, but indicative costs are £5–9	Case study 5: £8.14 Case study 7: £12.96 Case study 8: £17.61

Indicative extraction cost by case study (£ per tonne (£/t)) is based on 100 m travel in wood and 25 m on road unless specified.

Table 3 Harvesting options: pros (✓) and cons (✗) need to be considered in light of overall performance (continued).

	Manually portable winches	Skidders			
		Farm	Purpose-built county	Small tracked	ATC Skid Arch 'Sulky'
Cost(s)	✓ Low capital cost. ✗ High unit cost.	✓ Relatively low capital cost/low sophistication. ✗ Only gives competitive unit costs over shorter extraction distances.	✓ Relatively low capital cost/low sophistication. ✓ Competitive unit costs over shorter extraction distances.	✓ Relatively low capital cost/low sophistication. ✓ Equipped with stacking blade. ✓ Low unit costs over shorter extraction distances.	✓ ATC cost varies. ✓ Attachments low cost ✗ Relatively high unit costs.
Environment	✓ Low ground impact.	✗ May cause considerable terrain damage on vulnerable sites. ✗ May cause considerable crop damage.	✗ May cause considerable terrain damage on vulnerable sites. ✗ May cause standing tree damage/root damage.	✓ Lower ground pressure than many other tractors. ✗ Will cause site damage on wet and on other vulnerable sites.	✓ The Arch itself has lower potential for ground damage. ✗ High traction force and low weight from ATC can cause ground damage.
Site	✓ Suitable for all woodland types. ✓ Allows access to difficult sites. ✓ Suitable for use on steep banks and wet soils. ✗ Suited mainly to small thinnings.	✓ Suitable for all woodland types. ✓ Manoeuvrable within crops. ✗ Not suited to wet sites or slopes > 30%.	✓ Suitable for all woodland types. ✗ Not suited to wet sites.	✓ Suitable for all woodland types. ✗ Not suited to wet sites. ✗ Track damage sensitivity on rough sites.	✓ Suitable for all woodland types. ✓ Manoeuvrable, but trailed load limits turning radii. ✓ Can cope with some steep ground. ✗ Roughness can cause problems. ✗ Brash/waste can cause problems.
Plan and organise	✓ Easy access. ✓ Easy transportation. ✗ Low load capacity. ✗ Suited to distances <40 m, only sustainable on small jobs.	✓ Can be used for other agricultural activities. ✗ Low load capacity. ✗ Suited to distances <150 m. ✗ Requires conversion space at roadside.	✓ Can be used for other agricultural activities. ✗ Load capacity up to 5 m³. ✗ Suited to distances m <250 m. ✗ Potential for site damage higher than any other system. ✗ Route planning essential to avoid terrain/crop damage. ✗ Requires conversion space at roadside.	✓ Improved traction on up/down slopes. ✓ Able to cross narrow drains/ditches. ✗ Low load capacity. ✗ Suited to distances <150 m. ✗ More sensitive to side slopes than wheeled.	✓ Easy access. ✓ Easy transportation. ✗ Low load capacity, suited only to small jobs. ✗ Suited to distances <150 m.
Health and safety	✗ Some manual handling involved. ✗ Limited load control on downhill slopes.	✗ Some manual handling involved.	✗ Some manual handling involved.	✗ Some manual handling involved.	✗ Some manual handling involved.
Indicative extraction costs (£/t) by case study	Case study 5: £7.13	Case study 3: £3.85 Case study 10: £5.88	Case study 1: £7.26 (primary handling); Total £9.89 (including secondary handling) Case study 4: £4.90 Case study 5: £6.69 Case study 6: £28.13 Case study 8: £5.63	No case study data available, but indicative costs are £5–7	Case study 9: £15.32 Case study 13: £11.69

Table 3 Harvesting options: pros (✓) and cons (✗) need to be considered in light of overall performance (continued).

	Cableway systems			Terrain chip
	Highlead	Gravity system	Skyline	
Cost(s)	✓ Low capital cost. ✓ Competitive unit costs over shorter extraction distances.	✓ Low capital cost. ✗ Competitive unit costs over shorter extraction distances.	✗ High capital cost. ✗ High unit costs therefore generally only used on sites where forwarding/ skidding is not an option.	✓ Moderate cost depending on components used. ✓ Purpose-built units are expensive.
Environment	✓ Low ground impact. ✓ Allows access to difficult sites. ✓ Low levels of site disturbance. ✗ Some potential for stem damage.	✓ Low ground impact. ✓ Allows access to difficult sites. ✓ Low levels of site disturbance. ✗ Some potential for stem damage.	✓ Low ground impact. ✓ Allows access to difficult sites.	✗ Can cause site damage on wet sites, subject to route planning, construction and maintenance.
Site	✓ Suitable for all woodland types. ✓ Suited mainly to small thinnings or shorter extraction distances. ✓ Suitable for use on steep banks and wet soils.	✓ Suitable for all woodland types. ✓ Suitable for steep banks using up hill extraction only. ✓ Suited mainly to small thinnings.	✓ Suitable for all woodland types. ✓ Suitable for use on steep banks and wet soils.	✗ Not suited to wet sites. ✗ Limited maneuverability.
Plan and organise	✗ Low load capacity. ✗ Suited to distances up to 150 m, but dependent on concavity of terrain. ✗ Setup time, but lower than other cable systems. ✗ Best suited for high product density. ✗ Stacking space required at roadside. ✗ May require secondary extraction.	✗ Low load capacity. ✗ Suited to distances up to 300 m. ✗ Setup time. ✗ Best suited for high product density. ✗ Stacking space required at roadside. ✗ May require secondary extraction.	✗ Low load capacity. ✗ Suited to distances >300 m. ✗ Setup time. ✗ Best suited for high product density due to high unit cost.	✗ Low load capacity. ✗ Suited to distances <250 m. ✗ Best suited for high product density. ✗ Slope <25%. ✗ High organisational input required re presentation of residues.
Health and safety	✗ Some manual handling involved.	✗ Some manual handling involved.	✗ High level of skill required therefore training essential. ✗ Some manual handling involved.	✗ Some manual handling involved with non-loader feed units.
Indicative extraction costs (£/t) by case study	No case study data available, but indicative costs are £6–11, depending on: • Tree size • Volume extracted • Extraction distance.	No case study data available, but indicative costs are £11–20.	No case study data available, but indicative costs are: • Timber master winch extracting from thinning can cost £8–14 • Syncrofalke hydraulic winch (capital cost £210 000) these are expensive to run and costs can exceed £20. Note: This is a wide-ranging subject. The costs are very, very variable depending on: • Machine type • Age • Equipment used • The carriage type • Also all the other items as per highlead on page 21.	Case study 12 – total cost £29.99.

CONCLUSIONS

The success and financial viability of any harvesting operation depends on the site; access and distance to road-side; methods used and the scale of the operation. Extraction machinery in particular will be a key influencing factor. Some systems may be inappropriate for small woods.

Costs vary widely according to the harvesting system used and are subject to the many factors already discussed. However, in simple terms, costs of extraction in thinning are higher than in clearfelling, with basic costs increasing between £1 and £2 per m^3 for every additional 100 m of extraction. Current indicative costs for extraction are shown in Table 5.

In broad terms the findings from the case studies are:

- Forwarding tends to be more cost effective than skidding, which is considered to be inefficient for longer extraction distances (>250 m)
- Where difficult sites require maximum manouverability and flotation, mini forwarders should be considered where appropriate.
- Forwarding using the appropriate machine is likely to cause less ground disturbance on drier sites than skidders and terrain chippers, with small-scale forwarders causing significantly less site disturbance.
- Skyline operations tend to be the most expensive option, their use being dictated by site and setup time constraints.
- System machine choice must take account of:
  - –Machine availability
  - –Machine flexibility
  - –Differing machine/labour costs within and between areas
  - –Site conditions
- Unit costs vary according to the cost factors charged to the primary and or secondary operations, that is, if the primary operation is to fell, extract and convert, irrespective of fuelwood production, and then the costs associated with those operational factors will already be incurred. Where this is the case, secondary operations such as fuelwood harvesting should be costed as such.
- In general terms harvesting costs increase when:
  - –Slopes increase
  - –Uphill extraction is used
  - –Lower volume and product densities are harvested
  - –Smaller product volumes or sizes are harvested
  - –Poor tree and product forms are worked and produced
  - –Access is poor or difficult
  - –Extraction is over longer distances.

Table 5 Extraction costs in thinning on different terrain types

Terrain steepness	Extraction method
Steep	**Cable-crane systems**: range from £10–25 m^{-3} Cable extraction, first thinning: £20–25 m^{-3} depending on the equipment and method, e.g. 1. Chainsaw fell, convert in the wood and extract shortwood: up to £25 m^{-3}. 2. Chainsaw fell, whole-tree extract between £12 m^{-3} and £15 m^{-3} (additional processing: £3–4 m^{-3}) £15–19 3. Chainsaw fell, (sub thin) and extract again depending on the operation would range between £10–12 m^{-3}
Moderate	**Skidder** (for example Ford County type): range from £5 m^{-3} to £12 m^{-3} **Portable winch** (short distance only): range from £3 m^{-3} to £6 m^{-3} **Forwarder:** range from £3 m^{-3} to £12 m^{-3}
Easy/flat	**Forwarding systems** (medium/large): range from £3 m^{-3} to £12 m^{-3} **Skidder** (for example Ford County type): range from £5 m^{-3} to £12 m^{-3} **All Terrain Cycle equipment:** range from 13 m^{-3} to £17 m^{-3} **Small scale forwarder** (mini): range from £4 m^{-3} to £15 m^{-3}

Early broadleaved thinnings

- Lower volume returns, coupled with higher unit costs, make them the least profitable option.
- Pole length working is generally the cheapest system, but there is often little difference between skidding and forwarder shortwood options.
- Wire loaders are always the most expensive option in terms of hourly production costs, but they are one of the lowest capital cost units.
- On easy terrain a farm tractor-based forwarder is likely to be as cost effective as a larger purpose built unit, depending on extraction distance.

Mixed broadleaved coppice

- Harvesting costs for machine/system combinations on each site were similar and choice is likely to influenced by other factors such as availability, capital cost and site / environmental constraints.
- On steep sites (>50%), purpose built forwarders are the most expensive option (forwarding is at its limits on these slopes).

Crownwood, scrub and residues

- ‘Pre-commercial thinnings’ are often felled and left on site, however there may be some cost benefit in utilising material as woodfuel.

- Crown wood can be a cost effective fuel resource although the correct harvesting system needs to be adopted, that is, skidding, forwarding (to stump or roadside) or terrain chipping, subject to the correct machine choice.
- The only case study on terrain chipping showed it to be expensive and not cost effective. However the major factor influencing this was inappropriate machine choice, and the study demonstrated that there was significant room for improving outputs by using a suitable machine.

NOTE: The data drawn together in this guidance are compiled from the work carried out by Forest Research over the past ten years. The data are site specific and for the crop types dealt with during the studies. However, no specific cost comparison base has been established from these trials. The information provided is a summary of the Energy Technology Support Unit (ETSU) report: *Supply of wood fuel from small-scale woodlands for small-scale heating*. The report comprises a series of thirteen case studies undertaken by the Technical Development Branch of Forest Research. Where possible information has been updated or added to the original data. The case studies provide indicative outputs, costs and basic system descriptions for the sites studied, and where possible recommend appropriate systems of work.

REFERENCES AND USEFUL SOURCES OF INFORMATION

ABERDEEN UNIVERSITY (1990).
Wood fuel strategies, vol. 1. Report B 1176-P1.
Aberdeen University, Aberdeen.

ABERDEEN UNIVERSITY (1990).
Wood fuel strategies, vol. 2. *Harvesting trials summaries*.
Report B 1176-P2.
Aberdeen University, Aberdeen.

BORDER BIOFUELS Ltd. (1996).
Forest industry wood fuel supply. B/W1/00420/REP.
Border Biofuels Ltd, Tweed Horizons Centre, New Town, St. Boswells, Melrose, TD6 OSG.

BORDER BIOFUELS Ltd. (1996).
An assessment of the commercial cost of farm-scale wood fuel Procurement and processing. B/W2/00518/REP.
Border Biofuels Ltd, Tweed Horizons Centre,
New Town, St. Boswells, Melrose, TD6 OSG.

CRE (1995).
Wood as a domestic heating fuel. BM5/0488/04/REP.
CRE Group Limited, Stoke Orchard, Cheltenham, Glos, GL52 4RZ.

ENERGY TECHNOLOGY SUPPORT UNIT (1999).
Supply of wood fuel from small-scale woodlands for small scale heating. Report produced for ETSU by Technical Development Branch, Forest Research. ETSU Report: B/Ul/00554/REP.1999. ETSU, AEA Technology Environment, Harwell, Didcot, Oxfordshire, OX11 ORA.

LRZ Ltd. (1995).
Fuel wood from undermanaged woodlands.
B/M4/00487/30/REP. LRZ Ltd. (Now Econergy Limited, 35 Gwydir Street, Cambridge, CB1 2LG)

NISBET, T., DUTCH, J. AND MOFFAT, A. (1997).
Whole-tree harvesting: a guide to good practice.
Forestry Commission Practice Guide.
Forestry Commission, Edinburgh.

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