Biomass fuel assessment for the Z-squared combined heat and power plant

A report from

Andrew Tolfts, BioRegional Development Group, January 2006

This report is supported by:

One Planet Living

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The Three Planet Problem

BioRegional and our partners have been working to provide practical solutions and initiatives to make it easy for communities and individuals to reduce their ecological footprints in order to live sustainably within the carrying capacity of one planet. One of these initiatives, a joint venture with WWF, is One Planet Living (OPL). It aims to make sustainable living easy, attractive and affordable throughout the world.

One Planet Living: A world in which people everywhere can lead happy, healthy lives within their fair share of the Earth's resources.

The One Planet Living partnership between BioRegional and WWF aims to:

- Build a worldwide network of One Planet Living Communities to demonstrate One Planet Living in action
- Establish One Planet Living Centres in each OPL community as a focus for education and training
- Promote One Planet Living and its guiding principles to bring about change among governments, businesses and individuals.

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1	Zero Carbon	6	Sustainable Water
2	Zero Waste	7	Natural Habitats & Wildlife
3	Sustainable Transport	8	Culture & Heritage
4	Local & Sustainable Materials	9	Equity & Fair Trade
5	Local & Sustainable Food	10	Health & Happiness

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Executive summary

Z-squared is a 2,000 home development for 5,000 people proposed for the Thames Gateway. It aims for zero fossil energy consumption within its buildings and zero waste to landfill. A planned energy centre integrates power and heat supply and use from several renewable sources: wind, anaerobic digestion of putrescible waste, energy from residual waste through gasification or pyrolysis, and a biomass fuelled combined heat and power (CHP) plant.

The biomass CHP would have an annual requirement for up to 35,000 oven dry tones of wood chip, equivalent to approximately 64,000 tonnes of fresh wood chip. To minimise environmental cost this should be supplied from local sources within 40 miles, be made from waste wood, or come from woodlands and energy crops managed to enhance biodiversity as well as produce fuel.

Organisations considering installing wood chip systems for heating or CHP are very often concerned about the availability and security of the fuel supply.

A literature review supplemented by a questionnaire survey, interviews, site visits and practical trials form the basis of the report. The supply of wood chip from tree surgery arisings, woodlands and forests, energy crops, and waste timber were investigated. Existing and likely new markets for wood chip were considered in assessing the availability of wood chip for Z-squared.

Investigations for this report showed that the potential fuel supply from London and its immediate environs is large and will not constrain biomass use in the medium term. A minimum estimate of the fuel available annually from the different supply sectors, after allowing for present users, is given below:

Source of woodchip	moisture content %	fresh tonnes	equivalent weight (oven dry tonnes)
Tree surgery waste	45	50,000	27,500
Forestry	45	150,000	82,500
Sawmills	30	2,000	1,400
Waste wood in London	25	200,000	150,000
Energy crops	30	100,000	70,000
Total		**502,000**	**331,400**

Potentially available wood chip fuel in and around London

The result of the assessment is that there is sufficient wood chip available for Z-squared and other new users – at least 500,000 tonnes a year in and around London. It will be available locally at prices similar to current levels. An expansion of production capacity is required. Increasing fossil fuel prices will increase the competitiveness of biomass and allow wood chip prices to rise. This, together with more demanding targets for the diversion of biodegradable waste from landfill, will stimulate investment in wood chip production to supply a steadily growing biomass fuel market in London.

The biomass fuel market is expected to become the dominant use for recycled timber and tree surgery waste in the region, contributing to national waste management targets. As prices for biomass rise:

- new sources of wood chip such as woody residues from composting operations will develop
- planting of energy crops will increase
- more chip will be produced from woodland management benefiting woodland health, biodiversity, and rural economies.

Woodlands, including coppice woodlands in South East England might once again become a vital source of renewable energy for London as they were in pre-industrial times.

Contents

Glossary

AD	Anaerobic Digestion
C&D	Construction and Demolition
CA site	Civic Amenity (waste disposal) site
CCA	Copper-Chrome-Arsenate
CHP	Combined Heat and Power
DEFRA	Department for the Environment, Food and Rural Affairs
FC	Forestry Commission
IPPC	Integrated Pollution Prevention and Control regulations
kWh	Kilowatt hour
LTOA	London Tree Officers' Association
MAI	Mean Annual Increment of a woodland in cubic meters per hectare per year
mc	moisture content
MW_e	MegaWatts of electricity
MW_{th}	MegaWatts of thermal energy (heat)
odt	oven dry tonnes
p/kWh	pence per kilowatt hour
PAWS	Plantations on Ancient Woodland Sites
PTO	Power Take Off on a tractor
ROCs	Renewable Obligation Certificates
SH+P	Slough Heat and Power
SRC	Short Rotation Coppice
SRF	Short Rotation Forestry
TDB	Technical Development Branch of the Forestry Commission
tpa	tonnes per annum
WID	Waste Incineration Directive
WWF	Worldwide Fund for Nature

1 Background

If everyone on this planet were to consume natural resources and pollute the environment as we currently do in the UK, we would need three planets to support us[1]. Reducing our ecological footprint to one planet is crucial in terms of ensuring long term sustainability.

In June 2003, BioRegional, with WWF, published *One Planet Living in the Thames Gateway*[2]. The study focussed on the Thames Gateway region and investigated the implications of building 200,000 new homes to different environmental standards. It found, through ecological footprinting analysis, that UK residents could reduce their "three planet lifestyle" by approximately one planet through their lifestyle choices and living in a sustainable home. To save the second planet and live within our fair share of the earth's resources, we must also reduce the impact of our shared infrastructure and services.

In November 2004, BioRegional published *Enabling One Planet Living in the Thames Gateway*[3], a concept design report for the Z-squared project. This is an infrastructure-led design for a 5,000 person (2,000 home) mixed-use, and mixed tenure development which takes tried and tested technologies and integrates them to achieve zero carbon emissions from the energy required for heating, cooling and electricity and close to zero waste to landfill.

Renewable energy is essential to achieve zero carbon emissions over the planned life of Z-squared and an energy centre is planned to bring together heat and power generation from wind, gas from anaerobic digestion of organic wastes, a pilot scale energy from waste plant and a biomass fuelled combined heat and power (CHP) plant.

Taking into account the likely use of a conventional boiler or gasifier based CHP system this study's scope was restricted to wood chip and miscanthus (elephant grass). Other forms of biomass, such as poultry litter, animal waste and sewage sludge were thought unlikely to be a viable fuel for a CHP at Z-squared since they would require different combustion technology. The report assesses the different sources of wood chip fuel potentially available for the proposed CHP plant from London and the surrounding area. The probable development of the market for wood chip as fuel is considered. The basis of the report is a desk study of existing information supplemented by original research and interviews with companies and other organisations currently or potentially concerned with the wood chip supply chain.

A CHP plant of between 3.5MW_e and 4MW_e output is proposed for Z-squared, although the size of plant required depends on whether it is run to provide a base load for the site, meets the average consumption over the year or tracks demand and varies output continuously. Biomass CHP systems are normally most efficient when run at a steady load. A 4 MW_e CHP plant would require up to 35,000 oven dry tonnes (odt), equivalent to 64,000 tonnes of fresh cut wood at 45 percent moisture content (mc)[4]. Supplies of wood chip production from tree surgery, forestry, sawmill co-products, waste wood and dedicated energy crops were assessed.

1.1 Format of this report

The report opens with an assessment of the different sorts of chippers available for processing wood available for fuel. This is most relevant to clean, fresh sources of timber from tree surgery, and forestry.

Each potential source of wood chip fuel is considered in turn with an assessment of the resource, the amount produced, current uses and the quantity potentially available for use as wood chip fuel in London. Information was gathered by literature searches supplemented where necessary by survey and other original research.

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[1] WWF (2004) *Living Planet Report 2004*
[2] BioRegional Development Group (2003) *One Planet Living in the Thames Gateway – A WWF-UK One Million Sustainable Homes Campaign Report*
[3] Durney J and Desai P (2004) *Enabling One Planet Living in the Thames Gateway*, BioRegional Development Group
[4] BioEnergy Devices (2004) *A scoping study into biomass CHP for Z-squared.*

The potential sources of fuel considered are:

- tree surgery waste
- forestry work
- energy crops
- wood diverted from the waste stream, and
- sawmill co-products.

The chapters on sources of wood chip are followed by a consideration of the present and likely future markets for wood chip in the medium term, covering the period within which Z-squared is likely to be built. The additional infrastructure needed to increase the capacity for wood chip production from each source is considered. Finally, conclusions about the availability of sufficient fuel for Z-squared and likely proportions of fuel from different sources are presented together with more general conclusions about the total quantity of wood chip fuel available for use in London.

2 Equipment for wood chip production in London

This chapter reports on evaluations of wood chippers designed primarily to process fresh, green logs rather than pallets and other post-user waste timber. Processing capacity for waste timber is well established in and around London as a result of increasing use of recycled timber in chipboard and other wood panel factories. Wood recyclers employ different types of machinery to make chip from processors of green logs due to the frequent presence of nails and other contaminants in waste timber.

BioRegional started investigations and practical trials of wood chip fuel production with the decision to install a biomass fuelled combined heat and power plant at the BedZED ecovillage. This small unit has a rated output of $130kW_e$ and $200kW_{th}$ and requires around 1200 tonnes a year of wood chip at 30% moisture content in full operation. To supply this fuel BioRegional set up a production unit in cooperation with London Borough of Croydon and City Suburban Tree Surgeons, a leading London firm of arboricultural contractors. This uses waste from tree surgery waste, arboricultural arisings, as the feedstock.

Tree surgery waste is one of the most difficult woody materials to process into fuel chip as it includes material of many different species:

- with a wide range of sizes, some exceeding 1.2m in diameter
- generally having poor form, containing many twisted and forked logs
- frequently cut into short lengths and ‘rings’ where trees are dismantled in confined spaces and carried off-site by hand

In London, many boroughs have disposal points for arboricultural arisings with an average of under 3000 tonnes a year dropped off at each site. To increase wood chip fuel production 4 or 5 sites for processing arboricultural arisings are needed in and around London. Keeping transport distances for arboricultural arisings as short as possible minimises unproductive time for contractors and reduces transport emissions, particularly important in a crowded urban environment.

This poses a problem for wood chip production. Large equipment is needed for efficient, low cost processing of the larger log sizes. By its very size this equipment has high throughputs yet the volumes available at each site are relatively low. Mobile chippers that can be moved between sites allow best use of equipment. Therefore, static chipping systems have not been considered in this evaluation.

The Z-squared project includes a biomass CHP as part of the renewable energy portfolio. At 3.5 – 4.0 MW_e this is 30 times bigger than the BedZED CHP and, depending on how it is operated, will consume up to 35,000 oven dry tonnes a year of biomass. Arboricultural arisings will be a major component of the fuel mix and finding a chipper to efficiently process this material into high quality fuel is critical to developing this supply. If a chipper can make high quality chip from arboricultural arisings it will also cope with most other types of green timber.

Nine different chippers were evaluated in production for this report and further literature research done. Most chippers in the UK are used on site where the trees are felled to reduce the volume of branches and tops prior to disposal. These chippers are normally hand fed and can take only fairly small diameter timber. Larger, high output, mechanically-fed machines are becoming more common as biomass heating and co-firing increase. The evaluation concentrated on larger chippers whenever possible.

2.1 Wood chip for fuel

Chip specifications vary according to the equipment used to burn or gasify the wood chip. In general, larger systems tend to be more tolerant of lower specification material and engineering solutions too expensive for smaller boilers can be used to avoid some potential problems. For example, fuel feed systems can employ hydraulic rams rather than augers to overcome blockages caused by long slivers and oversize chip.

Common fuel related problems in biomass heating and CHP systems include:

- Blockages in fuel feeding systems caused by oversize chips or long slivers. Most of these are produced from the last section of logs which twist round on passing through the in-feed rollers of the chipper. Longer lengths of timber, ideally tree length, give less opportunity for this and generally produce a chip with few long slivers or oversize chunks. Tree surgery waste, with its preponderance of short lengths and rings, is the most difficult material to chip cleanly.
- Damage from contaminants can be significant and result in expensive maintenance for boiler operators at all scales. Stones can block augers in small boilers and high grit levels and nails from waste wood lead to excessive wear in some designs. Contamination is a problem in large equipment too:
  - At Slough Heat and Power (SH+P), a combined heat and power plant using around 180,000 tonnes a year of biomass, a major shutdown in 2004 was caused by contaminants. The fluidised bed sand is recovered and reused after combustion and contaminants caused excessive wear in the pipes of the sand recovery system. They also resulted in rapid build up of clinker on the heat exchangers. SH+P now regularly test incoming biomass for contaminants and reject poor quality loads.
  - The CHP at BedZED includes a grate on which the wood chip sits as it gasifies. Stones in the fuel will be retained here and disrupt the airflow through the system. High numbers of larger stones would require periodic shut down of the system for their removal.
- Stones and grit also result in excessive clinker and ash, requiring more frequent de-ashing and increased wear in automated systems.
- In downdraft gasifier CHP systems, such as at BedZED, bridging across the gasifier is a potential problem. Wood chips mesh together and block the gasifier preventing the chip falling onto the grate. The cause can be either long slivers of material or excessive proportions of fines under 5mm. This was seen on one occasion at BedZED when a load of chip that contained 15% fines proved to be unusable. Some boiler systems are designed to take a wide range of sizes of wood chip but may not be highly automated or efficient.
- High moisture content leads to low net heating value of the wood chip as shown in the graph below. In many boilers, particularly smaller ones, wood chip over 30% moisture content leads to poor efficiency and may make the 'slumber mode' inoperative, limiting effectiveness as an automated system.

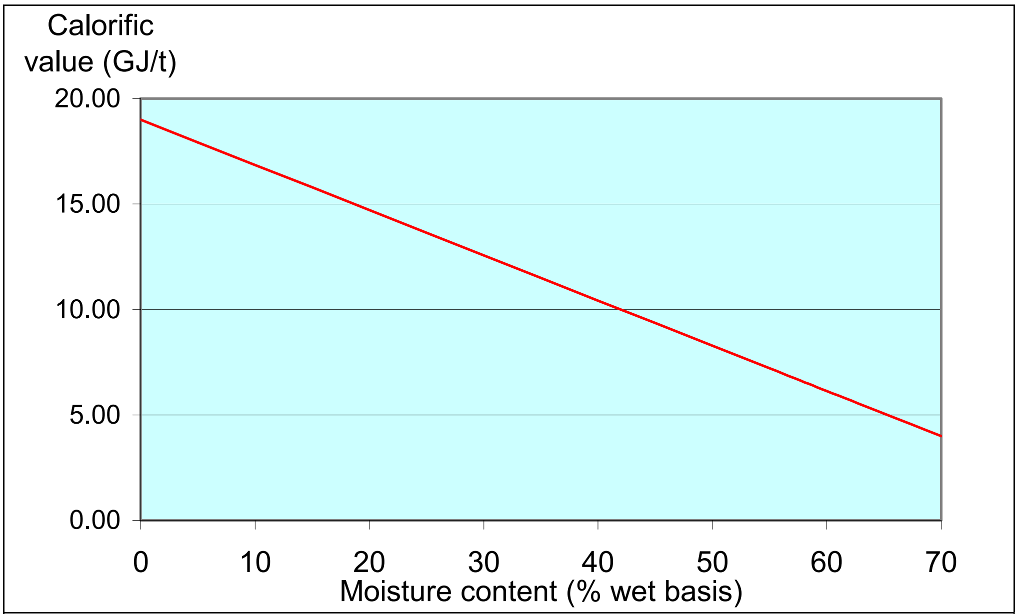


Figure 1. *Change in net calorific value of wood chip with moisture content*

2.1.1 High quality wood chip

For reliable operation, low running costs and to build confidence in specifiers of biomass systems a consistent supply of high quality wood chip is essential. Wood chip quality is determined by:

- The size assortment of the chips including slivers and fines matching the specification of the boiler or CHP system.

- Shape and 'chippiness'. Some boilers require free flowing material produced from a forestry chipper whereas others can use less cleanly cut material such as produced by a shredder fitted with cutting teeth.

- Moisture content in the range 15 – 30% is optimal for most boilers. Wood chip made from freshly cut material has a moisture content of 60%. In most Scandinavian countries payment is made on the net energy value of wood chip which takes account of moisture content. In this country large users such as SH+P have historically paid by the weight of wood chip delivered. This gives a perverse incentive to producers wanting to improve quality by making drier wood chip.

- Green content is an important determinant of quality. If green leaves are burned, emissions are alkaline due to chlorine in the chlorophyll. This is highly corrosive but is simply eliminated by storing the chip for 6-8 weeks until all green matter has turned brown. There is some loss of dry matter but also opportunity to dry the wood chip

- Contaminants, including ferrous & non-ferrous metals, paints, varnishes, chemical treatment, stones and grit are normally excluded in fuel specifications. Paints and varnishes may be allowed where residence time at the combustion temperature of over 850ºC exceeds 2 seconds. Few biomass boilers achieve this, almost all being designed to use clean wood. Ash from boilers using contaminated chip cannot be spread back in woodlands as fertilizer.

- Any species can be used for wood fuel but chip quality may change slightly with species. For example, some willows and Leyland cypress tend to produce elongated stringy 'chips' unless the chipper is properly set up with sharp blades. A well maintained and adjusted chipper will produce good quality chip from any species.

Sample specifications for a variety of equipment are shown in Table 1, giving an indication of the acceptable range of chip sizes and moisture contents. A biomass CHP at Z-squared would most likely have a size specification within this range and be able to accept wood chip up to 50% moisture content.

A lack of standards for the description of biomass fuels has been a barrier to development of the supply chain and some countries in Europe such as Austria have developed their own standards. In the UK British Biogen produced a classification for 3 grades of wood chip fuel, reproduced in Appendix 1. A European standard covering all forms of biomass reached final draft form in November 2003 (CEN/TC335/WG2). Extracts from this concerning wood fuel are included at Appendix 2. A Danish wood chip quality classification is included in Appendix 3.

Company	Equipment type	Chip size distribution			Slivers, max length	Green leaves	Moisture content	Contaminants
		Fines <5mm	Preferred chip sizes	Overs				
SH+P[5] (virgin chip)	Large fluidised bed boiler CHP	<5%	up to 100% 5-50mm In practice considerable flexibility is applied to this standard	max 50mm	not stated	none, must be withered	≤ 50%	No stones grit, metals or plastic, chemicals, rot decay or fire damage
SH+P (recycled wood)		<20%		max 50mm	not stated	n/a	≤ 20%	
Exus Energy[6]	gasifier for 130kWe CHP at BedZED	≤ 3%	6 – 11% 5-10mm 32 – 43% 10-20mm 39 – 45% 20-35mm	3% > 35m	150mm	none	≤ 50%	None, max 5% bark
Econergy Ltd[7]	boilers up to 100kW	≤ 20%	60-100% 5 – 16mm Austrian G30 grade	≤20% over 16mm	not stated	not stated	≤35%	none
Econergy Ltd	boilers over 150kW	≤20%	60-100% 5–35mm Austrian G50 grade	≤20% over 35mm	not stated	not stated	≤ 50%	none
Mercia Energy[8]	Heizomat boilers 100 – 850kW (standard auger)	≤ 15%	up to 100% 2–30mm	<10% 25-50mm	50mm max	none, must be withered	average 30%, max 35%	none
Mercia Energy	As above with heavy auger	≤ 15%	up to 100% 5–50mm		50mm max	none, must be withered	average 30% max 35%	none
Mercia Energy	Veto 30 – 250kW	≤15%	up to 100% 2-25mm	<10% 25-50mm	50mm max	none, must be withered	average 30% max 35%	none
Wood Energy Ltd.[9]	Binder and other boilers	not stated	maximum size 25-30mm in all dimensions			to be avoided	<25%	none

Table 1. Wood chip specifications for a variety of combustion equipment[10]

2.2 Types of chippers and shredders

There are three basic types of chipper used for fuel production in the UK as well as shredders fitted with teeth designed to cut rather than break the wood. In the draft European standard chippers are described as producing wood chips by cutting with sharp tools and shredders as making hog fuel by crushing with blunt tools. Hog fuel is not cleanly cut and does not 'flow' as easily as wood chip of similar size. Information given below about the types of chipper is summarised from reports prepared by the Forestry Commission's Technical Development Branch.

Disc chippers:

The most common type of chipper used in the UK. The chipper mechanism is based on a spinning disc, with blades usually set at right angles to the in-feed rollers. Fitted to the back of this flywheel are paddles whose function is to eject the cut material through a spout. Material is cut against an anvil plate fixed to the machine casing, which allows adjustment of the clearance between disc and casing.

The disc paddles may have serrated edges, as may the machine casing. These serrations, combined with a narrow clearance, act as 'sliver breakers' so that oversized chips may be further broken down.

5 Specification provided by TV Energy
6 Specification provided by Brian Williams of Exus Energy
7 Robert Rippengal provided information for equipment supplied by Econergy
8 Andy Russell, personal communication
9 Data from Wood Energy Ltd. website www.woodenergyltd.co.uk
10 Percentages are given by weight. Moisture content on wet basis

Experience shows that these devices are more or less effective, depending on the particular species being chipped and its freshness.

Chip size overall can be influenced by:

- in-feed roller speed. The faster the in-feed, the larger the average chips, while a slower in-feed may also produce a more consistently sized chip;
- the number of blades, fewer blades producing larger chips;
- the speed of disc rotation, above a minimum required to achieve sufficient air movement for chip outflow; and
- the angle of in-feed may be varied from the perpendicular to reduce machine stress and produce shorter chips.

Drum chippers:

In this type of mechanism, knives are mounted on a rotating drum. Blades are usually arranged along the length of the drum, but may be staggered rather than continuous. An anvil plate allows gap adjustment at the cutting edge, whilst the clearance between drum and casing normally increases behind this point to allow chip flow to the spout.

Chips are ejected by airflow generated either by a fan attached to the end of the drum, or by the blades themselves. Drum machines are often fitted with a screening system which prevents oversize chips being ejected, rather than sliver breakers. The size of chip produced is controlled by the apertures in the screen.

As with disc machines, chip size is influenced by in-feed speed, blade frequency and adjustment, and drum rotation speed. Additionally, timber diameter will affect the angle at which the cut is made, and so influence chip size and consistency. Most drum machines can take a mixture of forest residues and small, twiggy material, and round wood lengths.

Drum chippers often have slightly lower throughputs compared to disc chippers of a similar power, but produce a more consistent chip size as a result of the internal screen. If a screen with small mesh size is fitted the proportion of fines in the final product may rise due to larger chips being retained in the machine and re-cut. The in-feed aperture on drum chippers is often rectangular, much wider than it is high, in contrast to disc chippers which have an almost square in-feed. This makes drum chippers better suited for chipping the short ‘rings’ often produced from large logs in tree surgery operations.

Screw chippers:

In this type of chipper, not as common as the other two types in the UK, a conical screw spins in line with the in-feed, and the cutting edges of the screw are used to draw in offered material. As with the other designs, material is cut against an anvil plate, which may be adjusted.

Blade alignment is fixed, as the cutting edge is integral to the screw. The screw pitch chiefly influences chip size, although slowing the machine may cause more oversize chips to be produced. There is no other means of adjusting the chip specification.

The cutting edge is continuous, and the timber is ‘sliced’ rather than ‘chopped’ into chips. In comparison with other designs, screw units are quieter and commonly use less power. The cutting edges are also less prone to damage from feed contaminants than disc or drum blades. Screw chippers are designed to chip forest thinnings and longer logs and are not available in sizes large enough for some of the logs found in tree surgery waste.

Airflow for ejection of the chips is achieved by the use of a disc attached to the base of the screw cone, and sliver breakers may be mounted at this point.

Shredders

A wide range of shredders are available which use high or low speed drums equipped with teeth that tear and crush rather than cut feedstock. In-feed is by a powered conveyor. All can be used to reduce timber but give a ragged finish to the final product which causes it to tend to stick together rather than flow, leading to problems with fuel feeding in some equipment. Chip quality can be improved by changing the teeth to ones equipped with chisel edges and ensuring that feed speed and screen size are optimised.

Shredders are often equipped with magnets making them well suited to processing waste timber and pallets. They are in widespread use on waste recycling and composting sites.

2.2.1 Chippers used in the UK

Information on chippers available in the UK was taken from independent assessments of their performance carried out by the Forestry Commission's Technical Development Branch, interviews with equipment suppliers, and practical trials of machines using tree surgery waste as feedstock.

The vast majority of chippers used in the UK are hand fed and most are used for volume reduction of branches and small diameter timber at roadside by tree surgeons. Production of fuel grade chip is incidental. Small chippers are not suited to production of high volumes of chip since the maximum input diameter is too small and prolonged periods of hand feeding would not be acceptable on health and safety or job satisfaction grounds. The relative merits of the different types of chippers can however be assessed from hand fed chippers.

Forestry Commission trials

The Forestry Commission's Technical Development Branch (TDB) has evaluated chippers for small scale production on several occasions, assessing the productivity, factors influencing chip quality and cost of production.

In 2000 an assessment of 3 disc chippers was made to evaluate the effect of the moisture content of timber chipped on chip quality and whether sliver breakers were effective[11]. The models tested were a *Gandini 007 TPS*, a *Farmi CH 260* and a *Biber 5K*. The trial showed that:

- moisture content had no demonstrable effect on chip quality;
- increasing PTO speed reduced the average chip size in the Biber, concentrating chip in the 2-25mm class; and
- sliver breakers eliminated slivers but had little effect on oversized chips. They were ineffective when chipping oak branchwood instead of stemwood.

In 2004 a new set of assessments was done by TDB comparing the suitability of a selection of disc, drum and screw chippers for small scale fuel chip production.[12] A summary of the machine performance is given in Appendix 5.

Using several species of timber in pulpwood lengths the machines on trial produced varying quality of chips. The highest quality chip (suitable for use in small boilers and conforming to the European standard (CEN) grade P65) was produced by the Heizohack, Laimet, Farmi, TP and Greenmech machines. The Schliesing 550ZX and Jensen chippers produced a wider range chip sizes and the large size of some chip put it in the CEN P100 grade, suitable for larger boilers. The results of grading are given in Appendix 5.

Although all but one of the samples contain sufficiently few large slivers to meet the P65 classification, the number of fines produced might mean that the product would be unacceptable for use in domestic sized boilers.

The limited duration of the trial did not allow much time for fine tuning of machine settings to improve chip quality.

The TDB trials clearly show that all types of chippers can successfully be used to produce fuel grade chip from pulpwood length timber. The trial was limited by the capacity of the chippers. None except the Heizohack could take timber over 260mm diameter. The Heizohack had a 400mm maximum diameter. This small capacity would limit their usefulness as chippers for tree surgery waste timber. The limiting factor on productivity is likely to be the ability to feed the machine which requires considerable physical effort over an extended period.

[11] Vickers G, July 2000, Woodfuel chipping – Phase III trials, Forestry Commission, Rugely.
[12] Webster P, March 2005, Chipper Review 2004, Forestry Commission Internal Report.

Chipper assessments carried out by BioRegional

Nine different machines have been assessed using tree surgery waste as the feedstock over the past two years. The first trials allowed a clearer definition of the features required for chipping tree surgery waste. The key requirements are:

- ability to take large diameters and wide rings. Large logs can be split but this is a time consuming process which significantly increases production costs.
- good control of sliver production for high quality wood chip without screening.
- reduced demands for physical labour, both to improve working conditions and reduce costs. Mechanical loading is essential for high volume production.
- mobile equipment that can be taken from site to site as required.

The chippers assessed covered the 3 different types of chippers: drum, disc and cone screw as well as shredders configured to produce fuel grade hog chip. Wherever available high output models suitable for large scale production were chosen. These are essential for making fuel chip at the scale required for Z-squared or a well developed wood heat market in London.

Tree surgery waste was used as the feedstock for all machines, in contrast to the longer pulpwood used in Forestry Commission tests. The short logs and rings frequently resulted in a high proportion of slivers in the resulting chip. A summary of machine performance is given in Table 2 and observations for the machines tested are given in Appendix 6.

At the Croydon wood chipping site set up by BioRegional a second hand Rudnick and Enners drum chipper is performing well despite its age (see Table 2). Chip quality is good and productivity sufficient to cope with incoming material. With only a few thousand tonnes of material to chip each year at Croydon a second hand machine is a reasonable compromise between the need to chip large logs and the cost of high capacity chippers. The chipper may be used at several similar sites around London to increase utilisation levels.

2.3 Conclusions

The design of chippers is continually being refined and as demand for wood chip fuel increases, new makes of chipper are becoming available in this country. Matching a chipper with the feedstock available requires careful evaluation of machines available. Machines suitable for most situations are now available and a wide range of second hand equipment can be bought in Europe where the production of wood chip fuel has a longer history than in the UK.

There are now more high capacity, mechanically fed chippers operating in the UK than ever before. Investment is being made in these machines with the aid of capital grants as the market for wood chip grows. Co-firing of biomass at power stations is predicted to increase the demand for chip from forestry and arboriculture and will stimulate further investment in large chippers suitable for both forestry derived wood and tree surgery arisings. It is anticipated that chipper availability will keep pace with demand for wood chip.

Chipper type	chipping system	feeding system	input size	output rate	chip quality	fines <5mm	overs >35mm	slivers >150mm	comments/conclusions	cost
Bandit Beast 3680 recycler operated on contract to SITA and Croydon Council	shredder equipped with special chipping teeth integral screen and metal extraction magnet	front end loader, excavator & grab or similar onto conveyor	20-100 cm+	70-80t/day in Croydon yard	poor, long and fibrous	>15%	>20%	nothing over 100mm	produced for SH+P. Smaller screens would increase fines and decrease output	
Bandit Beast 3680 recycler operated by Material Change Ltd.	shredder fitted with special chipping teeth, integral screen and metal extraction magnet	front end loader, excavator & grab or similar onto conveyor	up to 1.3m diameter	100 t/day (estimate)	sample good with few fines or slivers	very few	very few	none in sample supplied	good quality in sample – impressive if representative – but machine not seen operating	
Bandit XP280 fitted with in-feed conveyor	disc chipper without screen or sliver breakers	in-feed conveyor can take material from front end loader or grab but blockage problems - mostly hand fed	450x450 mm	trials showed around 3t/day	v good from long timber lengths, poor from short logs	< 2%	not too many if large slivers excluded	excessive with short logs	could not cope with short logs from arboricultural waste, these led to frequent blockages and excessive production - up to 50%+ of v large slivers - more like kindling	
Heizohack HM 6-400	drum chipper with integral screen	hand fed	400 x 540 mm	8t in 3 hrs, say 20t/day, rated at 21t/hr but would need crane feeding	good	5-10%	<10%	nothing >110mm	Demo by Richard Slatem of Fuelwood could do the job but limited by manual feeding. Would it be faster with a crane? can get versions with 1400mm wide in-feed	
Heizohack HM 14-800 K	drum chipper with integral screen	crane fed, powered in-feed bed	800x1400 mm	rated at 25t/hr, Home Grown Timber get 100t/day					Viewed working at Home Grown Timber's yard. Good productivity and acceptable quality for most applications.	
Jenz HEM 700	drum chipper with integral screen	front end loader, excavator & grab or similar onto conveyor		200t/day						

Chipper type	chipping system	feeding system	input size	output rate	chip quality	fines <5mm	overs >35mm	slivers >150mm	comments/conclusions	cost
Erjo 7/65 RC chipper and hightip hopper mounted on forwarder	drum chipper with integral screen	crane fed, mounted on forwarder	650x470 mm	60t/day chipping arb arisings for BioRegional		not assessed			difficult to feed large volumes of short logs into the chipper as no powered in-feed table. better suited to longer lengths and whole tree chipping.	
Laimet HP 21	conical screw chipper	hand fed, larger versions crane fed	200 mm max							
Rudnick & Enners	drum chipper with integral screen	crane fed onto in-feed chute - no powered in-feed bed	550 x 1200 mm	still being commissioned when tested. 50t/day expected	very good, even with short logs and rings	5-10%	very few	none seen	Designed for fuel chip production. Now operating at Croydon yard with arboricultural arisings. Chip too small for BedZED CHP but a different screen will allow large chip to be produced.	

Table 2. Performance of chippers tested with tree surgery waste

3 Tree surgery waste

Tree surgery waste (also known as arboricultural arisings) has been recognised as an under-utilised resource in London for at least the past 10 years. In 1996 the London Tree Officers Association (LTOA) report *Timber Stations for London*[13], made an initial estimate that over 60,000 m^3 of woody material is produced annually, involving major disposal issues and representing a substantial potential resource. This was followed by a more detailed survey in 2000, reported in *The London BioEnergy Report*[14]. This increased the estimate to a minimum of 106,000 tonnes a year from tree work carried out by local authorities in the capital's streets and parks.

The 2000 survey was limited to contractors working for local authorities and although these companies also work in the private sector not all firms doing tree work in London were surveyed. Also, since 2000 a growth in the use of arboricultural arisings as fuel has been reported anecdotally, notably at SH+P. Increasing costs for disposal to landfill are expected to have increased the range of alternative disposal methods. The survey was therefore repeated for this report in cooperation with the LTOA to gain a more complete picture of the quantity of arisings produced annually and give insight into changing patterns of use and disposal.

The drivers for increasing positive use of tree surgery waste as fuel are intensifying:

- Increased fossil fuel prices make biomass a more attractive fuel with cost per kWh now below mains gas
- The London Mayor's policy of requiring 10% on-site renewable energy generation in larger developments has stimulated interest in biomass as the most cost effective way of meeting this target.
- Improved availability of efficient boilers and more professional service levels from installing companies.
- Breakthrough technologies in small scale biomass CHP systems will lead to increased demand.
- Increasing levels of landfill tax, now at £15/tonne but set to rise to £35/tonne in the medium term.

Inclusion of pallets in the ambit of the packaging recycling notes (PRN) system makes an additional, complementary source of wood chip increasingly available.

3.1 Objectives of the present survey

The specific objectives of the project are:

i. To assess the volumes of material generated by arboricultural operations on an annual basis within London.

ii. To estimate the current financial costs of disposal to contractors.

iii. To discuss methods for processing the material into a uniform biomass fuel suitable for use at a Z-squared development.

iv. To identify current uses of arboricultural arisings and the amount potentially available for large scale new developments such as Z-squared.

3.2 Methods

The London Tree Officers Association's full membership is made up of all the Tree Officers working for the 33 London Boroughs. The LTOA also has associate members comprising of consultants, contractors, nurseries, suppliers, other local authorities, individuals etc. The LTOA is in a key role as a point of contact

[13] LTOA (1996) *Timber Stations for London.* Report for the London Tree Officers Association.
[14] Bright I (2001) *The London Bioenergy Report* Econergy Ltd for the London Tree Officers Association.

for most larger tree contractors as LTOA members direct a large part of all tree work in London. The membership recognises the problem of tree waste disposal and assisted by providing details of contractors operating in their areas.

In the 2000 survey no attempt was made to extend coverage to contractors working exclusively for private clients, who were assumed to be smaller. For this survey additional arboricultural firms were identified through the Yellow Pages and included in the survey.

To determine volumes of woody material generated in London from arboricultural arisings, a questionnaire (Appendix 7) was prepared for circulation to 161 tree surgery contractors identified as working in the London area.

Disposal of arisings is the responsibility of the contractor in almost all cases and is a cost item for contractors. Most material is chipped on site to reduce the bulk of the load and number of disposal journeys. While a number of strategies are adopted to reduce costs, in most cases contractors do not record volumes of material disposed.

Contractors are well aware of the number of vehicle journeys made to dispose of the material during a working week and so the questionnaire was formulated to allow contractors to express volumes of material in terms of vehicle movements and size. Contractors were also asked to provide information on tipping charges where these were incurred and to provide their own estimates of volumes disposed.

A map of London was provided with the questionnaire, on which contractors were asked to mark the location of their yard, the main area of work and where arisings are tipped. Comments were invited on use made of the arisings and methods of disposal.

The work carried out by the contractors who received questionnaires is predominantly from Local Authority contracts but also includes private work in gardens. No attempt was made to distinguish tree surgery contractors in London engaged entirely on private work. There are undoubtedly landscape companies and other contractors engaged in tree work who were not covered by the survey so the results should be regarded as a conservative estimate of the material potentially available.

The questionnaire contains an assurance of confidentiality. Contractors have been assigned an identification number to permit cross-referencing of information between the tables.

3.3 Results

3.3.1 Volumes of woody arisings generated by arboricultural operations.

36 of the 167 contractors who received a questionnaire responded. One of these was based in Bury St Edmunds, out of the Z-squared catchment area but working in London, making it a sample of 21% of the 166 tree surgery contractors. The number of contractors contacted was an increase of 32, or 24% on the previous survey taken 5 years ago. This reflects the attempt to widen the scope of the survey to include contractors not working for Local Authorities. The reply rate was lower, percentage wise and in real terms than the previous survey. Not all of those who responded chose to answer all sections of the questionnaire. Contractors were asked to provide their own estimates of material disposed of and to provide information on movements of vehicles disposing of arisings.

3.3.2 Contractors estimates of disposal volumes

Contractors were invited to estimate the total volumes of arisings from tree surgery operations on a volume or weight basis. Where the reply is expressed in cubic meters this has been converted to tonnes by applying a conversion factor used in the *London BioEnergy Report* obtained from Gristwood & Toms, who regularly sell chipped arboricultural arisings by weight. Their estimate of the average weight of chipped arboricultural arisings on a full lorry with 50m^3 load capacity is 17.5 tonnes giving a conversion factor of 2.86 m^3/tonne. This figure has also been applied to contractor estimates of log volumes since it is assumed that these refer to stacked volumes, not volumes of measured timber. The average density of freshly harvested measured logs of all species (FC Mensuration Tables) is slightly less than 1 tonne/m^3, but much of the volume in a measured stack consists of air spaces. Using the range of values from Forestry Commission tables for stacked timber, the conversion factor of 2.86 provides a reasonably conservative estimate of weights obtained from the volume of a stack of timber bearing in mind that logs in the back of a truck are loose piled.

A summary of contractors' estimates of disposal costs and volumes is shown in Table 3 and the full table of results is in Appendix 8.

	Quantity disposed of		average price
Cost of disposal	**cubic meters**	**tonnes**	**per tonne (£)**
Free	30,525	10,673	-
under £15/t	17,320	6,056	6.2
£15 – 24.99/t	46,71	1,738	18.91
£25 – 39.99/t	32,29	1,129	28.33
£40 or more/t	97,54	3,411	48.88
Overall	65,799	23,007	11.70

Table 3: Summary of disposal costs

The 30 contractors who provided estimates of total annual volumes or weights disposed of an average 767 tonnes of arboricultural arisings per year with individual values ranging from 30 to 4,028 tonnes. Applying the average figure to all 166 contractors contacted in London produces a total of 127,322 tonnes of arboricultural arisings per annum based on contractors' estimates.

Both the average estimated annual volume and the range of individual values are consistent with the previous survey, providing a certain confidence in their accuracy. The London-wide estimate of arisings based on these figures can be seen to have increased by 20%, due to the increase in number of contractors included.

However, the accuracy of the contractors' own estimates cannot be easily verified. Some figures, based on weighbridge bills, will be extremely accurate; others may have been derived from "back of an envelope" calculations. Inconsistencies within the survey forms returned by some contractors make it clear that data quality is not very good. Confidence limits for the total figure are likely to be high given the high deviation of individual values around the mean figure. Although contractors were requested to provide information on material generated by operations in London it cannot be guaranteed that some have not included material generated from operations outside London in their estimates.

3.3.3 Estimates of disposal volumes from vehicle movements

For operational purposes, most tree contractors do not need to know the volumes of arisings disposed of and therefore are not likely to make the calculation. Contractors were asked to describe vehicle movements to the point of disposal to provide a check on contractors own volume estimates. The questionnaire was designed for simplicity to increase the number of replies. 32 contractors provided information on vehicle movements compared to 30 who provided their own estimates of volumes disposed. The information from replies to this section of the questionnaire are shown in Appendix 9.

Given the variety of vehicles engaged in disposal of arisings, an exact calculation of load volumes would involve measurement of the load for each model of vehicle engaged in this work. Individual load measurements were taken of a number of vehicles in the Transit pickup size range and a 7.5 tonne Ford Cargo belonging to one of the contractors in the survey. An average load volume of 4m^3 was applied to all van sized vehicles, excepting Land Rovers where a figure of 1.5m^3 was used. All contractors who use lorries and who responded to the survey gave the tonnages for their vehicles, and this was applied pro rata to the load volume of 10 m^3 per 7.5 tonne Ford Cargo (3.7 x 2.2 x 1.25m). For example, a 5 tonne lorry is calculated to carry a load of 5 / 7.5 x 10 m^3 = 6.6 m^3.

These estimates can be compared with further data from two contractors who responded to the 2005 survey and estimated load weights on a number of their vehicles. The contractor's estimates are shown below alongside the volumes estimated using the above pro rata rate:

	Contractor estimate (m^3)	Pro rata estimate	Contractor under-estimate
Cabstar 3.5 tonne	3	4.67	36%
Movano 3.5 tonne	4	4.67	14%
Isuzu 3.5 tonne	4	4.67	14%
Isuzu 6.5 tonne	7	9.33	25%
Transit 35 cwt	2.86 m^3 (1 tonne)	4	29%
Cargo 7.5 tonne	4.29 m^3 (1.5 tonnes)	10	57%
17.5 tonne truck and crane	8.58 m^3 (3 tonnes)	23	63%

Table 4: Comparison of contractors' estimated and inferred loading of vehicles

These are estimates by contractors, and do not constitute accurate weighings, but it can be seen that applying the pro rata scale to these vehicle sizes may over-estimate the load volumes. For the first contractor, a comparison of 1 load per vehicle gave an overestimate of 30% and the second contractor of 135%. It is recommended to undertake further load weighings of a range of vehicles to increase accuracy of this estimation method. Combined with volume measurements this will also allow checking of the conversion factor supplied by Gristwood and Toms.

Calculating the tonnages of arboricultural arisings using contractors' statements of vehicle movements produces an average per contractor, based on a 48 week year, of 1468 tonnes per year, slightly less than in the last survey reflecting the inclusion of smaller contractors working exclusively in private gardens. This yields a total tonnage for the 166 contractors in London of 243,688 tonnes, compared with the figure of 127,322 tonnes derived from contractors' estimates.

Comparing total tonnages for individual contractors obtained from their estimates against those from vehicle movements reveals some wide discrepancies. As demonstrated by the two contractors' load estimates detailed above which suggested overestimation of between 30 and 135% of the pro rata rate, the values for volume per load should be checked against a wider range of contractors vehicles to gain greater accuracy. Estimates of volumes from contractors' vehicle movements assumes that all vehicles are fully loaded when tipped, and this is clearly not always the case. The questionnaire was designed for ease of completion to ensure as high a return as possible. More work needs to be done to verify the tonnages calculated from vehicle movements.

For the purposes of this report the lower figure from contractor's estimates of 127,322 tonnes is assumed to be closest to the true value.

3.3.4 Disposal methods

Contractors adopt a variety of strategies to dispose of arboricultural arisings. The range of methods employed is summarised below and the full results are given in Appendix 10:

Disposal methods employed for wood chips by the contractors surveyed include tipping for free to farmers, supply to equine centres or paddocks, mulch for landscape contractors, allotments, nature gardens as well as encouraging customers to keep material for use on their own gardens. 21 of the 36 contractors mention supplying mulch for use in gardens or for landscaping and 8 mention supply to equine centres, paddocks or zoos. A new development since the previous questionnaire is that 9 contractors now also mention supply to Slough or other Combined Heat and Power plants. Two contractors mentioned delivery to local authority or commercial green waste composting centres. As in the previous survey, only a few of the larger scale contractors with their own yards process the material further by screening or composting, and none process the material to produce a high grade horticultural product suitable for the retail market. However, 15 contractors mention generating some income through sale of mulch or logs.

Logs may be tipped free or sold to firewood merchants. This appears to be a limited market and there are difficulties in disposing of coniferous logs in this manner. Many pay for log disposal. A number mention splitting for firewood for personal or local use and a minority of contractors occasionally burn their arisings.

End use	Number of contractors
Mulch in domestic or commercial use	21
Firewood logs	16
Equestrian surfacing, footpaths etc.	9
Wood chip for energy at Slough and elsewhere	9
Composting	8
Landfill/waste disposal	3
Burning	2
Left with customers	2
Play surfacing	2
London Zoo	2

Table 5: End uses for arboricultural arisings

Contractors are generally resourceful in disposing of their tree waste. A number of contractors own or rent land to stockpile their waste for subsequent disposal. Some pay for disposal at commercial waste reception sites, which will go to landfill or to be composted. In general the larger contractors are, through necessity, more organised about disposal of arisings and a high proportion of smaller companies dispose to tip.

The majority of contractors have several disposal options, utilising the most cost effective method depending on type of material, vehicle miles entailed, cost of tipping charges etc. From the contractors' comments, there is a high level of support for the option of disposal to a biomass fuel processing facility (17 contractors expressed a direct interest), though there are reservations about paying to tip.

3.3.5 Disposal costs

Table 3 summarises the disposal costs of the contractors.

34 contractors responded to the question "Do you currently pay for waste disposal?". 15 said yes, 4 pay charges on some of their material and 15 pay no charges. This distribution was very similar to that of the previous survey. Of the 15 who do not pay for disposal, 7 were strongly in favour of the option of disposal to a local fuel processing facility.

The answers to the question "Cost per tonne to dispose" are reported in Appendix 8. It is assumed that costs per tonne include VAT, figures have been adjusted to include VAT where otherwise stated by contractors. 15 of the contractors surveyed pay a weighted average price of £26.64 per tonne to dispose of material to tip. This is slightly less than the average charge in the last survey (£28.35/t) and the lack of increase is surprising in light of increasing landfill charges. The range of disposal charges is greater in the present survey with several contractors reporting a cost of £60/tonne or more, with the highest cost

£175/t compared to a maximum of £40/tonne in the previous survey. This suggests that increased landfill costs are being reflected in some disposal charges, but this is balanced by the emergence of Slough Heat and Power as an end user which helps to keep disposal charges in check for others.

As the market for wood chip as fuel develops London-wide and the price increases in line with gas prices it will be possible to invest in processing facilities to raise chip quality to make a fuel suitable for smaller boilers whilst reducing the gate fee charged to contractors. The possibility of a free tip for arboricultural arisings in London at a commercial fuel production depot is a real, though still distant possibility.

Of those who do not pay tipping charges on a tonnage basis, a number rent land where material is held for subsequent disposal. Of those who say that they do not pay for disposal and where the contractor owns land, there are still costs involved. Storage of material ties up land that might be used for other purposes and there are materials handling costs in loading vehicles for onward disposal. Since disposal is not a core business activity it is unlikely that contractors using land rented or owned will have calculated the true costs of disposal.

A major consideration in disposal costs is distance travelled. No information was sought in this study on transport costs but, anecdotally, a 3 man tree surgery gang with Transit and equipment will cost around £90/hr. Tipping charges, at a typical cost of £25 per tonne for a fully loaded Transit carrying $6m^3$ (2 tonnes), will be £50. Reducing travelling distances and times therefore plays a large part in deciding disposal options and this is reflected in the contractors' comments.

Generally contractors welcome the concept of free disposal of arisings to a fuel processing facility close to the area of operations. It may be possible to charge a gate fee for material disposal to such a site but this would have a negative impact on volumes received.

3.3.6 Trends and changes since 2000 survey

As expected, the quantity of arboricultural arisings is in line with that found in the previous survey. The 20% increase in available quantity identified by the survey reflects inclusion of companies not working for local authorities rather than a real increase in the amount tree waste in London.

Disposal of tree waste continues to test the ingenuity of contractors. Many have developed several alternative markets for chip and logs but a significant number still report disposal problems. There is an increase in the maximum gate fee reported by contractors from £40/tonne to £60/tonne (and in one case £175/tonne) demonstrating that disposal through traditional routes to landfill is becoming more costly. This is balanced by a number of contractors reporting a lower cost of disposal and some of the larger ones making alternative arrangements for sale of the chip as fuel to Slough Heat and Power.

Many arboricultural contractors have their base of operations outside London and often take arisings back to base at the end of the working day. This takes time and limits the amount of debris that can be removed in a day. Compared to local disposal it increases CO_2 emissions. As disposal of arisings is not a core part of their business and is a cost rather than a revenue stream, a series of conveniently located drop off points for logs and chip around London would be attractive for many contractors.

3.3.7 Future trends

The market for arboricultural chip as fuel has developed significantly over the past 5 years with the emergence of Slough Heat and Power as a major customer. Over the next few years a broader market is expected to develop as other installations are made including the biomass CHP system for Bracknell town centre and numerous smaller biomass heat systems across London, each of which will, on average, use several hundred tonnes of chip a year. The drivers for this are:

- the policy changes to promote renewable energy in the capital through the 10% on-site renewables requirement for larger new developments; and

- the increasing cost of fossil fuel. With wood chip at 1.2p/kWh compared to gas prices approaching 2p/kWh the lifetime costs for a biomass heating system are now often below mains gas.

The price of natural gas is predicted to continue rising in the longer term. Demand for fossil fuels has risen rapidly with economic growth in China and India while new discoveries of oil and gas are not keeping pace with extraction rates.

If arboricultural arisings are to be used in smaller heating systems investment will have to be made to improve its quality as fuel. Chip will have to be screened to remove oversize chip and fines and will need to be dried to under 30% moisture content. Economies of scale to justify investment in facilities to achieve this is easier to achieve at site where chip from smaller contractors can be aggregated. Drier, screened chip will also be more valuable as fuel at Z-squared.

3.3.8 Estimated volumes available for Z-squared

Although at least 127,000 green tonnes a year of arboricultural arisings are produced annually in London, not all of this will be available for Z-squared. Existing markets other than fuel will continue, particularly those where disposal at no cost to the contractor can be achieved. Examples include footpath and equestrian gallop surfacing, and horticultural mulch. As the price of fossil fuels rises, the gate fee charged for disposal to the fuel market can be reduced and more of the material diverted to fuel use.

Existing fuel users will continue to play a big role in the market and new users will emerge in the medium term, so caution is necessary in estimating the material available to Z-squared. Collection of detailed information about the quantities for different end uses was beyond the scope of the present survey, and the estimates below are based on uses indicated by respondents

	Green tonnes	Balance - green tonnes
Estimated total available	127,000	127,000
Slough Heat and Power	30,000	97,000
Existing alternative markets	50,000	47,000
New biomass fuel users	11,000	36,000
Potentially available for Z-squared		**36,000**

Table 6.: Estimated fuel availability for Z-squared

It will be impractical to collect the entire 36,000 green tonnes that are theoretically available for Z-squared. 20,000 green tonnes (10,000 odt) a year of tree surgery waste is estimated as the contribution to the annual fuel requirement for Z-squared from arboricultural arisings in London. Significant investment in the fuel supply infrastructure will be required. This will only occur if the wider biomass fuel market develops. Therefore, with a large untapped potential source of fuel, Z-squared and other biomass developments are complementary rather than competitive.

3.3.9 Cost of wood chip from tree surgery waste

In the past disposal of wood chip and logs has been a cost to the tree surgery contactors and this continues to be the case as wood chip fuel increases in popularity. The price is set by the cost of competing fuels, principally mains natural gas in London and alternative sources of wood chip. The income to wood chip producers has two elements: the gate fee and price received for the chip. The gate fee is still essential to the viability of fuel chip production from tree surgery waste in London.

Cost of production is influenced by:

- scale of operation, larger sites with larger equipment tend to be cheaper to run as labour intensity is reduced;
- integration with other work in, say, a tree surgery company; and

- the quality of chip produced.

An undemanding specification, such as for SH+P commands a lower price, typically £20-25/tonne for chip at 45% mc, equivalent to £36-45/odt. A higher quality chip suitable for use in smaller boilers, screened and dried to under 30%mc will attract a higher price around £35-40/tonne, equivalent to £50-57/odt. Z-squared will have to pay similar prices according to the quality and moisture content of the chip received in order to compete with smaller heat only installations.

3.4 Further work required

To refine the estimate of the amount of tree surgery waste available in London and prepare for the development of a fuel supply chain additional work is required, including:

- verification of the quantity available by measurement of weight and volume of chip and logs on a range of truck sizes;
- investigation and testing of cost effective ways of chip drying;
- identification of locations for strategically placed potential aggregation yards for chip and logs around London;
- evaluate the practical experience of contractors already supplying fuel chip through in depth interviews and site visits;
- continued monitoring of new biomass heating and CHP schemes in and around London and their impact on fuel availability for Z-squared.

4 Forestry

For more than ten years the price woodland owners receive for their timber has been declining. Owners of large plantations of conifers in upland areas of northern and western Britain have increased mechanisation and maintained a positive cash flow even at depressed price levels. In SE England a fragmented woodland resource with many different owners makes it impossible to achieve the same economies of scale. In addition, markets for the region's predominantly hardwood timber have reduced with the closure of a pulp mill in Kent and a continuing slow decline in the number and capacity of hardwood sawmills.

At the same time Government policy has shifted its focus from the historical emphasis on timber production which had been in place since the foundation of the Forestry Commission in 1919. The new priorities are wider public benefits such as visual amenity, biodiversity conservation and access to woodlands for recreation. Changes to the grant support system now being introduced in the England Woodland Grants Scheme reflect the shift in policy.

The use of timber from woodlands in modern wood heating systems is seen by many woodland owners and foresters as one of the few new markets for the small timber from sized thinning which can grow and at least in part replace markets lost in the last 20 years. Reinvigorated thinning and coppicing programmes will bring many of the public benefits sought by the Government without the need for grant aid.

4.1 Woodland in South East England

County	Forest type:						Total ha	Woodland cover as % of total land area
	Conifer	Broad - leaved	Mixed	Coppice	Coppice –w-stds	Un-productive		
Kent	3,236	19,321	4,732	5,997	3,411	2,791	**39,488**	10.6
Surrey	5,677	19,962	8,315	218	699	2,693	**37,564**	22.4
Essex	1,245	15,574	1,523	88	441	583	**19,454**	5.3
Hertfordshire	2,094	11,126	1,454	12	148	669	**15,503**	9.5
London	15	5,061	232	53	140	406	**5,907**	3.9
Total	12,267	71,044	16,256	6,368	4,839	7,142	117,916	9.6

Table 7. Forest types and area in London and surrounding counties[15]

The South East is well wooded with 14.1% of the land area covered by trees. With 22.4% tree cover Surrey is the most densely wooded county in England[16]. There is a wealth of broadleaved woodland, much of which was traditionally managed as coppice or coppice with standards. There are also significant areas of conifers, mostly Scots pine which naturalised on former heathland. A summary of woodland types in London and surrounding counties is given in Table 7.

A high proportion of the broadleaved woods are ancient semi-natural woodland with high biodiversity values and other areas carry plantations on ancient woodland sites (see Table 8.). Where the latter occur on Forestry Commission land there is a policy of restoration to the appropriate mix of native species over the next 20 years.

Many coppice areas are now neglected or converted to high forest . The former rich biodiversity has declined as the woods grew dense with scant ground vegetation and a sparse shrub layer. Their value for wildlife diminished with marked declines in the species dependent on woodland herbs and shrubs.

TP[15]PT Forestry Commission, 2002, National Inventory of Woodland and Trees, East of England and South East England Regional Reports, Forestry Commission

[16] 2002, National Inventory of Woodland and Trees – South East Region, Forestry Commission, Edinburgh

For example, dormice, nightingales, and butterflies such as the pearl bordered fritillary and wood white are key species whose range and abundance have reduced considerably over the last few decades.

County	Ancient semi-natural woodland	Plantations on ancient woodland sites	Total ancient woodland (ASNW + PAWS)	Ancient woodland as % of total land area
Kent	18,780	8,280	27,060	7.2
Surrey	6,640	2,640	9,280	5.5
Essex	6,900	1,400	8,300	2.3
Hertfordshire	3,085	2,015	5,100	3.1
London	2,030	190	2,220	1.4
Total	**37,435**	**14,525**	**51,960**	**4.2**

Table 8. Ancient woodland in London and surrounding counties.[17]

A new large scale commercial use for low quality hardwoods and traditional coppice produce will enable reinstatement of management in these woodlands. They have been shown to respond well to renewed management even after 50 years of neglect with rapid regrowth of native species. Having an economic use for the timber produced enables long term management with minimum grant support.

Areas where plantations occupy ancient woodland sites (PAWS areas) also respond well to removal of conifers and other planted species. The Forestry Commission and Woodland Trust have a programme for restoration of PAWS sites to native woodland over the next 20 years. The timber produced as a result of this will be suitable as wood fuel.

4.2 Wood fuel production from woodlands

All the conventional forest products, both sawlogs and small roundwood, can be used for fuel production. Not all will be available since better returns are available in other markets. Wood fuel may allow harvesting of material previously left in the woodland. The main classes of forest produce which will contribute to wood fuel production are:

Brash: The tops and side branches from harvested trees and any other material that is normally left behind on the woodland on harvesting. Not all will be available as fuel as some is used as ‘brash mats’ for machines to travel over in the woods. Specialist brash baling machinery has been developed in Scandinavia. but in the UK brash collection is uneconomic so far. The South East does not have the large areas of conifer woodland needed for these machines. They will most likely be operated first in upland areas.

Pre-commercial thinnings: These are whole trees taken out to improve the crop that are too small for existing uses. It may be economic to extract and chip them for fuel.

Poor quality crops and scrub: There are significant areas, particularly of broadleaves, where quality is so poor that they cannot be sold on existing markets. Use for wood chip fuel offers the prospect of clearing these areas and replanting them to create a more valuable crop or converting them to alternative uses.

Small roundwood: Significant amounts of hardwood small roundwood are sent from the region to the St Regis pulpmill in South Wales. This demand is expected to continue at around the current levels [18]. Coniferous small roundwood is also produced in the region and is slightly cheaper than hardwood small roundwood as markets are more distant.

TP[17]PT Pryor S.N. and Smith S., 2002 The area & composition of plantations on ancient woodland sites. The Woodland Trust.
TP[18] Mike Henderson, timber purchaser, St Regis pulpmill, personal communication

Potential wood fuel resources countrywide were assessed in a major project by the Forestry Commission in 2003[19]. The estimates for forestry derived material used the national forest inventory of 2001 as a data source. All forms of ownership for woodlands 2ha and over are included and the potential output of all forestry products including tips and branches not normally harvested are included in the estimates. Adjustment is made for areas that should be excluded on environmental grounds such as steep slopes but no account is taken of economic feasibility. This is excluded since changing market conditions, financial support and harvesting technologies alter where economic harvesting can take place.

The estimates from the Woodfuel Resource Study therefore represent a maximum potential availability. Tailored predictions for new projects are available from the Forestry Commission and these were obtained centred on a point at Dagenham within the Thames Gateway. Estimates for a radius of 25 and 40 miles were obtained to represent the ideal local supply and distance within which 2 delivery trips a day could be made respectively – see Figure 2.

For the estimate of available forestry timber for Z-squared only the small round wood from 7-14 cm diameter and poor quality stems were included. Larger stems were excluded since they are more valuable as sawlogs and brash left out as it is unlikely to be viable to collect it. Although some small roundwood has other uses this is compensated by a proportion of larger stems being available for fuel production. Tables 9 and 10 summarise the timber potentially available.

Year		Stemwood		Poor stems	All brash	Total	7-14 and poor stems
from	to	7-14	14+				
2006	2006	*3,800*	10,025	24	3,255	17,105	3,824
2007	2011	3,168	10,426	24	3,010	16,628	3,193
2012	2016	2,661	10,725	25	2,734	16,144	2,685
2017	2021	2,027	9,810	24	2,340	14,201	2,051

Table 9. Potential fuel wood available within 25 miles of Z-squared in oven dry tonnes[20]

Year		Stemwood		Poor stems	All brash	Total	7-14 and poor stems
from	to	7-14	14+				
2006	2006	18,119	51,107	747	14,554	84,527	18,866
2007	2011	15,600	55,154	725	14,019	85,498	*16,325*
2012	2016	13,374	56,225	679	12,959	83,237	14,054
2017	2021	11,207	53,190	539	11,876	76,812	11,745

Table 10. Potential fuel wood available within 40 miles of Z-squared in oven dry tonnes[21]

The amounts in the tables above indicated as available for wood fuel as roughly 2,500 odt a year within 25 miles and 15,000 odt a year within 40 miles, equivalent to 5,000 and 30,000 green tonnes a year. These figures need adjustment to take account of existing users and other factors which reduce the area that will be made available for fuel chip production.

The catchment area for Z-squared is a relatively small part of the South East region which has a total annual growth of timber of over 1 million cubic meters or 500,000 odt. The main competition for hardwood small roundwood comes from the St Regis pulp mill in South Wales and the local firewood log market. St Regis expect to maintain their current level of intake in the medium term [22]. This is drawn from across the region and is not expected to significantly affect availability for Z-squared. Sporadic local shortages of logs for firewood in the London area have been reported (Simon Levy, personal

TP[19]PT MacKay H, Hudson JB, Hudson RJ (2003) *Woodfuel Resource in Britain* prepared by the Forestry Contracting Association and Forestry Commission for the Department of Trade and Industry. See HTUwww.woodfuelresource.org.ukTUH

[20] Source: Forestry Commission, tailored estimated based on data from Woodfuel Resource Study, 2003

[21] Source: Forestry Commission, tailored estimated based on data from Woodfuel Resource Study, 2003

[22] Mike Henderson, Head of timber buying, St Regis Pulp Mill, personal communication

communication), reflecting the increasing popularity of wood burning stoves. This may give a degree of localised competition for small diameter hardwood. No overall estimates are available of the amount of firewood logs sold in the London area and a significant amount is made from arboricultural arisings rather than thinnings and fellings in woodland. The overall impact will be modest, probably taking under 2,000 odt a year from woodland within 40 miles of London

Figure 2. *25 mile and 40 mile catchment areas for Z-squared*

The main uses for softwood small roundwood are in the pulp and panel board production. The mills that produce these are located near the main source of supply in the west and north of the country. The South East is the least favoured source of supply with consequently low prices paid. The emergence of a new market for fuel can be expected to stimulate renewed thinning activity and improved management, provided the price paid covers the cost of the thinning operation. Many of the PAWS sites were planted with conifers. As these are removed over the next 20 years additional timber will come onto the market.

Woodlands in SE England tend to be small. Some were planted and managed as much for game bird cover as for timber production. 31% of the total woodland area is in woods under 20ha; almost half in woods under 50ha (see Table 11). Almost a quarter of the woodlands receive no or very little management[23]. There are several reasons for this:

- Many are bought by individuals for amenity and lifestyle reasons and the owners often have only a limited knowledge of woodland management.
- Small woodlands are often difficult of access and expensive to harvest due to the small scale with relatively high overheads.
- Skilled labour to do felling and extraction work in the woods is becoming increasingly scarce and is now a real constraint on expanding production. Mechanical harvesting of coppice has been successfully introduced by the Forestry Commission but will only be economic in larger woodlands and may not be appropriate in ancient woodlands with high biodiversity values.

[23] English Rural Development Programme website. www.defra.gov.uk/erdp/docs/sechapter/default.htm

- Timber prices are too low for economic harvesting and sale into existing markets, particularly for small woodlands. Many owners 'shut the gate' to the woodlands to limit losses.

County		Ha per woodland:							total woodland area (ha)
		<10	10-<20	20-<50	50-<100	<100	100-500	>500	
Kent	%	17	11	17	14	60	26	14	37,855
	ha	6,480	4,357	6,605	5,306	22,748	10,027	5,080	
Surrey	%	12	7	10	6	35	28	36	37,397
	ha	4,617	2,574	4,035	2,414	13,640	10,245	13,512	
Essex	%	32	17	19	9	77	17	6	15,451
	ha	4,983	2,571	2,943	1,383	11,879	2,598	973	
Herts.	%	28	14	19	10	71	15	14	12,835
	ha	3,616	1,865	2,374	1,307	9,163	1,927	1,746	
London	%	30	16	24	16	86	14	0	5,942
	ha	1,765	970	1,419	975	5,129	813	0	
Total	%	20	11	16	10	57	23	19	109,480
	ha	21,461	12,337	17,376	11,385	62,559	25,610	21,311	

Table 11. Sizes of woodland in London and surrounding counties[24]

Cost of production to roadside for thinning in SE England are estimated at £25 – 30 per cubic meter in larger woods and £27 – 37 per cubic meter in small woods[25] Modest rises in timber prices will make management of larger woodlands viable but small woodlands would require increases of up to 50% in timber prices to make early thinnings break even[26]. Small roundwood is often sold below these prices, cross-subsidised by sales of sawlogs and other higher value products.

One way of encouraging more woodland into management is to increase timber prices. The current price for wood chip (£40/t at 30% moisture content) is, after allowing for cost of chipping, at a similar level to sale as pulpwood. Thinning for fuel chip alone will not be profitable for most small woodlands.

Grant funding is another way of promoting woodland management. The new grant structure being introduced for England by the Forestry Commission includes the Woodland Management Grant. Within this funding may be available for thinning to improve the condition of the woodlands. Woodland Improvement Grants directed at biodiversity enhancement may enable the reintroduction of coppicing in some areas.

It is estimated that 25% of the woodlands will remain unmanaged without large scale changes in the price of timber or management grants and an allowance for this is made for in estimating timber availability from forestry.

Significant quantities of chip are now being supplied from heathland restoration projects, supported by European Union funding. As the clearance work is subsidised by grant funding for the restoration it allows users such as SH+P to pay below the cost of production from conventional forestry operations, currently £20.00 - £25.00/tonne delivered. This is not sustainable in the long term as funding for restoration work will cease in a few years when the bulk of the target area is cleared. It is assumed that a minimal amount of chip from heathland restoration will be supplied to Z-squared.

There is a large concentration of woodland in Kent, East and West Sussex and Surrey between 40 and 50 miles from Z-squared. Much of the traditional coppice area is concentrated here in the Weald and

[24] data from 2001 National Inventory of Woodlands and Trees
[25] Lewis D, Manley W, 2004 *Funding woodland management in South East England through wood and timber sales* Royal Agricultural College, Cirencester
[26] ibid

wood chip production would be a return to the traditional pattern of fuel production for London. Additional wood chip will almost certainly be available from these areas and a nominal amount has been included in the estimated availability.

4.3 Probable wood chip supply from woodland management

Woodland has the potential to be a significant source of supply to a Z-squared CHP, provided that a sufficiently high price is paid for the timber. It is likely that less than 2000 green tonnes will be available from within 25 miles and the 40 miles radius is a more realistic catchment distance. Table 12 shows the best estimate of wood fuel likely to be available from woodlands for Z-squared.

	Green tonnes	Balance - green tonnes
Potential supply within 40 miles[27]	30,000	30,000
LESS 25% unmanaged woodland	7,500	22,500
LESS local firewood market	4,000	18,500
LESS supply to St Regis pulpmill	7,000	11,500
PLUS timber from heathland clearance	200	11,700
PLUS timber from over 40 miles*	3,000	14,700

* timber from over 40 miles is included in this estimate in view of the large amount available 40-50 miles from Z-squared.

Table 12. Estimated quantity of wood chip available from woodland for a CHP at Z-squared

The amount of chip sourced from woodland will depend on price. For the woodland owner the minimum price is set by the cost of production – it must at least break even and should be competitive with other markets such as pulpwood sales. St Regis pay up to £20 at roadside for hardwood pulp so the indicative price structure is:

cost per tonne at roadside (£)	20
haulage	12
cost of chipping	6
delivered cost /t at 50% mc	38

The commonly quoted price for chip delivered at 30% moisture content in London is £40/t giving an energy cost of 1.12p/kWh. Green chip (50% moisture content) at £38/t is equivalent to around 1.62p/kWh - more expensive than many other sources of biomass. It is still competitive with mains gas which is now (July 2005) being supplied to bulk purchasers at 1.7 –2.0p/kWh.

Due to its higher cost and longer average transport distance wood from forestry thinnings and clear fellings is unlikely to be the first choice for the Z-squared CHP. Not all of the available timber will be bought by Z-squared as other, cheaper sources of wood chip will be preferred. It is estimated that uptake will be 9,000 tonnes.

4.4 Further work required

The woodland inventory is well developed and potential wood chip production reliably estimated. Likewise, current uses for timber from the area are well documented. Changes in timber sales should be monitored, and their impact on fuel availability for Z-squared assessed. One major change may be due to increased co-firing in power stations.

[27] from Woodfuel Resource Survey (small roundwood and poor quality trees)

5 Energy crops

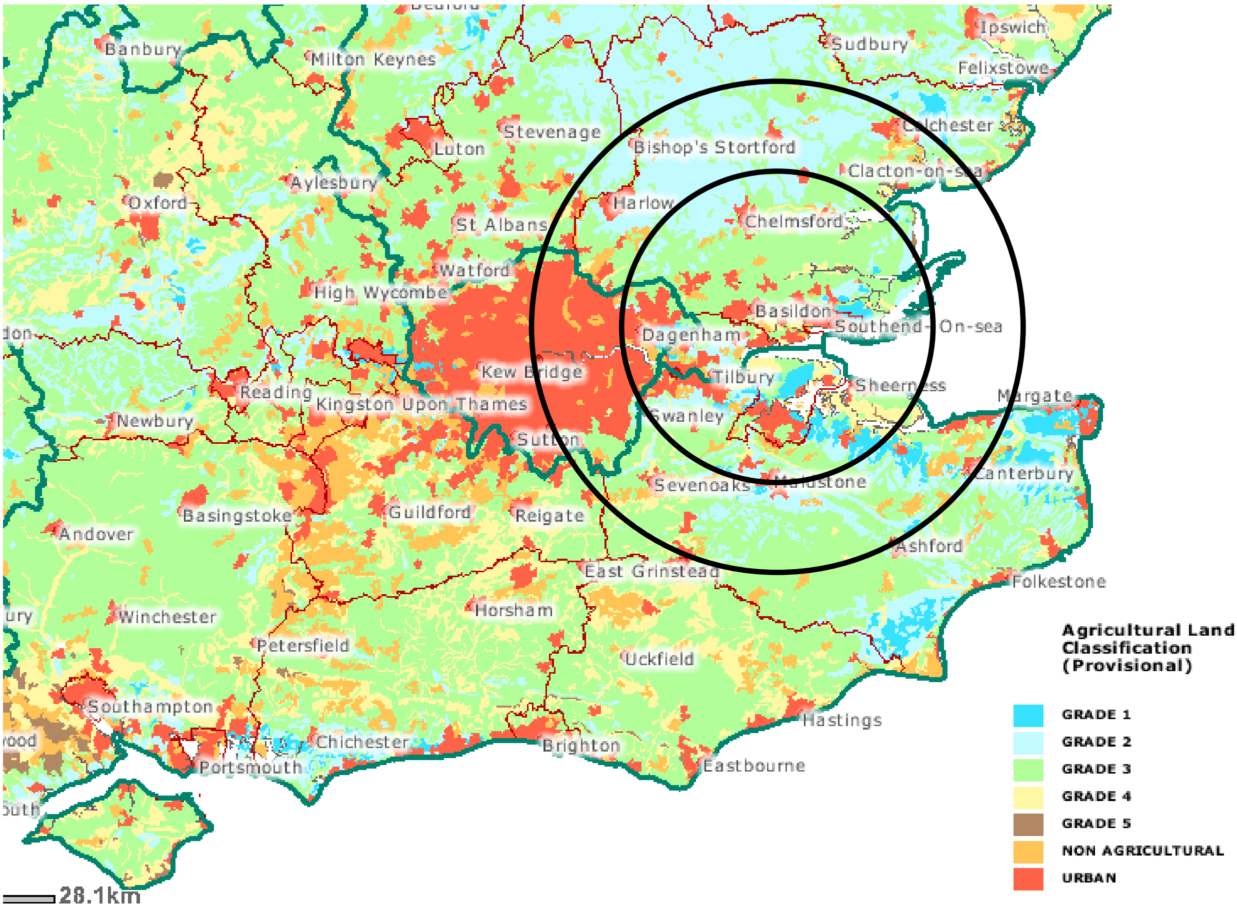
Energy crops have a number of positive attributes contributing both to renewable energy and rural economies:

- they increase the amount of biomass available to a plant in a specific location;
- if grown under a long term contract they increase the security of fuel supplies;
- they can increase biodiversity compared to annual arable crops they replace; and
- they are a means of diversification for farmers compatible with agri-environmental schemes.

As a fuel source for Z-squared they fit well with bioregional principles by creating a local, renewable fuel supply. They are also a disposal route for ash from the biomass CHP and residual waste from the anaerobic digester, both of which can be used as fertilizer.

5.1 Land availability

Recent changes in the Common Agricultural Policy and introduction of the Single Payment Scheme give greater opportunities for farmers to diversify into energy crops since areas growing energy crops can form part of a SPS claim. Energy crops may be planted on set-aside land and still qualify for support under the Energy Crops Scheme (ECS)[28]. Both *Miscanthus* and Short Rotation Coppice (SRC) are regarded as environmentally benign and are acceptable under the Environmental Stewardship Scheme.



Source www.magic.gov.uk

Figure 3. *Agricultural Land classification near Z-squared. showing 25 and 40 mile catchment areas.*

[28]Rural Payments Agency/Defra *Set-aside handbook and guidance for England: 2005 edition.*

The Biomass Taskforce estimate that up to 2020 1 million hectares of agricultural land will be available for non-food uses. A significant proportion of this could be planted with energy crops[29].

For commercially attractive yields energy crops should be planted on good quality land of agricultural land classifications 1-3 normally used for arable crops. The map (Figure 3.) shows the agricultural land classification for the area around Z-squared. If planting is supported under the ECS there is a requirement that it should be planted within a radius of 25 miles of the intended point of use. This radius has been increased on several occasions on a case by case basis, often to 50 or 60 miles. For Z-squared with its relatively small requirement of 35,000 odt/yr the 25 mile supply radius would be adequate in a rural area. In the Thames Gateway however, a wider catchment area is needed to include sufficient agricultural land. With a wider catchment there is scope for better integration in the landscape as only a small percentage will need to be planted with energy crops.

5.2 Short Rotation Coppice

5.2.1 Description

Short rotation coppice (SRC) is close planted rapidly growing varieties of willow or occasionally poplar harvested every 2-5 years, normally every 3 years. This report will concentrate on willow as by far the most widely planted type of SRC. In Britain selected clones of the willow *Salix vimnalis* or common osier are used. SRC is a woody perennial crop with new coppice growing rapidly in the spring following harvesting in winter. Removal and conversion to other crops is relatively easily achieved as the willow varieties used have a fibrous root system and no tap root.

SRC is the most widely planted energy crop in Britain at the moment and along with *Miscanthus* receives exclusive support under DEFRA's Energy Crops Scheme. SRC was first planted on a commercial basis in 1992 and by June 2002 some 2000 ha had been established. A further 170 ha were planted by September 2004[30]. Almost half is in Yorkshire and the Humber, planted to supply the ill fated ARBRE project. Just 99 ha have been planted in London and the South East up to 2002[31]. SRC has a longer history in other European countries, notably Sweden.

SRC will grow on a wide range of sites with soils as different as heavy clay and sand provided the pH is in the range 5.5-7. It can succeed on sites with relatively low nutrient levels including sites reclaimed from gravel workings and colliery spoil[32] or on restored landfill sites[33]. The main determinants of yields are water availability, weed control (especially during establishment), light and temperature. Soil compaction can substantially reduce yields. Water availability will be the limiting factor on yield in many plantations in the eastern half of England due to low rainfall. Irrigation with waste water from sewage treatment works is a possible way to overcome this but western areas of Britain with a wetter climate may have more reliably high yields.

Nutrient requirements are modest and SRC is regarded as a low input crop. Fertilization with sewage sludge, animal waste slurry, or leachate from landfill have all been assessed and found to be feasible[34]. There is a high capture rate of nutrients by the extensive fibrous roots of willow SRC with lower levels of nitrogen reaching the water table than with fertilized grassland or arable cropping.

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[29] Biomass Task Force (August 2005) *Emerging conclusions and recommendations.* Available from the DEFRA website www.defra.gov.uk
[30] Forestry Commission (2004) *Forestry Statistics 2004*, Forestry Commission, Edinburgh
[31] McKay H, Hudson J.B., Hudson R.J.(2003) *Woodfuel Resource in Britain*, Forestry Contracting Association/Forestry Commission
[32] DEFRA (2002) *Growing short rotation coppice: best practice guidelines*.
[33] Cranfield University website www.silsoe.cranfield.ac.uk/iwe/research/lanfillsites.htm accessed on 17/03/04
[34] B9 Energy Biomass Ltd (undated) *Biomass Integration with landfill*. A project funded by the Shanks First Fund. DEFRA (2002) *op sit*.

5.2.2 Potential yields

Research trials have shown yields of up to 21 odt/ha in the first year of the first rotation, but yields have been rather variable between sites and for different varieties. The average for the variety 'Jorunn' for the first 3 year rotation over 21 sites was 8.8 odt/ha/yr. Higher yields was expected from the second rotation as the stools are better developed and this proved to be he case with an average yield for the first year of the second rotation of 18.22 odt/ha/yr, still with considerable variability between sites. The experimental work is borne out in practice with an average of around 7 odt/ha/yr achieved on the first rotation and higher than this in subsequent harvests.

There is an active breeding programme for SRC willows to increase the yields towards the theoretical maximum quoted for willow in the UK of 22 odt/ha/yr. A 'realistic' target of average 15t/ha/yr within 5 years and 18 odt/ha/yr in 10 years has been set[35]. Recent introductions do grow faster than established clones such as Jorrun. Another target of the breeding programme is to increase resistance to *Melampsora* rusts which can reduce yields and cause mortality.

5.2.3 Growing SRC

The best sites for SRC have well drained clay or sandy loam soils although good crops can be grown on other soils. Erosion by wind or rain is a risk just after planting as there is little cover leaving bare ground exposed. On light sandy soils wind blown sand can damage the emerging willow shoots. To limit the risk of erosion, only sites with only moderate slopes are recommended for planting. Site with slopes over 15% must be avoided.

The visual impact of SRC in the landscape has to be taken into account as the crop can reach 7-8 metres before harvest. In practice willow SRC has been well accepted and visual intrusion has not been a problem. Under the Energy Crops Scheme consultation is required to ensure there is no deleterious environmental impact.

The plantation design is dictated by the need to fit into the surrounding landscape and operational requirements. Headlands of at least 8m width are needed at each end of the rows to turn vehicles and equipment. The headlands are normally grassed and managed with a limited cutting regime to enhance biodiversity. Up to 20% of the plantation area may be left unplanted as headlands and access rides or to safeguard features such as hedges.

The techniques for establishment of SRC are well developed. Standard agricultural machinery is used to prepare the site with herbicides used to clear the site of perennial weeds in the autumn and spring before planting in spring or early summer with specialised equipment. Standard spacing gives 15,000 plants per hectare balancing the cost of planting against increasing yield at first harvest. In the first winter the stems are cut back to create the multi-stemmed coppice stools A final herbicide application is made and the crop left to grow until harvest in year 4.

No fertilizer is applied in the first year but chemical fertilizers or sewage sludge is used following the cut back of stems in the first winter. Adding nutrients has been shown to be beneficial where the soil is poor and is expected to bring increased benefits after several harvests have taken place, since these remove significant quantities of nutrients. In some cases atmospheric inputs are at similar levels so the system is neutral overall but in others, especially on light sandy soils 70kg/ha/yr of nitrogen is recommended. Newer, higher yielding varieties may remove more nutrients from the site. However, as the crop grows it becomes impossible to apply fertilizer, especially in the form of digested sewage sludge or other bulky organic wastes. Applying 250kg/ha of nitrogen in digested sewage sludge or other well composted organic matter in the spring following harvesting is acceptable since the nitrogen is released only slowly over a number of years and there is efficient uptake of nutrient by the extensive root system of the willow. For Z-squared this could offer a disposal route for digestate from the anaerobic digester.

[35] Information from the BioMat Net website www.nf-2000.org/secure/Other/F1087.htm

Pests and diseases have not been serious so far for SRC, but only a small area has been planted. By using willow, an indigenous plant many potential pests come with associated organisms that control them, although large areas of willow monoculture might still be vulnerable to periodic pest outbreaks. The main causes for concern are:

- rabbits and hares in the establishment phase which are controlled by fencing;
- Melampsora rusts normally occurring late in the growing season. Chemical control is physically difficult, environmentally inadvisable and financially not viable. Control is by planting a mix of clones rather than blocks of single clones and selecting and breeding resistant strains of willow. This is likely to be an ongoing process as the rusts continue to evolve.
- Chrysomelids (willow beetles) are the most significant pest of willow SRC and can remove 90% of the leaves in summer, reducing yield by 40%. Recommended control methods are monitoring of population levels and targeted spraying of insecticide where the beetle larvae are congregating.

5.2.4 Harvesting

Specialist machinery is required for harvesting. There are 3 techniques used:

1. The coppice is cut and tied in bundles then stacked on the headlands before collection. This allows natural drying over a few months without degradation of the rods. Chipping the dried rod leads to higher levels of fines than chipping fresh material. This may be a problem in some applications such as small gasifiers.
2. The coppice is cut and chipped in a single operation, then blown into a trailer. This is the cheapest system at the moment but fresh chip piles (up to 60% moisture content) can heat up quickly and start to decay with consequent loss of dry matter. As the chip dries out dry matter loss stops. Longer term storage of chip in the open where it can be re-wetted is not recommended. The opportunistic use of ventilated floor grain driers which are not used all year round is being considered fro chip drying.
3. An intermediate system where the coppice is cut into billets and blown into a trailer. This avoids the heating problems associated with direct chipping and allows ventilation in the pile for natural drying. However the larger piece size of the billets can require further chipping with some equipment.

No matter which method is used there will inevitably be losses of biomass during harvesting and transport so the effective yield per hectare used in the cost calculations below is 7 odt/ha/yr for the first rotation and 9 odt/ha/yr for the next 4 rotations, after which replanting is considered necessary.

5.2.5 Environmental impacts

SRC is considered a ‘green’ crop with limited environmental impacts from properly designed planting schemes. Compared to the arable areas and grassland it replaces:

- Well designed SRC plantations are not visually intrusive and have not caused controversy to date. There is only a small area established and there may be more reaction as SRC occupies a larger proportion of the landscape near to a large user such as the Sembcorp plant on Teeside or power stations co-firing with biomass.
- Biodiversity is increased both in the large headlands at field boundaries and within the established crop. An increased range of insect and bird species are found.
- With less fertilizer being applied less frequently than for arable crops infiltration of nutrients to the water table is reduced. SRC is potentially suited to use in nitrate sensitive zones. The establishment phase is the only time when there might be a significant loss of nutrients from the system as a flush of nitrogen is released, particularly if grass leys are ploughed in.
- water use by SRC is higher than for any agricultural crop or grassland, and is only exceeded by fast growing coniferous plantations. However, suitable land for SRC is only a small proportion of the total land area in a catchment and it is unlikely that SRC will cover more than 5% of any

catchment. The effect on overall water yield will most likely be marginal but may give rise to concern in the drier eastern half of the country such as the Thames Gateway

5.2.6 Costs

Establishment costs for SRC are given by a number of sources showing close agreement on the overall cost. A typical establishment costing is shown in Table 13. This is based on planting 15,000 cuttings per hectare.

Establishment costs	**£/ha**
Rabbit fencing	420
Ground preparation (cultivation, ripping if required, power harrow, sprays & fertilizer application)	109
Herbicides	65
Cuttings	900
Planting and rolling	157
Weed control	195
Cut back	115
Total	**1,961**

Table 13. Costs for establishment of SRC[36]

A grant from the Energy Crops Scheme is available to support SRC planting. This is currently set at £1000/ha for SRC but the Energy Crops Scheme is due to end in April 2007. It is likely to be replaced but the rate of support may differ in any new scheme.

The overall cost of production for an oven dry tonne of willow SRC biomass is summarised in Table 14.

cost per growing/harvesting cycle	**£/odt**
Crop production[37]	7.45
Growers margin (20%)	1.49
Harvesting	12.00
Chip storage	2.3
On farm loading and handling costs	8.70
Haulage cost	24.00
Land restoration	4.65
Total per odt delivered	**60.59**

Table 14. Overall costs of production for SRC[38]

Drax Power are currently offering farmers in Yorkshire £45/odt for willow SRC for co-firing[39]. The main beneficiaries are farmers who planted SRC in anticipation of the ARBRE project starting up and were left with crops but no market. Based on the costing above £45/odt is not an economic price and must rise to achieve larger scale planting of SRC. Alternatively, cheaper establishment methods or reduced transport costs could be found, though this seems unlikely. Drying in field will only reduce transport costs only marginally since trucks are filled to volume capacity even with green chip.

To supply Z-squared with 1000 tpa of SRC chip 116 ha are required. Allowing for 20% unplanted area the land required for a thousand tonnes of SRC is 145 ha.

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[36] WINBEG Fuel Supply Review, Bio-Renewables, 2004

[37] Assumptions for Table 14: Establishment costs spread over total tonnage produced per hectare over 16 years, i.e. one harvest of 21 odt/ha and 4 harvests of 27 odt/ha
no cost for inputs after establishment phase (sewage sludge as fertilizer)

[38] Based on WINBEG Fuel Supply Review, Bio-Renewables, 2004 from Bullard M., Heaton R., Nixon P. (2004) *Biomass fuel assessment for WINBEG,* Bio-Renewables Ltd., Ely

[39] Gareth Gaunt of Renewable Energy Growers in an interview with Radio 4's Farming Today programme, July 2005

5.2.7 Poplar SRC

Poplars have been used occasionally in SRC systems and qualify for similar grant support to willow. Yields from experimental planting of poplar SRC was more variable than willow and clear site preferences can be seen. On some sites poplar grew more rapidly than the willows and on other sites the reverse was true. Poplar's full potential is seen on fertile sites that are moist but not waterlogged. Production costs are similar on a per hectare basis.

Most poplar clones now grown have been developed to give rapidly growing single stemmed trees and when managed in an SRC system fewer stems per coppice stool are produced than with willows. This leads to larger heavier stems at harvest for similar yields which may be an advantage for some applications where better chip quality is needed. There is some evidence that a longer rotation, maybe 5 years is needed to maximise poplar SRC yields.

There is no breeding programme for poplar SRC in Britain[40] but work on the use of genetic markers for poplar SRC breeding is being undertaken at Southampton University[41] with the aim to increase productivity and improve resistance to disease, particularly rusts.

5.3 Miscanthus

Miscanthus is a genus of fast growing tropical grasses increasingly planted commercially in the UK, notably in East Anglia and SW England. Commercial crops are almost exclusively of a sterile hybrid variety *Miscanthus x giganteus*. Growers are attracted to Miscanthus by its relatively simple agronomy, limited requirement for specialised machinery, high yield, annual rather than triennial income (with SRC) and a growing number of end uses.

The area of Miscanthus planted under the Energy Crops Scheme has increased rapidly in recent years from 52 ha in September 2002 to 539 ha in 2004. with applications for a further 169 ha still being processed. There is a growing body of experience in growing and using the crop as fuel with the successful use in Energy Power Resources' straw burning Ely Power Station.

In SW England a farmers cooperative, Bical, is promoting Miscanthus for a number of end uses in addition to energy generation including horse bedding, as bio-composites in applications such as plant pots and for thatching. It may also be possible to produce miscanthus pellets for fuel and cat litter.

Miscanthus[42] requires similar growing conditions to maize but starts growing at a lower temperature (6ºC). However it is vulnerable to late spring frosts which can effectively shorten the growing season. A large proportion of lowland Britain is suitable and will give high yields. It is tolerant of a wide range of soils but prefers a pH between 5.5 and 7.5. Soils that become waterlogged over winter should be avoided as harvesting is done in early spring.

Around 20,000 rhizomes per hectare are planted in March or April with a potato planter or specialised equipment which has higher outputs. The site for planting must be cleared of perennial weeds before planting. As with other energy crops, complete weed control until the site is fully occupied is essential for good growth. In Miscanthus this is achieved using herbicides by the summer of the second year. After this the crop effectively shades out any competition.

Nutrient requirements for Miscanthus are modest due to the efficient translocation of nutrients to the rhizomes at the end of the growing season. As the crop is developing in the first 2 years additional nutrients may be needed. These can be supplied from farmyard manure or sewage sludge applied in the spring as growth starts. Once established only a small quantity of micronutrients may be required.

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[40] BioMatNet website: www.nf-2000.org/secure/Other/F1087.htm accessed on 04/08/05
[41] Southampton University Plants and Environment Lab.: www.soton.ac.uk/~taylor/projects_biomass.htm accessed on 17/03/04
[42] Information taken from *Planting and growing Miscanthus: best practice guidelines.* DEFRA, published 2001.

5.3.1 Yields

The first years growth is only 1-2 odt/ha and is not worth harvesting. Second year yields are in the range 4-10 odt/ha. Yields continue to increase, reaching a plateau after 3-5 years which may exceed 20 odt/ha on the best sites. The variation in time required to reach the sustained yield is due to planting density, soil type and climate. Limited moisture supply and exposure will also delay attainment of maximum yield.

Yield may vary significantly from year to year. Modelling done for the miscanthus in SW England found that yields could vary from 35% to 125% of the average value. Miscanthus yield is particularly sensitive to late frosts and drought and is better suited to the western half of Britain than the South East. Despite this average yields of between 16 – 22 odt/ha are predicted for mature miscanthus in the Z-squared catchment, based on climatic data for 1961-1990[43]. As with other energy crops there is the potential to increase yield and decrease the annual variability in yield by irrigation with waste water from sewage treatment. The efficient capture of nutrients and extensive fibrous root system of miscanthus would act as a bio-filter.

An average annual yield of 13 odt/ha/yr at the point of use has been assumed in working out the cost of production to take account of losses in transport and storage and bare areas within the crop. This is similar to long term yields achieved in trials on good sites covering a range of soils types.

The potential yields are higher and prospects for increasing yield are good. There is a good deal of variation in wild populations of miscanthus as a basis for any breeding programme.

5.3.2 Pests and diseases

Miscanthus species have a number of pests and diseases in their native range in Asia. If they reach this country they could be more serious than in Asia as the accompanying organisms that feed on pests and control their numbers will not be present. Some common diseases of cereals such as barley yellow dwarf virus have been found infecting miscanthus and may limit yields. So far no significant insect pests have been reported as attacking miscanthus in Europe or the UK.

5.3.3 Environmental impacts

Visual amenity

Miscanthus grows up to around 3m tall which is comparable to forage maize so will not cause a great change in the appearance of the countryside. Leaving it standing over the winter before spring harvest is a new element but is not a radical difference likely to spark protest.

Soil and water

There is concern that harvesting miscanthus in the spring when the soils are soft from the winter rains may lead to compaction, reduced percolation of the water through the soil profile and increased runoff. Experience to date has shown that this is not so but that dense network of rhizomes and miscanthus stubble are able to support the weight of harvesting machinery better than willow SRC.

As the soil is not disturbed by annual cultivation soil erosion rates are as low as 0.2 t/ha/yr, much less than for an annual cereal crop (21.8 t/ha/y)[44].

Water use by miscanthus is higher than with permanent grass and wheat. However the amount of miscanthus likely to be planted in a catchment will not cause any noticeable difference in base flows for the whole catchment. Miscanthus can potentially be of use in areas liable to flooding. Due to the greater water use soil under miscanthus will start the winter with significantly higher soil water storage capacity. Thus more rainfall can be stored before deep percolation and runoff occurs, reducing flooding[45].

[43] Bullard M., Heaton R., Nixon P. (2004) *Biomass fuel assessment for WINBEG,* Bio-Renewables Ltd., Ely
[44] Bullard M., Heaton R., Nixon P. (2004) *Biomass fuel assessment for WINBEG,* Bio-Renewables Ltd., Ely
[45] Stephens W (2002) report to DEFRA NF0416 (in Bullard et al, 2004)

Because of low inputs, high levels of nitrogen capture by an extensive rooting system and lack of cultivation Miscanthus energy crops will tend to reduce nitrate leaching.

Biodiversity impacts

Miscanthus has an increased biodiversity compared to cereal crops. Soil organic matter increases due to leaf litter left on the soil surface, resulting in 3 times the number of earthworms[46]. The leaf litter, which is essentially undisturbed, also provides a stable habitat for an increased number and range of species of all types of invertebrates. There are also more mammals and birds found with specialist species such as the reed warbler utilising the crop as a nesting site.

There is no requirement for headlands with miscanthus so the range of habitats provided is less than with short rotation coppice but there is no doubt that miscanthus is environmentally benign.

5.3.4 Costs

The establishment cost for miscanthus inferred from Bullard et al (2004) is £2250/ha based on planting 20,000 rhizomes per hectare. Other authors give slightly lower figures, typically around £1800/ha. A planting grant of £920 is available through the energy crops scheme. The Energy Crops Scheme is due to end in April 2007. It is likely to be replaced but the rate of support may differ in any new scheme.

The overall cost of production for an oven dry tonne of miscanthus biomass is summarised in Table 15.

cost per growing/harvesting cycle	**£/odt**
Crop production[47]	8.63
Growers margin (20%)	1.73
Harvesting	13.27
Chip storage	2.00
On farm loading and handling costs	7.10
Haulage cost	11.90
Total per odt delivered	**44.63**

Table 15. Overall costs of production for miscanthus[48]

To supply Z-squared with 1000 tpa of miscanthus 93 ha are required.

The delivered moisture content to the end user is normally under 25%. The power station at Ely receives miscanthus at an average 16% moisture content.

5.3.5 Alternative energy grasses

Other grasses that have potential as energy crops are currently being studied as alternatives to miscanthus. These include reed canary grass (*Phalaris arundinacea*), the giant reed (*Arundo donax*) and reed canary grass (*Panicum virgatum*)

Suitability for use in Z-squared

Miscanthus and other straws and grasses require different handling and processing equipment to wood chip if delivered in bales, the preferred means of transport. When shredded the resulting “chip” may not be suitable for use in some equipment, or may need to be blended with other fuels such as wood chip.

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[46] Stephens W (2002) report to DEFRA NF0416 (in Bullard et al, 2004)

[47] Assumptions for Table 15: Average annual yield delivered to the end user 10.7 odt/ha
Establishment costs spread over total tonnage produced per hectare over 16 years, with a total of 154 odt/ha harvested
no inputs after establishment phase

[48] Based on WINBEG Fuel Supply Review, Bio-Renewables, 2004 from Bullard M., Heaton R., Nixon P. (2004) *Biomass fuel assessment for WINBEG,* Bio-Renewables Ltd., Ely

The high silica content of some straws can cause problems with some combustion equipment. These factors would need to be taken account of in specification of the CHP at Z-squared if miscanthus and other straws are to be used.

5.4 Short rotation forestry

Short rotation forestry (SRF) is a form of energy cropping where trees are grown on a single stem for 6-8 years. When felled they are not normally coppiced, but new trees are planted as with a conventional forestry crop. If coppiced the stems will be thinned to leave just one or two per stool at an early age. Unlike short rotation coppice all operations can be done with conventional forestry equipment.

Species selection is crucial to obtaining the high yields predicted for SRF. Native trees will not grow at the rates that look possible with new species for British forestry. Most of the interest to date has centred on Eucalyptus species with *E.gunnii* and *E. nitens* showing great promise in the few small trials to date. In the light of predicted climate change selecting species such as these eucalyptus that are adapted to a more Mediterranean climate with hot dry summers

Advantages claimed for SRF over short rotation coppice (SRC)

- no specialised equipment is required for SRF, unlike SRC, where specialised planters, harvesting equipment and chippers. Readily available conventional forestry equipment is required
- it is easier to apply waste water and sewage sludge as fertilizer as there is space between the rows of trees, particularly if there is a row thinning at age 4.
- higher yields than SRC with 15 odt/ha/yr predicted for SRF against 9-10 odt/ha/yr for SRC. The aim with improved silviculture and selected planting stock is to reach 20 odt/ha/yr. It is also well ahead of elephant grass (Miscanthus) the other widely promoted energy crop.
- a lower percentage of sapwood and higher density timber reduces the loss of dry matter through degradation in storage compared with SRC willow and poplar.
- fuel quality is also improved due to the larger size of the stems with SRF. This results in a lower percentage of bark in the wood chip. Fresh bark from young stems has a higher percentage of chlorine which can lead to increased corrosion when co-fired in boilers designed for acidic coals. (Bennett C., personal communication).
- most species proposed for SRF are ‘pre-adapted’ to climate change as they are from Mediterranean or seasonally dry, warmer climates.

5.4.1 Choice of species

Any species chosen for SRF must have very rapid growth, be tolerant of frost and high winds found in Britain, have no known potentially serious pests and diseases, and not degrade the land on which it is grown. Some of the fastest growing plantation species are eucalypts. Astonishing yields of up to 80 m^3/ha/yr (around 37 oven dry tonnes/year) have been obtained from clonal Eucalyptus in Brazilian research plots and around 45 m^3/ha/yr (21 odt) in normal production areas[49]. Yields in the UK would not reach these levels but experience in Spain and Portugal shows that with appropriate species selection and reasonable growing sites significant increases in growth rates over native trees can be expected on lowland sites in England.

Figure 4. *4 year old* Eucalyptus nitens *growing on very poor soil in Nottinghamshire*

[49] Freezailah, B.Y.C. (1998) *A case for tropical forestry plantations.* CIFOR News number 19, June 1998

A limited number of eucalyptus species screening trials were established in the UK in the 1970s and 80s but enthusiasm waned after a particularly hard winter in 1981/82 killed many very young trees. The fastest growing species were *E. gunnii and E. nitens* and *E. gunnii* also had the best cold tolerance of the species tested[50]. With over 500 Eucalyptus species to choose from other fast growing species better suited to British conditions may be found. Breeding techniques for eucalyptus are well developed and rapid gains in growth rates and dry matter production can be expected from a properly designed breeding programme. Micro-propagation has facilitated the development of clonal planting material cutting the time for the results of a breeding programme to reach the field.

The early trials used what seed they could find, often from a single tree per species, so the results may not be representative of the species as a whole. However, where species have grown well, further work is justified.

Re-evaluation of the eucalyptus species trials, evaluation of Spanish and Portuguese plantations and consideration of improved management techniques led to planting of a series of trial plots around the country in 2001. Despite poor weeding and extremely poor sites in some cases the results were sufficiently encouraging for establishment of a 40 ha pilot plantation at Dane Hill in Nottinghamshire in May 2005. This is designed as a demonstration plot to encourage other landowners to plant with the resulting biomass to be used for co-firing at the nearby Drax Power Station.

Figures 5 & 6. *3 month old* Eucalyptus nitens *(including some hybrids), Dane Hill, Nottinghamshire, July 2005*

The trial was planted with *E. gunnii* and *E. nitens* seedlings brought from Spain and southern France. At 3 months old the pilot plantation looks well established despite late frosts just after the trees were planted. There are almost no dead trees and rapid growth has started (see photos). This is encouraging but until this latest round of trials, which have received much more intensive silviculture than the earlier ones, have reached at least four or five years old – or preferably the predicted felling age of 8 years – uncertainty over the ultimate performance of eucalyptus in SRF will remain.

[50] Bennett C.J. and Leslie A.D. (2003) *Assessment of a* Eucalyptus *provenance trial at Thetford and implications for* Eucalyptus *as a biomass crop in lowland Britain*, Quarterly Journal of Forestry, Vol 97 No. 4

Other species than eucalypts also have potential for SRF. These include a group of southern beeches (*Nothofagus* species) from South America, in particular *N procera, N obilqua* and the evergreen *N dombeyi*. As with the eucalypts there has been concern over the frost hardiness of these species but better matching of seed collection zones with British climatic conditions and selection in the existing plantings in this country should overcome this.

5.4.2 Predicted growth rates

The full potential of *Eucalyptus gunnii* and *E. nitens* has not been demonstrated in Britain because early trials used standard establishment techniques and not the intensive control of competitive grasses and other weeds necessary for rapid, complete establishment. Following apparently severe frost damage, the 1981 trials in Thetford were left almost untended, yet surviving trees have grown rapidly. Well tended SRF crops would undoubtedly exceed the maximum 18.2 m^3/ha mean annual increment (8.2 odt/ha) in this trial. The current 40ha trial will show what can be expected in a normal production situation. 15 odt/ha/yr is anticipated.

For *Nothofagus* growth rates are lower than those predicted for eucalypts with 20 m^3/ha/yr (10 odt/ha/yr) given as the potential for lowland Britain for trees grown on long rotations for timber[51]. This is comparable to SRC and *Miscanthus* yields but higher growth rates can be expected in well managed SRF systems.

5.4.3 How SRF works

Almost all trees follow the same pattern of growth; they start relatively slowly as they establish themselves then have a period of rapid growth and development before the growth rate begins to slow. To get the most timber from a forest plantation the trees will be felled just as the growth rate begins to decline, at the age of maximum mean annual increment (maximum MAI). This may be reduced if there is a limited amount of water or nutrients or another factor on the site but will occur even if there are no site limitations.

Faster growing trees go through the first two phases of growth quicker, and reach their maximum MAI earlier than slower growing trees even if they can potentially be very long lived. In Britain oak trees are felled at over 100 years old, ash at around 60 years and a fast growing sitka spruce at 40 years or less. The very fast growing trees used in SRF may well reach their maximum MAI at 15 years or less, but insufficient research work has been done to demonstrate this.

In order to get the best out of the trees competition from grass and weeds is reduced to a minimum. For eucalypts, work worldwide has shown that any competition from grass and weeds when the trees are young is detrimental, resulting in permanent reductions in growth rate. A black plastic mulch has been used in recent trials in the UK. As with short rotation coppice, SRF is well suited to irrigation with waste water from sewage treatment works and is suitable for fertilisation with treated sewage sludge which will help to replace nutrients lost in the harvested crop and maintain rapid growth rates in dry summers.

5.4.4 Potential environmental impacts

In India, Spain and Portugal eucalyptus plantations have been held responsible for reducing water yields, reducing valuable native habitats and biodiversity, and loss of the most productive land to agriculture as this gives best growth rates. Planting eucalypts on a large scale in Britain would be controversial despite a long history of introduction of non-native tree species. Their very distinctive appearance and smell make them an obvious target for those concerned to maintain the countryside and native species.

Well grown eucalypt plantations have little if any undergrowth laying them open to charges of “sterilizing the landscape”. As new species very different from the indigenous flora there will be few native insects, other invertebrates, birds, mammals, fungi and other plants well adapted to living with eucalypts.

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[51] Savill P.S. (1991) *The silviculture of trees used in British forestry.* CAB International, Oxford

Biodiversity within *Eucalyptus* woodlands will almost certainly be lower than in nearby woodland of native species. Some problems experienced elsewhere such as high levels of water use are unlikely to be severe since the planting and rainfall patterns will be different. Rather than large contiguous areas there will be smaller blocks of SRF scattered through the countryside unlikely to total more than around 5% of the land area.

The appearance of a eucalypt SRF plantation with its glaucous foliage is strikingly different to anything in the countryside just now and may be controversial. It is more obvious than either SRC or *Miscanthus* and may lead to opposition in much the same way as any change in the countryside does. A good example is the number of objectors to wind farm projects. However, good design of plantings can do much to mitigate any adverse impact and improve integration with the existing landscape. The Nottingham trial plantation has eucalypts on only 70% of the site and includes native species such as oak, birch, and willow as well as leaving some areas unplanted. Allowing public access for recreation increases familiarity and acceptability.

Nothofagus has a history of use in British forestry and is more closely related to native British species. Ecological studies show that many of the species dependent on oak are found on *N. procea* and *N. obliqua* and that they supports a higher diversity of species than native beech. The evergreen *N. dombeyi* has not been as widely planted and the diversity it supports has not been fully assessed. The appearance of the deciduous *Nothofagus* is very similar to other trees such as hornbeam and is not expected to be controversial.

With the predicted change in species suitability in different areas of the country with climate change[52] beech and oak will be much less suited to south east England. Large scale change of tree species is inevitable and SRF offers an opportunity to plant better adapted trees and maintain a wooded landscape.

5.4.5 Cost of growing SRF

The cost of planting SRF is slightly higher than conventional forestry plantations because of the more intensive weed control needed and the possible installation of a waste water irrigation system. A figure of around £2000/ha is given[53]. This is comparable to costs for establishing SRC and *Miscanthus*. Similar levels of grants are expected for all energy crops. The total costs of production of wood chip are summarised below:

Cost element	Cost per odt (£)
Crop production[54]	7.40
Growers margin (20%)	1.48
Harvesting cost	21.81
Chipping and loading	7.27
Transport	21.81
Total	**59.77**

Table 16. Overall production cost for SRF

Despite higher growth rates this is similar to the delivered cost for SRC and higher than *Miscanthus* which are given as £60.59 and £48.63 respectively in a recent assessment for the proposed biomass power station at Winkleigh in Devon[55]. This is due to the shorter period between full re-establishment (9

[52] Broadmeadow M and Ray D (2005) *Climate change and British woodland,* Forestry Commission Information Note FCIN069, June 2005
[53] Chris Bennett, FBS (Woodlands Solutions) Ltd., personal communication
[54] Assumptions for table 18: Yield 15 odt/ha/yr
Felling after 9 years
No inputs after establishment phase
Crop production costs assume establishment grant of £1000/ha
[55] Bullard M, Heaton R, Nixon P (2004) *Biomass Fuel Assessments for WINBEG*, Bio-Renewables Ltd. Ely

years for SRF and 15-16 years for SRC and *Miscanthus*). Options to extend the period before full re-establishment is required include:

- Coppicing after the initial harvest. Limited observations show that, unlike many eucalypts, *E. gunnii* and *E. nitens* do not coppice particularly well in England, with only around 70% of stumps re-growing. A second coppice crop from an SRF plantation may be possible since initial growth will be very rapid, occupying the site and suppressing weeds. However this would only reduce costs by £3.29/odt, a marginal difference.
- One or two thinnings of the SRF crop have the potential to extend the time before final felling while maintaining very rapid growth rates. Limited experience in *Eucalyptus* trials of 20 years old and over show that trees can continue to grow rapidly up to this age. The southern beeches are already grown on a small scale for timber production and continue to grow at similar rates up to age 20.
- An additional benefit of longer rotations is the possibility of producing higher value sawlogs. The southern beeches are less dense than European beech but are among the most important timber species in Chile and Argentina. Eucalypts are less well known as timber species in the UK but have been widely used in other countries.
- Reducing the cost of harvesting and chipping through measures such as whole tree harvesting will have a direct impact on the delivered price of wood chip. If combined with sewage sludge fertilization and return of ash to the woodlands there should be no reduction in site productivity through nutrient removal.

5.4.6 Grant aid for SRF

SRF can be registered as an energy crop for co-firing but falls outside the very narrow definition of crops that qualify for support under DEFRA's Energy Crops Scheme. This is restricted to *Miscanthus* or SRC of willow and poplar. This places a significant barrier to innovation in the energy crops sector.

The trial SRF plantation in Nottingham was grant aided under the Woodland Grant Scheme and also qualified for the Farm Woodland Premium Scheme, and Community Woodland Supplement. This combination of grants more than paid for the establishment costs. The Woodland Grant Scheme has now been replaced by the revised England Woodland Grant Scheme's Woodland Creation Grant. It has been decided that SRF will not be aided under the Woodland Creation Grant, a critical loss of income for farmers considering planting SRF.

5.4.7 Conclusions and recommendations for SRF

SRF has potential to meet increasing need for energy crops but is only at an early stage of development. With careful design even *Eucalyptus* plantings can be acceptable in the landscape but other species may offer better biodiversity and amenity benefits. Establishment costs at present are rather high but the major costs are for harvesting, chipping, drying and transport. These costs can be reduced by developing new working practices and improved equipment.

Some of the actions required for the rapid development of SRF in England are:

- evaluation of species with potential for SRF in a changing climate in Eucalyptus, Nothofagus and other genera
- seed collections from areas with matched climatic conditions for eucalypts and Nothofagus followed by provenance trials. The provenance trials to be established with the best current operational techniques in several locations throughout the country. The national collection of Nothofagus at Wakehurst Place is a valuable initial resource.
- collection of definitive growth and yield data over a range of sites through a series of trials throughout the country
- demonstration/confirmation of best establishment techniques
- if justified by the results of establishment trials and early growth rates, start a breeding programme specifically for SRF
- investigate thinning regimes, optimal rotation lengths, and the possibility of coppicing

- determine effect of waste water and sewage sludge on yield, capture of nutrients and assess potential leaching problems
- investigate biodiversity, water and other environmental impacts compared to SRC and Miscanthus.
- extend the scope of the Energy Crops Scheme to include SRF in recognition of its value as a farm diversification measure or include it within the ambit of the England Woodland Creation Grant. The latter is preferable since it is not tied to any specific end user and can thus support a growing number of small biomass users.

Figure 7. *Nothofagus procera*
Potential species for SRF

Figure 8 *Nothofagus oblique*

5.5 Comparison of SRC, Miscanthus and SRF

Current estimated yields for the 3 types of energy crop and comparative data on costs and moisture content are given in Table 17.

Crop	Yield (odt/ha/yr)	Area to produce 1000 odt/yr (ha)	Estimated delivered cost (£/odt)	Expected moisture content on delivery (% wet basis)
Miscanthus	10.7	93.5	44.63	16
SRC	8.6	116.2	60.59	25[56]
SRF	15.0	66.7	59.77	30[57]

Table 17. Comparative yields and costs for SRC, miscanthus and SRF

Miscanthus is undoubtedly the cheapest option but suffers from a high degree of yield variability unless irrigated. It may also be unsuitable for the equipment selected for the Z-squared CHP as it differs significantly from wood chip that will be the main fuel for the CHP. SRF is still in the early stages of development and a high degree of uncertainty comes with the yield and cost estimates. If a second coppice crop is possible in an SRF system the overall cost per oven dry tonne will be reduced. Where land is in short supply SRF has the advantage of the highest yields. With irrigation miscanthus yields would also increase and could well exceed those obtained from SRF.

[56] Assumes dried in field for some months before chipping. Could be delivered fresh at 50% mc
[57] Assumes stacked to dry at forest roadside for 6 months to dry before delivery

All three types of energy crop promise higher yields and better disease resistance as a result of tree selection and breeding programmes. Yields of 20-25 odt/ha/yr are the target for all three types of energy crop in the medium term (10 years). Willow SRC have active breeding programmes in the UK, and some basic scientific work being done for poplar SRC. Initial work is being done to select promising idotypes of *Miscanthus* as the basis for a breeding programme but there is currently no UK breeding programme. Work elsewhere in Europe may result in cultivars with improved yield in Britain.

Short rotation forestry is a new concept without a breeding programme so far. The Biomass Task Force led by Sir Ben Gill have noted its potential and in their report recommend that SRF be included in a urgent review of the potential contribution of forestry to biomass production[58] with a deadline of June 2006.

Energy crops are unlikely to be a major component of the fuel mix for the Z-squared biomass CHP, but will contribute to fuel security and offer opportunities for disposal of digestate from the anaerobic digester and ash from the CHP.

5.6 Further work required

5.6.1 SRC and Miscanthus

Basic planting and cultural techniques are well known for both SRC and Miscanthus and no work specific to Z-squared is required. On-going research and breeding work is expected to result in higher yielding, disease resistant clones. As more experience is gained in harvesting and drying SRC standard methods which limit dry matter losses and reduce costs will be come clear. For Z-squared the needs are:

- to monitor technical developments and the growth of the industry for co-firing in terms of its impact on the cost per tonne produced;
- work on fertilization of SRC and Miscanthus with organic wastes, such as AD plant digestate;
- once a site is agreed, to identify areas where SRC and Miscanthus could be grown to supply Z-squared;
- when the technology for Z-squared is known re-evaluate the suitability of Miscanthus as a fuel.

5.6.2 SRF

SRF is at a much earlier stage of development than SRC and Miscanthus, showing great promise but without significant areas that have been grown and harvested in the UK. More basic research needs to be done before SRF is promoted on a large scale for Z-squared. This is a major project which is beyond the scope of a single medium sized project such as Z-squared. The FC's Forest Research branch or potential large biomass users such as power stations are more likely to lead the development of SRF. The major needs are to:

- test a wider range of species including more *Eucalyptus* species and hybrids, and several South American *Nothofagus* species over a variety of site conditions including those in the Thames Gateway;
- compile information on the costs of SRF when used on a larger scale;
- document growth rates and produce yield tables for SRF;
- investigate the costs and benefits of thinning at age 4 or 5 to extend the rotation;
- trials of coppicing for a second rotation SRF crop;
- assess the environmental impacts of species that have not been widely planted in the UK, particularly their effect on local biodiversity

[58] Biomass Task Force (August 2005) *Emerging conclusions and recommendations.* Available from the DEFRA website www.defra.gov.uk

6 Waste wood

Waste wood is an under-utilised resource. In their interim report of June 2005, the Government's Biomass Task Force report that out of a total of 18m tonnes of waste wood produced nationwide each year only 1.4m is recycled. The remainder goes to landfill[59]. London and SE England show a similar pattern of waste wood use.

Nationally use of waste wood has been led by the panel board industry, principally to make chipboard, and they remain the dominant buyer. Around London, Slough Heat and Power (SH+P) are the largest user. They had a licence to burn 100,000 tonnes of recycled wood a year but have recently increased this to 200,000 tonnes a year. Recycled wood is attractive to SH+P since it is drier (20 – 25% mc) and has a higher net energy content, roughly double that of fresh biomass[60].

Waste wood comes from a range of sources including construction, demolition, post consumer waste via civic amenity (CA) sites, commercial waste and waste from wood using industries such as furniture manufacturers and joinery workshops. Waste wood is heterogeneous:

- it varies in size from large dimensioned timber to sawdust;
- it may contain screws, nails, grit and stone which can be relatively easily removed; or
- it may be contaminated with paints or other surface coatings, contain glues or be pressure treated with creosote or preservatives containing copper, chrome and arsenic which make it unsuitable for use in many biomass burners.

Wood is recovered either by specialist wood recyclers or by general waste management companies. Panel board mills require clean wood chip and sorting of incoming timber to separate contaminated timber is an essential first step. Most (65%) of the wood is delivered in to the recyclers by their clients and some 85% of this is pre-sorted before delivery. Wood recyclers in the South East deal with 240,000 tonnes a year of waste wood, an estimated 210,000 tonnes coming wood directly from source and the remainder via waste management companies.

The wood recycling infrastructure and supply chains are considered in more detail below.

6.1 Use of waste wood in heating and power generation

Waste is defined as "any substance or object which the holder discards or is required to discard" in the European Waste Framework Directive. Once classified as waste, if burned it is subject to regulation under the Waste Incineration Directive (WID). The guidance on the WID makes it clear that it is permitted to burn waste wood without being subject to regulation under WID provided that the wood is uncontaminated by halogenated organic compounds or heavy metals[61]. These will be present in preservative treated waste timber such as old fencing materials and may be contained in surface coatings. Combustion is defined in the directive to include the use of products from gasification and pyrolysis as well as conventional incineration.

6.1.1 Renewable Obligation Certificates (ROCs)

Renewable obligation certificates have to be produced by energy suppliers to demonstrate that a set percentage of their electricity comes from renewable sources The percentage required is steadily rising from the present 5.5 percent to reach 15.4 percent by 2015/16[62]. As a renewable source of energy, biomass can be used to generate ROCs along with electricity. The viability of stand alone biomass power plants and CHP plants normally depends on generating tradable ROCs. Biomass plants using

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59 www.defra.gov.uk/farm/acu/energy/biomass-taskforce/interim-report.pdf last accessed on 23rd August 2005.
60 JP Management Consulting (Europe) Ltd. and Urban Harvest Ltd. (August 2005) *Wood Recovery Infrastructure in South East England*. A report for the Waste & Resources Action Programme, Banbury available at www.wrap.org.uk
61 *Guidance on: Directive 2000/76/EC on the Incineration of Waste Edition 2* available on the DEFRA website at http://www.defra.gov.uk/corporate/consult/ppc-wid/guidance.pdf accessed on 23/08/05.
62 Department of Trade and Industry website http://www.dti.gov.uk/renewables/renew_2.2.1.htm accessed on 23/08/05

either virgin or recycled biomass qualify for ROCs provided 98% of the energy produced is derived from biomass. The price of ROCs is predicted to remain high despite increasing supply from other renewable generators, such as wind power.

6.1.2 Use of Waste Wood for Power Generation

Contaminated wood can be used for heat and power generation, and qualify as renewable energy under the ROCs regulations, provided it is used in equipment that is fitted with filters and monitoring equipment to ensure that pollution levels are within the limits set by the Environment Agency or local authorities under Integrated Pollution Prevention and Control (IPPC) regulations i.e. it is WID-compliant equipment

The second edition of the WID Guidance clarifies the status of different types of wood waste. Timber from construction and demolition sites is assumed to be contaminated and the onus is on the waste recycler to demonstrate otherwise. Untreated wood products such as pallets which may have become contaminated during use are excluded from WID since the contamination is accidental and not a result of deliberate treatment. This changes the position prior to 2004 where pallets were subject to WID. The justification for the change is that:

- pallets are no longer treated with preservatives but heat treated to eliminate pests;
- contamination is a rare event and would be only on the surface of the timber;
- when burned contaminated chip is hugely diluted by chip from clean pallets and other wood chip that are burned at the same time.

This is an important regulatory change and makes a significant volume of timber available for use in all biomass appliances since pallets and other packaging are 30% of all waste wood in London. Pallets are easily separated from mixed waste and lend themselves to recovery from mixed wood waste streams such as construction and demolition (C&D) waste and wood coming from civic amenity (CA) sites.

Other clean timber is harder to segregate. Techniques to identify wood treated with copper containing preservatives are in development but have not yet reached commercial use[63]. The vast majority of preservatives used in pressure treatment of wood contain copper, both those in current use and those that have been superseded such as copper-chrome-arsenate (CCA). The techniques developed so far are better suited to labour intensive sorting operations commonly employed in community wood recycling enterprises and may not be appropriate to large scale recycling plants dealing with mixed demolition waste.

6.2 Waste wood in London and the South East

A recent study for WRAP [64] estimated that 950,000 tonnes a year of wood is discarded in the South East, the majority of which is generated in London and its hinterland. The figures from this study are used in this section as giving the best estimate of waste wood available to projects in and around London. The WRAP report defines the South East as Greater London, Kent, East and West Sussex, Surrey, Hampshire, Oxfordshire, Northamptonshire, Buckinghamshire and Hertfordshire. This is a wider catchment than considered for other biomass sources for Z-squared but fits the large scale of wood recycling operations. The main markets for recycled wood chip in the South East are either at SH+P to the west of London or at panel board mills in Scotland, Wales, Northern England and South West England

[63] Sawyer, Gervais and Irle, Mark (2005) *The Chromazurol S Colour Indicator Technique to Detect Copper Contamination in Wood Waste for Recycling. A Guide for Use.* Waste & Resources Action Programme, Banbury
[64] JP Management Consulting (Europe) Ltd. and Urban Harvest Ltd. (August 2005) *Wood Recovery Infrastructure in South East England*. A report for the Waste & Resources Action Programme, Banbury available at www.wrap.org.uk

The WRAP study found the following percentage breakdown for sources of waste wood:

Source	Percent of total
Construction and demolition	35%
Packaging	30%
Municipal waste	25%
Wood using industries	5%
Other sources	5%

Table 18. Sources of waste wood in SE England

Of the 950,000 tonnes of waste wood produced each year, 280,000 tonnes a year (29%) is recovered through specialist wood recycling companies and general waste management companies and 20,000 tonnes a year (2%) is sent directly from the waste producer to the end user. The remaining 650,000 tonnes (69%) ends up in landfill along with residual waste.

6.2.1 Construction and demolition

London Remade[65] estimates that 14 million tonnes of C&D waste are produced annually each year in London. Wood is less than 5% of this with an estimated 330,000tpa produced in the South East[66]. There is potential to reclaim and reuse structural timber and separation of wood is important in maintaining the quality of recycled aggregates.

C&D waste is generated across the region from demolition, new build and refurbishment projects at all scales. Major developments such as Heathrow Terminal 5 or the London Olympics site produce local concentrations of all materials, including wood. Modern working practices in C&D industries increasingly allow reuse of materials on site, particularly aggregates. Wood is not so easy to manage on site as it normally needs to be de-nailed and graded before reuse.

Segregation at source gives the best recovery rates for wood with the lowest contamination levels. It is easier to achieve during construction than demolition. On larger sites segregation at source is easier to organise and often results in reduced disposal costs as wood can be delivered direct to a recycler. Many smaller sites still produce mixed waste which is more expensive for recyclers to process. Segregation at source is recognised as best practice in, for example, the Considerate Constructors Scheme[67] and adoption of best practice for segregation is increasing.

Even where wood is collected separately it still comprises a mix of clean and treated solid timber and composite materials. It must be further sorted to produce uncontaminated wood chip suitable for use in non-WID compliant biomass burners. The composition of waste wood from C&D has been studied at sites across England[68], see Table 19. 51.2% of the waste in this study was untreated hardwood and softwood timber, and shows a pattern of high proportions of untreated wood across construction, refurbishment and demolition projects. Pallets are a significant part of this untreated timber. It is considered to be representative of all C&D sites and indicates the assumption by some parts of the wood reprocessing industry that wood from demolition sites contains high levels of contamination is a misconception.

Specialist facilities for recycling C&D waste can increase recycling rates significantly compared to handling through general waste management companies. Techniques for separating demolition waste into its different fractions are increasingly sophisticated. They use either air or water to separate materials of different densities[69]. Large scale plants requiring substantial investment are able to reduce

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[65] http://www.londonremade.com/recycling_reprocessing_construction.asp accessed on 27/08/05
[66] *Wood recovery infrastructure in SE England,* WRAP, op cit.
[67] http://www.considerateconstructorsscheme.org.uk
[68] Seabrook, Gary and Bridgwater, Eric, (2004) Network Recycling, *Compositional Assessment of Treated Wood Waste*, WRAP, Banbury
[69] EnviroCentre Ltd. (undated, 2003?) *A report on the demolition protocol*, London Remade.

the amount of manual sorting. For example, London Remade and Day Group invested over £7m in an aggregates recycling facility in London[70]. There are no large scale integrated C&D waste recycling plants in the London area that produce timber as a commercial product.

That integrated C&D recycling plants can be commercially viable is shown in other countries. For example, in the USA, ERRCO Recycling takes in 227,000 tonnes a year of mixed C&D waste producing metals, aggregate, woodfuel chips and sand for landfill cover. Just 8-9% of oncoming material is not recycled and has to be sent to landfill. Landfill charges are similar those current in the UK at $50-75/ton (£31-46/t) and the fuel chip price at just under £20/tonne delivered is slightly lower than in the UK. The proportion of timber in the waste is much higher than in the UK (55% against <5%), reflecting the popularity of timber frame construction in the USA[71]. The wood chip is separated in a water tank but is produced at around 25% moisture content. retaining high value as fuel. In such a system there would be no separation of clean timber. Despite this the concept of a large scale integrated C&D waste processing facility for London merits further evaluation.

Type of wood	**Type of treatment**								
	Creosote	**Laminated/ Veneered**	**Painted**	**Stain**	**CCA**	**Varnished**	**M-emulsion**	**Untreated**	**Total**
Hardwood						0.46		0.59	1.05
Softwood			2.49		5.53	0.18	1.57	**50.19**	**60.68**
Blockboard									
Chipboard		1.85			9.67			2.45	13.97
Hardboard		0.03						0.24	0.28
Insulation Board									0.00
MDF		0.04	0.42		0.2			1.08	1.74
OSB								9.26	9.26
Plywood		0.18	1.24					11.60	13.01
Total	0.00	2.09	4.16	0.00	15.40	0.64	1.57	76.14	100.00

Table 19. Percentage composition of C&D waste wood.[72]

Skip waste from smaller construction and refurbishment sites is even more mixed than other C&D waste with furniture and large household goods disposed of through this route. Many skip companies have limited recycling facilities and send skips to a landfill site without sorting. Interviews and site visits to landfill operators showed that little attempt is made to recover timber waste. On one site 6m^3 skips are weighed on receipt and if over 2 tonnes they are sent for aggregate and metals to be recycled. Pallets and other timber are manually separated before crushing and screening. These are sent on to specialist timber recyclers. Skips that weigh less than 2 tonnes which would contain a higher proportion of timber are sent straight to landfill.

6.2.2 Packaging waste

Packaging waste, mostly in the form of pallets is concentrated around large areas of industrial and commercial activity such as airports, harbours, industrial estates and retail complexes. Traditional pallets have been used an average of 8 times before final disposal but pallets are increasingly designed as single use items tailored to the specific product that is being shipped.

Packaging is a relatively concentrated source of mostly clean timber, and as such is an attractive source of clean fuel chips. The recent survey for WRAP estimated that packaging provides 30% of waste wood in the South East, 285,000tpa. Much packaging waste is delivered to specialist wood recycling firms at a

[70] http://www.londonremade.com/recycling_reprocessing_construction.asp
[71] January 2005 *From tree to fuel: Woodfuel supply chain infrastructure in the USA* Report of a DTI global watch mission available at http://www.oti.globalwatchonline.com/online_pdfs/36317MR.pdf
[72] Seabrook, Gary and Bridgwater, Eric, (2004) Network Recycling, Compositional Assessment of Treated Wood Waste, WRAP, Banbury

lower cost than disposal to landfill. A typical gate fee is £8-14/tonne against landfill gate fees of £28-42/tonne including taxes in the London area.

6.2.3 Civic Amenity sites

Civic amenity (CA) sites are increasingly separating timber from other waste by providing separate skips for timber waste. This contains a mix of everything from old fence panels and furniture to pallets and off cuts from DIY work.

The composition of wood waste from CA sites was studied recently[73] giving the results summarised in Table 20. A much higher proportion of this is contaminated than for C&D waste with just 14.52% classified as untreated. Interviews with waste transfer station managers showed that most of the untreated wood is pallets which are easy to identify and remove for separate reprocessing.

Type of wood	Type of treatment										
	creosote	laminated/ veneered	painted	stain	cca	varnished	m-emulsion	untreated	unknown	other	total
Hardwood	0.44	0.20	0.14	0.52		0.03		0.19	0.39	0.30	2.21
Softwood	1.04		11.03	8.91	12.56	6.39	0.26	5.57	2.69	0.08	48.52
Blockboard		0.05	0.08	0.04				0.32	0.03		0.53
Chipboard		29.42	0.52		0.79			2.47	0.01	0.14	3.35
Hardboard		1.07	0.67					0.33			2.07
Insulation Board								1.53	0.21		1.74
MDF		1.37	0.82	0.14	0.11	0.04		1.34		0.06	3.89
OSB		0.12						0.32			0.43
Plywood		0.18	1.21	1.16		0.22		2.19	0.44	0.08	5.48
Other						0.11		0.07	1.00		1.18
Not Known								0.20	0.41		0.61
Total	1.48	32.40	14.47	10.77	13.47	6.79	0.26	14.52	5.17	0.67	100

Table 20. Percentage composition of CA waste wood[74]

6.2.4 Wood using companies

More than 1500 companies using wood as their main raw material were identified in Greater London, from sectors shown in the Table 21. In addition waste wood is produced as off cuts by timber merchants and DIY stores. The type of waste varies with the company but in general will include both clean timber and timber contaminated with paint, glues and preservative treatment. In contrast to other sources of waste wood a significant proportion will be sawdust and shavings. This makes it less suitable for use in some combustion equipment, including downdraught gasifiers.

Most of the companies involved are small and produce correspondingly small quantities of waste wood. Some use their waste for space heating and it does not enter the waste wood market. Waste wood from small firms is often disposed of through the major waste management companies using large, 1100 litre wheelie bins. These are collected and mixed with other commercial waste, ending up in landfill.

Potentially, waste sawdust and shavings are a good raw material for pellet production. If clean sawdust is available, pellets suitable for use in all appliances, including domestic stoves can be produced. If the waste contains contaminants pellets can still be produced but must be used in WID-compliant equipment.

[73] ibid
[74] ibid

Type of company	Number identified in Greater London
Balustrade and hand rail manufacturers	18
Cabinet makers	110
Carpenters and joiners	811
Chair frame manufacturers	1
Coffin and casket makers	1
Furniture manufacturers	256
Built-in and fitted furniture	99
Joinery manufacturers	188
Kitchen furniture manufacturers	24
Pallet and case manufacturers	30
Wooden staircase manufacturers	7
wood workers, carvers and turners	45
TOTAL	**1,590**

Table 21. Wood using companies in Greater London.

Further investigation of waste produced by wood using companies is required to quantify how much is available, its composition, the extent of contamination and existing arrangements for disposal. The potential for dedicated collection services for waste wood from smaller companies should be examined.

6.2.5 Markets for recycled wood

Recycled wood chip in the South East currently has two major markets, as a raw material for panel production and as fuel. The end use of waste wood in the South East is summarised in the Table 22. Slough Heat and Power dominate the energy market and have recently increased the amount of recycled wood they can take to 200,000 tpa. The delivered price offered by SH+P at £20-25/tonne is similar to that offered by their main competitors, the panel mills. The panel mills are much further away from London than Slough located in the northern and western Britain (see Figure 9.). Consequently they incur higher transport costs, reducing the return to producers. A significant additional local market such as a biomass CHP at Z-squared would be welcomed by producers of recycled chip in the South East.

The minor markets for recycled wood chip are expected to grow slowly with the only significant increase in demand coming from the energy sector. How fast this will grow is difficult to estimate as there are many small to medium sized projects in the planning stage which, like Z-squared, can be supplied from a variety of sources in addition to waste wood.

End use	Annual quantity ('000 tonnes)
Energy	130
Panels	115
Animal bedding	10
Mulch	10
Equestrian	5
Other	30
Total reused	**300**
Disposed of in landfill	650
Total waste wood	**950**

Table 23. End use for waste timber in SE England[75]

An additional factor is the amount of recycled timber that will be taken by large coal fired power stations for co-firing. To date co-firers have avoided recycled wood, taking the view that it is difficult to demonstrate that recycled wood is non-contaminated and thus WID compliant. The co-firers have concentrated on increasing the supply from energy crops which are required to be 75% of biomass intake by 2011 under the co-firing regulations. Co-firers are increasingly using imported biomass such as oil palm residues or olive stones until such time as energy crops are available. However, the revised guidance to WID makes it clear that pallets are regarded as non-contaminated and there is no barrier to their use as biomass fuel. Once this is more generally known more recycled timber may be used in the three co-firing plants in the South East, at Kingsnorth, Tilbury and Didcot.

[75] WRAP (2005) *Wood recovery infrastructure in SE England*

Figure 9. Location of major recycled wood chip users[76]

6.2.6 Wood recycling industry structure

Waste management companies

Most waste wood is handled by general waste management companies. These are integrated companies that work in all parts of the waste chain from collection to landfill site operation. Wood comprises less than 5% of the total waste stream and is not a high priority for recycling. Most ends up in landfill. 125,000 tpa of wood waste is recovered by waste management companies in SE England of which 30,000 tonnes is delivered to wood recyclers, 40,000 tonnes delivered directly to end users and 55,000 tonnes goes to landfill despite being separated initially. The landfilled part is used primarily for on-site road construction.[77].

The information provided in the WRAP report was supplemented by interviews with 5 waste management companies active in London. They confirmed that timber was not seen as a priority for recycling due to limited markets and the labour intensive methods required to separate timber from the general waste stream. Most waste companies concentrated on recycling aggregates and mixed recyclables collected from households.

The key to increasing timber recovery is to ensure that the net cost of recycling is less than the cost of landfill, currently £35/m^3, to the landfill site operator. With landfill in increasingly short supply diversion of material even at a marginal net revenue is attractive since it extends the working life of a site.

Composting residues

An increasing number of general waste management companies compost green waste to comply with Government targets and European Directives by diverting material from landfill. The final stage of compost production is screening the composted green waste to removed oversized material. Inspection

[76] WRAP (2005) *Wood recovery infrastructure in SE England*
[77] ibid

at the Croydon Council composting site and Viridor's Beddington landfill confirmed that the screened out material is almost all woody biomass with potential as a biomass fuel. This has several advantages:

- It is relatively pure, with only minor contamination from plastics;
- It is relatively dry having been through the composting process;
- There are large quantities in locations with good access for lorries and loading equipment already available on site. For example, the Viridor site at Beddington produces oversize material screened out of finished compost is 40% of the original green waste intake. At the moment this oversized material goes to the landfill site as top cover. It could be sent through the composting system again but this is not very effective in further breaking down this woody material.

Potential problems include:

- the physical characteristics of the screened out material which tends to knit together. This may cause difficulties in final use. It may bridge in the in-feed systems of smaller boilers and fail to flow satisfactorily into the combustion chamber
- screened out material is difficult to process with currently available machinery[78]. Trials are under way but suitable chipping equipment still has to be identified.
- as with other biomass fuels best results are obtained with moisture contents under 25%. Methods being developed to dry fresh wood chips should be applicable to material screened out of composting systems.

Until the quality of compost screenings as fuel are proven and processing techniques developed it is more appropriate for them to be used in larger applications tolerant of a wider range of chip sizes and moisture contents, or in district heating or CHP systems with low grade heat available for drying. Potentially it is a cheap source of biomass available in large quantities. Assessment of its potential for use as fuel at Z-squared requires further work on its composition and development of effective processing methods.

Wood recyclers

Specialist wood recycling companies were originally set up to supply wood chip to the panelboard industry. However, London and the South East are remote from the main centres of production. The South East is a more expensive source of raw material for the panel mills due to long distance the chip must be taken. Consequently, the volumes taken from the South East vary considerably.

Wood recyclers generally collect wood from a restricted geographic area or wood of the particular type required by their customers. This is in contrast to general waste management companies which have complete regional or national coverage and an obligation to accept a wide variety of wastes. In the South East wood recyclers recover 210,000 tonnes of waste wood directly from source of which 80% is delivered in by the client to the recycler. Much of this is pre-sorted before delivery. An additional 30,000 tonnes is delivered in by general waste management companies. Currently only a small amount of wood processed by recyclers originates at CA sites but this is expected to rise as segregated wood collection is introduced at more CA sites.

In the past many recyclers have accepted only clean waste wood as this was required by the panelboard industry. Now, mixed waste is more readily accepted. All wood is weighed on receipt and a gate fee charged to the supplier. This is currently £8 – 14 per tonne for mixed wood waste[79] but varies with locally available markets, the amount and type of contaminants, and cost of landfill locally. Additional markets could be served immediately and would be welcomed as a chance to diversify by wood recyclers. There is an estimated 100,000 tonnes a year excess capacity in wood recyclers in SE England[80].

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[78] Myles MacKay, personal communication
[79] http://www.letsrecycle.com/prices/woodArchive.jsp
[80] *Wood recovery infrastructure in SE England,* WRAP, op cit.

Chip quality

The quality of chip produced from recycled wood is variable. Chip from recycled wood seen on a visit to SH+P was anything from crudely crushed pallets (rejected by SH+P) to consistently sized chip within their specification. Much recycled chip is produced using shredders and tends to knit together more easily than chip from forestry style chippers, leading to an increased probability of bridging, especially in small scale equipment.

Figure 10. Chip made by a forestry chipper

Figure 11. Chip made using a shredder

A further problem is that despite a specification that requires nails to be removed chip from recycled timber was not entirely clean. This could lead to serious operational problems in equipment with a fixed grate, such as a downdraught gasifier, and increased wear in other types of combustion plant. At Z-squared, incoming chip from recycled sources could be screened to remove oversize chip and metals taken out with overhead magnets. The oversize chip could be reprocessed. Obviously, this would increase the capital cost of the Z-squared plant. Working with suppliers to ensure they understand the specifications and rigidly enforcing the specification for incoming chip may be a more cost effective way of achieving acceptable chip quality.

6.3 Conclusions

There is considerable potential for increasing wood chip fuel production from waste with under-utilised capacity at present. Further development of the supply chain depends on a growing market. Segregation of contaminated and uncontaminated timber is important as failure to do this will lead to recycled timber being rejected for use in non-WID equipment. To overcome this difficulty a mix of larger, WID compliant fuel chip users like SH+P and smaller non-WID-compliant plants are required to make best use of waste wood. Z-squared could be built as a WID-compliant plant but if sufficient supplies of clean timber are available it would save capital costs, simplify management and make ash disposal easier if Z-squared used only clean wood chip.

Significant amounts of sawdust and shavings are available within London, particularly from smaller wood using companies. Sawdust and shavings are a good raw material for pellet production. If the waste is uncontaminated and can be proved to be so the resultant pellets can be used in any equipment, including small domestic pellet stoves and boilers. Pellets can also be made from contaminated wood provided the pellets are then used in WID compliant boilers

The supply chain can be developed through two approaches:

1. Increase segregation at source, including CA sites and work with waste management companies to increase diversion before wood enters the general waste stream. The potential for dedicated

collections from smaller wood waste producers should be assessed with the aim of lowering disposal costs to producers and providing low cost fuel for biomass users
2. Develop new working methods to separate wood from the general waste stream, especially pallets, other packaging and C&D waste.

C&D waste offers good potential to increase production of both clean and contaminated wood chip. Techniques for the separation of wood from demolition waste are increasingly sophisticated. Experience in other countries such as the USA is available to guide developments in the South East.

Waste from CA sites and construction projects have higher levels of contamination than other sources of waste wood making them less attractive as a fuel source for Z-squared. Packaging, demolition and post manufacture waste offer the best potential to increase supplies of clean wood chip for Z-squared.

In the longer term, composting residues cold prove to be a significant new source of biomass fuel. Development work is needed to confirm suitability for fuel production and to develop practical production methods to ensure consistent high quality.

The amount of wood chip that can be provided for Z-squared from waste depends on the acceptance by DEFRA and the Environment Agency that recycled wood is clean and not subject to the WID. Robust methods to separate clean and contaminated timber before chipping are required. If these are available up to 15,000 tpa of wood chip at 25% mc could be available from waste, even with increased intake by SH+P, co-firing in power stations and use of uncontaminated waste derived wood chip by smaller biomass heat boilers.

6.4 Further work required

The diversity of waste wood streams and the variety of collection and processing routes means several actions are needed to further develop waste wood as fuel. These include:

- investigation of the potential for a London wood pellet plant using sawdust and shavings from wood using firms and supplying the growing number of domestic pellet users;
- evaluation of the potential for a dedicated wood waste collection service for small wood using businesses to divert it from the general waste stream;
- promotion of segregation at source in C&D industries spreading from large to smaller sites;
- support to LAs considering the introduction of wood waste collection on CA sites;
- more detailed investigation of capacity in wood recyclers, working with them to meet the fuel specifications for all sizes of boiler and CHP, including Z-squared;
- full assessment of the potential of compost screenings as fuel, to include:
    - composition of the screenings and any contaminants such as grit, stones and plastics;
    - suitable equipment for processing the screenings into a consistent sized fuel;
    - cost effective means of drying the material prior to use as fuel;
    - the total quantity potentially available for fuel;
    - likely costs of production and an economic evaluation of its use as fuel.

7 Sawmill co-products

SE England has historically been a centre of hardwood sawmilling, reflecting the predominance of broadleaved woodlands in the region. However, the last 30 years have seen a steady consolidation of the industry with many medium sized and large mills merging or closing, in common with hardwood sawmills elsewhere in the UK. This is reflected in the declining volumes of hardwood logs processed by sawmills included in the Forestry Commission's annual *Timber Statistics* reports (see Figure 12 and Table 24.)

There are few large softwood sawmills within easy reach of Z-squared. The most significant is some 90 miles away, near Southampton. Many smaller sawmills process both hard and softwoods.

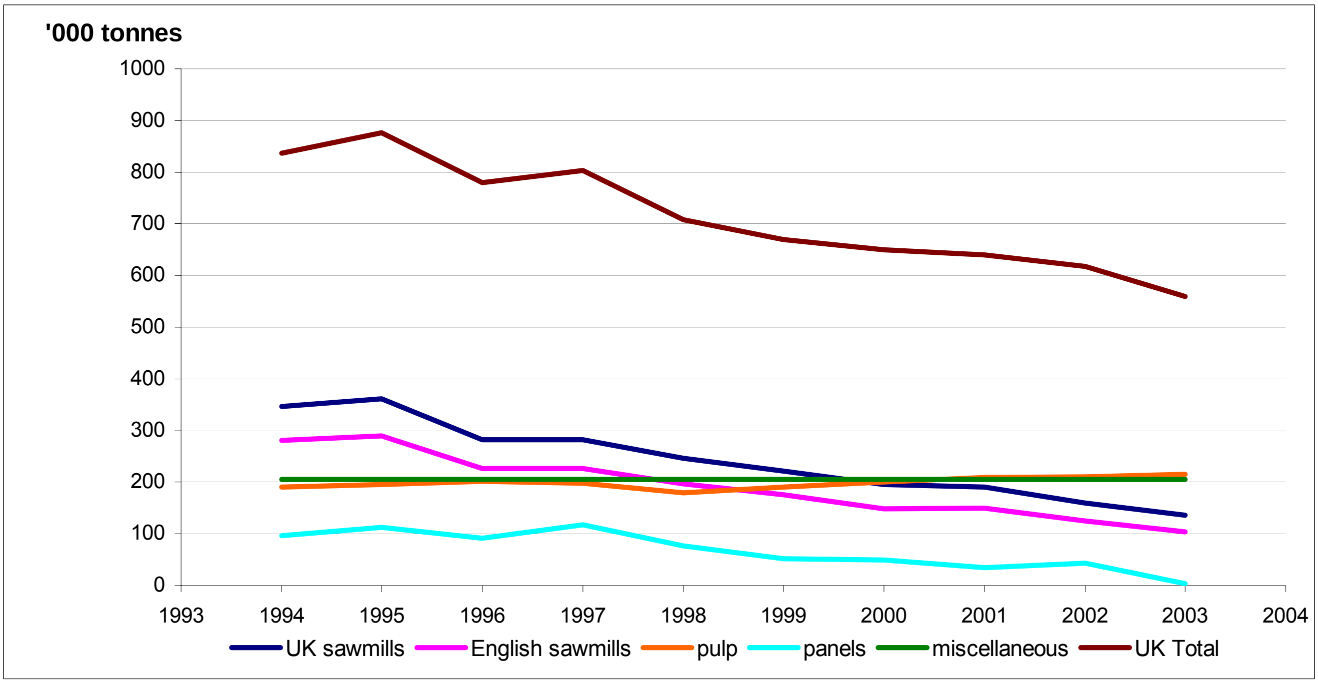

Figure 12. Volumes of hardwood timber reported as used in England[81]

The reasons for the failure of sawmills in the South East are complex and include:

- increasingly competitive imports from North America, Eastern Europe and elsewhere;
- substitution of hardwoods with plastics and treated softwoods in many uses;
- high cost of labour in SE England and competition for that labour from other employers, leading to a shortage of skilled manpower;
- lack of investment sawmills (e.g. in kiln drying) leading to poor quality products not well accepted in the marketplace;
- a fragmented industry with many smaller sawmills leading to lack of economies of scale which would allow the benefits of investment and automation to be gained;
- the decline of the traditional rural estate where the woodland often supported a small sawmill producing for the estate and other local users;
- poor uncoordinated marketing from a fragmented industry, giving problems of quality, market profile and consistency of supply; and
- poor access to the main marketing channels through timber merchants, hence a lack of recognition of the qualities of the available timber from specifiers and end users.

[81] Forestry Commission Timber Statistics reports.

Year	UK sawmills	English sawmills	pulp	panels	miscellaneous[82]	UK Total
1994	346	281	190	96	205	837
1995	362	290	196	113	205	876
1996	282	226	202	91	205	780
1997	282	227	198	118	205	803
1998	246	197	180	77	205	708
1999	222	176	191	52	205	670
2000	195	149	200	50	205	650
2001	191	150	209	35	205	640
2002	160	125	210	43	205	618
2003	136	104	215	4	205	560

Table 24. Production and use of hardwood logs in the UK.[83]

Successful sawmills, both large and small, have concentrated on adding value, often finding niche markets for specialist products. An example is Norbury Park Sawmill near Dorking in Surrey, which produces a wide range of oak waymarkers and noticeboards, widely used by local authorities and other public bodies. There is though a potential oversupply of hardwood sawlogs in the SE with more growing each year than are being harvested. One recent development is an increasing number of very small and mobile sawmills operating around the region, often cutting a few trees on each site.

7.1 Large sawmills

There are two large hardwood sawmills in the region. One is RF Morgan & Co. of Strood, Kent, 25 miles from Z-squared. Until recently this processed imported and UK produced hardwood logs and was a significant consumer of logs from the SE. When last visited in 2003 it was making large quantities of chip suitable for use at Z-squared. However, the mill no longer saws logs but buys in ready sawn timber for further processing to their customers specifications[84]. Wood chip production from this process is negligible. Morgans has been discounted as a source of wood chip for Z-squared in this report. The main waste products from the mill are sawdust and shavings, presently sold to board mills. These are relatively dry and would be a suitable feedstock for a wood pelleting mill.

The second is W.L. West & Sons based near Petworth, East Sussex who are one of the larger hardwood sawmillers in the country, certainly the largest hardwood sawmill in the South East. It is 80 miles from the likely Z-squared site. They are keen to develop markets for the waste timber they produce, including wood chip for fuel. Around 1000 tonnes at 25% moisture content (1350 green tonnes) of waste timber suitable for wood chip are produced each year (Dave West, personal communication).

There are no large softwood mills close to Z-squared. The nearest large mill is RF Gidding & Sons of Totton, near Southampton, some 115 miles from Z-squared. Before a fire in late 2004, Giddings were sending approximately 50,000 green tonnes a year of wood chip as fuel to Slough Heat and Power. The mill is being rebuilt and is due to reopen in early 2006 when chip will once more be available. A wood chip fuelled on-site CHP was being considered by Giddings but no decision has been taken to go ahead with this. If it is installed availability of chip for other users will be reduced. Due to its distance from Z-squared and the uncertainty over the supply, Giddings has not been included in the estimate of wood chip available for Z-squared. It is worth considering as a back up supplier in case of supply problems elsewhere.

[82] includes local firewood and charcoal production and unsawn fencing. There is no reliable survey or data source for hardwood harvested from woodlands except those owned by the Forestry Commission. Non-FC hardwood timber production is estimated
[83] Forestry Commission
[84] Phone interview on 2nd August 2005.

7.2 Other sawmills

A search for sawmills using the yellow pages website listed 43 in South East England[85] and a further 27 were found advertising in two recent *Woodlots* newsletters[86] and the Surrey County Council website[87] (see Appendix 11). Some of the latter are mobile mills that leave small amounts of waste in many places. Many are the result of other forestry contractors or tree surgeons diversifying and adding value to their output. All except the largest mills are of limited value as a source of wood chip for Z-squared since they produce at most a few hundred tonnes of waste suitable for chipping a year, and often have established disposal methods for their waste, such as local firewood or charcoal markets.

There are a number of estate-based sawmills still operating in the region for example those on the Balcombe Estate, Cowdray Estate and the Norbury Park Sawmill near Dorking which is now run by the Surrey Wildlife Trust. All produce several hundred tonnes of 'waste' each year but this is often used for firewood or may be used as wood chip fuel within the estate (as the Cowdray Estate plans to do). The Norbury Park Sawmill does not have such good outlets for its waste, has a continuing disposal problem as their business expands and recently brought in a contractor to make wood chip from their waste to sell to SH+P.

7.3 Wood chip available for Z-squared

The supply of wood chip as sawmill co-product is limited, yet still worth considering as it is concentrated in a few locations. A total of equivalent to 2200 green tonnes is estimated to be potentially available as shown in Table 25.

	weight available (tonnes)	equivalent weight (oven dry tonnes)	equivalent weight (green tonnes)
W.L. West & Sons Ltd[88]	800 @ 25% mc	600	1090
Estate sawmills (e.g. Balcombe, Norbury Park)[89]	600 @ 30% mc	420	763
Smaller sawmills**	300 @ 30% mc	210	381
TOTAL		**1230**	**2234**

Table 25: ODT equivalent of sawmill wood chip available for Z-squared

[85] SE England covers Kent, E. Sussex, W. Sussex, Surrey, Hampshire, Oxfordshire, Buckinghamshire and Hertfordshire
[86] The *Woodlots* newsletter covers Kent, E. Sussex, W. Sussex and Surrey.
[87] http://www.surreycc.gov.uk/sccwebsite/sccwspages.nsf/LookupWebPagesByTITLE_RTF/Sawn+timber?opendocument last accessed 18/08/05.
[88] 25% moisture content as on site kilning facilities, a mix of kilned and green material
[89] 30% moisture content, off cuts air dried

8 Wood chip markets and their likely development

The raw material from which wood chip is made can be sold into other markets and wood chip has a number of uses aside from fuel. Upstream and downstream alternatives both influence the availability and cost of wood chip for fuel and are considered below.

A significant alternative market for round timber from both forestry and tree surgery is as firewood. Also, around 200,000 tpa of small roundwood from forestry is sold as pulpwood to South Wales. Neither of these markets is expected to show significant growth in the foreseeable future, nor will they constrain the amount of timber available as fuel chip for the next 5 years.

Once chipped, there are several different markets available. Table 26 summarises the suitability of chip from different sources for various markets. As better processing technologies become available, the end markets for chip from a particular source expand. The Waste and Resources Action Programme (WRAP) has funded development work and supported processing capacity leading to the acceptance of recycled wood chip in a number of different market sectors.

	Market:						
Source	**Panel manufacture**	**Pellet fuel manufacture**	**Biomass power station & CHP (including Z-squared)**	**Co-firing**	**Smaller heating & CHP**	**Surfacing**	**Mulch**
Tree surgery	No, mixed species and bark percentage unacceptable	No, too much bark and leaf , too wet	Yes, increasing	No information	Yes if screened and dried	Yes, major use for footpaths and equestrian	Yes, major use
Forestry	Yes, softwood preferred but moving to recycled chip	Not yet used	Technically suitable but other fuels are cheaper	Yes, trials at Drax and other power stations	Yes, must be seasoned to under 30% mc for some systems	Suitable and used but competition from cheaper alternatives	Suitable and used but competition from cheaper alternatives
Energy crops:							
SRC	No	No, bark content high and too costly	Yes, if funded under Bio-energy Capital Grants will have to use energy crops	Yes, will have to use 75% energy crops	Yes, but expensive unless grown for own use	Suitable and used but cheaper alternatives	Suitable and used but cheaper alternatives
Miscanthus	Trials have been made but no large scale use	Not known	Yes but may be fuel handling/processing issues	No information	No	No	No
SRF	Yes, potentially	Similar to forestry	Yes. Expensive?	Yes. Expensive?	Yes, potentially	Yes, but costly.	Yes, but costly.
Waste wood:							
Packaging **C&D** **CA sites** **Post-manufacture**	Yes, clean chip from waste a major and growing source of raw material	Yes, clean chip very suitable. Pellets from contaminated wood for use in WID compliant boilers.	Yes, clean chip very suitable. Contaminated chip for use in WID compliant boilers.	Yes, clean chip very suitable. Contaminated chip for use in WID compliant boilers.	Yes, a good value fuel, but only clean chip acceptable	Yes, promoted by WRAP	Yes, promoted by WRAP

Lesser amounts of wood chip are used for animal bedding and in in-vessel composting systems.

Table 26. Acceptability of wood chip from different sources in end markets

The fastest growing use for biomass in SE England is as an energy source. Large scale power generation has been led by Slough Heat and Power which is expanding its intake of wood chip. Other large scale biomass power and CHP plants have been proposed in other regions, most notably SembCorp Utilities' CHP on Teeside which will use 300,000tpa of wood chip.

Co-firing of biomass with coal is being trialled in the large power stations at Didcot, Tilbury and Kingsnorth using several types of biomass including imported oil palm waste, cereal residues and olive stones. The impact of co-firing on the overall biomass market is uncertain since:

- the proportion of biomass used is low at the moment but may increase as operators become familiar with the different fuels and their preparation. The trend may be a gradual increase in the amount of biomass used for co-firing;
- 75% of the biomass is required to be energy crops by 2011 under the regulations for the Renewables Obligation, so a large demand for biomass from other sources may only be short term;
- in the short term the generators may find importing biomass more profitable;
- uptake of co-firing and planting of energy crops has been slower than anticipated.

Drax Power, in Yorkshire, which currently produces 7% of the UK's electricity now co-fires commercially and is actively seeking wood and other types of biomass. As power stations in the South East move towards commercial co-firing demand for biomass produced in the region will increase. The overall effect on supply and demand is expected to be modest for installations within London and the Thames Gateway since the price paid by large power generators for biomass other than energy crops is expected to be similar to SH+P. CHPs such as proposed for Z-squared and smaller heat only installations can afford to pay higher prices as they tend to have higher overall efficiencies.

The number of medium and small scale biomass boiler and CHP installations is expected to grow rapidly driven by the planning requirements for renewable energy in London and the favourable lifetime costs for biomass boilers. Adoption of biomass is also expected to grow outside London, for example with the installation of a biomass CHP as part of the Bracknell town centre development. At present, there is not a commercially proven small scale (less than 1 MW_e) CHP system available. When one becomes available uptake will probably be rapid. There are many projects in the feasibility and planning stages. Over the next 5 years there may well be 100 biomass thermal installations in and around London, each using around 200tpa of wood chip. 20,000tpa of wood chip is a large quantity, but well within the potential production of London.

The probable development of the market over the next 5 years will not approach the limits of what could be produced in the South East. Increased wood chip fuel use will further develop the supply chain infrastructure. Larger numbers of chip suppliers and users working within the wood resource limits will add confidence to people considering installing wood chip systems and spur additional investment from producers.

9 Carbon intensity

Biomass fuels, including wood chip, are not strictly carbon neutral. Fossil fuels are used in growing, processing and transporting biomass as well as in the manufacture of the plant and equipment used at all stages in of production and use.

A detailed analysis of the carbon intensity of the different fuels is outside the scope of this report. However, the carbon cost of the wood chip use at Z-squared can be minimised by:

- avoiding fuels that are grown intensively, for example using large amounts of artificial fertilizers and herbicides, or that require irrigation unless as part of a foul water treatment strategy;
- minimising the transport distance;
- considering what would happen if the wood chip were not used for fuel. For example, a proportion of arboricultural waste is still landfilled where it may give rise to methane emissions, 20 time more potent than carbon dioxide as a greenhouse gas;
- ensuring that drying of chip is done in a way that avoids fossil fuel use, for example by using low grade waste heat from the Z-squared CHP.

These factors tend to favour fuel made from tree surgery arisings or waste in the locality of Z-squared. These are produced in any case and can be regarded as 'free' in carbon terms when they are discarded. In common with wood chip from other sources, they incur a carbon cost for processing and transport to the final point of use.

The carbon cost of forestry material is determined almost entirely by the harvesting, chipping and the distance it has to be transported, since planting and tending woodlands in the South East tends not to use heavy equipment or fertilizers. Timber stacked on forest roadside will dry to below 30% mc over a few months. For SRC and Miscanthus, inputs of energy used in site cultivation, fertilizers and herbicides are made during the establishment phase with few subsequent inputs other than harvesting and fertilization with low energy intensity sewage sludge or similar products. However, transport distance may be significantly longer than for fuels from waste.

10 Developing a supply chain for Z-squared

With an annual requirement for 35,000 odt of wood chip, Z-squared will add to the increasing demand for biomass fuels. New investment will have to be made to access the different biomass resources potentially available across the capital. Z-squared is expected to stimulate investment by others involved in wood processing rather than invest directly in the supply chain. The main sources of uncontaminated biomass in and near London are arboricultural arisings, forestry timber, waste pallets, and waste wood collected by local authorities at civic amenity sites, construction waste and post-manufacturing waste. Very few energy crops of short rotation coppice or miscanthus have been planted in SE England and it would take several years to establish a significant energy crop resource.

Biomass is a bulky, low density, low value product. Chipping at the point of production or collection is often required to increase amounts loaded on lorries and to ease material handling. Delivery to Z-squared will be by walking floor or tipping bulk lorries of around 70-90m^3 capacity or in 30m^3 hook lift bins. These are readily available for hire.

A fundamental decision is whether or not to have wood chipping, screening and contaminant removal facilities at Z-squared, or follow the model of Slough and buy in all biomass ready processed. The advantages of having chipping facilities at Z-squared are:

- quality control can be strictly enforced protecting the investment made in the CHP itself and aiding reliability;
- it enables a buffer stock of small roundwood timber on site, provided space can be made available in a high density development. By having a stock of 4 weeks timber on site the security of the fuel supply is ensured;
- flexibility is built in to the supply arrangements, in particular a much wider range of forestry and SRC materials will be available to Z-squared, adding to security of supply and overcoming any under-capacity in the supply side as the market develops;
- transport and handling of fuel is minimised, shortening the supply chain and potentially saving costs and environmental impacts
- The overall cost of chip may be lower than for buying in processed chip since a large chipper at Z-squared, fully utilised will have higher productivity in terms of both fuel and labour.

The disadvantages are:

- a higher capital investment;
- more space is needed if a buffer stock of logs is to be kept on site for fuel security;
- processing on site may not fit well with nearby residential or commercial areas. This may restrict where the energy centre is built.

Where ready-processed chip is bought, payment should be on a net energy content after taking account of the moisture content. Simple, robust sampling procedures are in use in other countries. If logs are bought, current industry practice should be followed.

Each source of wood chip has different infrastructural needs to establish or expand the supply and meet the quality requirements for fuel. These are considered below.

10.1 Tree surgery arisings

Some larger tree surgeons already supply wood chip fuel to SH+P but this is to a less exacting standard than required for smaller boilers where smaller chip sizes and lower moisture levels are often required. The specification for Z-squared is likely to be closer to SH+P than the specification for smaller boilers. A series of aggregation centres around London are needed where wood chip and logs can be dropped off by contractors. They must be convenient for tree surgery contractors, particularly small firms, to drop off waste. They could be based at existing facilities such as waste transfer stations or yards already operated by tree arboricultural contractors. They should aim to:

- minimise transport distance for contractors and delivery to Z-squared;
- make sure the material is handled as few times as possible; and
- collect sufficient biomass for large scale, low cost processing.

Having a larger number of aggregation points will increase overheads and make it difficult to justify investment in facilities for high quality wood chip fuel production. A compromise of 5 or 6 aggregation yards around London is the most likely outcome.

The infrastructure and equipment required to produce high quality wood chip fuel from arboricultural arisings is:

- space and concrete hardstanding with good access for large vehicles;
- covered storage for finished product which will allow further drying;
- a weighbridge for incoming and outgoing chip measurement;
- screening facilities to remove oversize chip and other contaminants;
- a chipper capable of chipping the large diameter logs;
- simple, low cost drying facilities; and
- materials handling equipment for logs and chip.

Some equipment, such as the chipper can be bought in mobile configuration and shared between several sites, moving from one to another as logs accumulate.

Experience at the Croydon TreeStation, which has recently started production, will enable lessons to be learned which can be applied elsewhere. The Croydon TreeStation was set up by BioRegional with the support of London Borough of Croydon both as a demonstration project and to supply fuel for the Croydon area on a commercial basis. It is now being run in partnership with City Suburban Tree Surgeons Ltd. The capacity of the site is 6,000 tonnes a year, smaller than would be required in other aggregation centres around London.

Based on evaluations in this report large drum chippers are the most appropriate type of machine for use in London. They are able to process both arboricultural arisings and, provided the correct blades are fitted, are equally capable of chipping waste pallets and clean timber from demolition sites. Drum units are capable of chipping material across the full width of the drum, and can therefore incorporate a larger in-feed ‘throat’ than equivalent sized disc machines, whose intake is limited by the radius of the disc.

10.2 Forestry

There is an existing supply structure for forestry material which previously supplied sawlogs to local mills and small roundwood to pulp mills in Kent and South Wales. The pulp mill in Kent closed some years ago and the only large user of small roundwood from the region is the St Regis pulp mill in South Wales. Woodland work is at a historically low level and shortage of skilled manpower is reported in the South East. However, as chip prices rise in line with fossil fuels the supply of small roundwood for chipping is becoming increasing attractive.

No specific activity is required to further develop the forestry supply chain by Z-squared. It should respond to price signals. Supply could be in the form of logs for chipping at Z-squared or chip delivered straight from the field. Chipping into trucks is common practice in other countries and fits in well with the pattern of forestry operations. Chip from forestry operations is normally of high quality provided chipping equipment is well maintained.

One change in working practices that may be necessary is to season the timber in the woods before chipping to achieve a moisture content of 30% or below.

10.3 Energy crops

Under current arrangements, grants for energy crops are only made where there is a supply agreement with an end user such as Z-squared. Some SRC and miscanthus may be available on the open market, but only very limited amounts within reach of Z-squared. Because of the long term relationship between the grower and end user it is possible to tailor the chip to the specification best suited for the combustion equipment.

SRC or other energy crops will not be planted in anticipation of the Z-squared CHP. Once construction is agreed, work with landowners and farmers to start planting energy crops can start. Several companies and other organisations now offer to organise energy crop supply for large users such as Z-squared.

SRC could be chipped during harvesting and delivered green but this reduces its effective energy content unless there is a separate drying process. Perhaps better for Z-squared is harvesting SRC as billets or in bundles which, unlike fresh chip, dry without composting over 3-4 months. Once dry, these could be chipped in field or delivered in to Z-squared and chipped just before use. In any case, mobile equipment already available on farms will be used and no specific investment in infrastructure is required to secure the supply for Z-squared.

10.4 Sawmill co-products

Sawmill co-products are normally chipped on site and dispatched as soon as possible. They have moisture content which depends on how the waste is generated. A large softwood mill, such as Giddings, produces chip with moisture content over 40% whereas a hardwood mill resawing seasoned timber will produce wood chip at 25%. Payment for sawmill co-product should be adjusted for moisture content.

10.5 Waste wood

The existing specialist wood recyclers can offer a good quality chip cleaned of nails and other metals, from their existing operations. Whilst potential to expand their output by 100,000tpa is reported by WRAP much of this will be taken up by large users such as SH+P and additional capacity will be needed.

Some of this may come from current recyclers investing further in their businesses as the market grows but the largest potential for increasing wood chip recycling lies with the general waste management companies. They are recycling increasing quantities of wood, including that separated at CA sites, but opportunities exist for additional capacity particularly targeting C&D waste. There is potential for an integrated site that recovers wood along with aggregates and metals from C&D waste. This would be a major investment of the sort made by London Remade and the Day Group in 2003 for aggregates and glass. The wood chip resulting from such a site would contain contaminated timber and could only be used in WID-compliant equipment.

The large number of small wood using firms which produce segregated wood waste presents an opportunity to recover high quality wood fuel since most of the timber used is kiln dried to around 15% mc. There may be potential for a dedicated collection service but before any scheme is set up a more detailed investigation of the type of waste produced (sawdust and shavings, chips or offcuts; clean or contaminated), and where it is produced is needed. This will allow its suitability for wood chip or pellet production to be assessed. If there is sufficient available a wood pellet mill for London may be justified. Depending on the technology chosen, pellets may not be useful for Z-squared.

10.6 Infrastructure required at Z-squared

If chipping facilities are set up at Z-squared, the infrastructure needed will include:

- Sampling facilities to test for moisture content and pay on the basis of net embodied energy. This is common practice elsewhere in Europe and gives an incentive to suppliers to improve fuel quality. Tests should be done to monitor contamination levels and loads rejected if necessary.
- Screening to remove oversize chips and debris and equipment for the removal of metals and other contaminants as wood chip is received into the plant. Oversized reject chip will be re-chipped on site or, if contaminated with plastics and other waste transferred to Z-squared's energy from waste plant. Experience at Slough Heat and Power shows significant levels of contaminants can be expected. At Slough these have led to increased wear on the boilers and significant downtime over the past two years. Z-squared has an advantage as a new system in that some problems can be eliminated at the design stage.
- In-house chipping to process locally produced arboricultural arisings, clean waste wood, forestry material and perhaps short rotation coppice delivered to the site. Chipping on site has the potential to reduce transport, avoid double handling and give strict control of contamination.
- A yard to hold a buffer stock of logs in case of supply difficulties. Logs are preferred to chips since they can be stored for over one year without significant deterioration. The size of the logyard will depend on available land and how many weeks supply storage is required.
- Consideration should also be given to including drying facilities at Z-squared using low grade waste heat from the CHP.

10.7 Z-squared fuel supply strategy

The fuel supply to Z-squared should aim to source its fuel:

- locally wherever possible
- from forestry and energy crops to contribute to biodiversity conservation and the rural economy
- to use waste that might otherwise go to landfill
- in a cost effective way and
- in a way that minimises the carbon intensity of the fuel supply.

The fuel mix in Table 27 is a 'mature' mix for the Z-squared CHP, i.e. what is expected after the supply infrastructure has developed in the first few years:

	Moisture content %	Fresh tonnes a year	Oven dry tonnes a year	% of total ODTs	Cost £/tonne delivered	Cost £/odt
Tree surgery waste	45 or	20,000	5,500	15%	20	45.45
	30 if dried		7,000	19%	40	57.14
Forestry	45	9,000	5,000	14%	32	58.18
Sawmill co-product	30	1,700	1,250	3%	25	35.71
Clean waste wood	25	15,000	11,250	31%	25	33.33
Energy crops	30	9,300	6,500	18%	42	60.00
Total		**55,000**	**36,500**			
Average cost					**30.80**	**47.95**

Table 27. Breakdown of wood chip supplies for Z-squared including clean waste wood[90]

[90] 1. Energy crop cost assumes SRC , miscanthus is around £45/odt if it is suitable for use in Z-squared
2. Drax Power are offering 45/ odt delivered for short rotation coppice Reported by Gareth Gaunt of Renewable Energy Growers Ltd. on the BBC's Farming Today programme, 29th June 2005. The price above is based on production costs estimated in the WINBEG fuel review.
3. SH+P pay on weight, with a reduction if the chip is very wet. £20-25 is paid for green chip at an average moisture content of 40%. They are looking at assessing moisture content on incoming loads and paying according to net energy content.

For a least cost fuel supply, the proportion of waste wood should be maximised. Over-reliance on this single source of wood chip would render Z-squared vulnerable to markets changes such as an uplift in the price paid by panel mills for recycled chip. Processing capacity on site, including drying using low grade waste heat, would enable cheaper unprocessed tree surgery waste to be effectively used, avoiding competition with smaller biomass installations for higher quality screened and dried tree surgery waste.

It is unlikely that the full amount of energy crops or tree surgery waste will be available at the start up of the CHP. Additional supplies of sawmill co-product and forestry small roundwood from further than 40 miles away can make up the Z-squared CHP's requirements. A move to more locally-produced tree surgery waste and energy crops will reduce the carbon cost of the fuel supply without affecting the overall fuel costs.

If it is decide not to use waste wood due to the possibility of contaminated timber being included in the supply, a more proactive approach to developing alternative local fuel sources will be required. The quantity of tree surgery arisings could be increased, particularly if SH+P moves to taking a higher proportion of waste wood. Taking forestry timber from more than 40 miles away will greatly increase the potential supply from Kent, Sussex, Surrey and Hampshire. In the longer term, more energy crops can be established within easy reach of Z-squared. Not using waste timber will increase the average fuel cost to Z-squared to £52.77/odt.Table 28 summarises a probable wood fuel supply scenario if it is decided not to use waste wood.

	Moisture content %	Fresh tonnes a year	Oven dry tonnes a year	% of total ODTs	Cost £/tonne delivered	Cost £/odt
Tree surgery waste	45 or	27,000	7,800	21%	20	45.45
	30 if dried		9,000	25%	40	57.14
Forestry	45	21,725	11,950	33%	32	58.18
Sawmill co-product	30	1,700	1,250	3%	25	35.71
Energy crops	30	9,300	6,500	18%	42	60.00
Total		**59,725**	**36,500**			
Average cost					**32.25**	**52.77**

Table 28. Breakdown of wood chip supplies for Z-squared excluding waste wood

4. Biomass boilers have higher capital costs than similar sized natural gas boilers. To maintain competitiveness with natural gas and give a realistic payback time for extra capital cost a delivered price of £40/tonne at 25% moisture content for fuel is quoted in London (Stewart Boyle, Wood Energy Ltd., personal communication).

11 Conclusions

The supply chain for wood chip fuel in SE England is only now becoming established in response to the demand from SH+P. The rapid growth in wood chip use at Slough over the last 5 years shows that the fuel supply chain can respond even from a very low level of activity.

Organisations considering installing wood chip systems for heating or CHP are very often concerned about the availability and security of the fuel supply. Investigations for this report showed that the potential fuel supply from London and its immediate environs is large and will not constrain biomass use in the medium term. A minimum estimate of the fuel available annually from the different supply sectors, after allowing for present users, is given in Table 29

Source of woodchip	moisture content %	fresh tonnes	equivalent weight (oven dry tonnes)
Tree surgery waste	45	50,000	27,500
Forestry	45	150,000	82,500
Sawmills	30	2,000	1,400
Waste wood in London	25	200,000	150,000
Energy crops	30	100,000	70,000
Total		**502,000**	**331,400**

Table 29. Potentially available wood chip fuel in and around London

Z-squared’s requirement is a maximum of 35,000 odt. This can easily be accommodated within the potentially available fuel. The likely breakdown of sources for this is given above in section 10.7.

The drivers for development of wood heating and biomass CHP in London are:

- The Mayor’s requirement for 10% on-site generation of renewable energy in large developments;
- rising prices for natural gas and other fossil fuels;
- in some cases, the rising cost of alternative disposal as waste to landfill;
- corporate social responsibility programmes which increase awareness of environmental issues and the need for a low carbon economy.

The industry and wood chip supply chain are still at an early stage of development. The emergence of SH+P as a large has driven development so far. Producers of lower cost sources of biomass: waste wood, sawmill co-products and tree surgery arisings were the first to invest in supply infrastructure. At current prices of £20-£25 per tonne delivered it is not economic to supply SH+P with chip from woodland or energy crops except as a by product of other activities such as heathland restoration.

Following a marked increase in interest in biomass heating systems under 1MW, the market for high quality fuel chip suitable for these smaller boilers is expected to start growing rapidly within 2 years. New investment in wood chip fuel production facilities will be required if local sources of wood are to be used. Potential investors include existing forestry contractors, wood recycling companies, tree surgery companies, waste management companies and community wood recycling initiatives.

Very large users of biomass, such as the 3 power stations in SE England may also step up intake of biomass in the next 2 years. So far they have had no impact on the supply of wood chip since, unlike Drax Power in Yorkshire, they are still at a trial stage for co-firing. Also, they have eschewed waste wood and relied on imported biomass (palm oil residues, olive stones, almond shells etc.) leaving this source of wood chip available for others. As they move to full scale co-firing local power stations may follow Drax’s example and start buying local timber.

The long term effect of co-firing on regional wood chip supplies is hard to evaluate. By 2011, 75% of their biomass must come from energy crops. The rest could be sourced locally or imported. The impact on local woodfuel markets is expected to be slight as the higher efficiency of biomass heating systems compared to power generation enables them to pay more for fuel. Even if a shortage of ROCs caused their price to rise steeply power stations are likely to turn to imported biomass rather than local supplies.

The biomass fuel market is expected to become the dominant use for recycled timber and tree surgery waste in the region, contributing to national waste management targets. As prices for biomass rise:

- new sources of wood chip such as woody residues from composting operations will develop
- planting of energy crops will increase
- more chip will be produced from woodland management benefiting woodland health, biodiversity, and rural economies.

Woodlands, including coppice woodlands in South East England might once again become a vital source of renewable energy for London as they were in pre-industrial times.

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Appendix 1. British Biogen wood chip classification

Wood Chip:
Wood chip size grades are important. Wood chip burning plant will generally operate best on material between 2 and 25mm maximum dimension. However, it is accepted the fuel production methods do produce a wider range of particle sizes than this. Very fine dusty material can upset combustion in a boiler, and large chunks and long stringy material can block feed systems, so any grading system will put limits on these constituents.

Consultation with fuel suppliers and boiler manufacturers has been used to produce a retail grading system which reflects the variation in fuel tolerance of different combustion systems. British BioGen expects to review the grading system periodically to ensure that it continues to meet supplier and user needs, and to make sure it is compatible with the harmonised EU grades currently under development. Wholesale suppliers and purchasers may wish to agree different specifications to suit their particular needs.

Retail wood chip is described by three grades; **Super**, **Fine** and **Coarse.**

Size	**<2mm**	**2 – 25 mm**	**25 – 50mm**	**50 - 100mm**	**100 – 200 mm**
Description	*Dust*	*Small*	*Medium*	*Oversize*	*Slivers*
Super	<15%	Any	0%	0%	0%
Fine	<15%	Any	10%	2%	0%
Coarse	<15%	Any	Any	<30%	<2%

Max of 5% tramp material. No stones >25mm. Chipped Oversize and Sliver material is assumed to be "long and thin" – material greater than 50 mm square is unacceptable.

Standard definition: A standard wood chip sample may be tested by measuring the percentage of material (by dry weight) passing through a series of sieves having round holes of 200, 100, 50, 25, and 2 mm in diameter. Slivers passing end-on through the 100mm grid should be picked out and added to the slivers fraction. Tramp material and hard stone material should be separated from the smaller fractions by hand.

Appendix 2. Extracts from the draft European standard for biomass fuels

The draft European Technical Specification for solid biofuels – fuel specification and classes. Document N94 of CEN/TC335/WG2).

TEMPLATE FOR THE PREPARATION OF CEN STANDARDS
English version **1.3**

This template is used as a basis for printing and further processing of European standards. Basic knowledge of the functionality of the word processor is required for the template to function as intended.

Reference is made to the document: ***User guide for CEN template – 1998***.

This front page must always be completed when a new document is created. Fields with the icon: ✍ is to be replaced with actual information. Most of these fields are located on this cover page. Click once on the symbol, then enter the relevant text. Press Ctrl-A followed by F9 when this page has been completed in order to update all references.

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Solid biofuels</td></tr>
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Feste Biobrennstoffe - Brennstoffspezifikationen und -klassen</td></tr>
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Biocombustibles solides – Classes de biocombustibles et spécifications</td></tr>
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Enxxx/TC 335-WG2

Date: November 2003

EURxx

CEN/TC 335

Secretariat: SFS

Solid biofuels – Fuel Specifications and Classes

Feste Biobrennstoffe - Brennstoffspezifikationen und -klassen
Biocombustibles solides – Classes de biocombustibles et spécifications

Foreword

This document is a final draft document for the Technical Specification of Fuel Specifications and Classes of Technical Committee CEN/TC 335, "Solid biofuels".
This document is currently submitted to the TC to be prepared for the Formal Vote.
Annexes A, B, C and D are informative.

Woody biomass

11.1.1 Forest and plantation wood

Forest wood and plantation wood in this category may only have been subjected to size reduction, debarking, drying or wetting. Forest wood and plantation wood includes wood from forests, parks and plantations and from short rotation forests.

11.1.2 Wood processing industry by-products and residues

Wood by-products and wood residues from industrial production are classified in this group. These biofuels can be chemically untreated (for example residues from debarking, sawing or size reduction, shaping, pressing) or chemically treated wood residues as long as they do not contain heavy metals or halogenated organic compounds as a result of treatment with wood preservatives or coating.

11.1.3 Used wood

This group includes post consumer/post society wood waste. With respect to treatment the same criteria apply as with respect to '' wood processing industry by-products and residues": i.e. the used wood may not contain heavy metals or halogenated organic compounds as a result of treatment with wood preservatives or coating.

11.1.4 Blends and mixtures

This refers to blends and mixtures of woody biomass in the categories 1.1 – 1.3 in Table 1. The mixing can be either intentional (blends) or unintentional (mixtures).

Table 2 — Major traded forms of solid biofuels.

Fuel name	Typical particle size	Common preparation method
Briquettes	**Ø>25 mm**	**Mechanical compression**
Pellets	**Ø<25 mm**	**Mechanical compression**
Fuel powder	**<1 mm**	**Milling**
Sawdust	**1 – 5 mm**	**Cutting with sharp tools**
Wood chips	**5 – 100 mm**	**Cutting with sharp tools**
Hog fuel	**Varying**	**Crushing with blunt tools**
Logs	**100 – 1000 mm**	**Cutting with sharp tools**
Whole wood	**>500 mm**	**Cutting with sharp tools**
Small straw bales **Big straw bales** **Round straw bales**	**0,1 m3** **3,7 m3** **2,1 m3**	**Compressed and bound to squares** **Compressed and bound to squares** **Compressed and bound to cylinders**
Bundle	**Varying**	**Lengthways oriented & bound**
Bark	**Varying**	**Debarking residue from trees** **Can be shredded or unshredded**
Chopped straw	**10 – 200 mm**	**Chopped during harvesting**
Grain or seed	**Varying**	**No preparation or drying**
Shells and fruit stones	**5 – 15 mm**	**No preparation**
Fibre cake	**Varying**	**Prepared from fibrous waste by dewatering**

NOTE: Also other forms may be used.

Figures in the informative Annex B describe the particle size differences between different wood fuels and also the difference between wood chips and hog fuel.

Table 7 —Specification of Properties for Wood Chips.

	Master table			
	Origin: According to clause 6.1 and Table 1.		Woody Biomass (1)	
	Traded Form:		Wood Chips	
Normative	**Dimensions** (mm)*)			
		Main fraction > 80 % of weight	Fine fraction < 5%	Coarse fraction max. length of particle,
	P16	3,15 mm ≤ P ≤ 16 mm	< 1 mm	max 1 %* > 45 mm, all < 85 mm
	P45	3,15 mm ≤ P ≤ 45 mm	< 1 mm	max 1 %* > 63 mm
	P63	3,15 mm ≤ P ≤ 63 mm	< 1 mm	max 1 %* > 100 mm
	P100	3,15 mm ≤ P ≤ 100 mm	< 1 mm	max 1 %* > 200 mm
	Moisture (w-% as received)			
	M20	≤ 20 %	Dried	
	M30	≤ 30 %	Suitable for storage	
	M40	≤ 40 %	Limited for storage	
	M55	≤ 55 %		
	M65	≤ 65 %		
	Ash (w-% of dry basis)			
	A0.7	≤ 0,7 %		
	A1.5	≤ 1,5 %		
	A3.0	≤ 3,0 %		
	A6.0	≤ 6,0 %		
	A10.0	≤ 10,0 %		
	Nitrogen, N (w-% of dry basis)			
	N0.5	≤ 0,5 %	Nitrogen is normative only for chemically treated biomass	
	N1.0	≤ 1,0 %		
	N3.0	≤ 3,0 %		
	N3.0+	> 3,0 % (actual value to be stated)		
Informative	Net calorific value $q_{p,net,ar}$ (MJ/kg as received) or energy density, E_{ar} (kWh/m^3 loose)		Recommended to be specified when retailed.	
	Bulk density as received (kg/m^3 loose)		Recommended to be stated if traded by volume basis in categories (BD200, BD300, BD450)	
	Chlorine, Cl (weight of dry basis, w-%)		Recommended to be stated as a category Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+(if Cl >0,1% the actual value to be stated)	

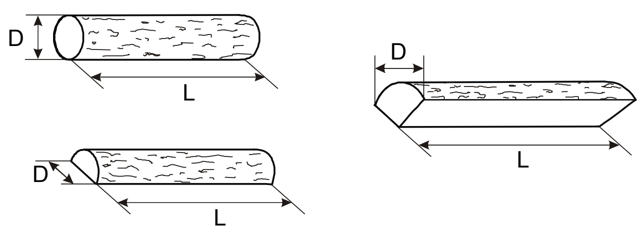
*NOTE. The numerical values for dimension refer to the particle sizes passing through the mentioned round hole sieve size (3,15 mm, 16 mm, 45 mm, 63 mm and 100 mm). Dimensions of actual particles may differ from those values especially the length of the particle.

Table 8 —Specification of Properties for Hog fuel.

	Master table			
	Origin: According to clause 6.1 and Table 1.		Woody Biomass (1)	
	Traded Form:		Hog fuel	
Normative	**Dimensions** *(mm)			
		Main fraction > 80% of weight	Fine fraction < 5% of weight	Coarse fraction, max. length of a particle, mm < 1 % of weight
	P45	3,15 mm ≤ P ≤ 45 mm	< 1 mm	> 63 mm
	P63	3,15 mm ≤ P ≤ 63 mm	< 1 mm	> 10 mm
	P100	3,15 mm ≤ P ≤ 100 mm	< 1 mm	> 200 mm
	P300	3,15 mm ≤ P ≤ 300 mm	< 1 mm	> 400 mm
	Moisture (w-% as received)			
	M20	≤ 20 %	Dried	
	M30	≤ 30 %	Suitable for storage	
	M40	≤ 40 %	Limited for storage	
	M55	≤ 55 %		
	M65	≤ 65 %		
	Ash (w-% of dry basis)			
	A0.7	≤ 0,7 %		
	A1.5	≤ 1,5 %		
	A3.0	≤ 3,0 %		
	A6.0	≤ 6,0 %		
	A10.0	≤ 10,0 %		
	Nitrogen, N (w-% of dry basis)			
	N0.5	≤ 0,5 %	Nitrogen is normative only for chemically treated biomass	
	N1.0	≤ 1,0 %		
	N3.0	≤ 3,0 %		
	N3.0+	> 3,0 % (actual value to be stated)		
Informative	Net calorific value $q_{p,net,ar}$ (MJ/kg as received) or energy density, E_{ar} (kWh/m^3 loose)		Recommended to be specified when retailed.	
	Bulk density as received (kg/m^3 loose)		Recommended to be stated if traded by volume basis in categories (BD250, BD350, BD450)	
	Chlorine, Cl (weight of dry basis, w-%)		Recommended to be states as a category Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+(if Cl >0.10% the actual value to be stated)	

*NOTE. The numerical values for dimension refer to the particle sizes passing through the mentioned round hole sieve size (3,15 mm, 16 mm, 45 mm, 63 mm and 100 mm). Dimensions of actual particles may differ from those values especially the length of the particle.

Table 9 — Specification of properties for Log woods.

	Master table		
	Origin: According to clause 6.1 and Table 1.	Woody Biomass (1.1)	
	Traded Form:	Log woods	
Normative	**Dimensions** (mm)		
	Length (L) and thickness (D) (maximum diameter of a single chop)		
	P200-	L < 200 mm and D < 20 ignition wood	
	P200	L = 200 mm ± 20 mm and 40 mm ≤ D ≤ 150 mm	
	P250	L = 250 mm ± 20 mm and 40 mm ≤ D ≤ 150 mm	
	P330	L = 330 mm ± 20 mm and 40 mm ≤ D ≤ 160 mm	
	P500	L = 500 mm ± 40 mm and 60 mm ≤ D ≤ 250 mm	
	P1000	L = 1000 mm ± 50 mm and 60 mm ≤ D ≤ 350 mm	
	P1000+	L > 1000 mm actual value has to be stated and D has to be stated	
	Moisture content (w-% as received)		
	M20	≤ 20 %	Oven-ready log
	M30	≤ 30 %	Seasoned in the storage
	M40	≤ 40 %	Seasoned in the forest
	M65	≤ 65 %	Fresh, after cut in the forest
	Wood To be stated if coniferous or deciduous wood or mixture of these is used.		
Informative	Energy density, E_{ar} (kWh/m^3 loose or stacked)	Recommended to be specified when retailed.	
	Volume, m^3 solid, stacked or loose as received	To be stated which volume is used when retailed (m^3 solid, m^3 stacked or m^3 loose)	
	Proportion of split volume	No split (=mainly round wood) Split: more than 85% of volume is split Mixture: split and round wood as a mixture	
	The cut-off surface	To be stated if the cut-off surface of log woods are even* and smooth* or ends of log woods are uneven	
	Mould and decay	If significant amount (more than 10% of weight) of mould and decay exists it should be stated. In case of doubt particle density or net calorific value could be used as indicator.	

* NOTE: Use of chainsaw is considered to be smooth and even.

Table 10 —Specification of Properties for Sawdust.

	Master table	
	Origin: According to clause 6.1 and Table 1.	Woody Biomass (1)
	Traded Form:	Sawdust
Normative	**Moisture** (w-% as received)	
	M20 ≤ 20 % M30 ≤ 30 % M35 ≤ 35 % M55 ≤ 55 % M65 ≤ 65 %	Dried Suitable for storage Limited for storage
	Ash (w-% of dry basis)	
	A0.7 ≤ 0,7 % A1.5 ≤ 1,5 % A3.0 ≤ 3,0 % A6.0 ≤ 6,0 %	
	Nitrogen, N (w-% of dry basis)	
	N0.5 ≤ 0,5 % N1.0 ≤ 1,0 % N3.0 ≤ 3,0 % N3.0+ > 3,0 % (actual value to be stated)	Nitrogen is normative only for chemically treated biomass
Informative	Net calorific value $q_{p,net,ar}$ (MJ/kg as received or energy density, E_{ar} (kWh/m^3 loose)	Recommended to be specified.
	Bulk density as received (kg/m^3 loose) Chlorine, Cl (weight of dry basis, w-%)	Recommended to be stated if traded by volume basis in categories (BD200, BD300, BD350) Recommended to be stated as a category Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+(if Cl > 0,10 % the actual value to be stated)

NOTE: Particle size for sawdust is considered to be homogenous. Particle size distribution could be specified if requested.

Table 11 —Specification of Properties for Bark*.

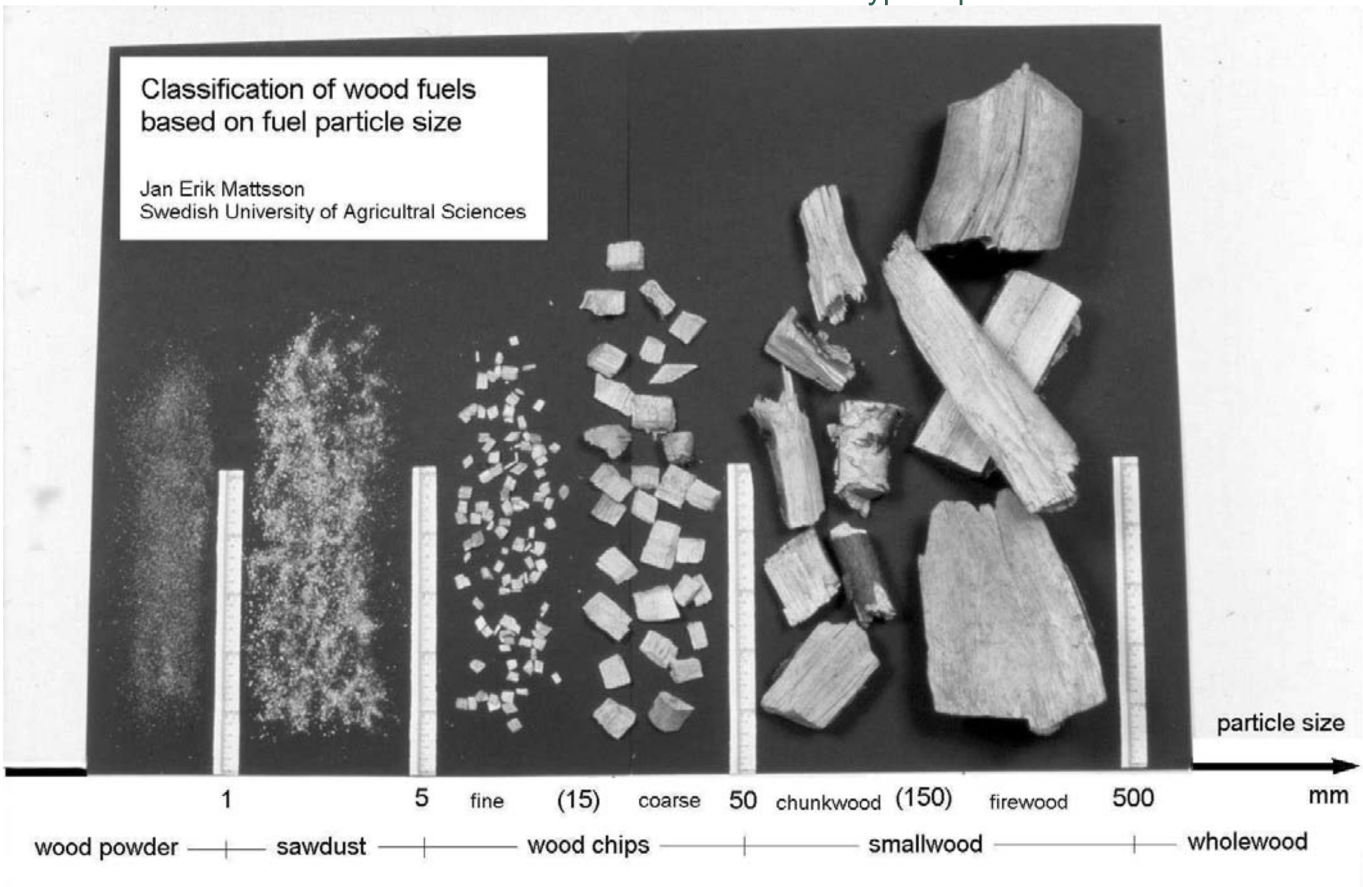
	Master table		
	Origin: According to clause 6.1 and Table 1.		Woody Biomass (1.1.5, 1.2.1.2, 1.2.2.2, 1.3.1.2, 1.3.2.2)
	Traded Form:		Bark
Normative	**Moisture** (w-% as received)		
	M40 M50 M60 M70	≤ 40 % ≤ 50 % ≤ 60 % ≤ 70 %	
	Ash (w-% of dry basis)		
	A0.7 A1.5 A3.0 A6.0 A12.0	≤ 0,7 % ≤ 1,5 % ≤ 3,0 % ≤ 6,0 % ≤ 12,0 %	
	Nitrogen, N (w-% of dry basis)		
	N0.5 N1.0 N3.0 N3.0+	≤ 0,5 % ≤ 1,0 % ≤ 3,0 % > 3,0 % (actual value to be stated)	Nitrogen is normative only for chemically treated biomass
	Shredding		
	To be stated if bark is shredded into pieces or unshredded		
Informative	Net calorific value, $q_{p,net,ar}$ (MJ/kg as received) or energy density, E_{ar} (kWh/m^3 loose)		Recommended to be specified.
	Bulk density as received (kg/m^3 loose)		Recommended to be stated if traded by volume basis in categories (BD250, BD350, BD450)
	Chlorine, Cl (w-% of dry basis)		Recommended to be stated as a category Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10+ (if Cl > 0,10% the actual value to be stated)

* NOTE: Also cork is included.

Annex B
(Informative)

B. Illustrations of typical forms of wood fuels

B1. Classification of wood fuels based on a typical particle size



B2. Difference between wood chips (left) and hog fuel (right). Source: SLU.

Annex C
(Informative)

C. Typical values* of solid biomass fuels

C1. Typical values for virgin wood materials, with or without insignificant amounts of bark, leaves and needles

Parameter	Unit	Coniferous wood (1.1.2.2 and 1.2.1.1)		Deciduous wood (1.1.2.1 and 1.2.1.1)	
		Typical value	Typical variation	Typical value	Typical variation
Ash	% w/w d	0,3	0,2 – 0,5	0,3	0,2 – 0,5
Gross calorific value $q_{gr,daf}$	MJ/kg daf	20,5	20,2 – 20,8	20,2	19,5 – 20,4
Net calorific value $q_{n,daf}$	MJ/kg daf	19,2	18,8 – 19,8	19,0	18,5 – 19,2
Carbon, C	w-% daf	51	47 - 54	49	48 - 52
Hydrogen, H	w-% daf	6,3	5,6 – 7,0	6,2	5,9 – 6,5
Oxygen, O	w-% daf	42	40 - 44	44	41 - 45
Nitrogen, N	w-% daf	0,1	< 0,1 – 0,5	0,1	<0,1 – 0,5
Sulphur, S	w-% daf	0,02	< 0,01 – 0,05	0,02	< 0,01 – 0,05
Chlorine, Cl	w-% daf	0,01	< 0,01 – 0,03	0,01	< 0,01 – 0,03
Fluorine, F	w-% daf	< 0,0005	< 0,0005	< 0,0005	< 0,0005
Al	mg/kg d	100	30 - 400	20	< 10 - 50
Ca	mg/kg d	900	500 – 1 000	1 200	800 – 20 000
Fe	mg/kg d	25	10 – 100	25	10 – 100
K	mg/kg d	400	200 – 500	800	500 – 1 500
Mg	mg/kg d	150	100 – 200	200	100 – 400
Mn	mg/kg d	147		83	
Na	mg/kg d	20	10 – 50	50	10 – 200
P	mg/kg d	60	50 – 100	100	50 – 200
Si	mg/kg d	150	100 – 200	150	100 – 200
Ti	mg/kg d	< 20	<20	<20	<20
As	mg/kg d	< 0,1	< 0,1 – 1,0	< 0,1	< 0,1 –1,0
Cd	mg/kg d	0,10	< 0,05 – 0,50	0,10	< 0,05 – 0,50
Cr	mg/kg d	1,0	0,2 – 10,0	1,0	0,2 – 10,0
Cu	mg/kg d	2,0	0,5 – 10,0	2,0	0,5 – 10,0
Hg	mg/kg d	0,02	< 0,02 – 0,05	0,02	< 0,02 – 0,05
Ni	mg/kg d	0,5	< 0,1 – 10,0	0,5	< 0,1 – 10,0
Pb	mg/kg d	2,0	< 0,5 – 10,0	2,0	< 0,5 – 10,0
V	mg/kg d	< 2	< 2	< 2	< 2
Zn	mg/kg d	10	5 – 100	10	5 - 100

*NOTE Data is obtained from a combination of mainly Swedish, Finnish, Danish, Dutch and German research. The values only aim to describe properties that can be expected in Europe in general.

Annex C *(continued)*
(Informative)

C2. Typical *values for virgin bark materials

Parameter	Unit	Bark from coniferous wood (1.1.5 and 1.2.1.2)		Bark from deciduous wood (1.1.5 and 1.2.1.2)	
		Typical value	Typical variation	Typical value	Typical variation
Ash	% w/w d	4	2 – 6	5	2 – 10
Gross calorific value $q_{gr,daf}$	MJ/kg daf	21	20 - 23	21	20 – 23
Net calorific value $q_{n,daf}$	MJ/kg daf	20	19 – 21	20	19 – 21
Carbon, C	w-% daf	54	51 - 56	55	52 - 56
Hydrogen, H	w-% daf	6,1	5,9 – 6,5	6,1	5,9 – 6,5
Oxygen, O	w-% daf	40	36 - 43	40	36 – 43
Nitrogen, N	w-% daf	0,5	0,3 – 1,2	0,3	0,1 – 1,0
Sulphur, S	w-% daf	0,10	0,02 – 0,20	0,10	< 0,02 – 0,20
Chlorine, Cl	w-% daf	0,02	<0,01 – 0,05	0,02	< 0,01 – 0,05
Fluorine, F	w-% daf	0,001	< 0,0005 – 0,002		
Al	mg/kg d	800	400 - 1200	50	30 - 100
Ca	mg/kg d	5 000	1 000 – 15 000	15 000	10 000 – 20 000
Fe	mg/kg d	500	100 – 800	100	50 - 200
K	mg/kg d	2 000	1 000 – 4 000	2 000	1 000 – 5 000
Mg	mg/kg d	1 000	400 – 3 000	500	400 – 600
Mn	mg/kg d	500	9 – 840	190	
Na	mg/kg d	300	70 – 2 000	100	20 – 1 000
P	mg/kg d	400	20 – 600	400	300 - 700
Si	mg/kg d	2 000	500 – 5 000	10 000	2 000 – 20 000
Ti	mg/kg d				
As	mg/kg d	1,0	0,1 – 4,0		
Cd	mg/kg d	0,5	0,2 – 1,0	0,5	
Cr	mg/kg d	5	1 – 10	5	
Cu	mg/kg d	5	3 – 30	5	2 – 20
Hg	mg/kg d	0,05	0,01 – 0,1,	< 0,05	
Ni	mg/kg d	10	2 – 20	10	
Pb	mg/kg d	4	1 – 30	5	
V	mg/kg d	1,0	0,7 – 2,0		
Zn	mg/kg d	100	70 – 200	50	7 – 200

NOTE Data is obtained from a combination of mainly Swedish, Finnish, Danish, Dutch and German research. The values only aim to describe properties that can be expected in Europe in general.

C3. Typical values* for virgin wood materials, logging residues

Parameter	Unit	Coniferous wood (1.1.3)		Deciduous wood (1.1.3)	
		Typical value	Typical variation	Typical value	Typical variation
Ash	% w/w d	2	1 – 4	1,5	0,8 – 3
Gross calorific value $q_{gr,daf}$	MJ/kg daf	21	20,8 – 21,4	20	19,7 – 20,4
Net calorific value $q_{n,daf}$	MJ/kg daf	20	19,5 – 20,0	19	18,4 – 19,1
Carbon, C	w-% daf	52	50 - 53	52	50 – 53
Hydrogen, H	w-% daf	6,1	5,9 – 6,3	6,1	5,9 – 6,3
Oxygen, O	w-% daf	41	40 – 44	41	40 – 44
Nitrogen, N	w-% daf	0,5	0,3 – 0,8	0,5	0,3 – 0,8
Sulphur, S	w-% daf	0,04	0,01 – 0,08	0,04	0,01 – 0,08
Chlorine, Cl	w-% daf	0,01	< 0,01 – 0,04	0,01	< 0,01 – 0,02
Fluorine, F	w-% daf				
Al	mg/kg d				
Ca	mg/kg d	5 000	2 000 – 8 000	4 000	3 000 – 5 000
Fe	mg/kg d				
K	mg/kg d	2 000	1 000 – 4 000	1 500	1 000 – 4 000
Mg	mg/kg d	800	400 – 2 000	250	100 – 400
Mn	mg/kg d	251		120	
Na	mg/kg d	200	75 - 300	100	20 – 200
P	mg/kg d	500		300	
Si	mg/kg d	3 000	200 – 10 000	150	75 – 250
Ti	mg/kg d				
As	mg/kg d	0,3			
Cd	mg/kg d	0,2		0,1	
Cr	mg/kg d				
Cu	mg/kg d				
Hg	mg/kg d	0,03		0,02	
Ni	mg/kg d				
Pb	mg/kg d	3		5	
V	mg/kg d				
Zn	mg/kg d				

* NOTE Data is obtained from a combination of mainly Swedish, Finnish, Danish, Dutch and German research. The values only aim to describe properties that can be expected in Europe in general.

Annex C *(continued)*
(Informative)

C4. Typical values* for virgin wood materials, short rotation coppice

Parameter	Unit	Willow (Salix) (1.1.1.3)		Poplar (1.1.1.3)	
		Typical value	Typical variation	Typical value	Typical variation
Ash	w-% d	2,0	1,1 – 4,0	2,0	1,5 – 2,5
Gross calorific value $q_{gr,daf}$	MJ/kg daf	20,3	20,0 - 20,6	20,2	20,0 – 20,4
Net calorific value $q_{n,daf}$	MJ/kg daf	18,8	18,4 -19,2	18,8	18,6 - 19,1
Carbon, C	w-% daf	49	47 - 51	49	47 – 51
Hydrogen, H	w-% daf	6,2	5,8 – 6,7	6,3	5,8 – 6,7
Oxygen, O	w-% daf	44	40 - 46	44	40 - 46
Nitrogen, N	w-% daf	0,5	0,2 – 0,8	0,4	0,2 – 0,6
Sulphur, S	w-% daf	0,05	0,02 – 0,10	0,03	0,02 – 0,10
Chlorine, Cl	w-% daf	0,03	<0,01 – 0,05	< 0,01	< 0,01 – 0,05
Fluorine, F	w-% daf	0,01			
Al	mg/kg d	-	3 – 1 000		
Ca	mg/kg d	5 000	2 000 – 9 000	5 000	4 000 – 6 000
Fe	mg/kg d	100	30 – 600		
K	mg/kg d	3 000	1 700 – 4 600	3 000	2 000 – 4 000
Mg	mg/kg d	500	200 - 800	500	200 – 800
Mn	mg/kg d	97	79 – 160		
Na	mg/kg d	-	10 – 450		
P	mg/kg d	800	500 – 1 300	1 000	800 – 1 100
Si	mg/kg d	-	2 – 7 200		
Ti	mg/kg d	10	< 10 – 50		
As	mg/kg d	< 0,1	< 0,1	<0,1	< 0,1 – 0,2
Cd	mg/kg d	2	0,2 – 5	0,5	0,2 – 1
Cr	mg/kg d	1	0,3 - 5	1	0,3 – 2
Cu	mg/kg d	3	2 - 4	3	2 – 4
Hg	mg/kg d	< 0,03	< 0,03	< 0,03	< 0,03
Ni	mg/kg d	0,5	0,2 - 2	0,5	0,2 – 1,0
Pb	mg/kg d	0,1	0,1 – 0,2	0,1	0,1 – 0,3
V	mg/kg d				
Zn	mg/kg d	70	40 - 100	50	30 – 100

* NOTE Data is obtained from a combination of mainly Swedish, Finnish, Danish, Dutch and German research. The values only aim to describe properties that can be expected in Europe in general.

Annex D1
(Informative)

Examples of possible causes for deviant levels for different properties, woody biomass

Property	Deviation	Possible causes *)
Ash, d	High value	Contamination with soil/sand Higher content of bark than specified Inorganic additives Chemical treatments such as paint, preservation
Net calorific value $q_{net,d}$	Low value	Content of combustible material with lower calorific value as e.g. glues
Net calorific value $q_{net,d}$	High value	Content of combustible material with higher calorific value as e.g. resin, vegetable or mineral oils, plastic
N, daf	High value	Higher content of bark than specified Glue Plastic (laminate)
S, daf	High Value	Higher content of bark than specified Organic additives as corn flour, potato flour Inorganic additives containing sulphur compounds Treatment with chemicals containing sulphur, as sulphuric acid
Cl, daf	High Value	Higher content of bark than specified Origin of wood from coast near locations and exposed from sea water Contamination during storage/transportation by road salting Preservation chemicals
Si, d	High Value	Contamination with soil/sand Higher content of bark/needles/leaves than specified
Ti, d	High Value	Paint
As, d	High Value	Preservation chemicals
Cd, d	High Value	Paint Plastic
Ni, d	High Value	Contamination from working up machinery Mineral oils
Pb, d	High Value	Environmental contamination (e.g. Traffic) Paint Plastic

NOTE: Chemically treated wood waste that may contain halogenated organic compounds or heavy metals, is not included in the scope of the standard. As the presence of such materials or the remains of other materials may occur accidentally, examples for these incidents are given also.

Source: dk-Teknik and Elsam Engineering (Denmark)

Appendix 3. Danish wood chip fuel quality description

Name	**Hole size**	**Fine**	**Medium**	**Coarse**	**Air spout**	**Gasifier**
Dust	3.15mm	<10%	<8%	<8%	>2%	<4%
Small	3.5 – 8mm	<35%	<30%	<20%	>5%	<8%
Medium	>8 - 16mm	*	*	*	>60%**	>25%
Large	>16 - 45mm	<60%	*	*	>60%**	>60%***
Extra Large	>45 - 63mm	<2.5%	<6%	*	<15%	>60%***
Overlarge	>63mm	<0.25%	<0.6%	<3%	<3%	>60%***
Overlong 10	100-200mm	<1.5%	<3%	<6%	<4.5%	<6%
Overlong 20	>200mm****	0%	<0.5%	<1.5%	<0.8%	<1.5%

* *not defined* ** These two classes together make up a minimum of 60%

*** These three classes together make up a minimum of 60%

**** Particles with the following dimensions are not allowed:

- longer than 500mm with a diameter >10 mm
- larger than 30 x 50 x 200 mm

Size distributions to be measured with a rotating screen developed with support from the Danish Energy Agency. The screen eliminates the over-long particles before sorting the remaining particles into six classes by means of 5 screens with round holes of 3.15, 8, 16, 45 and 63mm diameter. This is based on the ISO Standard 3310/2. The overlong particles are sorted by hand into two classes 100-200 mm and over 200 mm.

Source: Serup H et al, 1999, *Wood for Energy Production*, Danish Energy Agency

Appendix 5 Chippers for small diameter timber

Assessed by Forestry Commission Technical Development Branch in 2004

Machine performance. – source: Forestry Commission, 2005

Chipper model	Type and rpm.	Motive power	Timber input Species	Mean vol. (m^3)	Mean dia. (cm)	Outp utm^3/ hour	Moisture content %	Fuel use (l/m3)	Noise dB(A) .
Heizohack HM5-400	Drum 540	Valtra T180	Birch	0.017	10	2.97	42.59	1.85	91 to 93
			Pine	0.047	17	4.41	62.83	1.59	
			Pine	0.020	11	2.73	60.96	1.96	92
Laimet HP21	Screw, 650	Valtra T180	Birch	0.014	9	2.85	45.18	1.97	94 to 95
	800		Pine	0.016	10	2.65	60.65	2.62	94
Schliesing 550 ZX	Disc 1000	New Holland TM140	Birch	0.014	9	3.34	42.84	N/A	95
			Pine	0.022	12	4.79	61.08	N/A	95
			Pine	0.041	16	4.02	61.76	N/A	96
Farmi CH 260	Disc 1000	Valtra T180	Birch	0.014	9	2.74	40.54	3.71	95
			Pine	0.019	11	3.85	62.90	2.51	95
			Pine	0.043	16	6.89	46.01	1.85	96
TP 100VM	Drum	Self (16hp)	Birch	0.009	7	0.70	49.12	N/A	93
TP 150	Disc	Self (27hp)	Birch	0.012	8	1.67	51.01	N/A	94
			Pine	0.018	11	1.96	62.74	N/A	94
TP 200	Disc 1000	Valtra T180	Birch	0.017	10	3.06	63.79	3.49	94
			Pine	0.019	11	2.92	65.11	2.84	94
Farmi CH 260 c/w Loader	Disc (45° feed) 1000	Valtra 8150	Birch	0.044	16	4.95	46.33	3.53	N/A
			Pine	0.011	8	2.46	63.36	“	N/A
			Birch	0.010	8	2.41	43.75	“	N/A
Jensen A240	Disc 1000	Valtra 105 hp	Birch	0.017	10	4.17	37.10	N/A	118
			Pine	0.020	11	5.08	59.98	1.28	117
Greenmech 19-28	Disc Blade	Self	Pine	0.018	10	5.29	59.11	N/A	N/A
			Birch	0.017	10	4.20	38.04	N/A	N/A
Greenmech 220 Series			Birch	0.014	9	3.92	39.09	1.88	N/A
			Pine	0.017	10	4.10	60.17	2.21	N/A

Chip size found during trials – source: Forestry Commission, 2005

Chipper model	Species	>100mm	>85 to 100mm	>63 to 85mm	>45 to 63mm	>16 to 63mm	>16 to 45mm	>3.15 to ~16mm	Fines
Heizohack HM5-400	Birch						10.3	84.4	5.3
	Pine						11.6	87.5	0.9
	Pine				3.1		12.5	81.3	3.1
Laimet HP21	Birch	0.05		2.2		81.45		10.2	2.2
	Pine			13.4	9.4		48.2	25.6	3.4
Scheising 550ZX	Birch	7.97			13.27		29.1	46.95	2.7
	Pine			3.1	3.1		29.7	62.5	1.6
	Pine	4.7	3.1	9.4	7.8		32.8	34.4	7.8
Farmi CH260	Birch			3.1	1.6		25.0	67.2	3.1
	Pine			2.8		12.9		81.4	3.9
	Pine				3.1		17.2	75.6	3.1
TP100VM	Birch			4.7	3.1		39.1	50.0	3.1
TP150	Birch				3.1		21.9	71.9	3.1
	Pine				3.1		14.1	78.1	4.7
TP200	Birch				3.1		20.3	75.0	1.6
	Pine			1.6	3.1		25.0	67.2	3.1
Jensen A240	Birch	4.1	0.6	3.2	6.0		51.1	33.2	1.7
	Pine	1.3	1.5	3.3	7.8		38.2	45.1	2.9
Farmi CH260 c/w loader	Birch		0.01	1.95	7.86		70.48	18.54	1.17
	Birch			2.6	6.3		50.3	38.5	2.3
	Pine	0.2		2.3	4.0		57.5	32.9	3.2
Greenmech 19-28 Arborist	Pine	0.3	0.3	0.3	1.3		8.4	81.8	7.6
	Birch	0.6	0.2	1.3	1.8		36.1	54.6	5.4
Greenmech 220 MT55	Birch	2.3	1.0	1.5	3.2		24.3	63.4	4.4
	Pine	0.4		2.1	1.4		21.5	67.5	7.1

Appendix 6 Evaluation of chippers trialled by BioRegional

Laimet HP21
A hand fed screw cone chipper with 180mm maximum diameter input requiring a tractor of 135hp or over. The cost of the chipper was £7,300 when purchased in 2001. This was the first chipper tested by BioRegional and required the logs to be split to fit into the chipper. Nevertheless, the irregular shape of the arboricultural waste gave rise to many blockages. This time consuming, manually intensive task increased the cost of production considerably to a minimum cost before delivery of £45/tonne at 30% moisture content[91]. This is clearly uneconomic but using a larger Laimet chipper would reduce costs and make a similar high quality product.

Observations on chip quality with ash pulpwood were similar to the Forestry Commission's findings – a very clean chip of consistent size was produced. With the short lengths and rings in arboricultural arisings however many oversize chunks and slivers were produced. Without sliver breakers screening would be required to guarantee suitable fuel for smaller boilers and the CHP

Bandit XP 280 with in-feed conveyor
A self powered disc chipper with a 125hp engine in the configuration tested. Cost £42,000. Maximum log size 460mm. This was first demonstrated without the in-feed conveyor and chipped and mix of longer material and short logs loaded by hand. Chip quality was adequate although some short logs produced large slivers. Advice was that fitment of an in-feed conveyor would solve this problem and allow mechanical loading of the chipper enabling one man operation.

Further testing with the in-feed conveyor showed conclusively that the bandit XP280 could not process the short logs and ring with frequent blockages reducing output to very low levels, an estimated 3 tonnes in 3 days. Short logs and rings gave rise to almost 50% of very large slivers the size of kindling. Sliver breakers are not presently available for this chipper.

The Bandit XP280 is a high throughput chipper designed for log lengths over 1m or whole tree chipping. When used for this it produces large quantities of high quality chip suitable for use in most applications. It is not suited to tree surgery waste due to excess sliver production and a narrower in-feed opening than in comparable drum chippers, limiting its usefulness for chipping rings.

Erjo 7/65 RC
This is a drum chipper with integral screen taking 470mm maximum diameter timber. As tested, it was mounted on a forestry forwarder base along with a crane and high tip receiving bin for chip. The new price for this combination is over £250,000. All machines in this country have been bought second hand and refurbished at a considerable discount to the new price. In Europe the chipper is often mounted on lorries for increased manoeuvrability. Two forwarder mounted examples were seen working, one on hire at BioRegional's yard in Croydon.

Loading with the crane was difficult due to the small piece sizes in arboricultural arisings. The lack of a powered in-feed bed meant that the crane had to be used to push logs towards the in-feed rollers. This significantly reduced output with just 60t/day produced against 200t/day in a well laid out forestry or land clearance operation.

Chip quality from arboricultural arisings was not good enough for use at the BedZED CHP without further screening due to a large number of slivers over 150mm. Similar quality problems were seen in the forest when chipping willow which gave rise to long fibrous chips. Good maintenance and sharp knives are essential for good chip quality.

The Erjo chipper is better chipping forestry material and whole trees rather than arboricultural arisings and would not be a first choice for use in the urban environment of London

Heizohack chippers

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[91] Tolfts A, March 2002, *Results of a pilot study of wood chip production for BedZED CHP plant at Croydon Central Nursery site, Conduit Lane.* Internal BioRegional report

Heizohack units are tractor powered drum chippers with integral screens in a variety of sizes. Construction and operating principals are similar for all models. Two models were assessed for this report.

The HM 6-400 K has a 400mm maximum input diameter requiring a tractor with a minimum of 75hp. Cost in February 2005 was £20,490. It was favourably reviewed in a recent Forestry Commission assessment using 3m pulp wood. It was tested by BioRegional with tree surgery waste on two occasions. These tests showed the importance of in-feed speed and tractor power in determining chip quality and in particular the proportion of fines. The internal screen was effective in reducing the number of oversize chip and fines to low levels but some out of specification material was produced. Hand loading the chipper with tree surgery waste was facilitated by the short in-feed conveyor

The HM 14-800 is a larger machine costing £61,000. It has an 800mm maximum input diameter requiring a tractor of at least 200hp. 250hp is recommended to maintain output levels. The HEM 14-800 would be able to cope with around 85% of the logs received in the Croydon yard. It was seen working at Home Grown Timber headquarters and was used at Croydon. It is robustly constructed with relatively straightforward maintenance requirements.

Loading is with a crane, grapple or with and the short in-feed conveyor makes it easy to operate on tree surgery waste. Chip quality is similar to the smaller Heizohack and screening would be needed to guarantee no oversize slivers were present in the chip.

Jenz HEM 700
This is the largest mobile chipper in the Jenz line up and is fitted with a 450hp engine. The new cost is £167,000. A 600hp version is available for £184,000. The maximum diameter chipped is 700mm. Like the other chippers in the Jenz range and most European chippers designed to make fuel chip it is a drum chipper with internal screen. This can be changed according to the maximum size of chip required.

The machine was seen working at FHC's premises near Lightwater, Surrey processing a full range of tree surgery arisings into fuel for supply to Slough Heat and Power. It is mounted on skids and transported between sites by a hook-lift lorry. On the ground in the working position there is easy access to the large in-feed conveyor which can be loaded with a grab or front end loader. Similarly specified units are used as fixed installations in larger district heating and CHP schemes in Germany.

Chip quality was good with new knives fitted. There were very few oversize chips or slivers. It is the most powerful, highest performance chipper seen with outputs of over 200t/day achieved with suitable feedstock. It is robustly constructed and is relatively quiet in operation offering a good mix of power, performance and mobility. It would be well suited to work in London.

But it is also expensive. Other smaller Jenz machines are cheaper and can be bought in a tractor powered version. However the ability to process larger size material is compromised with the HEM 560 only able to take material up to 560mm. Second hand machines are available but are also expensive in comparison to other makes of chipper. For example a reconditioned HEM 560 was available recently for £79,000.

Rudnick and Enners
An 8 year old Rudnick and Enners chipper fitter with a loading crane was also assessed. It was purchased in Austria in May 2005 and cost around £38,000 including transport and overhaul. The equivalent new machine costs £250,000. It is a drum chipper with internal screen able to process logs up to 550mm diameter, powered by a 420hp engine. The machine was being commissioned so it is not possible to give a good estimate of its output in routine use. It is designed specifically to produce fuel chip and a high quality product was produced from tree surgery arisings including rings and short logs. It was ideal for all types of boiler with the screen fitted but may need to be changed to a screen with larger apertures if producing for the BedZED CHP or Slough Heat + Power. A larger screen size will help to increase output.

The lack of an in-feed conveyor is the only significant drawback compared to other large chippers. However the in-feed chute can be inclined so that short lengths will slide down into the feed rollers

Bandit Beast 3680 high speed shredder

Shredders are designed to comminute a range of materials which may include old electrical goods, timber and green waste. A low quality chip, described as 'hog fuel' in the draft European standard, is normally produced from waste timber and logs. Improvement in chip quality is possible by fitting teeth with sharp cutting edges a facility offered by both Bandit and Jenz.

An adapted Bandit Beast 3680 in Croydon produced 70 tonnes a day over a 2 week period but quality was poor. There were excessive fines and many long slivers up to 200mm long. There was also contamination with stones and grit due to poor loading technique. It would not have been acceptable for most boilers or the BedZED gasifier but some was accepted by Slough Heat and Power.

A second sample produced from logs by a Bandit Beast 3680 was received from Material Change Ltd. This was of much better quality than that made in Croydon with few fines and no slivers. A different tooth type and changes in operating speed may explain the improvement in quality, providing the sample was representative. It suggests that adapted shredders are a viable option for one off processing of large stockpiles of logs. Hiring in a shredder for less than 500 tonnes of logs is uneconomic due to high transport charges. With regular supplies of large quantities of timber a better quality of chip will be produced by a purpose built chipper.

There are many different makes of larger chipper available in both Europe and North America in addition to the ones reviewed above. The largest have power units of over 1000hp but the physical size and cost of the largest machines require consistently high throughputs which may not be available in London.

Appendix 7. Questionnaire for Tree Surgery Contractors

Name
and
Address

6th June 2005

Dear contractor,

11.1.4.1.1 A Growing Use for Tree Surgery Waste

In 2001 the LTOA organised a survey of tree contractors in London which indicated that 100,000 tonnes of wood chip and logs are produced in the capital each year from tree surgery. This presented a disposal problem but equally an opportunity as a potential local renewable energy source for heating and combined heat and power (CHP) production. Regular increases in Landfill Tax will make disposal increasingly expensive so other uses for tree surgery waste must be developed.

In 2001 the possibility of using arboricultural arisings from London as fuel in a power station in East Anglia did not prove viable but now there is growing interest in smaller scale schemes within London. The Mayor's requirement for 10% renewable energy in large new developments, supported by actions by individual boroughs, has prompted this interest. Typically, a biomass boiler in these developments will use several hundred tonnes of chip a year. If the market is to grow and develop the developers need to know wood chip is available. The amount coming from local tree surgeons (and other sources such as waste wood) needs to be verified.

Larger biomass schemes have been proposed for the Thames Gateway but are only at an early stage. They would not be operational until 2009 at the earliest but a reliable assessment of available fuel will increase the chances that these schemes will be implemented. Therefore, the LTOA are repeating the survey done in 2001 to improve its accuracy and see what changes in the pattern of production and use of arboricultural arisings has occurred. Landfill taxes are increasing steadily and a sustainable method of dealing with the industry's waste would benefit the industries profile as well as generating savings in disposal costs.

If you would like to be involved you will find attached to this letter a map, questionnaire and details of acceptable waste[92]. We ask that you;

- Draw on the map to show the: location of your yard
  Where you tip chips and waste
  The main area of your work
- Complete the questionnaire.

I would be grateful if you could return the map and questionnaire to me by Monday 20th June 2005 at the latest. If in the mean time you have any enquiries or suggestions, please feel free to contact me.

Yours sincerely

Becky Hesch
Executive Officer

[92] **Acceptable waste:**
Almost all material produced during arboricultural work is suitable for fuel chip production. Logs, other solid timber and branches including leaves are acceptable. small diameter woody material, such as hedge trimmings, are not suitable for duel production as the proportion of leaf is too high. They should be disposed of along with other garden green waste.

Contamination with grit, stones earth and similar materials must be avoided as it leads to excessive wear in boiler systems. Timber that has been treated in any way or contains nails in it, such as old fence panels or pallets cannot be accepted.

LTOA Survey of Tree Surgery Waste; Volumes and Movement: Contractor Questionnaire.

In developing the wood chip fuel market it is hoped to keep disposal costs to a minimum and avoid the increasing costs of waste disposal. We recognise that contractors cannot carry waste long distances so several drop off yards are needed around London to increase the incentive to contractors. To maximise the survey's usefulness we need as much detailed information as possible and give the assurance that details will be kept confidential. No firms will be identified in the final report of the survey.

1) Do you currently pay for waste disposal?	Yes / No
2) Cost per tonne to dispose	£
3) What were your tipping charges for the last financial year.	£
4) How much material did you dispose of last financial year? (volume or tonnage)	Estimate: or Actual:

6) Vehicle Details

Type of vehicle (i.e. 35cwt Transit):	Approximate number of loads tipped per week:

7) What uses, if any, are made of your waste by yourself or other people? If possible, give a rough estimate of the quantity for each use.

8) Contractors Comments

Company Name:______________________ Contact:______________________________

Please return completed questionnaire and map to Becky Hesch, LTOA, 3rd Floor Crowndale Centre, 218 Eversholt Street, London, NW1 1BD.
Tel:020 7974 4124 Mobile: 07771 976238

Appendix 8 Contractors estimates of disposal costs and volumes

Contractor ID No	Pay for Disposal?	Cost/ tonne to dispose	Tipping charges £/year	Notes on tipping charges	Material Disposed m3/yr	Material Disposed tonnes/yr	Notes on material disposed
1	Yes	£1.25	£60		1160	406	40m3 mulch 2000 logs
2	not included as based in Bury St Edmunds						
3	No					100	chip
4	No					200	
5	No					1440 5	chip wood logs
6	Sometimes	£6	£12,250	£4-£8	875	306	500m^3 mulch 300t logwood
7	Yes	£8		£175/ 60m^3 (around 30t)	1000	350	Mostly chip. 3 t firewood
8	No					350	hard logs 400m^3 chip 600m^3 Slough
9	Yes	£45	£140			175	
10	No				2000	700	70% energy 30% mulch
11	Yes	£66	£6,500			90 20	brushwood logwood
12							
13	Yes		£3,000			2800	
14	Sometimes	£15	£3,000			200	
15	Yes	£27	£16,951	£20 per load	1800 m^3 (847 loads)	629	
16	Yes	£40	unknown		unknown	1.25	
17	No					75	
18	No					2600	
19	No						
20	Yes	£20	£1,200			80	
21	No				11520	4028	
22	Sometimes	£12.50	20,000	£10-15/t charges		2500	50% chip 50% unchip
23	Yes	£175 council £22.50 private tip. Assume average £98.75		£87.50 per 0.5t to council tip, £40 per load to private dump	1200	420	

Contractor ID No	Pay for Disposal?	Cost/ tonne to dispose	Tipping charges £/year	Notes on tipping charges	Material Disposed m3/yr	Material Disposed tonnes/yr	Notes on material disposed
24	No					500	
25	Yes	15.66	£3,500		596	208	
26	Yes	£50	£1,500			30	18t logs
27	Yes	£42	£14,646			400	
28	No		0		2080m	600	
29	Sometimes	£40				1920	
30	No						
31	Yes	£55	£3,000			40	
32	Yes	£15	£7,500			500	
33	No					75	
34	No						
35	Sometimes	£20	£5,000			1250	$600m^3$ mulch $400m^3$ paths
36	Yes	£60	£500				
Total tipping charges (£/year)			**£95,747**				
Average annual tipping charges (15 replies)			**£6,383**				
Total material disposed (tonnes/year)			**22997**				
Average material disposed (30 replies)			**767**				
Average tipping cost per tonne where charges paid (19 replies)			**£38**				
Pay for disposal:	**Yes**		**15**				
	No		**15**				
	Sometimes		**4**				

Appendix 9 Estimates of volumes from vehicle movements

Contractor	Vehicle	Load volume m^3	Loads per week	Volume per wk (m^3)	Volume per yr (48wks) m^3	Tonnes per year (tonnes)	Total per contractor
1	Transit 35 cwt	4	4.5	18	864	302	302
2	--	--	--	--	--	--	--
3	--	--	--	--	--	--	--
4	Transit 35 cwt	4	5	20	960	336	336
5	12 x 35 cwt	4	4	16	768	269	806
	2 x 62 cwt	4	4	16	768	269	
	2 x 75 cwt	4	4	16	768	269	
6	3.5 tonne tipper	4.7	5	23.5	1128	394	656
	35 yd^3 bin	26	0.6	15.6	748.8	262	
7	2x35 cwt Transit	4	12	48	2304	806	806
8	7.5 ton Leyland	10	3	30	1440	503	1175
	35 cwt Transit	4	5	20	960	336	
	35 cwt Transit	4	5	20	960	336	
9	35 cwt Transit	4	4	16	768	269	269
10	Cabstar 3.5ton	4.67	5	23.35	1120.8	392	1959
	Movano 3.5 ton	4.67	5	23.35	1120.8	392	
	Izuzu 3.5 ton	4.67	5	23.35	1120.8	392	
	Isuzu 6.5 ton	9.33	5	46.65	2239.2	783	
11	Nissan Cabstar 3.4t	4.7	3.5	16.45	789.6	276	276
12	---	---	---	---	---	---	---
13	Transit tipper x 3	4	45	180	8640	3021	4723
13	Mitsubishi 6.3t tipper	8.4	10	84	4032	1410	
	grab and tip	8.4	0.5	4.2	201.6	70	
	timber lorry 25t	33	0.4	13.2	633.6	222	
14	2x7.5 ton tippers	10	6	60	2880	1007	1007
15	1x35 cwt Transit	4	13	52	2496	873	4028
	1x35 cwt Transit	4	13	52	2496	873	
	1x35 cwt Transit	4	13	52	2496	873	
	1x35 cwt Transit	4	13	52	2496	873	
	1 x trailer	4	8	32	1536	537	
16	Transit 3.5cwt	4	4	16	768	269	269
17	Transit 35cwt	4	2	8	384	134	134
18	3.5t daily	4.7	5	23.5	1128	394	4003
	7.5t Euro Cargo	10	5	50	2400	839	
	7.5t Euro Cargo	10	5	50	2400	839	
	17t Cargo grab	23	5	115	5520	1930	
19	Isuzu x2	10	6	60	2880	1007	1007
20	3.5t gvw tipper	4	0.5	2	96	34	34
21	Unimog v1300 $10m^3$ trailer	10	12	120	5760	2014	4028
	Ford tractor 12 m^3 trailer	12	10	120	5760	2014	
22	3x35 cwt Transit	4	15	60	2880	1007	11832
	4x7.5cwt Cargo	10	30	300	14400	5035	
	1x17.5t hiab	23	15	345	16560	5790	
23	35 cwt Canter	4	7.5	30	1440	503	503
24	2x7.5t Fords	10	6	60	2880	1007	1007
	1x35cwt Ford tipper	4	0	0	0	0	
25	4.5 cwt Iveco	4	3	12	576	201	285
	3.5 cwt Transit	4	1	4	192	67	
	1.0 cwt D21	4	0.25	1	48	17	

Contractor	Vehicle	Load volume m^3	Loads per week	Volume per wk (m^3)	Volume per yr (48wks) m^3	Tonnes per year (tonnes)	Total per contractor
26	Transit mwb	4	2	8	384	134	134
27	Transit tipper	4	4	16	768	269	269
28	4x35cwt Transit	4	16	64	3072	1074	1074
29	Transit x8	4	5	20	960	336	2014
	Cargo x 2	10	5	50	2400	839	
	grab x 2	10	5	50	2400	839	
30	35 cwt	4	4	16	768	269	269
31	Toyota Hilux 900kg	1.2	3	3.6	172.8	60	60
32	3.5t Transit	4	4.5	18	864	302	604
	3.5 t LT	4	4.5	18	864	302	
33	2 x 35 cwt Transit	4	6.5	26	1248	436	436
34	2x 3.5 cwt Transit	4	10	40	1920	671	1007
	3.5 cwt Isuzu	4	0	0	0	0	
	6 cwt Canter	4	5	20	960	336	
35	2 x 6.5 cwt Iveco tipper ($10m^3$)	10	6	60	2880	1007	1678
	2 x 6.5 cwt Iveco tipper ($10m^3$)	10	4	40	1920	671	
36	---	---	---	---	---	---	---
	Total volume (m^3)			**115560**			
	Average volume (32 replies)				**4200**		
	Total weight (tonnes/year)			**40406**			
	Average weight (32 replies)				**1468**		

Appendix 10 Contractors comments

Contractor ID	Comments
1	Mulch sold 40 m^3, 2000 logs sold. This needs to be implemented, can't wait!
2	Love to help but out of catchment area in Bury St Edmunds Suffolk
3	Timber is tub-ground to 50mm and mixed with wood chippings, Produce approx 100 tonnes per year. Sold to Slough power Station. Base in Northampton outside mapped area.
4	Mulch sales per bag/load. Most of our works are June 8-15
5	30 ton per week is delivered to Slough Heat and power, 5 ton domestic wood fire logs. Remaining debris used as horticultural mulch
6	Garden mulch 500m^3. Logwood for fuel 300 tonnes. Any green waste disposed of without coming back to our yard goes for recycling. Sometimes we have to pay haulage, if we chip then it generally goes free of charge or we may get paid. In our yard brush is chipped and logs sold for fuel
7	Small amount of firewood around 3 tonnes per annum. We intend to process more and could do. We bring nearly all waste back to yard where it is stockpiled then removed using a tele-handler to load artics Cord wood is burned.
8	Hard wood logs are split and sold at our farm shop. 400 m^3 of chip to landscape contract 2004. We have 600m3 to go to Slough bio-energy. Would very much welcome local disposal site, as I'm sure other contractors would. We produce quite a lot of wood chip and strive to be as environmentally sensitive as possible regarding disposal
9	Wood chip to rides, mulch. Logs to firewood. Disposal of waste in urban areas is prohibitively costly. Annually charges go up to such a degree that its impossible to cover the expense without pricing myself out of the market.
10	70% renewable energy, 30% mulch. All arisings are stored at Dorking yard.
11	Brushwood goes U/A Cleanaway transfer station to composting site. Logwood to farm trust, converted to logs. I also hire in chipper and operator for bigger jobs. He takes chips away and these are used on a farm. Guestimate 30 tonnes per year extra
12	Supply Slough Power Station so would not be included in survey.
13	Wood chip- our teams supply landscape section with chip. All log wood is chipped and sent to slough power station. All remaining chip that we produce daily is sent to slough. The green waste facility is carried out for our whole company by an outside contractor. Having a contractor separate from our company makes recycling a lot easier. None of our material is sent to landfill, any excess material is composted.
14	No use for wood chip as yet, some wood logged and used for firewood. We lack time to process wood chip, reloading onto transport vehicles can be costly and time consuming. Suitably located depots in and around London to drop off chip or logs could be an ideal solution, most tree companies may accept little or no payment for their waste
15	All wood chips recycled for mulch, logs etc, used in farmer's log boiler to heat farm buildings. We would be very interested in using an alternative waste facility if it will reduce our tipping/transport costs.
16	I use the logs in the winter to make firewood. I deliver a truck load which is about 1250kg.
17	I tip at Richmond Park golf course maintenance yard. Used to line pathways. Logs are tipped at windmill (Commons conservators) who split and sell on as firewood. This is long overdue, but why cannot the local authorities offer free tipping at local transfer stations?
18	Currently we find homes for about 70% of all chip waste, paths equestrian sites, nurseries etc, and for about 98% of logs. The remaining wood chip we stockpile hoping it will eventually rot away. When we have approached the biomass sites (eg Slough) they have been very disinterested in our product even after it has been screened to produce excellent quality.

Contractor ID	Comments
19	If left on site, chippings used by customer in their garden or logs burned on fire. Waste otherwise left at our yard. Some chippings picked up and used for reselling to customers for use in their gardens. Some logs sold for personal fires, but most burned to make more space in the yard. Our area of work extends to most of Buckinghamshire, large area of Berkshire and some of Oxfordshire. The larger logs are wasted at our yard; a way of using these more effectively would be useful.
20	Sometimes used for garden mulch. The only available 'local' municipal site is Nathan Way in ECHH (?) and they want £65/ton to dump arboricultural waste - outrageous! No wonder people fly tip - we don't!
21	Mulch, horse ménages, dog kennels, local authority landscape department. Mulch around tree planting schemes as part of ongoing maintenance and to local landscape companies. Have developed market for our chips over last 25 years; disposal is not a problem as my customers like a chunky chip. My yard is not on your map, but we have a certificate of lawfulness to store, process, convert and sell our products.
22	Some to Slough power station. Some to Norfolk farmers mulch, some for landscapes. The more chip options that open the better.
23	We encourage our clients as much as possible to allow us to chip on site and keep some log material. Spread on the beds the chip makes excellent mulch. We also donate a certain volume to equestrian use for gallops etc. I think local authorities should have in place facilities for disposing green waste as reasonable cost. There is a bio-tip site as Sundridge but it is only for council contract use, paid for no doubt by us.
24	We sell some wood chip for play areas or as mulch and we compost it. Some goes to Slough power station. We also recycle wood as logs. This idea is excellent especially if there were drop off areas around London
25	Minimal log and garden mulch sales. Due to not owning or managing our tip site the owner is not separating chip from brush, and therefore our resale of chip is very restricted. If sites are local enough we would happily use, however if any distance away, more hassle for employers therefore limited use. Our yard could be arranged more suitably, would a 'roving' grab service be viable?
26	Logs for firewood approx 18 tonnes. We are a very small business so we obviously don't have a great deal of waste, but where possible all of our green waste is recycled. I'm very happy to see this kind of recycling being given the proper attention. Keep it up - thanks!
27	Sadly goes to landfill. We would very much like to recycle, however there are not any recycling facilities in the area we work.
28	Renewable energy, landscape (mulch), stables, other (footpaths, childrens' play areas). We currently manage to give away most of what we produce.
29	We supply a heat and power company (Edmonton Waste Station, and others at Aldershot and Enfield), riding stables, allotments and London zoo. Long journeys. Years of tipping. Wasted time and money. Only recently started selling wood chip. Need to sell more. Need more hard standing work area, mostly within the M25 but others too.
30	Stables (for paddocks etc)
31	London zoo (branches for animals) or tip. Logs for firewood
32	All tipped at green waste site and is recycled for farm use. Always interested in additional locations and schemes. Please keep me posted.
33	We sell as mulch and logs but are gaining stock that we cannot dispose of
34	----
35	Mulching jobs throughout the company (~ 600m3 last year). Also farmers in Essex for waterlogged ground and bridle paths etc (~400m3 last year) We are currently recycling all chipped waste, just logs we can't clear easily. Would be happy to lose it all to one source
36	Recycled small trees and garden waste.

Appendix 11 Sawmills in South East England

a) Sawmills listed on Yell.com for SE England

Eynsham Park Sawmill
Cuckoo Lane , North Leigh , Witney , OX29 6PS
Tel : 01993 881391

Mortons Mobile Mill (unit10)
Fieldside Farm , Doddershall , Quainton , Aylesbury , HP22 4DQ
Tel : 01296 655081
Call Mobile 1st : 07733 164248

J Lewis Tree Surgery
Home Mead, Field End , The Lee , Great Missenden , HP16 9NA
Tel : 01494 837481

The Timber Mill
60 Elder Close , Badger Farm , Winchester , SO22 4LH
Tel : 01962 851518

Balcombe Estate Sawmill
Balcombe Estate Office , Haywards Heath Rd , Balcombe , Haywards Heath , RH17 6QN
Tel : 01444 811446

L.P Gaskin
East Upton Manor Timber Yard , Carters Rd , Ryde , Isle of Wight PO33 4BP
Tel: 01983 563575

Holmsley Mills Ltd
Holmsley Saw Mills, Holmsley , Burley , Ringwood , Hampshire BH24 4HY
Tel: 01425 402507

Lenham Oak & Fencing
Magazine House , Lenham Heath , Maidstone , Kent ME17 2BU
Tel: 01622 858404

Ben Nicolson Tree Services
Isemongers Farm, Peaslake Rd , Ewhurst , Cranleigh , Surrey GU6 7NR
Tel: 01483 548754

Willows Sawmills
Millwood Lane , Maresfield , Uckfield , East Sussex TN22 3AS
Tel: 01825 763509

Barns Branch & Co.Ltd
Brook St , High Wycombe , Buckinghamshire HP11 2EQ
Tel: 01494 525761

Herriard Sawmills Ltd
The Sawmill , Herriard , Basingstoke , Hampshire RG25 2PH
Tel: 01256 381585

William Wallace
Home Farm, Baynards Park , Cranleigh , Surrey GU6 8EQ
Tel: 01483 548000

L.A Contractors
63, Serpentine Rd , Fareham , Hampshire PO16 7EE
Tel: 01329 231557

Gibbs Brothers Sawmill and Fencing Contractors
Kitesbridge Farm , Asthall , Burford , Oxfordshire OX18 4HL
Tel: 01993 878600

A & G Lillywhite
Charlton Saw Mills , Charlton , Chichester , West Sussex PO18 0HU
Tel: 01243 811609

Layton Timber
Pyrton Hill, Station Rd , Pyrton , Watlington , Oxfordshire OX49 5DF
Tel: 01491 613222

Rose & Son
Sawmills, Mill Lane , Henley-On-Thames , Oxfordshire RG9 4HD
Tel: 01491 575354

M Martin
9, Common Rd , Headley , Thatcham , Berkshire RG19 8LS
Tel: 01635 268579

R.F Giddings & Co.Ltd
Ringwood Rd Sawmills, Ringwood Rd , Bartley , Southampton , Hampshire SO40 7LT
Tel: 023 8081 3157

JW Shepherd
1 Thorney View, St. Peters Rd , Hayling Island , Hampshire PO11 0RU
Tel: 023 9246 5654

Morgan & Co (Strood) Ltd
Knight Rd , Strood , Rochester , Kent
ME2 2BA
Tel: 01634 290909

Bluebell Sawmills
Hicknahan Farm , Littleworth Common ,
Burnham , Slough , Berkshire SL1 8PG
Tel: 01753 648081

Orlestone Oak Saw Mill
Nickley Wood , Shadoxhurst , Ashford , Kent
TN26 1LZ
Tel: 01233 732179

Longdown Sawmill
The Estate Yard, Longdown , Marchwood ,
Southampton , Hampshire SO40 4UH
Tel: 023 8029 2473

Hascombe Woodyard
Church Rd , Hascombe , Godalming , Surrey
GU8 4JF
Tel: 01483 208525

A.J Scott
Polebrook Farm, Hever Rd , Hever ,
Edenbridge , Kent TN8 7NJ
Tel: 01732 864729

Rovasaw Mobile Sawmill
Temple House, Quarry Rd , Oxted , Surrey
RH8 9HF
Tel: 01883 715400

Surrey Sawmills
70, Wrecclesham Hill , Wrecclesham ,
Farnham , Surrey GU10 4JX
Tel: 01252 891795

Castle Handling Products
Ockham House , Bodiam , Robertsbridge ,
East Sussex TN32 5RA
Tel: 01580 830685

Stansted Sawmill Ltd
Stansted Park , Rowland's Castle , Hampshire
PO9 6DU
Tel: 023 9241 2445

Ayot Green Sawmill Ternex Ltd
27, Ayot Green , Ayot St. Peter , Welwyn ,
Hertfordshire AL6 9BA
Tel: 01707 324606

C.J's Sawmills Ltd
Unit 2, Fleet Hall Road, Rochford
Essex, SS4 1NF
Tel: 01702 541200

Williams & Son
18, Ayot Green , Ayot St.Peter , Welwyn ,
Hertfordshire AL6 9BA
Tel: 01707 320182

R.F. Rowe
Ham Farm , Southwick , Fareham , Hampshire
PO17 6AU
Tel: 023 9237 8394

Norbury Park Sawmills
Fetcham Downs , Fetcham , Dorking , Surrey
RH5 6DN
Tel: 01372 457377

Southill Sawmills Ltd
Southill Park , Southill , Biggleswade ,
Bedfordshire SG18 9LJ
Tel: 01462 813604

Duke & Brown
The Hanger , Freemans Farm, Elder St ,
Wimbish , Saffron Walden , Essex CB10 2XA
Tel: 01799 516084

The Saw Mill
Boldre Grange, Southampton Rd , Boldre ,
Lymington , Hampshire SO41 8PT
Tel: 01590 671362

Rustic Crafts Workshop
Bixley Lane , Beckley , Rye , East Sussex
TN31 6TH
Tel: 01797 260522

Copford Farm Sawmill
Copford Farm, Dern Lane , Waldron ,
Heathfield , East Sussex TN21 0PN
Tel: 01435 813472

Eastside Timber
Units 1-3,Britannia Works , Monro Industustrial
Estate , Station Approach , Waltham Cross ,
Hertfordshire EN8 7LX
Tel: 01992 700087

C.N & S.C White
Pallance Gate Farm, Pallance Gate , Newport ,
Isle of Wight PO30 5UA
Tel: 01983 292926

b) Sawmills and sawmillers advertising in *Woodlots* newsletter (April/May and June/July 2005 issues) and listed on Surrey County Council website[93]

Contact	Name	Town	County	postcode	telephone	mobile	fax	email
	AJ & PM Scott	Edenbridge	Kent		01732 864729	07768 300002	01732 864686	
	Balcombe Estate Sawmill	Balcombe	W. Sussex		01444 811446	07887 868248		jamie.woodcutter@btopenworld.com
Nick Raeside	Biowoodlands	Forest Row	E. Sussex	RH18 5NT	01342 825608	07968 994528		nick@biowoodlands.co.uk
	Challenge Fencing	Cobham	Surrey	KT11 3LY	01932 866555			
Donald Macdonald	Cowdray Estate	Midhurst	W. Sussex		01730 812423	07860 962098		donald@cowdray.co.uk
	D. R. Woods & Son	Cranleigh	Surrey	GU6 8QP	01483 273925			
	Dolmen Conservation		Kent/Sussex		01233 860022		01233 861430	enquiries@dolmen-conservation.co.uk
AW Darby	Eartham Sawmill	Chichester	W. Sussex		01243 814747	07977 775614		
Malcolm Jeffery	English Oak Direct	Hever	Kent		01342 850555		01342 850555	info@englishoakdirect.co.uk
	English Woodlands Timber	nr. Midhurst	Sussex		01730 816941		01892 549036	sales@ewtimber.co.uk
Paul Goulden	GM Hardwoods	Andover	Hampshire		01264 738200			gmhardwoods@aol.com
	Hascombe Woodyard	Hascombe	Surrey	GU8 4JF	01483 208525	07889 967299		
	Honeysuckle Bottom Sawmill	East Horsley	Surrey		01483 282394			
	Norbury Park Sawmill	Dorking	Surrey	RH5 6DN	01483 284101			
	Orlestone Oak Sawmill	Shadoxhurst	Kent		01233 732179		01233 732179	
Rick Rowe	R. F. Rowe	Fareham	Hampshire	PO17 6AU	02392 378394	07973 468026		
	Rother Forestry	Tenterden	Kent		01580 763754	07788 645524		rotherforestry@hotmail.com
	Ryall and Edwards	Redhill	Surrey		01342 842288			
Martin Pigg	Sisland Sawmill	nr. Horsham	Surrey		01953 788335	07793 241469		martpigg@hotmail.com
	Surrey & Sussex Hardwoods	Dorking	Surrey		01306 711896	07719 296331		
	Sussex Oak & Iron		Sussex		01243 811472	07971 419058	01243 811475	joe@sussexoak.co.uk

[93] http://www.surreycc.gov.uk/sccwebsite/sccwspages.nsf/LookupWebPagesByTITLE_RTF/Sawn+timber?opendocument last accessed 18/08/05.

Contact	Name	Town	County	postcode	telephone	mobile	fax	email
Andrew Holloway	The Green Oak Carpentry Co Ltd		Hampshire		01730 895049	01730 895225		enquiries@greenoakcarpentry.co.uk
John W Jones	The Timber Mill	Romsey	Hampshire		01962 851518	07966 396419		contact@thetimbermill.com
	Thomlinson's Sawmill	Haywards Heath	Sussex		01444 454554			thomlinsons-sawmill@telinco.co.uk
	Treespanner Timber Co.	Dormansland	Surrey	RH7 6PD	01342 871529	07713 083625		treespanner@tiscali.co.uk
	Willows Sawmill	Uckfield	Sussex		01825 763509		01825 766768	
Dave West	W. L. West & Sons	nr. Petworth	W. Sussex		01798 861611		01798 861633	
Nick Hilton	Woodwise Forestry Services	Heathfield	E. Sussex		01435 864397			nick@nickhilton.fsnet.co.uk
Bryan Kinnear			Sussex/Surrey/Kent		01825 740767	07944 086306		bryan.kinnear@virgin.net
Dave Bonsall		nr. Heathfield	E. Sussex		01435 863200	07771 662534		davidbonsall@woodland-trust.org.uk
Grant Roffey		Plaistow	W. Sussex		01403 751535	07973 826189	01403 751534	groffey@mac.com
Paul Becker		Balcombe			01444 811003	07887 623114		thebeckers@eurobell.co.uk
Philip Donker					01342 811964	07808 719723		philidonker@hotmail.com
Pierre Woodward		Ashford	Kent		01304 851728			
Tom Ottaway			Sussex/Surrey/Kent		01323 844844	07876 567264		tottawayuk@yahoo.co.uk

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