WOODFUEL RESOURCE IN BRITAIN: MAIN REPORT

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FINAL REPORT

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EXECUTIVE SUMMARY

Objectives

1. The objectives of the study were to:
- estimate the woodfuel resource from traditional forests, sawmills, urban areas, roadsides, powerline routes and short rotation coppice in a sound and consistent way and at the finest resolution justified by the data
- forecast future availability of the resource from traditional forests
- summarise information at a medium geographical and temporal scale in paper and electronic form
- provide commentary on potential commercial availability, making clear the location and general scale of existing competing markets
- allow the user, via an interactive website, to sift through summarised information to identify the woodfuel type of interest
- allow the user to submit an electronic request with a defined area of interest, resource type, and a future time interval (with an undertaking to provide the user with refined information within one working week at minimal cost)
- develop a dynamic tool to update summary data tables with the purpose of both meeting users' information needs more exactly and facilitating the process of updating tables as new information becomes available or existing information is refined

2. Two outputs have been produced in addition to the original objectives:
- data were summarised for English Regions to assist strategic decision making
- a methodology was developed to estimate the current and future carbon pools in all components of tree biomass, excluding the fine roots, in Britain; the facilities developed for the main project – summarisation at a range of scales and forecasting periods - are especially valuable in this context

Methods

3. Traditional forestry. Two sources of information on the existing forest resource (>2 ha) are available: the subcompartment database for areas managed by Forest Enterprise (an agency of the Forestry Commission) referred to here as public forest and the National Inventory of Woods and Trees for all other forest areas (referred to here as private forest). Growth rates for the parts of the stem presently marketed are obtained from these data sources. Relationships were determined to extrapolate from this portion of the stem to all biomass components (excluding fine roots). These relationships were used in conjunction with existing forecasting models to estimate future growth of all tree components. In the case of harvesting residues, site and environmental constraints on the fraction of the biological production that could be taken off harvesting sites were determined for each of the 30 Forest Enterprise Forest Districts; estimates are therefore described as 'operationally available'.. These constraints were extrapolated to all other forests using best available information.

4. Sawmill co-product was derived from the 2000 Annual Sawmill Survey and the co-incident Biennial Sawmill Survey. These provide information on volume, form and use of co-product.

5. Arboricultural arisings were estimated by questionnaire to arboricultural companies, tree officers and local authorities.

6. Short rotation coppice. The area established since 1992 was determined from the databases of the Woodland Grant Scheme and the Energy Crops Scheme. Biomass production was estimated using assumptions of average annual yield.

7. None of the estimates takes account of the costs of harvesting, extracting, comminuting, drying or transporting the biomass; in some instances estimates are therefore described as 'potential' since few energy end-uses are sufficiently developed to give definite figures for paying capacity.

Results

Traditional forestry.

Current.

8. The current annual biomass production (excluding fine roots, stumps, and deciduous leaves) that can be removed from harvesting sites once site constraints have been taken into account is 5.63 million oven dried tonnes (odt). The annual production of operationally available resource for all end markets is mainly in Scotland and England (2.59 and 2.21 million odt respectively) with Wales producing about 15% of the total. Within England the main resources are in the South West and South East Region. Within Scotland the total annual production of operationally available biomass of all harvestable tree components is over 200 thousand (k) odt y^{-1} in each of the following districts: Tay, Cowal and the Trossachs, the Scottish Lowlands, Scottish Borders, Galloway and Ae. There is greater a range in resource availability within English Forest Districts than in Scotland. On one hand the operationally available resource in the South East District is over 400 k odt y^{-1}, while Peninsular and Kielder have resources of 257 and 315 k odt y^{-1} respectively but on the other hand, Northants has an operationally available resource of just 56 k odt y^{-1}. Of the four districts in Wales, Llanmyddfri has the greatest resource at 275 k odt y^{-1}. A substantial fraction of the annual biomass production is stemwood of sufficient diameter that it is unlikely to be made available for woodfuel. Availability of small roundwood (i.e. a diameter of 7-14 cm) will depend on price and competing markets. Poor quality stems might already be used for firewood on an informal basis though it is probable that most is currently unused and could be made available for woodfuel. There are few current markets for branches and stem tips (stems less than 7cm in diameter).

9. In the private sector, the annual operationally available biomass is estimated to be 3.61 million odt y^{-1} for Britain as a whole. Poor quality stems, branches, stem tips and small roundwood contribute 279 k, 316 k, 21 k and 560 k odt y^{-1} respectively, giving a total of 1.18 million odt y^{-1}. In all three countries the poor quality stem category is dominated by broadleaved species. Branches and stem tips are mainly broadleaved species and spruces. The species composition of small roundwood differs within GB with availability in Scotland and Wales being dominated by spruce but with a more even split among the species groups in England; availability of small roundwood will depend on price and competing markets. If we take a more conservative view of the fractions available for energy end uses and consider just poor quality stems, tips and branches, the operationally available biomass from the annual harvest is reduced from 1.18 million odt y^{-1} to 615k odt y^{-1}.

10. Although the public forest managed by Forest Enterprise has a considerably smaller standing biomass than the private sector, it is generally more productive with the annual potential operationally available resource estimated at 2.02 million odt y^{-1}. Branches, stem tips and small roundwood contribute 94k, 10k and 472k odt y^{-1} respectively giving a total of 577k odt y^{-1}. In Forest Enterprise, stemwood is not classified by quality therefore there is no public sector entry in the poor quality category. In all countries, branch, stem tips, and small roundwood are dominated by spruce which comprises 60% of the total operationally available biomass though in England pines are also important contributors to the branch and tip categories. If we take a more conservative view of the fractions available for energy end uses and consider just poor just tips and branches, current felling plans indicate that 105k odt is harvested annually and operationally available.

11. If we assume that all the poor quality stems, tips and branches plus 10% of the small roundwood could be made available to energy end uses without disruption of existing markets, we estimate that 823k odt y^{-1} would be available from traditional forests for new energy uses. Public forest managed by Forest Enterprise has the potential to provide 22% of this with the bulk being available in the private sector.

Forecast

12. In the private sector, the total operationally available biomass of small roundwood, poor quality stems, stem tips, and branches together increases from 1.18 million odt y^{-1} in 2003-2006 to 1.27 million odt y^{-1} by the third forecast period, i.e. 2012-2021, and then decreases slightly to about

1.22 million odt y^{-1}. The main increase is in spruce; broadleaved species and pine remain about the same and there is a decrease in the biomass produced by conifers other than spruces or pines. If we take a more conservative view of the fractions available for energy end uses and consider just poor quality stems, tips and branches, the forecast annual biomass harvest increases from 615k odt y^{-1} in 2003-2006 to about 666k odt y^{-1} by the third period. The increase is largely due to spruce, particularly in Scotland.

13. The predicted quantities of operationally available biomass from the public sector are about four times smaller than that predicted from the private sector. Considering first the categories small roundwood, tips, and branches (in the public sector there is no equivalent category to poor quality stems), the total biomass remains around 575k odt y^{-1} across Britain as a whole for the first two forecast periods and then falls slightly to reach 557k odt y^{-1} by 2017-21. The biomass of spruce, the dominant species group, increases from about 358k odt y^{-1} in the present period to about 379k odt y^{-1} by 2017-2021 with much of the increase occurring in the first 5 years. As with the private sector, most of this increase occurs in Scotland. The overall spruce increase is balanced by the decrease in biomass of pine and the other conifers. Considering just tips and branches, current felling plans will lead to a general increase in harvested biomass from about 105k odt y^{-1} to 110k odt y^{-1}. Much of the increase occurs within spruce by the second prediction period. The forecast increase in broadleaved tips and branches in the final period is counterbalanced by the decrease in conifers other than spruces or pines.

Sawmill co-product

14. The annual production of co-product in Britain is estimated at 859 k odt y^{-1}. Almost half (47%) of the co-product comes from Scottish mills with 34% from England and 19% from Wales. Within England there are striking contrasts - the West Midlands accounts for 35% of English production and 12% of British output but the neighbouring East Midlands produces less than one tenth of this. The other important English Region is the North East.

15. Overall, 66% is in the form of chips, 20% is sawdust and 11% is bark. About 2% is already used as woodfuel with most being used by the sawmills themselves and only 3 k odt y^{-1} sold externally as firewood – firewood production is concentrated in the South West and the East Midlands. Latest estimates indicate that overall 83% of the total co-product is already sold to the wood processing industries with almost no differences between countries. Miscellaneous markets account for 15% of co-product.

Arboricultural arisings

16. The average annual biomass of arboricultural arisings produced per respondent was 258 odt. If the average is applied to the estimated total number of contractors (2,174) this gives a total of 561 k odt y^{-1} of arboricultural arisings across Britain. To obtain more refined figures, respondent averages calculated separately for Scotland, Wales and English were used giving a total GB estimate of 472 k odt y^{-1}. Almost all arisings are in England (94% total). Total non-marketed arisings are estimated at 321k odt y^{-1}, i.e. 68% of total estimated arisings. Utility work companies produce an additional 20 k odt annually (11 k in England, 6 k in Scotland and 3 k in Wales) giving a total of 492 k odt y^{-1}.

17. The waste woody material segregated from collected household waste and civic amenity sites across Britain is 179 k odt y^{-1} (WRAP, 2002). If this material is included, the total availability of this potential wood fuel resource is estimated to be 670 k odt y^{-1}.

Short rotation coppice

18. The total area planted up to June 2003 under the Woodland Grant Scheme and the Energy Crops Scheme is 2086 ha of which the vast majority (95%) is in England. Assuming an average annual production of 8 odt ha^{-1} y^{-1}, this equates to 17 k odt y^{-1}. Within England, just under half is within the Yorkshire and Humber Region with the East Midlands being the other main area of short rotation coppice (SRC).

19. Of the total area planted in England (1987 ha), 21% has been established under the Energy Crops Scheme which is conditional on the crop having a guaranteed energy end market; this applies particularly in the East Midlands. Many of the earlier crops established under the

Woodland Grant Scheme in the Yorks and Humber Region were contracted to Project Arbre but their availability on the open market is uncertain at present.

Total

Present potential resource in the absence of competing markets

20 The total potential operationally available woodfuel in Britain during the present forecast period of 2003-06, in the absence of competing markets, is 3.1 million odt y^{-1}. The main sources are small roundwood followed by sawmill co-product (potential to contribute around 1.03 and 0.86 million odt y^{-1} respectively) with arboricultural arisings providing about 14% of the total. Approximately equal quantities are available in England and Scotland but the composition is substantially different. Arboricultural arisings form the major element in England though sawmill co-product, small roundwood, and branches are all significant components. In Scotland and Wales, small roundwood and sawmill co-product are the dominant resources with all other potential resource streams playing only a minor part. Unless establishment of fast growing species as short rotation coppice increases substantially, it will remain a minor component of the potential woodfuel mix.

Current potential operationally available woodfuel resource (in the absence of competing markets) by country (thousand oven dried tonnes y^{-1})

Product	England	Scotland	Wales	Britain
Stemwood 7-14cm diameter	298	606	128	1032
Poor quality stemwood	94	113	70	278
Stem tips	14	12	5	31
Branches	225	116	68	410
Sawmill co-product	290	404	166	859
Arboricultural arisings	456	22	14	492
Short rotation coppice	16	0.6	0.2	17
Total	1,382	1,268	449	3,119

Present potential resource taking account of existing industries

21 The potential GB resource that could be made available to new woodfuel projects without serious disruption to existing wood-using industries is estimated to be 1.26 million odt y^{-1}. Assumptions on market availability are:

- 10% of the small roundwood
- 100% of the poor quality stemwood, stem tips and branches
- 10% of sawmill co-product
- 100% unmarketed arboricultural arisings
- 100% of material from clearance of utilities and roadside maintenance
- 80% of short rotation coppice in England, i.e. all coppice other than that established under the Energy Crop Scheme, and 100% short rotation coppice in Scotland and Wales.

Current potential operationally available woodfuel resource (in the presence of competing markets) by country (thousand odt y^{-1})

Product	England	Scotland	Wales	Britain
Stemwood 7-14cm diameter	30	61	13	103
Poor quality stemwood	94	113	70	278
Stem tips	14	12	5	31
Branches	225	116	68	410
Sawmill co-product	29	40	17	86
Arboricultural arisings	313	18	10	341
Short rotation coppice	13	0.6	0.2	14
Total	707	356	180	1,263

22 The databases compiled within this project can be interrogated for smaller geographical areas to identify the zones of greatest development potential and to evaluate the risks of regional or local imbalances in supply and demand created by new energy end use markets.

Future potential resource in the absence of competing markets

23 Operationally available woodfuel in the form of small roundwood, poor quality stems, branches, tips and foliage from traditional forestry is expected to remain relatively stable at just under 2 million odt y^{-1} up to 2020.

24 Even though the smaller and poor quality fractions are expected to remain relatively stable, the availability of larger dimension material is expected to increase substantially. Assuming the sawmilling sector expands to use this resource, co-product will increase proportionately.

25 Operationally available arboricultural arisings cannot be forecast with any certainty but seem unlikely to change dramatically.

26 Availability of short rotation coppice will depend on many factors of which Renewables Obligation co-firing conditions, CAP reform, support schemes, proof of energy end-markets and profitability of coppice relative to alternative crops are likely to be the most influential.

Significance of estimated resource

27 The total operationally available resource (3.1 million odt y^{-1}), if used for electricity generation, equates to 3.6 terawatt-hours y^{-1} or TWH_e y^{-1} (assumes calorific value of 20GJ odt^{-1} and 25% conversion efficiency) or 0.44 gigawatts or GW (assumes a generating time of 8000h per annum). The 10% UK electricity target for renewable generation is equivalent at present to 3 GW of which about 1 GW is hoped to come from biomass. If all the operationally available woodfuel is used to generate electricity it could therefore provide just under half of the notional target for biomass. This estimate should be reduced by a factor of three if existing markets are considered.

28 If woodfuel is used to generate heat, the operationally available resource of 3.1 million odt y^{-1} would generate about 12.1 TWH_{th} y^{-1} (assuming 85% conversion efficiency). This estimate should be reduced by a factor of three if existing markets are considered.

29 In the future, biomass could be used to produce transportation fuels. The current annual demand is 1600 petajoules or PJ (1 petajoule = 1,000 terajoules or 1,000,000 gigajoules). The conversion efficiency of woody biomass to ethanol or methanol is about 65% (Eyre *et al.* 2002). If all the

operationally available woodfuel is used to produce transportation fuels this would give about 40PJ y^{-1}, i.e. 2.5% of current demand. EU Directive 2003/30/EC states that 5.75% of all petrol and diesel must be replaced by biofuels by 2010. This estimate should be reduced by a factor of three if existing markets are considered.

30 Woodfuel would not be delivered (or used) in an oven-dried condition. The above estimates do not account for the energy required to evaporate the moisture contained in woodfuel because it can be very variable from one form of material to another and from one season to another. Ideally woodfuel will be dried using passive drying or waste heat to maximise efficiency of the overall process.

Limitations and uncertainties

31 We are confident in the base data for this study but there are uncertainties and limitations. Three of the main issues are:

- our estimate of constraints on residue harvesting in the private sector should be verified
- deadwood has not been included but could be a significant additional resource in areas where it is too windy to thin stands regularly.
- in view of the large resource identified in the branchwood of broadleaved woodlands, this estimate should be further validated and refined.

32 Forecasts of biologically available resource are subject to changes in silvicultural system - generally expected to reduce woodfuel yields - and to a lesser extent climate change, which is expected to increase overall tree growth.

33 Forecasts of the operationally available resource are subject to technological developments; some are likely to have positive effects on woodfuel availability but others are likely to reduce availability. A particular uncertainty is the response of the forestry sector, both the growing and the processing sectors, to the opportunities presented by a developing woodfuel market.

34 Though predictions of commercially available resource are not part of this study, we have tried to estimate the quantity of woodfuel that could be made available without significantly affecting existing industries. The assumptions behind these estimates are open to question.

35 If the data presented in this study are extended to estimate commercial availability of woodfuel to energy markets, a further layer of uncertainty must be taken into consideration. The effects of competing and inter-related markets are difficult to predict especially as most wood products are traded internationally. Commercially available woodfuel will also be highly influenced by regulation, incentives and support mechanisms affecting not only energy markets but also waste recovery and recycling.

CONTENTS

Part 2

Appendices (separate document)

1. INTRODUCTION

1.1. General

There is both a clear policy framework - from many Government Departments as well as the devolved administrations - and substantial funding to support increased use of woodfuel.

1.2. Policy background

1.2.1 Climate change mitigation

The government policy on renewable sources of energy is part of their wider approach to climate change. The UK is committed to reducing CO_2 emissions from 1990 rates by 12.5% (20 MtC y^{-1}) during the five-year period 2008-12 and has set a larger, voluntary target to reduce emissions by 20% (30 MtC y^{-1}) by 2010 with the longer term aim of a 60% reduction by 2050. Furthermore the EU Renewable's Directive 2001 recognises the need to promote renewable energy sources as a priority measure given that their exploitation contributes to environmental protection and sustainable development.

The report of the Royal Commission on Environmental Pollution *Energy – the Changing Climate* (2000) highlights the need for urgent action to avoid problems from increasing greenhouse gas emissions as a result of increasing demands for energy. One policy instrument is outlined in the DTI publication *New and Renewable Energy: Prospects for the 21st Century; Conclusions in response to the Public Consultation* (1999) which states that the Government wants to promote a climate of opportunity and to encourage innovation so that renewables can become increasingly cost effective and competitive with other more traditional energy sources. The Climate Change Programme identifies an integrated package of measures to reduce greenhouse gas emissions; these include an action point to continue the current rate of afforestation. The Programme also states that the most effective way for the agriculture and forestry sectors to contribute to reductions in greenhouse gas emissions is though the production of energy crops and woodfuel.

1.2.2 Energy

In January 2000, the Government stated its intention to obtain 10% of UK electricity from renewable sources of energy by 2010. The Renewables Obligation, which applies in England and Wales, and the Renewables Obligation (Scotland) were introduced in April 2002 requiring electricity suppliers to source and supply 10% of their electricity from renewables by 2010.

The Performance and Innovation Report (2001) fed into a wider review of Energy Policy culminating in the publication of the Energy White Paper in January 2003 which set an aspirational target of 20% green electricity by 2020 for the UK. In Scotland a higher target has been set - an aspirational target of 40% green electricity by 2020 which is equivalent to 2000-2500MW new renewables generation by 2020 or a constant build of 120-150 MW per annum. *Options for a low carbon future* (Future Energy Solutions, 2003) concludes that renewables need to be contributing at least 30% of our electricity generation if the UK is to achieve a 60% reduction in carbon emissions by 2050.

EU Directive 2003/30/EC states that 5.75% of all petrol and diesel must be replaced by biofuels by 2010 - the transportation sector accounts for more than 30% of final energy consumption in the EU. The Energy White Paper restates the Government's commitment to support research and development of bio-ethanol production from biomass because of its potential to deliver substantial carbon-savings as well as wider environmental benefits. The paper estimates that up to 5% of total future fuel use could come from biodiesel and bioethanol by 2020 and clearly signals support for use of biofuels from biomass from farm wastes, forestry residues, coppice crops and possibly also domestic waste.

There is no Government or devolved administration target for use of renewables in heat-only installations.

1.2.3 Forestry

While the Forestry Commission is keen to play its part in meeting the wider government objectives, there are additional important reasons for supporting the development of woodfuel. Woodfuel has the potential to provide an additional market for thinnings and poor quality final crops as well as a new market for forest residues and precommercial thinnings. Total softwood availability in Britain is expected to increase by approximately 50% over the next 20 years to a peak about 15 million m^3 of stem timber around 2017-2021 falling thereafter to around 10 million m^3 by 2042-46 (Smith *et al.* 2001); implications for potential woodfuel supply are discussed in 4.7 and 5.3. Removal of forest residues at the end of rotation could make it easier to achieve high stocking densities at regular spacing in the next rotation, reduce the period between felling and planting, and reduce the risk of pest damage to newly planted stock. A woodfuel market could support more active stand management, which in turn could bring about stand regeneration, a more diverse stand structure and an increase in biodiversity. Last but not least it could stimulate rural development. Thus woodfuel could play a part in ensuring the economic, environmental and social sustainability of forestry.

Forestry is a devolved issue. All three forestry strategies - A New Focus for England's Woodlands (1998), Forests for Scotland: the Scottish Forestry Strategy (2000), and Woodlands for Wales: The National Assembly for Wales' Strategy for Trees and Woodland (2001) - mention woodfuel in a very positive light. 'Woodlands for Wales' for example includes 'fostering the development of renewable-energy based on wood' as one of its strategic objectives.

1.3 Mechanisms to promote development of the renewables industry

Energy policy is a reserved matter (though renewables are devolved). The UK Government uses a combination of regulation, fiscal incentives and support schemes to further their policies.

The Non-Fossil Fuel Obligations (NFFO) were the main influence in the development of renewable sources of energy over the last decade. Almost all operational NFFO projects use landfill gas from municipal waste; the few biomass projects in operation within GB use straw or chicken litter.

The Climate Change Levy began in April 2001 – all non-domestic customers using electricity from non-renewable sources of energy pay an additional 0.43 p kWh^{-1}. In this way suppliers who sell electricity from renewable sources to non-domestic customers are able to obtain a refund of 0.26 to 0.34 p kWh^{-1}.

The Renewables Obligation (Statutory Instrument 2002/914), which operates in England and Wales, and the Renewables Obligation (Scotland) (Scottish Statutory Instrument 2002/163) came into effect in April 2002. They impose targets on electricity suppliers for the proportion of electricity that must be derived from renewable resources including biomass. The target in England and Wales is 10% electricity from renewable resources by 2010 while in Scotland the target is 18% by 2010 reflecting Scotland's greater existing hydropower capacity.

The Performance and Innovation Report on the use of renewable energy sources published in 2001 set in train a range of bio-energy support schemes with a total funding of nearly £350 million over four years. These include:

- the Bio-energy Capital Grants Scheme to fund the deployment of large scale, state-of-the-art electricity and combined heat and power (CHP) generation; deployment of biomass heating and small-scale CHP; and demonstration of new technologies. The Capital Grants should lead to at least 100 MW of electricity from biomass and significant penetration of biomass in the heat market in the UK.
- Grants for physical and market infrastructure to facilitate the development of the enabling infrastructure for energy crops and forestry woodfuel.
- Capital grants for community and household schemes. A key criterion is that schemes must be able to demonstrate a strong local community or household interest.

The Welsh Assembly Government will shortly introduce support to establish a small-medium scale woodfuel industry in Wales. Capital funding will total £6.3 million over 4 years with the objective of delivering, via 70 small and medium schemes, 25 MW thermal and 2.5 MW electrical energy. Grants will range from 35-50% of total installed cost.

The Pre-Budget report of November 2002, proposed the introduction of a 20 p l^{-1} reduction in tax on bioethanol. This was confirmed in the budget of March 2003 which set the introduction date as January 2005.

1.4 Current Usage

1.4.1 NFFO plants

To date in the UK, the total energy generated by woody biomass is less than 1 MW_e net declared capacity (out of a total of approximately 1 GW_e delivered by NFFO); these are relatively small-scale combined heat and power plants in Northern Ireland. Wood is used indirectly in several chicken litter power plants, e.g. Eye (13 MW_e), Glanford (13 MW_e), Thetford (39 MW_e) and Westfield (10 MW_e).

1.4.2 Domestic

Information on domestic wood fuel use is rather scarce being limited in our knowledge to three surveys – one for DTI and two for the Forestry Commission. In 1989, energy statistics compiled by ETSU estimated 900 thousand green tonnes of annual firewood usage. Early estimates by the Forestry Commission were 250 thousand green tonnes per annum (k gt y^{-1}). The most authoritative survey dates from 1997 when questions about household usage were included in an Omnibus Survey carried out by Research Surveys of Great Britain during two consecutive weeks in March 1997; this gave a representative survey of around 2000 adults.

Of the 2000 respondents, 9% used wood as a fuel at home (equivalent to about 2 million homes) either on its own or with other fuels. Wood was used regularly by 38% of the wood-using respondents with the remainder using it occasionally. Only 8% of wood-using respondents used it as their main heating fuel.

Total domestic usage was estimated from the percentage of households getting deliveries in particular ways. For example half of the wood-using respondents collected their own woodfuel; assuming they collect 0.1 tonnes gives a total of 100k green tonnes for that group. Of the 9% using woodfuel, 8% got regular truckloads; assuming this represents about 3 tonnes per year gives a total of 480k tonnes per year. When all four groups are taken into account, the total annual usage was estimated at 1.2 million green tonnes firewood or approximately 600 thousand oven dried tonnes per annum (k odt y^{-1}).

In spite of the limited general data, there are many examples of woodfuel boilers being used for heating, mainly in heat-only units or occasionally in combined heat and power units, throughout the UK. Table 1 lists examples in England and Wales. The combined capacity is at least 6MW with a further 20MW under development by Slough Heat and Power. Since the list is not comprehensive this figure is an underestimate of current heat generation and woodfuel usage but does illustrate that they can be locally important.

Table 1. Examples in England and Wales of small scale use of woodfuel for heating giving location and rating where known.

Location	Rating (kW)
England	
Boughton Pumping Station	300
Ecotech Discovery Centre and Business Park, Swaffam	250
Drayton Estate, Northamptonshire	270
Weobley School, Worcester	350
Park Farm Industrial Estate, Buntington, Herts	120
Shenstone School, Cannock, Staffs	350
Dunstall Court, Redditch, Worcs	
Heart of the National Forest	
Elvendon Priory, Goring-on-Thames, Oxfordshire	300
West Dean Estate, Chicester, West Sussex	773 + 440
Combe Farm and Cottages, Seaton, Devon	35
Nutwell Farm, Taunton	
Open University, Milton Keynes	
Beddington Zero Energy Development, Sutton, London	$130kW_e$
Worcester County Hall, Worcester	700
Lee Moor Farm, Rennington, Northumberland	80
Devon Chulmleigh, Devon	
Dartington Trust, Dartington, Devon	
Cornwall County Council, Launceston, Cornwall	
AF Hill and Sons, Fenwick, Worcs	
Paddock House Farm, Sicklinghall, North Yorkshire	150
The Earth Centre, Nr Doncaster, South Yorkshire	
Wycombe Environment Centre, High Wycombe, Bucks,	23
Slough Heat and Power Station, Slough, Berks	20000
Grove Hill Farm 2000, Thame, Oxon	
Dorney Reach, Dorney Reach, Berks	12
Oxford Eco House, Oxford	
East Surrey Hospital, Surrey	
Norbury Hill Sawmill, Norbury Hill, Surrey	
Woodland Enterprise Centre, Flimwell, E Sussex	
Betteshanger I, E Sussex	100
Wales	
Centre for Alternative Technology, Machynlleth, Powys	50
National Botanic Gardens, Llanarthe, Carmarthen	100
Biocentre, Brynmenyn Industrial Estate, Bridgend	500
Nant-y-Garreg Farm, Sarron, Carmarthernshire	50
Connection UK	Medium
St Fagan's, Cardiff	Medium

1.4.3 Industrial

The main industrial use is of sawmill co-product for producing heat to dry timber. Data from the Sawmill Survey 2000 (Balachandran and Henderson, 2001) gives the GB total usage as just under 24k m^3, 20k of which was in Scotland with England and Wales totalling 4k m^3.

1.5 Proposed usage

Eight of the eleven successful projects selected in the first round of the Bio-energy Capital Grant Scheme for biomass heating and small scale CHP propose to use woodfuel (see Appendix 1).

Three of the six large/medium scale electricity and CHP projects announced so far will use a proportion of forest biomass or co-product. The project in Northern Ireland will use mainly sawmill co-product.

1.6 Existing estimates of availability

1.6.1 GB and regional estimates of woodfuel from traditional forests

Six previous studies are summarised in Table 2. In general these focus on harvesting residues and indicate a current resource of around I million odt y^{-1} woodfuel increasing towards 2010.

Table 2. Previous estimates of woodfuel resource (k oven dried tonnes y^{-1}).

Study	Date	Estimated resource (k odt y^{-1}).	Material
Mitchell and Matthews 1980	1977	550	Residues from thinnings and clearfell of conifer and broadleaved crops.
	1996	1,140	
Atkins *et al.* 1984	1984	1,000	Residues from thinnings and clearfell from commercial conifer crops
Hare *et al.* Unpublished	2006	1,190	Residues from thinnings and clearfell from commercial conifer crops
Mitchell *et al*. 1990	1989	650	Residues from thinnings and clearfell from commercial conifer crops
	2010	1,120	
Hudson, 1993	2000	800	Residues, residuals and bark from commercial conifer crops
	2006	1,010	
Hudson, 1997	1998	1,144	Forestry residues, precommercial thinnings, residuals plus arboricultural arisings and some elements of sawmill co-product. Some constraints due to site taken into account.
	2013	1,728	

Mitchell et al. (1990) estimated, in addition to residues, conifer whole trees and hardwood whole trees. The most complete study (Hudson, 1997) includes forestry residues and residuals (e.g. dead wood) plus arboricultural arisings and some elements of sawmill co-product and for the first time attempts to take account of the site factors that limit woodfuel availability.

1.6.2 Regional and local estimates of woodfuel from traditional forests

Several of the studies listed above split their estimates by country and forest district. Hudson (1997) for example used forest production and the use of different types of harvesting system in the seven GB areas used by Forest Enterprise (an agency of the Forestry Commission) pre-1996. This suggested that the greatest resource was in Wales and South Scotland (73k and 63k odt respectively) with least available in N England (25k odt).

Forest Enterprise (Wales) analysed small roundwood production in Welsh Assembly Government woodland (Forest Enterprise Wales, 2002). Wales was split into 25 Working Zones in which availability of potential woodfuel was estimated from a knowledge of the growing resource and existing markets. These were aggregated to give figures for four areas within which transportation of fuel was sensible and finally aggregated to give country estimates. For the period 2002-2006, potential biomass volume is estimated at 1.5 k gt y^{-1} in the North, 10.8 k gt y^{-1} in Mid-Wales, 31.2 k gt y^{-1} in the West and 49.2 k gt y^{-1} in the South increasing to 4.7, 13.1, 33.1, and 75.1 k gt y^{-1} for the four areas for 2006-11.

As supporting information for feasibility studies for major wood-using developments in Scotland, Scottish Enterprise and the Timber Growers Association commissioned a confidential study of softwood availability from the private sector in Scotland and Northern England. Data have been taken into consideration but are not presented in this report.

There have been numerous estimates of resource in the English regions during the formation of Regional Development Plans but in general these use broad assumptions about the resource and contain little data of a new and authoritative origin.

To our knowledge there are also the following local resource in the public domain.

- Gwynedd (Gwynedd biomass feasibility study. Dulas, 1998)
- South Caernarfon (Fuel supply for the proposed biomass system at South Caernarfon Creameries near Y Ffor in Gwynedd. October 2000)
- Ceredigion (The Ceredigion biomass fuel supply study. British Biogen, 2002)
- Dyfi Valley (The potential sustainable biomass fuel resource from forest and woodland sources within the Dyfi Valley Eco-Partnership area. 2002)
- Chilterns (Assessment of availability of wood material in the Chilterns AONB and immediate vicinity for energy generation. Render 2002)
- Grampians (Tonnage of low grade softwood in Grampian. Grampian Woodlands Company, 2002)

1.6.3 Arboricultural arisings

Trees and woodlands are managed intensively in urban areas due to their proximity to roads, buildings, structures and services. Arboricultural arisings refer to the woody arisings from harvesting, pruning and safety operations that are carried out in urban areas, semi-rural areas and at rail and road sides on single trees or small copses. Much of this work is done by Councils and Local Authorities but private arboricultural and forestry contractors also harvest and process significant quantities of biomass each year.

It has proved impossible in the past to accurately gauge the quantities of material coming forward on a national scale each year or the current methods of disposal. However the Waste Policy Unit of the Department of the Environment (Ogden, 1997) and other organisations have begun to identify the proportions of this type of material generated in the UK. The main studies are:

- Hudson (1997) included a review of arboricultural residues. The study estimated 484 k odt y^{-1} of potential wood fuel from arboricultural arisings in Britain.

- The London Tree Officers' Association (LTOA) made an initial estimate of 54 k m^3 y^{-1} of woody material generated by arboricultural operations within London (LTOA, 1996 see www.bioregional.com/urba/urba2.htm). They concluded that this represented a substantial potential resource but one with major disposal issues.

- In a study of the potential for developing a biomass fuel supply from tree management operations in London, Ecoenergy Ltd in partnership with the LTOA estimated that arboricultural operations carried out in London by contractors working for local authorities generate 100 k gt y^{-1} (approx. 50,000 odt y^{-1}) of material suitable for processing into biomass fuel (Bright, 2001).

Options for on-site disposal of arboricultural arisings are limited and much of it is transported away from the site. Local authorities, parks management organisations, arboricultural contractors and landscape companies may have local arrangements for utilisation. Nevertheless, a large quantity of the material is disposed to landfill, which incurs costs and has environmental implications. The introduction of a landfill tax in October 1996, with a standard rate of £7 t^{-1} for biodegradable waste, has led to the adoption of waste minimisation and recycling policies as priorities for many Local Authorities, waste handling agencies and arboricultural contractors. The current landfill tax escalator, introduced in 1999, commits the Government to raise the standard of tax for active waste by £1 t^{-1} each year until 2004-05 when it will have reached a rate of £15 t^{-1}. The intention to increase landfill tax by at least £3 t^{-1} y^{-1} in future years from 2005/06 and an indication that the tax would increase to £35 t^{-1} in the longer term (Defra, 2003) must encourage tree work contractors to look for an alternative disposal methods of the arisings. The high costs of the disposal of woody material in urban areas create particular opportunities for its use for energy production (British Biogen, 2002).

Although this study does not include waste wood, it is worth noting the estimated quantities. Other sources of potential woodfuel include waste woody material arisings segregated from collected household waste and civic amenity sites. In a recent study this was found to be 358 k gt y^{-1} (approx. 179 k odt y^{-1}) for England, Scotland and Wales (WRAP, 2002).

1.7 Limitations of previous studies.

1.7.1 Types of resource

One of the major limitations of previous studies is that they include only part of the potential resource that could be considered available.

- Timber prices for solid wood have fallen sharply since most of the previous estimates to the point that, in certain situations, small dimension stems, which have not been included in previous estimates, could become available to energy end-uses.
- Sawmill co-product is a second important potential resource previously underestimated; the only other attempt to include mill co-product was limited to bark and a portion of the offcuts.
- Few studies include arboricultural arisings yet Hudson (1997) estimates, using two different methods, the resource to be around 500 k odt y^{-1}.

1.7.2 Technical limitations within the traditional forestry sector

- Forestry Commission yield tables of stem biomass (as published in Forestry Commission Booklet 48) have been extended by using simple adjustments to give estimates of the other tree components. To a great extent these adjustments have been based on unsupported assumptions. In particular, estimates of branch biomass are very approximate for broadleaved species.

- The approach to estimating the effects of site conditions on the amount of residue and residuals that might be removed from harvesting sites was not consistent from one part of the country to another.
- Few estimates include detailed forecasts of the future resource.

1.7.3 Time relevance

- Sawmill capacity has changed; in general there are now fewer but larger mill.
- Previous studies predated the recent trends in both the pulp and the panel sectors for increasing use of recycled materials at the expense of sawmill co-product or small roundwood.

1.7.4 Data presentation format

Results of national studies were presented in paper form summarised by country or region. In the present situation, planners, policy makers and developers would be better served by a more refined system which would ideally allow them to define

- an area of interest, e.g. a region, a Local Authority or a location and transportation distance
- a type of resource, e.g. thinnings from broadleaved forests or sawmill bark;
- a future time interval.

1.7.5 Consideration of competing markets

No national studies and only a few local studies have indicated existing uses that might be expected to compete for the available resource. The Welsh study of small roundwood resource is an exception – it considers the impact of the main markets (pulpwood, particle board and fencing) on woodfuel availability.

1.8 Objectives

The objectives of the study were to:

- estimate the present potential *operationally* available resource from traditional forests, sawmills, urban areas, roadsides, powerline routes and short rotation coppice in a sound and consistent way and at the finest resolution justified by the data
- forecast future availability of the resource from traditional forests
- summarise information at a medium geographical and temporal scale in paper and electronic form
- provide commentary on potential *commercial* availability, making clear the location and general scale of existing competing markets
- allow the user, via an interactive website, to sift through summarised information to identify the woodfuel type of interest
- allow the user to submit an electronic request with a defined area of interest, resource type, and a future time interval (with an undertaking to provide the user with refined information within one working week at minimal cost)
- develop a dynamic tool to update summary data tables with the purpose of both meeting users' information needs more exactly and facilitating the process of updating tables as new information becomes available or existing information is refined

2. SCOPE

2.1 Sources of woodfuel.

This study covers the following sources of woodfuel:

- Forests and woodlands. This includes:
    - harvesting residues. In this study we define these as the tips of the stems (defined as having a diameter of <7 cm for the purposes of this report) and side branches. These fractions are often called ‘lop and top’ or ‘brash’.
    - small roundwood, i.e. small stems cleaned of side branches with a diameter of 7 to14 cm
    - poor quality final crops. Though large enough to be used for timber these are of such poor form that they are normally left on site or they may currently be cut for firewood.
    - traditional coppice. Certain species, in particular hazel and sweet chestnut, can regenerate new stems from the base following harvesting of the previous stems. These are occasionally grown on their own but are traditionally grown along with single stemmed trees of high timber value.

  This study did not include:
    - small (<2ha) private woodlands since we anticipate that this resource will be too dispersed to justify inclusion. Woodland less than 2ha accounts for 4.5% of the total woodland area in GB. This is discussed further in 5.7.1.
    - trees outside woodland (but excluding urban trees) since we anticipate that this resource will be too dispersed to justify inclusion. There are approximately 123 million trees outside woodland; this is approximately 3.5% of the total trees in the British countryside (excluding urban trees).
    - standing deadwood, i.e. trees that have died due to excessive shading by their neighbouring trees, drought, or disease. A few standing dead trees may be left to provide wildlife habitats but most are normally felled along with the living trees. They are currently left on site since the timber is not suitable for present markets. However, standing deadwood does represent a potential woodfuel resource especially as the moisture content is lower than for living trees. Although the number and volume of trees that have died in any previous 5 year period can be estimated, it was not possible in the time available to estimate the accumulated mass over the crop’s life and the decrease in mass and energy content through degradation and decomposition. To avoid confusion, data for deadwood that has been produced in the previous 5 years has not been included.
    - forked stems and ‘butt reducings’

- Sawmills. Approximately 50% of the volume of stem wood that is sold to sawmills can be converted into timber in the form of planks, batons etc, and the remainder (co-product), which can include bark, chips, and sawdust and slabwood, is normally sold for a variety of different purposes.

- Urban areas, transport corridors (roads and railways) and routes of powercables. The products of fellings, thinnings and prunings of trees in these areas (‘arboricultural arisings’), are generally left on site in the form of chippings or removed to land fill sites. A small proportion is currently used for energy end markets.

- Short rotation coppice. In these systems, cuttings are planted at close spacing, normally on good quality, ex-agricultural ground, and cut back after one year to encourage the generation of multiple stems from the base. These new stems are cut in 2-4 years depending on growth rate; this cycle can be repeated many times until the base and root system begin to loose vigour or availability of more productive varieties justifies replacement.

This study does <u>not</u> include recycled or waste wood. Parallel studies are attempting to quantify, or already have quantified, these resources.

2.2 Woodland ownership

This study covers:

- public forest managed by Forest Enterprise, an agency of the Forestry Commission, on behalf of the Government and devolved administrations
- forest managed by other government departments, such as the Department of Defence
- woodland owned by non-governmental organisations, such as the Woodland Trust
- privately owned woodland

We have described the last three categories as 'private' because the base data are collected in the same way and one that differs from the method used to assess the public forest. Strictly speaking the terms should be 'Forest Enterprise' and 'all other' but we judged that this could lead to confusion.

2.3 Geographical scale

The smallest unit used for data presentation in this paper report is the Forestry Commission Forest District (see Figure 1) for traditional forests. The smallest unit for other data is the English Region (see Figure 2) because the forest district level was either not justified due to scarcity of data or because data could be traced back to the individual data provider thereby breaking confidentiality agreements given when data were originally collected. Forest District and English Region data can be collated at country and GB level.

Figure 1. Showing Forestry Commission Forest Districts as at 2003

Figure 2. Map showing English Regions as at 2003.

2.4 Timescale

Estimates of current resource are based on the most recent information (details are given in Methodology). In addition the potential resource from forests and woodlands is forecast into the future using well established procedures to estimate production based on knowledge of the existing types of forests, their growth rates, and expected felling age. The available resource is not predicted for SRC, arboricultural arisings or sawmill co-product.

2.5 Economics

This study estimates potential operationally available resource, i.e. the quantity that it would be possible to make available at roadside taking biological, environmental and operational factors into account. It does not take economic feasibility into account, for example it does not exclude resource on the basis that harvesting and extraction might be too expensive. Judgements about economic feasibility are the potential developers' responsibility. Moreover the decision is likely to change through time depending on a host of factors, in particular financial support structures and incentives, transportation costs, harvesting costs, timber prices, and prices paid by competing markets. The effect of recycling is especially difficult to predict. Our approach has been to provide a sound and consistent basis for estimates of the resource available at roadside in a way that facilitates decisions on woodfuel developments.

2.6 Competing markets

It is important to state that this study has not identified in detail how much resource is currently committed in long term contracts. In the context of the present study, this qualification applies to timber down to 7cm diameter (mainly softwood) and sawmill co-product. Instead we show the position of the main wood-using industries since in general each will source most of its raw material from as close as possible to the point of use.

Appendix 2 gives the location of the main wood-using industries - sawmills (Figure A1a), and pulp/paper mills and panel mills (Figure A1b); it is important to understand that sawmills compete for small roundwood but are also a source of co-product. The wood panel industry has taken on average over the past 10 years about 1.5 million gt y^{-1} of small roundwood directly from British forests and another 1.7 million gt y^{-1} of co-product from sawmills; over the past four years an increasing proportion of the panel sector's raw material has come from recycled wood and was estimated to be around 0.9 million gt in 2002, almost a quarter of the total raw material intake to the panel industry. This trend is expected to continue in view of the planned incentives to reduce landfill. The paper products sector takes about 0.8 gt y^{-1} small roundwood annually and it too has increased its use of recycled paper. The trends for increasing use of recycled material are expected to decrease the usage and/or price of small roundwood and sawmill co-product.

Long term availability must also be considered. The annual production of larger dimension softwood is expected to rise substantially up to 2020. Although new papermills and an expansion of existing papermills have been mooted, none has reached the planning stage. The reality is that there are no guaranteed markets for the expected increase in production.

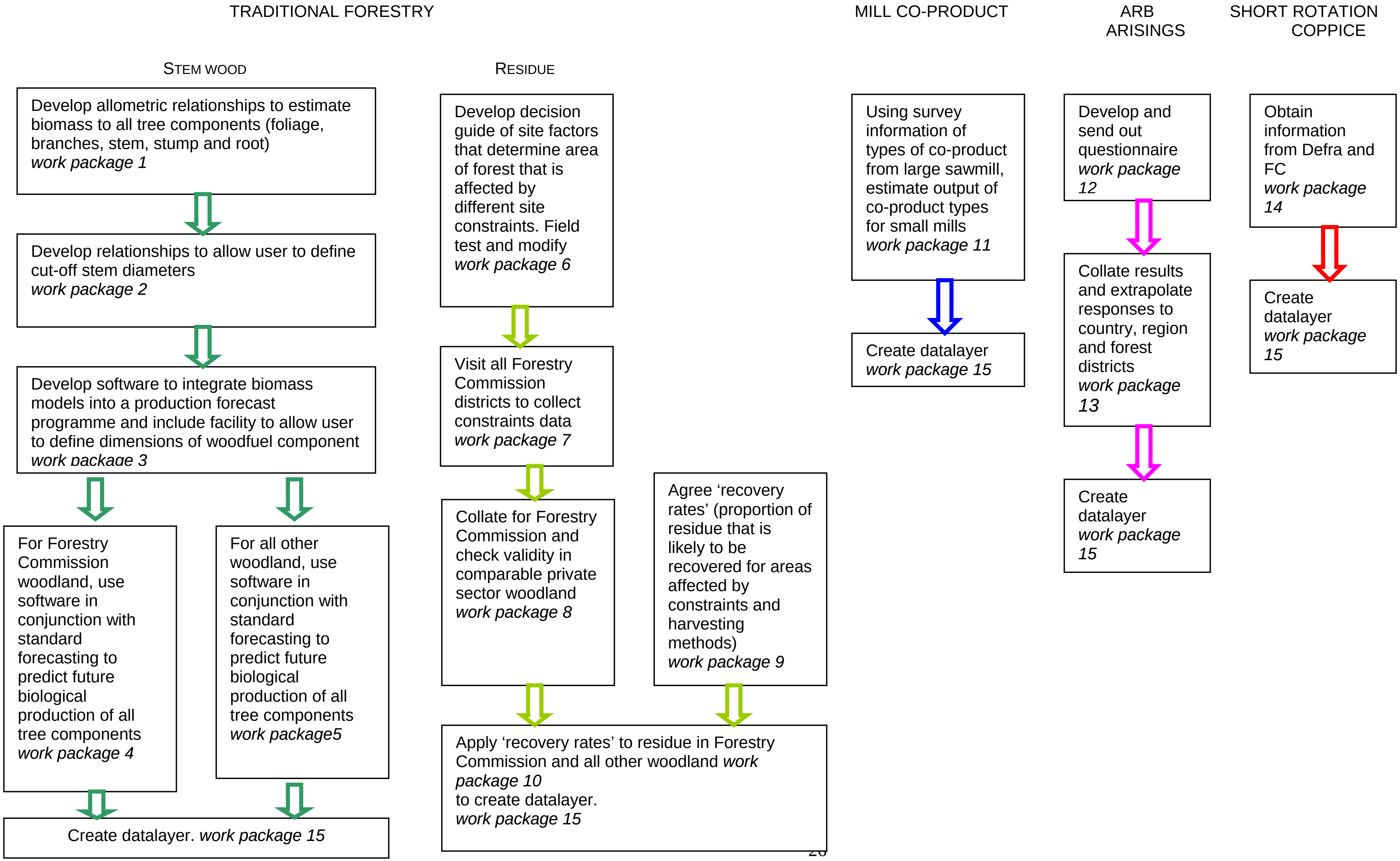
2.7 Actual availability for energy end-uses

Actual availability can only be determined through negotiation between supplier and customer and will be dependent on commercial factors as well as existing contracts. Appendix 2 gives useful contacts.

3. METHODOLOGY

3.1 Overview

There were fifteen work packages carried out as seven parallel tasks, all feeding into the master database, the GIS, and finally the webpage development. Within parallel tasks there were often sequential stages and linkages between tasks. The structure is outlined in Figure 3.


TRADITIONAL FORESTRY
MILL CO-PRODUCT
ARB ARISINGS
SHORT ROTATION COPPICE
STEM WOOD
RESIDUE
Develop allometric relationships to estimate biomass to all tree components (foliage, branches, stem, stump and root) work package 1
Develop relationships to allow user to define cut-off stem diameters work package 2
Develop software to integrate biomass models into a production forecast programme and include facility to allow user to define dimensions of woodfuel component work package 3
For Forestry Commission woodland, use software in conjunction with standard forecasting to predict future biological production of all tree components work package 4
For all other woodland, use software in conjunction with standard forecasting to predict future biological production of all tree components work package5
Create datalayer. work package 15
Develop decision guide of site factors that determine area of forest that is affected by different site constraints. Field test and modify work package 6
Visit all Forestry Commission districts to collect constraints data work package 7
Collate for Forestry Commission and check validity in comparable private sector woodland work package 8
Agree 'recovery rates' (proportion of residue that is likely to be recovered for areas affected by constraints and harvesting methods) work package 9
Apply 'recovery rates' to residue in Forestry Commission and all other woodland work package 10 to create datalayer. work package 15
Using survey information of types of co-product from large sawmill, estimate output of co-product types for small mills work package 11
Create datalayer work package 15
Develop and send out questionnaire work package 12
Collate results and extrapolate responses to country, region and forest districts work package 13
Create datalayer work package 15
Obtain information from Defra and FC work package 14
Create datalayer work package 15

3.2 Traditional forestry.

3.2.1 Basic data.

Public forest managed by Forest Enterprise, an agency of the Forestry Commission, is regularly surveyed at the stand level. There is a rolling programme of resurveying to update the database – the subcompartment database.

All other forests are sampled – data on individual stands are not collected. These include forests that are privately owned as well as those that are managed by other Government departments (such as the Ministry of Defence) and charities (such as the Woodland Trust and RSPB); for convenience these are referred to as privately owned woodlands. Aerial photographs are used to describe location, size and type of forest. A proportion of main woods greater than 2 ha is then visited and plots are sampled for species, age and stocking (number of stems ha^{-1}). Information on smaller woods and trees is obtained by random sampling in about 0.06% of the land area of small woods (0.10 to 2ha), linear features, groups, and individual trees. It does not include data on developed land of 2 ha and more. Fuller details of the private sector protocols and assessments are given in the National Inventory of Woodland and Trees (Forestry Commission, 2002).

In both sectors, inventory data on tree stocking, diameter and height at a particular age are used to predict yield class. Yield class, in conjunction with an assumed management regime, can be used to estimate the annual volume increase up to the time when growth rates begin to flatten off. For example a yield class (YC) of 16 means that the stand of trees is increasing in stem volume (in this case the stem >7cm diameter) at a rate of $16m^3\ ha^{-1}\ y^{-1}$. Information on species, planting year and YC are held on the subcompartment database for each stand in the public sector and for each sample plot in the private sector. In general, similar data are collected in both private and public forest but there are a few exceptions. In the context of this study, the main difference to note is that stem quality for 7+cm diameter material is assessed in private woodland but not in the public sector forest. In the private sector if the stems are so badly bent or forked that a timber end use is unlikely, they are classified as ‘poor quality’ stems.

3.2.2 Tree biomass

A full description of the methods used to extrapolate from a knowledge of species, current volume of 7+cm diameter stems and yield class to biomass of all other tree components is given in Appendix 3. The methods are outlined here in four workpackages:

- Estimating tree components from basic stand data (WP1).
- Allowing user to define cut-off diameter (WP2).
- Integrating Workpackages 1 and 2 into a production forecast system (WP3).
- Forecasting production of all biomass components for FC woodlands (WP4).

3.2.2.1 Estimating tree components from basic stand data (WP1) (see Appendix 3, 4, and 5 for details)

Assessments of volume per hectare in standing tree stems are readily available from records maintained on Forestry Commission permanent sample plots and also in published yield models. Stem volume estimates can be converted to biomass (in units of oven dry tonnes per hectare) by multiplying by the appropriate average nominal specific gravity for the species of wood in question.

For tree components other than the stem, species-specific equations were developed to enable biomass to be computed from the variables that were more readily available. This required a comprehensive review of data on the biomass allocation to tree parts other than stems. Relevant data from the scientific literature and Forestry Commission sources were collated and processed into a consistent dataset.

The bulk of data on the biomass of different tree components has been collected on individual trees rather than for whole stands, therefore a system needed to be devised that would permit the upscaling of biomass estimates from tree to stand (i.e. per-hectare) scale. The methodology adopted consisted of three stages as follows.

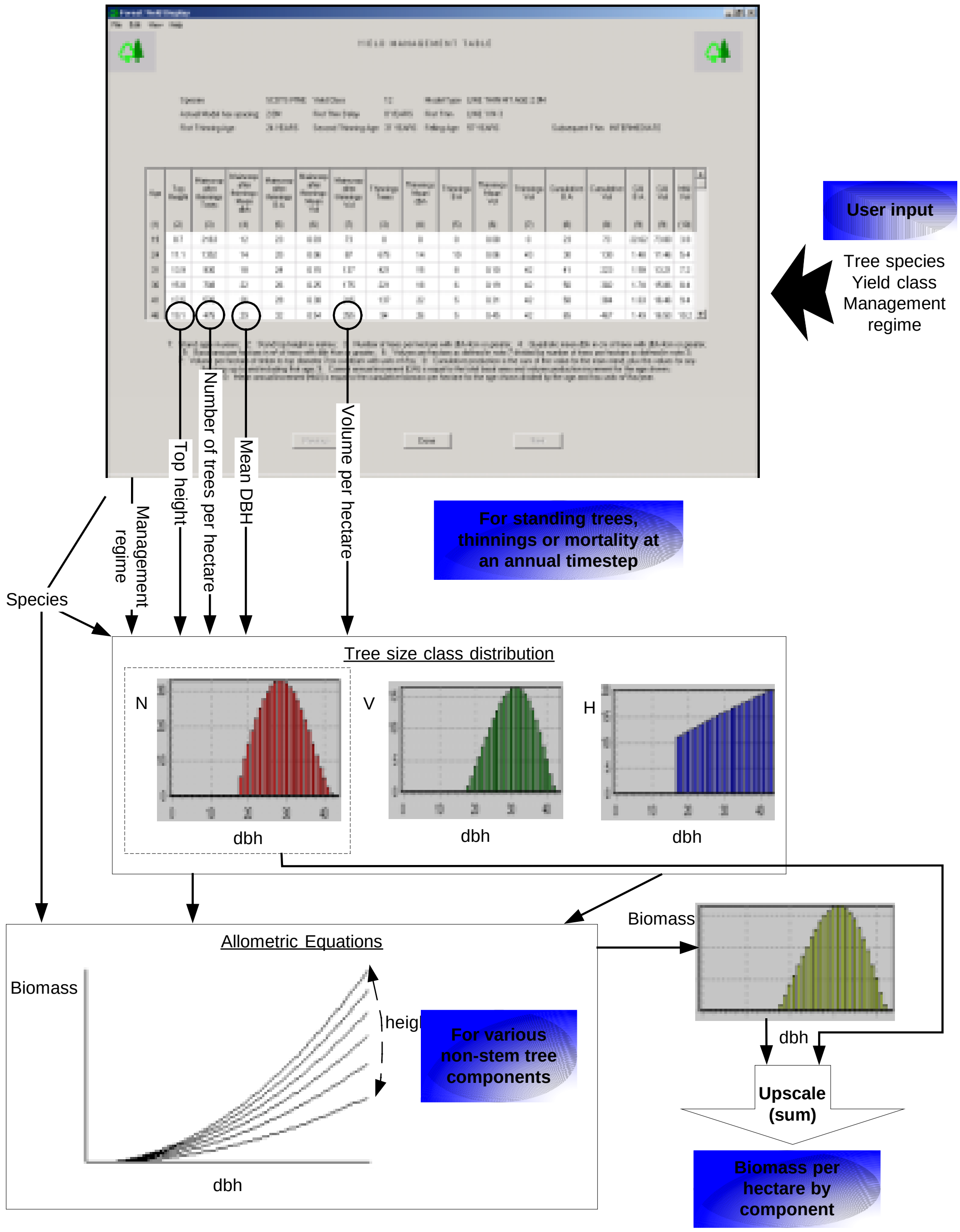
In the first stage, species-specific allometric relationships were constructed for estimating the root, branch and foliage mass of individual trees from standard mensurational variables, i.e. tree diameter at breast height (dbh), i.e. 1.3 m, and/or height. Details of these allometric relationships can be found in Appendix 3. For some groups of species it was impossible to distinguish significant differences in allometry and a common relationship was assumed. For certain tree species, generally minor species in terms of British forestry, there were insufficient data for the calibration of a reliable relationship. In these cases it was assumed that allometry followed the pattern characterised for another species or species group. The assignment of this 'nearest available' result was based on:

- the range of alternative results available
- dendrological considerations
- knowledge of growth characteristics of different tree species in Britain (Hamilton and Christie, 1971; Hamilton, 1998).

The second stage involved the development of models for estimating the distribution of different tree sizes (in terms of dbh and height) in a stand of trees based on stand-scale mensurational variables available as outputs from models used in production forecasting (e.g. mean dbh, top height, numbers of trees and volume per hectare). Appendix 4 gives details of the methodology adopted and also a description of the models produced.

In the third stage, existing computer-based yield models were integrated with the tree size-class distribution models and allometric relationships to generate stand-scale biomass estimates. The computer code comprising this integrated suite of models and equations formed a major module of a program designed to estimate the biomass per hectare in specified components of trees. This program, known as BSORT, was developed specifically to provide the forecasts required as outputs for this project. The integration of sub-models and equations within BSORT is illustrated in Figure 4.

Figure 4. Illustration of structure of main module of BSORT computer program for estimating biomass of tree components.



3.2.2.2 Allowing user to define cut-off diameters (WP2).

At present whole tree stems and part of stems smaller than 7cm diameter are generally left in the forests and are not marketed. In anticipation of the development of a woodfuel market, we have built in the facility to look at new methods of harvesting. Firstly the methodology developed under WP1 and implemented as part of BSORT can be used to estimate the biomass of woody material potentially available in stems of trees down to 4 cm dbh. Secondly under WP2 additional facilities were built into the BSORT program to permit the user to specify the cut-off diameter between traditional wood products and potential woodfuel. For example, if there are profitable markets for stem material down to 12 cm diameter and also for woodfuel but not traditional markets for material of intermediate size, an option would be to designate as woodfuel all the top of the tree to the point where the diameter reached 12 cm as opposed to 7 cm as at present. Accordingly the BSORT program estimates stemwood biomass below and above any specified cut-off diameter.

This report and website summary data use fixed cut-off diameters but this capability can be used in the refined forecasting service if the user defines a non-standard diameter as the maximum cut-off point for woodfuel.

3.2.2.3 Integrating Workpackages 1 and 2 into a production forecast system (WP3).
This facility within BSORT was implemented by integrating the program with an existing forest products assortment forecasting program, ASORT. The ASORT program was originally developed to provide forest managers with estimates of the potential volume of products of different specifications available from given forest stands (Rollinson and Gay, 1983). In order carry out such a forecast, ASORT requires as input data:

- the numbers of trees and volume per hectare in the stand of interest.
- the distribution of tree size classes (in terms of dbh and height) in the stand of interest.
- specifications for the products to be cut from the stand (in terms of maximum and minimum top/bottom diameters and minimum and maximum product lengths, with or without length increments, or fixed product lengths, as appropriate).

Sub-models of the BSORT program already generated the stand and tree size-class information required as input data to ASORT, therefore it was possible for BSORT to call ASORT effectively as a subroutine, passing these data as arguments (Figure 5). For the purposes of this project, it was possible to define a simple specification for the different stem wood products in terms of minimum top diameters. A facility was then provided enabling the user to invoke BSORT, providing as input data one or more cut-off diameters of interest. BSORT then called ASORT with the simple product specification and cut-off diameters as arguments. ASORT then generated estimates of biomass per hectare in stem wood above and below these cut-off diameters which were returned as arguments to BSORT and could then be reported to the user. To permit thorough testing of the completed BSORT model, a stand-alone user interface was developed. This could be used to quickly enter values for species, yield class, management regime, stand age and other relevant input variables which were then passed to BSORT. The interface could also be used to display outputs from BSORT for checking. A screenshot of the BSORT user interface with example input data and results is shown in Figure 6. This interface may have wider applications.

Figure 5. Illustration of interface between main BSORT module and ASORT computer program for forecasting biomass in stemwood components

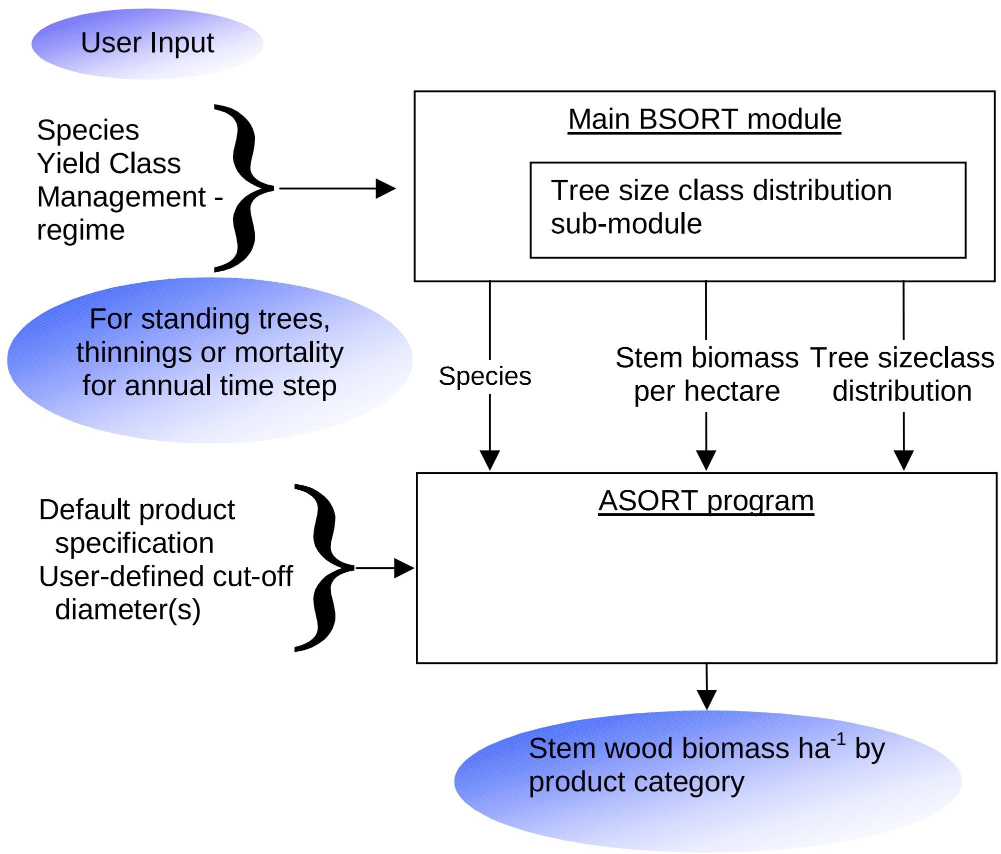
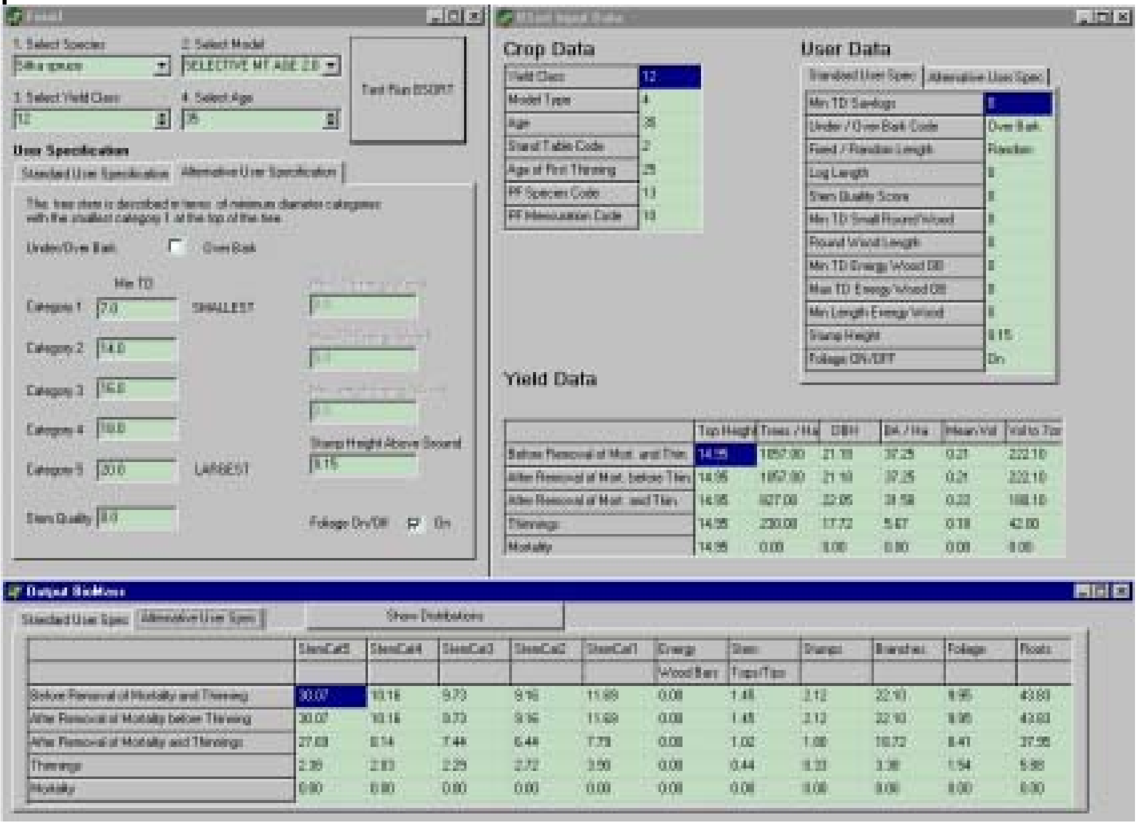


Figure 6. Screenshot of the BSORT model showing an example of model inputs and predictions



3.2.2.4 Forecasting production of all biomass components for Forestry Commission woodlands (WP4).

The new version of the FC Production Forecast program in conjunction with BSORT was run to give predictions of biomass for tree components for each of 30 Forest Districts using data on forest cover, species, yield class, age and Forest Design Plans from the sub-compartment database that relate to the district. One significant difference from the standard Forest Enterprise forecast is that only land classified as high forest or windblown is included in the standard published production forecasts for FE; within these categories, land for which timber production is not the main management aim is removed and regarded as non-forecastable. The present study used all land that has a tree species (including arboreta other such stand types) therefore indicating the maximum potential wood fuel resource from Forestry Commission land. For these stands all data used for forecasting timber production had already been surveyed and was present in the sub-compartment database.

The combined Production Forecast/BSORT system gave estimates of quantities of biomass on an oven-dry weight basis for:

- the stem (as divided up according to cut-off diameters that could specified the user)
- stem tips (i.e. material between the specified lowest cut-off diameter on the stem and the tip the main stem)
- woody branches
- foliage
- tree stumps
- the woody root system

The estimation of quantities of biomass in the stump as opposed to the main stem depends on an assumption about the cutting height. This could be defined by the user as part of the input variables to the forecast. Estimation of biomass in the stump and stem was carried out as an integral part of the calculations of the ASORT program described earlier.

Full details of assumptions made in the biomass production forecasts for the 30 Forest Districts are listed in Appendix 6, including an explanation of any differences compared to the standard production forecast of stem volume for the Forest Enterprise estate.

3.2.2.5 Forecasting production of all biomass components for private sector woodlands (WP5).

The procedure is generally similar to that outlined above except that:

- the private sector forecasting model has slightly different assumptions (see Appendix 7)
- the private sector uses felling plans as opposed to Forest Design Plans and
- private sector woodland data are derived from the National Survey rather than the sub-compartment database.

3.2.3 Forest residues.

3.2.3.1. Developing a decision guide of site factors affecting residue availability (WP6)

<u>Background</u>

WP4 and WP5 provide estimates of the biomass produced annually in the form of branches and foliage - we describe this as the 'potential biologically available harvesting residues'. However the proportion that can be removed from the site will generally be much less than the biological availability – we describe this as the 'potential operationally available harvesting residues'. The difference between biological availability and operational availability can be considered as two separate steps. Firstly there can be constraints on whether harvesting residues should be taken from the site; these are usually environmental in nature and restrict operational practices. These constraints are covered in WP6. Secondly even if harvesting residues may be removed, it may not be possible with current methods and machinery to physically collect and lift all the offered harvesting residues off the ground and transport it out of the forest; this is covered in WP9.

<u>Site constraints on forest operations</u>

Many factors influence how much of the biologically available harvesting residues may be offered for woodfuel. The UK Forestry Standard (Forestry Commission, 1998) sets out the overarching principles of sustainable forest management; a supporting set of Guidelines gives practical recommendations. In the private sector, failure to follow the Guidelines can result in grant aid being withheld. Also the UK Woodland Assurance Standard (1998) sets out detailed guidance that woodland owners and/or managers must follow if they wish to gain FSC certification for their produce. For example, the Forestry Commission has a policy to prohibit the removal of harvesting residues from sites at risk of nutrient depletion. Also soil protection is a common constraint because residues are often required to avoid soil disturbance or damage by harvesting machinery. The need for soil protection is dependent on soil type and the time of harvesting with wetter soils and winter harvesting operations more likely to need residues than dry sites and summer harvesting operations.

<u>Decision-making guide (Appendix 8 contains the guide in full)</u>

A guide was produced to help Forest District staff, usually the harvesting manager, quantify the extent of the various site constraints in each Forest District. The purpose of the guide was to:

- identify the many factors that can influence the proportion of biologically available harvesting residues that can be made available to woodfuel markets
- develop a method to take account of these factors in a consistent way across the country
- allow forest managers to include their knowledge of local factors
- create a database of the hectarage within each district and species group that is influenced by each type of constraint

The guide comprised:

- a brief description of the project
- the general methodology for estimating potential operationally available resource as background for forest staff
- a more detailed section explaining the various constraints and how to assess them
- a description of potential harvesting systems
- details of the decision tree and example forms

The guide went through several iterations within the working group and field checking with a number of Harvesting Managers and District Managers before it was sent to all Forest Districts.

The following constraints were taken into account:

- restoration. A few sites are being felled prematurely, usually because of a change in policy or ownership, before the trees have reached an age for conventional markets
- conservation areas, e.g. raptor nesting sites and deadwood retentions
- soil and water acidification. A precautionary approach was used based on the protocols set out in the Forestry Commission *Forests and Water Guidelines (2003).* The Guidelines prohibit the removal of harvesting residues (since these are disproportionately rich in base cations compared to the main stem wood) from areas identified as Critical Load Exceedance Squares and adjacent squares. These are 10 km squares identified, on the basis of sensitivity and inputs of pollutants, as particularly at risk of acidification.
- soil fertility. Risk was assessed as either high (no harvesting residues offered) or low (all residue offered) based on general soil types according to Pyatt (1982) and Forestry Commission Practice Guide *Whole-tree Harvesting - A Guide to Good Practice* (1998). Local managers, based on their knowledge of current growth and fertiliser requirements, could allocate a portion of the 'low risk' area to 'high risk' if they thought that removal of harvesting residues was likely to risk nutritional deficiencies in the next rotation.
- soil protection. Risk of ground damage was assessed first on the basis of soil type. Within each species group, ground was allocated into three categories (high, intermediate and low risk) according to the Forestry Commission *Forests and Soil Conservation Guidelines* (1998). Soil types at high risk were judged to require all their harvesting residue to support harvesting machinery so none was offered for woodfuel. (The exception here is that some of these sites might be felled manually with whole trees pulled from the felling position to a forest roadside using a cablecrane to lift the tree above the soil surface. In these cases, harvesting residues would be offered regardless of the soil constraints.) At the other end of the spectrum, harvesting residues from soils of low ground damage risk are generally all offered even though a small proportion of these area - in particular wetter pockets, main extraction routes and steep slopes - will require some residues to be retained for soil protection. The decision on intermediate soil types is slightly more complicated – in addition to the particular requirements on wetter areas, main extraction routes and steep slopes as above, there may be a more general requirement for brash mats as determined by the time of year and climatic conditions when harvesting is taking place. For example, all of the harvesting residues might be needed in wetter parts of the country especially if winter harvesting is common.
- slope. Trees on very steep sites, if they are harvested at all, are generally felled manually with whole trees pulled from the felling position to a forest roadside using a cablecrane. In these cases we have assumed that all residues are offered as woodfuel.

3.2.3.2. Data gathering (WP7)

The Guide and a covering letter were sent to all Forestry Commission Forest Districts. Districts were visited within the following 2-4 weeks during January and February 2003 by a member of the project team to help in the understanding of the decision tree and data capture.

Managers were asked to consider the total area of forest in their district and subdivide it into the hectarage in each of four species groups: spruces, pines, other conifers and broadleaves. The area in each group was further divided into the three main soil groupings described previously under soil protection. Managers then had to work through a sequence of decisions that allocated the area in each of the species and soil groupings according to constraints. These data were recorded electronically within a routine to check that the subdivisions for the areas affected by each constraint added up to the declared total.

All data from Forest Districts were entered in to excel spreadsheets and checked.

3.2.3.3. Collation of data from Forest Districts and extension to the private sector (WP8)

Data from Forest Districts were collated, inconsistencies checked with Harvesting Managers, and the area figures converted into percentage figures. The agreed table is given in Appendix 9.

Information on constraints in the private sector that might have an influence on operationally available resource is not available directly therefore it has been inferred from information gathered in WP6 and 7 for the public sector. It is recognised that the forest holdings, site types and management objectives in the private sector differ from those in the public sector. Therefore the collated constraints table was circulated to a number of private forest management companies and woodland owners to assess how valid these constraints are if extended from the public to the private sector. This led to a refinement of the table for certain areas for the private sector (Appendix 10) but this remains a weakness of the Woodfuel Resource Study.

3.2.3.4. Recovery rates of operationally available harvesting residues (WP9)

Best available information on harvesting, handling and residue collection methods was used to produce a table of recovery rates (Appendix 11). Key documents covering British conditions are:

- Forestry Contracting Association 2000. Forest residue baling due diligence assessment. Proving and transport trials.
- Hudson, J.B. and Hudson, R.J. 1998. Review of wood fuel from precommercial thinning in Great Britain.
- Forestry Commission Technical Development Branch reports.

Our estimates were also informed by experience in other countries. It is accepted that not all harvesting residues can be recovered in energy harvesting operations. Generally, all non-merchantable stems and tops are recovered, along with large volume of limbs but some scattered limbs and needles remain on the site. For example, in New Brunswick (Canada), approximately 5,970 m^3 ha^{-1} of residue already gathered in piles was recovered for comminution while an average of 1,713 m^3 ha^{-1} or 29 % of residue remained on site, giving 71 % recovery (Desrocher *et al.,* 1992). Hakkila (2003) gives very similar figures for Finland where he concluded that the recovery of residues from the final harvest, irrespective of the system applied, extracted only some 70 % of the crown mass.

The quantity of residues available from energy harvesting operations depends on tree and stand characteristics as well as the harvesting system used:

- Routhier (1982) measured the recovery of branch and tip biomass of merchantable trees of two species when various tree harvesting methods were used.
    a. black spruce *(Pinus mariana* Mill). Recovery of limbs and tops following harvesting with feller-bunchers and tops following harvesting with feller-bunchers and grapple skidders was 66% for frozen trees (i.e. in winter conditions) and 69 % for unfrozen trees (i.e. at other times of year). Recovery of black spruce limbs and tops following harvesting with a Koehring feller-forwarder was higher – 90 % for unfrozen trees and 72 % for frozen trees.

b. balsam fir *(Abies balsamea L.).* Recovery of branches and tips following harvesting with feller-bunchers and grapple skidders was 75 % for unfrozen trees compared to 60 % for frozen trees following manual logging and cable skidding.

- Zundel (1986) estimated the biomass recovery in jack pine *(Pinus banksiana* Lamb.) following manual logging and cable skidding at 76 % for unfrozen trees and 68% for frozen trees. A significant proportion of the total tip and branch biomass of merchantable trees was left in the cutover during the felling and transportation phases.

- Puttock (1987) studied recovery rates in a two-pass system, i.e. the initial harvest removes the merchantable pulpwood while the recovery of harvesting residues and noncommercial standing timber follows as a separate operation. The standing trees are cut using either manual or mechanized systems and forwarded in full-tree form to roadside where they are chipped. The harvesting residues are collected, chipped in the stump area and forwarded to trucks at roadside. The recovery rate was 95 % of the total biomass available.

- With mechanical felling and cable skidding, approximately 69 % of the branches and tips were brought to roadside and 31 % left on forest ground, compared to 90 % and 10 % respectively left on the forest floor when a feller forwarder was used (Puttock, 1989).

- Technically harvestable biomass reserves (residues from integrated operations) are estimated to be 67-70 % (Hakkila, 2003)

3.2.3.4 Estimating operationally available resource (WP10)

The present and predicted estimates of biologically available harvesting residues for a given species group and Forest District are split according to the proportion of ground falling into the various constraints categories and then multiplied by the estimated recovery rates.

3.3 Mill co-product (WP11)

Information is derived from the 2000 Annual Sawmill Survey and the co-incident Biennial Sawmill Survey carried out by the Forestry Commission Economics and Statistics Unit (Balachandran and Henderson, 2001). Both are voluntary and cover mills that carry out primary processing of British timber while excluding mills that use only imported timber and those that only saw roughsawn timber or small roundwood. Annual reports cover a wider range of mills but collect a more limited set of data than the periodic surveys.

Annual Survey 2000 contacted 374 sawmills of which 52% responded therefore figures represent 193 sawmills. Data included sawmill size, log consumption, and sawnwood production for both hardwoods and softwoods. Additional information was collected from 40 of the 78 mills that produced at least 5000 m^3 sawnwood annually. Information included capacity, consumption, log size category, species, market classification and importantly in the present context, use of co-product. Information on co-product use from the larger mills was used to estimate use in the smaller mills for which there was no direct information assuming that usage remained proportional to log consumption across sawmill size.

Use of co-products had, for both hardwoods and softwoods, the following categories:
- sold to wood processing industries in one of five forms – sawdust, slabwood, peeled chips (bark has already been removed therefore no bark is included), unpeeled chips (bark still attached), and other
- other sales including those to agriculture in one of six forms - sawdust, slabwood, peeled chips, unpeeled chips, firewood and other
- sold as bark
- burnt on site for heat generation

- disposed by burning or as rubbish

Thus the sawmill survey can be used to give an overview of the total volumes and the split in likely co-products. However, because of confidentiality conditions guaranteed to survey respondents, it cannot be used to identify the output of individual sawmills. The compromise has been to:

- summarise data by country and English regions since this level of amalgamation does not compromise the confidentiality of the respondents.
- provide individual mill data of the principal sawmills since they already are well known and their representative body (the UK Forest Products Association) has agreed to the use of data. The list of mills, which are identified in the Forestry Industry Handbook 1998, has been updated in light of the most recent sawmill survey information giving a total of 37 softwood and 15 hardwood sawmills. These 52 mills represent over 80% of all sawnwood production therefore they also represent the vast majority of co-product that is potentially available for woodfuel. They include the 23 mills that in 1997 handled over 25,000 m^3 sawnwood production and the 19 that handled 10,000 to 25,000 m^3 sawnwood production.
- seek permission from the non-UKFPA mills with over 5000 $m^3 y^{-1}$ sawnwood production to include their data.

3.4 Arboricultural arisings (WP12)

3.4.1 Questionnaire

Contractors involved in operations generating arboricultural residues were identified from the records of the Arboricultural Association, the Forestry Contracting Association and the London Tree Officers' Association plus UK yellow pages listings of 'tree work contractors'.

The Forestry Contracting Association, with help from the Arboricultural Association, developed a questionnaire (Appendix 12) giving a short description of the larger project and its objectives. The questionnaire then asked for information on:

- the location. The questionnaires looked at the geographical area covered by the contractor and the geographical area of disposal or marketed arisings, in order to identify the potential resource and its availability throughout England, Scotland and Wales
- the weight or volume of residues from arboricultural work, utilities lines clearance, and track and roadside maintenance handled on an annual basis in the form of stem wood, branch wood and wood chips
- normal disposal method - in almost all UK tree work operations, disposal of arisings is the responsibility of the contractor
- any current markets
- the proportion of current disposals that might be available for woodfuel

Approximately 2,000 questionnaires were sent to arboricultural companies, tree officers and local authorities. Questionnaires were also sent to contractors involved in clearance of utility lines and track and roadside maintenance.

Where the reply was expressed in m^3 it was converted to tonnes by applying different conversion factors. The average density of freshly harvested measured logs of all species (Forestry Commission Mensuration Tables) is slightly less than 1 tonne m^{-3}. Therefore, the following conversion factors were used: 0.9 tonne m^{-3} for stem and branch wood, 0.33 tonne m^{-3} for wood chips, and 0.15 tonne m^{-3} for foliage (Larsson and Norden, 1992). To convert green tonnes into oven dry tonnes a moisture content of the fresh material of 50 % wet basis was assumed.

3.4.2 Extrapolation to country, region and forest district (WP13)

Total values for each of stem wood, branch wood, wood chips and foliage produced and already sold to alternative markets were estimated by multiplying the respondent average by the total number of contractors in one of three ways:

- Britain
- Scotland, Wales, England and also the nine English Regions
- 30 Forest Districts. For some Scottish Forest Districts, survey data were insufficient to give an accurate Forest District arboricultural arisings total, so a national Scottish average was used. In other cases (also in Scotland) there were not enough contractors working in these Forest Districts to establish an accurate average arising weight. In the above cases, for further calculations a national Scottish Forest District average arising weight figure was used. As a result of the wide range of volumes of arisings produced within the contractors who responded to the questionnaire, in some Forest Districts the deviation was so high that the average weight arisings were not accurate. To avoid this deviation, any figures far away from the median were not used in the statistical analysis.

The companies involved in clearance of utility lines and roadside maintenance could not supply figures broken down by region or Forest District therefore only GB and country estimates are presented.

An estimated quantity of arboricultural residues per capita was calculated using information on arisings from the arboricultural contractors (this study) and waste woody collected arisings (WRAP, 2002) plus population data in the latest 2001 census (Office for National Statistics & General Register Office for Scotland, 2002). Figures were calculated for Regions and Forest Districts in England and Wales. Forest District estimates could not be calculated in Scotland because survey data cover more than one Forest District.

3.5 Short rotation coppice (WP14)

Data on short rotation coppice came from two sources: the database for the Woodland Grant Scheme under which crops prior to April 2000 were established and the database for the Energy Crops Scheme under which later crops in England were established. These databases provide information on the location, planting date and area. Yields have been estimated by assuming that the average yield is 8 odt ha^{-1} y^{-1}. As the area of short rotation increases, the assumptions should be refined.

4. RESULTS

4.1 General

This report is written as a stand-alone document but, for the sake of clarity, only top-level data are presented and discussed. In general, country and English Region data are presented in the main text. Data at the Forest District level, where available, are generally presented as Appendices. Finer level detail is available on the website which allows the user to define for example the area, species group, owner type, resource type, and forecast period of interest – approximately 6000 combinations are possible. Still finer resolution of the geographical area, cut-off diameter, forecast period and forecast interval is available by submitting a request through the website.

Results are given in oven dry tonnes (odt). We recognise that no woodfuel is sold in this dry form, however it is the very variety of moisture contents for different products which necessitates that all products must be expressed in a common unit in order that different resource streams can be compared. Typical moisture contents and volumes are given in Appendix 13 along with typical calorific values and conversion factors.

4.2 Traditional forestry

4.2.1 Standing biomass (Table 3)

The biomass of trees amounts to 319 million odt (excluding fine roots, leaves of deciduous trees and privately-owned woods smaller than 2 ha). This is dominated by broadleaves in England (29% total), followed by spruces in Scotland (22%) and pines in Scotland (10%). The bulk (227 million odt) is in private ownership with only 92 million odt in the public sector.

Table 3. Standing biomass in Forestry Commission and other woodland (oven dried tonnes)

Area	Species group	Biomass component										
		Stemwood					Tips	Branches	Foliage	Roots	Stumps	Total
		7-14cm	14-16cm	16-18cm	18+ cm	Poor quality						
Scotland	Pines	6,381,156	2,520,693	2,059,363	6,919,688	508,480	767,340	4,661,942	2,097,757	6,480,569	486,451	32,883,440
	Spruces	11,376,384	5,185,432	4,402,780	14,245,201	143,341	1,148,741	10,539,347	4,776,571	16,845,876	959,847	69,623,520
	Other conifers	1,384,869	670,239	680,988	4,030,751	193,059	162,833	1,352,794	606,690	2,262,748	154,325	11,499,295
	Broadleaves	1,191,341	559,222	572,549	4,108,777	4,043,403	262,019	4,945,228	0	8,047,662	256,293	23,986,494
Total Scotland		**20,333,750**	**8,935,586**	**7,715,680**	**29,304,417**	**4,888,283**	**2,340,933**	**21,499,311**	**7,481,018**	**33,636,855**	**1,856,916**	**137,992,749**
Wales	Pines	385,719	166,077	144,909	517,329	4,051	44,357	270,501	121,895	371,764	29,090	2,055,691
	Spruces	2,012,403	946,734	870,879	3,467,387	1,149	210,058	1,926,290	867,520	3,170,577	173,414	13,646,413
	Other conifers	617,442	330,326	371,025	2,854,983	37,202	69,738	715,131	317,028	1,262,041	79,326	6,654,241
	Broadleaves	762,999	374,963	404,101	2,949,751	3,048,421	152,782	3,408,342	0	5,511,395	176,343	16,789,096
Total Wales		**3,778,563**	**1,818,100**	**1,790,914**	**9,789,450**	**3,090,823**	**476,935**	**6,320,264**	**1,306,443**	**10,315,777**	**458,173**	**39,145,441**
England	Pines	2,345,480	1,167,888	1,138,172	7,127,201	209,702	266,165	2,403,161	1,054,096	3,212,513	258,553	19,182,928
	Spruces	2,165,824	986,124	876,856	3,561,499	20,441	233,603	2,100,320	945,584	3,161,485	188,956	14,240,691
	Other conifers	1,232,942	670,426	758,053	6,833,541	339,784	143,690	1,726,908	752,638	2,822,353	179,920	15,460,255
	Broadleaves	5,891,914	2,760,136	2,963,174	25,196,640	4,423,899	941,008	18,770,500	0	30,758,594	971,543	92,677,408
Total England		**11,636,160**	**5,584,574**	**5,736,255**	**42,718,881**	**4,993,826**	**1,584,466**	**25,000,889**	**2,752,318**	**39,954,945**	**1,598,972**	**141,561,282**
GB total		**35,748,473**	**16,338,260**	**15,242,849**	**81,812,748**	**12,972,932**	**4,402,334**	**52,820,464**	**11,539,779**	**83,907,577**	**3,914,061**	**318,699,472**

4.2.2 Current annual production of potential operationally available biomass

4.2.2.1 Overview

The current annual production of potential operationally available biomass (excluding fine roots, stumps and leaves of deciduous trees) is 5.63 million odt (Table 4) – potential operationally available biomass is defined in section 2.5 and 3.2.3.1. It should be noted that:

- a substantial fraction is stemwood of sufficient diameter that it is unlikely to be made available for woodfuel
- availability of small roundwood will depend on price and competing markets
- poor quality stems might already be used for firewood on an informal basis but it is probable that most of this is currently unused and could be made available for woodfuel
- there are few current markets for branches and stem tips

At a gross level, the potential resource is mainly in Scotland and England (2.59 and 2.21 million odt annual production respectively) with Wales producing about 15% of the total. Table 5 shows that within England there are substantial resources in the South West and South East Region.

Table 4. Present annual production of potential operationally available biomass by country within the Forestry Commission and private sector area, thinning and felling (oven dried tonnes y^{-1})

Area	Species group	Biomass component								
		Stemwood					Tips	Branches	Foliage	Total
		7-14cm	14-16cm	16-18cm	18+	Poor quality				
Scotland	Pines	166,502	63,843	52,993	187,089	5,114	2,643	14,440	6,487	499,112
	Spruces	378,648	195,873	184,295	714,191	4,996	8,143	76,621	34,459	1,597,225
	Other conifers	50,711	24,465	25,033	155,914	5,366	1,169	9,991	4,474	277,122
	Broadleaves	10,754	7,543	9,204	77,999	97,679	465	15,103	0	218,747
Total		**606,615**	**291,724**	**271,525**	**1,135,193**	**113,155**	**12,420**	**116,155**	**45,420**	**2,592,206**
Wales	Pines	15,459	6,718	5,926	19,626	228	673	3,894	1,762	54,286
	Spruces	77,911	40,379	40,358	191,694	39	2,777	27,539	12,288	392,984
	Other conifers	26,886	14,748	17,069	144,961	1,972	1,413	15,285	6,751	229,087
	Broadleaves	7,553	4,692	5,467	49,562	68,638	589	21,879	0	158,379
Total		**127,809**	**66,537**	**68,820**	**405,843**	**70,877**	**5,452**	**68,597**	**20,801**	**834,736**
England	Pines	83,841	40,302	38,229	249,040	4,010	3,751	34,552	15,110	468,835
	Spruces	90,159	44,513	42,954	200,931	665	2,424	23,904	10,640	416,192
	Other conifers	53,150	27,586	30,727	291,409	2,079	2,830	32,100	14,075	453,957
	Broadleaves	70,826	42,746	51,402	475,649	87,816	4,617	134,821	0	867,876
Total		**297,976**	**155,147**	**163,312**	**1,217,029**	**94,570**	**13,622**	**225,377**	**39,825**	**2,206,860**
GB total		**1,032,400**	**513,408**	**503,657**	**2,758,065**	**278,602**	**31,494**	**410,129**	**106,046**	**5,633,802**

Table 5. Present annual production of potential operationally available biomass by English Regions within the Forestry Commission and the private sector area, thinning and felling (oven dried tonnes y^{-1})

Area	Species group	Biomass component								
		Stemwood					Tips	Branches	Foliage	Total
		7-14cm	14-16cm	16-18cm	18+	Poor q				
North East	Pines	15,281	5,710	4,467	19,032	195	303	1,764	789	47,542
	Spruces	45,572	21,136	19,745	75,207	457	642	5,149	2,314	170,221
	Other conifers	4,389	2,349	2,570	17,701	382	105	911	407	28,814
	Broadleaves	2,833	1,752	2,103	19,292	4,973	0	0	0	30,953
Total		**68,075**	**30,947**	**28,885**	**131,232**	**6,007**	**1,050**	**7,824**	**3,510**	**277,530**
North West	Pines	7,506	3,145	2,793	17,734	526	366	2,787	1,226	36,083
	Spruces	20,644	10,797	10,826	50,835	285	938	9,167	4,096	107,589
	Other conifers	3,534	1,988	2,377	22,163	1,252	204	2,179	966	34,662
	Broadleaves	4,299	2,760	3,275	28,872	32,376	0	0	0	71,580
Total		**35,983**	**18,690**	**19,271**	**119,604**	**34,439**	**1,508**	**14,133**	**6,288**	**249,914**
Yorkshire	Pines	10,944	4,718	4,139	20,721	374	491	3,337	1,487	46,210
and the	Spruces	6,756	3,455	3,260	16,039	0	255	2,685	1,198	33,648
Humber	Other conifers	6,367	3,055	3,247	25,555	103	287	2,416	1,083	42,111
	Broadleaves	6,634	4,616	5,683	52,368	8,073	388	14,175	0	91,937
Total		**30,701**	**15,844**	**16,329**	**114,683**	**8,550**	**1,421**	**22,613**	**3,768**	**213,906**
East	Pines	5,838	3,104	3,037	23,748	745	417	4,346	1,903	43,138
Midlands	Spruces	904	278	197	566	0	76	357	162	2,541
	Other conifers	1,337	718	785	5,991	154	98	859	384	10,325
	Broadleaves	6,483	3,787	4,536	37,146	12,599	626	18,207	0	83,383
Total		**14,562**	**7,887**	**8,555**	**67,451**	**13,498**	**1,217**	**23,769**	**2,449**	**139,387**
West	Pines	5,529	2,766	2,553	13,976	0	181	1,498	667	27,168
Midlands	Spruces	3,051	1,760	1,894	15,189	0	105	1,451	633	24,083
	Other conifers	7,060	3,630	4,130	47,115	694	312	3,792	1,654	68,387
	Broadleaves	5,320	3,326	4,163	58,341	12,973	0	0	0	84,123
Total		**20,960**	**11,482**	**12,740**	**134,621**	**13,667**	**598**	**6,741**	**2,954**	**203,761**
East of	Pines	14,710	8,378	8,974	55,634	1,151	918	9,245	4,045	103,056
England	Spruces	1,319	631	531	2,263	0	30	256	115	5,145
	Other conifers	2,235	1,257	1,452	14,190	86	143	1,687	738	21,788
	Broadleaves	9,921	5,873	7,058	70,390	3,854	768	24,166	0	122,029
Total		**28,185**	**16,139**	**18,015**	**142,477**	**5,091**	**1,859**	**35,354**	**4,898**	**252,018**
South East	Pines	17,092	8,757	8,450	68,633	19	649	6,834	2,938	113,371
	Spruces	3,345	1,633	1,531	7,996	72	195	1,796	798	17,366
	Other conifers	7,959	4,357	4,947	45,754	129	359	4,401	1,920	69,826
	Broadleaves	20,611	12,517	15,177	142,270	0	1,043	30,490	0	228,586
Total		**49,007**	**27,264**	**30,105**	**264,653**	**220**	**2,246**	**43,521**	**5,656**	**429,149**
South West	Pines	8,278	4,390	4,422	35,878	0	460	4,795	2,070	60,292
	Spruces	8,145	4,189	3,992	22,271	6,478	409	4,308	1,912	45,226
	Other conifers	19,554	9,736	10,410	94,022	169	1,142	12,842	5,636	153,511
	Broadleaves	17,047	9,471	11,365	124,465	3,843	1,186	36,977	0	204,353
Total		**53,024**	**27,786**	**30,189**	**276,636**	**10,490**	**3,197**	**58,922**	**9,618**	**463,382**

A more detailed insight into the distribution of resource across Britain can be gained by looking at the figures for the 30 Forest Districts (Table 6). Within Scotland, the total annual production of operationally available biomass of all harvestable tree components is over 200 k odt y^{-1} in each of Tay, Cowal and the Trossachs, the Scottish Lowlands, Scottish Borders, Galloway and Ae. Inverness, Moray, Buchan, Kincardine, and West Argyll have between 100 and 200 k odt y^{-1} operationally available resource. Dornoch, Fort Augustus, Lochaber and Lorne have just under 100k odt y^{-1}. There is greater a range in resource availability within English Forest Districts than in Scotland. On one hand the operationally available resource in the South East District is estimated at 433 k odt y^{-1}; Kielder, and Peninsular have resources of 315 and 257 k odt y^{-1} respectively. On the other hand, Northants has an operationally available resource of 56 k odt y^{-1}. Of the four districts in Wales, Llanmyddfri has the greatest resource at 275 k odt y^{-1}, Coed y Mynydd and Coed y Gororau are intermediate (234 and 197 k odt y^{-1} respectively) with Coed y Cymoedd having 129 k odt y^{-1}. Although a substantial fraction is stemwood of sufficient diameter that it is unlikely to be made available for woodfuel and availability of small roundwood will depend on price and competing markets, the trends in geographical distribution of components that might be made available to energy end markets will be similar to those identified above.

Table 6. Present annual production of potential operationally available biomass within Forest Districts within the Forestry Commission and the private sector area from thinning and felling (oven dried tonnes y^{-1})

Forest District	Species Group	Biomass Component								
		Stemwood					Tips	Branches	Foliage	Total
		7-14cm	14-16cm	16-18cm	18+	Poor q				
Dornoch	Pines	19,296	7,302	5,590	11,972	165	46	232	106	44,710
	Spruces	7,384	3,566	3,068	10,516	159	81	733	331	25,838
	Other conifers	2,263	885	827	5,379	92	11	73	33	9,563
	Broadleaves	118	80	93	445	12,909	19	599	0	14,262
Total		**29,061**	**11,833**	**9,578**	**28,312**	**13,325**	**157**	**1,637**	**470**	**94,373**
Inverness	Pines	31,053	11,513	9,740	42,301	1,661	289	1,716	765	99,038
	Spruces	10,181	5,298	5,179	23,052	0	173	1,644	737	46,264
	Other conifers	3,078	1,564	1,746	14,423	1,072	99	1,107	487	23,576
	Broadleaves	1,501	1,134	1,415	8,948	12,499	36	1,107	0	26,641
Total		**45,813**	**19,509**	**18,080**	**88,724**	**15,232**	**597**	**5,574**	**1,989**	**195,519**
Fort Augustus	Pines	9,199	3,696	3,116	10,015	1,667	43	251	113	28,100
	Spruces	10,367	5,078	4,743	20,406	339	110	986	440	42,469
	Other conifers	2,648	1,058	1,004	7,937	937	17	155	69	13,827
	Broadleaves	545	361	421	3,263	7,819	15	506	0	12,930
Total		**22,759**	**10,193**	**9,284**	**41,621**	**10,762**	**185**	**1,898**	**622**	**97,326**
Moray	Pines	22,255	9,482	8,508	31,794	0	196	1,277	569	74,080
	Spruces	7,365	3,881	3,822	15,642	0	154	1,443	649	32,957
	Other conifers	2,749	1,429	1,496	9,338	75	44	413	184	15,728
	Broadleaves	425	318	385	2,836	0	10	326	0	4,300
Total		**32,794**	**15,110**	**14,211**	**59,610**	**75**	**404**	**3,459**	**1,402**	**127,065**
Buchan	Pines	11,694	4,487	3,763	11,633	20	92	491	221	32,401
	Spruces	13,272	7,800	8,157	38,483	0	236	2,522	1,127	71,597
	Other conifers	2,529	1,396	1,531	8,676	31	35	317	143	14,658
	Broadleaves	341	263	322	1,783	0	8	241	0	2,958
Total		**27,836**	**13,946**	**13,773**	**60,575**	**51**	**371**	**3,571**	**1,491**	**121,614**
Lochaber	Pines	7,249	2,874	2,408	5,710	321	37	219	99	18,916
	Spruces	12,799	6,351	5,862	22,730	531	112	987	443	49,814

	Other conifers	2,771	1,113	940	3,722	58	27	171	78	8,880
	Broadleaves	454	328	424	6,606	11,288	14	957	0	20,071
Total		**23,273**	**10,666**	**9,634**	**38,768**	**12,198**	**190**	**2,334**	**620**	**97,681**
Kincardine	Pines	12,367	4,479	3,675	17,981	0	331	1,958	873	41,664
	Spruces	6,963	3,851	3,868	22,515	0	187	2,187	968	40,539
	Other conifers	3,073	1,542	1,640	9,173	0	107	877	394	16,805
	Broadleaves	948	731	886	5,026	1,779	27	783	0	10,180
Total		**23,351**	**10,603**	**10,069**	**54,695**	**1,779**	**652**	**5,805**	**2,235**	**109,188**
Lorne	Pines	1,371	549	456	964	70	20	104	48	3,581
	Spruces	16,725	8,252	7,553	26,559	297	367	3,146	1,419	64,318
	Other conifers	2,355	1,100	1,038	4,963	284	56	392	177	10,365
	Broadleaves	515	396	535	7,748	9,179	0	0	0	18,374
Total		**20,966**	**10,297**	**9,582**	**40,234**	**9,830**	**443**	**3,642**	**1,644**	**96,638**
Tay	Pines	19,501	6,331	4,817	17,487	187	1,199	5,906	2,668	58,096
	Spruces	20,861	10,944	10,080	43,260	962	1,069	10,671	4,787	102,635
	Other conifers	5,952	2,936	3,074	18,719	790	351	3,015	1,352	36,188
	Broadleaves	1,886	1,340	1,620	11,517	8,082	270	7,982	0	32,696
Total		**48,200**	**21,551**	**19,591**	**90,983**	**10,021**	**2,889**	**27,574**	**8,807**	**229,615**
West Argyll	Pines	4,449	1,835	1,640	3,502	0	49	256	116	11,847
	Spruces	37,100	17,894	16,144	56,351	0	581	4,903	2,213	135,185
	Other conifers	1,705	737	688	3,338	78	14	97	44	6,701
	Broadleaves	660	432	524	5,483	5,280	0	0	0	12,379
Total		**43,914**	**20,898**	**18,996**	**68,674**	**5,358**	**644**	**5,256**	**2,373**	**166,112**
Cowal and Trossachs	Pines	4,200	1,438	1,064	2,317	0	180	851	387	10,437
	Spruces	35,004	18,570	17,899	73,522	40	894	8,615	3,869	158,413
	Other conifers	4,698	2,072	2,083	13,583	441	124	1,010	453	24,463
	Broadleaves	858	498	562	5,483	7,819	14	602	0	15,836
Total		**44,760**	**22,578**	**21,608**	**94,905**	**8,300**	**1,212**	**11,078**	**4,709**	**209,149**
Scottish	Pines	7,005	2,992	2,583	11,525	709	49	402	177	25,442
Lowlands	Spruces	35,402	18,086	16,113	54,585	1,524	1,016	9,408	4,251	140,384
	Other conifers	3,513	1,794	1,812	9,266	822	72	562	254	18,095
	Broadleaves	1,599	1,101	1,326	12,121	8,831	30	1,048	0	26,057
Total		**47,519**	**23,973**	**21,834**	**87,497**	**11,886**	**1,167**	**11,420**	**4,682**	**209,978**
Scottish Borders	Pines	4,458	1,903	1,619	10,728	315	41	364	158	19,586
	Spruces	49,703	26,840	25,492	94,465	444	1,637	15,134	6,818	220,532
	Other conifers	4,430	2,254	2,301	13,757	159	74	596	268	23,838
	Broadleaves	334	203	245	1,852	2,975	8	256	0	5,873
Total		**58,925**	**31,200**	**29,657**	**120,802**	**3,893**	**1,760**	**16,350**	**7,244**	**269,829**
Galloway	Pines	9,848	3,724	2,863	4,907	0	43	215	98	21,698
	Spruces	62,559	31,174	28,616	94,736	529	318	2,840	1,284	222,056
	Other conifers	5,097	2,618	2,703	13,887	502	68	508	230	25,614
	Broadleaves	292	181	232	3,015	4,987	8	405	0	9,120
Total		**77,796**	**37,697**	**34,414**	**116,545**	**6,018**	**437**	**3,968**	**1,612**	**278,488**
Ae	Pines	2,558	1,238	1,149	4,255	0	28	200	89	9,517
	Spruces	52,965	28,289	27,700	117,370	171	1,207	11,402	5,123	244,226
	Other conifers	3,850	1,966	2,152	19,753	26	69	697	308	28,821
	Broadleaves	280	177	214	1,872	4,231	6	290	0	7,070

Total		**59,653**	**31,670**	**31,215**	**143,250**	**4,428**	**1,310**	**12,589**	**5,520**	**289,634**
Kielder	Pines	16,740	5,981	4,555	18,584	0	338	1,884	844	48,926
	Spruces	54,531	25,541	24,037	91,918	540	766	6,222	2,796	206,351
	Other conifers	4,391	2,308	2,534	17,516	419	105	915	409	28,596
	Broadleaves	2,724	1,739	2,099	18,582	5,695	0	0	0	30,840
Total		**78,386**	**35,569**	**33,225**	**146,600**	**6,654**	**1,209**	**9,021**	**4,049**	**314,713**
North West England	Pines	5,021	2,416	2,318	16,906	632	233	2,213	964	30,701
	Spruces	12,050	6,629	6,887	36,614	62	544	5,874	2,616	71,276
	Other conifers	3,046	1,739	2,094	19,259	598	173	1,852	822	29,583
	Broadleaves	4,157	2,673	3,157	25,597	34,466	0	0	0	70,051
Total		**24,274**	**13,457**	**14,456**	**98,376**	**35,758**	**950**	**9,939**	**4,402**	**201,611**
North York Moors	Pines	9,950	4,344	3,867	19,939	576	448	3,125	1,389	43,637
	Spruces	6,530	3,354	3,182	16,300	0	248	2,656	1,184	33,452
	Other conifers	6,436	3,180	3,472	28,979	58	290	2,558	1,144	46,115
	Broadleaves	5,487	3,822	4,653	37,024	3,780	306	9,987	0	65,060
Total		**28,403**	**14,700**	**15,174**	**102,242**	**4,414**	**1,292**	**18,326**	**3,717**	**188,264**
Sherwood	Pines	6,718	3,525	3,408	26,381	549	464	4,681	2,054	47,780
& Lincs	Spruces	806	331	286	1,517	0	58	448	200	3,647
	Other conifers	1,599	934	1,101	9,563	158	111	1,055	470	14,991
	Broadleaves	5,616	3,460	4,088	29,688	13,132	519	14,652	0	71,156
Total		**14,739**	**8,250**	**8,883**	**67,149**	**13,839**	**1,152**	**20,836**	**2,724**	**137,574**
West	Pines	5,178	2,597	2,397	13,166	0	169	1,420	632	25,559
Midlands	Spruces	2,181	1,286	1,405	11,713	0	75	1,092	476	18,227
	Other conifers	5,772	2,992	3,443	40,175	602	256	3,222	1,400	57,862
	Broadleaves	3,662	2,351	2,934	38,729	11,375	0	0	0	59,050
Total		**16,793**	**9,226**	**10,179**	**103,783**	**11,977**	**500**	**5,734**	**2,508**	**160,698**
Northants	Pines	1,880	844	680	2,619	367	146	1,008	452	7,996
	Spruces	769	262	178	458	0	66	349	159	2,240
	Other conifers	862	456	486	3,422	0	68	567	254	6,114
	Broadleaves	2,552	1,421	1,744	18,169	6,539	287	9,372	0	40,083
Total		**6,063**	**2,983**	**3,088**	**24,668**	**6,906**	**567**	**11,296**	**865**	**56,433**
East Anglia	Pines	12,269	7,090	7,796	50,822	1,556	762	8,143	3,552	91,990
	Spruces	776	383	340	1,657	0	16	147	65	3,385
	Other conifers	1,469	844	974	8,631	84	90	1,093	478	13,664
	Broadleaves	7,373	4,288	5,082	44,093	2,515	567	15,526	0	79,445
Total		**21,887**	**12,605**	**14,192**	**105,203**	**4,155**	**1,435**	**24,909**	**4,095**	**188,484**
Forest of Dean	Pines	2,115	1,214	1,224	9,144	0	158	1,687	733	16,275
	Spruces	2,446	1,382	1,422	8,574	0	173	1,990	878	16,864
	Other conifers	5,604	2,954	3,281	32,587	97	411	5,011	2,185	52,130
	Broadleaves	5,393	3,037	3,696	43,536	2,317	485	15,441	0	73,905
Total		**15,558**	**8,587**	**9,623**	**93,841**	**2,414**	**1,227**	**24,129**	**3,796**	**159,174**
South East England	Pines	16,023	8,134	7,792	61,998	331	830	8,471	3,649	107,229
	Spruces	3,339	1,607	1,482	7,512	63	229	2,044	910	17,187
	Other conifers	7,311	4,008	4,561	41,881	0	463	5,538	2,429	66,190
	Broadleaves	21,520	12,973	15,586	138,166	4,420	1,760	48,399	0	242,824
Total		**48,193**	**26,722**	**29,421**	**249,557**	**4,814**	**3,282**	**64,452**	**6,988**	**433,430**

Peninsular	Pines	1,902	943	923	6,414	0	97	891	391	11,560
	Spruces	5,507	3,077	3,084	20,011	0	201	2,468	1,088	35,437
	Other conifers	12,518	6,073	6,556	70,307	0	790	9,501	4,138	109,883
	Broadleaves	8,503	4,985	6,025	58,007	355	692	21,444	0	100,011
Total		**28,430**	**15,078**	**16,588**	**154,739**	**355**	**1,780**	**34,304**	**5,617**	**256,891**
New Forest	Pines	6,047	3,213	3,269	23,068	0	106	1,029	450	37,182
	Spruces	1,225	662	652	4,657	0	50	613	267	8,125
	Other conifers	4,142	2,098	2,226	19,090	64	73	789	346	28,828
	Broadleaves	3,838	1,996	2,337	24,059	3,223	0	0	0	35,451
Total		**15,252**	**7,969**	**8,484**	**70,874**	**3,287**	**229**	**2,431**	**1,063**	**109,586**
Coed y	Pines	4,241	1,865	1,695	6,142	92	151	886	400	15,471
Mynydd	Spruces	22,547	11,643	11,677	54,809	0	746	7,351	3,281	112,053
	Other conifers	6,679	3,831	4,545	36,330	1,151	237	2,640	1,165	56,577
	Broadleaves	1,191	692	769	7,926	32,981	128	6,406	0	50,092
Total		**34,658**	**18,031**	**18,686**	**105,207**	**34,224**	**1,262**	**17,283**	**4,846**	**234,193**
Coed y	Pines	2,395	992	815	2,514	0	153	864	392	8,124
Gororau	Spruces	18,180	9,514	9,707	50,657	0	873	8,990	3,993	101,913
	Other conifers	6,459	3,451	3,976	33,568	149	429	4,658	2,061	54,750
	Broadleaves	1,089	697	854	11,370	18,549	0	0	0	32,559
Total		**28,123**	**14,654**	**15,352**	**98,109**	**18,698**	**1,455**	**14,512**	**6,446**	**197,346**
Llanmyddfri	Pines	2,952	1,177	990	2,833	136	151	817	369	9,425
	Spruces	26,268	13,599	13,337	61,420	39	880	8,578	3,839	127,959
	Other conifers	9,185	4,858	5,550	50,796	673	548	6,039	2,658	80,307
	Broadleaves	2,837	1,817	2,134	19,509	16,666	375	13,555	0	56,893
Total		**41,242**	**21,451**	**22,011**	**134,558**	**17,514**	**1,954**	**28,989**	**6,866**	**274,584**
Coed y	Pines	5,872	2,685	2,426	8,137	0	218	1,328	601	21,266
Cymoedd	Spruces	10,917	5,624	5,637	24,809	0	278	2,620	1,175	51,060
	Other conifers	4,564	2,608	2,999	24,268	0	199	1,949	867	37,454
	Broadleaves	2,436	1,486	1,710	10,757	442	86	1,918	0	18,835
Total		**23,789**	**12,403**	**12,772**	**67,971**	**442**	**781**	**7,815**	**2,643**	**128,615**

4.2.2.2 Private sector.

Of the total 227 million odt standing biomass in private sector forests, 3.61 million is estimated to be potential operationally available biomass on an annual basis either at final felling or at thinning (Table 7). Poor quality stems, branches, stem tips (i.e. less than 7 cm diameter), and small roundwood (i.e. 7-14 cm diameter), comprise a total biomass of 1.18 million odt y^{-1}, i.e. 279k, 316k, 21k and 560k respectively (an additional 66k odt y^{-1} of foliage is attached to the operationally available residues). In all three countries the poor quality stem category is dominated by broadleaved species. Branches and stem tips are mainly broadleaved species in England and Wales and spruces in Scotland. The composition of small roundwood differs within GB with potential availability in Scotland and Wales being dominated by spruce but with a more even split among the species groups in England; availability of small roundwood will depend on price and competing markets.

Table 7. Present annual production of potential operationally available biomass by country within the private sector area, thinning and felling (oven dried tonnes y^{-1})

Area	Species group	Biomass component								
		Stemwood					Tips	Branches	Foliage	Total
		7-14cm	14-16cm	16-18cm	18+	Poor quality				
Scotland	Pines	79,422	26,496	26,496	122,240	5,114	1,680	9,536	4,259	279,051
	Spruces	210,200	102,355	102,355	374,620	4,996	5,827	54,241	24,445	887,744
	Other conifers	30,764	14,095	14,095	88,873	5,366	842	7,091	3,178	164,216
	Broadleaves	9,041	8,380	8,380	73,022	97,679	455	14,988	0	210,277
Total		**329,427**	**151,326**	**151,326**	**658,755**	**113,155**	**8,804**	**85,856**	**31,882**	**1,541,288**
Wales	Pines	3,883	1,641	1,641	6,511	228	183	1,220	546	16,016
	Spruces	26,897	13,192	13,192	59,448	39	1,011	9,383	4,197	127,819
	Other conifers	12,538	8,428	8,428	82,610	1,972	704	8,258	3,626	125,147
	Broadleaves	6,786	5,164	5,164	48,045	68,638	543	21,340	0	154,895
Total		**50,104**	**28,425**	**28,425**	**196,614**	**70,877**	**2,441**	**40,201**	**8,369**	**423,877**
England	Pines	46,882	20,813	20,813	151,502	4,010	2,299	21,337	9,263	278,557
	Spruces	31,009	15,435	15,435	85,032	665	1,241	12,581	5,580	167,419
	Other conifers	36,817	22,271	22,271	233,130	2,079	2,049	24,227	10,586	350,797
	Broadleaves	66,233	49,961	49,961	467,279	87,816	4,290	131,492	0	848,226
Total		**180,941**	**108,480**	**108,480**	**936,943**	**94,570**	**9,879**	**189,637**	**25,429**	**1,644,999**
GB total		**560,472**	**288,231**	**288,231**	**1,792,312**	**278,602**	**21,124**	**315,694**	**65,680**	**3,610,164**

4.2.2.3 Public sector (Table 8).

Although the public sector has a considerably smaller standing biomass than the private sector, it is generally more productive with the annual potential operationally available biomass through final felling and thinning estimated at 2.02 million odt (cf. the standing biomass of 92 million odt). Branches, stem tips, i.e. less than 7 cm diameter, and small roundwood, i.e. 7-14 cm diameter, contribute 0.58 million odt y^{-1}, i.e. 94 k, 10 k and 472 k odt respectively. Stemwood is not classified by quality therefore there is no public sector entry in the poor quality category. There are few current markets for branches and stem tips but availability of small roundwood will depend on price and competing markets. In all countries, branch, stem tips, and small roundwood are dominated by spruce which comprises 60% of the total harvested biomass though in England pines are also important contributors to the branch and tip categories.

Table 8. Present annual production of potential operationally available production by country within the Forestry Commission area, thinning and felling (oven dried tonnes y^{-1})

Area	Species group	Biomass component							
		Stemwood				Tips	Branches	Foliage	Total
		7-14cm	14-16cm	16-18cm	18+				
Scotland	Pines	87,080	33,540	26,497	64,849	963	4,904	2,228	220,061
	Spruces	168,448	84,812	81,940	339,571	2,315	22,381	10,014	709,481
	Other conifers	19,947	10,458	10,938	67,040	327	2,900	1,296	112,906
	Broadleaves	1,713	830	824	4,977	10	116	0	8,470
Total		**277,188**	**129,640**	**120,199**	**476,437**	**3,615**	**30,301**	**13,538**	**1,050,918**
Wales	Pines	11,576	4,914	4,285	13,115	489	2,675	1,216	38,270
	Spruces	51,014	26,725	27,166	132,246	1,767	18,156	8,091	265,165
	Other conifers	14,348	7,739	8,641	62,351	709	7,027	3,125	103,940
	Broadleaves	767	312	303	1,517	46	539	0	3,484
Total		**77,705**	**39,690**	**40,395**	**209,229**	**3,011**	**28,397**	**12,432**	**410,859**
England	Pines	36,959	17,852	17,416	97,538	1,452	13,215	5,847	190,278
	Spruces	59,150	28,638	27,519	115,899	1,183	11,323	5,060	248,772
	Other conifers	16,333	7,948	8,456	58,279	782	7,873	3,489	103,160
	Broadleaves	4,593	1,590	1,441	8,370	327	3,329	0	19,650
Total		**117,035**	**56,028**	**54,832**	**280,086**	**3,744**	**35,740**	**14,396**	**561,860**
GB total		**471,928**	**225,358**	**215,426**	**965,752**	**10,370**	**94,438**	**40,366**	**2,023,637**

4.2.3 Forecast harvested biomass

4.2.3.1 Overview

Future availability of operationally available biomass is based on knowledge of the present growing stock; plans for thinning and harvesting; and present technologies and harvesting systems. All three elements have associated uncertainties (see below) therefore the forecasts are indicative and not guaranteed.

Information on the present growing stock does not represent exactly all British forests and woodlands but even so, for present purposes, data are sufficiently accurate down to a Forest District level. There is however greater uncertainty about the future climate and the response of forests to that climate (Forestry Commission, 2002). This applies to both direct effects (e.g. in the absence of nutrient and water limitations, growth is expected to increase due to increased CO_2 and temperature) and indirect effects (e.g. higher winter temperatures are expected to increase the fecundity of deer and reduce tree growth through increased browsing).

Harvesting and thinning plans are not binding and will be influenced by a range of factors: policy related, practical and commercial. These are likely to have significant consequences for future woodfuel resources even though they cannot be quantified at the moment. The probable effects of these issues are covered in the discussion but are raised here to emphasis the uncertainties associated with forecast woodfuel supply.

<u>Policy</u>

The main examples of recent policy shifts are:

- increasing use of alternatives to large clear felling systems
- certification
- restoration of ancient woodland sites
- extended rotations in long-term retentions

- increasing use of species mixtures

Technological.
Woodfuel harvesting is not undertaken on any scale in Britain therefore judgements about the effect of technological developments and improvements in systems for multiple product harvesting on future availability are doubly difficult. While most of these changes are likely to affect the economics of woodfuel harvesting rather than the technical feasibility of removing biomass from the woodland site, some may well alter operational availability, for example:

- cable-crane harvesting
- harvesting of long tops
- allocating a larger proportion of the stem for woodfuel at time of felling and converting
- use of alternate brash mats for machinery flotation

Commercial.
Timber prices will continue to be the main influence on harvesting activity especially in the private sector. Predictions of future timber markets are extremely difficult as are the other inter-related markets for small roundwood, sawmill co-product, and recovered wood; forecasts are subject to uncertainties due to regulation and incentives affecting woodfuel markets directly but also indirectly through policies on waste and landfill. One particularly difficult aspect to predict is the effect of the development of a strong woodfuel market which in itself will influence harvesting plans and the techniques used.

4.2.3.2 Private sector
Small roundwood, poor quality stems, stem tips, branches and foliage together increase from 1.24 million odt in 2003-2006 to 1.35 million odt by the third forecast period (2012-2016); the total potential operationally available biomass then decreases slightly to about 1.30 million odt (see Table 9 and Figure 7). The main increase is in spruce; broadleaved species and pine remain about the same and there is a decrease in the biomass produced by conifers other than spruces or pines.

If we take a more conservative view of the fractions available for energy end uses and consider just poor quality stems, tips and branches, the forecast biomass harvested annually increases from 615k odt in 2003-2006 to about 666k odt by the third period. The increase is largely due to spruce, particularly in Scotland.

Please note that the comparatively stable forecast has been thoroughly checked. Reasons why woodfuel availability direct from the forest is expected to remain more or less constant while overall stemwood volumes increase significantly are discussed in section 5.3.

Figure 7. Long term forecast trends in potential operationally available biomass in the private sector from felling and thinning in Britain as a whole (oven dried tonnes y^{-1})

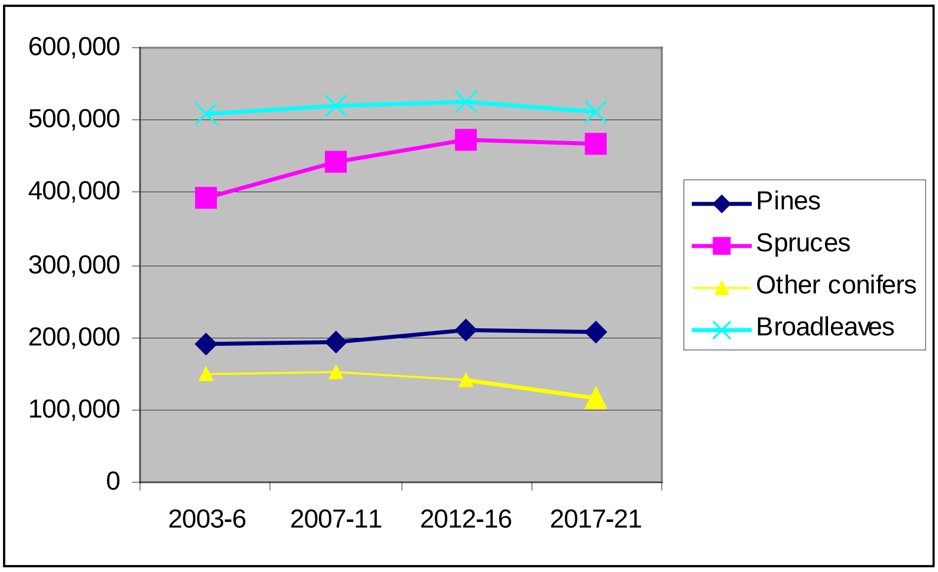


Table 9. Private sector forecast of potential operationally available biomass as a result of thinning and felling by country, period, species group, and biomass component (oven dried tonnes y^{-1})

Area	Forecast period	Species group	Biomass component					
			7-14cm diameter stems	Poor quality stems	Branches	Tips	Foliage	Total
Scotland	2003-06	Pines	79,422	5,114	1,680	9,536	4,259	100,011
		Spruces	210,200	4,996	5,827	54,241	24,445	299,709
		Other conifers	30,764	5,366	842	7,091	3,178	47,241
		Broadleaves	9,041	97,679	455	14,988	0	122,163
		Total	**329,427**	**113,155**	**8,804**	**85,856**	**31,882**	**569,124**
	2007-11	Pines	87,724	6,187	1,450	9,975	4,438	109,774
		Spruces	235,040	6,828	6,425	66,895	30,016	345,205
		Other conifers	31,658	5,418	890	8,111	3,629	49,707
		Broadleaves	9,805	95,935	459	15,946	0	122,145
		Total	**364,227**	**114,368**	**9,224**	**100,927**	**38,083**	**626,831**
	2012-16	Pines	102,436	10,230	1,447	11,683	5,184	130,979
		Spruces	241,366	10,390	6,681	76,049	33,906	368,392
		Other conifers	26,678	4,672	754	7,717	3,435	43,256
		Broadleaves	12,444	91,954	513	18,054	0	122,966
		Total	**382,924**	**117,246**	**9,395**	**113,503**	**42,525**	**665,593**
	2017-21	Pines	97,523	12,699	1,358	13,321	5,868	130,769
		Spruces	233,339	9,673	6,432	77,727	34,489	361,661
		Other conifers	19,470	3,856	540	6,327	2,795	32,988
		Broadleaves	12,348	84,694	527	17,787	0	115,356
		Total	**362,680**	**110,922**	**8,857**	**115,162**	**43,152**	**640,774**
Wales	2003-06	Pines	3,883	228	183	1,220	546	6,061
		Spruces	26,897	39	1,011	9,383	4,197	41,526
		Other conifers	12,538	1,972	704	8,258	3,626	27,099
		Broadleaves	6,786	68,638	543	21,340	0	97,306

		Total	**50,104**	**70,877**	**2,441**	**40,201**	**8,369**	**171,992**
	2007-11	Pines	4,600	160	211	1,486	664	7,122
		Spruces	29,305	64	1,101	11,032	4,917	46,420
		Other conifers	11,875	2,089	690	8,598	3,755	27,007
		Broadleaves	6,153	68,953	497	22,224	0	97,826
		Total	**51,933**	**71,266**	**2,499**	**43,340**	**9,336**	**178,375**
	2012-16	Pines	4,230	124	195	1,542	684	6,775
		Spruces	29,911	99	1,121	12,286	5,454	48,869
		Other conifers	11,007	1,122	649	8,534	3,706	25,018
		Broadleaves	5,860	57,934	430	21,330	0	85,554
		Total	**51,008**	**59,279**	**2,395**	**43,692**	**9,844**	**166,216**
	2017-21	Pines	3,708	125	180	1,614	711	6,338
		Spruces	28,697	136	1,077	12,531	5,540	47,981
		Other conifers	8,143	942	471	7,144	3,064	19,764
		Broadleaves	5,284	57,071	419	21,246	0	84,020
		Total	**45,832**	**58,274**	**2,147**	**42,535**	**9,315**	**158,103**
England	2003-06	Pines	46,882	4,010	2,299	21,337	9,263	83,792
		Spruces	31,009	665	1,241	12,581	5,580	51,077
		Other conifers	36,817	2,079	2,049	24,227	10,586	75,758
		Broadleaves	66,233	87,816	4,290	131,492	0	289,831
		Total	**180,941**	**94,570**	**9,879**	**189,637**	**25,429**	**500,458**
	2007-11	Pines	39,537	4,419	1,885	22,266	9,553	77,660
		Spruces	30,337	696	1,140	13,855	6,094	52,121
		Other conifers	33,368	4,367	1,910	25,638	11,116	76,399
		Broadleaves	64,028	88,284	4,086	142,380	0	298,778
		Total	**167,270**	**97,766**	**9,021**	**204,139**	**26,763**	**504,958**
	2012-16	Pines	33,589	4,443	1,603	23,167	9,858	72,659
		Spruces	31,238	1,075	1,115	15,541	6,777	55,746
		Other conifers	28,636	7,131	1,664	24,970	10,749	73,151
		Broadleaves	67,208	85,362	4,284	160,937	0	317,790
		Total	**160,671**	**98,011**	**8,666**	**224,615**	**27,384**	**519,346**
	2017-21	Pines	29,742	4,389	1,438	24,243	10,229	70,041
		Spruces	31,283	1,321	1,090	16,592	7,195	57,480
		Other conifers	21,876	7,110	1,269	22,447	9,564	62,266
		Broadleaves	64,283	81,272	4,138	163,177	0	312,870
		Total	**147,184**	**94,092**	**7,935**	**226,459**	**26,988**	**502,657**
GB total	**2003-06**		**560,472**	**278,602**	**21,124**	**315,694**	**65,680**	**1,241,574**
	2007-11		**583,430**	**283,400**	**20,744**	**348,406**	**74,182**	**1,310,164**
	2012-16		**594,603**	**274,536**	**20,456**	**381,810**	**79,753**	**1,351,155**
	2017-21		**555,696**	**263,288**	**18,939**	**384,156**	**79,455**	**1,301,534**

4.2.3.3 Public sector (Table 10)

The predicted quantities of potential operationally available biomass from the public sector are about half that predicted from the private sector.

Considering first the categories small roundwood, tips, branches and foliage (there is no equivalent category to poor quality stems in the public sector), Table 10 shows that the total biomass remains around 617k odt y^{-1} across Britain as a whole for the first two forecast periods and then falls slightly to reach 599k odt y^{-1} by 2017-21. The biomass of spruce, the dominant species group, increases from about 358k odt in the present period to about 379k odt y^{-1} by 2017-2021 with much of the increase occurring in the first 5 years (Figure 8). As with the private sector, most of this increase occurs in Scotland. The overall increase is balanced by the decrease in biomass of pine and the other conifers. Wales and England are expected to have overall a small decrease in woodfuel availability.

Considering just tips and branches, current felling plans will lead to a general increase in potential operationally available biomass from about 105 k odt y^{-1} to 110 k odt y^{-1}. Much of the increase occurs within spruce by the second prediction period. The forecast increase in broadleaved tips and branches in the final period is counterbalanced by the decrease in conifers other than spruces or pines.

Please note that the comparatively stable forecast has been thoroughly checked. Reasons why woodfuel availability direct from the forest is expected to remain more or less constant while overall stemwood volumes increase significantly are discussed in section 5.3.

Figure 8. Long term forecast trends in potential operationally available biomass in the Forestry Commission from felling and thinning in Britain as a whole (oven dried tonnes y^{-1})

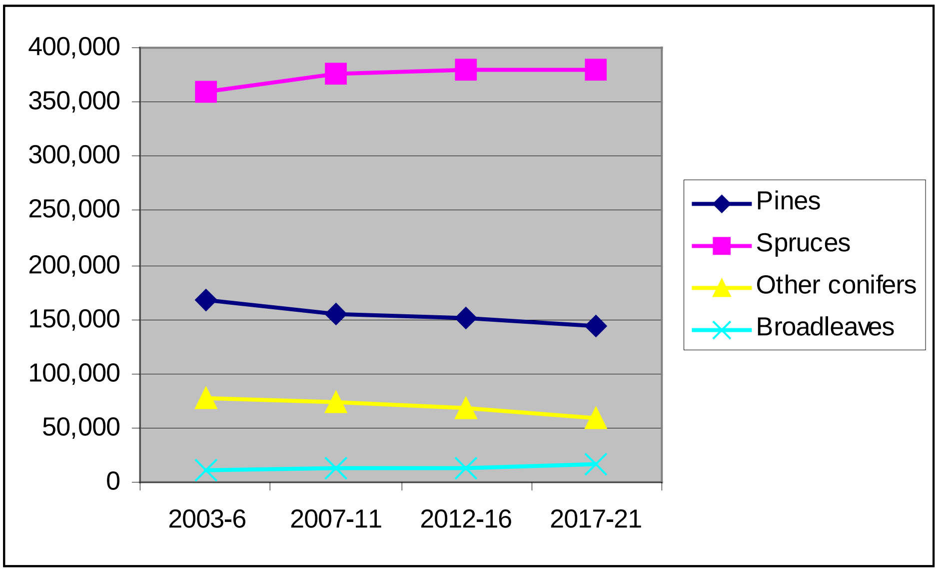


Table 10. Public sector forecast of potential operationally available biomass by country, period, species group, and biomass component (oven dried tonnes y^{-1})

Area	Forecast period	Species group	Biomass component				
			7-14cm diameter stems	Branches	Tips	Foliage	Total
Scotland	2003-06	Pines	87,080	963	4,904	2,228	95,175
		Spruces	168,448	2,315	22,381	10,014	203,158
		Other conifers	19,947	327	2,900	1,296	24,470
		Broadleaves	1,713	10	116	0	1,839
		Total	**277,188**	**3,615**	**30,301**	**13,538**	**324,642**
	2007-11	Pines	83,701	834	4,627	2,098	91,260
		Spruces	198,291	2,707	28,543	12,707	242,249
		Other conifers	21,602	348	3,094	1,386	26,429
		Broadleaves	1,820	12	168	0	1,999
		Total	**305,414**	**3,901**	**36,432**	**16,191**	**361,937**
	2012-16	Pines	82,951	819	5,002	2,260	91,032
		Spruces	204,590	2,702	29,997	13,314	250,603
		Other conifers	19,927	319	2,861	1,278	24,385
		Broadleaves	1,805	11	169	0	1,985
		Total	**309,273**	**3,851**	**38,029**	**16,852**	**368,005**
	2017-21	Pines	77,194	774	5,478	2,451	85,898
		Spruces	215,095	2,884	32,978	14,601	265,558
		Other conifers	19,484	312	2,806	1,251	23,852
		Broadleaves	3,346	26	362	0	3,733
		Total	**315,119**	**3,996**	**41,624**	**18,303**	**379,041**
Wales	2003-06	Pines	11,576	489	2,675	1,216	15,956
		Spruces	51,014	1,767	18,156	8,091	79,028
		Other conifers	14,348	709	7,027	3,125	25,209
		Broadleaves	767	46	539	0	1,352
		Total	**77,705**	**3,011**	**28,397**	**12,432**	**121,545**
	2007-11	Pines	7,763	307	2,027	913	11,010
		Spruces	39,502	1,328	16,295	7,187	64,311
		Other conifers	11,023	553	5,780	2,563	19,919
		Broadleaves	717	35	427	0	1,178

		Total	**59,005**	**2,223**	**24,529**	**10,663**	**96,418**
	2012-16	Pines	6,936	267	1,898	851	9,952
		Spruces	39,287	1,304	17,555	7,666	65,812
		Other conifers	9,321	489	5,166	2,285	17,262
		Broadleaves	605	35	463	0	1,102
		Total	**56,149**	**2,095**	**25,082**	**10,802**	**94,128**
	2017-21	Pines	6,834	261	1,839	825	9,760
		Spruces	36,024	1,210	15,861	6,944	60,039
		Other conifers	7,282	365	4,174	1,827	13,648
		Broadleaves	529	31	454	0	1,014
		Total	**50,669**	**1,867**	**22,328**	**9,596**	**84,461**
England	2003-06	Pines	36,959	1,452	13,215	5,847	57,472
		Spruces	59,150	1,183	11,323	5,060	76,716
		Other conifers	16,333	782	7,873	3,489	28,477
		Broadleaves	4,593	327	3,329	0	8,249
		Total	**117,035**	**3,744**	**35,740**	**14,396**	**170,914**
	2007-11	Pines	31,031	1,297	14,334	6,268	52,929
		Spruces	51,431	982	11,388	5,044	68,845
		Other conifers	14,882	724	8,434	3,710	27,751
		Broadleaves	4,981	340	4,278	0	9,599
		Total	**102,325**	**3,343**	**38,434**	**15,022**	**159,124**
	2012-16	Pines	30,169	1,216	13,315	5,819	50,519
		Spruces	47,427	913	10,822	4,777	63,939
		Other conifers	13,507	661	8,394	3,654	26,215
		Broadleaves	4,862	311	4,459	0	9,632
		Total	**95,965**	**3,101**	**36,990**	**14,250**	**150,305**
	2017-21	Pines	28,211	1,141	13,343	5,806	48,501
		Spruces	38,238	774	10,355	4,523	53,890
		Other conifers	10,278	504	7,409	3,190	21,381
		Broadleaves	5,164	313	5,955	0	11,432
		Total	**81,891**	**2,732**	**37,062**	**13,519**	**135,204**
GB total	**2003-06**		**471,928**	**10,370**	**94,438**	**40,366**	**617,101**
	2007-11		**466,744**	**9,467**	**99,395**	**41,876**	**617,479**
	2012-16		**461,387**	**9,047**	**100,101**	**41,904**	**612,438**
	2017-21		**447,679**	**8,595**	**101,014**	**41,418**	**598,706**

4.3 Co-product

The annual production of co-product in Britain is estimated at 859 k odt (Table 11). Almost half (47%) of the co-product comes from Scottish mills with 34% from England and 19% from Wales. Within England there are striking contrasts with the West Midlands accounting for 35% of English production and 12% of British output but the neighbouring East Midlands producing less than one tenth of this (Table 12). The other important English Region is the North East.

The location of the major sawmills is shown in Appendix 2 Figure A1a which includes 62 of the 70 mills that have an annual consumption of >5000m^3. Mills in this size category account for 80+% of home-grown material processed through sawmills. Contact details are listed in Appendix 2.

Table 11. Estimated sawmill co-product by country and present use (oven dried tonnes y^{-1})

Present use		Scotland	Wales	England	GB
Sold to wood processing industries					
	Sawdust	67,847	33,602	57,292	158,742
	Slabwood	229	62	748	1,039
	Peeled Chips	255,387	102,934	129,249	487,570
	Unpeeled Chips	15,044	2,913	45,696	63,652
	Other	3,669	157	1,377	5,203
Other Sales					
	Sawdust	6,851	3,221	2,818	12,890
	Slabwood	44	1	3	48
	Peeled Chips	1,008	575	10,578	12,161
	Unpeeled Chips	2,870	174	2,367	5,411
	Firewood	790	214	1,937	2,941
	Other	871	26	56	953
Sold as bark		39,619	20,506	35,539	95,664
Burnt for heat		9,002	1,357	1,571	11,931
Disposed rubbish/ burning		407	41	349	797
Total co-products		**403,637**	**165,783**	**289,581**	**859,001**

Overall 66% is in the form of chips (peeled and unpeeled), 20% is sawdust and 11% is bark. About 2% is already used as woodfuel with most being used by the sawmills themselves and only 2,941 odt y^{-1} sold externally as firewood – firewood production is concentrated in the South West and the East Midlands (Table 12). Latest estimates indicate that overall 83% of the total co-product is already sold to the wood processing industries with almost no differences between countries (Table 11); the location of the major wood-using industries is shown in Appendix 2 Figure A1b. Miscellaneous markets already account for 15% of co-product.

Availability to woodfuel developments is difficult to predict but if we assume that 10% of all co-product could be made available without major effects on existing industries this gives 86k odt y^{-1}.

Table 12. Estimated sawmill co-product by English region and present use (oven dried tonnes y^{-1})

Area	Sawdust	Slabwood	Peeled Chips	Unpeeled Chips	Bark	Burnt for Heat	Firewood	Disposed	Other	Total
North East	8,332	169	22,555	15,447	3,785	145	54	50	78	50,615
North West	15,243	244	10,539	3,492	7,865	75	188	25	228	37,899
Yorkshire and the Humber	3,347	43	8,735	3,650	1,763	789	171	25	446	18,970
East Midlands	1,071	88	2,519	3,070	375	84	388	49	20	7,664
West Midlands	18,703	15	61,108	5,733	14,607	98	136	10	50	100,461
East of England	4,719	58	12,756	3,597	2,723	146	261	34	283	24,579
South East	3,822	60	13,589	2,098	2,172	57	266	114	13	22,190
South West	4,873	74	8,025	10,976	2,247	178	474	42	315	27,203
England	**60,110**	**751**	**139,827**	**48,063**	**35,539**	**1,571**	**1,937**	**349**	**1,433**	**289,581**

4.4 Arboricultural arisings

4.4.1 Responses

The total estimated number of contractors was 2,174. Their distribution throughout the three countries and the English Regions is shown in Table 13. Grouping by Forestry Commission Forest District is shown in Appendix 14.

Table 13. Distribution of the number of tree work contractors and number of contractors who responded to the questionnaire in the Countries and regions of Britain.

Countries and Regions	Number of contractors	Number of responses	Percent responses
England	**1,943**	**126**	**6.5**
South East	385	36	9.3
London	170	14	8.2
South West	258	18	7.0
East of England	270	13	4.8
West Midlands	196	11	6.2
East Midlands	205	10	4.9
Yorks & Humber	180	7	3.9
North West	204	11	5.4
North East	75	8	10.7
Scotland	**126**	**16**	**12.7**
Wales	**105**	**8**	**7.6**
GB total	**2,174**	**150**	**7**

Of the 2,174 contractors who received a questionnaire, 150 replied giving a response rate of 7%; some of the respondents chose to answer part of the questionnaire.

4.4.2 Average, GB and Regional arisings

The 150 contractors who provided estimates of total annual volumes or weights disposed of an average of 258 odt y^{-1} of arboricultural arisings with individual values ranging from 10 to 5,670 odt. If the average figure of 258 odt y^{-1} is applied to the estimated number of 2,174 contractors this gives a total of 560,892 odt y^{-1} of arboricultural arisings. Applying averages calculated separately for English, Scottish, and Welsh respondents gives a total GB estimate of 472,170 odt y^{-1}(Table 14). The vast majority of arisings are in England (94% total).

Table 14. Estimated* annual arboricultural arisings for each of the countries and English Regions of Britain by the material produced (oven dried tonnes y^{-1}).

Countries and regions	Stemwood	Branchwood	Wood chips	Foliage	Total arisings
England	**241,443**	**85,569**	**103,513**	**14,500**	**445,025**
South East	63,718	17,518	25,025	2,888	109,149
London	28,135	7,735	11,050	1,275	48,195
South West	14,319	7,869	11,868	774	34,830
East of England	23,220	12,825	9,531	1,080	46,656
West Midlands	6,272	4,998	2,999	1,176	15,445
East Midlands	34,850	8,610	18,650	1,341	63,451
Yorks & Humber	56,305	4,990	7,794	3,240	72,329
North West	10,574	16,074	11,346	1,451	39,445
North East	4,050	4,950	5,250	1,275	15,525
Scotland	**5,766**	**3,872**	**5,307**	**1,201**	**16,146**
Wales	**3,565**	**4,325**	**2,123**	**987**	**11,000**
GB total	**250,774**	**93,766**	**110,943**	**16,688**	**472,170**

* The figures include estimates for non-responses.

If the country estimates are split on the basis of the number of contractors within each area, figures for English regions (Table 14) and Forest Districts can be obtained (Appendix 15). The contribution of the South East is about 25% of the total English resource with Yorks and Humber and the East Midlands also providing substantial arisings; these three regions provide in total more than half the arisings in England and Britain as a whole. These trends are reflected at Forest District Level. There is a relatively even split across the 4 Welsh districts. In Scotland however, most arisings come from the Scottish Lowlands which provide 36% of the Scottish total.

4.4.3 Form of arisings (Table 14)

Of the total GB resource, approximately half (53%) was in the form of stem wood and 23% was already chipped with 20% as branchwood. Foliage represented a minor component. These trends are set by the three dominant English regions but there are notable geographical differences in the composition of the arisings. The North West and North East of England for example produce more arisings in the form of branchwood and chips and less as stem wood than average; branchwood is the most common form of arisings in both Wales and North West England.

4.4.4 Arisings without a current market

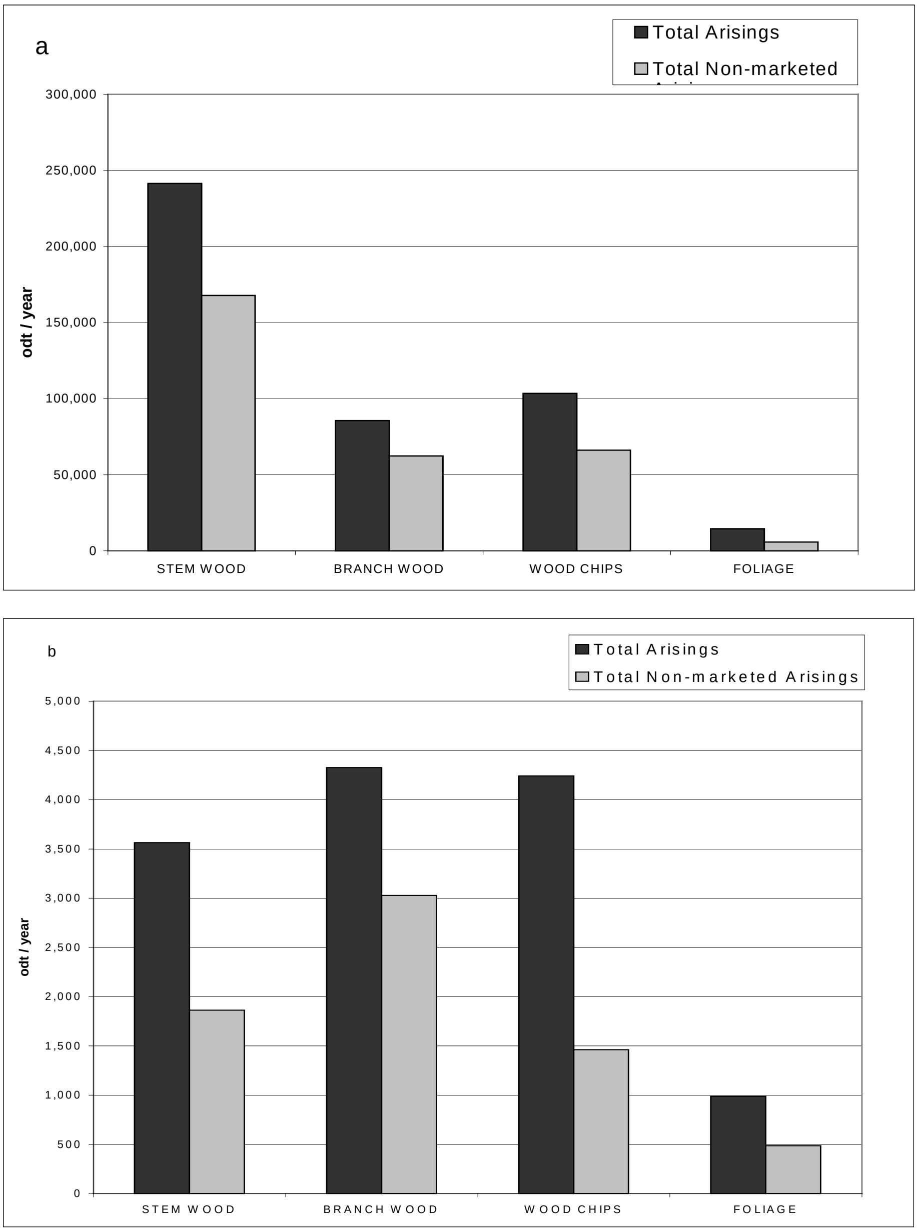
The average percentage of non-marketed stem wood, branch wood, wood chips and foliage for respondents was multiplied up to a GB, country and regional level (Table 15 and Figure 9) and Forest District (Appendix 16). Total non-marketed arisings are estimated at 321,493 odt y^{-1}, i.e. 68% of total estimated arisings. Within some areas, a lower proportion of the total is available, e.g. Yorks and Humber (34%) and West midlands (46%), but 80% of arisings in East England and the East Midlands do not have an existing market. Over GB as a whole, a slightly higher proportion of branchwood does not have an existing market (73%) compared to the other components. As with the other woodfuel resources, actual availability will be dependent on the prices offered for woodfuel end uses in comparison to those being offered by competing markets.

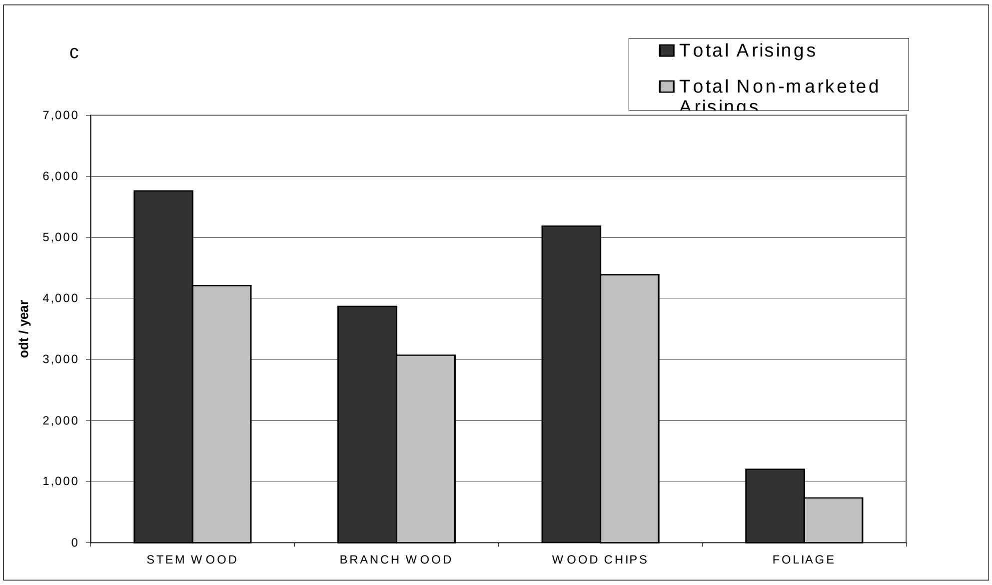
Table 15. Estimated* annual non-marketed arboricultural arisings for each of the Countries and regions of Britain (oven dried tonnes y^{-1}).

Countries and regions	Non-marketed Stem wood	Non-marketed Branch wood	Non-marketed Wood chips	Non-marketed Foliage	Total Non-marketed Arisings
England	**167,863**	**62,355**	**66,173**	**5,815**	**302,206**
South East	54,863	12,513	13,937	1,348	82,661
London	24,225	5,525	6,154	595	36,499
South West	14,345	4,644	7,559	464	27,012
East of England	18,403	11,880	6,750	324	37,357
West Midlands	3,724	3,038	255	98	7,115
East Midlands	29,008	6,765	13,838	1,025	50,636
Yorks & Humber	14,130	1,710	7,794	180	23,814
North West	6,915	12,655	5,453	956	25,979
North East	2,250	3,625	4,433	825	11,133
Scotland	**4,214**	**3,074**	**4,391**	**769**	**12,448**
Wales	**1,864**	**3,029**	**1,462**	**486**	**6,841**
GB total	**173,941**	**68,458**	**72,026**	**7,070**	**321,495**
%	**69**	**73**	**65**	**42**	**68**

* The figures include estimates for non-responses.

Figure 9. Marketed and non-marketed arisings in (a) England, (b) Wales and (c) Scotland (oven dried tonnes y^{-1})





4.4.5 Arisings from utility line-clearance and roadside maintenance

Three companies involved in clearance of utilities and roadsides responded representing nearly 70% of this business. Arisings produced by contractors undertaking utility line-clearance and roadside maintenance are estimated at 19.6 k odt (11.2 k odt y^{-1} in England, 5.7 k odt y^{-1} in Scotland, and 2.7 k odt y^{-1} in Wales). Network Rail is quantifying their potential resource with a view to using and/or marketing woodchip but data are not yet available (N Strong, pers. comm.)

4.4.6 Arboricultural arisings from waste streams (data from other studies)

Across Britain, the waste woody material arisings segregated from collected household waste and civic amenity sites was found to be 179 k odt y^{-1} (WRAP, 2002); this is likely to be an underestimate because information of waste in some Local Authorities is not given. These data were allocated to English Regions and Forest Districts (Tables 16 and Appendix 23 respectively).

Table 16. Total estimated* arboricultural arisings produced for England (including Regions), Scotland and Wales (oven dried tonnes y^{-1}).

Countries and regions	Arboricultural arisings	Collected waste arisings	Arboricultural arisings + Collected waste arisings	Utility works arisings	Total arisings
England	**445,025**	**159,835**	**604,860**	**11,200**	**616,060**
South East	109,148	35,496	144,644		
London**	48,195	10,072	58,267		
South West	34,830	16,510	51,340		
East of	46,656	24,679	71,335		
West Midlands	15,445	15,650	31,095		
East Midlands	63,451	8,547	71,998		
Yorks &	72,329	17,750	90,079		
North West	39,446	25,853	65,299		
North East	15,525	5,278	20,803		
Scotland	**16,146**	**12,871**	**29,017**	**5,700**	**34,717**
Wales	**11,000**	**6,006**	**17,006**	**2,700**	**19,706**

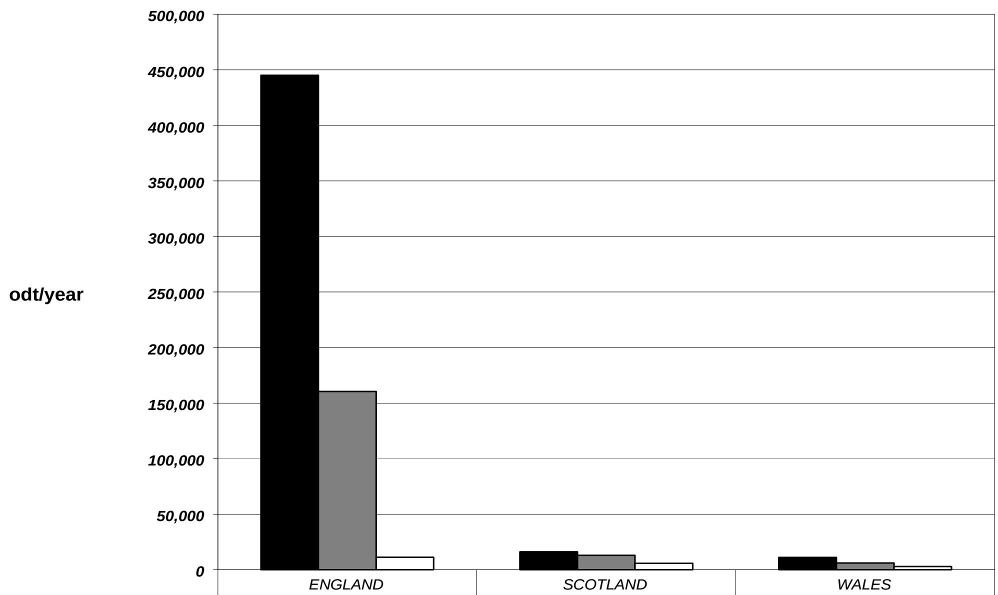
GB total	**472,171**	**178,712**	**650,883**	**19,600**	**670,483**

* The figures include estimates for non-responses. ** Figures for collected waste arisings were not available for almost 50% of the London Local Authorities.

4.4.7 Estimates of total arisings

If woody arisings segregated from collected municipality household waste are added to the arboricultural residues produced by arboricultural contractors (492 k odt y^{-1}) the total potential wood fuel resource from arisings is estimated to be 670 k odt y^{-1} (Figure 10). Estimates at Forest District level are given in Appendix 17.

Figure 10. Total estimated arisings for England, Scotland and Wales (oven dried tonnes y^{-1}).



	ENGLAND	SCOTLAND	WALES
Arboricultural Arisings	445,024	16,028	11,000
Waste collected Arisings	160,333	12,867	6,005
Utility works Arisings	11,200	5,700	2,700

4.4.8 Per capita estimates

The population in Britain was 57,103,927 in the latest 2001 census (Office for National Statistics & General Register Office for Scotland, 2002). The average production of arisings $person^{-1}$ was 9.91 oven dry kg (odkg) y^{-1}. On a country basis, the figures are 12.32 odkg $person^{-1}$ y^{-1} in England, 5.86 odkg $person^{-1}$ y^{-1} in Wales, and 5.70 odkg $person^{-1}$ y^{-1} in Scotland (Table 17). Estimates at Forest District level are given in Appendix 18. The large urban areas in England could explain why the average production $person^{-1}$ of arboricultural arisings is higher in England.

Table 17. Estimated* production of arboricultural arisings per habitant and year (oven dry kilograms y^{-1}).

Countries and regions	Population	Arboricultural Arisings / hab	Waste Collected Arisings / hab	Total Arisings / hab
England	**49,138,831**	**9.05**	**3.27**	**12.32**
South East	8,000,550	13.64	4.32	17.96
London**	7,172,036	6.72	1.40	8.12
South West	4,928,458	7.07	3.35	10.42
East of England	5,388,154	8.66	4.58	13.24
West Midlands	5,267,337	2.93	2.97	5.90
East Midlands	4,172,179	15.03	2.05	17.08
Yorks & Humber	4,964,838	14.57	3.57	18.14
North West	6,729,800	5.86	3.84	9.7
North East	2,515,479	6.17	2.10	8.27
Scotland	**5,062,011**	**3.16**	**2.54**	**5.70**
Wales	**2,903,085**	**3.79**	**2.07**	**5.86**
GB total	**57,103,927**	**8.27**	**3.14**	**11.41**

* The figures include estimates for non-responses.

4.5 Short rotation coppice

The total area planted up to June 2003 with short rotation coppice under the Woodland Grant Scheme and the Energy Crops Scheme is 2086 ha of which the vast majority (95%) is in England (Appendix 22). Assuming an average annual production of 8 odt ha^{-1} y^{-1}, this equates to 16.7 k odt y^{-1}. Within England, just under half is within the Yorkshire and Humber Region with the East Midlands being the other main area of SRC. Estimates of short rotation coppice established under the Woodland Grant Scheme, the Energy Crops Scheme, and in combination at Regional/Conservancy level are given in Appendix 19, 20 and 21 respectively.

Table 18. Production of short rotation coppice assuming an average yield of 8 odt ha^{-1} y^{-1} (oven dried tonnes y^{-1})

Country/Region	Average Annual Production odt y^{-1}
England total	**15,899**
East of England	880
East Midlands	4,470
North East	466
North West	236
South East	*792
South West	964
West Midlands	388
Yorks & Humber	7,703
Scotland	**572**
Wales	**218**
GB total	**16,689**

* includes London

Of the total area planted in England (1987ha), 21% has been established under the Energy Crops Scheme which is conditional on the crop having a guaranteed energy end market; this applies particularly in the East Midlands where 196 of the total 558 ha falls into this category. Many of the earlier crops established under the WGS in the Yorks and Humber Region were contracted to Project Arbre but their availability on the open market is uncertain at present. However if we assume that all crops except those established under the Energy Crops Scheme are available for new woodfuel projects, this gives 13.2 k odt $y^{-1.}$

4.6 Total resource in 2003-2006

4.6.1 Potential resource in the absence of competing markets

The total potential operationally available woodfuel in Britain, in the absence of competing markets, is 3.12 million odt y^{-1}(Table 19). At a GB level the main source is small roundwood followed by sawmill co-product (potential to contribute around 1.03 and 0.86 million odt y^{-1} respectively) with arboricultural arisings providing about 14% of the total. Approximately equal quantities are available in England and Scotland but the composition is substantially different. Arboricultural arisings form the major element in England though sawmill co-product, small roundwood, and branches are all significant components. In Scotland and Wales, small roundwood and sawmill co-product are the dominant resources with all other resource streams playing only a minor part at the moment.

Table 19. Current potential operationally available woodfuel resource (in the presence of competing markets) by country (thousand oven dried tonnes y^{-1})

Product	Scotland	England	Wales	Britain
Stemwood 7-14cm diameter	606	298	128	1032
Poor quality stemwood	113	94	70	278
Stem tips	12	14	5	31
Branches	116	225	68	410
Sawmill co-product	404	290	166	859
Arboricultural arisings	22	456	14	492
Short rotation coppice	0.6	16	0.2	17
Total	**1,268**	**1,382**	**449**	**3,119**

4.6.2 Potential resource taking account of existing industries

The potential resource that could be made available to new woodfuel projects without serious disruption to existing wood-using industries is estimated to be 1.26 million odt y^{-1} (Table 19). Assumptions on market availability are:

- 10% of the small roundwood
- 100% of the poor quality stemwood, stem tips and branches
- 10% of sawmill co-product

- 100% unmarketed arboricultural arisings
- 100% of material from clearance of utilities and roadside maintenance
- 80% of short rotation coppice in England, i.e. all coppice other than that established under the Energy Crop Scheme, and 100% SRC in Scotland and Wales

Table 20. Current potential operationally available woodfuel resource (in the absence of competing markets) by country (thousand odt y^{-1})

Product	Scotland	England	Wales	Britain
Stemwood 7-14cm diameter	61	30	13	103
Poor quality stemwood	113	94	70	278
Stem tips	12	14	5	31
Branches	116	225	68	410
Sawmill co-product	40	29	17	86
Arboricultural arisings	18	313	10	341
Short rotation coppice	0.6	13	0.2	14
Total	**356**	**707**	**180**	**1,263**

4.7 Future resource

Operationally available woodfuel in the form of small roundwood, poor quality stems, branches, tips and foliage from traditional forestry is expected to remain relatively stable at just under 2 million odt y^{-1} up to 2020. There is a small increase in operationally available resource from private forests (1,242 k odt y^{-1} in 2003-6 to 1,301k odt y^{-1} in 2017-21) but also a small decrease in expected public sector resource (617 k odt y^{-1} in 2003-6 to 599 k odt y^{-1} in 2017-21).

Even though the smaller and poor quality fractions are expected to remain relatively stable, the availability of larger dimension material is expected to increase substantially. For example, stemwood of 18+cm diameter increases from 3.8 million odt y^{-1} in 2003-6 to 5.4 million odt y^{-1} in 2017-21. Assuming the sawmilling sector expands to use this resource, co-product will increase proportionately since, during conversion of logs to sawn timber, approximately 50% of the stem volume becomes co-product. In addition there is some indication that, compared to the present harvest, the form of larger dimension material is poorer than in material that will reach felling age in the next 20 or so years. Conversion efficiency is therefore expected to fall with a concomitant increase in co-product unless sawmilling technology can make parallel improvements.

Operationally available arboricultural arisings cannot be forecast with any certainty but seem unlikely to change dramatically.

Availability of short rotation coppice will depend on many factors of which Renewables Obligation co-firing conditions, CAP reform, support schemes, proof of energy end-markets and profitability of coppice relative to alternative crops are likely to be the most influential.

5. DISCUSSION

5.1 Potential resource taking account of existing industries

As stated earlier (Section 2.6 and 2.7), this report does not estimate what might be available to the market – we provide locations and contacts of potential suppliers plus locations of the current large scale users to assist potential developers in identifying potential resources and making initial contact with suppliers to open discussions about quantities, specifications and prices. Nevertheless we can use the current information to estimate quantities of material without markets at present. We estimate operationally available woodfuel that either is not marketed or does not have a market at 1.26 million odt (assumptions on market availability are: 10% of the annual small roundwood and sawmill co-product; 100% of the poor quality stemwood, stem tips and branches; 100% of unmarketed arboricultural arisings; 100% of material from clearance of utilities and roadside maintenance; 80% short rotation coppice, i.e. all coppice other than that established under the Energy Crop Scheme).

5.2 Potential resource and contribution to energy targets.

The total operationally available resource (3.1 million odt y^{-1}) if used for electricity generation equates to 3.6 TWH_e y^{-1} (assumes calorific value of 20 GJ odt^{-1} and 25 % conversion efficiency) or 0.44 GW (assumes a generating time of 8000 h y^{-1}). The 10% UK electricity target for renewable generation is equivalent to 3 GW of which about 1 GW is hoped to come from biomass. Thus if all the operationally available woodfuel is used to generate electricity this would provide just under half of the notional target for biomass. This emphasises the need to consider other sources of biomass, such as recovered wood, and to increase establishment of biomass crops with rapid early growth rates, such as short rotation coppice or energy grasses. Short rotation forestry could contribute to targets beyond 2010.

If woodfuel is used to generate heat, the potential operationally available resource of 3.1 million odt would generate about 12.1 TWH_{th} (assuming 85% conversion efficiency). There is no specific target for heat generation even though 40-50% of electricity is used to provide space heating.

In the future, biomass could be used to produce transportation fuels. The current annual demand in the UK is 1600 PJ (1 petajoule = 1,000 terajoules or 1,000,000 gigajoules). Conversion efficiency of woody biomass to ethanol, methanol or hydrogen is about 65 % (Eyre *et al.* 2002). If all the potential operationally available woodfuel is used to produce transportation fuels this would give about 40 PJ, i.e. 2.5 % of current demand. EU Directive 2003/30/EC states that 5.75 % of all petrol and diesel must be replaced by biofuels by 2010.

Woodfuel would not be delivered or used in an oven-dried condition therefore estimates do not account for the energy required to evaporate the moisture contained in woodfuel because it can be very variable from one form of material to another and from one season to another. Ideally woodfuel will be dried using passive drying or waste heat to maximise efficiency of the overall process.

5.3 Future production from forests

Overall timber production, i.e. stem wood of 7 cm diameter and greater, will increase from the current level of 11.87 million m^3 y^{-1} (approximately 5.9 million odt y^{-1}) to 16.48 million m^3 y^{-1} (approximately 8.2 million odt y^{-1}) around 2020 (Forestry Commission 2002). Estimated woodfuel availability does not increase in direct proportion. Potential operationally available biomass from small roundwood, poor quality stems, branches, tips and foliage increases from 1.86 million odt y^{-1} in the present forecasting period to 1.90 million odt y^{-1} in 2017-2021.

The comparatively stable forecast for woodfuel from traditional forestry has been thoroughly checked. The main reason for the comparative stability in woodfuel availability in spite of significant increases in total volumes is the predicted size distribution of the timber produced over the next 20 years. As can be seen from Figure 11, the softwood small diameter fractions remain relatively stable with most of the increased production taking place in the larger diameter classes. Once stands have closed canopy the crown biomass stays more or less constant even though the woody stem continues to increase in mass because growth of leaves and branches at the top is balanced by death of the foliage and branches lower down in the crown due to shading. Also, there is a clear trend in the private sector of increasing felling age (and hence average tree size) through time.

The following silvicultural factors will influence the total quantity and size distribution of tree components that will be available in future years – factors likely to increase woodfuel availability are discussed first:

- Thinning. Because of the poor markets for small roundwood over the past five years or so, some plantations have been left unthinned. More recently the introduction of certification has required that, provided plantations are in low wind risk areas, they must be thinned even if a profitable small roundwood market is lacking. The development of a strong demand for woodfuel would be a welcome potential market for small roundwood plus associated branches and tips.
- Restoration of ancient woodland sites. Removal of trees, usually conifers, planted on ancient woodland sites will increase all components of woodfuel supply in the short-term. However, productivity of the restored woodlands will be a low priority therefore in the longer-term potential woodfuel is likely to reduce. The extent of these sites and the timetable for their restoration is very variable across the country.
- Short rotation forestry. Use of single stemmed trees grown on short rotations of 12-15 years for woodfuel is an option under consideration at present. Some species appear to offer yields of over 10 odt ha^{-1} y^{-1} though, of the native species, only ash and alder have growth rates approaching this. If adopted on a significant scale, short rotation forestry could increase potential woodfuel particularly the stemwood components but only in the medium to long term.

- Increasing use of alternatives to large clear felling systems. A move away from large-scale clear felling systems towards multi-aged stands where felling is limited to small coupes or single stems is expected to reduce woodfuel supply though the extent is difficult to quantify. Harvesting of smaller coupes or single stems at frequent intervals is likely to mean that, averaged over a long period of time, a larger proportion of the harvesting residues will be required to provide brash mats for harvesting machinery. Smaller scale harvesting operations are also likely to make the economics of woodfuel collection less favourable though in the long run this could be offset by increased value of the larger diameter stems thought to be attainable through continuous cover systems. Alternatives to large clear felling systems are already practised in a small proportion of private estates where family ownership has facilitated the long-term consistency of planning needed to operate this system. Alternatives are being initiated in the public sector too, particularly in Wales where the Welsh Assembly Government has set a target of managing 50% of its woodland through low impact silvicultural systems by 2020 (Forestry Commission 2001). Large-scale pilot trials are underway in all three countries with a view to much wider use of alternatives to large clear felling systems in the future.

- Extended rotations in long-term retentions. Existing designations of long-term retentions are largely factored into the forecasts used in our study. Further expansion of the area set aside for long-term retentions, though likely to be small, is expected to reduce the availability of woodfuel.
- Increasing use of species mixture. Overall this is expected to reduce woodfuel availability. One option on nutrient poor sites that would otherwise require fertiliser application to achieve satisfactory growth of spruce is to grow spruce in mixture with a 'nurse' species such as pine. This system can achieve similar growth of the spruce component when grown mixed but in the absence of fertiliser input compared to pure spruce with fertiliser inputs. In general the nurse species have slower growth rates and smaller branchwood components than spruce.

The following technological factors will modify the operationally available woodfuel – factors likely to increase woodfuel availability are discussed first:

- Harvesting of long tops (see Appendix 8 for details). If a strong woodfuel market were to develop, it would justify modifying operational practice so that the tops of stems with branches attached could be laid to one side for woodfuel whereas the side branches cut off the lower stem could be used for brash mats to support the harvesting machinery. This would increase the recovery rates of stem tops and branches.
- Allocating a larger proportion of the stem for woodfuel at time of felling and converting. Present operational practice is to cut the stem at 7cm diameter but if a strong woodfuel market were to develop, it would be possible to alter this diameter to increase the quantity of woodfuel product. The exact cutting diameter would be an economic judgement based on the relative prices for woodfuel and other markets for small dimension wood.
- Cable-crane harvesting. This is the most favourable system for residue extraction since the entire stem with branches attached is taken to the forest road side therefore recovery rates are high and the logistics of collection and bundling are much better than in systems where the tips and branches are left dispersed across the harvesting site where the stem is cut. Cable-crane harvesting is restricted to steep slopes and very sensitive sites because it is expensive. Recently, use of cable-crane harvesting has been decreasing in favour of advanced shortwood systems that are cheaper and can operate on steeper ground systems but have lower recovery rates.

5.4 Woodfuel without markets in the future

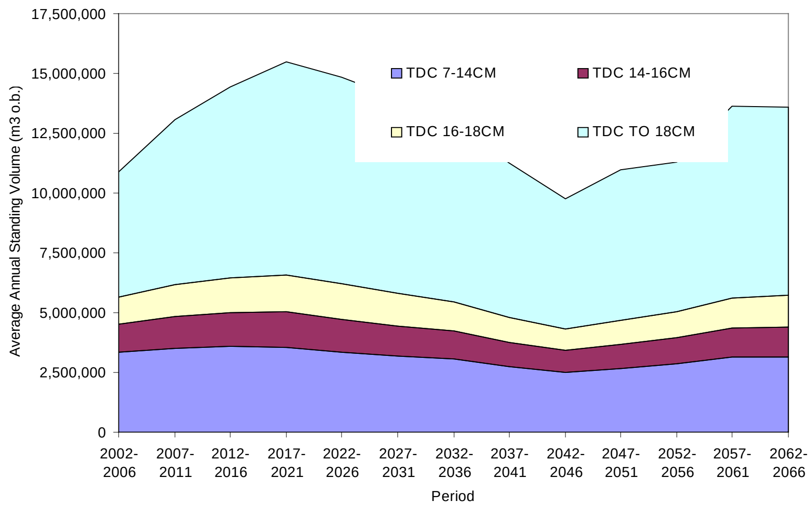
In the short to medium term, harvesting residues, deadwood, butt reducings, large forked stems and precommercial thinnings are unlikely to have substantial markets other than for energy end uses. Use of these biomass components (and sawmill co-product) as a source of primary and secondary chemicals is being investigated but at best these uses will be significant only in the medium-long term.

Other possible markets for stemwood and co-product are an additional line at an existing paper mill or a new pulp mill. Both will require large investment and have been under discussion for several years without concrete commitment. Woodpanel manufacture is the second main market for home-grown wood and co-product but expansion seems unlikely in view of the over capacity in the European market. Sawmills are the third large market for home-grown timber but their requirement is for the larger dimension material with higher market value in contrast to both the pulp and panel sector which take only small roundwood (in addition to co-product and recycled material). As can be seen from figure 11, the bulk of the forecast increase in production is thought to be in the larger dimension categories. If sawmill capacity increases to take advantage of this raw material supply, approximately 50% of any increased capacity will be potentially available to energy markets as sawmill co-product.

Some small roundwood is currently exported mainly to Scandinavia. This less than 5% at present though there is some anecdotal evidence that this market might become a significant competitor for small roundwood in the future.

Options for on-site disposal of arboricultural arisings are limited and much of it is transported away from the site. A large quantity of the material is disposed to landfill, which incurs costs and has environmental disadvantages. The high costs of the disposal of woody material in urban areas create particular opportunities for its use for energy production (British Biogen, 2002). The current landfill tax escalator, introduced in 1999, commits the Government to raise the standard of tax for active waste by £1 t^{-1} each year until 2004-05 when it will have reached a rate of £15 t^{-1}. The intention to increase landfill tax by at least £3 t^{-1} in future years from 2005/06 and the declared intention that the tax will increase to £35 t^{-1} in the longer term (Defra, 2003), are likely to increase the availability of arboricultural arisings for energy end uses.

Figure 11. Forecast softwood stemwood production (through standard forecasting models) by stem diameter (m^3 y^{-1}) where o.b. = over bark and TDC = top diameter class



Forestry Commission

5.5 Arboricultural arisings

Present estimates agree well with previous studies. Firstly, estimates of arboricultural arisings derived in the present study (474 k odt) are very close to previous estimates of 468-500k odt which were estimated in two quite different ways (Hudson, 1997). Secondly, the London Bioenergy Report estimated that arboricultural operations carried out in London by contractors working for local authorities generate some 50 k odt y^{-1} of material suitable for processing into a biomass fuel (Bright, 2001). The population living in the London area is 7,172,036 habitants (Office for National Statistics, 2002) therefore the average production of arisings can be estimated at 6.97 odkg $person^{-1}$ y^{-1}. This figure is similar to the 6.72 odkg $person^{-1}$ y^{-1} of arisings derived from responses of arboricultural contractors in the London area in the present survey.

5.6 Short rotation coppice

The present potential of SRC has been calculated using simple assumptions. Estimates could be refined by accounting for planting year, which will influence growth rates and point in the harvesting cycle, and site conditions, which will influence yield. However, given the limited extent of SRC, data are probably adequate for present purposes.

In future, the strategic planting of SRC close to the location of biomass enduses should be assessed taking into account other possible resources, land capability, farmer attitudes and landscape considerations. Estimates of potential production are available through Macaulay Land Use Research Institute for Scotland and the Environment Agency constraints mapping for England. Information from the site yield trials across UK should inform future decisions on yield predictions and site selection (Armstrong, 1996; Tubby and Armstrong, 2002).

5.7 Limitations

5.7.1 Omission of small private woodlands

Small (<2ha) private woodlands were excluded even though they account for 4.5% of the total woodland area in Britain since we anticipate that this resource will be too dispersed to justify consideration. This omission can be evaluated from Table 21, which gives the extent and species composition of small private woodlands in the three countries and English Regions. Small woodlands are of significance in some regions (e.g. East of England, East Midlands, and West Midlands) where they comprise more than 10% of the total wooded area but they are generally less than 5% of the total. Details split by county are given in Appendix 22.

Table 21. The contribution of small woodlands (i.e. <2ha in area) and traditional coppice by country and English Region.

Region	Area of woodland < 2ha (ha)	Small woodlands as % of total Woodland Area	Area of Coppice (ha)
England	**75,063**	**6.8**	**22,384**
North West	4,839	5.0	107
North East	2,013	2.0	0
Yorkshire & Humber	1,955	2.1	493
East Midlands	10,162	12.7	167
East of England	26,019	18.7	1,443
West Midlands	13,482	13.7	1,080
South West	6,412	3.0	1,898
South East	9,886	3.7	17,004
London	296	4.8	193
Scotland	**28,698**	**2.2**	**1,183**
Wales	**16,734**	**5.8**	**488**
GB Total	**120,495**	**4.5**	**24,055**

5.7.2 Environmental and operational constraints in the private sector

Extension of site constraints from land managed by Forest Enterprise to privately owned land is subject to error. Compared to privately owned land, the Forest Enterprise estate is generally poorer (less fertile, wetter, more exposed and more remote from markets), especially in Scotland but these differences are not quantified. Therefore for this study, the constraints recorded in Forest Enterprise at a Forest District level were reduced according to the consensus of the study's Working Group about relative land holdings in each Forest District. Other aspects that are more difficult to account for, e.g. private owners may have other objectives, such as recreation and sport shooting, which can mitigate against active forest management, have not been taken into account at all.

5.7.3 Growth rates of traditional coppice

Traditional coppice is locally important. At present however, yield data are not collected systematically and no tailored forecasting procedure is available to estimate productivity. At present their biological potential has been estimated assuming that they respond as high forest with comparatively low growth rates. Table 20 shows that, although this concern applies to only 24 k ha across Britain, it is of significance in South East England.

5.7.4 Reserve contained in undermanaged woodlands

In sustainably managed forests, harvesting should roughly equal production but it is known that a sizeable proportion of woodlands, especially broadleaved woodland, have not been thinned according to recommendations. In England for example, 50% of broadleaved woodland is thought to be underthinned. Should woodfuel provide a profitable market, it is possible that this would stimulate renewed forest management and result in the production of an initial wave of woodfuel that would exceed the longer-term sustainable level of harvesting and thinning. This study has not quantified the extent of the delayed harvest.

5.7.5 Verification of arboricultural arisings

Although our estimates of total arboricultural arisings agree well with previous studies, there is uncertainty about the estimates of its form and present markets. These aspects were not verified.

5.7.6 Factors affecting commercial availability

Environmental and site constraints have been taken into account in estimating operationally available resource but actual market availability is heavily influenced by price. Timber prices - timber is the most valuable market for the growers - will continue to be the main influence on harvesting activity especially in the private sector.

Actual availability to energy end markets cannot be predicted with certainty. The principal reasons are discussed below.

- Price predictions for material where there are competing markets are complex. Three factors make this especially difficult:
  - markets within the forest and forest products sector are highly inter-related (see Figure 12)
  - timber, pulp, chips and pellets are global commodities therefore prices are subject to currency fluctuations as well as international supply and demand
  - there are numerous regulations, incentives and support mechanisms influencing energy markets and waste recovery and recycling. Recent changes in market conditions due to land fill tax and incentives to encourage re-use and recycling are not accurately reflected in estimates of co-product availability. There has been a clear trend to increasing use of recycled wood by the panel sector where it has grown to about 450 k odt y^{-1} between 1998 and 2002 accounting now for about quarter of raw material intake (approximately 2.1 million odt). If this trend continues it will create further downward pressure on prices to growers and sawmillers.
- One particularly difficult aspect to predict is the effect of the development of a strong woodfuel market, which in itself will influence both supply and demand.
- Some potential woodfuel streams are not used in Britain at the moment therefore accurate costings are not available for British conditions. For example, branches of broadleaved trees have been identified as a major potential resource but these are not harvested on any scale even in Scandinavia. It is also important to recognise that residue harvesting costs in Scandinavia cannot be translated to Britain for several reasons. In Scandinavia there is generally:
  - flatter terrain facilitating more efficient logistics
  - residues can be collected in winter when the ground is frozen therefore there is less need for brash mats to support heavy machinery resulting in better recovery rates
  - the large scale operations tend to be carried out within integrated companies so that it is not necessary to generate a profit to the grower
  - residue compactors are relatively common resulting in increased efficiency of transport
  - cheaper transportation

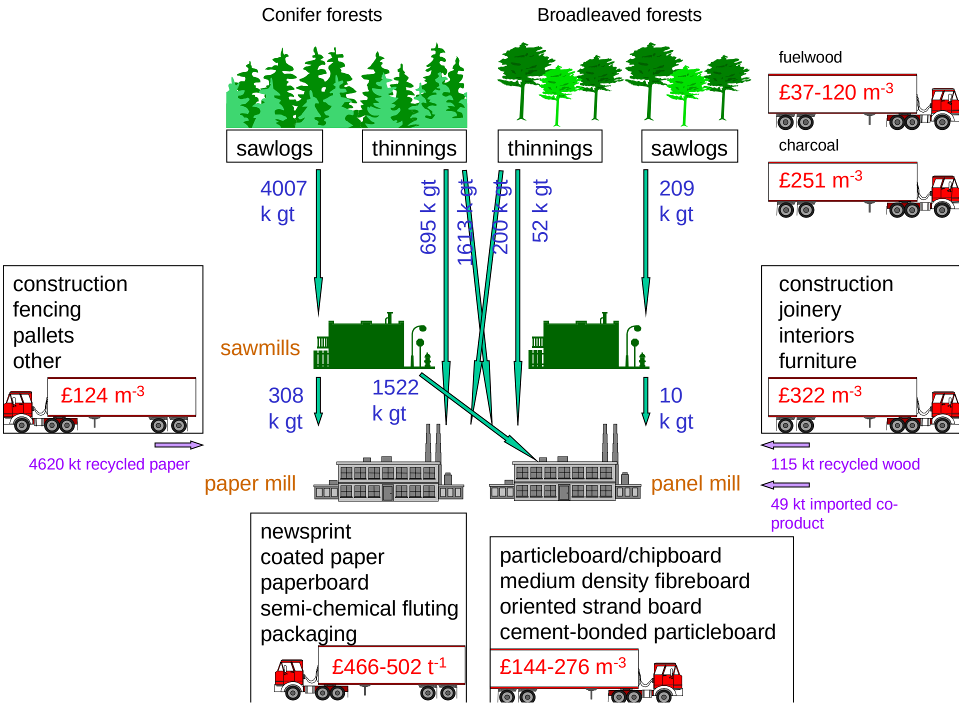


Figure 12. A representation of biomass flows in the forest industry (figures taken from the Forest Industry Handbook 1998 based on data from 1996-8).

6. FURTHER REQUIREMENTS

The site constraints used to estimate the operationally available harvesting residues from the private sector should be improved. An attitudinal survey of private owners would give part of the answer but more accurate information on site conditions is also required. This is a substantial task, in particular obtaining soils information.

Biomass allocation to branches of broadleaved species is based on a relatively small dataset. In view of the large resource identified in the branchwood of broadleaved woodlands, this estimate should be further verified and refined if necessary.

In view of the potential resource in privately owned broadleaved woodlands, it will be important to develop appropriate and efficient handling systems and compile cost information especially for small-medium scale operations.

This study did not include an estimate for standing deadwood (or harvesting residuals), i.e. trees that have died due to excessive shading by their neighbouring trees, drought, or disease. A few standing dead trees may be left to provide wildlife habitats but most are normally felled along with the living trees. They are currently not extracted since the timber is not suitable for present markets but standing deadwood does represent a potential woodfuel resource especially as the moisture content is lower than for living trees. Although the number and volume of trees that have died in any previous 5 year period can be estimated, it was not possible in the time available within the project to estimate the amount that would be available at any particular harvesting time. This would require an estimate of the accumulated mass over the crop's life and the decrease in mass and energy content through degradation and decomposition.

Our estimates for arboricultural arisings cover companies and Local Authorities but not individuals processing trees on an informal basis. The scale of woodfuel produced by individuals is probably small overall but may well be relatively more important in the rural areas of Scotland and Wales. Potential woodfuel produced informally by individuals should be evaluated.

Consideration should be given to refining our methodology for estimating the contribution of short rotation coppice if planting takes place on a significant scale. The contribution from energy grasses might also be worth including in the future.

The ideal tool for planners and developers considering biomass projects is a GIS that contains all potential biomass sources. The following 'clean' sources should be included: traditional forestry, sawmill co-product, arboricultural arisings and SRC – as quantified in this study – and also clean waste wood (for example from furniture manufacturing and construction), clean recovered wood (e.g. crushed pallets), straw, and energy grasses. Information on the potential contribution of wood that has been chemically treated should also be made available on the database since there will be situations where use of chemically treated wood gives economic benefits with no environmental or social disbenefits.

7. CONCLUSIONS

All the objectives of the study were met. The biologically available woodfuel resource from British forests has been estimated in a sound and consistent way and from this we have estimated the operationally available resource from traditional forests in the present forecast period and in the future. Current resources from sawmills, arboricultural arisings and short rotation coppice have also been estimated. Best available information has been used to indicate how much of the resource is not marketed at present and is therefore potentially available for energy end uses without taking competing markets into account. Though not objectives of the study, we have estimated the resource that could be made available without disruption of existing wood-using industries and provided commentary on potential commercial availability, making clear the location and general scale of existing competing markets. Data have been summarised at a medium geographical and temporal scale in paper and electronic form. An interactive website allows the user to sift through summary information in order to identify the woodfuel type of interest and also define an area of interest, a type of resource, and a future time interval. The user can submit, via the website, a detailed request for more refined information.

Two outputs have been produced in addition to the original objectives. Firstly, we have summarised data at English Region level to help regional planning for renewable energy. Secondly, this project has delivered an extremely valuable method of estimating the carbon pools in standing woody biomass. Biomass has been estimated for all tree components (except fine roots) and can be easily converted to carbon values. Moreover the data can be easily summarised at a range of spatial scales and forecast over a range of time periods. The GIS allows carbon pools to be estimated for any user-defined area and component through time.

We consider that the data are the most reliable available and will serve as a very useful basis for strategic thinking, planning and project development. Nevertheless there are limitations to the study. These have been identified and future actions to remedy them suggested. Uncertainties in the forecast of biologically available and operationally available biomass are discussed but cannot be quantified at present. Past planting patterns plus the response of woodlands to anticipated climate change are likely to increase the biologically available woodfuel. On the other hand, changes in silvicultural systems and forest management to reflect the wider environmental and social objectives, which are becoming increasingly common especially in the public forest, are likely to decrease the woodfuel availability.

The total potential operationally available resource is estimated to be 3.1 million odt y^{-1}, with unmarketed material estimated at 1.3 million odt y^{-1}. Across Britain as a whole, the greatest uncommitted resource lies in branches and poor quality stems while arboricultural arisings are the single biggest uncommitted resource in England – on present data, arboricultural arisings are of minor importance in Wales and Scotland. In the absence of competing markets the main potential source of woodfuel is small roundwood followed by sawmill co-product (potential to contribute around 1.03 and 0.86 million odt y^{-1} respectively). Assuming that 10% of both could be made available to new woodfuel projects without disruption to existing wood-using industries, a realistic but conservative figure for current availability from each is approximately 100k odt y^{-1}. Thus sawmill co-product and small roundwood direct from growers represent major potential sources of woodfuel in all three countries.

If all the operationally available woodfuel (3.1 million odt y^{-1}) is used to generate electricity this would provide 3.6 TWH_e y^{-1} - just under half of the notional target for the contribution of biomass to the UK government's target of 10% electricity to be supplied from renewable source by 2010. This emphasises the need to consider other sources of biomass, such as recovered wood, and to increase establishment of biomass crops with rapid early growth rates, such as short rotation coppice or energy grasses. If woodfuel is used to generate heat instead of electricity, the operationally available resource of 3.1 million odt y^{-1} would generate about 12.1 TWH_{th} y^{-1}; 40-50 % of electricity is used to provide space heating. If all the operationally available woodfuel is used to produce transportation fuels this could provide about 40 PJ y^{-1}, i.e. 2.7% of current demand; EU Directive 2003/30/EC states that 5.75 % of all petrol and diesel must be replaced by biofuels by 2010. These estimates do not account for the energy required to evaporate the moisture contained in woodfuel.

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