



**NNFCC**

The Bioeconomy Consultants



## **Lignocellulosic feedstock in the UK**

**November 2014**

**A report for the Lignocellulosic Biorefinery Network**

**Authors:**

**Davide Di Maio and David Turley**

**Reviewer:**

**Lucy Hopwood**

**Disclaimer**

While NNFCC considers that the information and opinions given in this work are sound, all parties must rely on their own skill and judgement when making use of it NNFCC will not assume any liability to anyone for any loss or damage arising out of the provision of this report.

## NNFCC

NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and bio-based products.



NNFCC, Biocentre,  
York Science Park,  
Innovation Way,  
Heslington, York,  
YO10 5DG.

Phone: +44 (0)1904 435182  
Fax: +44 (0)1904 435345  
E: [enquiries@nnfcc.co.uk](mailto:enquiries@nnfcc.co.uk)  
Web: [www.nnfcc.co.uk](http://www.nnfcc.co.uk)

## Executive Summary

NNFCC was commissioned by the Lignocellulosic Biorefinery Network (LBNet) to survey the potential availability of existing domestic lignocellulosic non-food crop feedstock wastes and residues to support the development of UK biorefineries. The objective was to assess the current availability of domestic crop and forest residues; dedicated biomass crops; green waste and waste from the paper industry. Current competing uses for these materials were identified and the potential to expand the resource examined. Impacts of regional and temporal variability were considered and data on costs and composition were collated.

The analysis highlighted that the UK has nearly 16 million tons of biomass waste arising from the feedstocks studied. The greatest contributions to this total are from green waste, agricultural straw and a significant amount of waste paper that is currently collected but not recycled in the UK. Nearly 5 million tons/year of green waste are collected in the UK, accounting for 31% of the total. Exported waste paper accounts for 27% of the potential resource. The third largest contributor is surplus agricultural straw which is currently uncollected and is chopped and returned to soils, this accounts for around 25% of the identified potential resource.

The availability of biomass varies significantly by region and by type. The richest regions in biomass supply were found to be the Eastern and Southern regions of England. However, Scotland has the highest potential availability of forest residues and a considerable amount of collected green waste.

The feedstocks with the most reliable year-round supply are likely to be green waste, paper waste and forest residues. However, they can be subject to significant variation in composition over time (green waste composition is seasonal) or due to variation in mixing of different constituents (forest residues are affected by bark and wood ratios and paper residues are affected by degree of virgin and recycled pulp use). Straw and energy crops are likely to provide the most consistent composition, but with seasonal harvests require storage provision to ensure year-round supply.

Many of these feedstocks have alternative uses including use for power generation, as compost media, or for use in livestock bedding. However, finding alternative higher value outlets could result in diversion to other uses or encourage greater rates of collection (e.g. straw and harvest residues)

In other cases residues are waste products (e.g. paper industry by-products) where a cost may otherwise be incurred to dispose of such materials. Diversion to higher value uses would improve returns throughout the associated supply chains.

## Contents

1	Background.....	6
2	Analysis of biomass resources from forest harvest residues .....	7
2.1	Introduction .....	7
2.2	Current Availability .....	7
2.3	Potential future supply .....	9
2.4	Factors affecting availability.....	9
2.4.1	Haulage costs .....	9
2.4.2	Seasonality of supply.....	11
2.5	Competing uses.....	11
2.6	Cost of Feedstock.....	11
2.7	Composition of feedstock.....	12
3	Analysis of biomass resources from municipal green waste .....	15
3.1	Introduction .....	15
3.2	Current availability .....	15
3.2.1	Segregated green waste .....	15
3.2.2	Non segregated green waste .....	16
3.3	Potential future supply .....	17
3.3.1	Segregated green waste .....	17
3.3.2	Non segregated green waste .....	17
3.4	Factors affecting availability.....	18
3.4.1	Separated green waste .....	18
3.4.2	Non separated green waste .....	18
3.5	Competing uses.....	18
3.6	Cost of feedstock .....	19
3.7	Composition of feedstock.....	19
4	Analysis of biomass resources from energy crops .....	21
4.1	Introduction .....	21
4.2	Current availability .....	21
4.2.1	Miscanthus.....	21
4.2.2	Short Rotation Coppice (SRC) .....	22
4.3	Potential future supply .....	23
4.4	Factors affecting availability.....	24

4.4.1	Seasonality.....	24
4.5	Competing uses.....	24
4.6	Cost of feedstock .....	24
4.7	Composition of feedstock.....	25
5	Analysis of biomass resources from the paper industry .....	26
5.1	Current availability .....	26
5.1.1	Residues from paper production .....	26
5.1.2	Residues from paper recycling.....	26
5.1.3	Recycled paper collected for export .....	26
5.2	Potential future supply of residues from paper production and recycling.....	27
5.2.1	Residues from paper pulping operations.....	27
5.2.2	Residues from paper recycling.....	27
5.3	Factors affecting availability of residues from papermaking .....	28
5.4	Competing uses.....	28
5.5	Cost of feedstock .....	28
5.6	Composition of feedstock.....	29
6	Analysis of biomass resources from agricultural straw residues .....	30
6.1	Introduction .....	30
6.2	Current availability .....	30
6.3	Potential future supply .....	32
6.4	Factors affecting availability.....	33
6.4.1	Seasonality of supply.....	33
6.5	Competing uses.....	33
6.6	Cost of feedstock .....	34
6.7	Composition of agricultural straw residues.....	35
7	Conclusions .....	37
8	Appendix I. Regional distribution of biomass resources by type .....	43
9	Appendix II. Regional distribution of biomass resources by composition .....	44

## 1 Background

NNFCC was commissioned by the Lignocellulosic Biorefinery Network (LBNet) to survey the potential for domestic supply of lignocellulosic feedstocks for biorefineries in Great Britain. The objective was to assess the current availability of domestic crop and forest residues and dedicated biomass crops and accounting for competing uses for these materials. The potential to expand the future supply of such resource was also examined. Impacts of regional and temporal variability were considered and data on costs and composition were collated where available.

The identified feedstock of specific interest included:

- cereal straw (total and by type)
- rape straw
- other crop residues
- forest residues
- forest brash
- paper industry waste (including lignin)
- municipal green waste
- SRC willow
- miscanthus

## 2 Analysis of biomass resources from forest harvest residues

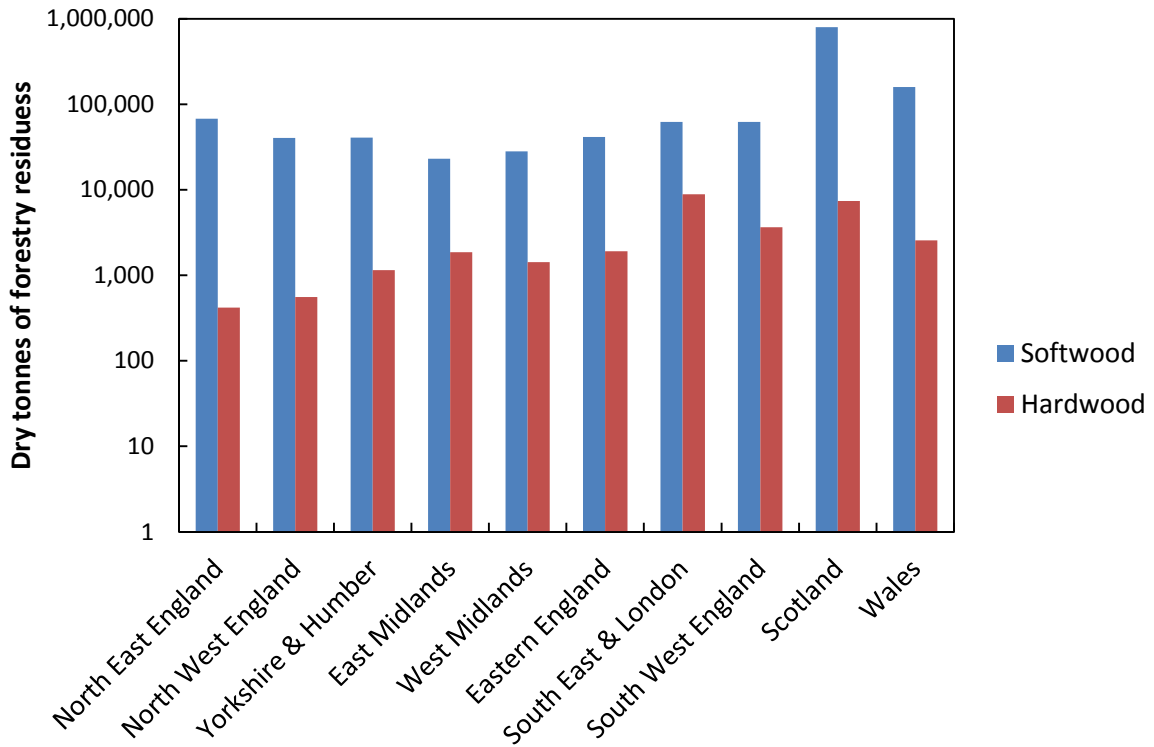
### 2.1 Introduction

Timber, composite-board and to a lesser extent paper markets drive the planting and harvesting of UK forests and provide the highest value outlets for wood of the appropriate quality. However, the by-products of this industry provide resource for other potential markets. The resource available includes residues left from the harvesting operation; bark, tops and branches, and in some cases tree stumps that are normally left in the forest after felling.

### 2.2 Current Availability

Forest harvesting residues are not part of national statistics so the current availability must be estimated from known data. An indication of potential forest residue arisings can be gained from timber harvest predictions, given that forests have a defined lifetime. The total area of woodland in Great Britain is 2.75 M ha, comprising 1.57 M ha of conifer and 1.17 M ha of broadleaf woodland. Scotland has the majority of woodland at 49%, England 41% and Wales 10%. The following procedure and assumptions were used in calculating the available harvest residues:

- Data on the production of total harvested roundwood was taken from the Forestry Commission's 25 year forecast for softwood availability [1].
- The ratio of harvest residues to harvested wood was assumed to be 0.32 [2].
- The density of wood is assumed to have an average of 0.5 t/m<sup>3</sup> [2].
- The environmentally sustainable proportion of forest residues that could be removed without affecting soil nutrient levels and soil stability is assumed to be 50% of the total residue arising [2].
- Arisings, measured in green tonnes, are assumed to have a moisture content of 50%.
- Due to numerous sites being unsuitable for extracting residues (e.g. due to mountainous terrain or other logistical access problem), it is assumed that residues can only be collected from 80% of the available resource.
- Data was not available for individual harvest arising in each English region. This quantity was therefore estimated by taking account of the woodland area in each region and typical softwood and hardwood harvesting volumes for a unit area.



**Figure 1. Sustainably sourced and recoverable dry tonnes of forest residue waste in the Great Britain arising from hardwood and softwood harvesting operations.**

Note that the graph is shown with a log scale. The tonnage of softwood residues is nearly 2 orders of magnitude greater than that of hardwood.



**Table 1. Sustainable and recoverable dry tonnes of forest waste arisings in Great Britain for hardwood and softwood. FC = forestry commission owned land; Private = other land.**

	Softwood			Hardwood		
	FC	Private	Total	FC	Private	Total
North East England	35,776	31,994	67,769	81	339	419
North West England	14,614	25,803	40,417	272	287	559
Yorkshire & Humber	13,565	27,180	40,745	351	798	1,149
East Midlands	8,922	14,196	23,118	1076	792	1,869
West Midlands	8,360	19,732	28,091	433	989	1,423
Eastern England	17,877	23,691	41,569	555	1,358	1,913
South East & London	12,719	49,409	62,127	5,765	3,105	8,870
South West England	18,728	43,596	62,324	1,545	2,093	3,637
Scotland	337,600	456,640	794,240	720	6,640	7,360
Wales	86,560	72,080	158,640	960	1,600	2,560
Total	554,720	764,320	1,319,040	11,760	18,000	29,760

## 2.3 Potential future supply

The potential future supply of forest residues was calculated using data from NFI [4]. Only data for softwood was considered in this forecast as forest harvest residue arisings from hardwood represent only 2% of the total available resource. The regional breakdown is shown in Table 2. Figure 2 shows the future trend for Great Britain. The amount of forest harvest residues is predicted to rise in future years up to 2031, mainly from the contribution of Scottish forest plantations. After this period harvest timber volumes are expected to decline in line with historic planting trends, which will also affect availability of harvest residues.

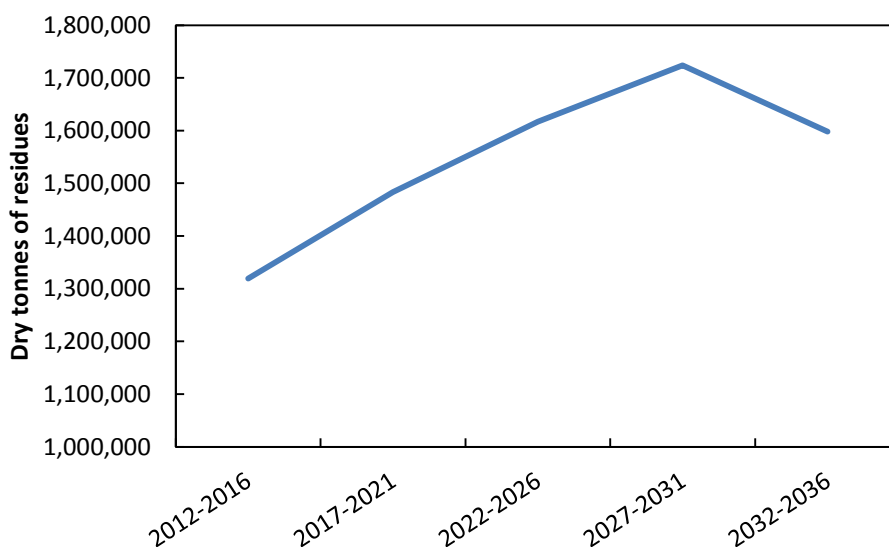
## 2.4 Factors affecting availability

### 2.4.1 Haulage costs

Transport plays a big role in the wood supply chain. Timber haulage costs represent in the order of 50% of the delivered cost of roundwood [4]. Harvest residues would be equally if not more strongly affected due to their relatively low bulk density compared to roundwood timber. Haulage costs are increased by accessibility problems and distance to the market. Remote forests are therefore more susceptible to being uneconomic to collect harvest residues from [4]. The development of greater mechanisation, opportunities to densify by baling or roadside chipping can help increase the cost effectiveness of haulage.

**Table 2. Regional forecasted trend for softwood forest harvest residues (odt).**

	2012-2016	2017-2021	2022-2026	2027-2031	2032-2036
North East England	28,400	27,760	39,360	39,040	31,600
North West England	54,320	60,640	46,400	56,720	50,880
Yorkshire & Humber	28,320	33,440	30,000	35,120	25,680
East Midlands	14,160	13,680	15,680	12,960	12,960
West Midlands	28,800	31,760	28,480	23,600	42,800
Eastern England	26,000	31,840	28,160	35,040	38,320
South East & London	47,840	47,280	52,880	52,960	45,680
South West England	51,360	58,320	43,840	51,200	41,680
Scotland	669,040	758,720	897,040	994,880	891,440
Wales	140,080	160,320	152,080	120,640	137,440
Total	1,088,320	1,223,760	1,333,920	1,422,160	1,318,480



**Figure 2. Future predicted dry tonnes of softwood harvest residues in Great Britain.**

## 2.4.2 Seasonality of supply

Forest harvesting operations include stand thinning, removal of damaged and diseased trees as well as clear felling, which means that harvesting operations are occurring regularly through the year when ground conditions permit access. Harvest material including brush, has a high moisture content at harvest, so typically is left in situ to air dry. This may be at the point of harvest, or in piles or bales by roadsides awaiting collection. This means that year-round supply could be co-ordinated relatively easily, though there would be a need for storage of chipped material at the receiving site to mitigate against risk of extended delays to delivery especially over the winter period.

## 2.5 Competing uses

Forestry residues can be put to the same use as sawmill products and recycled wood as feedstock for the production of wood pellets and briquettes for use in bioenergy production. A total of 301,000 tonnes of wood pellets and briquettes are estimated to have been made in the UK in 2013 [5]. The UK is a very significant and growing importer of wood pellets [6] for the biomass power sector. These are primarily sourced from North America, the Baltics and Southern Europe, where chip and pellet prices are lower and significant tonnages can be sources to meet the demands of large biomass combustion plants. This should leave more localised UK resources available for alternative uses.

## 2.6 Cost of Feedstock

As they are not commonly collected, forest harvest residues do not currently have a price in the open market. Therefore, only a price estimate can be provided. Forest residues are largely underutilised in Europe, with the exception of Scandinavian countries [7] where some prices are reported. In general, the production cost largely depends on the following criteria:

- transportation distance
- storage and drying
- degree of mechanisation
- steepness of the terrain
- type and size of the machines used
- labour costs in the country

Previous reports [8] show a price ranging from 18 to 50 £/odt.

## 2.7 Composition of feedstock

Forestry residues include the following:

- Distorted wood
- Small round wood
- Branches
- Stumps
- Tops
- Bark
- Brash

Wood, in general terms, is a mixture of cellulose, hemicellulose, lignin, extractives and minerals. The ratio between these components varies between wood species, based on provenance and with the specific part of the tree (stem wood, bark, branches, needles/leaves, stumps and roots). The approximate composition of soft and hard wood is summarised in Table 3. The typical composition for two typical British softwood trees are shown in Table 4 and 5.

**Table 3. Typical composition (%) of stemwood [9].**

	Cellulose(%)	Hemi-cellulose(%)	Lignin(%)	Extractives(%)	Minerals(%)
Hardwood	40 - 50	25 - 35	20 - 25	2-8	0.2 - 0.8
Softwood	40 - 45	25 - 30	25 - 35	1-5	0.2 - 0.4

**Table 4. Typical composition (%) of Scots Pine [10].**

	Cellulose	Hemicellulose	Lignin	Extractives
Stem wood	40.7	26.9	27.0	5.0
Bark	22.2	8.1	13.1	25.2
Branches	32.0	32.0	21.5	16.6
Needles	29.1	24.9	6.9	39.6
Stump	36.4	28.2	19.5	18.7
Roots	28.6	18.9	29.8	13.3

**Table 5. Typical composition of Norway spruce [10].**

	Cellulose	Hemicelluloses	Lignin	Extractives
Stem wood	42.0	27.3	27.4	2.0
Bark	26.6	9.2	11.8	32.1
Branches	29.0	30.0	22.8	16.4
Needles	28.2	25.4	8.4	43.3
Stump	42.9	27.9	29.4	3.8
Roots	29.5	19.2	25.5	15.7

Table 4 and Table 5 show the variability in composition between different parts of a tree. Forest residues will therefore always have a variable composition reflecting the mix of the various components in the final product.

Generally, there are small and subtle differences in the major cellulose component between hardwoods and softwoods. However, the composition of the hemicellulose component can be very different. The xylan content of softwoods such as Spruce species and Scots Pine is typically around 7% but this can rise to 20% or more in hardwoods like birch, and can reach 35% in some birch species. Hence, these species are preferable where xylose is the target. The difference in hemicellulose composition in different species can affect the efficiency of hydrolysis process and the final sugar yield.

The constituent lignin alcohols (lignols); p-coumaryl, coniferyl, and sinapyl are incorporated into lignin in the form of phenylpropanoids; (p-hydroxyphenyl, guaiacyl, and syringyl respectively). Again, there are differences in the ratio of aromatic alcohols that predominate in soft and hardwood lignin. Guaiacyl tends to dominate softwood lignin, while a mixture of guaiacyl and syringyl forms dominate hardwood lignin.

Extractives are a very wide range of diverse chemical substances concentrated in the bark, needles and in the sapwood. Typically they account for 2-3% of wood composition. These constituents are phenolics, fats, waxes, terpenes, terpenoids and aliphatic alcohols in a variety of forms. The main commercial interests are resins (a source of natural turpentine) and tannins.

The ash content of forest harvest residues typically ranges between 1 and 3%. Increasing levels of bark tend to increase the ash content.

## References

1. [NFI 25 year forecast](http://www.forestry.gov.uk/pdf/NFI-Statistical-Analysis-Report_UK-25-Year-Forecast-Softwood-Availability.pdf/$FILE/NFI-Statistical-Analysis-Report_UK-25-Year-Forecast-Softwood-Availability.pdf), [http://www.forestry.gov.uk/pdf/NFI-Statistical-Analysis-Report\\_UK-25-Year-Forecast-Softwood-Availability.pdf/\\$FILE/NFI-Statistical-Analysis-Report\\_UK-25-Year-Forecast-Softwood-Availability.pdf](http://www.forestry.gov.uk/pdf/NFI-Statistical-Analysis-Report_UK-25-Year-Forecast-Softwood-Availability.pdf/$FILE/NFI-Statistical-Analysis-Report_UK-25-Year-Forecast-Softwood-Availability.pdf)
2. S .Searle, C. Malins, Availability of cellulosic residues and wastes in the EU, icct, [www.theicct.org](http://www.theicct.org), October 2013
3. [Wood fuel Task Force Update Report 2011, Forestry Commission](http://www.forestry.gov.uk/pdf/WoodfuelTaskForceUpdateReport_2011.pdf/$FILE/WoodfuelTaskForceUpdateReport_2011.pdf), [www.forestry.gov.uk/pdf/WoodfuelTaskForceUpdateReport\\_2011.pdf/\\$FILE/WoodfuelTaskForceUpdateReport\\_2011.pdf](http://www.forestry.gov.uk/pdf/WoodfuelTaskForceUpdateReport_2011.pdf/$FILE/WoodfuelTaskForceUpdateReport_2011.pdf)
4. [Transport - the profit and loss of forestry](http://www.timbertransportforum.org.uk/Upload/Documents/41_FEG_paper.pdf), [http://www.timbertransportforum.org.uk/Upload/Documents/41\\_FEG\\_paper.pdf](http://www.timbertransportforum.org.uk/Upload/Documents/41_FEG_paper.pdf) accessed on 16/10/2014
5. Forestry commission, UK Wood Production and Trade, 2013 provisional figures.
6. Forestry commission, Forestry Statistics 2014.
7. Procurement of forest residues, AeBiom, 2007.
8. Use of sustainably-sourced residue and waste streams for advanced biofuel production in the European Union: rural economic impacts and potential for job creation, NNFCC, 2013
9. <http://www.carbolea.ul.ie/wood.php> accessed on 21/11/2014.
10. Forest Refine, [www.biofuelregion.se](http://www.biofuelregion.se), accessed on 16/10/2014.

### 3 Analysis of biomass resources from municipal green waste

#### 3.1 Introduction

Green waste in this study is defined as biodegradable waste comprising garden or amenity land residues, including grass and hedge trimmings and horticultural green waste. Green waste is often collected via municipal curb-side collection schemes or through private waste management contractor businesses [1]. It is typically collected for recycling, via composting.

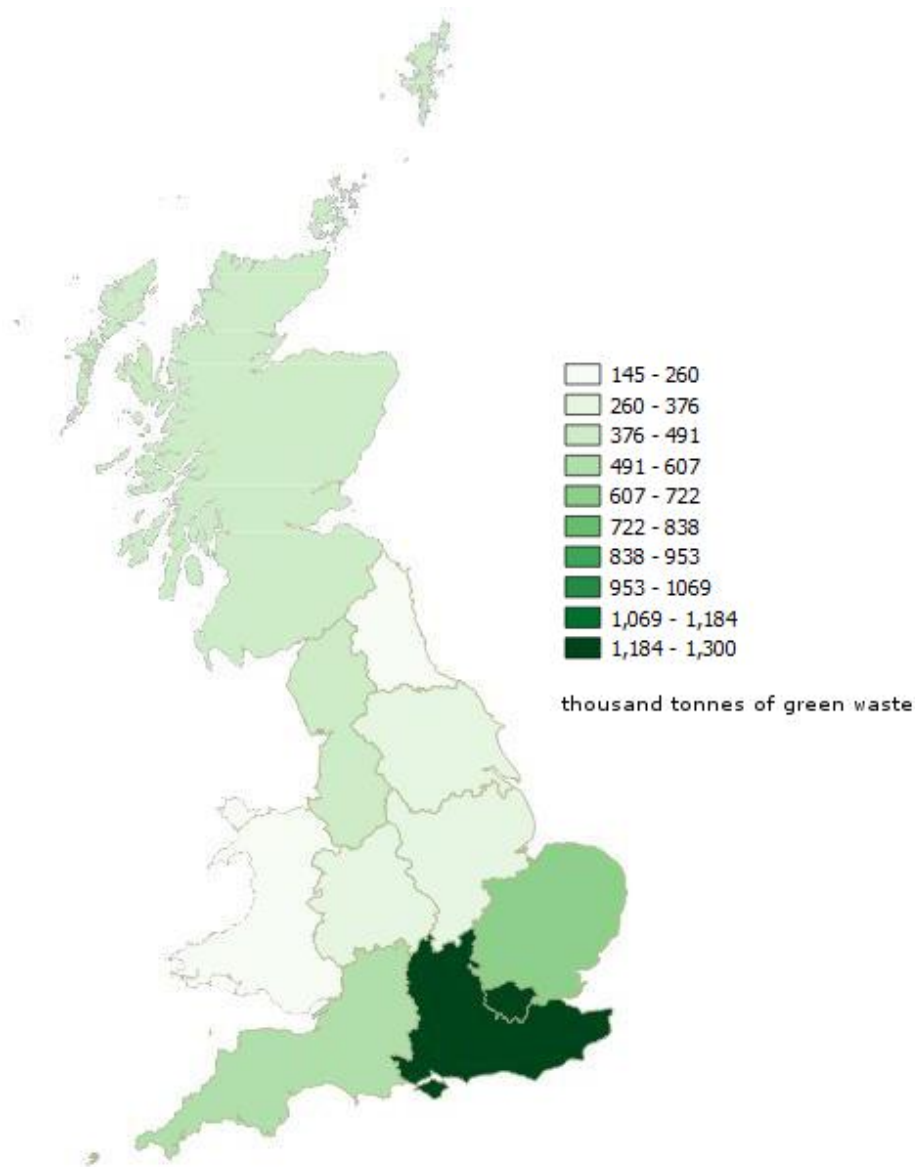
#### 3.2 Current availability

##### 3.2.1 Segregated green waste

Data on green waste arisings are not clearly defined in waste statistics provided by the local authorities. Such data is often aggregated within that for 'organic and recyclable material'. From the Official Defra "Statistics on waste managed by local authorities in England in 2012/13" [2], it was found that waste comprises 40% of the total municipal waste collected for recycling. It is therefore possible to estimate the green waste from the recycled waste. The accuracy of this approach was verified against green waste data for the year 2007, produced by Wrap [3]. Only Scotland [4] and Wales [5] report the amount of green waste arisings as a separate figure from the rest of the organic waste. A summary of the results for 2013 is shown in Table 6 and in Figure 3.

**Table 6. Regional green waste production in 2013.**

	<b>Thousand tonnes of green waste</b>
North East	195.8
North West	597.5
Yorkshire and Humber	420.6
East Midlands	403.0
West Midlands	597.5
East Anglia	531.8
South East and London	1155.2
South West	478.4
Wales	242.8
Scotland	419.8
Total	5042.5



**Figure 3. Geographical distribution of green solid waste collected in 2013. The value of collected green waste for each region falls within the range indicated by the corresponding colour.**

### 3.2.2 Non segregated green waste

Where green waste is not segregated it will form part of the municipal waste stream. Mechanical and Biological treatment MBT and Mechanical Heat Treatment (MHT) facilities have developed to help sift such waste streams to remove recyclates (metal, plastic, glass) and to treat the remaining material which has an enhanced bio-based content (typically waste wood, non-recoverable paper, textiles and green waste etc.), via processes such as composting or anaerobic digestion (MBT Plants) or autoclaving (MHT plants).



The resulting separated materials (of greater or lesser biological origin depending on the processes used) where dry can be pelleted to produce refuse derived fuels, which are used in power generation. Other treatment facilities such as MHT processes using autoclaves produce a biological 'floc' material which can be put to other uses, including use as feedstock for anaerobic digestion facilities for heat and power generation, or potentially as a feedstock for Industrial Biotechnology.

Such feedstocks will need treating with caution until any contaminant loadings are verified and it is determined how these may affect any subsequent biological processes.

There are 31 MBT or MHT waste pre-treatment facilities in the UK currently capable of treating around 5 million tonnes of municipal waste in the UK. Around 35-45% of the waste input stream is recovered as a usable feedstock, but this is very dependent on individual plant configurations and equipment. Around 50-60% is typically of biological origin. The current treatment capacity could potentially give rise to 1.75 to 3 million tonnes of feedstock of which around half is bio-based ligno-cellulosic feedstock.

### 3.3 Potential future supply

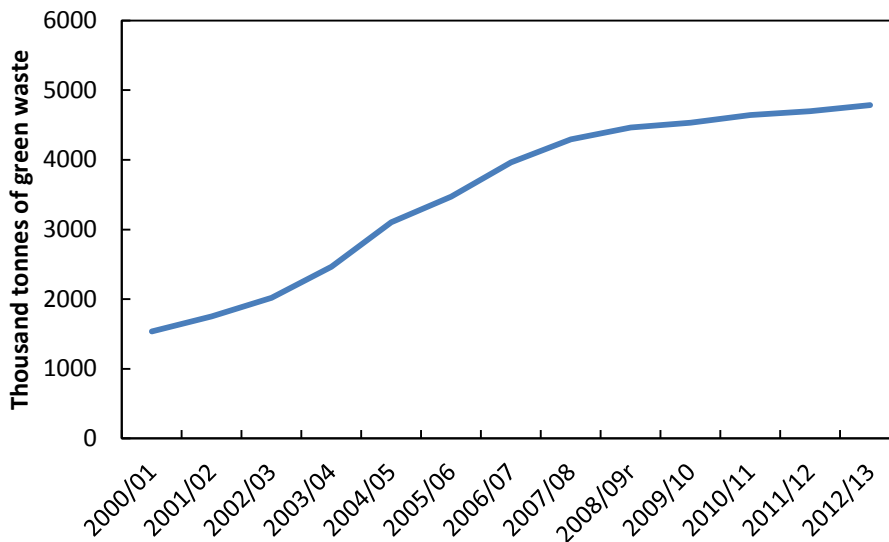
#### 3.3.1 Segregated green waste

The historical trend for green waste arisings in England is shown in Figure 4. The amount of green waste collected by local authorities has increased over the last decade. This reflects increased rates for separated green waste collection to enable local authorities to reach stretching recycling targets. The Waste Framework Directive and its associated Waste Hierarchy determine the priorities for UK waste treatment options. The hierarchy of options in priority order are: prevention, re-use, recycle/compost, or recover for energy before considering disposing into landfill.

The UK has improved its waste management practices largely due to the introduction of the landfill directive and the waste framework directive, which sets a target of recycle/reuse of 50% by 2020 for households. A report by the Green Investment Bank [6] highlights that the UK is only average in terms of recycling ability compared to other European countries, which suggests that there is still a lot of scope for improvements in collecting such usable waste streams.

#### 3.3.2 Non segregated green waste

There are plans for further MBT facilities to double the treatment capacity up to around 10 million tonnes. This treatment capacity could potentially give rise to 3.5 to 6 million tonnes of feedstock of which around half is bio-based ligno-cellulosic feedstock.



**Figure 4. Trend in segregated green waste production in England.**

### 3.4 Factors affecting availability

#### 3.4.1 Separated green waste

Separated municipal green waste collections are more frequent in the spring, summer and early autumn months reflecting the active growth period of the respective component streams. This material is currently aggregated in 'windrows' on hard standing to compost over a long period. This means that material would always be available to meet appropriately-scaled operations. However, such stands are left uncovered to encourage the process of decomposition. To preserve as much biomass as possible, these stands would need to be kept dry and aerated, which would mean adding roofing protection, turning to aid drying and potentially some forced ventilation to prevent deterioration.

#### 3.4.2 Non separated green waste

Green waste that enters the municipal waste stream becomes an integral part of a wide range of bio-based feedstocks which can be segregated into refused derived fuel (RDF), as green waste represents only one of a number of composite feedstocks, year-round supply could be guaranteed.

### 3.5 Competing uses

Where green waste is currently collected separately, it is typically composted using a windrow process to produce soil conditioners, mulches, constituents for top soil or

turf dressing. These applications are limited by end of waste regulations, which can limit where and how such materials are used to reduce any possible environmental contamination risks.

Such operations are classed as 'recycling' and help local authorities meet government imposed recycling targets. This has been the preferred option for local authorities and typically is contracted to external parties on long-term contracts. In such circumstances, it can be difficult to repurpose use of such materials to other uses.

Defra have a process to enable consideration of alternative disposal options that contravene the waste hierarchy principles, if it can be demonstrated that better environmental benefits will accrue from adoption of alternative waste processes, for example for use in low carbon energetic applications. However, the main problem is the current locking-in of such waste streams under existing waste disposal contracts that may prevent alternative use, until contracts come up for renewal. This will limit access to such materials.

RDF is currently exclusively used in power generation through combustion in waste incineration directive compliant plants.

### 3.6 Cost of feedstock

Due to its inhomogeneity, composition and geographical variability. It is difficult to put a price to green waste. In many cases companies even have to pay to dispose of it. It is reasonable to assume that green waste should come at (nearly) no cost.

### 3.7 Composition of feedstock

Composition of green waste will vary depending on geographical location, whether this includes business or residential waste, and time of the year. Because of this large variability only a rough estimate of the composition can be given. Assuming the majority of green waste is composed of grass cuttings and hedge and branch cuttings, the composition of the main structural compounds should be in a range between that of grasses and trees. This is summarised Table 7.

The ash content of green waste is likely to lie somewhere between that of miscanthus and wood as it is mainly comprised of grass and woody materials.

**Table 7. Estimated composition of green waste.**

	<b>Grass</b>	<b>Softwood</b>	<b>Hardwood</b>	<b>Total range</b>
Cellulose	32-39	35-44	40-50	32-50
Hemicellulose	31-43	25-30	25-30	31-42
Lignin	3-6	25-35	20-25	3-35

## References

1. Wikipedia, [http://en.wikipedia.org/wiki/Green\\_waste](http://en.wikipedia.org/wiki/Green_waste), accessed on 16/10/2014.
2. Statistics on waste managed by local authorities in England in 2012/2013, Defra, 2013.
3. Commercial and industrial organic waste arisings - a gap analysis, Wrap, 2009.
4. [Scotland government website](#), accessed on 16/10/2014.
5. [Welsh government website](#),  
<https://statswales.wales.gov.uk/Catalogue/Environment-and-Countryside/Waste-Management/Recycling-Destinations/Recycling-Tonnages-by-Material-FacilityType> accessed on 16/10/2014.
6. Green Investment Bank, The UK residual waste market, July 2014.
7. A survey of the UK organics recycling industry in 2012, Wrap.

## 4 Analysis of biomass resources from energy crops

### 4.1 Introduction

A dedicated biomass energy crop is a crop plant grown specifically to produce biomass, typically for use in solid-biomass heat and power applications, or potentially for use in lignocellulosic applications. These plants tend to be high-yielding perennial crops. In the UK, miscanthus and short rotation coppice (SRC) derived from willow or poplar have been the most widely planted species.

### 4.2 Current availability

Compared to conventional arable crops, biomass crops have only been planted on a very small area of land to date and it has proved difficult to gather reliable data on the total areas planted. Defra undertook a specific exercise in 2012 to examine the extent of planting of crops for non-food uses, including bioenergy crops. This study primarily relied on gathering data from payment schemes supporting the establishment of energy crops. Unfortunately such schemes were not implemented in the Devolved Administrations, so it was not possible to obtain information on energy crops from Scotland and Wales through such means. From the English scheme data, it was found that 9,400 ha of miscanthus and 2,300 ha of SRC had been planted under recent Energy Crop Scheme payment regimes up until closure in 2013. The regional split of this planting data was used to derive estimates of regional energy crop biomass arisings in England.

#### 4.2.1 Miscanthus

Miscanthus is primarily grown for the renewable heat and electricity market. It is harvested annually. Regional data on estimated harvestable tonnage is summarised in Table 8.

**Table 8. Tonnes of harvestable Miscanthus grown in England assuming a yield of 15 dry tonnes/hectares/year [1] (based on areas declared in the Defra June Survey of Agriculture and Horticulture (2010) [2]).**

Region	tonnes
North East	0
North West	1,845
Yorks Humberside	34,035
East Midlands	39,135
West Midlands	28,740
East of England	8,850
South East	6,825
South West	21,870
Total England	141,300

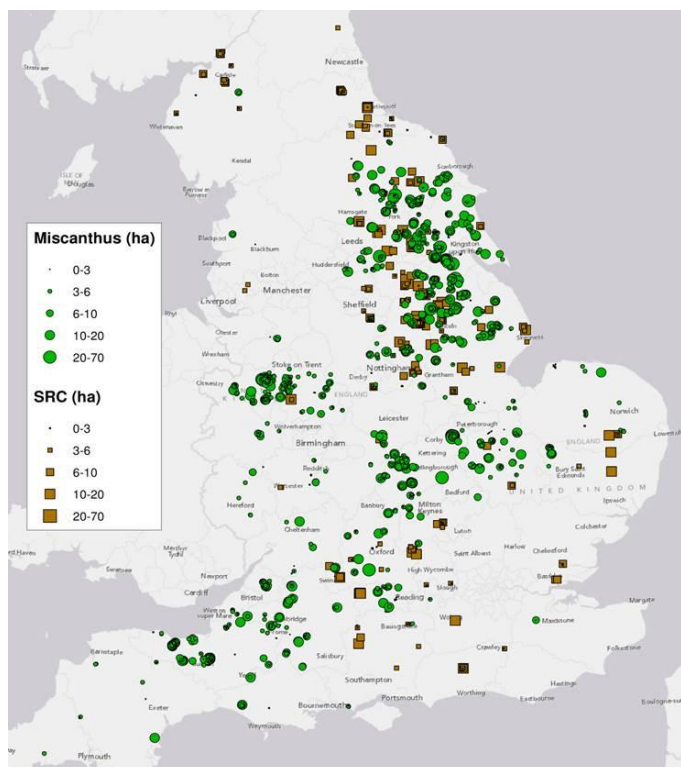
## 4.2.2 Short Rotation Coppice (SRC)

Willow or poplar species when managed as short rotation coppice are harvested typically every three years. The estimated tonnes of SRC produced in England are shown in Table 9.

Figure 5 shows the map of where Miscanthus and SRC are currently planted in England.

**Table 9 . Tonnes of SRC grown in England assuming a yield of 8 dry tonnes/hectares/year [1] (based on areas declared in the Defra June Survey of Agriculture and Horticulture (2010) [2]).**

Region	tonnes
North East	1,824
North West	1,024
Yorks Humberside	4,808
East Midlands	7,328
West Midlands	216
East of England	1,176
South East	2,296
South West	328
Total England	19,000



**Figure 5. Distribution of Miscanthus and SRC planting in England, based on Natural England data for ECS plantings [3].**

### 4.3 Potential future supply

Historical data on production from Miscanthus plantations is shown in Figure 6 [1] which reflects changing crop areas. Defra warns that the apparent decrease in area from 2009 may be due to sampling variation in the survey. The short rotation coppice historical data for England is shown in Figure 7 and evidences a decline in crop area as growers removed uneconomic stands.

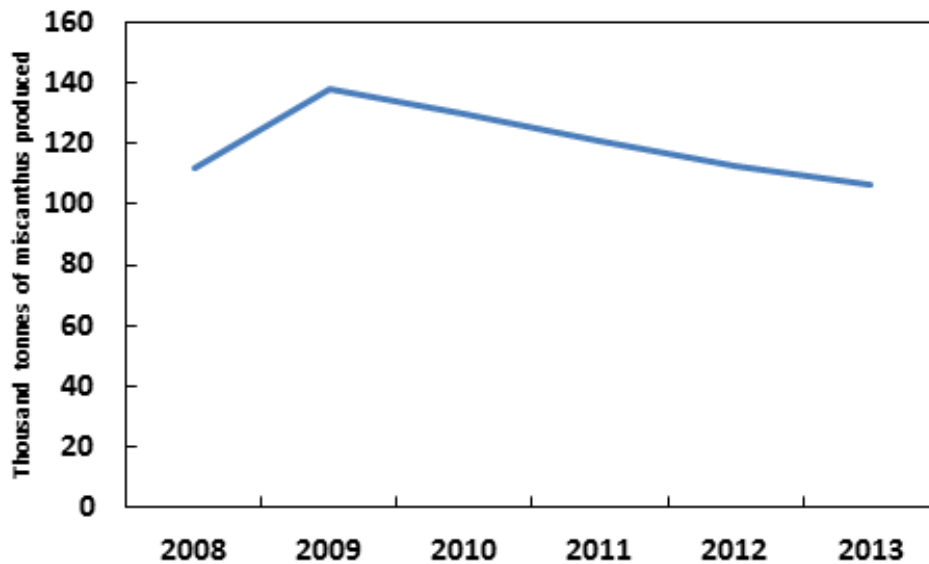


Figure 6. Trend in Miscanthus production (thousand, odt) in England between 2008 and 2013.

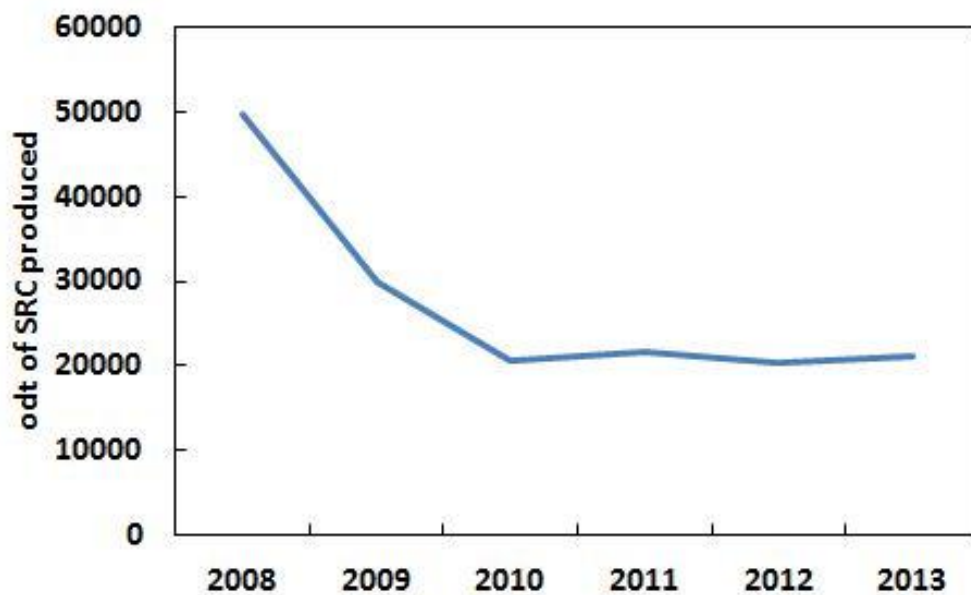


Figure 7. Trend SRC production (odt) in England between 2008 and 2013.

## 4.4 Factors affecting availability

The potential for scale up is currently restricted by the planting and harvesting capacity, grower acceptance and technology compatibility.

The availability of government-supported schemes, which previously subsidised the costs of crop establishment has been a significant factor influencing the growth of this sector. However, after closure of the previous scheme in summer 2013 there are currently no plans for government to re-open a similar support scheme.

Returns to growers are relatively small compared to those from conventional arable crops.

In response to the above issues, there is not expected to be a significant increase in planting and availability of UK energy crops in the near future.

### 4.4.1 Seasonality

Both miscanthus and SRC are harvested in the winter period, when miscanthus has senesced and willow and poplar are dormant. Material is typically baled or chipped on-site and then removed to covered storage where it is dried and aired. This means that reserves have to be built up and stored to maintain year-round supply. Typically this involves a mix of both on-farm and on-site storage.

## 4.5 Competing uses

Energy crops are nearly all grown for use in the energy sector. Some is also used in animal bedding applications. It is likely to be a relatively constrained resource in the UK in the near-term.

## 4.6 Cost of feedstock

Chopped Miscanthus is estimated to sell between £45 and £70/tonne, depending on moisture content (typical energy contract price of £60/fresh tonne delivered (around 16% moisture content)). Short rotation coppice sells for around £65/odt (delivered).



## 4.7 Composition of feedstock

**Table 10. Composition of Miscanthus [4], Willow [5], Poplar [6].**

	Miscanthus	Willow	Poplar
Lignin	6-13%	25%	22-25%
Cellulose	31-55%	30%	35-48%
Hemicellulose	25-38%	45%	19-22%
Cellulose+hemicellulose	61-89%		

The ash content of miscanthus varies from around 2-3.9%. Leaving in-field overwinter can reduce nutrient levels and therefore ash content. SRC and willow will have an ash contents similar to forest harvest residues at 1-3%.

## References

1. UK Agriculture website, <http://www.ukagriculture.com/crops/miscanthus.cfm> accessed on 20/10/2014
2. Area of Crops Grown For Bioenergy in England and the UK: 2008 – 2012. Defra 2013..
3. ETI and E4Tech report.
4. Miscanthus, Iain Donnison, IBERS, <http://www.epsoweb.org/file/1026>, accessed on 20/10/2014
5. Secondary cell wall composition and candidate gene expression in developing willow (*Salix purpurea*) stems, *Planta*. 2014; 239(5); 1041-1053, February 2014.
6. The cultivation of poplar short rotation coppice, Bart Tambuyser, Biocore,

## 5 Analysis of biomass resources from the paper industry

### 5.1 Current availability

#### 5.1.1 Residues from paper production

There are currently 52 paper mills operating in the UK; they use 1.1 million tonnes of wood pulp, of which 0.9 Mt are imported [1]. As residues from processing amount to on average 35% of the material entering pulp and paper mills [3], the total process residues in 2013 amounted to nearly 0.4 million tonnes.

#### 5.1.2 Residues from paper recycling

7.9 million tonnes of paper were collected for recycling in 2013, of which 3.8 m tonnes were used domestically. The paper recycling industry converts waste or old paper to make cardboard sheets or other lower grades of paper. As paper fibres can typically only be recycled 6 times before the fibre quality declines to unusable levels, the waste from the paper recycling industry comprises paper rejects and sludges. The solid by-product streams of paper recycling are:

- deinking sludge, which contains minerals, ink and cellulose fibres that are too small to be withheld by filtration.
- Coarse rejects: produced during early filtration steps. These rejects contain a high content of cellulose fibres.

Arisings of such materials in the UK are given in Table 11.

**Table 11. Residues from paper recycling industry in the UK (2008) [6].**

	Amount (kton DM)
Deinking sludge	556
Effluent sludge	90
Other sludge	4
Coarse rejects	119

This gives a combined total residue arising from virgin and recycled paper production of around 1.16 million tonnes.

#### 5.1.3 Recycled paper collected for export

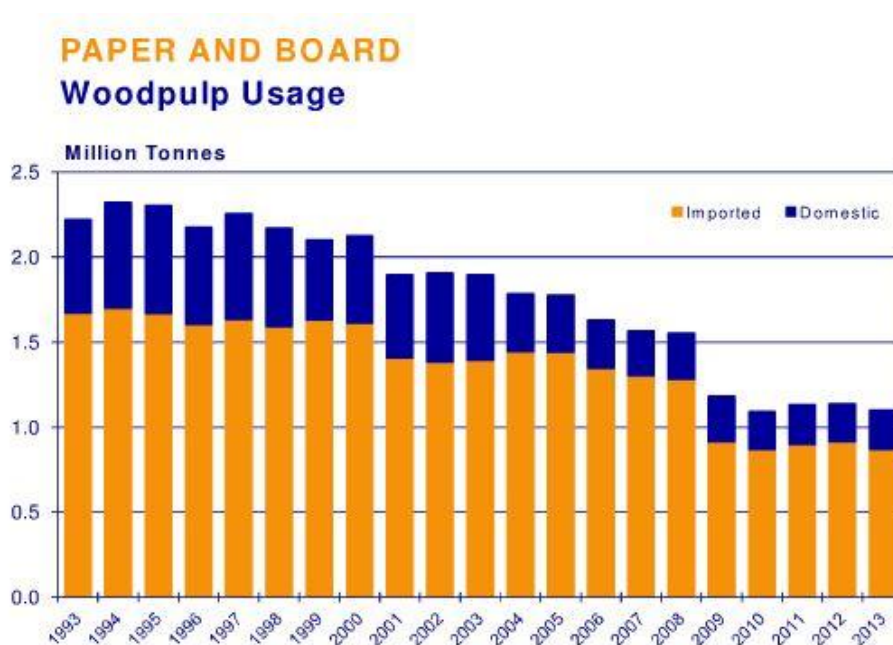
In addition to the above residues from paper and card pulping processes, 4.2 m tonnes of paper collected for recycling is currently exported for processing abroad. Much of this is currently exported to China, but this market demand is declining. In the absence of a domestic demand, this segregated resource could be directed towards other uses in the UK.

## 5.2 Potential future supply of residues from paper production and recycling

### 5.2.1 Residues from paper pulping operations

Figure 8 shows imported and domestic woodpulp usage in the UK. After a decline between 1993 and 2009 (which mirrored mill closures), woodpulp use has stabilised. It's unlikely that domestic processing of pulp is going to increase in the near future. Market research studies [3] suggest that the UK paper industry will decline at a compound annual rate of 4.5%.

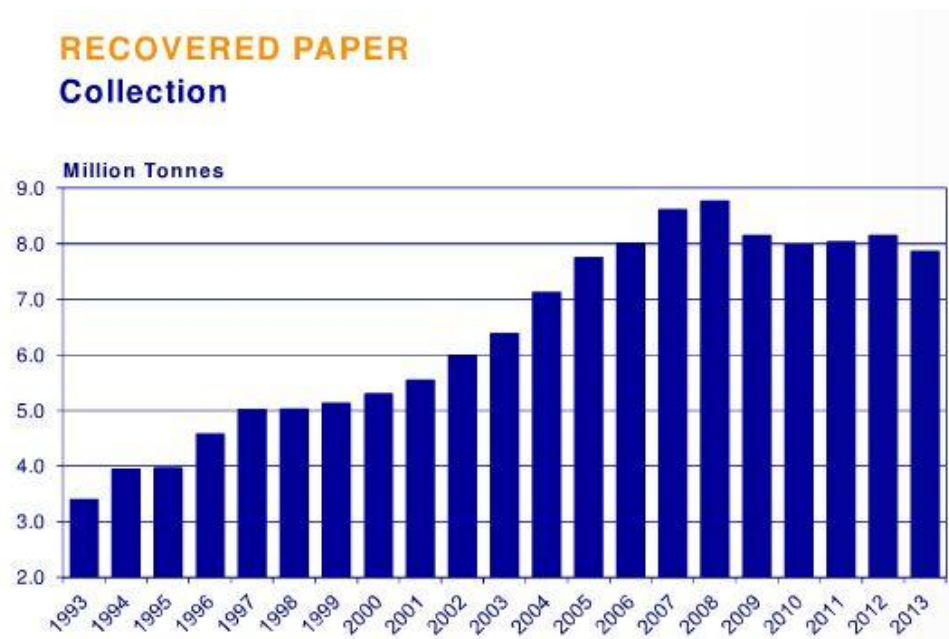
This suggests that the availability of paper processing by-products is unlikely to increase from current levels.



**Figure 8. Trend of woodpulp usage in the UK between 1993 and 2013 [1].**

### 5.2.2 Residues from paper recycling

Figure 9 shows the amount of paper collected for recycling between 1993 and 2013. The amount collected rose until 2009 and then stabilised at around 8 Mt per annum. Given that much of this (53%) is exported currently and the market for this is now less certain, collection rates are not expected to increase in the near term. However more of the collected paper resource could be used domestically for other uses as some of the existing export market demand declines.



**Figure 9. Trend of paper recovery in the UK between 1993 and 2013 [1].**

### 5.3 Factors affecting availability of residues from papermaking

The paper industry is expected to decline further due to the switch to electronic media for communication and storage [7]. This decline will affect the availability of waste from the pulp and paper industry.

Due to the nature of the industry, year round supply of material would be available.

### 5.4 Competing uses

Paper mill sludge is currently burnt for energy either in the processing plant or offsite or alternatively disposed of in landfill. Both options represent relatively low value returns to, or in the case of waste disposal costs on the paper business.

### 5.5 Cost of feedstock

Woodpulp is traded on the open market and the current price is \$806.62/metric ton. It was not possible to identify the cost of residues derived from paper processing or recycling. As a waste product they are likely to be available on a fee for removal and disposal basis or as a zero costs feedstock (otherwise the producer would incur a fee for safe disposal).

## 5.6 Composition of feedstock

Sludge waste from woodpulp paper production has a complex and variable chemical composition [8]. Typically it contains:

- Trace elements from ink (Zn, Pb, Cu, Cr, Ni, Hg, Co, As, Se, Sb, and V)
- Resin fatty acids (RFA)
- Chloroform (due to the introduction of chlorine during a bleaching stage)
- Hemicellulose (4.1+- 0.3%) [9]
- Cellulose (21.1+- 1.4%) [9]
- Lignin (13.9 +-0.6) [9]
- Ash (48.5 +-1.2%) [9]

## References

1. CPI review, 2013-14, Change and Challenges
2. Forestry commission website, [www.forestry.gov.uk](http://www.forestry.gov.uk), accessed on 21/10/2014
3. G.M.Scott, A. Smith, S. Abubakr Sludge Characteristics and Disposal Alternatives for Recycled Fiber Plants, USDA Forest Service, 1995 Recycling Symposium
4. Composition of local authority collected waste (2007), [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/142004/Composition\\_of\\_local\\_authority\\_collected\\_waste.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/142004/Composition_of_local_authority_collected_waste.pdf), accessed on 20/11/2014.
5. Statistics on waste managed by local authorities in England in 2012/2013 (DEFRA).
6. Maximum value from paper for recycling, towards a multi-product paper mill, cepi, 2011
7. Paper & Paperboard Manufacturing in the UK: Market research report, [www.ibisworld.co.uk](http://www.ibisworld.co.uk), accessed on 1/10/2014
8. W.E. Mabee, Study of woody fibre in papermill sludge, University of Toronto, 2001
9. A. Mukhopadhyay, P. Vadlani, R. Mulukutla, F. Renk, Bioconversion of paper mill waste to value-added chemicals, TAPPI EPE Conference, 2009
10. M. Ioelovich, Waste paper as promising feedstock for production of biofuel, J. Scientific Research and Report, v 3(7) pp 905-916 (2014).

## 6 Analysis of biomass resources from agricultural straw residues

### 6.1 Introduction

The straw resource in the UK, is mainly derived from wheat, barley, oil seed rape (OSR) and to lesser extent oats. Straw is normally collected for use in the livestock sector and the remainder is chopped and returned to soils.

Barley and oat straw are typically baled and removed from fields for use as a source of roughage in livestock feed rations. Wheat straw has a lower feed-value than barley or oat straw but is widely used for animal bedding. Other smaller markets for wheat straw include use as fuel for heat and power generation and small volumes are used in the mushroom and winter carrot industries. Due to its relatively low bulk density, transport costs for hauling straw any significant distance are high. So, in the absence of nearby livestock or other markets for straw, it is typically more cost effective to plough straw back into soil [1].

### 6.2 Current availability

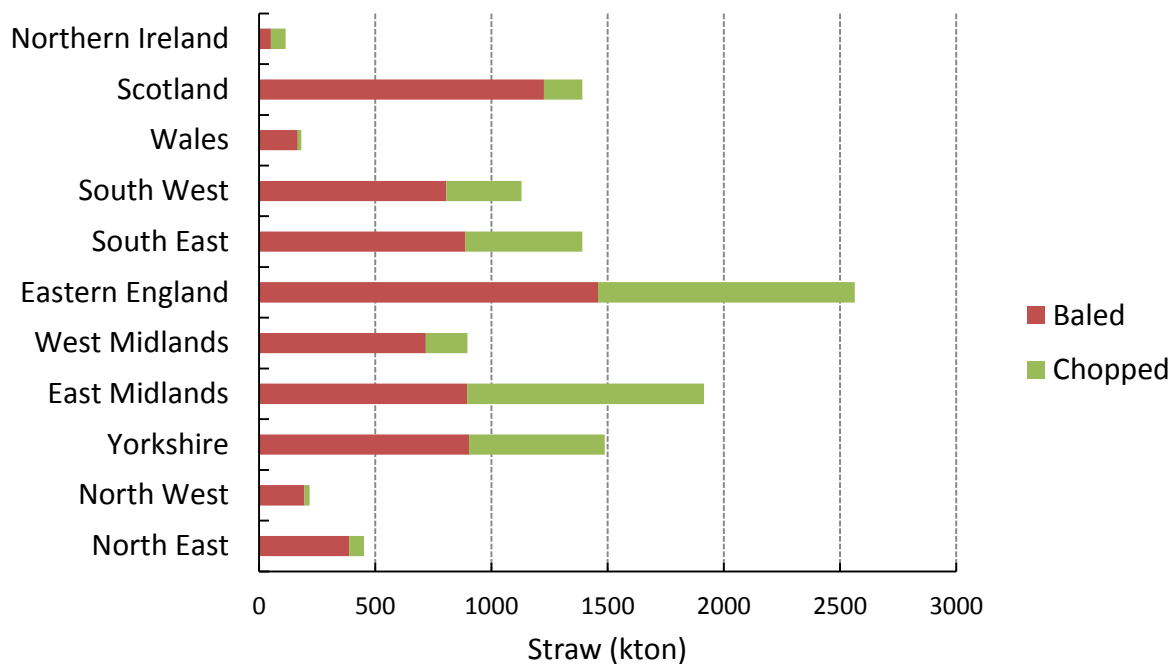
Whilst data on cereals and OSR production is publicly available [2], data on straw production from these crops is not. To calculate straw yields, data for relevant crop areas and yields were used to calculate the total average production for the last 5 years. Harvest indices were then used to calculate total straw production. The harvest index is defined as the ratio between grain yield on a dry basis and the total crop dry weight at harvest. Production data was averaged for the period 2009 to 2013.

The majority of agricultural straw is derived from wheat in nearly all regions apart from Scotland where barley prevails. Wheat and oilseed straw production is concentrated in the arable eastern part of the UK and these represent the resources that are currently most available and underutilised (assuming rates of collection could be increased).

Results of the straw analysis are shown in Table 12 and in Figure 10.

**Table 12. Total straw production, collected straw, residual uncollected straw in the UK, 5y average (kton).**

	Straw production 5y average (kton)					Straw production that is typically collected (baled), 5y average (kton)					Residual straw that is currently uncollected (chopped and incorporated into soil), 5y average (kton).				
	Wheat	Barely	Oats	OSR	Total	Wheat	Barely	Oats	OSR	Total	Wheat	Barely	Oats	OSR	Total
North East	246	121	22	62	<b>452</b>	221	110	20	37	<b>389</b>	25	11	2	25	<b>62</b>
North West	93	105	14	6	<b>218</b>	85	96	12	2	<b>195</b>	8	9	1	4	<b>23</b>
Yorkshire	942	369	25	152	<b>1488</b>	518	336	23	27	<b>904</b>	424	33	2	125	<b>584</b>
East Midlands	1,388	225	38	264	<b>1,915</b>	625	205	34	32	<b>896</b>	764	20	3	232	<b>1,020</b>
West Midlands	600	154	57	86	<b>897</b>	510	140	52	15	<b>718</b>	90	14	5	70	<b>179</b>
Eastern England	1,852	421	32	259	<b>2,564</b>	982	383	29	65	<b>1,458</b>	871	38	3	194	<b>1,105</b>
South East	942	233	67	149	<b>1,391</b>	603	212	61	12	<b>888</b>	339	21	6	137	<b>503</b>
South West	635	336	62	97	<b>1,130</b>	438	306	57	5	<b>806</b>	197	30	6	92	<b>325</b>
Wales	80	62	14	26	<b>183</b>	78	56	13	20	<b>167</b>	2	6	1	6	<b>15</b>
Scotland	407	910	75	0	<b>1,392</b>	329	828	68	0	<b>1,226</b>	77	82	7	0	<b>166</b>
Northern Ireland	39	69	7	0	<b>115</b>	25	21	6	0	<b>52</b>	14	48	1	0	<b>63</b>
<b>Total</b>	<b>7,225</b>	<b>3,006</b>	<b>413</b>	<b>1,100</b>	<b>11,745</b>	<b>4,414</b>	<b>2,693</b>	<b>376</b>	<b>216</b>	<b>7,699</b>	<b>2,811</b>	<b>313</b>	<b>37</b>	<b>885</b>	<b>4,045</b>



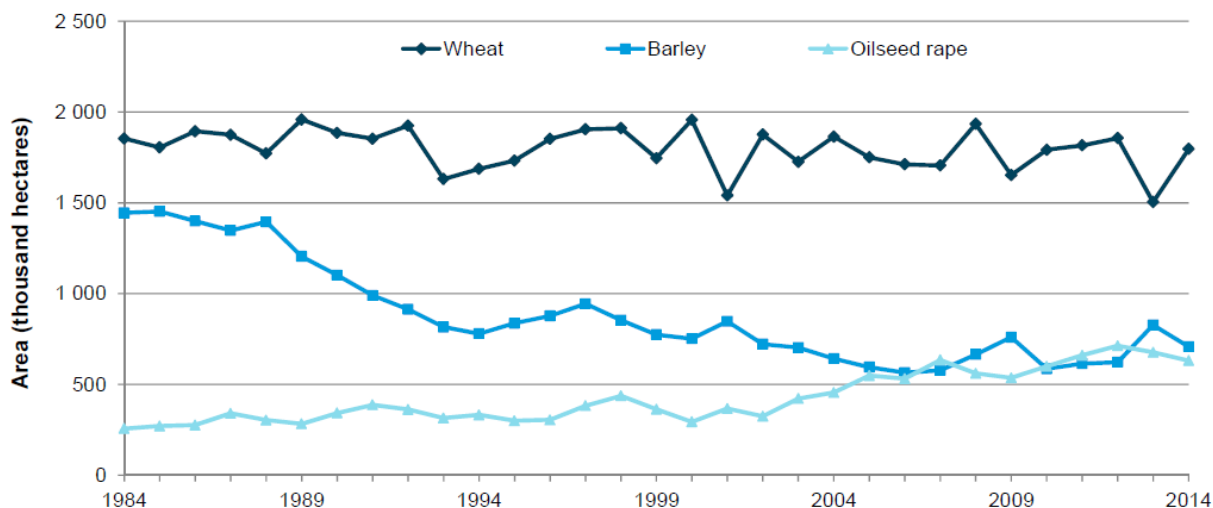
**Figure 10. Regional comparison of straw production from all crops (baling, chopping and total).**

### 6.3 Potential future supply

The availability of straw is primarily driven by the area of each relevant crop and by any changes in demand, primarily from the livestock sector. In the latter case such changes are relatively slow and are unlikely to affect straw availability in the short to medium term on a national basis, though localised problems can occur, for example though expansion in pig production in an area.

The UK national wheat area fluctuates between 1.5 and 2 million hectares (m ha) with dips in area following wet autumns where planting is delayed (see Figure 11). The barley area has stabilised after a long period of decline. The oilseed rape area has expanded in recent years, driven by the biodiesel market. However, this opportunity is now declining and the oilseed rape area is likely to reduce below 0.5m ha. The wheat straw resource is therefore likely to remain relatively stable. Most barley straw is consumed by the livestock sector. The oilseed rape straw resource is likely to decline in the short term, but still represents an underutilised resource.





**Figure 11. Historical trend of area planted for wheat, barley and oilseed rape.**

## 6.4 Factors affecting availability

Where there are concerns over soil organic matter content there is resistance to removal of straw as it is used to improve soil structure and nutrient status. As a result not all farmers are willing to collect straw. In addition, in difficult wet harvest periods, farmers may be more reluctant to delay field operations to collect straw.

### 6.4.1 Seasonality of supply

The collection of straw is focussed around a very narrow window of opportunity between harvesting and planting of following crops, typically a matter of a few weeks. Industries relying on straw feedstock therefore, need to ensure adequate storage. As with energy crops, this is typically achieved by encouraging a mix of on-farm and site storage, with growers or intermediaries supplying during defined periods on contract agreements. Straw needs to be kept dry and aerated or store losses can be high.

## 6.5 Competing uses

As seen previously, straw has many potential uses. All these uses compete for the availability of this resource and influence the uncertainty regarding its potential availability for alternative uses. The straw resource that is currently returned to land most accurately represents the resource available for other uses that would not compete with existing uses. However, the value of this material to land in terms of organic matter and soil nutrients should not be underestimated. The value placed on these benefits means some farmers will be reluctant to bale and collect straw.

## 6.6 Cost of feedstock

The price of straw varies according to geographical location, period of the year, and availability and is driven by livestock and increasingly bioenergy demand. The availability of straw differs considerably in different regions reflecting the dominance of different farm types in terms of degree of arable cropping. Generally prices are lower in the Eastern regions and the South (areas of relative straw surplus). In Wales and Western regions straw tends to fetch a higher price due to limited availability. The long term historical fluctuation in straw price is shown in Figure 12. The regional variation in straw price is shown in Figure 13, and demonstrates the fall in price in the late summer as new straw supplies become available in areas of greatest supply.

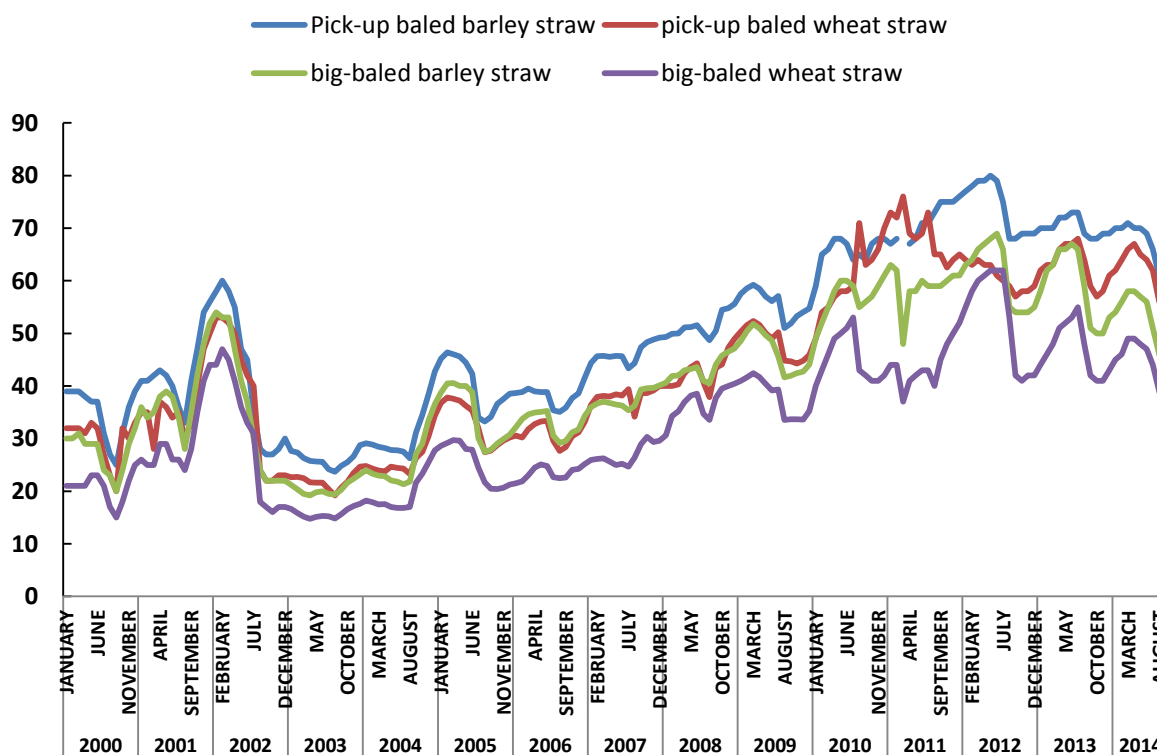


Figure 12. Variability of straw price in the UK (2000-2014) [4].

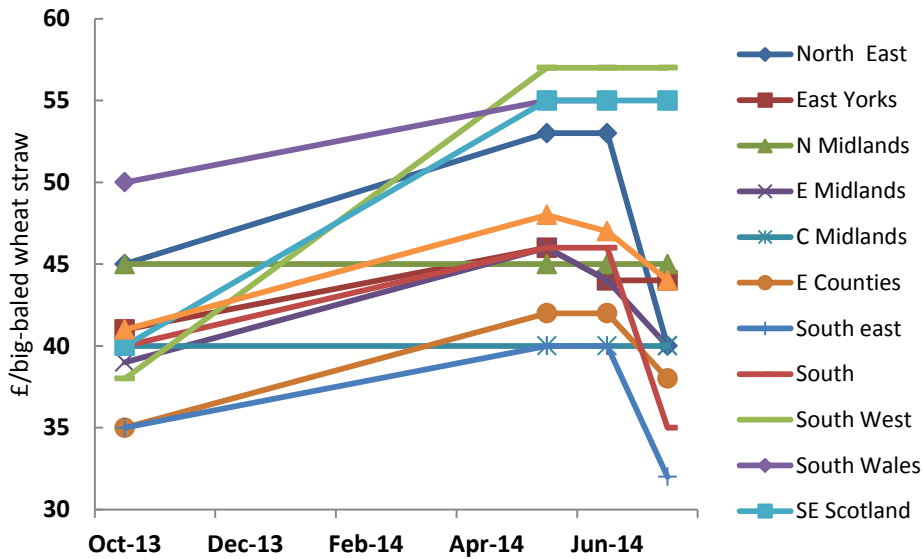


Figure 13. Examples of regional variability of price.

## 6.7 Composition of agricultural straw residues.

Table 13. Composition of cereal and OSR straw [5-11].

%	Wheat	Barley	Oat	OSR
Lignin	15-21	14-19	16-19	18-23
Cellulose	33-40	31-45	31-48	35-40
Hemicellulose	20-25	27-38	23-38	27-31
Ash	3-10	2-7	2-7	3-8

## References

1. National and Regional supply/demand balance for agricultural straw in Great Britain, J. Copeland, D. Turley, 2008
2. Structure of the agricultural industry in England and the UK at June, DEFRA.
3. Marketing Study for Biomass Treatment Technology, Technical Appendix 1, October 2009.
4. [http://www.dairyco.org.uk/market-information/farm-expenses/hay-straw-prices/#.VFJiZ\\_msWSo](http://www.dairyco.org.uk/market-information/farm-expenses/hay-straw-prices/#.VFJiZ_msWSo) accessed on 30/10/2014
5. <http://digital.csic.es/bitstream/10261/51774/1/Structural%20Characterization%20of%20Wheat%20Straw%20Lignin%20as%20Revealed%20by.pdf> accessed on 31/10/2014

6. Thermochemical characterisation of straw and high yielding perennial grasses, *Industrial Crops and Products*, 36(2012) 449-459.
7. <http://www.afdc.energy.gov/biomass/progs/search3.cgi?25773> accessed on 31/10/2014
8. [http://ipst.gatech.edu/faculty/ragauskas\\_art/technical\\_reviews/cellulose%20pentosan%20lignin%20ash%20ag%20content.pdf](http://ipst.gatech.edu/faculty/ragauskas_art/technical_reviews/cellulose%20pentosan%20lignin%20ash%20ag%20content.pdf) accessed on 31/10/2014
9. Potential bioethanol and biogas production using lignocellulosic biomass from winter rye, oilseed rape and faba bean, *Biomass and Bioenergy* 31 (2007) 812-819.
10. [http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1027&context=textiles\\_facpub&sei-](http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1027&context=textiles_facpub&sei-) accessed on 31/10/2014
11. Compaction characteristics of barley, canola, oat and wheat straw, *Biosystem Engineering* v104, issue 3, (November 2009) 335-344.

## 7 Conclusions

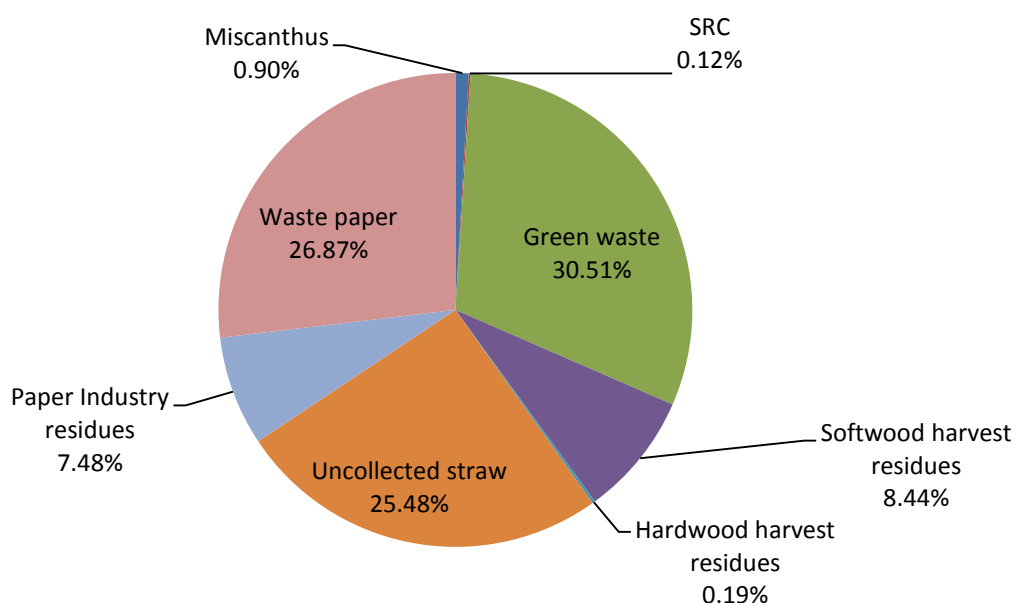
This study examined the potential biomass resource that could be available in Great Britain from forest residues, green waste, energy crops, the paper industry and currently unused straw.

A total resource amounting to 15.6 million tonnes was identified which included:

- Forestry residues as described in Section 2.
- Segregated green waste garden residues, as described in Section 3.
- Energy crops as described in Section 4 (England only).
- Waste from the paper industry (both virgin and recycled paper) as discussed in Section 5
- Segregated waste paper which is not currently recycled in the UK (the full analysis of this resource was outside the original scope of the study).
- Straw that is not currently baled, as described in Section 6.

Of the above, the majority represent residues for which there is either currently no commercial demand or driver to collect (forest and straw residues that are currently left in-situ), or they are treated as wastes and disposed of at least cost (green waste, paper industry residues and paper for recycling) or are used in low-value energy applications (paper wastes and dedicated biomass energy crops).

The largest contributors to this biomass resource are green waste, waste paper and straw residues (Figure 14). The waste paper fraction represents segregated paper and cardboard collections that are currently exported from the UK. A detailed breakdown of the waste paper resource was out of the scope of this report, but totals are included for completeness (see Appendix I for raw data).



**Figure 14. Proportion of identified biomass resources by type**

The research highlighted the regional availability of each biomass resource, where such data was available. Significant variation was found in the availability of biomass both by region and by type. A summary can be observed in Figure .

This indicates that:

- Scotland is the region with the highest availability of forest harvest residues.
- The South East and London region has the highest availability of green waste.
- Eastern England and East Midlands have the highest availability of straw residues.
- Energy crops form only a small proportion of the total, in all regions.

Combining the results of regional biomass availability and composition, the regional distribution of available lignin, hemicellulose and cellulose was estimated (Figure ).

The large variation between the minimum and maximum values is mainly caused by the uncertainty in the composition of certain biomass types (e.g. green waste) (the underpinning data can be found in Appendix II).

- The largest lignin resource can be found in Scotland, because of the large forest residues resource in this region.
- The East and South East are the richest in cellulose and hemicellulose.

Future trends for the different waste streams were analysed.

- The Softwood harvest residue resource is predicted to increase by 30% by 2030, but actions to encourage collection will be required.
- The collected green waste resource could potentially increase if the current trend towards segregated collections is maintained.
- The residual straw resource is relatively stable, but as with forest harvest residues, actions will be required to encourage collection and to compensate for loss of nutrients and potentially organic matter addition to soil that is forgone if removed.
- The paper residues resource is unlikely to increase due to the contraction of the paper market
- The energy crop resource is unlikely to increase in the near future in the absence of public support to encourage planting. The existing resource is also likely to be consumed within the renewable heat and power sector.

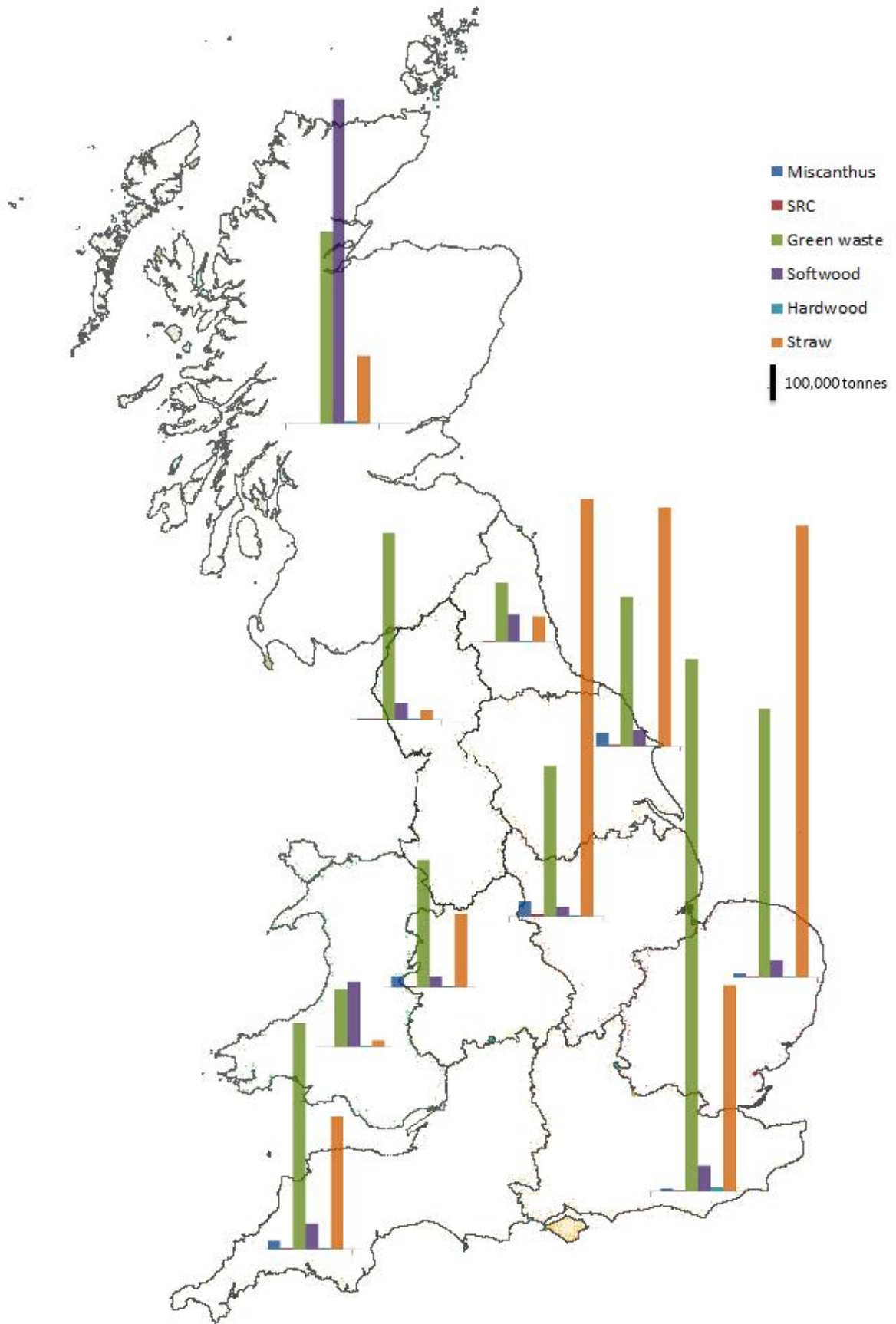


Figure 15. Availability of biomass residues by region.

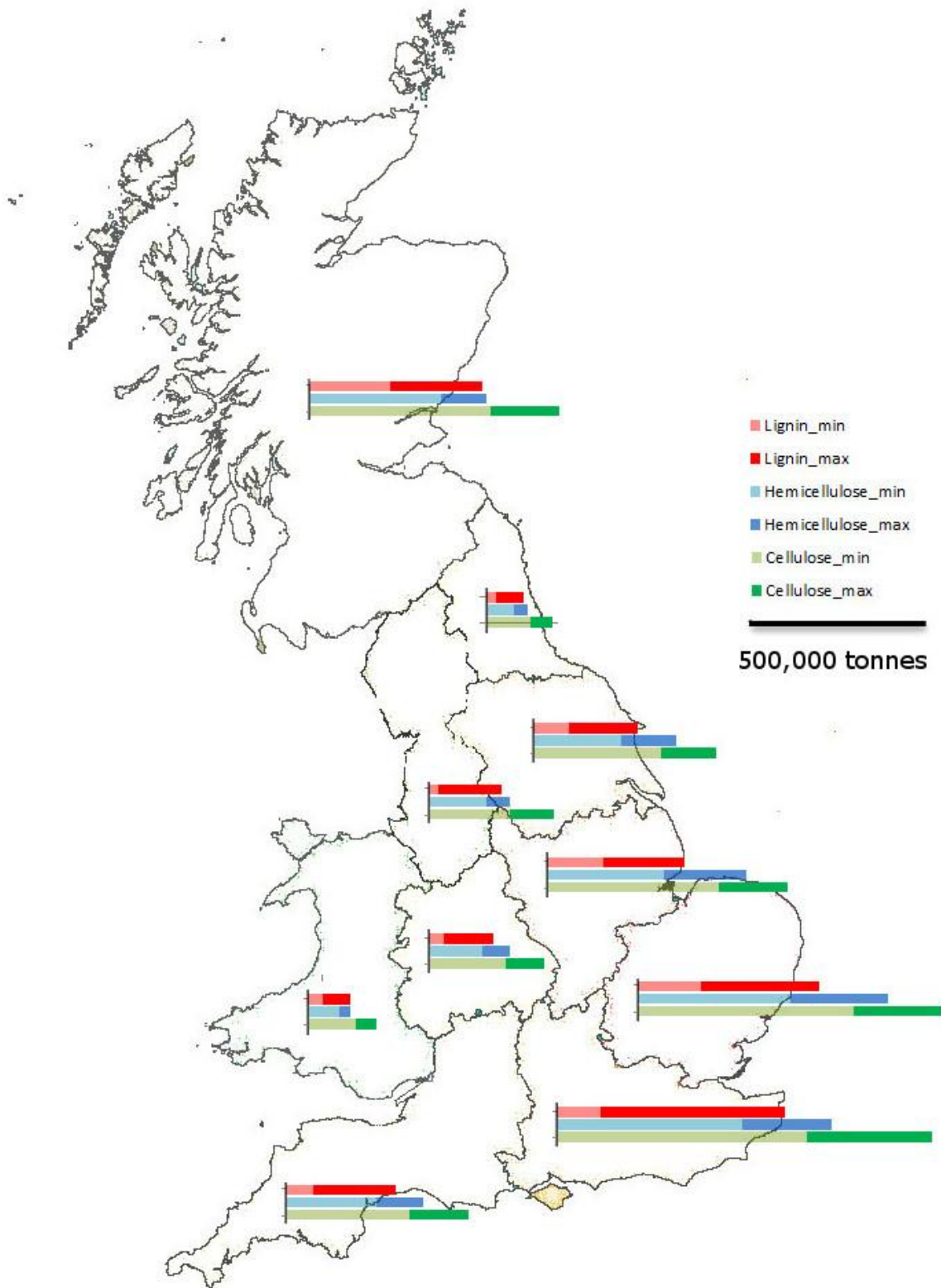


Figure 16. Distribution of lignin, hemicellulose and cellulose

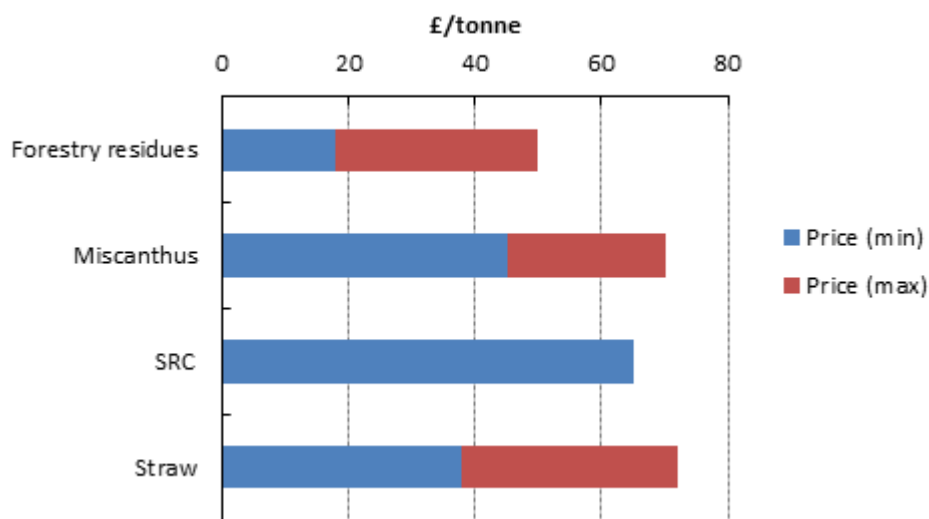


The analysis highlighted that different biomass feedstock had different temporal characters that affected whether long term storage was required

- 1) Green waste, recycled paper and forest residues are typically available year-round from existing collection points in the case of green waste and paper, these would need to be developed for forest harvest residues, or could be linked to existing sawmills.
- 2) In contrast, straw and energy crops are harvested within specific timeframes and require storage and protection to maintain quality over a long period.

Figure shows the price comparison (where known) between the different types of biomass considered. For the commercially developed biomass resources the range of prices show significant overlap. The price of forest residues can only be taken as an estimate at this stage in the absence of any significant commercial development in the UK.

Residues from the paper industry and green waste are anticipated to be available at zero or little costs at the point of arising as they are considered waste materials.



**Figure 17. Price comparison between the different lignocellulosic biomass types.**

On balance, green waste and forest residues are potentially good candidates as feedstocks for large scale biorefinery plants, being available at relatively low cost, and in significant tonnages. Similarly such materials are less subject to seasonal variability in supply. However it's also important to consider consistency in the composition of the feedstock as biological systems can be very sensitive to small changes, impacting on process efficiency. Residues such as green waste could be

contaminated with pesticides and have high fertiliser loadings that may complicate matters. Similarly, residues from the paper industry will contain variable proportions of chemicals that may affect biological processes.

The feedstocks with most consistent composition and low levels of other contaminants should be energy crops, straw, and forest residues. The latter two are available in significant quantities and in focussed concentrations that can be readily accessed through existing supply chains and should be available at relatively low cost as biomass resources.

## 8 Appendix I. Regional distribution of biomass resources by type

**Table 14. Regional distribution of biomass resources by type (tonnes)**

	Miscanthus	SRC	Green waste	Softwood	Hardwood	Straw	Total
North East	0	1,824	145,046	67,769	419	62,471	277,530
North West	1,845	1,024	456,930	40,417	559	22,710	523,485
Yorks and Humb	34,035	4,808	366,123	40,745	1,149	584,149	1,031,009
East Midlands	39,135	7,328	367,545	23,118	1,869	1,019,637	1,458,632
West Midlands	28,740	216	311,760	28,091	1,423	179,470	549,700
East of England	8,850	1,176	656,031	41,569	1,913	1,105,447	1,814,986
South East & London	6,825	2,296	1,300,347	62,127	8,870	502,917	1,883,382
South West	21,870	328	552,349	62,324	3,637	324,501	965,009
Wales			141,542	158,640	2,560	15,303	318,045
Scotland			470,679	794,240	7,360	165,937	1,438,216
<b>Total</b>	<b>141,300</b>	<b>19,000</b>	<b>4,768,352</b>	<b>1,319,040</b>	<b>29,760</b>	<b>3,982,542</b>	<b>10,259,994</b>

## 9 Appendix II. Regional distribution of biomass resources by composition

**Table 15. Regional distribution of biomass resources by composition (tonnes)**

	<b>Lignin min</b>	<b>Lignin max</b>	<b>Hemicellulose min</b>	<b>Hemicellulose max</b>	<b>Cellulose min</b>	<b>Cellulose max</b>
North East	31,504	109,975	79,748	117,210	127,419	189,117
North West	29,165	216,010	165,676	234,337	233,789	363,620
Yorks and Humb	107,626	308,169	256,202	416,573	371,014	531,158
East Midlands	165,204	403,085	341,004	579,377	501,017	699,534
West Midlands	44,962	191,526	153,531	234,335	223,840	336,506
East of England	187,572	532,468	445,392	730,554	629,153	889,645
South East & London	130,989	666,005	540,181	801,431	726,382	1,093,939
South West	81,156	322,554	264,982	399,898	359,825	532,634
Wales	47,407	126,990	91,469	123,775	138,734	200,427
Scotland	238,554	507,312	385,351	515,270	527,472	727,443
<b>Total</b>	1,032,635	3,274,119	2,643,788	4,035,549	3,711,226	5,374,906

## NNFCC

NNFCC is a leading international consultancy with expertise on the conversion of biomass to bioenergy, biofuels and bio-based products.



NNFCC, Biocentre,  
York Science Park,  
Innovation Way,  
Heslington, York,  
YO10 5DG.

Phone: +44 (0)1904 435182  
Fax: +44 (0)1904 435345  
E: [enquiries@nnfcc.co.uk](mailto:enquiries@nnfcc.co.uk)  
Web: [www.nnfcc.co.uk](http://www.nnfcc.co.uk)