Investigating a Connection between European Wood Pellet Demand and Harvesting Patterns in the South East United States

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Abstract

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Challenging targets for renewable energy generation across Europe has led to increasing demands for biomass. Biomass plays a key role in European renewable energy, providing 46% of all renewable energy across Europe in 2013, predominantly through wood energy. Wood pellets have become an important traded biomass commodity in Europe, where consumption of wood pellets reached over 20 million tonnes in 2014.

Many European countries are able to meet their biomass demand domestically, however increasing volumes of wood pellets are now traded both within the EU and imported from outside the EU. The United States is the largest producer of wood pellets globally and the biggest trading partner to the EU, providing 20% of European wood pellet demand in 2014. Much of this production is located in the US South, where there is an annual production capacity of 8 million tonnes of wood pellets.

Wood pellet production is linked to other forest industries, with forty per cent of wood fibre for pellets derived from sawmill residues, so it is logical for pellet production to be located in areas with active forest industries. The US South is a major hub of wood production, harvesting over 224 million tonnes of wood in 2014, 5.4 million tonnes of which was fibre for wood pellets.

Markets play an important role in harvesting decisions, specifically the value of different wood products. Sawlog harvesting (as the most valuable product) is very responsive to changes in pricing, as seen through the decline in harvesting as sawlog value dropped between 2005 and 2009. The value of pulpwood increased significantly between 2011 and 2014, with softwood and hardwood pulpwood prices increasing by 63% and 160% respectively. However, in response to this significant increase in value, harvesting increased only by 6% for softwood and 3% for hardwood, suggesting that pulpwood value is not a significant enough driver to influence changes in harvesting.

The insensitivity of pulpwood harvesting to changes in value suggests that wood pellet demand is unlikely to drive changes in harvesting, however could potentially encourage more positive management of forests through providing a market for low value material. Further work should be carried out to consider the potential for woody biomass demand to influence forest management and recommendations should be proposed on how the impacts of this could be measured.

Declaration

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No portion of the work referred to in this Thesis has been submitted in support of an application for another degree or qualification at The University of Manchester or any other University or other Institute of learning

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1. Introduction

1.1 Opening Statement

Since the industrial revolution, levels of anthropogenic greenhouse gas emissions in the atmosphere have been progressively increasing. These increased greenhouse gas emissions have been strongly linked to the rising surface temperatures of the Earth and the corresponding climate impacts (IPCC., 2014). The evidence for the human interaction on climate change has been growing each year and in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was created with the aim of stabilising atmospheric GHGs (United Nations, 1992). The Conference of the Parties in Paris in December 2015 reaffirmed the global ambition to hold global average temperature to "well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C" (UNFCCC, 2015).

In order to bring this ambition into reality, the 195 countries of the United Nations Framework Committee on Climate Change (UNFCCC) set out their best efforts on emissions reductions through Intended Nationally Determined Contributions (INDC's) (Victor, J 2015). Moving forward, countries need to put in place effective policy frameworks in order to meet these emissions reductions and avoid the consequences of a 2°C global temperature increase. Burning fossil fuels accounted for 60% of greenhouse gas emissions in 2010 and so the decarbonisation of the energy sector is a key focus if global warming is to stabilise to a safe level (IPCC., 2014). Moving away from carbon-intensive methods of energy generation such as combustion of coal and increasing the share of renewable energy generation is necessary to achieve this decarbonisation (IPCC., 2014). The ambitions to hold average temperate below 2°C above pre-industrial levels is built upon the use of negative-emission technologies, as 86% of the IPCC scenarios where a 2°C is achieved assume large scale uptake of negative emission technologies, such as Biomass with Carbon Capture and Storage (BECCS) (Anderson, K., 2015).

The EU has set an overall target for renewable energy generation of 20% of total energy generation by 2020, apportioned across member states. The share of the target for each country is based on a standard increase from the amount of renewable energy produced in 2005 and also takes into account the wealth of each country, so wealthier countries take on a more challenging target (Klinge Jacobsen et al., 2014). This translates to a UK target (legislated under the Climate Change Act) of 15% renewable energy by 2020 (Climate Change Act, 2008).

National Renewable Energy Action Plans (NREAP) for the European Union suggests that woody biomass will be an important contributor to renewable energy, with current volumes anticipated to almost double in volume (Blennow et al., 2014). Industrial wood pellets for use in Europe are very dependent on imports and the total imported volume of wood pellets into the EU-27 has more than doubled between 2009 and 2012 (Hoefnagels et al., 2014). The US provides 29% of global wood pellet production, with much of this production concentrated in the Southern states (Galik and Abt, 2015). Total global wood pellet consumption is thought to be around 22-25 million tonnes each year, with these figures expected to increase to between 50 and 80 million tonnes per year by 2020 (Goetzl, 2015). The UK is the major importer of pellets from the US, accounting for 53% of all US exports to the EU (Abt et al., 2014).

Although the majority of woody biomass is derived from residues from the wood processing industry, the South East USA will likely have an increased use of forest residues, due to the downturn of sawmilling because of the depression in the construction industry, which reduces the available wood processing residues (Hoefnagels et al., 2014). The drive for bioenergy in the EU has stimulated an import market for wood pellets in the US (Galik and Abt, 2015) and it is therefore important to consider the potential impact this increasing demand is having on forest practices in this region.

This study presents desk-based research focussing on: assessing the current reliance on biomass energy across Europe; the production and trade of wood pellets for energy generation; the production of wood pellets across the South East United States; changing trends in harvesting in the US South and changing trends in prices of different wood fractions. Further understanding of each of these areas will allow conclusions to be drawn about the impact of the creation of this demand for wood pellets in the US to meet renewable energy targets in Europe.

1.2 Rationale

The rationale for this study stems from the uncertainty around the impact of an import demand for bioenergy created by renewable energy targets in Europe. Europe has set ambitious targets for the uptake of renewable energy, aiming for 20% of all energy to be generated from renewable sources by 2020 and bioenergy is a key contributor to these targets in many European countries. There is uncertainty around the size of wood pellet demand in Europe, and the manifestation of this demand into an import requirement from outside the EU has raised concerns about the impact of biomass demand on the global forest resource. If renewable energy targets become more challenging in the future, it is likely that the current use of biomass for energy will increase and is not clear how an increased demand would translate into trading partnerships, or indeed, if there is sufficient biomass resource to meet additional demand.

This study quantifies the current demand for industrial wood pellets for electricity generation in Europe and then critically assesses the impact that the introduction of this new market has had on harvesting trends in the US South, which has become the major global hub of global wood pellet production. The US South is made up of the following 13 states: Texas, Virginia, Florida, North Carolina, South Carolina, Alabama, Georgia, Mississippi, Tennessee, Louisiana, Kentucky, Arkansas and Oklahoma (Wear and Greis, 2012).

This study takes a top down approach and assesses the location of wood pellet plants in the US South and then infers the demand from these plants has added to forests. This study aims to consider the wider impacts of the application of bioenergy as a method of displacing coal for electricity production by considering the observed impacts on the forest and the potential for wider impacts on forest industry markets.

1.3 Problem Statement

Renewable energy targets in the EU are incentivising the move towards large scale use of bioenergy, which has resulted in the creation of an import market for wood pellets, consequently boosting wood pellet production in the US South East. Immediate action is needed to keep global warming below the level of a 2 degree temperature increase (Anderson and Bows, 2011). A rapid replacement of carbon intensive methods of energy generation is one key way in which we can curb greenhouse gas emissions and bioenergy can play an important role in this replacement. However, the use of bioenergy is constrained by the resources available. It is possible that an uncontrolled and dramatic increase in demand for bioenergy could lead to unsustainable forest management practices, which would have negative global warming impacts, if this resulted in a reduction in the carbon stored on land.

Wood has been used throughout history for heating and cooking, but more recently developments in technology have expanded the applications of wood as a replacement for fossil fuels into; electricity generation, transport fuels, bioplastics, textiles and more. Wood is already widely used as an energy source across Europe, but the use of wood in the form of pellets for large scale electricity generation is an emerging and rapidly growing area and questions remain around the current and potential future scale of this new market. The increased use of biomass for energy in Europe has led to some countries becoming net importers of wood pellets from outside of the EU, leading to questions about the insufficiency of biomass resource within Europe. The concentration of wood pellet supply in the United States also raises questions about the sustainability of this supply due to the rapid introduction of this new market and the scale of the demand.

1.4 Aims & Objectives

The aim for this work is to understand the demand for wood pellets across the European Union and consider the potential impact of this demand on harvesting patterns in the South East USA. In order to meet this aim, this study is split into three separate objectives.

- Objective 1: assess the current demand for wood pellets across the European Union and assess the importance of bioenergy in meeting decarbonisation targets across Europe

- Objective 2: investigate current trade flows of wood pellets and identify important sources of wood pellets for meeting European wood pellet demand

- Objective 3: quantify the current demand for raw material for wood pellets in the South East United States and investigate if this demand has driven any changes in harvesting in the region

1.5 Structure of the study

This section of the introduction describes the storyline of the study and explains how the data collected is presented to address the aim of the study.

Chapter 1 - Introduction

Chapter 1 introduces the context to this study, providing the background and rationale for studying this issue. This section lays out the scope and the aims and objectives of the study.

Chapter 2 – Methodology

The Methodology section outlines the steps taken to quantitatively assess data in order to reach conclusions which meet the aims and objectives of this study. Chapter 2 describes the decisions taken on the data sources used and the method in which data is compared or assessed.

Chapter 3 – Literature Review

Chapter 3 provides a detailed literature review on this topic, covering the areas this study touches on; climate change and the need for renewable energy, biomass in electricity generation, introduction to forestry and the different types of forest biomass used in wood pellets.

Chapter 4 – Analysis of bioenergy demand in Europe

Section 4.1 focusses on understanding the demand for wood pellets across Europe and adds context on how the use of wood for energy contributes towards meeting decarbonisation targets in Europe. Using Eurostat data on total energy generation and generation from renewable technologies, section 4.1.1 assesses the reliance of different member states on bioenergy in meeting their 2020 renewable energy targets. Section 4.1.2 considers the potential parallel between the forested area in a country and their reliance on biomass energy in meeting renewable energy targets. This study focusses on wood pellets, as this market has seen a recent dramatic growth and pellets are more likely than wood chips to be imported and used for large scale electricity generation.

In section 4.2, statistical data on imports, trade and production of wood pellets is assessed to quantify the demand for wood pellets across Europe. Section 4.3 concentrates on the supply of wood pellets from the US South, which can be identified as the largest producer of wood pellets globally. This section adds some initial context to harvesting trends in the United States and shows that the production of wood pellets is a relatively small component of total wood products produced in the United States.

Chapter 5 – Analysis of Demand on Forests of the US South

Section 5.1 considers the potential impact of the introduced demand of fibre for wood pellets on the exporting regions. Publicly available data shows that the US South is the major exporter of wood pellets to Europe, so this concentration of demand can pose a risk of over-exploitation of the forest resource for bioenergy. Section 5.1.1 compares the estimated fibre demand for wood pellets to the actual volume of wood harvested for pellets in the South East United States to understand if this fibre demand is met solely from harvested material, or if fibre is also obtained from other sources.

Section 5.1.2 looks at trends in the production of different wood products, as pellet production is currently small proportion of total harvesting, it seems unlikely that this relatively small additional demand will lead to deforestation, but it could possibly distort trends in wood products. Section 5.1.3 then looks at the state of Georgia as a specific case study, as it holds the largest concentration of pellet plants, to test if changes in harvesting can be seen when assessed on a micro level.

To be able to analyse changes in markets, it is necessary to look at changes in prices of wood products in comparison to harvesting trends and section 5.2 compares the value of the material used for wood pellets compared to other wood products. Section 5.2.1 looks at the prices of different wood products, comparing the stumpage price for pulpwood as harvesting for pellet production has been introduced, before looking at historic changes in wood prices as markets have been introduced or declined. Section 5.2.2 then compares changes in the value of different wood fractions to harvesting levels to consider the level to which harvesting of lower value wood products is influenced by price.

Chapter 6 – Emerging Themes and Discussion

Section 6.1 highlights the emerging trends from the analysis of European demand for wood pellets and considers the potential for increased demand in the future. Section 6.2 brings together findings from this study which have relevance to biomass trade, including exploring the connection between forest cover and the use of bioenergy. This section also considers the implications of findings on potential future trade relationships for biomass.

Section 6.3 discusses the findings around the supply of wood pellets from the US South, including conclusions on the feedstocks used in pellet plants and the reasons for the locations of plants in certain regions. Section 6.4 then discusses the findings on the material used in pellet plants and the impact of this demand on the forest, before considering the implications of these findings.

Section 6.4 discusses the findings of the analysis on changes in the prices of different wood fractions and discusses the reasons for fluctuations in price. The influence of prices on harvesting patterns is discussed in this section, along with suggestions as to the likelihood of the wood pellet market to influence final felling decisions. The interactions between markets for different wood products are discussed in this section and the potential for markets for low value wood products, such as forest bioenergy to influence forest management decisions is also explored here.

Chapter 6 also considers the limitations of this study and makes recommendations for further work which could progress this area of research.

Chapter 7 - Conclusion

Chapter 7 concludes on the findings of this study.

2. Methodology

2.1 Section 3 – Literature Review

A detailed literature review is a necessary part of this research. In order to meet the project aim of understanding potential impacts of wood pellet demand on forest practices, a strong understanding must first be gained on both the use of wood energy and standard forest practices. The literature review is carried out with the intention of assessing the knowledge which is currently available on the subject and to identify gaps in knowledge. For some of this research, it is necessary to use relevant legislation or government-issued text to interrogate the policy framework in which the demand for wood pellets sits. To find this information, the review uses either the author's knowledge of bioenergy policy in the UK, or internet search engines. For the academic texts, this study uses Science Direct and Google Scholar, using search terms specific to each section of the literature review, e.g. "wood", "biomass", "electricity", "industrial". Where possible, preference was given to more recently published studies, as the wood pellet market has developed within the last 10 years and is evolving quickly. However, for background information on forestry and forestry practices, where data is more well-established, there is no preference for more recently published data.

2.2 Analysis

2.2.1 Section 4.1

Section 4.1 looks at the current use of wood for energy across Europe and figure 4.1 compares the proportion of wood energy in renewable energy and total energy for different member states of the EU 28. In order to do this, data on current uses of bioenergy across Europe is extracted from the Eurostat data interrogation tool and compared against data on total energy generation in different member states (Eurostat, 2016a). Extracting data on total energy generation and proportion of generation from different renewable energy sources into Microsoft Excel provides the ability to chart the data in different ways to highlight any trends.

Figure 4.4 then considers the potential connection between reliance on wood for energy and the available forest resource in that country. Eurostat holds data on the total energy produced from biomass and data which can be accessed from the FAO data explorer shows the proportion of land covered by forest in each country. These two separate datasets, once downloaded into Excel can be combined and compared to consider the potential for a correlation in forest cover and reliance on biomass as a form of energy.

2.2.2 Section 4.2:

The desire to increase renewable energy generation has stimulated a market for the global trade of wood pellets. Understanding the origin of wood pellets used for energy in Europe is a key objective of this study and therefore section 4.2 looks at the increase in wood pellet trade in the years between 2009 and 2014. Eurostat requires any trade over certain volumes to be reported and held in the Eurostat database, including wood pellets. Data on the trade of wood pellets can be extracted from the Eurostat data explorer and exported to Excel to highlight the major producers, exporters and importers of pellets. In order to consider the scale of the recent increase of the wood pellet trade, changes in trade of wood pellets can be identified by comparing trade of wood pellets in 2009 and 2014.

Table 7 then makes an assumption of wood pellet consumption in each country by taking the total production of pellets in each country, subtracting any exports of pellets and adding any imports. This allows an estimation of the total consumption of wood pellets across the EU to be calculated.

2.2.3 Section 4.3:

As the United States is found to be a major producer of wood pellets, section 4.3 then looks at this production in the context of other wood products in the United States. Using the FAO data explorer, it is possible to explore and download data on total production of wood products on an annual basis, allowing this data to be compared to the relatively recent introduction of the wood pellet industry.

Section 4.3 goes on to consider the trends in wood industries in the United States. Data on total production of wood products in the US over time can be compared to data on the prices of different wood products in the US South over time, to consider fluctuations in markets in the 10 years before 2013. Data on prices of wood products can be taken from the Forest 2 Market report, US South Wood Trends, but requires some modifications in order to compare this data against the FAO data on wood production. Forest 2 Market report their price data separately for softwood and hardwood, but for this comparison, an average price of all wood products was required. 75% of the sawn wood produced in the United States is non-coniferous, so a weighted average price for sawlogs can be calculated, using 75% for non-coniferous wood and 25% for coniferous. However, the FAO data does not split pulpwood data into coniferous and non-coniferous, so the price for pulpwood could assume a 75% weighted average for softwood, which is reasonable due to the predominance of softwood harvesting across the United States.

Section 4.3 then outlines the current production of wood pellets in the US South, showing where this demand is located and the assumed volume of wood fibre these pellet plants will require. A dataset of pellet plant locations in the US South can be compiled using publicly available data, such as Bioenergy Magazine and a report from Forisk and then edited and expanded using industry knowledge (Forisk, 2015; (Biomass Magazine, 2015). In order to calculate the assumed demand for wood fibre, the reported capacity for wood pellet production can be multiplied by two. The multiplication by two is based on industry knowledge of the conversion factor for raw wood fibre to pellets, supported by a reference to this conversion in the Lynemouth State Aid decision published by the European Commission (European Commission, 2015). The locations of these pellet plants can then be tracked on a map using Google Earth and searching for the pellet plant addresses. Exporting ports can be added to the map by carrying out an internet search using google for export ports in the same region.

2.2.4 Section 5.1:

Section 5.1 aims to compare the assumed demand for wood fibre against actual harvesting data, to begin to quantify the actual effect of this introduced market and new demand on harvesting patterns. The results of calculating a demand for wood fibre in section 4.3.3 can be compared against reported harvesting for wood pellets to show the actual demand on the forest from the rise of the wood pellet industry. Forest 2 Market's US South Wood Trends report published data on harvesting for different purposes in the US South specifically (Forest 2 Market, 2015). Forest 2 Market is the most appropriate data to use in this case, as it holds the most accurate and complete data on harvesting and wood pricing in the US South and is one of the very few data sets able to separate out harvesting for wood pellets compared to harvesting for other wood products (Forest 2 Market, 2015).

The data provided by Forest 2 Market data also provides the ability to assess any trends in the harvesting of different wood products since the introduction of an export demand for wood pellets. Data on harvesting volumes of different products can be presented graphically in Microsoft Excel in order to assess potential trends. In order to compare the data provided by Forest 2 Market against publicly reported data by the US Government, the US Forest Service's "evalidator" application can be used to download data on forest resource. Harvesting data for Georgia can be downloaded from the Evalidator tool as a specific case study to do a more detailed exploration as the state with the most pellet plants. The US Government's Timber Product Output tool also provides information on the volumes of different types of removals and the number of wood processing mills in a region (FIA, 2015b). The dataset for removals of different wood types can be presented in an excel graph as a stacked bar chart, with the numbers of mills in Georgia shown as lines on a secondary axis to allow better comparison of data.

2.2.5 FIA data availability issues:

There are certain issues with data availability in FIA reported information, which means that only 5 years of data can be shown for Georgia in section 5.

Table 1: FIA data availability for the south-eastern states

Alabama	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Florida					2010	2011	2012	2013	2014	
Georgia					2010	2011	2012	2013	2014	
Louisiana				2009	2010	2011	2012	2013	2014	
Mississippi				2009	2010	2011	2012	2013	2014	
North Carolina				2009	2010	2011	2012	2013	2014	2015
South Carolina				2009	2010	2011	2012	2013	2014	
Texas (east)		2007	2008	2009	2010	2011	2012			
Virginia				2009	2010	2011	2012	2013	2014	

When data is extracted from FIA using evalidator, a sampling error is displayed for each dataset. Where the sampling error is shown to be over 10% for a particular dataset, this data should be excluded from analysis to avoid misrepresentation of data.

2.2.6 Section 5.1.3:

As shown in table 1, in many states data is only available for a small section of years. In figure 5.5, only data for the years 2010 – 2013 is presented as these are the years where the majority of states held data. 2014 data is removed from this analysis as the total sampling error was too high to be considered reliable. Texas (East) was not presented in this graph as it was the only state where data for 2013 was not available.

2.2.7 Section 5.2:

In figure 5.6, the data presented in the quarterly price summaries created by Timber Mart South is averaged to show trends in standing timber prices of different wood products over time. In figures 5.7 and 5.8, data on prices of softwood and hardwood are compared, with each graph showing a different dataset in order to compare the different datasets to consider reliability. In figure 5.9, data from the Forest 2 Market US South wood trends report is presented as a graph to allow comparison of harvesting and price trends. Harvesting of different wood products are shown as a stacked bar chart, with price trends shown as a line chart on a secondary axis to ensure ease of comparison.

2.3 Data Sources – Analysis

This study uses multiple sources of data and decisions are taken throughout this research as to the most appropriate data source. Table 2 states each data source used in this research and describes the reason why this data source is the most appropriate.

Table 2: Data Sources used in the Study

Section	Data Source	Data	Rationale – why this data source was selected
4.1.1. Figure 4.1	Eurostat. Total renewable energy generation, total use of wood for energy, total energy generation (Eurostat, 2016a)	Comparing the proportion of wood from energy across different member states of the EU.	Eurostat holds the most complete dataset (holding over 1.2 billion statistical data values) in one harmonised reporting tool, to allow reliable comparison of data from different countries.
Figure 4.2	Eurostat. Primary production of renewable energy from different types (Eurostat, 2016a)	Graphical representation of the different renewable energy generation used across Europe	Eurostat holds the most complete dataset (holding over 1.2 billion statistical data values) in one harmonised reporting tool, to allow reliable comparison of data from different countries.
Figure 4.3	Eurostat. Primary production of energy from solid biofuels between 1995 and 2013 (Eurostat, 2016a)	Graph to show which countries generate the highest total levels of energy from solid biofuels.	As this data is used to draw comparisons with figures 4.1 and 4.2 around the reliance on bioenergy and total generation, it was necessary to use the same data source to ensure consistency.
Figure 4.4	FAO 2015 - % wooded area in each member state (FAOSTAT, 2016) and (Eurostat, 2016a),	A graph to compare the proportionate reliance on wood for energy against the percentage forest cover in each country	FAO compiles data across the globe on forestry statistics, presenting a comparable set of data for all European countries. Global forest resource data is collected every 5 years.
Figure 4.5	Eurostat – production and trade of wood pellets (Eurostat, 2016a)	Graph to show the production, import and exports of wood pellets from each major country	Eurostat holds the most complete dataset (holding over 1.2 billion statistical data values) in one harmonised reporting tool, to allow reliable comparison of data from different countries.

Table 8 and Figure 4.6	FAOSTAT. Wood product production (FAOSTAT, 2016).	Data to show the major producers and consumers of wood pellets.	FAO compiles data across the globe on forestry statistics, presenting a comparable set of data for all European countries. Global forest resource data is collected every 5 years.
Figure 4.6	Forest 2 Market. Average sawtimber and pulpwood prices (Forest 2 Market, 2015).	Graph to show a 10 year trend in harvesting of various wood products, compared against the average prices for these wood products, to assess trends in wood markets in this region.	Forest 2 Market can be considered to hold some of the best available data on harvesting and wood prices in the US South, as data is collected on each and every sale of wood products, creating the most comprehensive set of data available. Forest 2 Market are an independent third party, who do not own or manage any timberland, nor are involved in any wood product buying or selling. The data produced through Forest 2 Market is subject to strict anti-trust laws in the United States. This data covers the following states: Georgia, South Carolina, North Carolina, Virginia, Florida, Texas, Louisiana, Mississippi and Alabama.
Table 10	(Biomass Magazine, 2015), (Forisk, 2015) and company websites.	Table showing the wood pellet producers in the South East United States	No single source of data was considered to be robust enough and so the data presented in this study was a compilation of available data, which was then fact checked against data shown on company websites and edited with my own knowledge of the industry.
Figure 4.7 and 5.4	FIA's Timber Product Output summary	Graph to show trends in extraction of different wood products, compared against the number of wood processing mills in Georgia	The US Forest and Inventory Analysis programme analyses and reports forest health and productivity information every 5 years and is the best available information on forest inventory in the United States.
Figures 5.1, 5.6, 5.8	Forest 2 Market's US South Wood Trends Report (Forest 2 Market, 2015).	FIgure 5.1 shows the assumed wood fibre demand for pellets compared to the actual harvesting of material for pellets. Figures 5.6 and 5.7 show changing prices of different harvested wood fractions over time.	Forest 2 Market can be considered to hold some of the best available data on harvesting and wood prices in the US South, as data is collected on each and every sale of wood products, creating the most comprehensive set of data available. Forest 2 Market are an independent third party, who do not own or manage any timberland, nor are involved in any wood product buying or selling. The data produced through Forest 2 Market is subject to strict anti-trust laws in the United States. This data covers the following states: Georgia, South Carolina, North Carolina, Virginia, Florida, Texas, Louisiana, Mississippi and Alabama.
Table 11	Capacity of pellet plants in Georgia – Google Maps and Company Websites	A table to show the wood pellet producers based in Georgia and the major wood fibre	A search for 'pellet plant' in Georgia on Google Maps confirmed the data presented in table 9 Using a search engine, the websites of each pellet plant was found and the capacity of the plant reported there was used here. This was considered to be the best available data as this

		types reported to be used in the plants	information does not exist anywhere else as independently verified data.
Figure 5.3	Harvesting data in Georgia, using FIA data (FIA, 2015b).	Graph to show recent trends in harvesting of sawtimber and poletimber size wood in Georgia	FIA data for harvesting is considered to be the best available information, as this information is not available anywhere else which covers all forest types for every state in the United States. This breadth of information is necessary to ensure consistency of data analysed.
Figure 5.8	Timber Mart South standing timber prices (Timber Mart-South)	Data to show the changing value of pulpwood across the US South	Timber Mart South data was selected for this analysis to present a comparison of the Forest 2 Market data and to consider accuracy.

3. Literature Review – Research Context

3.1 Climate change and the need for renewable energy

In order to better understand the increased demand for biomass, it is important to understand the reason behind the drive towards renewable energy and the legislative framework behind this. This chapter explains the theory of global warming, why the move to renewable energy generation is necessary and introduces the use of biomass as an energy source.

3.1.1 Global warming theory

Since the late 19th century, the average earth temperature is thought to have increased by 0.6°C and alongside this rising temperature, greenhouse gases (GHGs) have been continuously increasing (IPCC., 2014). Greenhouse gases in the atmosphere are thought to trap the re-emitted longer-wave terrestrial radiation from the earth's surface causing a warming effect (Klass, 1998). It is this trapped re-emitted radiation that is thought to be the cause of the increasing global temperatures, as depicted in Figure 3.1 (Klass, 1998).

The Earth experiences a natural greenhouse effect, through water vapour and carbon dioxide in the atmosphere, but since the late 19th century the abundance of greenhouse gases has increased significantly, though the increase of anthropogenic greenhouse gases (Anderson et al., 2016). The major anthropogenic greenhouse gases include carbon dioxide, methane and nitrous oxide, of which carbon dioxide receives the most attention, as atmospheric CO_2 is known to have increased by 35% during the 20th Century (IPCC., 2014).

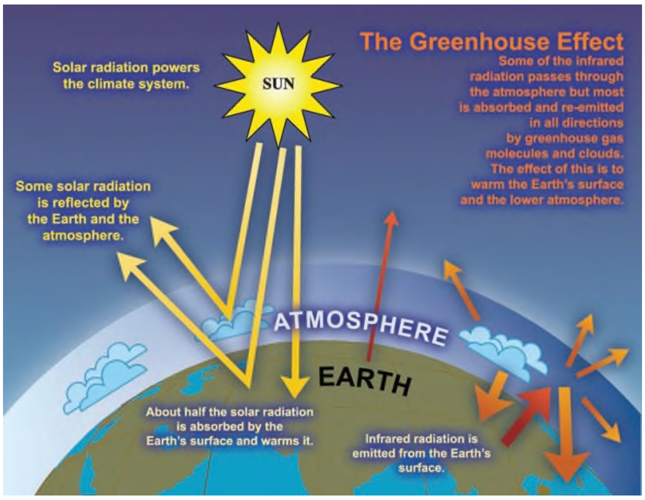

Figure 3-1: Diagram of the greenhouse effect. From (IPCC, 2007).

3.1.2 Greenhouse gases and the carbon cycle

Carbon dioxide is a key greenhouse gas, however carbon regularly cycles between the four major reservoirs: atmospheric carbon, terrestrial carbon, geologic carbon and oceanic carbon (Dhillon and von Wuehlisch, 2013). The IPCC Third Assessment Report discussed the carbon cycle and the huge exchanges of carbon which take place between these reservoirs in biological processes (IPCC, 2001). The movement of these large volumes of carbon highlights the importance of balance within these systems, as atmospheric CO_2 is only stable when these processes are in equilibrium (Schlesinger, 2005). Certain human activities can change this balance, for example, deforestation which reduces the carbon stored on land and burning fossil fuels, which increases the carbon released into the atmosphere (IPCC, 2001). Burning fossil fuels actually has smaller net GHG emissions than most natural carbon exchanges, but when combusting fossil fuels, there is no counteracting storage of CO_2, so all fossil fuel burning adds to the imbalance of CO_2 (Schlesinger, 2005).

Almost 70% of greenhouse gas emissions from human activity are related to energy production, so the reduction of carbon-intensive energy production is a key goal for industrialised countries (Höök and Tang, 2013). Different methods of energy generation produce varying levels of CO_2, with coal the most carbon intensive at 907 kg of CO_2 per MWh of electricity produced (DUKES, 2014). Figure 3.2 shows the range of different GHG emissions associated with the various methods of electricity generation and it is clear that coal and natural gas have far higher emissions compared to renewable sources. Figure 3.2 includes the life cycle emissions from these generation options, not simply operational emissions.

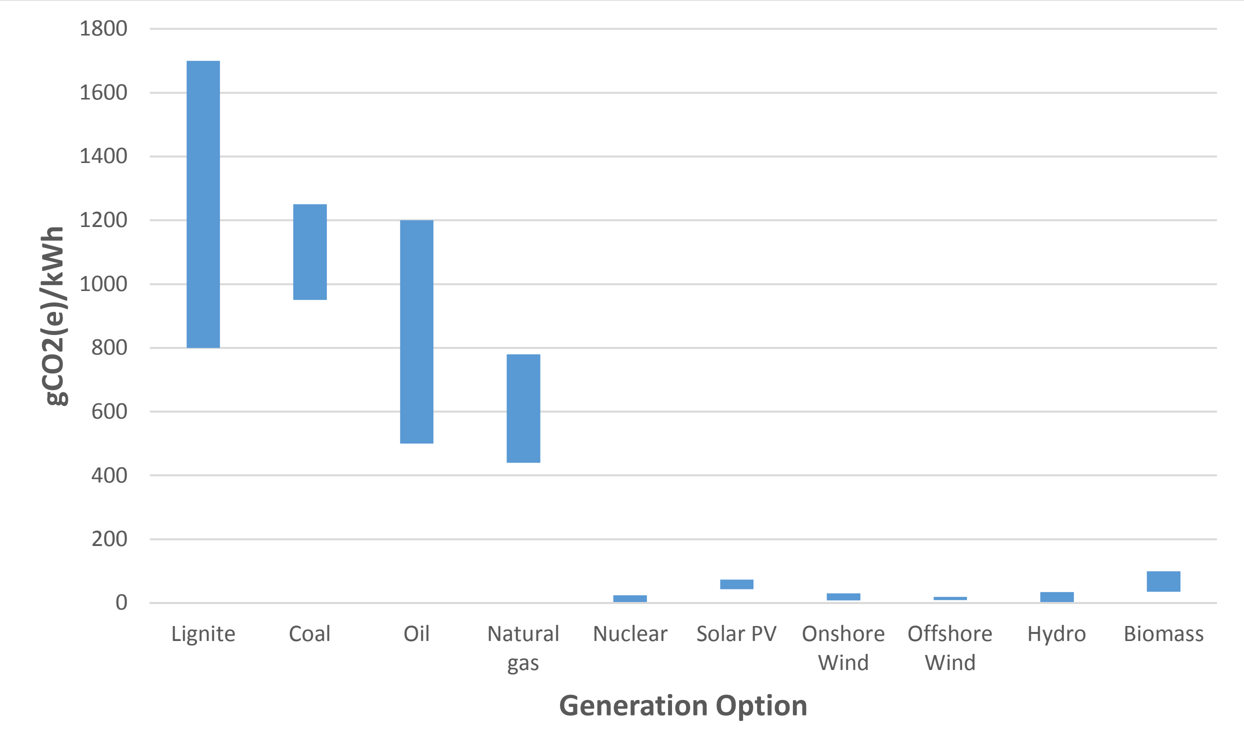

Figure 3-2: GHG emissions from different methods of electricity generation, including life cycle emissions. Adapted from (Weisser, D. 2007).

In 2012, 40% of the UK's electricity was generated from coal, so it is clear that a shift towards renewable electricity could have a significant impact on carbon dioxide emissions in the UK (DUKES, 2014).

3.1.3 Global legislation

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was created with the aim of stabilising atmospheric GHGs (United Nations, 1992). In 2012, under the Doha amendment to the Kyoto Protocol, these nations agreed to targets of reducing their emissions by 80% before 2050 (Doha Amendment, 2012). An important driver which led to this commitment was the 'Brundtland Report' which highlighted (among other things) that 70% of the total energy supply in the world is used by only industrialised nations which make up only 25% of the population (World Comission on Environment and Development, 1987). Following recommendations from the Brundtland report, the commitment for industrialised countries was set, but in recognition of the current low energy use in developing countries and their growth potential, it was accepted that developing countries are permitted to increase their energy use but should be watchful of emissions (Kyoto Protocol, 1997).

3.1.4 Renewable Energy in the UK

The 15% target for the UK's renewable energy supply can be broken down into electricity, transport and heat energy, with around half of the renewable energy demand currently being met through the electricity industry (Ward and Inderwildi, 2013). This 15% target can be broken down into three separate targets; 30% of electricity produced from renewables, 10% of all fuel and 12% of all heat (Renewable Energy Directive, 2009). In 2012, 4.1% of the UK's energy was produced from renewable sources, highlighting the challenge involved in meeting our target of 15% by 2020 (DECC, 2013a). In 2013, 15% of the UK's electricity was from renewable sources, meaning we are half way to the 30% renewable electricity by 2020 requirement, suggesting the electricity is progressing faster than transport and heating (DUKES, 2014).

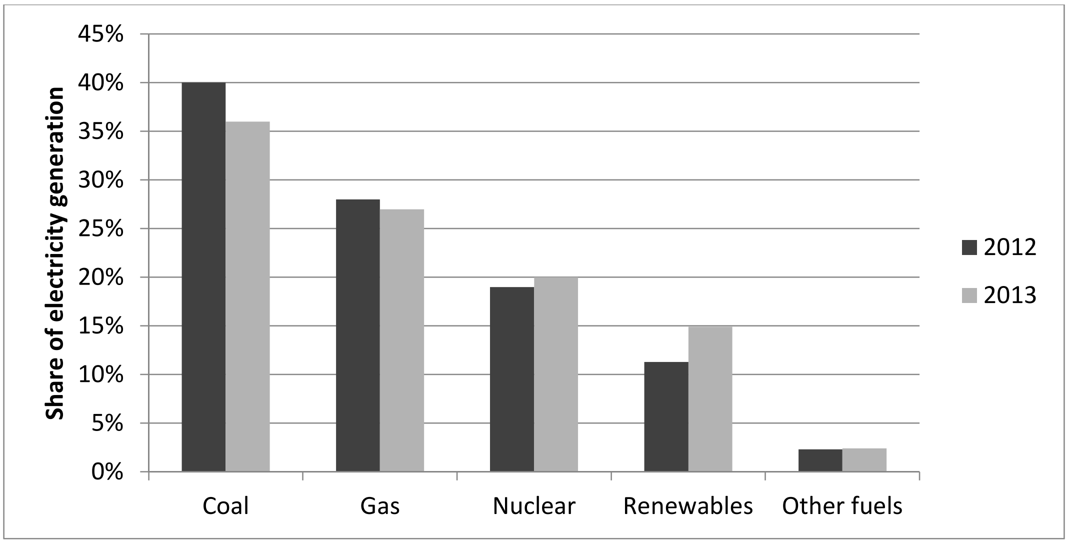

Figure 3-3: *Electricity generation in the UK by different fuel types – comparison of 2012 and 2013 generation. Adapted from (DUKES, 2014).*

Figure 3.3 shows the UK's current heavy reliance on fossil fuels, with almost 70% of electricity in 2012 produced from coal and gas. Considering the change between 2012 and 2013, the shift away from fossil fuels is evident, with coal and gas both reducing their share in the mix and an increase in the proportion of renewables and nuclear (DUKES, 2014).

Globally, renewable electricity generation in 2010 was produced primarily from hydro power (82%), with wind and bioenergy equally the second largest sector, providing 8.1% each and geothermal, solar and marine energy comprising the rest. In contrast to the global averages, the renewable electricity mix in the UK is primarily from wind power and biomass (DECC, 2014a). The UK has strong potential for wind power and have harnessed this potential, with the UK now having more deployed capacity of off-shore wind than any other country (DECC, 2013a). Between 2012 and 2013, all renewable technologies in the UK increased their generation, other than hydro power, which declined due to lower levels of rainfall (DECC, 2013a). Electricity demand is generally inconsistent and electricity supply needs to generate at the right times and the right levels to meet demand. In order to do this, electricity must be able to move around the system and generation must be within our control and be able to respond to demand (DECC, 2012). Biomass is the one low carbon technology which can be used in all areas of renewable energy (electricity, heat and transport fuel), can be cost-effective and reliable because it is not dependent on changes in the weather (DECC, 2013a). This means that biomass is able to respond to the demands of the grid, adding a security of renewable energy supply in times of low wind or rainfall (DECC, 2013a).

3.1.5 Control mechanisms for UK renewable energy

There are separate mechanisms in the UK to control the different forms of renewable energy (electricity, heat and transport fuel). Renewable electricity in the UK is controlled through the Renewables Obligation (RO) which places an obligation on every electricity supplier to provide a certain proportion of their electricity from renewable sources, this requirement can be met by purchasing proof of renewable electricity generation (Renewables Obligations Certificates) from generators (Connor, 2003). The Renewables Obligation is regulated by OFGEM (Office of Gas and Electricity Markets), who monitor and report on renewable energy generated and sold in the UK (Ofgem.gov.uk, 1). Other forms of renewable energy are also controlled through government mechanisms, such as the Renewable Transport Fuel Obligation (RTFO) for renewable fuel and the Renewable Heat Incentive (RHI) and the Renewable Heat Premium Payment (RHPP) for renewable heat (DUKES, 2014).

3.2 Bioenergy and Biomass

The definition of biomass is any plant-based organic matter (Saidur et al., 2011). The underlying principle behind using biomass fuels is that the carbon dioxide released in combustion is the same amount which is absorbed from the atmosphere as the plant grows and is therefore carbon neutral, excluding total life cycle assessed greenhouse gas emissions (Demirbas, 2004). In 2012, global deployment of biomass was estimated at 10% of the primary energy supply (around 51EJ) with future increases predicted (IREA, 2014). Over the last 50 years, the use of wood fuel in developing countries has been steadily increasing, as populations have increased (FAO, 2001).

Outside of the traditional use of wood fuel in developing countries, more modern uses of bioenergy in developed countries have also increased, as a requirement for countries to move to renewable energy has led to a significant increase in biomass use for electricity generation (IEA, 2015). Future levels of bioenergy use are expected to increase significantly, with predicted deployment levels in 2050 of between 100 and 300EJ (Lamers, 2013). Use of plant biomass for electricity production has increased rapidly in the UK, as shown in Figure 3.4.

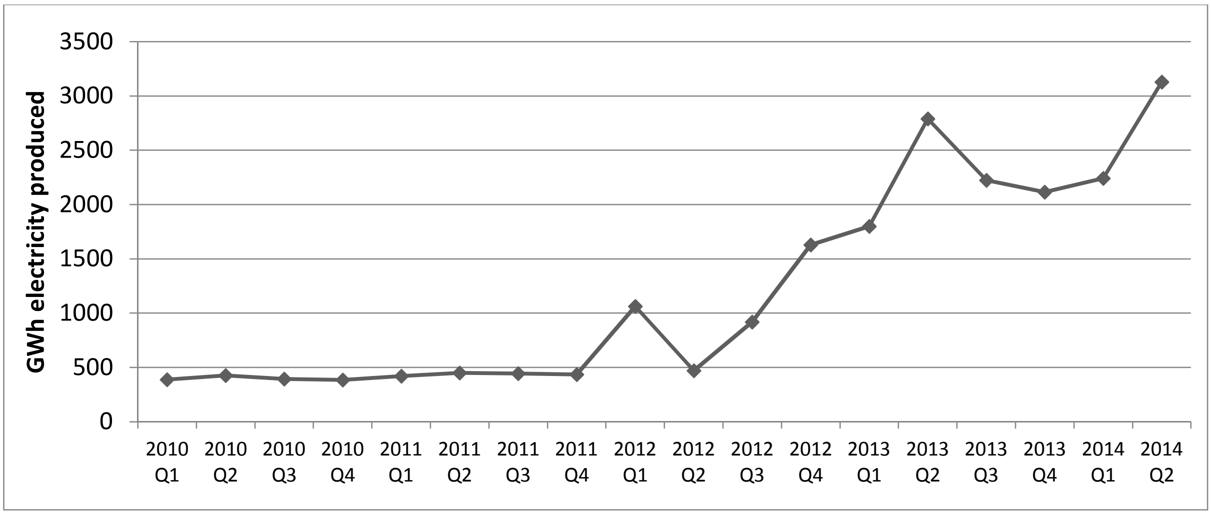

Figure 3-4: GWh electricity produced from plant biomass in the UK since 2010 (DECC, 2014a)

Figure 3.4 shows the rapid increase in plant biomass use for electricity generation in the UK between 2010 and 2014 (DECC, 2014a). The majority of solid biomass use is derived from wood, which is supported by both Table 3 and academic texts (Junginger, 2014; Lamers, 2013).

Table 3: All solid biomass reported to Ofgem used in the UK between April 2012 and March 2013, including power stations, CHP plants and biomass used for renewable heat.

Fuel type	**Total (tonnes)**
Anaerobic Digestion	-
Biomass	5,715,860
(of which wood)	**4,785,155**
Energy Crop	26,393
Gasification/Pyrolysis - Gas	70
Total	**5,742,323**

Table 3: Data from (Ofgem (2015).

3.2.2 Woody biomass for electricity generation

There are certain physical properties of interest in woody biomass for electricity generation: energy content, moisture content, ash content, fixed carbon, alkali metal content and the ratio of cellulose to lignin (McKendry, 2002). However, air dried wood has around half the net calorific value of coal and half the carbon content, which means some processing may be required to fully capture the energy in the material before combustion (Robert Matthews et al., 2014). Considering the predicted large volumes of material required, trade from other countries is likely to be necessary, and so biomass must be processed in a way which lends itself to transport. Pelletised biomass has improved handling and storage possibilities because of their uniform quality, as well as reduced levels of contaminants and improved energy density (Junginger et al., 2008; Mäkelä et al., 2011). This reduced level of contaminants has an impact on reducing problems in combustion, such as corrosion or slagging in the boiler and also eliminates or minimises any potentially toxic components which could be released during combustion (Vassilev et al., 2013).

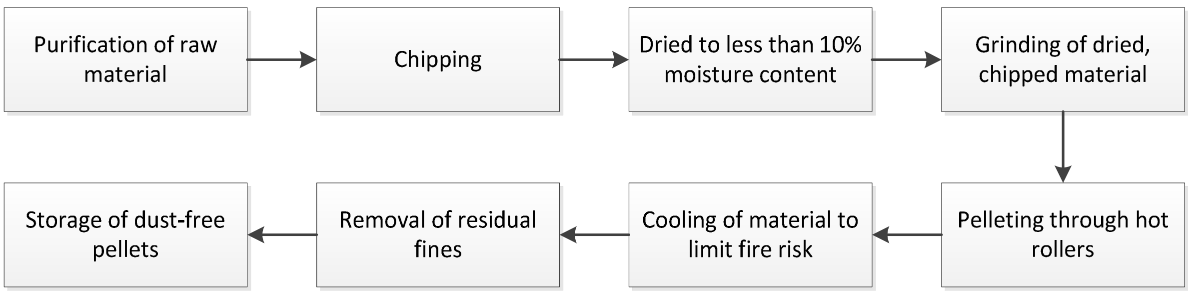

Figure 3-5: Original diagram showing the process of making biomass pellets. Data from (Di Giacomo and Taglieri, 2009).

Figure 3.5 depicts the basic steps in the pelleting process. The material is scanned to remove any contaminants before chipping, then the material is dried, lowering the moisture content of the material which ultimately leads to more efficient combustion (Ståhl et al., 2004). Following drying, the material is ground further before going through the pellet presses. The act of compressing the dried biomass into pellets makes transportation more efficient and controls the moisture content throughout the material (Ståhl et al., 2004). This compression also increases the energy content and the density in the material and decreases the ash and moisture content (Di Giacomo and Taglieri, 2009). Pelletised biomass has been shown to have more than three times the density of wood chips: 650 kg/m^3 compared to 200 kg/m^3 (Di Giacomo and Taglieri, 2009).

Renewable energy in the UK is controlled through the Renewables Obligation, which is monitored by Ofgem. Each year, Ofgem publish the Sustainability data provided by generating stations. Table 4 shows the data reported by UK power stations and is constrained to show woody biomass only. The table shows the importance of North America in providing wood-based biomass for the UK electricity industry.

Table 4: Use of woody biomass for electricity generation in the UK between April 2013 and March 2014, showing the origin of the pellets

Units: tonnes	Canada	UK	Europe	South Africa	USA	USA, Canada	Total
Clean Wood Chip		245,238					245,238
Forestry Wood		79,436					79,436
Pellets	1,402,051	14,230	473,810	5,160	1,579,387	1,704	3,476,342
Sawdust		33,728					33,728
Steam exploded pellets			218				218
Torrified black pellets					184		184
Virgin Chip		8,114					8,114
Virgin Wood		658,107					658,107
Woodchip		283,788					283,788
	1,402,051	**1,322,641**	**474,028**	**5,160**	**1,579,571**	**1,704**	**4,785,155**

Table 4: Data from (Ofgem, 2015).

Table 4 is derived from the Ofgem Biomass Sustainability Dataset and reflects the findings of Lamers that the majority of biomass for industrial use comes from Canada and the USA, predominantly in the form of pellets (Lamers, 2013). There is still a lot of uncertainty over the future demand of wood pellets in the UK, but an upper limit of 16 million oven dry tonnes annual requirement has been estimated (Pöyry, 2014). When considering the potential volumes of biomass required against the relatively small harvested volumes in the UK, it becomes clear that imports are vital.

The USA is predicted to be an important future source of wood pellets (Pöyry, 2014). The US South currently has 20 million oven dry tonnes of surplus biomass and this excess is predicted to remain until 2020, making this area an attractive sourcing potential for wood pellets (Pöyry, 2014). Processing residues are the main component of wood pellets produced in the US South, however the declining demand for timber has led to less availability of sawmilling residues and consequently an increased use of forest products, such as pulpwood (Hoefnagels et al., 2014).

3.2.3 Sustainability Requirements of Wood Pellets in the UK

The Renewables Obligation was first implemented in the UK in April 2002, but it was not until April 2011 that the Renewables Obligation incorporated sustainability criteria into these requirements (Ofgem, 2011). In 2011, the requirements were to report on:

- Greenhouse gas criteria of the biomass: GHG emissions from the generation of one MJ of electricity, to ensure the material is truly low carbon compared to fossil fuel generation. The upper limit for GHG emissions at this point was set to 79.2g $CO_{2\ eq}$/MJ electricity produced
- Land criteria: the land type the biomass was sourced from in January 2008, to ensure the sourcing of biomass is not causing land use change and increasing carbon emissions

In April 2014 guidance was published on the sustainability criteria, with amendments which increased the robustness of the sustainability requirements for UK biomass. The UK is now considered to have introduced some of the strictest sustainability standards in the world (Ofgem, 2014). In 2014, the requirements were subtly amended, to report monthly on:

- GHG criteria, with a tightening trajectory for the GHG limit from 2020
- Land criteria, or the timber standard (for woody biomass)

The Land Criteria is based on the UK Timber Procurement Policy and covers social, economic and environmental impacts of Sustainable Forest Management (DECC, 2014b). The requirements also included an annual audit report, which requires verification of monthly reported figures by an independent auditor and additional unverified profiling data on the biomass used.

3.2.4 Summary

It is clear that bioenergy will have an important part to play in reaching the UK's renewable energy targets, and projections suggest a big part of meeting that target will involve imports of woody biomass, so it is important to understand the impact of these sourcing activities in other countries. This chapter has shown that the USA is exporting large volumes of wood pellets to the UK, with projections suggesting these imports will increase between 2015 and 2027. Current pellet production in the USA has a capacity of around 6.2 million tonnes annually, but with the total wood pellet demand for the UK potentially increasing to a maximum of 16 million tonnes of biomass, it is important to consider how this increase in pellet production could impact the forest industry today.

3.3 Forestry

The Southeast United States are an important sourcing region of wood pellets, with an increased demand expected in the near future. In order to understand the impact of this new demand it is important to first understand the forest industry in this area and the surrounding regulatory framework. There are different types of material which could be considered under the category of 'forest biomass', including forest residues, wood industry residues, energy crops or waste wood (Spellman, 2011).

3.3.1 Wood pellet sourcing

Wood residues from industry and waste wood are the most commonly used materials in wood pellets for bioenergy (Agostini et al., 2013). Figure 3.6 shows the stages of lumber production and the material lost at each stage, as each side of the log is cut to create parallel lines in the lumber (Wagner and Burley, 2004). In an efficient sawmill, 50% of the log can be made into lumber, with the remaining 50% of the logs as by-products (bark, chips and sawdust), with efficiency increasing when the logs delivered have less taper and a bigger diameter (Wagner and Burley, 2004).

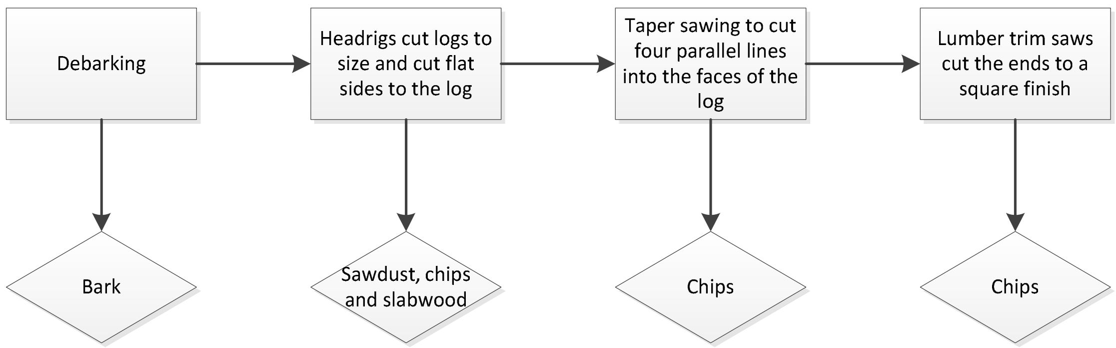

Figure 3-6: the different stages of lumber production and the by-products produced at each stage.

Figure 3.6: adapted from (Wagner and Burley, 2004).

Following a harvest, there are usually unused parts of the merchantable trees which are left behind and these logging residues are one type of biomass which would be considered under the 'forest residues' category (Spellman, 2011). Under-sized trees, which would not be merchantable as saw logs, dead wood and poor quality trees can also fall under the forest biomass category (Spellman, 2011). Pre-commercial thinnings including small trees, limbs, bark, tops and un-merchantable stems are considered forest residues (Hoefnagels et al., 2014).

3.3.2 Woody Biomass sourcing in the UK

Table 5: Woody biomass declared by UK power stations between April 2013 and March 2014.

Units: tonnes	**Canada**	**UK**	**Europe**	**South Africa**	**USA**	**USA, Canada**	**Total**
Wood Chip	-	1,195,247	-	-	-	-	1,195,247
Forestry Wood		79,436					79,436
Sawdust		33,728					33,728
Pellets	1,402,051	14,230	474,028	5,160	1,579,571	1,704	3,476,744
Total	1,402,051	1,322,641	474,028	5,160	1,579,571	1,704	4,785,155

Table 5: Data from (Ofgem, 2015).

Table 5 highlights a difficulty with the pellet industry, as generators in the UK purchase woody biomass as ‘pellets’ and the components of the pellets were not required to be reported on during 2013-2014. The pellet industry essentially bridges the gap between the forest industry and the biomass industry and reporting is not fully developed (Lamers, 2013). However, changes to UK legislation during 2014 mean that this information will become available. The Renewable Obligation Order states that biomass used must be reported by consignment and the guidance published in June 2014 stated that for material to be considered as one ‘consignment’, it must have identical sustainability characteristics (including country of origin and the feedstock classification) (Ofgem, 2014). Generators were given a deadline of 31 March 2015 to incorporate the definition of consignment in their monthly reporting, meaning that that Ofgem published data for the compliance year 2015-2016 will include the feedstock classifications used in the pellets (Ofgem., 2015).

Although the exact proportion of different materials used in US-produced wood pellets cannot be quantified, it has been suggested (Hoefnagels et al., 2014) that US pellet producers are likely to have a stronger dependency on forest residues, as the downturn of the housing market has led to a decrease in sawn wood production and therefore, there are less readily available processing residues (Lamers, 2013). This statement is supported by data published by Drax Group plc. on their corporate website (Drax Group, 2015), which shows that nearly all biomass sourced from Canada in 2014 was derived from sawmill residues and sawdust, compared to the US, where only 16% was composed of processing residues.

Table 6: Biomass consumed by Drax Group plc in 2014, broken down by country of origin and feedstock type (unit: tonnes).

	Bark	Sawdust	Slab wood	Sawmill Residues	Forest residues	Diseased Wood & Storm	Thinnings	Long rotation forestry	Short Rotation Forestry	Short Rotation Coppice	Agricultural residues, (Oats	Straw and Miscanthus	Total
Canada	3,436	52,613	-	761,281	56,110	442	8,877	-	-	-	-	-	**882,758**
Estonia	-	34,635	-	55,031	-	-	61,530	-	-	-	-	-	**151,196**
Germany	-	10,425	-	869	1,738	-	4,344	-	-	-	-	-	**17,376**
Latvia	-	92,953	-	72,084	75,977	-	64,447	1,653	-	-	-	-	**307,114**
Poland	-	549	-	46	90	-	229	-	-	-	-	-	**914**
Portugal	-	30,891	660	17,772	116,202	25,843	32,631	-	10,289	-	-	-	**234,288**
South Africa	-	-	-	5,304	-	-	-	-	-	-	-	-	**5304**
UK	-	711	-	457	3,912	-	-	-	-	6154	4,589	97,520	**113,343**
USA	-	168,829	-	222,047	942,039	164,410	805,815	12,374	-	-	64,834	-	**2,380,348**
Total	**3,436**	**391,605**	**660**	**1,134,891**	**1,196,070**	**190,695**	**977,873**	**14,027**	**10,289**	**6154**	**69,423**	**97,520**	**4,092,643**

Table 6: Data from (Drax Group, 2015).

The USIPA (the US Industrial Pellet Association) state on their website that typical wood pellets are composed of mill residues, tops and limbs, thinnings and low quality wood (USIPA, 2015). This is supported by Table 6, produced by Drax, which indicates that almost 40% of the biomass sourced from the US was derived from thinnings, adding further confidence to the importance of thinnings as a biomass feedstock (Drax Group, 2015).

3.3.3 Forestry in the US South

Productive forests are labelled 'timberland' in the US, which includes any forested land which can produce wood products at a rate of 0.57 cubic metres, per acre per annum (NAFO, 2013). The US South specifically has 226 million acres of forest and almost 213 million acres of timberland, making it the most productive region of the US (NAFO, 2013). The US South provides around half of all timber produced in the US, constituting 62% of all harvesting in 2006, which is more than the rest of the United States combined, due to a higher concentration of 'working forests' which can be defined as forests which are managed to produce wood products (USDA, 2011).

The US South, in addition to being the main timber producer of the United States, also has a greater percentage of private forest owners, specifically family forest owners, holding an average of just 29 acres of forest land (NAFO, 2013; Wear and Greis, 2012). Loblolly, slash pine and longleaf pine plantations are very common in this region, but the common naturally occurring forest types are swamps, forest wetlands, hardwood and pine mixed stands, upland hardwoods and upland pines (Mitchell et al., 2014).

3.3.4 US Forestry – legislation and controls

National forests are controlled under the National Forest Management Act, 1976, which requires all forests to have a formal management plan including a requirement for public engagement, however, as described earlier, the majority of forests in the US South are privately owned and so are not subject to this Act (Alvarez, 2007). The Forest Service manages the national forests under this Act, but also plays a role in influencing the management of private forests through providing guidance and funding to forest owners, carrying out investigations into threats to forest health and advising on risk mitigation strategies (FAO, 2010a).

There are a certain number of federal laws in place to encourage the promotion of ecosystem services across the United States, which are applicable to all states in the federation (Mercer et al., 2011). The Soil and Water Resources Conservation Act, 1977, managed through the United States Department of Agriculture (USDA), assesses trends of soil and water resources on all land, manages conservation programs, provides assistance to landowners and produces annual analysis reports for Congress (NRCS, 1977). The Clean Water Act, as amended in 1972, is designed to protect the nations water and has far-reaching impacts on forestry, including regulations around forest roads, run-off caused from harvesting and controls over forest land in the immediate vicinity of water bodies (Clean Water Act, 1977).

However, State-wide legislation is important in the US, with each state retaining the responsibility for private forests in their state, which are controlled by their own forestry organisation and state forester, who can implement bespoke state laws, such as The Georgia Growth Planning Act or the Georgia Forest Fire Protection Act (Georgia Forestry Commission, 2009); (FAO, 2010a). Each state also has Best Management Practices (BMPs), which are tailored to the forest activities and geography in their state. As an example, the BMP for the State of Georgia refers back to federal law, providing further guidance on compliance, as well as providing the details of laws specific to the state (Georgia Forestry Commission, 2009). Over and above the law, state-specific BMPs set out the minimum expected practices for forest management and conservation, as well as prohibited activities and failure to meet these minimum guidelines can result in financial consequences (Georgia Forestry Commission, 2009).

3.3.5 Forest Management

Since the commercialisation of the forest industry, the key focus of working forests is to produce a continuous yield of wood products, but the increasing influence of environmental NGOs has created a shift towards forest management incorporating multiple values of the forest (Parrotta and Ronald, 2012). Around 43% of forests globally have a forest management plan, and although this is a large proportion, it includes areas of public ownership, where a management plan is in place, but very little active management occurs, perhaps because the land is set aside for biodiversity, aesthetic or cultural reasons (Siry et al., 2005).

Forest management always has an objective, which can include, but is not limited to, the following (Robert Matthews et al., 2014):

- Wood products output (timber, fencing, pulp, bioenergy etc.)
- Conservation of habitats, species or ecosystems
- Recreation
- Conserving or enhancing carbon stocks
- Conservation of soil and water resources
- Non-timber forest products (fruits, mushrooms, nuts etc.)
- Amenities for local communities

Figure 3.7 shows the key functions of the world's forests. 30% of forests globally are managed for the production of wood products and an additional 24% are managed for multiple uses, which may also include wood products (FAO, 2010c).

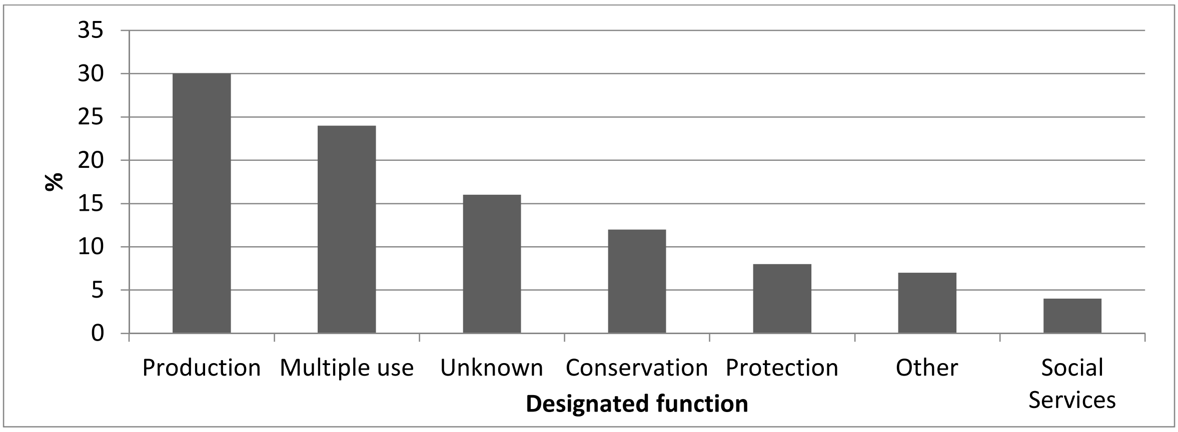

Figure 3-7: Designated functions of the world's forests. Adapted from (FAO, 2010c).

3.3.6 Managing a forest for production, 'working forests'

There is a general acceptance across the forest industry that where economic value can be derived from the forest, the forest will be more likely to be preserved as forested land. This understanding can be described as 'a wood that pays is a wood that stays' (Bullard, 2015). A brochure from WWF (an independent organisation who campaign for conservation of the natural world) published on the FSC website, describes the various ways that value can be obtained from forests and explains that this economic value will encourage land owners to keep their land as forest (WWF, 2015) The following section describes the ways in which a forest can be managed to maximise the economic value of the stand through timber production.

Trees are comprised of a large stem, roots and branches, but the stem of the tree holds the market value (Kellomäki, 1998). Year on year, trees fix carbon through the process of photosynthesis, adding layers of growth to the stem which form rings through the cross-section of the tree (Nowak et al., 2013). The diameter of the stem decreases towards the top of the tree as new growth is directed upwards, elongating the stem (Kellomäki, 1998). As the tree continues to grow, the stem forms much of the biomass in the tree, making up between 50 and 60% of the total tree biomass (Kellomäki, 1998). This fixation of carbon means the tree is a carbon sink which increases as the tree grows and decreases with the death and decay of the tree (Nowak et al., 2013).

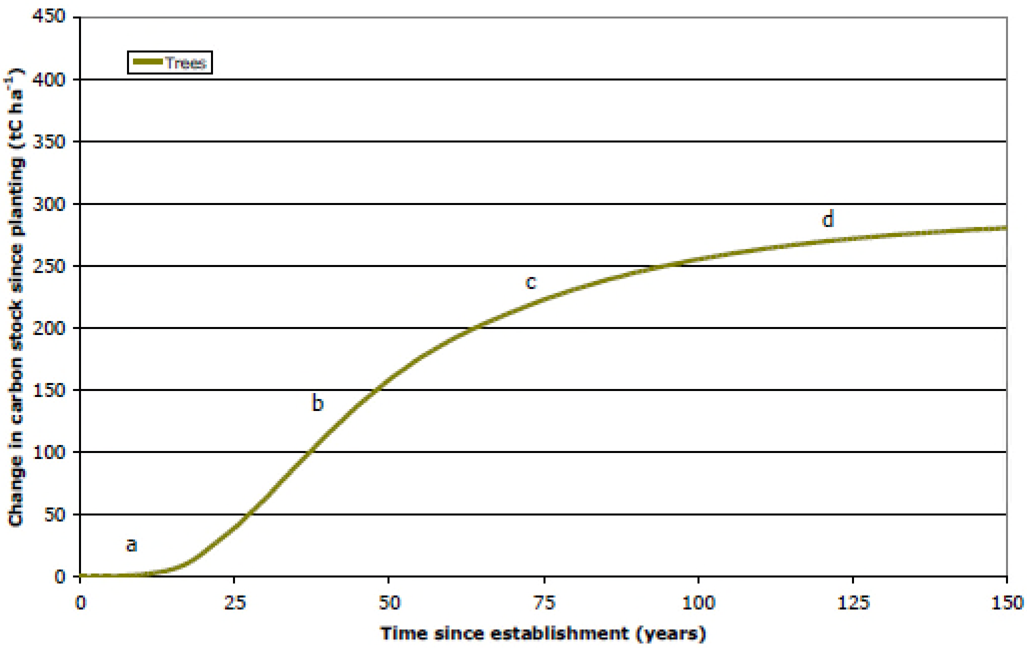

Figure 3-8 Carbon stock changes in a forest over time. From (Matthews et al., 2012).

Figure 3.8 plots the accumulation of carbon in a stand over time, assuming there are no management interventions. The trend of the graph shows the original period of (a) establishment, followed by the full-vigour phase (b) where trees are rapidly accumulating carbon (Matthews et al., 2012). As the trees reach maturity (c) the rate of carbon accumulation begins to level off, ending with stage (d), the long term equilibrium phase (Matthews et al., 2012). Figure 3.10 shows the proportional increase in value as the diameter increases.

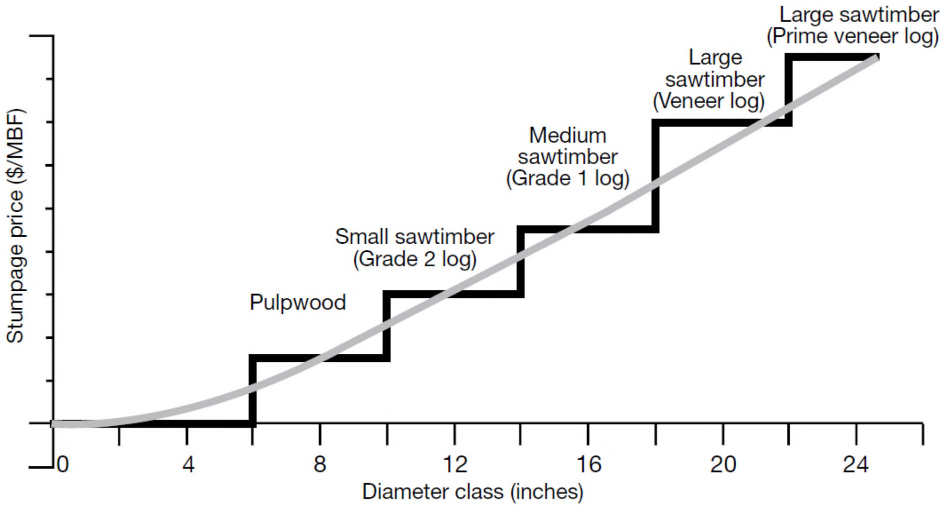

Figure 3-9 Changes in stumpage price as tree diameter increases. From (Klinge Jacobsen et al., 2014)

In Figure 3.9, it can be clearly seen that saw timber has a higher associated price than pulpwood, but this value is variable dependent on quality of the log and market conditions (Klinge Jacobsen et al., 2014).

3.3.7 Desirable qualities in saw timber

The definition of a saw log (and therefore the value) can vary geographically based on the tree species and the requirements of the saw mill. Saw mills have clear specifications on the requirements of the log, such as minimum length and specified diameter (Irving, 2014). There are usually also specific physical requirements for the material, such as requiring straight stems. Bent or misshapen trees can occur due to weather factors, such as wind or snow, or through planting issues (Kellomäki, 1998). In forestry terms, a 'knot' is where the base of a branch (where it meets the stem of the tree) becomes embedded within the stem during the growth period, the embedded horizontal branch then changes the direction of the grain (Kellomäki, 1998). The presence of knots is generally unwelcome in a saw log, as the change in the grain can create uneven cutting surfaces, make the wood more difficult to cut and can reduce the bending strength of the wood (Kellomäki, 1998). There are many other irregularities which can be seen in the standing timber which could reduce the value of the final saw timber, such as holes, lesions, wounds, butt swell etc. (USDA, 1989).

3.3.8 Managing a forest to maximise economic return

If the aim of the forest management is to optimise the commercial value of the forest, there are certain activities which can minimise the presence of the characteristics mentioned in 3.3.7. The different management techniques carried out on the forest stand are described collectively as the silvicultural system (USDA, 2006).

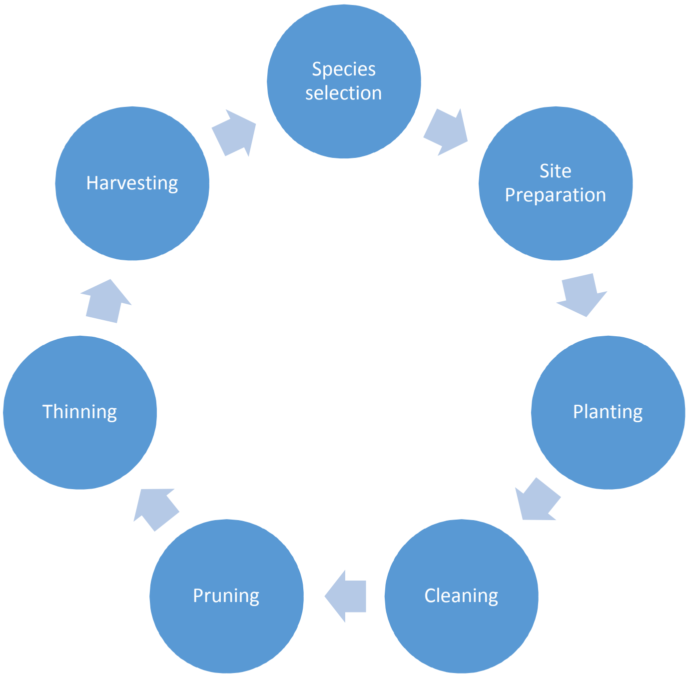

Figure 3-10. Schematic depicting the Stages of Forest Management. Data taken from (USDA, 2006).

Species selection is important in planted forests and naturally regenerated forests using introduced species, as different species will respond differently depending on the geography and nutrient and water availability of the stand (USDA, 2006). The correct choice of species for the site will have an important impact on the commercial value of the final crop of timber. Prior to planting, site preparation is important to give the best selective advantage to the crop (USDA, 2006).

As the trees first begin to grow, they are vulnerable to insects, disease and competition with other plants, so selective herbicides may be used, minimising competition for the young trees (USDA, 2006). Preparation of the soil is important before planting, so trenching or scarification is carried out (usually by dragging chains across the soil with a tractor) to avoid compaction of the soil (Béland et al., 2003). Scarification has the benefits of mixing the organic layers and minerals in the soil and spreading slash evenly across the site (Béland et al., 2003). Following planting, there is a very sensitive period where the seedlings have a high probability of mortality and during this period, weeding and 'cleaning' of the site takes place, continuously removing any other plants until the seedlings have grown taller than any competing vegetation (USDA, 2006).

During the full vigour stage, pruning takes place to reduce the occurrence of knots in the stem, this is where branches are cut off, usually during the autumn or winter months when growth rates are reduced, to allow maximum healing of the cut (USDA, 2006). As described previously, knot-free timber is more commercially valuable. The forest crown's function is to capture as much light as possible to increase photosynthesis, so new branches will grow at the very top of the stem, moving the canopy higher and maximising exposure to sunlight (Kellomäki, 1998). As the tree growth is directed upwards, the lower branches in the crown are in shade and tend to die off. It is for this reason that pruning is only recommended in the bottom half of the stem, as you are able to replicate this natural behaviour and at the same time minimise damage to the stem (Kellomäki, 1998). Of the stages in silviculture described in figure 3.10, thinning and harvesting have the largest impact on the forest health, as they both involve removal of whole trees. These stages are explained in greater detail below.

3.3.9 Forest thinning

Thinning is the key silvicultural approach which can improve the commercial value of a growing forest (Ratnam et al., 2014). The aim of a thinning operation is to remove a proportion of trees in a stand in order to push resources towards the remaining trees, allowing faster growth (Kerr and Haufe, 2011). In addition to improving the commercial value of the stem, thinning can also improve the species composition and growing conditions of the stand, however poorly-planned thinning could have severe impacts on economic return, if higher potential trees are removed before reaching maturity (USDA, 2006). Tree mortality within a stand is anticipated as part of natural succession, as the initial trees are subject to competition where weaker members of the stand die off, which could be considered a kind of self-thinning (Kellomäki, 1998). The density of trees in the stand has an important role to play in tree mortality. Larger trees need more resources to retain the degree of growth, meaning more space is required for larger trees (Kellomäki, 1998).

3.4 Influences on forests

3.4.1 Management Decisions in Privately Owned Forests

A study in 2008 found that only one fifth of private forest owners in the US had a formal management plan, two-fifths had obtained management advice and the remaining two-fifths were entirely unmanaged (Brett, 2008). Where there is no formal management plan in place, it is more difficult to understand the objectives and motivations of a forest owner.

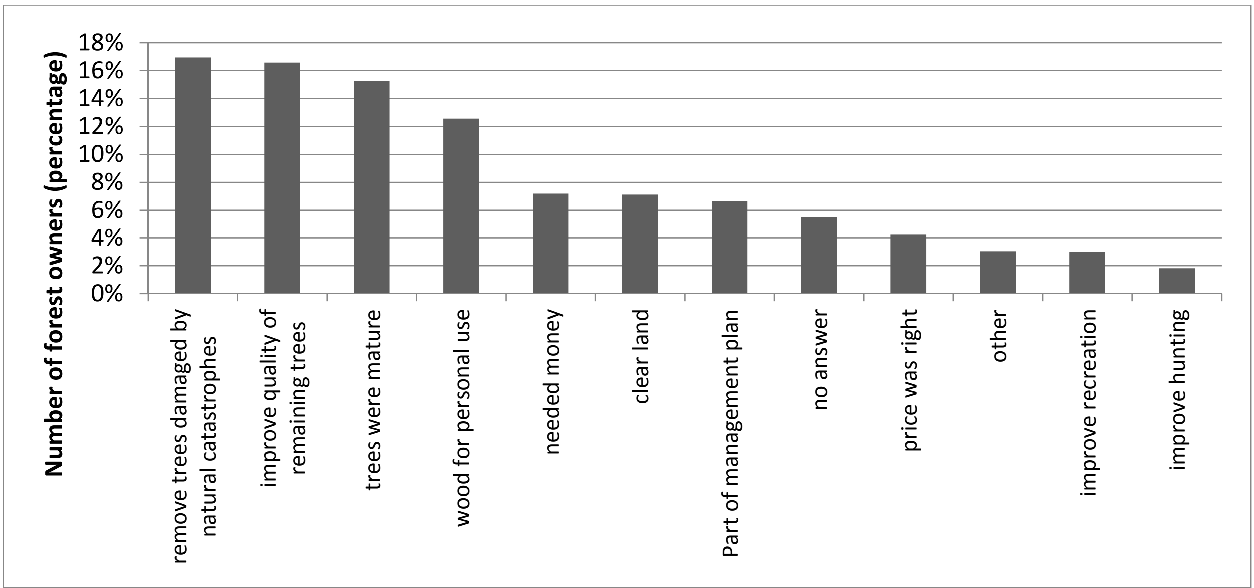

Figure 3-11 Reason for tree removal by US family forest owners in 2006. From (Brett, 2008).

Figure 3.11 gives an indication of the more complex motivations behind management and harvesting in privately held forests. Where the drive of the forest owner was for economic purposes, there is a significant risk that forest may not be managed in a sustainable way. If demand for forest products were to decline, with a parallel increase in demand for land for urbanization, there is a risk that these forest owners who are economically motivated would be likely to choose to convert their land to a different use (Alvarez, 2007). Conversely, where timber prices are competitive, the likelihood of land conversion is reduced and even in the case of increasing harvesting levels, the total biomass should not decrease significantly, as the increased investment in the land is likely to encourage forest management and restocking (Wear and Greis, 2012).

3.4.2 Harvesting:

Harvesting operations usually begin once the stand has reached a certain rotation age and dimension (Ratnam et al., 2014). Harvesting can occur as a clear-felling, where all trees in the stand are removed and then naturally regenerated or artificially replanted, creating a stand with a single age class (USDA, 2006). Alternatively, there are options for harvesting which do not involve cutting the entire stand, including seed-tree harvesting (where a few large trees remain to help establish the new crop), or shelterwood (where new stems grow around a selection of older trees, which remain to provide shelter for the new crop), or selection harvesting (where only specific trees or groups of trees are removed) (USDA, 2006). These types of harvesting which avoid clear-felling can also be known as Low Impact Silvicultural Systems (LISS). This type of harvesting would be preferred when landscape values are of high importance (USDA, 2006). Even-aged stands require an attractively simple type of management, although some forest owners may prefer selective harvesting types as they ensure a continuous presence of the stand (USDA, 2006). There are however there are other factors to consider in this decision, as certain tree-species require a lot of light and grow best in clear-cut systems, where others thrive better under the protection of a shelterwood system (USDA, 2006).

When a tree is harvested, it will be felled, de-limbed and topped on-site in the forest. In some cases, the stem will then be cut into the various product types, where material of the correct dimensions will be cut for different industries, which is reflected in Figure 3.13 (USDA, 2006).

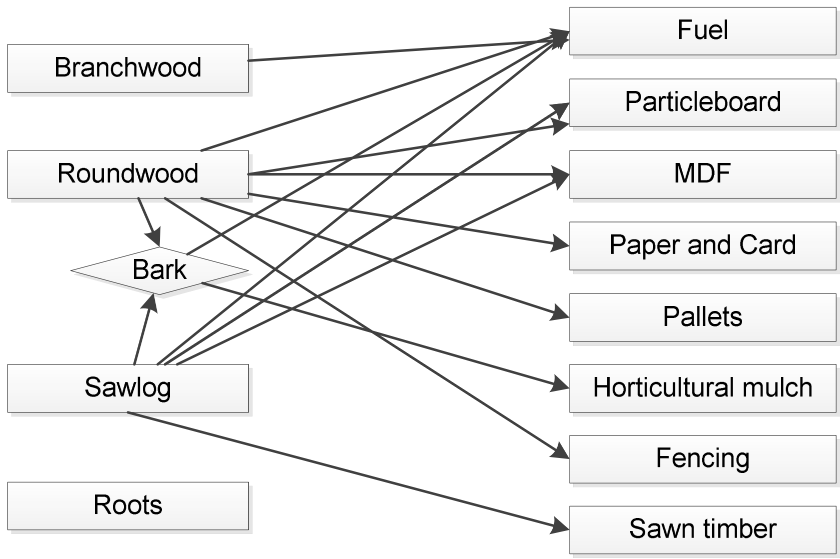

Figure 3-12 diagram showing the uses of different fractions of the tree. Adapted from (Matthews et al., 2012).

Figure 3.12 shows how an individual tree can be separated into various fractions and the different markets each of these fractions would be destined for. This diagram shows all potential markets for each fraction, but does not necessarily reflect realistic scenarios. Considering Figure 3.10, the price differential between sawn timber and pulpwood is clear, so you could assume that it's unlikely that saw logs would be used for fuel, particleboard or MDF, as it would not be economically attractive.

3.4.3 Influences on thinning decisions

Different forest types will have specific forest management objectives and it is these objectives which will influence forest management decisions. In addition to considering the objectives, forest managers must also consider the characteristics of the stand and any potential hazards, for example wind hazard (Kerr and Haufe, 2011). Trees in an unthinned stand tend to have long, thin stems and small crowns (as per Figure 6), which have little resistance to strong winds and must rely on surrounding trees for support (Kerr and Haufe, 2011).

The literature suggests that biomass demand could encourage management practices, specifically increased thinning regimes (Blennow et al., 2014; Eyre et al., 2015; Hastik et al., 2015). The updated billion ton report also supports this suggestion, describing the two major types of forest biomass as harvesting residues and some of the material extracted during thinning (Turhollow et al., 2014). The US timber products industry is currently facing difficulties following the economic crisis, which has created a decline in sawmilling and therefore investment into the forest (Hoefnagels et al., 2014). A thinning operation costs money, and although there can be devastating financial impacts from fire, disease or pests in an unthinned stand, the mitigation of these risks cannot be clearly compared against the cost of thinning the stand (Polagye et al., 2007).

Previous studies have tested the hypothesis that private forest owners would be more willing to harvest material for bioenergy through thinning, compared to shortening rotations or integrated harvests (Dorning et al., 2015). Stand thinning required a far lower price to change landowner's willingness to harvest, with only $50 per acre per year encouraging almost 20% of landowners to thin their forest for bioenergy, with this figure increasing to almost 70% of landowners when the incentive rises to $250/acre/year, however less than 10% of respondents were convinced to change their practices to either shortening rotation lengths or integrated harvests even with the highest offered price (Dorning et al., 2015). These findings support the fact that final harvesting decisions will be made based on the objectives of the forest, as economic incentive alone does not appear to encourage a forest owner to harvest their land for bioenergy.

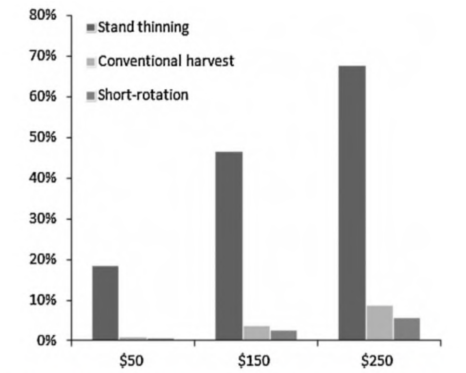

Fig. 2. Probability of feedstock production. The predicted probability (based on logit estimates) of the average landowner choosing to produce bioenergy feedstocks under each scenario. The monetary values along the *x*-axis are per acre per year.

Figure 3-13 Diagram showing private forest owner willingness to change to different forest management types. *(Dorning et al., 2015)*

The potential for thinning to create the material required for the bioenergy industry is a concept of interest in various countries at a government level, for example, the UK Woodfuel Strategy produced by the Forestry Commission suggested that by moving UK forests into management, an additional 2 million tonnes of forest biomass could be levied for the bioenergy industry (Forestry Commission England). Private forest owners could be considered more perceptible to influence, as the majority of these land owners do not have a formal management plan (Brett, 2008). However, it has been shown that where landowners are not dependent on the land for income, there is a lower potential for economic drivers to change management activities – as the other benefits are usually the key for the owner (such as privacy and aesthetic values) (Dorning et al., 2015).

3.4.4 Current research on the impact of wood pellet industry on forest decisions

There is considerable debate between NGOs and industry around the potential for the bioenergy industry to force final management decisions, however many academic papers seem to suggest this is an unlikely scenario, as saw log production is currently the most likely driver for final management decisions (Hastik et al., 2015). In the last 5 years, there have been significantly increased exports of wood pellets from the US to Europe and data suggests that the projected future demand for wood pellets in the US is likely to peak at around 10.7 million tonnes (Forisk, 2015). However, the future demand for woody biomass from the US will be constrained to sustainability requirements and efficient supply chains (i.e. close to port facilities for export) (Galik and Abt, 2015).

The pellet industry has been linked to existing forest industries in the southeast USA and the capacity to pay of the pellet industry will be the key factor in how these industries interact (Iriarte and Pelkmans, 2014). Pellet prices in the US South have remained stable over the last few years, with a range of 112 – 114 euros per tonne CIF ARA since 2007 (Iriarte and Pelkmans, 2014). Referencing studies carried out by Forest2Market and Poyry, this paper showed that the wood paying capacity of pellet mills is significantly below that of the pulp and panel industries (Iriarte and Pelkmans, 2014). The economics and the capacity to pay of the pellet industry would suggest that it is more likely that the pellet industry will source lower-priced pulpwood, rather than driving final felling of stands (USDA, 2013).

This additional demand raises questions over the impact on forestry, as increased demand is usually modelled as a risk to forest cover, although it is thought that in the longer term an increase in the value of different forest products could result in expanding forested areas (Abt et al., 2014). If an increased demand has been shown to lead to expanding forest areas and better growing forests, this is difficult to model. It can be assumed that this is the reason why the Biomass Emissions and Counterfactual model produced by DECC in 2013 modelled an increased demand through reducing rotation ages by 10 years (Stephenson and Mackay, 2014). However, reducing rotation ages would appear to be at odds with suggestions that increased demand encourages investment into the forest. A 2014 study looked at the potential for management objectives to move from higher value timber to bioenergy and showed that even if the financial incentive was sufficient, there was still a low engagement with the idea of managing a forest for bioenergy (Blennow et al., 2014).

Integrated harvesting is one way in which final harvest material could be used in the bioenergy industry, and a 2014 study on the willingness to harvest of US private forest owners showed that an increased price for woody biomass increased the willingness for a forest owner to carry out an integrated harvest, harvesting low value wood in addition to saw timber (Aguilar et al., 2014). However, this willingness only increased where the forest owner was already willing to harvest their land (Aguilar et al., 2014). The clear finding of this study was that stronger forest products markets at the higher end of the scale is more likely to have the impact of increased extraction of woody biomass, compared to increased prices at the bottom end of the scale (Aguilar et al., 2014).

4. Analysis – Supply and Demand

4.1 Demand assessment – current levels

The urgent need to decarbonise the energy sector is incentivising the use of renewable energy across Europe. Europe has challenging renewable energy targets to meet by 2020 and the literature review highlighted the relative importance of wood energy in meeting these targets. Recent trends in Europe show an increasing use of wood for energy, including an increasing use of imported wood pellets. This section of the study aims to address Objective 1, understanding the importance of biomass to European renewable energy targets.

4.1.1 Current bioenergy use across Europe

According to the literature, wood is a common form of energy in developing countries and the use of wood energy has increased in line with population growth (FAO, 2001). However, wood energy use has also increased within Europe through the large scale industrial use of biomass to displace combustion of fossil fuels and through residential use of wood energy for heating. Bioenergy is the only renewable that can provide energy in all three areas (electricity, heat and transport fuel) without additional technologies needed for storage or conversion of the energy, so it is to be expected that bioenergy is an important component of renewable energy generation. Figure 4.1 shows that many countries use solid biofuels as their major source of renewable energy, with some countries generating more than three quarters of their total renewable energy from wood (Latvia, Finland, Lithuania, Estonia and Poland). On average across the EU-28, 46% of renewable energy generation is from wood.

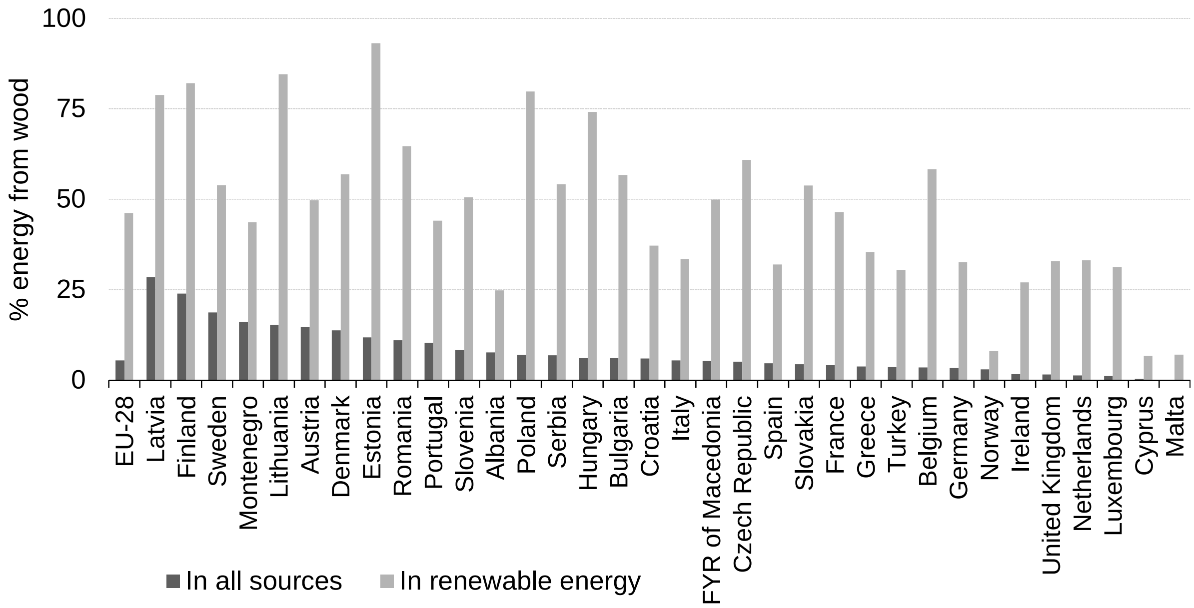

Figure 4-1: Wood use for energy in the EU 28 during 2013.

Figure 4.1 reference: (Eurostat, 2016a)

Figure 4.1 highlights the fact that some countries have a higher reliance on biomass compared to others, which can depend on the energy profile of the country and the investment which has gone into developing other renewable technologies. Figure 4.2 shows the renewable energy profiles of different countries across the EU and supports the strong reliance on solid biomass shown in figure 4.1. Figure 4.2 is ordered to show the countries with highest reliance on bioenergy at the top and it is clear that bioenergy is an important contributor in most countries. Outliers to this trend are Albania and Norway, which both get the majority of their renewable energy from hydro power, and Ireland and the UK, which generate a comparatively larger proportion of their renewable energy from wind.

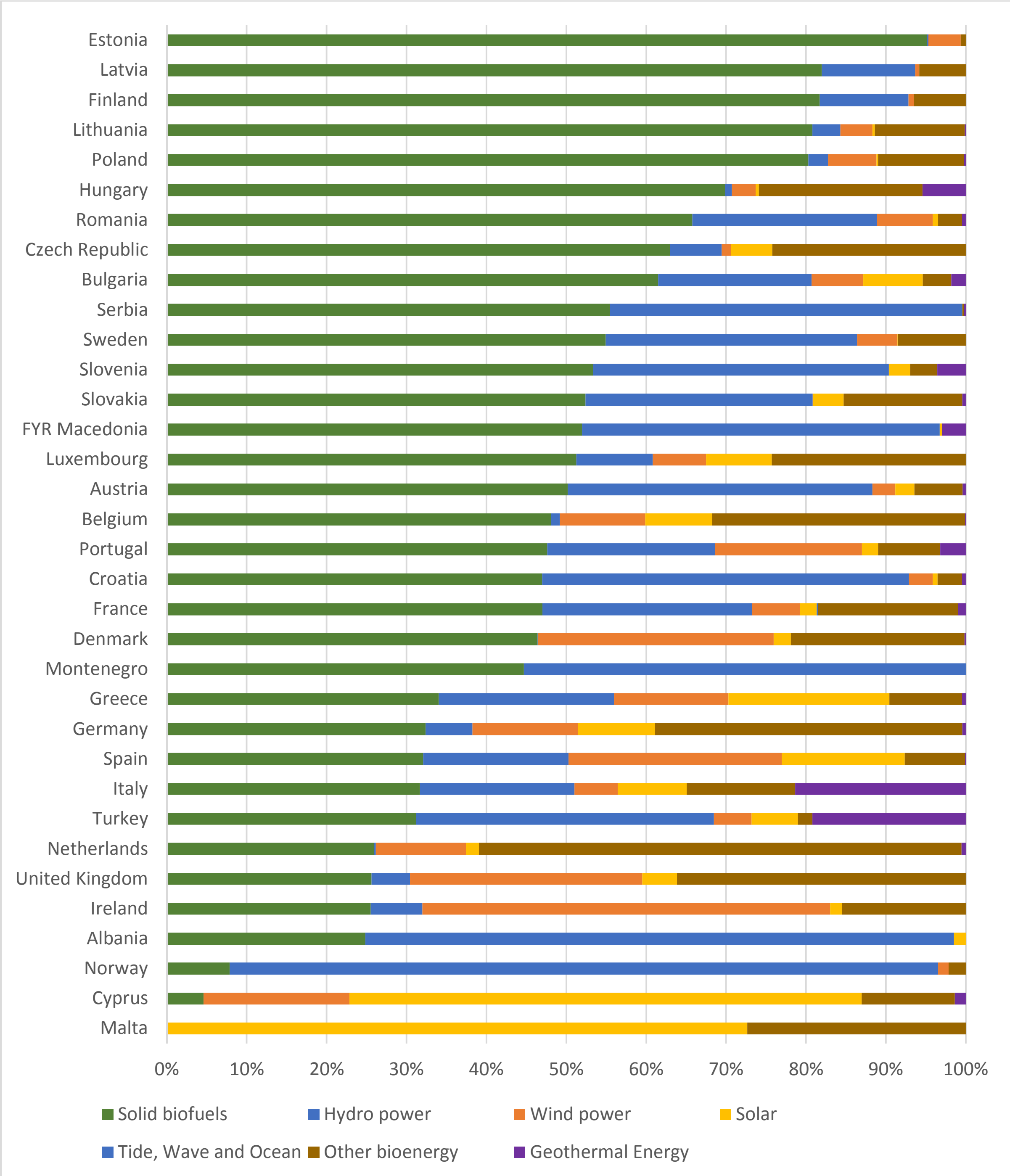

Figure 4-2 Primary Production of Renewable Energy across Europe in 2013.

Figure 4.2 reference: (Eurostat, 2016b)

Figure 4.2 highlights the important role biomass plays in renewable energy generation across the EU-28. There are many reasons why countries may choose to rely on different methods of renewable energy generation. Coastal countries, for example, tend to have better potentials for wind energy or hydro power, so investment into these technologies could be attractive. Countries with longer periods of sunshine could be more likely to have a reliance on solar, as suggested through the only two countries in Europe with a high reliance on solar energy, Cyprus and Malta. Figures 4.1 and 4.2 provide background into the proportion of energy derived from solid biomass, but are both silent on the actual amounts of energy produced and therefore the volumes of solid biomass required. Different sizes, population densities and GDPs of countries mean there will be different levels of energy demand. Figure 4.3 shows the countries producing the most energy from solid biomass and how this has changed since 1995.

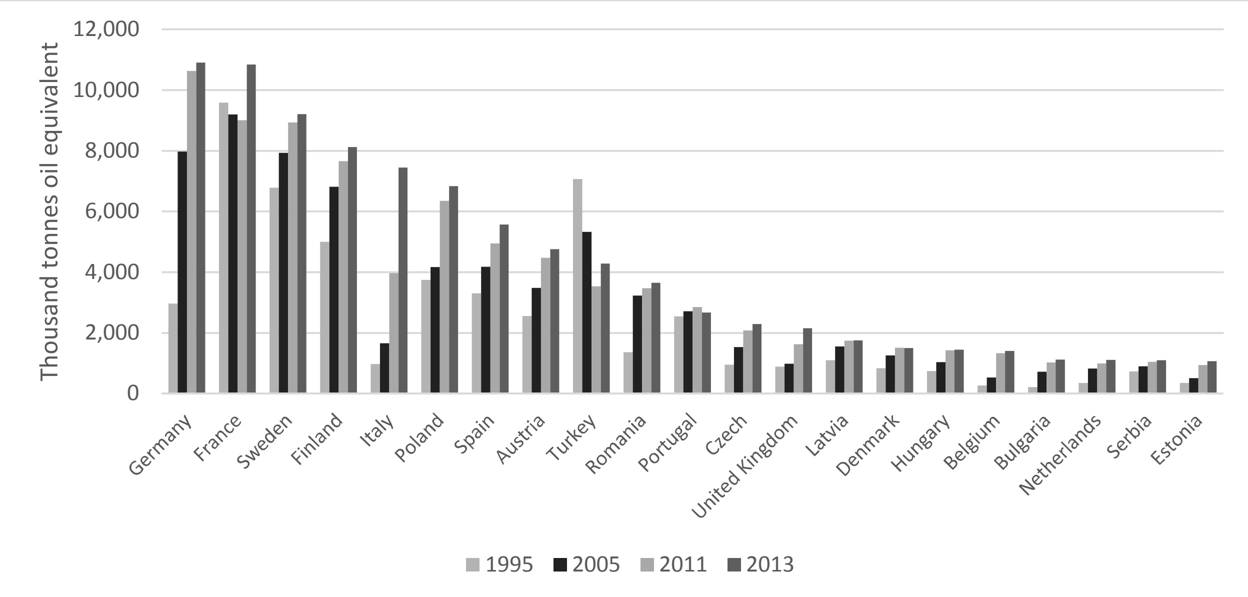

Figure 4-3 Countries with the highest primary production from solid biofuels in each year

Figure 4.3: (Eurostat Database, 2016)

Figure 4.3 is ordered to first show the countries producing the most energy from biomass. It is interesting to note that although in 2013, Germany has the highest total primary production from solid bioenergy across Europe, this only contributes 32% to Germany's total renewable energy production. This puts into context the greater total energy used in Germany compared to other European countries, due to its size and population. In the same context, it is clear that Estonia has the highest reliance on solid biofuels, providing 93% of total renewable energy and yet actually generates relatively low levels of energy from wood compared to larger EU countries.

Italy, Poland and Germany have all showed a notable increase in their primary production from biomass since 1995 and production in other countries has stayed generally stable, other than in Turkey, where the use of biomass has decreased. Figure 4.2 shows that in 2013, Turkey was generating energy from a relatively wide range of renewable technologies, so the development of these other technologies could explain the decrease in generation from bioenergy. On average, across Europe energy generation from bioenergy has increased by nearly 50% in the 10 years prior to 2013, from 61,328 TOE to 90,944 TOE.

4.1.2 Energy use and natural resources

A country's reliance on different types of energy generation could be correlated to the resources available in that country, such as Norway's focus on hydro power following significant investment and development into this technology (Regjeringen, 2016). Similarly, the significantly larger levels of wind generation in the UK, Ireland and Denmark can be attributed to subsidy regimes to encourage their development, but also to the fact that these coastal countries have relatively high wind potentials, with the UK being rated the most attractive European country to develop wind energy (Higgins and Foley, 2014). In regions which are more densely forested, it could be suggested that these areas are more likely to have a stronger focus on bioenergy through using the natural resources available. Figure 4.4 charts the proportion of total energy production from solid biofuels against the proportion of forested area in each country and a loose positive correlation can be seen, although this is clearly subject to numerous other factors.

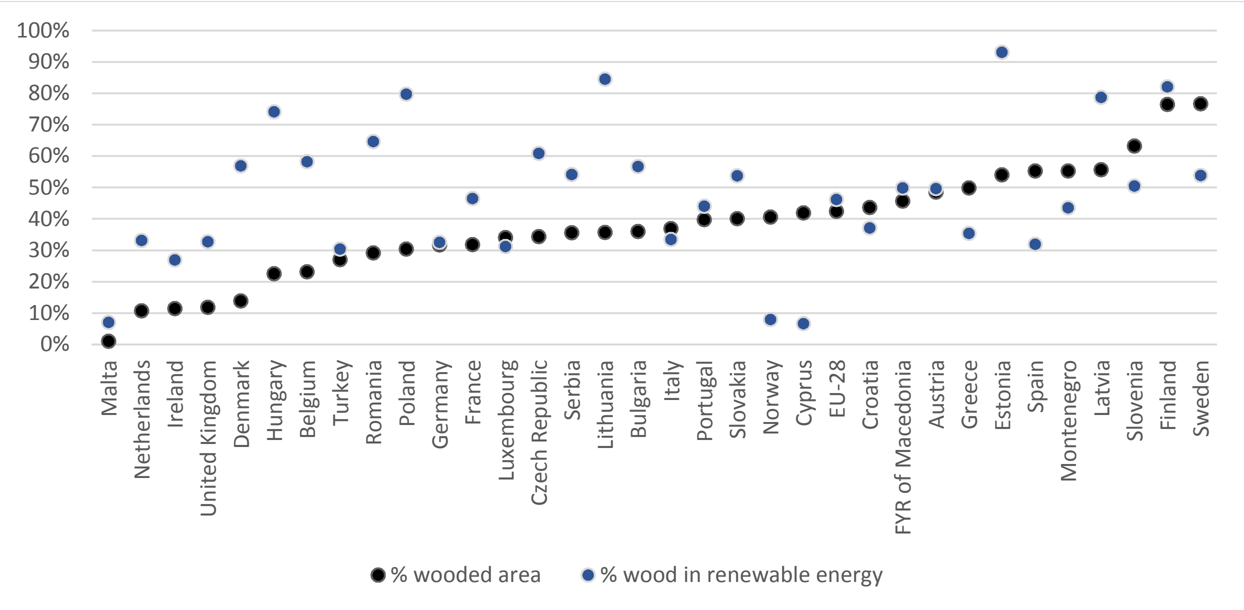

Figure 4-4: % forest cover in the EU 28 compared to % wood use in renewable energy

Figure 4.4 reference: (FAO, 2010b) compared to data from (Eurostat Database, 2016)

Figure 4.4 shows some countries to be outliers, relying more heavily on wood energy compared to their proportionate forest cover. Denmark, Hungary, Belgium, Romania, Poland, Lithuania and Estonia all have a far higher reliance on wood energy compared to their forested area. This could be attributed to renewable energy incentive programmes promoting bioenergy use, importing biomass, or the established uses of bioenergy. There could be many reasons why some countries choose to utilise their wood resource to a higher level, such as more active forest industries which mobilise comparatively more forest biomass for energy. Latvia, Estonia and Lithuania, interestingly all have high proportions of forested area but also show a higher than average dependence on renewable energy generation from wood. This may suggest that these regions are more active in their forest industries, with higher harvesting levels than other countries. However, an initial comparison of roundwood production against the available forest land showed that these regions do not appear to have higher proportionate harvesting levels than other member states (Eurostat data). The Baltic States (Latvia, Estonia and Lithuania) themselves hold very few natural resources of primary energy and are reliant on neighbouring countries (especially Russia) for imports of gas, electricity and oil. In a bid to move away from this heavy reliance on imports, Latvian governments have increase the use of wood, as one of the few available local resources (Sliogeriene, J. 2014).

Some countries however, have a lower reliance on wood energy compared to their total forest cover. Norway is a clear outlier, which could be attributed to the fact that 89% of renewable energy in Norway is from hydro, so there is limited demand for additional renewable energy. Cyprus has a strong reliance on solar thermal energy, providing 60% of total renewable energy, but Greece and Spain have a relatively equal mix of many different types of renewables and so do not have a strong reliance on any one energy source. Where countries have lower levels of forest cover, we could expect to see more imports as these countries strive to meet their renewable energy targets. This is certainly the case for the United Kingdom, Denmark, Belgium and the Netherlands, which can be seen in figures 4.5 and 4.6.

In figure 4.4, the average forested area for the EU28 correlates very well against the total EU reliance on wood energy, suggesting a potential for sharing natural resource through trade. The more densely forested countries which do not have a high reliance on their forest resource for bioenergy (such as Spain, Greece, Norway and Cyprus) could become exporters to forest biomass to EU countries with less available forest resource.

4.1.3 Summary

This section of the analysis aimed to quantify the current use of wood energy across the different member states of the European Union and understand the reasons behind varying focusses on different renewable energy technologies. The assessed data shows that energy from biomass is an important contributor to 2020 renewable energy goals, providing 46.2% of all renewable energy in the EU 28 in 2013. On average, energy generation from bioenergy across Europe has increased by nearly 50% in the 10 years prior to 2013, from 61,328 TOE to 90,944 TOE. As Europe moves towards a more renewable future, it is likely that the use of bioenergy will continue increasing.

It is possible that each country's choice of a renewable energy mix is dependent on their inherent natural resources, as suggested by the focus on solar energy in sunnier geographies and wind power focus in windier countries. There is a weak positive correlation between countries with a higher reliance on wood energy in total renewable energy generation and the proportion of forest cover in each country. In countries which have little reliance on woody biomass for energy, such as Norway (which generates much of their energy from hydro), there could be a potential for intra-EU trade of biomass to countries with lower levels of forest resource. As suggested through the case of the Baltic States, where countries have low natural resource for primary energy sources and a desire to move away from a reliance on imports, wood energy can have a role to play in allowing countries to become more self-reliant.

4.2 Demand assessment – Trade of woody biomass

Wood energy plays an important role in meeting the EU's renewable energy targets and imports may be necessary to meet these demands in certain countries. The literature review showed that compressing wood into pellets improved the handling of the material for transport, as well as improving the combustion properties. Due to the sharp increase in wood pellet production, the likelihood of traded biomass to be in pelletised form and the difficulties in tracking data for wood chips, this study will focus on wood pellet trade. This section of the analysis aims to address objective 2, by looking at trade patterns of wood pellets in the period 2009 to 2014.

4.2.1 Trade and Production of Wood Pellets

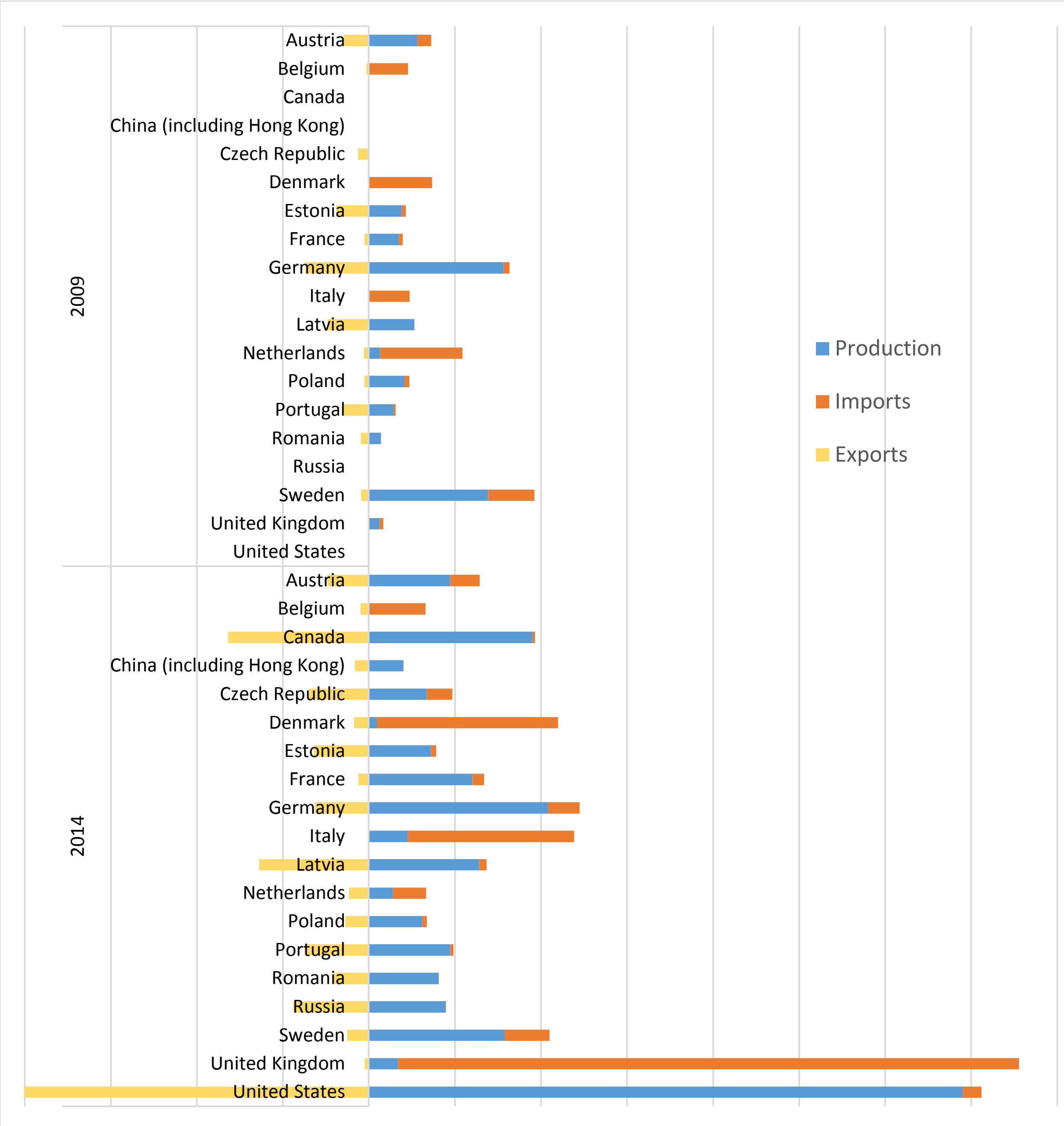

Figure 4-5 Trade of wood pellets inside and outside of Europe – comparison between 2009 and 2014

Figure 4.5 from (Eurostat Database, 2016)

Figure 4.5 shows that in 2009, Sweden and Germany were both major producers of wood pellets, with the Netherlands, Denmark and Belgium the major importers. In 2014, the scene has changed quite significantly with the production of wood pellets increasing by 2.5 times between 2009 and 2014. In 2014, the UK had become the major importer of wood pellets and the major producer (and exporter) was the United States. Interrogating HMRC data on imported wood pellets shows that only 30.4% of all wood pellet imports to the UK in 2014 were from within Europe (HMRC, 2016). Figure 4.4 showed that Latvia, Lithuania, Estonia and Romania all had relatively higher use of wood energy compared to their forested area and yet these areas are all also exporters of wood pellets.

Table 7: Assumed global wood pellet use

Unit: tonnes	**2009**	**2014**
United Kingdom	156,140	7,505,060
United States	-	3,114,930
Italy	470,920	2,374,930
Denmark	720,100	2,023,540
Sweden	1,831,160	1,845,840
Germany	894,060	1,821,150
France	339,660	1,214,390
Austria	433,580	805,830
Netherlands	1,029,160	428,900
Romania	45,310	399,900
Poland	419,100	398,000
Finland	129,390	314,010
Canada		292,720
Czech Republic	- 119,460	269,000
Spain	168,160	247,750
China (including Hong Kong)		236,880
Portugal	330	231,930
Switzerland	-	215,920
Slovenia	180,350	147,780
Estonia	48,570	140,830
Norway	47,840	114,050
Latvia	49,380	90,590
Brazil		56,500
Ireland	21,600	32,000
Lithuania	60	22,380
Greece	590	20,320
Russia		13,770

Table 7 (Eurostat Database, 2016)

Table 7 shows that the UK is the largest user of wood pellets, however figures 4.1, 4.2 and 4.3 also showed that the UK is behind the rest of Europe in its use of wood energy. This suggests that the UK is an outlier in the use of wood pellets instead of wood chip.

4.2.2 Current Demand for Industrial Wood Pellets in Europe

Table 7 uses reported data from Eurostat and shows that 23.5 million tonnes of wood pellets were produced globally in 2014. Wood chip use is not in scope for this study, as there is lower data availability for wood chip. In terms of production, the US was the largest producer of wood pellets and has been shown to be an important exporter to Europe. In the 5 years between 2009 and 2015, export capacity for wood pellets in the United States increased from nothing in 2009 to 6,900,000 tonnes in 2014. In 2014, wood pellet consumption across Europe was 20.5 million tonnes, 7.5 million tonnes of which were consumed in the UK. Data published by Ofgem shows that over 5.5 million tonnes of wood pellets were used in the UK for electricity generation in the financial year 2014/15, half of which were imported from the United States.

There do not appear to be policies in place to encourage further uptake of the use of wood pellets in bioenergy. The European Commission has recently published a consultation on potential EU wide sustainability criteria for woody biomass and has also launched two different State Aid investigations on UK subsidy contracts for the use of woody biomass, which suggests that further investment to expand the use of this technology seems unlikely. However, in 2014, bioenergy provided 46% of European renewable energy, which was 15.3% of total energy generation across Europe. 20.5 million tonnes of pellets are thought to be consumed in Europe in this period, so if all parameters stay constant as Europe moves to its target of 20% renewable energy generation, consumption of wood pellets could increase to 26.8 million tonnes of pellets by 2020. Demand for wood pellets could increase through current users of wood chip moving to using wood pellets in an effort to increase efficiency in generation, however this would be considered a movement from one type of demand for wood to another, rather than a new demand on wood resources. Projected future demand for wood pellets is not an objective of this study, so potential future levels of demand is not explored in detail here.

4.2.3 Summary

Although bioenergy has always been used across Europe, the use of wood pellets expanded significantly between 2009 and 2014 and by 2014 the global production of wood pellets in 2014 was 23.5 million tonnes, with European consumption comprising 87% of total production. Although there do not appear to be policies in place to further develop the use of wood pellets, if current parameters remain at current levels, the annual European levels of wood pellet consumption could reach 26.8 million tonnes by 2020.

The UK is the largest user of wood pellets, consuming 5.6 million tonnes of pellets for electricity generation between April 2014 and April 2015, however, the UK is not the largest user of wood energy suggesting that the UK is an outlier in their use of pellets as a form of wood energy. The US has become the largest producer of wood pellets in the years between 2009 and 2014, with a rapid rise in production levels, exporting over 4 million tonnes of wood pellets in 2014.

4.3 Supply – US South

Figure 4.5 showed that between 2009 and 2014, the United States saw a major increase in pellet production and became a key exporter of wood pellets to the EU. With demand in Europe expected to increase before 2020, it is important to consider the potential impact of this additional export demand on forests in this region.

4.3.1 Total production of wood pellets

The United States is currently the largest producer of wood pellets globally, exporting over 4 million tonnes of wood pellets in 2014, with the majority of these pellets destined for Europe. Current trends in EU demand suggest that the United States is a major exporter of wood pellets to the EU, so this study focusses on the potential impact of this demand on harvesting trends in the United States. Table 8 shows the production of wood pellets in the United States compares to the production of pulp and paper and highlight the relatively small size of this emerging market for wood pellets.

Table 8: Production of wood pellets compared to pulp and paper in the US (units: million tonnes)

Forest Product	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Pulp and Paper	183.82	184.89	187.56	180.16	165.96	175.60	174.51	171.29	170.33
Wood Pellet	*	*	*	*	*	*	*	4.10	5.00

Table 8 from (FAOSTAT, 2016).

*Data unavailable from 2005 - 2011

4.3.2 Historic trends in wood products in the United States

FAO provides international data on trade, but the product "wood pellets" was only given its own code to capture trade data in 2012, so data can only be interrogated for the last 3 years. Data from Eurostat and FAO shows that of the 6.9 million tonnes of pellets produced in 2014, 4 million were exported (Eurostat Database, 2016; FAOSTAT, 2016) . It is clear that the US is a major producer of pellets and the vast majority of these pellets are destined for export. Although the production of wood pellets is clearly increasing, this is still significantly lower than the production of other wood products in the United States. This is shown in figure 4.6.

Figure 4.6 shows that sawn wood is produced in the highest volumes, however this production has clearly declined between 2005 and 2009, where it then levels off. This decline has been attributed to the economic crisis, which created a serious decline in the construction industry, resulting in decreased demand for sawn wood for building. Between 2005 and 2009 the construction industry declined by 75%, the impacts of which can be clearly seen here in the trends for the production of sawn wood (Hodges, 2012). Pulp and paper is the second largest product type, with production remaining relatively stable during this crisis, at around 175 million tonnes of production each year. At the lower levels of production, lower value wood products can be seen; chips and particles, particle board and wood pellet production have all stayed relatively stable, at less than 50 million tonnes of annual production.

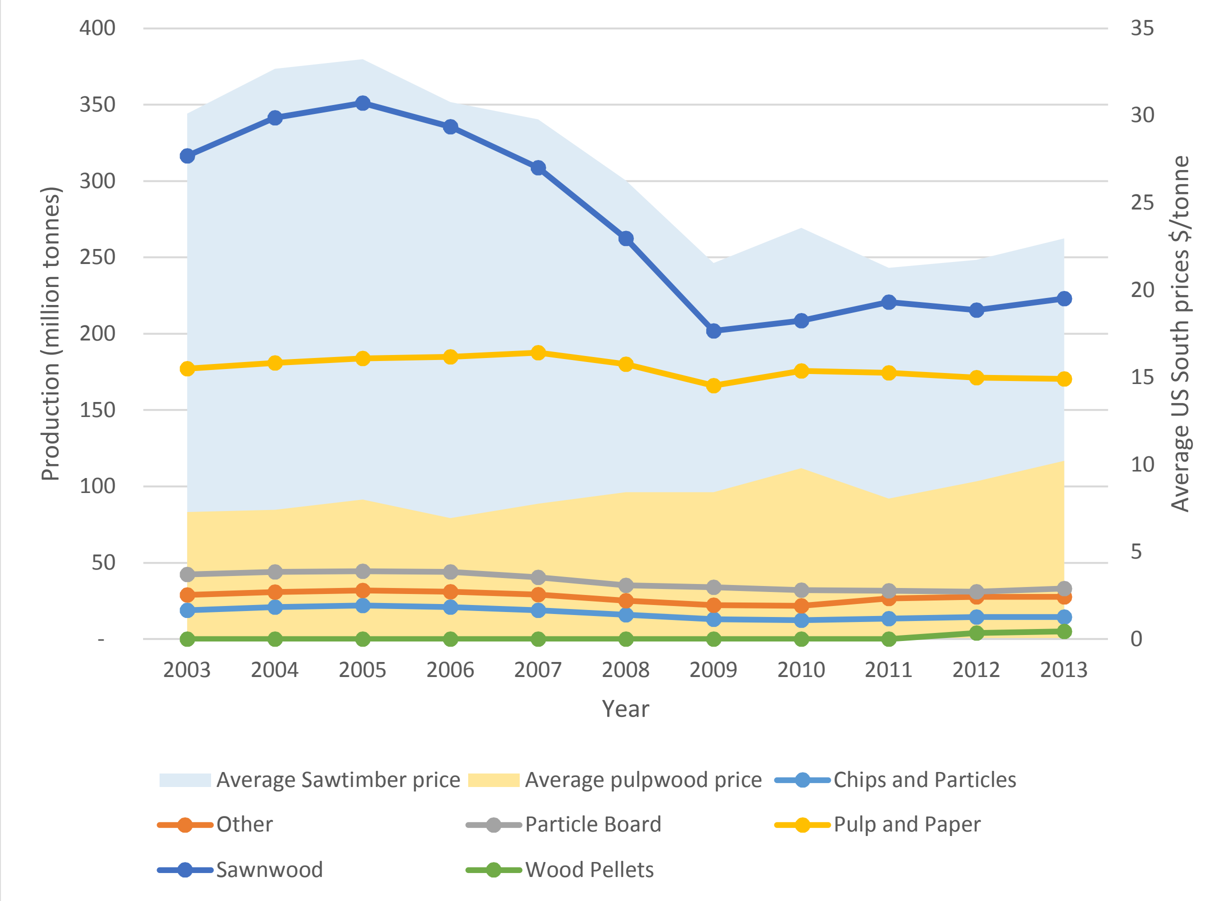

Figure 4-6 Trends in US wood production over 10 years

Figure 4.6: from FAO production data (FAOSTAT, 2016) combined with average data for delivered price for the US South East (Forest 2 Market, 2015).

Figure 4.6 compares wood production against average delivered price and shows that the dramatic decline in sawn wood production corresponds to a decline in sawn wood pricing in the US South East, from a high of $33 per tonne in 2005, to a low of $21.50 per tonne in 2009 (Forest 2 Market, 2015). Although pulpwood harvesting has stayed relatively stable, pulpwood prices did show a 34% increase between 2003 and 2010 (Forest 2 Market, 2015). It is of interest that there was such a significant decline in the value and production of larger, higher quality wood products and yet the production of lower value wood products has remained relatively stable, even as prices for this material increased by 34% between 2003 and 2010 (Forest 2 Market, 2015).

One explanation for the significant decline of saw log grade material compared to pulpwood grade, could be that forest owners were choosing to delay the final harvest of their stands, in order to wait for the market to recover where they would receive a better return for their harvest. The potential considerations for a forest owner when choosing when to harvest their forest stand incorporates many factors, including sustainability, legal and economic factors, such as timber prices (Jacobson, M. 2008). This will be explored in more detail in section 5.3. When looking at trends on such a large scale, it is difficult to identify the impacts of additional demand of wood for bioenergy. Therefore, the following section focusses harvesting trends specifically in the US South East region to compare any changes against the introduction of wood pellet demand.

4.3.3 Pellet Production in the US South

This study focusses specifically on industrial grade wood pellets (for electricity generation). There is a difference between the specifications of pellets used for heat (domestic use) compared to pellets for industrial use (used in electricity generation). Pellets for heat used in smaller boilers usually require a better quality pellet, with a higher density than industrial pellets. Eurostat data suggests that 3 million tonnes of wood pellets were produced and used domestically in the US in 2014, but in this study focusses purely on pellet plants producing industrial pellets for European markets. However, some pellet plants have the ability to produce both heat and industrial pellets, so not all pellets from the plants listed will be available for industrial use and similarly, not all will be available for export. Table 9 summarises the capacity for wood pellet production in the US South in each state. Almost 8 million tonnes of pellet capacity is either operating or under construction in this area currently.

Table 9: Industrial Grade pellet plants in US South States

State	Number of plants	Sum of Capacity (tonnes)
Alabama	3	655,000
Florida	1	650,000
Georgia	5	1,481,000
Louisiana	2	504,000
Mississippi	5	900,000
North Carolina	2	870,000
South Carolina	1	100,000
Texas	2	540,000
Virginia	4	706,000
Georgia	1	120,000
Louisiana	1	500,000
North Carolina	1	500,000
South Carolina	1	460,000
Total	**29**	**7,986,000**

Table 9: internet searches (full list in references), (Forisk, 2015), google maps and (Biomass Magazine, 2015) all compiled and edited with industry knowledge.

Table 10: Operating plants and plants under construction, capacity and assumed demand

State	Number of plants	Total pellet capacity (tonnes)	Assumed wood fibre demand (tonnes)
Alabama	3	655,000	1,310,000
Florida	1	650,000	1,300,000
Georgia	6	1,601,000	3,202,000
Louisiana	3	1,004,000	2,008,000
Mississippi	5	900,000	1,800,000
North Carolina	3	1,370,000	2,740,000
South Carolina	2	560,000	1,120,000
Texas	2	540,000	1,080,000
Virginia	4	706,000	1,412,000
	29	**7,986,000**	**15,972,000**

Table 10 sources: internet searches (full list in references), (Forisk, 2015), google maps and (Biomass Magazine, 2015) all compiled and edited with industry knowledge.

To make an assumption of the wood fibre demand required by these pellet plants, a conversion factor of 0.5 is used to create an assumed demand of raw wood fibre in each state (European Commission, 2015). Table 10 shows a higher level of pellet production in Georgia than other states. It is important to note that this data is limited to assume that all pellets are sourced from the state in which the pellet plant is located. In reality, the procurement radius of each pellet plant could cross into bordering states.

The literature shows that wood pellets are primarily made up of residues from harvesting or wood processing industry residues, so it would make sense for pellet plants to be located in regions with active harvesting or processing sites to ensure consistent supply of materials. Figure 4.7 shows that Georgia has the highest total harvesting of any of the states in this area, which could explain the higher concentration of pellet plants in this state. If more sawtimber is harvested, this increases the amount of logging residues available and if more sawmilling occurs, this increases the amount of processing residues available for use in wood pellets.

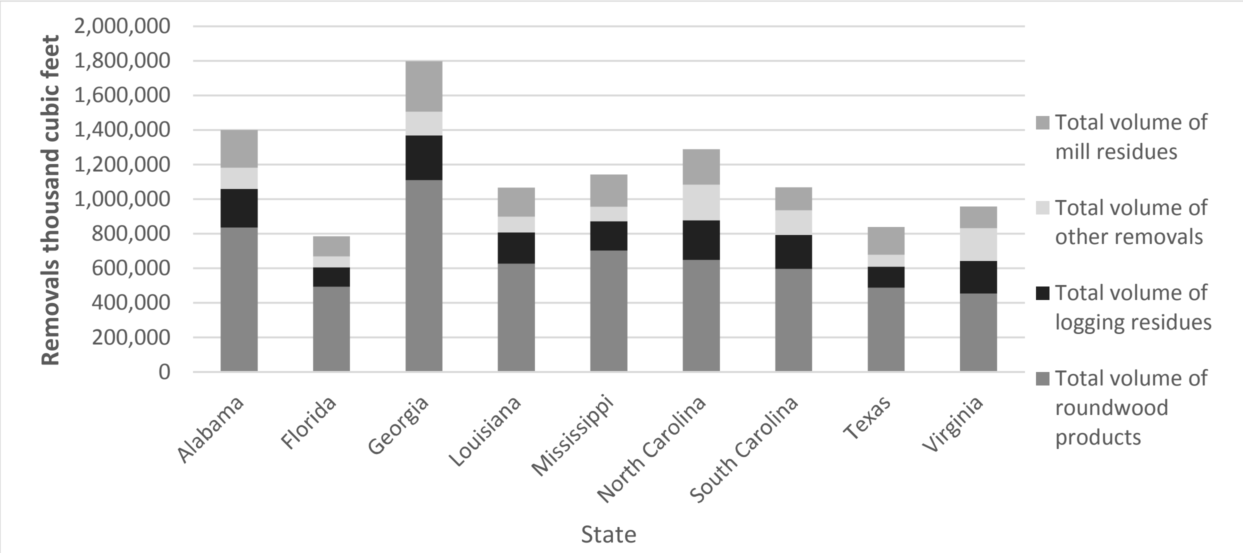

Figure 4-7: Total harvesting the US South East States (2009)

Figure 4.7 adapted from (FIA, 2015b).

The pellet industry in the US South has been one of rapid expansion and there are further proposals for construction of pellet plants in this region. It is not certain if all these proposed plants will be successful in their applications and will begin construction, as the market for wood pellets could be considered to be somewhat uncertain, as it is an industry based on subsidy regimes in other countries which are not guaranteed in the long term.

As per table 10 the current assumed wood fibre demand from pellet plants in the US South is 16 million tonnes. The literature shows that different feedstocks are used in the production of pellets, including but not limited to saw mill residues, thinnings, harvest residues, diseased wood and low quality roundwood. This means that we can assume that not all of this 16 million tonne demand will be translated to a demand on the forest. Section 5.1 will investigate the proportion of this total assumed demand which is likely to be sourced directly from the forest.

4.3.4 Pellet Plant Locations

There is a clear concentration of pellet plants in this region as shown in figure 4.8. The green pins show the exporting pellet plants listed in table 9 and the red pins show the major ports in the same region.

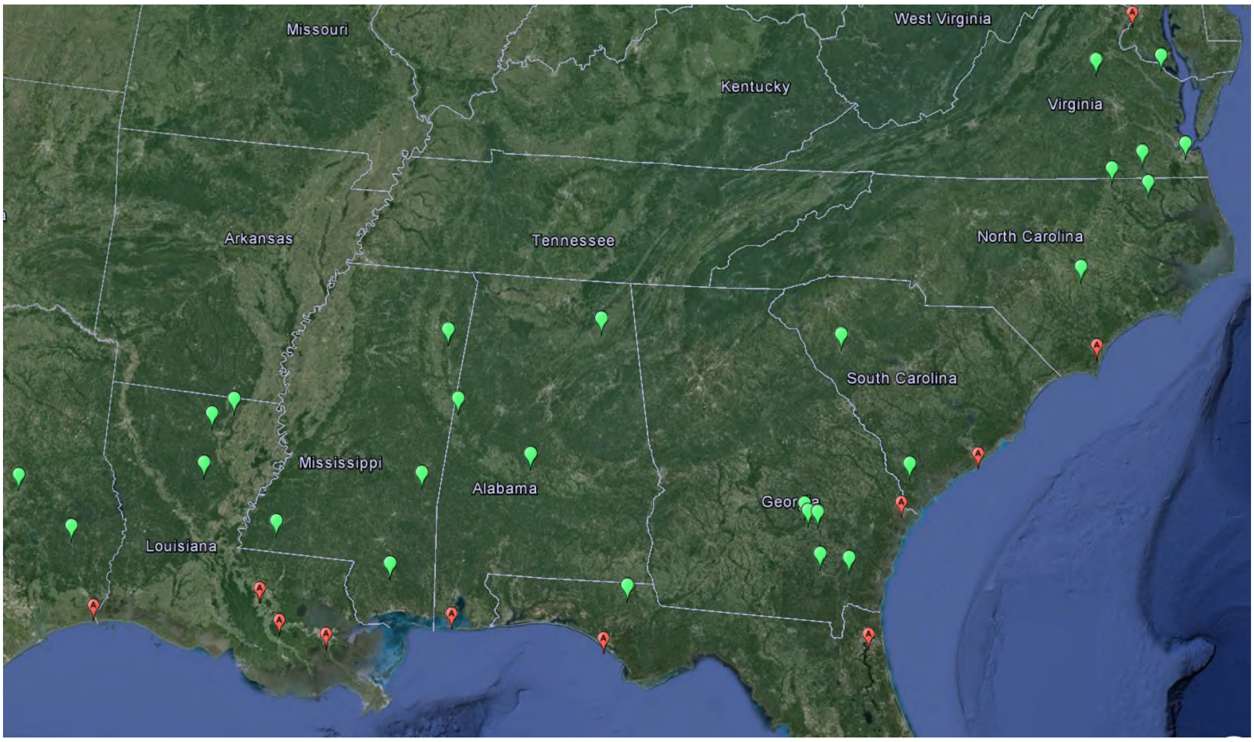

Figure 4-8: map of pellet plant locations

Figure 4.8 original image created from data in table 9

Figure 4.8 suggests that pellet plants are clustered around export port facilities. Proximity to a port would not only reduce freight costs for the pellet producer, but will also reduce the life cycle assessed GHG figure inherent in the biomass. However, clearly this is dependent on the mode of transport used and the availability of reliable transport infrastructure, such as connected roads or rail infrastructure. Across Europe, controls are in place to ensure that biomass used to meet renewable energy targets offers significant GHG savings compared to fossil fuels, so minimising emissions from transport is important.

4.3.5 Summary

Figure 4.5 shows the US to be the largest global producer of wood pellets globally, with much of this production capacity based in the US South. 8 million tonnes of industrial export wood pellet capacity is currently built or under construction in the US South, where there is also a concentration of other wood industries. The US South is the most productive region of the US (NAFO, 2013), regularly providing more than the rest of the United States combined (USDA, 2011).

It is beneficial for pellet plants to be located geographically close to higher value wood industries, such as sawmills, where there is a higher abundance of low value wood fibre for use in the pellet plant. As much of the wood pellet industry in the US South is produced for export, many pellet plants are located close to a port, which improves the efficiency of the supply chains.

5. Analysis – Impact on Forestry in the US South East

It is clear that production of wood pellets in the US South has increased significantly over the last decade, with 29 pellets mills currently operating or under construction. Although this additional demand is a relatively small fraction of the total harvested wood products, it is important to assess any changes which may have occurred in the forests of the US South in response to this demand. In 2013, the total harvesting of wood products in the UK was 11.8 million tonnes (Forestry Commission, 2014). When comparing this value to the 227 million tonnes of wood harvested annually in the US South, the UK's requirement for imported pellets becomes clear.

5.1 Regional harvesting trends in the US South East

The following data uses information provided by a report on wood supply trends in the US South written by Forest 2 Market.

5.1.1 Fibre sourcing for wood pellets

Figure 5.1 shows the assumed demand for wood fibre calculated in table 10 as a trend line and shows the actual harvesting for wood pellets reported by Forest 2 Market as a stacked bar chart.

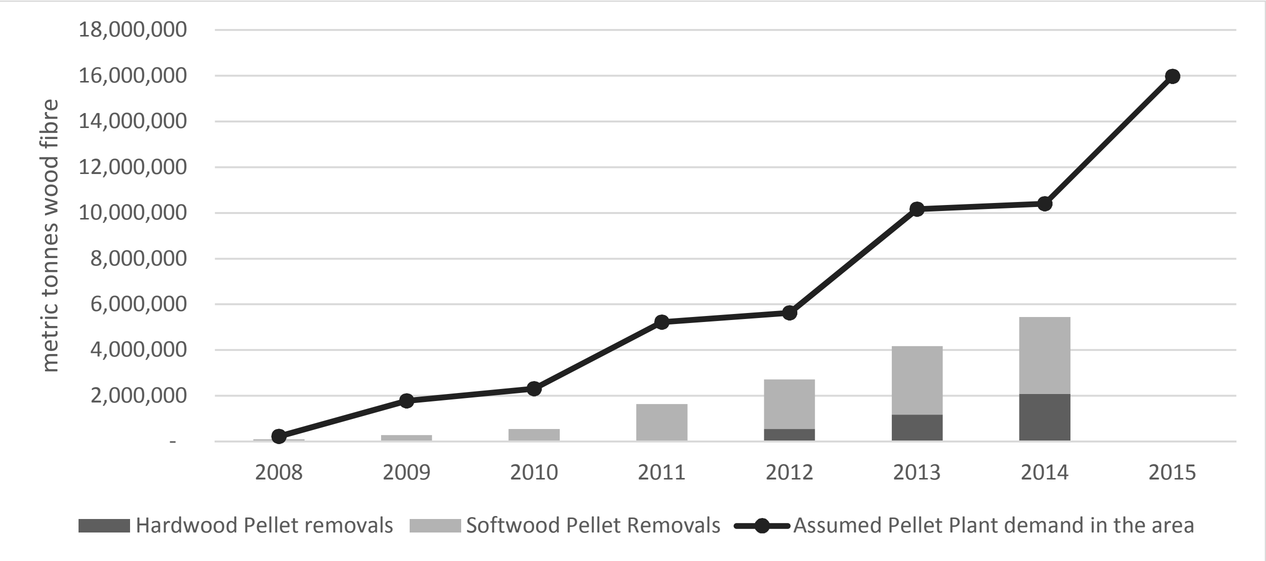

Figure 5-1: Total removals for pellets compared to assumed wood fibre demand in the South East US

Figure 5.1 Adapted from (Forest 2 Market, 2015) combined with industry knowledge

Figure 5.1 shows that the actual volume of material harvested for pellets is significantly lower than the assumed wood fibre demand. This could suggest three things:

1. The conversion rate of raw material to pellets is better than the 0.5 which has been assumed
2. Material is hauled from outside the 9 states covered in this set of data
3. Raw material is used in pellets which is not harvested directly from the forest, such as saw mill residuals

Suggestion 3 would seem to be the most likely explanation for this difference, as many pellet plants report the use of mill residues. This data would suggest that around 40% of pellet plant demand is met through secondary residues. The literature review showed that pellet plants use many different raw materials to make pellets, including saw mill residues, pre-commercial thinnings, the unused parts of merchantable trees left after a harvest and undersized, dead or poor quality trees. Figure 5.1 shows a direct correlation between the construction of pellet plants in this area and this introduced demand and harvesting for pellets, however, the total harvest volume is only 5.4 million tonnes, compared to total harvesting in the region of over 227 million tonnes. Figure 5.2 shows the trends in total removals in this region from the year 2000 to consider if this additional demand has had any impact on total harvesting trends or the harvesting of different wood products.

5.1.2 Trends in harvesting different wood products

In order to quantify the impact that the additional fibre demand for wood pellets is having on the forest, it is important to consider this demand in the context of the total harvesting in the region. Figure 4.6 highlighted that removals of saw timber declined by 42% between 2005 and 2009 (FAOSTAT, 2016), a trend which can also been seen at the narrower level of the South-eastern states specifically, in figure 5.2.

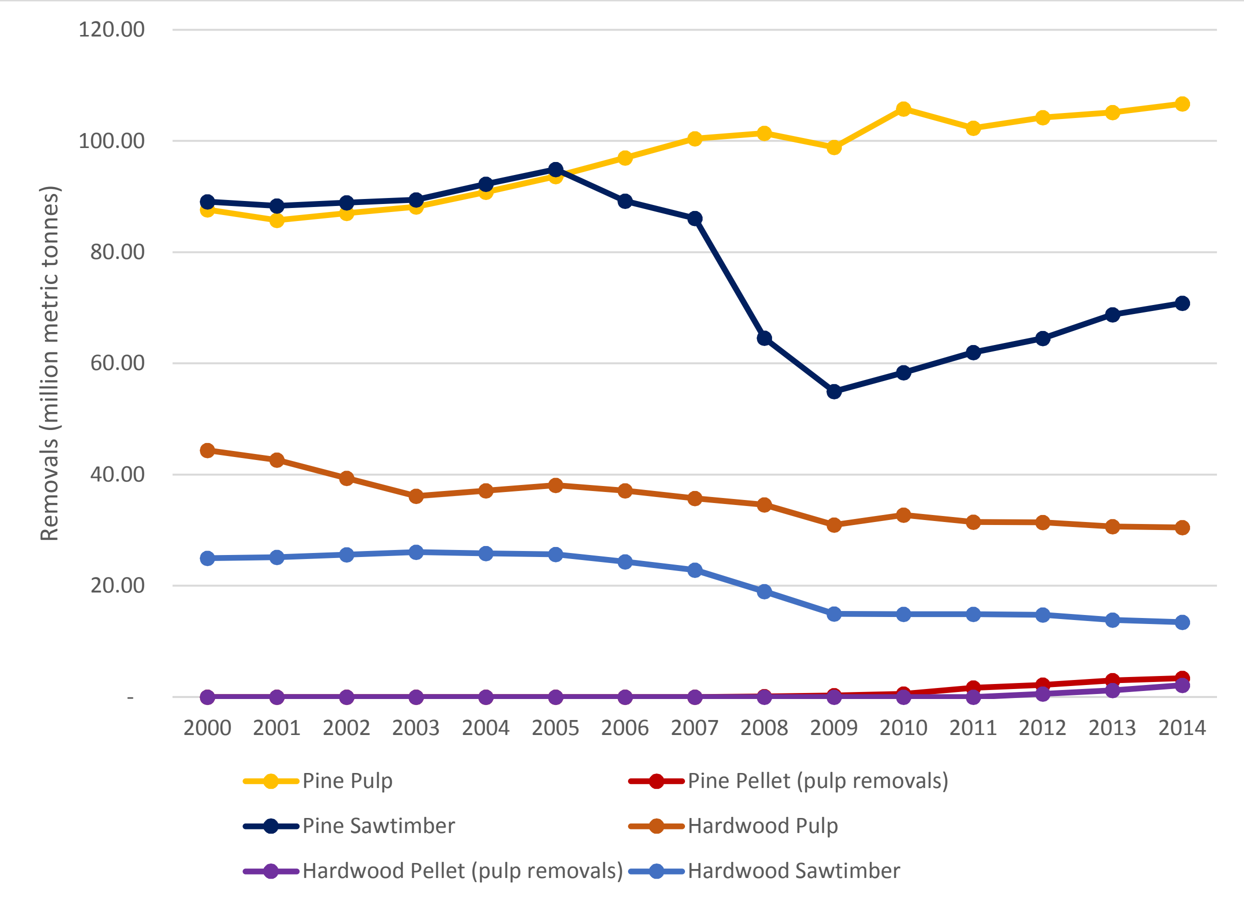

Figure 5-2: annual removals of pine and hardwood species in the US South for different wood products

Figure 5.2 adapted from (Forest 2 Market, 2015)

FIA data (FIA, 2015a) and figure 5.2 show that the vast majority of harvesting in this region is of pine species, corresponding to the predominance of pine plantations. However, figure 5.2 shows that hardwood harvests for pellets in 2014 was only slightly lower than softwood harvests (3.3 million tonnes of pine pellet removals compared to 2 million hardwood pellet removals) which suggests that a larger proportion of all hardwood harvested material is used in pellets compared to in other wood products. For some hardwood stands, such as bottomland hardwoods, silvicultural best practice recommends clear-cutting for the successful regeneration of bottomland oak species (Meadows and Stanturf, 1997). This recommendation would mean that for these types of forest, when saw log harvesting takes place, there will be a significant volume of low grade material harvested as a by-product, which could explain why there is proportionately more harvesting of pellet grade material for hardwood than softwood. However, figure 5.2 shows that the use of hardwoods in pellet production developed later that the use of softwoods and is still less utilised than softwoods in pellets and figure 4.8 shows that the majority of pellet plants in the US South are located in predominantly softwood areas.

The same trend can be seen in sawtimber for both pine and hardwoods, with a very clear decline in harvesting between 2005 and 2008. However, pine sawtimber appears to be recovering at a faster rate than hardwood sawtimber, which appears to be relatively stable but experiencing minor decreases in harvesting in 2013 and 2014. When hardwood and softwood are grouped together, the significant decline in sawtimber harvesting is stark, dropping from a high of 120.56 million tonnes in 2005, to a low of 69.94 million tonnes in 2009. Figure 5.2 shows that in this region, more pulpwood harvesting takes place than saw timber harvesting, which is supported by a report by FAO in 2012, which showed that 50% of all American saw timber is harvested from the southern states, however 75% of all American pulpwood comes from these states. This is contrary to the data shown in figure 4.6, which shows the production of sawtimber is higher than production of other products. There are two significant differences between these datasets; FAO data used in figure 4.6 shows production for the entire United States and shows production, rather than harvesting and therefore captures further processing and any conversion factors involved in the production of different products.

With a total harvest in this region of 227 million metric tonnes, it is difficult to assess trends arising from an additional 5.4 million of harvesting for wood pellets. Figure 5.2 shows that harvesting for pellet material was just 2.4% of the total harvesting in the US South, with harvesting for pulp and sawtimber making up 60.5% and 37% of total harvest respectively.

5.1.3 Georgia – harvesting trends

To get a more specific comparison of harvesting patterns on the ground, Georgia (as the state with the highest concentration of pellet plants) is used to assess the observed impact on the ground. Table 11 shows the pellet plants which are currently operational in Georgia, with a combined capacity for producing pellets of almost 1.5 million tonnes.

Table 11: Operational pellet plants in Georgia

Plant	Operational	Capacity	Materials used	Reference
Fram - Appling	2007 (130k t) 2012 (230k t)	230,000 tonnes	80% mill residuals,20% forest residuals	http://www.framfuels.com/mills.cms
Georgia Biomass	2011	750,000 tonnes	Majority thinnings	http://www.gabiomass.com/

Fram Telfair	2012	125,000 tonnes	80% mill residuals,20% forest residuals	http://www.framfuels.com/mills.cms
Fram Hazlehurst	2013	240,000 tonnes	80% mill residuals,20% forest residuals	http://www.framfuels.com/mills.cms
E-pellets	2013	150,000 tonnes	Majority mill residuals	http://www.epelletsgroup.com/en/

Table 11 from industry knowledge, google maps and company websites (ref above)

Data is not available earlier than 2010 for Georgia in evalidator (Inventory data for US forests), so longer term analysis of trends is not possible. However, the majority of the demand from pellet plants in this region began in 2011, so it is possible to consider changes in harvesting between 2010 and 2014 since the introduction of a new demand from the pellet industry. Comparing the demand of tonnes of pellets against the cubic feet of harvested material is a difficult comparison, as to convert from cubic feet to tonnes requires the species of the wood to be taken into account, as each species has a different density. The fraction of the wood used in pellets also plays a role, as the density of the wood changes between the bottom of the tree, the main stem and the top, which makes conversion difficult and fraught with assumptions. Therefore figure 5.3 shows data in 1000 cubic feet, to avoid the risk of error in conversion.

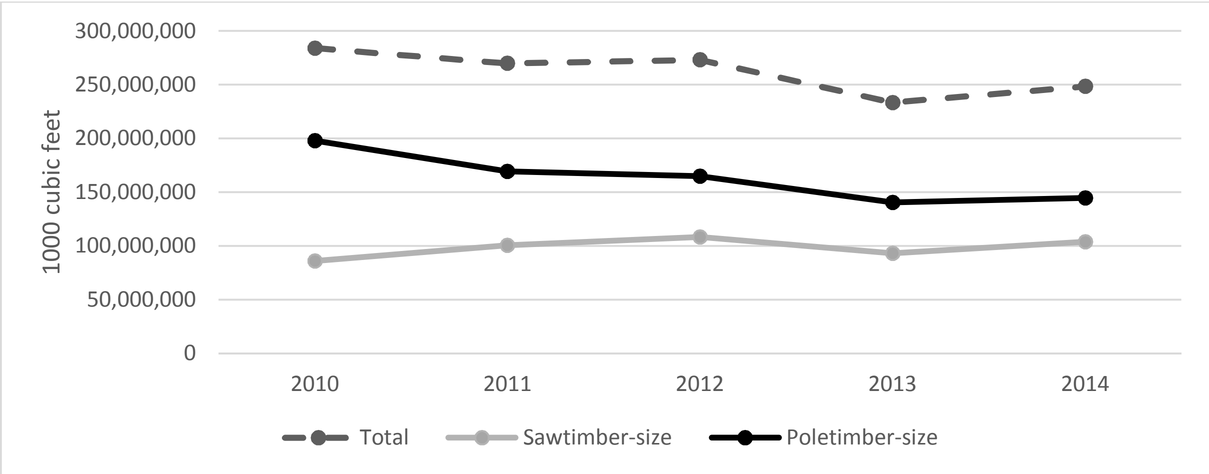

Figure 5-3: Harvesting trends in Georgia

Figure 5.3 from (FIA, 2015a).

Under FIA (FIA, 2015b), 'sawtimber' size is defined as a "live tree of commercial species containing at least a 12 foot saw log, or two noncontiguous saw logs 8 feet or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9.0 inches d.b.h. Hardwoods must be at least 11.0 inches d.b.h." Poletimber is defined as "Live trees at least 5.0 inches in d.b.h. but smaller than sawtimber trees". The FIA removals data for Georgia suggests that there has been a convergence in harvesting types (saw timber and pole timber) between 2010 and 2014 and shows that there has consistently been more removals of poletimber size material in Georgia than saw timber size. Figure 5.3 suggests that the harvesting of sawtimber size material has stayed relatively stable, but harvesting of poletimber size material appears to have declined slightly over this 4 year period, even as the market for wood pellets has been introduced.

Over this four year period, there has been a decrease in harvesting of material which could be used in pellets, which suggests that the introduced demand from pellet plants is not driving increased harvesting. As discussed previously, the demand for wood fibre for wood pellets is a small component of total harvesting in the US South, so it is important to compare trends in harvesting against other market forces in the region. Figure 5.4 charts the number of different wood processing plants in Georgia (trend lines) against the reported volumes of different wood products in the same time frame.

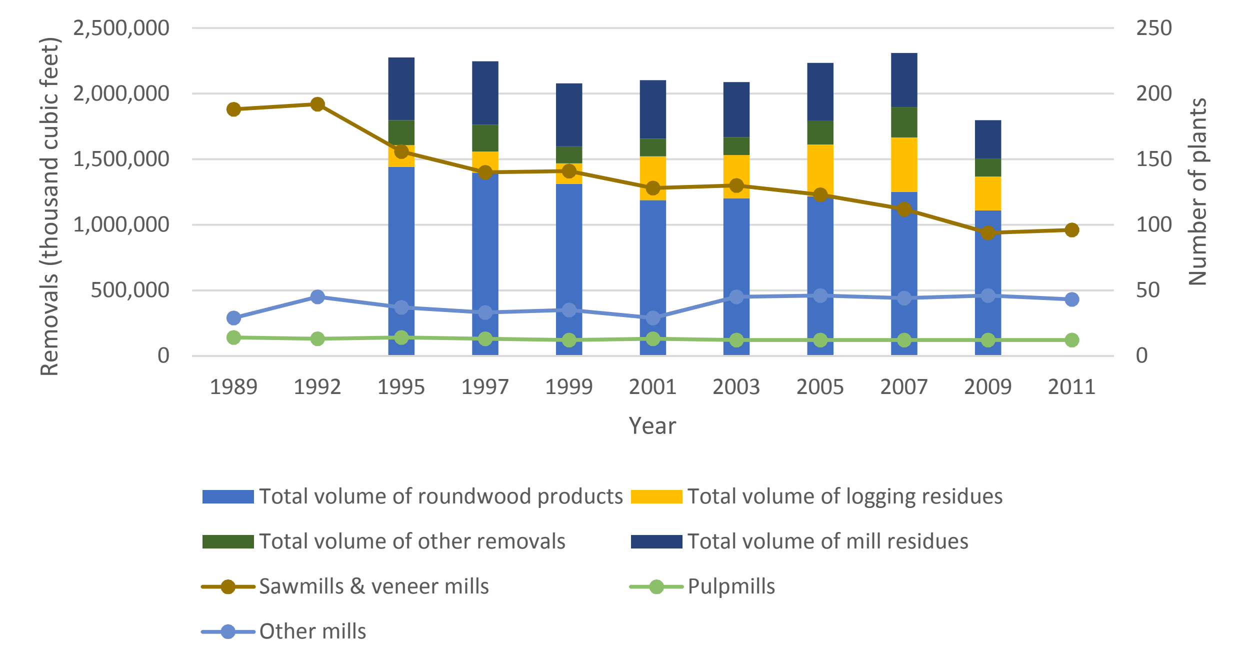

Figure 5-4 Removals in Georgia compared to the number of different mills

Graph adapted from (FIA, 2015b)

Figure 5.4 uses Timber Products Output data from FIA, which is not available after 2009 and therefore cannot be compared against the total harvesting in Georgia shown in figure 5.3. Figure 5.4 shows the number of sawmills and veneer mills has clearly decreased, in line with the findings on a regional basis and the impact of the economic crisis. This decrease in sawmills has happened alongside a decrease in roundwood production and a corresponding decrease in production of mill residues. Interestingly, although total roundwood removals has decreased, the volume of logging residues collected has increased. Logging residues are defined in this context as portions of trees left on the ground after harvesting roundwood products, or trees damaged as part of harvesting operations. If there is less value in sawlogs, then it could be possible that forest owners are selling more logging residues to improve the revenue from the forest, instead of leaving this material in the forest.

5.1.3 Age classes

Figure 5.2 shows a general decreasing trend of sawlog grade material and a slight increase in the harvesting of pulpwood grade logs. Therefore, it is hypothesised that the decrease in sawtimber harvesting in the US South is due to forest owners choosing to delay harvesting during the period of lower sawtimber prices. If this is the case, a shift in the age class distribution of forests would be observed. Using FIA data (FIA, 2015b), it is possible to report on the age classes of forests in the US South, however data is not available for every state for a long enough period of time to sufficiently understand trends. Figures

5.4 and 5.5 attempt to show the age profile of forests in the Southern US between 2010 and 2014, however, trends cannot be accurately identified over such a short time period. Ideally, this data needs to be assessed from 2000 to the present day, to identify if there has been a shift in age class distribution as a result of decreased sawtimber prices since 2005.

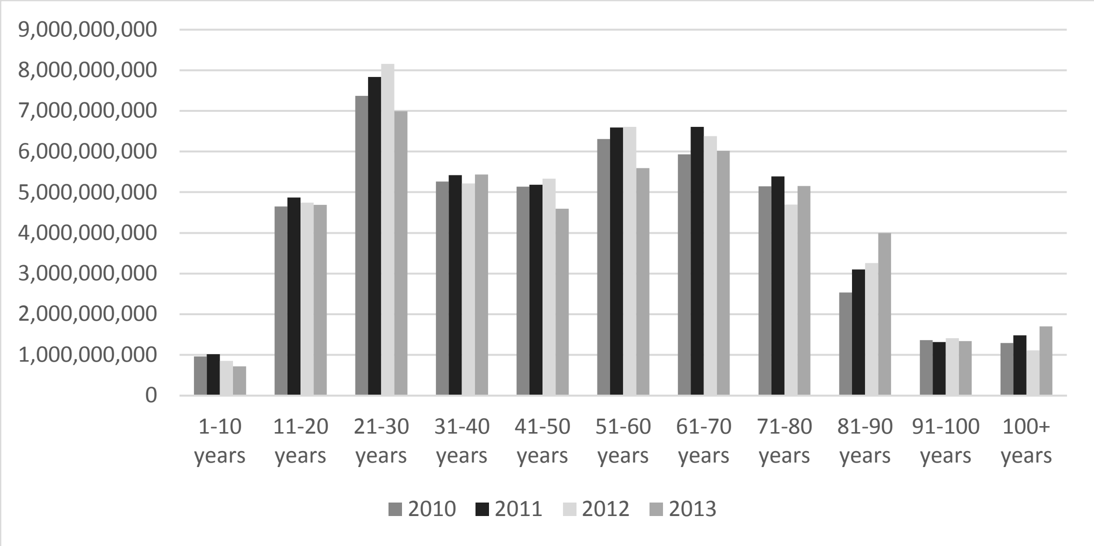

Figure 5-5: Trends in forest stand age class distribution across the US South East between 2010 and 2013 Figure 5.5 from (FIA, 2015b).

Figure 5.5 attempts to chart the age class distribution in forests of the South East US, however, data was only available for every state for the years 2010 to 2014, which is not enough of a time frame to be able to assess trends in a meaningful way.

5.1.4 Summary

The economic recession between 2005 and 2009 decreased demand for sawtimber, therefore decreasing the value and consequently harvesting, which caused harvesting of sawtimber to reduce by 42%. This shows that the value of harvested products has an important role to play in changing in forest dynamics. Currently, demand for harvested material for wood pellets is low in comparison to total harvesting in the US South (2.4%) and does not appear to be significant enough a volume to change forest practices. 5.4 million tonnes of wood was harvesting for pellets across the US South in 2014, 62% of which was softwood.

Around 40% of the fibre demand for wood pellets is met outside of forest harvesting, perhaps through the use processing residues from other industries or harvesting residues. Georgia is the state with the highest concentration of wood pellet plants, but is also the state with the greatest total harvesting, highlight the dependency of the wood pellet industry on other, higher value industries. Alongside the rise of the wood pellet industry in Georgia, total harvesting has actually decreased, suggesting that the introduced demand is not creating an increased demand on the forest. Figure 5.4 highlights the relationship between sawmilling activity and the availability of mill residues, as it is clear that as the number of sawmills in Georgia decreased, so did the amount of mill residuals available.

5.2 Wood prices and markets

The literature (Aguilar et al., 2014; Joshi et al., 2013; Junginger, 2014;) suggests that the bioenergy industry is unlikely to drive changes to final harvesting due to the lower capacity to pay compared to other markets. This section of analysis focusses on comparing the relative values of material used in wood pellets against other wood products.

5.2.1 Price of different wood fractions

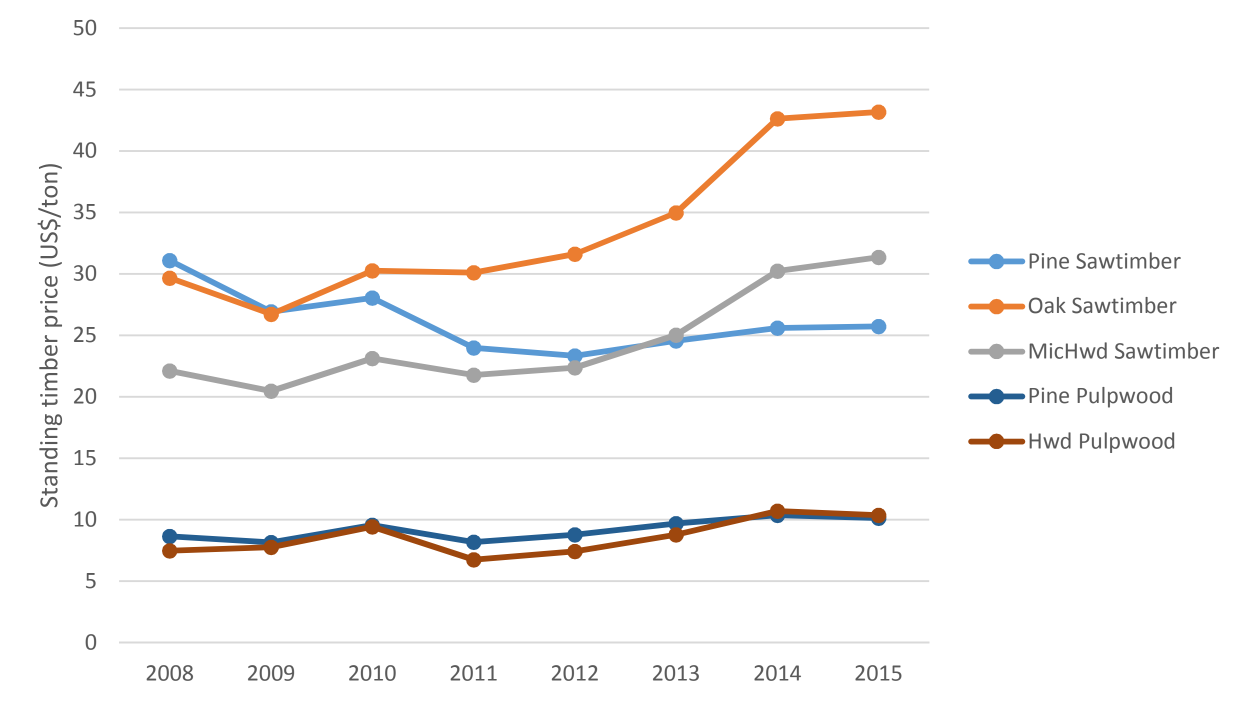

Figure 5-6 : Average standing timber price of different wood products across the US South

Figure 5.6 reference: (Timber Mart-South)

In 2008, oak sawtimber was of similar value to pine sawtimber, with mixed hardwood sawtimber of lower value. During the recovery from the economic recession, oak and mixed hardwood sawtimber have both increased in value above pine sawtimber. This increase in value of hardwood sawtimber is at odds to figure 5.2, which showed that hardwood sawtimber harvesting is recovering at a slower rate than pine sawtimber, which suggests that although the value has increased, this is not driving increased harvesting.

Although one suggestion could be that an increased value drives harvesting (which does not appear to be the case here), it could also be the case that a limitation on harvesting drives an increase in value. If harvesting is relatively low and there is not a significant supply of hardwood sawtimber in the market, the rules of supply and demand would increase the value of this type of material. Pulpwood prices of both hardwood and softwood are consistently below $10/tonne (around a third of the value of sawtimber), which explains the desire of many forest owners to increase the proportion of saw timber grade material in their stand to maximise economic return from their forest, as described in the literature review.

Figure 5.6 is adapted from data from Timber Mart South, a private foundation operating out of the Forestry School in the University of Georgia. The data collated and reported under Timber Mart South is an aggregate of multiple sources and reports average lows and average highs of prices (Timber Mart-South). Figure 5.7 shows similar data to figure 5.6, comparing hardwood and softwood pricing trends for both sawtimber and pulpwood, but is from a different data source – Forest 2 Market, where average harvesting and price data was made available to the public through their US South Wood Trends report (Forest 2 Market, 2015). Forest 2 Market data is collected at the transaction level, and is reported by both the buyer and the seller. The reported data is very similar between the two, which increases confidence in the data. Figure 5.7 shows that the average prices for sawtimber in the US South East were lower for hardwoods (non-coniferous), until 2009 when this trend reversed, which supports the data shown through Timber Mart South.

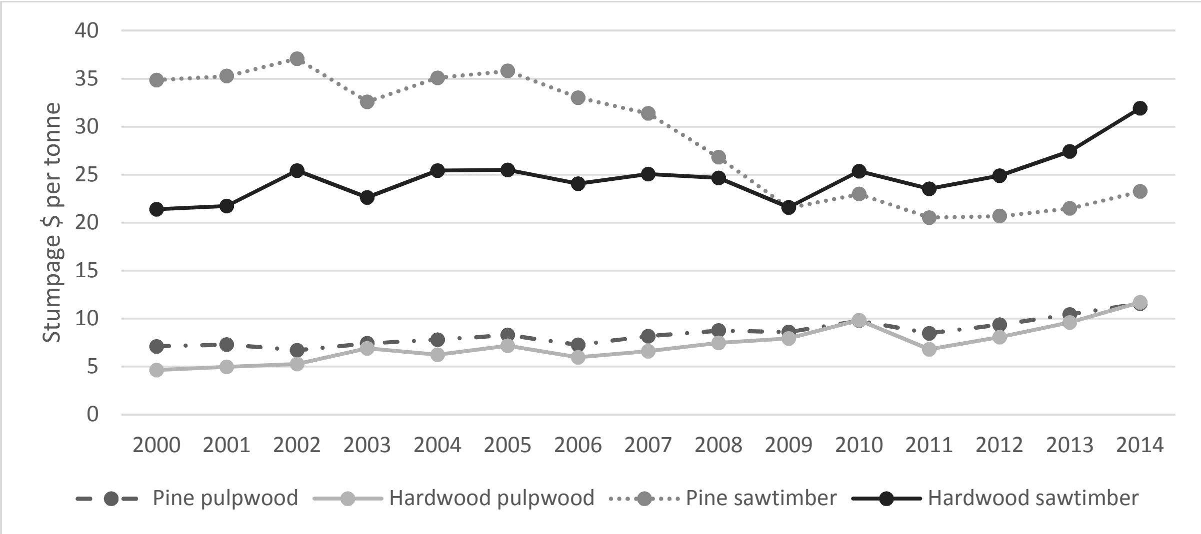

Figure 5-7: Graph showing the difference in stumpage price between saw timber and pulpwood

Figure 5.7 reference: (Forest 2 Market, 2015)

Sawtimber prices would appear to be more prone to fluctuations than pulpwood prices. Pine sawtimber had a significantly higher value compared to hardwood sawtimber in the early 2000s, but these prices appeared to converge between 2003 and 2009. In 2009 saw timber prices hit a low and the more rapid recovery of the hardwood sawtimber prices has resulted in hardwood sawtimber prices now overtaking pine sawtimber prices. Figure 5.8 shows more detailed trends in pulpwood prices over a longer time period and shows that although pricing of pulpwood in figure 5.7 seems relatively stable, there have actually been a number of changes in pricing historically, the most interesting being that hardwood pulpwood has moved from seemingly having almost no value in the 80s, to now being of equal value to softwood pulpwood.

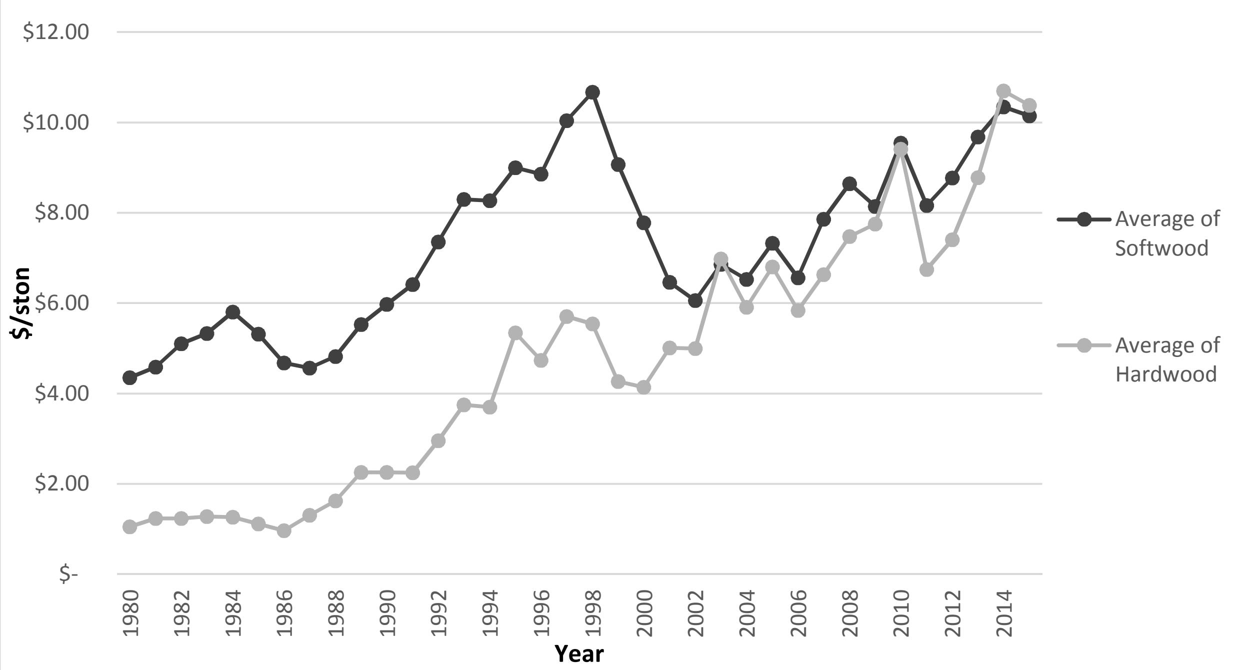

Figure 5-8: Average standing pulpwood price in the US South

Reference 5.8: (Timber Mart-South)

Figure 5.8 supports the data presented in Forest 2 Market's public summary analysis of wood market trends in the US South. In the 1990's, the Orientated Strand Board demand was introduced to the United States and presented a new market for pulpwood, which coincides with a significant increase in prices during the 90's. An increase in competition can increase prices, which can clearly be seen here, as the demand for OSB competes with traditional demand for pulp and paper. Conversely, many of the markets using pulpwood are also able to use clean processing chips from sawmills, so an increased availability of residue materials from sawmills could displace the use of pulpwood and decrease prices. In this context, it makes sense that pulpwood prices are increasing since 2005, as with a reduction in sawmilling, there are less residues available and therefore more demand for pulpwood.

5.2.2 Pulpwood price compared to total removals

Figure 5.9 charts the changes in price of pulpwood alongside the increased harvesting of low value material and suggests a correlation between the introduction of the new market for fibre for wood pellets and the increasing price between 2011 and 2014.

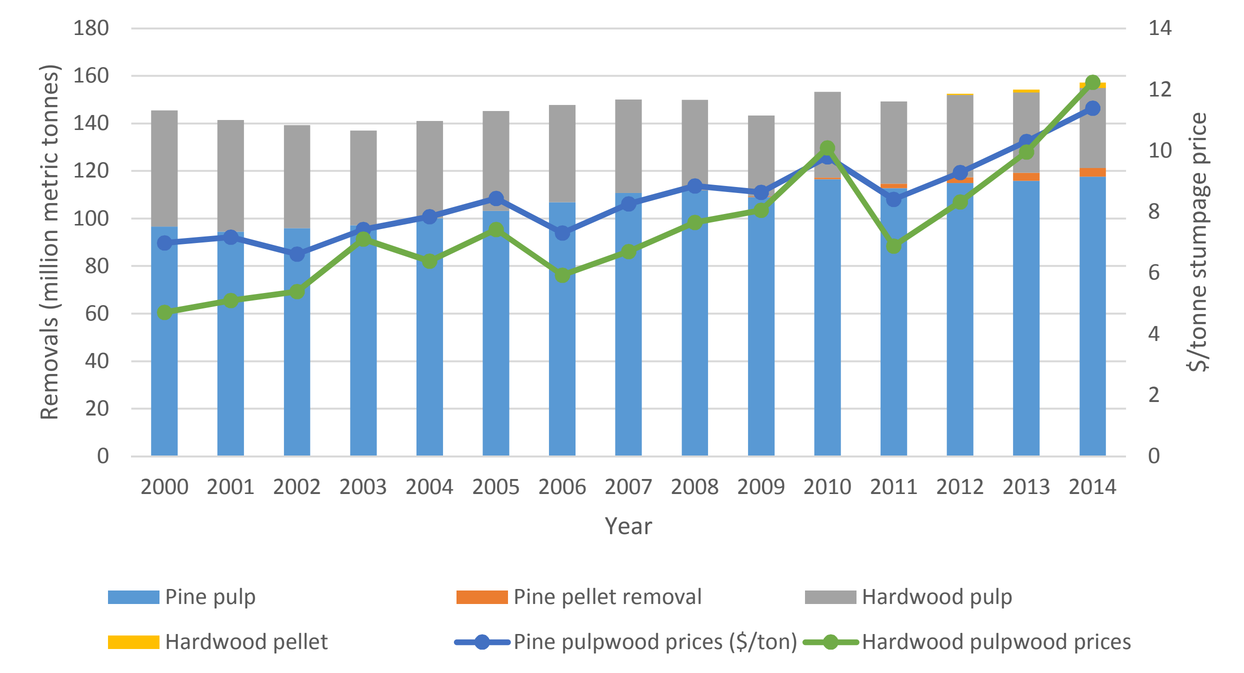

Figure 5-9: Pulpwood price trends compared to removals in the Atlantic region

Figure 5.9 derived from (Forest 2 Market, 2015).

Figure 5.9 shows that pine pulpwood prices have certainly increased since the introduced demand for pellet fibre in 2011, however it can also be seen that pine pulpwood prices were already increasing between 2006 and 2010, corresponding with a slight increase in pulpwood harvesting not used in pellets. Hardwood pulpwood prices also slightly increased between 2006 and 2010, even though harvesting of hardwood pulpwood slightly declined in this time. Prices of pulpwood have increased significantly since the rise of the wood pellet market in 2011. Pine pulpwood prices have increased by 63%, from $8.40/tonne to $11.38/tonne and hardwood pulpwood increasing even more significantly, by 160% from $6.87/tonne in 2011 to $12.23/tonne in 2014. Alongside these significant increases in price, there has been relatively modest increases in removals, with pine pulpwood removals increasing only by 6% and hardwood pulpwood increasing by only 3%. This suggests that increasing prices of pulpwood is unlikely to drive harvesting.

The increase in pulp price shown in figure 5.7 correlates very well to the introduction of the demand for wood pellets, so suggests causality. However, figure 5.8 shows the average stumpage price of pulpwood going further back to 1980 and shows significant fluctuations in prices, with significant increase in prices between 1986 and 1998 and a dramatic decrease between 1998 and 2000. It is likely that the introduction of new markets and demand into a region will have an impact on wood prices, however, market dynamics are complex, so causality cannot be proved. An example of this complexity is the sharp increase in prices of pulpwood in 2010, before the wood pellet market increased significantly, which then dropped again the following year, as wood pellet demand then began.

5.2.3 Summary

Section 5.1 suggested that markets for wood products have a significant influence over forest dynamics, as evidenced through the reduction in value of sawtimber resulting in a decline in sawtimber harvesting. Sawtimber prices appear to be more prone to fluctuations than pulpwood prices. The literature review highlighted that many productive forests have a management objective of producing sawlogs, which makes sense as this section shows that sawtimber is usually the most valuable products in the forest stand. It is therefore logical that harvesting decisions will be linked more closely to sawtimber prices and harvesting of sawtimber will be more sensitive to changes in price.

Pulpwood prices are far lower than sawtimber prices, but have gone through significant periods of change. Hardwood pulpwood specifically, has increased from a value of around $1/ton in 1980, to a value equal to pine pulpwood of around $10/ton in 2014. Since the rapid growth of the pellet industry in 2011, pine pulpwood and hardwood pulpwood prices have increased by 63% and 160% respectively. Pulpwood harvesting appears to be far less sensitive to fluctuations in value, as during the same period, softwood harvesting increased by only 6% and hardwood pulpwood harvesting increased by only 3%.

6. Discussion: Emerging Trends and Themes

6.1 EU Bioenergy Demand

Sections 4.1 and 4.2 of this study present the available data on the use of biomass for energy across Europe and analyse these findings to assess the scale of EU woody biomass demand. This section brings together the findings from sections 4.1 and 4.2 and discusses the wider themes and implications of these findings.

6.1.1 The importance of Bioenergy to EU renewable energy targets

Section 4.1.1 shows that in 2013, 46.2% of total European renewable energy generation was from wood, making bioenergy the largest single contributor to renewable energy across Europe. Energy generation from wood is increasing across Europe and is expected to continue as emission reductions targets become more challenging, as shown in figure 4.3. Objective 1 of this study aims to understand the role of bioenergy in meeting European decarbonisation targets and the data presented in section 4.1.1 shows that bioenergy, specifically energy from wood, has an important role to play. Bioenergy is not only important because of its contribution to energy generation, but also because of the flexibility of biomass as a resource for different methods of energy generation. Section 4.2 found that global production of wood pellets in 2014 was 23.5 million tonnes, a figure which is broadly consistent with findings in other studies (Goetzl, 2015).

6.1.2 Potential for an increased demand for woody biomass for energy

In the 10 years prior to 2013, bioenergy use across Europe increased by nearly 50% and future expansion of bioenergy seems likely, as outlined in section 4.1. However, a constraint in biomass supply is anticipated as populations increase, leading to an increased demand for food. Increased need for agricultural land for food production is expected to create a tension with land used for bioenergy as applications of bioenergy become more widespread (Lewandowski, 2015). In addition to the expansion of current applications of bioenergy, it is likely that as the world moves to reduce dependence on fossil fuels, there will be an increased focus on a 'bio economy', where fossil fuel based products are replaced with bio-based alternatives. This new demand is likely to add increased pressure on the biomass resource and create more competition for material currently used in bioenergy (Lewandowski, 2015).

In addition to tensions between different demands for harvested wood products, there is also a wider global requirement to increase the carbon sink on land, which means that afforestation, improving productivity and reducing the conversion of forest land to agricultural land must all be considered (IPCC., 2014). If the carbon sink can be increased (through afforestation or improved productivity) and forest biomass can be mobilised at the same time through the use of harvesting residues, processing residues or biomass derived from management techniques, woody biomass has the potential to have dual climate benefits through increasing the carbon sink on land while also creating bioenergy which can displace the use of fossil fuels.

In order to meet 2020 renewable energy targets, as outlined in section 4.2.2, following recent trends, we could expect the EU's consumption of wood pellets to increase from 20 million tonnes in 2014 to 26.8

million tonnes in 2020. It may be possible that as European countries continually increase their use of renewable energy, including through electricity generation from wind and solar, further use of biomass for electricity generation may be necessary. Solar, wind, tidal and wave energy are all less flexible methods of electricity generation, meaning that baseload renewable technologies will be required to back up electricity generation from these intermittent technologies (POSTnote., 2014). Mitigating the issues associated with inflexibility in electricity generation is important to ensure electricity can respond to demand (DECC, 2012). Mitigation of intermittent technologies could be through implementation of electricity storage facilities, better management of demand or through balancing intermittent generation with baseload electricity generation (Kyriakopoulos and Arabatzis, 2015). Using biomass electricity generation would be a preferable balancing mechanism to the use of carbon intensive gas or diesel generation to meet electricity demand in peak times, as keeping a reserve of fossil fuel generation is likely to increase the emissions related to electricity generated (POSTnote., 2014). Under this scenario, the use of bioenergy would increase above current expected levels.

6.1.3 Potential future demand: the UK case

Across Europe, bioenergy is dominant in heating, but in the UK biomass is dominant in electricity generation. The reason for this difference could be due to either: the UK's focus on the decarbonisation of the electricity industry due to the previous reliance on coal generation, or the possible cost-efficiencies of converting coal power stations to bioenergy through existing infrastructure. However, although the UK generated 20% of its renewable electricity from plant biomass in 2014, the UK government have outlined that biomass for electricity is considered a transitional technology only (DECC, 2013b). The UK energy minister announced recently that the UK aims for all coal fired power stations in the UK to close between 2023 and 2025, so conversion to biomass could be an option to replace this electricity capacity without building new infrastructure and connections to the grid (DECC, 2015). It is important to note that current support for biomass use in electricity generation is planned to end in 2027 as support for biomass under the Renewables Obligation ends. This limited time horizon constrains the potential for conversion, as there will be a reduced ability to recover the investment required for conversion in the planned timeframes.

Similarly, increased uptake of biomass for heating in the UK also seems unlikely, even though the UK is currently behind its target for both heat and transport. A consultation published by DECC on 3 March 2016 suggested a reduction in subsidies for the use of biomass in the heating sector and increased investment into heat pumps as a source of renewable heating, although the outcome is currently awaited, the support for biomass used for heating may be reduced (DECC, 2016). Significant increased demand for bioenergy in the UK seems limited at the moment for both electricity generation and heating, however if the trends identified in figure 4.3 continue, demand for bioenergy will increase further across Europe.

6.1.4 Wood chips and wood pellets

Figures 4.1 and 4.5 show that although the UK uses less wood for energy than the European average, the UK is actually the largest importer of wood pellets, suggesting it is an outlier in the use of pellets to harness the energy potential of wood. The UK generates 32.9% of its total renewable energy from wood, compared to an average of 46% across the rest of Europe. Section 4.2.1 identified that other European countries are using wood chip for energy generation, rather than wood pellets. Section 4.2.1 also identified that the UK is mainly depended on imported wood pellets for energy, rather than domestic supply. The literature review showed that wood pellets have improved handling properties and are denser than wood chips, leading to more efficient and economic transportation. These properties of pellets suggest that transportation and the need to import is why the UK relies on wood pellets rather than wood chip.

The UK also differs from other European countries because of the focus on wood energy in electricity generation, where the rest of Europe mainly uses wood energy for heating. The UK still has a significant challenge to meet the 2020 renewable energy target of 15%, with only 7% of total energy generated from renewable sources in 2015. As the UK has previously been heavily reliant on coal for energy generation, retrofitting the multiple coal power stations across the UK to burn biomass is a rapid way of reducing greenhouse gas emissions. It seems likely that this is the driver behind the UK being the largest importer of wood pellets, evidenced by the two major users of wood pellets in the financial year 2014/15, Drax Power Station and Ironbridge Power Station, which both moved from coal combustion to wood pellets.

6.2 Biomass resources and trade

The second objective of this study is to identify major trade in wood pellets and section 4.2.1 shows that the wood pellet industry has grown significantly in the last decade, with global wood pellet production increasing its 2009 levels by 2.5 times in 2014. If current levels of growth continue, European consumption of wood pellets could reach almost 27 million tonnes in 2020, up from a consumption of 20.5 million tonnes in 2014.

6.2.1 Reliance on bioenergy and resource availability

Section 4.1.2 explores the fact that different countries across Europe have varying levels of reliance on wood energy in total renewable energy generation. Figure 4.4 shows that there is a strong correlation between the average proportion of forest cover in the EU 28 and total reliance on bioenergy, suggesting there could be a place for intra-EU trade to facilitate uptake of biomass use in energy. This intra-EU trade is already beginning to take place, with significant volumes of biomass moving from the Baltic States to the UK and to Denmark.

In figure 4.4, it is clear that Denmark and the UK are both countries which have relatively low levels of forest cover and significant improvement required to meet their 2020 renewable energy targets, which could explain the reason behind the requirement for importing wood pellets. This finding is valuable as it highlights the necessity of imports to countries with lower resource availability and suggests the potential for symbiotic trade across Europe, where countries with high availability of biomass currently unutilised could find a revenue stream for that material from countries with lower levels of forest cover.

6.2.2 Potential for further intra-EU trade of wood energy

Section 4.2.1 shows that extra-EU production of wood pellets currently makes up 50% of the global wood pellet trade and that the US is an important import source of wood pellets for Europe, providing 20% of the total European demand in 2014. Intra-EU trading of wood pellets is also occurring, alongside wood chip trading between neighbouring countries. Trading of biomass would appear to be a sensible way of ensuring that biomass resources are used in a sustainable way, so areas with higher levels of available forest biomass can export this material to countries aiming to increase generation from bioenergy. Where natural resources are not abundant in a particular geographic area, importing from areas with an oversupply is a trend which has been seen historically, with the example of natural gas from Russia imported into Europe.

It is clear that certain European countries have a higher reliance on forest biomass than others, however there are certain outliers, such as Latvia and Estonia which have high levels of forest biomass use and yet are also exporters of wood pellets to other European countries. It does not appear that this increased availability of forest bioenergy is due to a more active forest industry with higher levels of total harvesting than other countries. Increased availability of forest biomass could be due to increased levels of forest management. The UK woodfuel strategy laid out that increased management of forests would mobilise higher levels of forest biomass, through the extraction of poor quality material to improve the value of the forest stand. This could explain the higher reliance on bioenergy in Latvia, Estonia and Lithuania, however an improved management would suggest a higher production of saw logs, but roundwood production in these areas does not appear to be comparatively higher than their European neighbours. In these examples, it would seem more likely that the increased reliance on bioenergy is due to established use of bioenergy, such as the widespread use of wood in district heating in Estonia.

An increased availability of forest biomass could also be due to negative impacts on forest health, such as forest fires or pest damage to the extent that the quality of the forest biomass is so poor it would not be possible to sell the wood into markets other than energy. One example of this is the mountain pine beetle epidemic in Canada, where the risk of damage was so high that the government increased the annual allowable cut in certain regions in order to harvest and process infected forests before the damage became too great (British Columbia, 2016). This increased sawmilling activity increased the availability of sawmill residues which could then be used in wood pellets for energy.

As increased mobilisation of forest biomass can be achieved through improved forest management, it could be suggested that sustainable sourcing of biomass through imports would be best focussed on regions with high forest density, but with little reliance on this forest biomass resource in some countries, such as Norway, where the vast majority of renewable energy is from hydro. More forest biomass could be mobilised across Europe to meet an increasing demand, but this must be controlled to sustainable levels. If an introduced demand for woody biomass manifested as an export potential in countries that are currently under-managing their forest resource, this could provide a financial incentive for improved management practices, if properly controlled. There are many other scientific studies which support this suggestion, but these findings usually focus on mobilising biomass for local use, rather than encouraging intra-EU trade for countries with a proportionately lower abundance on forest biomass (Díaz-Yáñez et al., 2013; Phillips et al., 2016; Verkerk et al., 2011).

It is hypothesised that if trade across Europe and mobilisation of forest bioenergy were incentivised, demand for bioenergy could be met solely through European production and the need for extra EU trade would reduce. This suggestion is supported by other studies which suggest Europe would be able to sustainably mobilise far greater levels of biomass compared to current levels (Díaz-Yáñez et al., 2013). However, it is important to consider the comparative benefits of more localised sourcing if this encourages more intensive management. In some regions, such as Canada, sawmill residues are burned where there is no market to sell this material. Avoiding burning this material and instead using it to displace fossil fuels could justify increased emissions from shipping and so localised sourcing may not always constitute the most sustainable source.

6.2.3 Implications of findings on demand and trade

If the use of wood for energy increases across Europe and is to be traded more readily, there may be a potential for wood which is currently used in the form of wood chip to be pre-processed into pellets for better handling and transport efficiencies, if longer transport distances are required. If wood chip is imported from other regions, converting this material into pellets would increase the density of the material, making shipping more efficient, requiring less fuel to transport and therefore improving the greenhouse gas saving of the biomass compared to fossil fuels.

One of the implications of subsidising energy generation from biomass is the creation and development of the global supply chains for biomass resources. An important element of the biomass sustainability is ensuring sourcing does not displace the production of other products, such as food or other commodities. In this context, forest bioenergy sourcing should be located in regions which have pre-established forest industries and therefore more readily available by-products which can then be used to meet forest bioenergy requirements.

Some European countries, such as Latvia and Estonia, have relatively high reliance on bioenergy in renewable energy, even in comparison to their high proportion of forest cover, but are also effective exporters of wood pellets. This increased mobilisation of forest bioenergy is achieved in both regions, while overall harvesting has remained within the permitted levels of the Annual Allowable Cut. This suggests that increased levels of forest biomass could also be mobilised sustainably from within other European forests, through more active management of the forest resource. If more forest biomass could sustainably be sourced from European forests, Europe could become more self-sufficient, negating the requirement for importing wood pellets. However, this suggestion could have wider implications than just forest biomass, as this suggestion could also be applied to other wood products which are currently imported into the EU.

6.3 Wood Pellet Supply – US South East

Section 4.2.1 shows that the US is a major exporter of wood pellets to Europe and is also a major hub of wood product trading globally. The US exports wood pellets predominantly to the UK, Denmark and the Netherlands, all areas with limited forest resource and challenging renewable energy targets. Wood processing industries in the United States are concentrated in the US South and the wood pellet industry follows the same trend. Analysis from figure 4.5 shows that the industrial pellet industry has grown rapidly in the US South, moving from the point of creation to 8 million tonnes of pellet capacity currently operating or under construction within the last 10 years.

6.3.1 Wood pellet plant locations

Table 9 shows there are 6.4 million tonnes of wood pellet capacity currently operating in Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas and Virginia. From figure 4.8 it can be seen that pellet plants are located within reasonable distance of port facilities for export. This proximity to export facilities minimises energy intensive ground transportation to help ensure the inherent GHG intensity of the wood pellets provides sufficient GHG savings compared to fossil fuels.

The findings of this study (4.3.3 and 4.3.4) suggest that pellet plants are located in areas with active forest industries, supporting the suggestion in the literature review that pellet production is very closely linked to other wood industries. This is supported by figure 4.7, which shows that Georgia, the state with the highest proportion of pellet plants also has the highest level of total harvesting and therefore more processing and harvesting residues available to supply the wood pellet market. From the conclusions in section 4.1.2, this study suggests that regions with more active forest activities are more likely to easily supply the wood pellet market through production of harvesting and processing residues.

6.3.2 Harvesting decisions in the US South

The most notable change in harvesting in the US South in the last 30 years is the dramatic decrease seen in sawtimber harvesting. Figure 5.3 shows that there was a very clear decrease in harvesting of sawtimber in the US South between 2005 and 2009 due to the economic recession and decreased demand for construction. Sawtimber harvesting is now recovering slowly, but has still not regained the harvesting levels seen prior to 2005. The decrease in price, which is closely aligned to the corresponding reduction in harvesting, suggests that forest owners are choosing not to harvest their forests. This choice would make clear economic sense, as the forest owner can wait until prices for sawtimber improve and the financial return on their harvest will be higher. There is however a limit to how long the harvest can be delayed before the possible financial return will be negatively affected. There will come a point where the forest becomes overly mature and some mortality in the stand begins to occur. In certain regions, there are also risks which increase as maturity of the forest increases, such as the risk of wildfire or pest/disease attack. In both cases, the economic value of the forest is damaged irreversibly.

6.3.3 Wood pellet demand for wood fibre

Figure 4.5 shows that there is an assumed demand for wood fibre for pellets in the US South of nearly 16 million tonnes. However, figure 5.1 then suggests that that around 40% of this wood fibre demand was obtained in the form of processing residues from sawmills or harvesting residues. The literature review (section 3.3) shows that raw materials used in wood pellets include saw dust, sawmill residues, harvesting residues (including tree tops, branches and low quality logs), diseased wood, fire damaged wood etc. The majority of the export pellet plants in this region report the use of some processing residues in pellet production. This is supported through figure 5.4 which shows the harvesting trends in Georgia and the slight recovery in harvesting of sawtimber size material between 2010 and 2014. However, the harvesting of pole-timber size material, which could be feedstock for a pellet plant (depending on quality and price), has decreased as a total. This decrease in total harvesting of smaller diameter logs during this period, even when a new market for this material had been introduced, suggests this new demand is having a relatively low direct impact on the forest.

On a regional basis, harvesting for wood pellets has increased from almost nothing to 5.4 million tonnes of harvesting in 2014. Section 5.1.2 showed that this new harvesting for wood pellets makes up 2.4% of the total harvesting in the region, so is a relatively minor component of the total demand, which supports the finding in section 5.1.3 that the new demand for fibre for wood pellets is having a low direct impact on the final harvesting patterns. Even considering three times the amount of demand for wood pellets compared to current levels, this additional demand still fits within the levels of harvesting which have previously been achieved in this region. Conversely, in the EU 27, it is thought that at least 20% of harvesting is for wood fuel (Verkerk et al., 2011).

6.3.4 Implications of findings on US South Wood Pellet Supply

This study shows that the emergence of the wood pellet market makes up 2.4% of total harvesting in the US South, however, in the context of the significant increase of demand, it appears more likely that this demand will be at least met with processing or harvesting residues. The impact of markets for both pulpwood and sawtimber is likely to lead to integrated harvests, where a stand is harvested and stems are sold into multiple markets. This kind of approach does not necessarily lead to lower carbon stock and the use of existing land for multiple purposes in this way could decrease the risk of land use changing to short rotation plantations for bioenergy.

It is clear that there is not an inexhaustible source of biomass globally which can be utilised for energy, which therefore suggests that a maximum upper limit of bioenergy may be prudent. However, another finding from this study is that sourcing of fibre for wood pellets is closely linked to other forest products industries, so more bioenergy material is likely to be available where other industries are active. The implications of this are that a limitation to bioenergy applications should be regional specific and specific to the feedstock used. For example, where biomass has no other market and would otherwise be burned on site or moved to landfill, using this feedstock in bioenergy has immediate positive carbon impacts and should be not be discouraged.

The findings on the economics of forestry suggest that there is not sufficient market influence from the value offered for pulpwood or from the bioenergy industry to result in significant changes in forest management or to influence decisions on final harvesting. It appears that for private forest owners there are other factors directly related to their management objectives, which influence management decisions.

6.4 Impact of prices and markets – what could happen in the future.

It is clear from figure 5.8 that markets and prices for different wood fractions fluctuate regularly, which is particularly evident through the dramatic increase in value of oak sawtimber and the fluctuations in pulpwood pricing over the last 30 years. Changes in the value of different wood fractions appear to be directly comparable to changes in demand and markets, with three examples of this evident in section 5.3:

– Reduction in price of sawtimber as a result of decreasing demand for timber for construction
– Increasing value of pulpwood due to the introduction of a demand from OSB mills
– Increasing value of pulpwood from the introduction of the pellet industry

6.4.1 Impacts of low sawtimber prices

Conclusions drawn from figure 5.1 and the literature review show that nearly half of wood fibre used in pellets is in the form of processing residues. Section 4.3.2 shows that low prices for sawtimber material has a clear impact on harvesting, suggesting forest owners are choosing to delay harvest until the revenue they would receive increases. Figure 5.5 shows that as sawtimber harvesting decreases, the amount of mill residues and logging residues also decreases. This therefore means that a decreased demand for sawtimber in this region would likely be detrimental for the biomass industry, as the amount of available low value wood fibre would decrease. This conclusion is supported by findings in other studies (Hoefnagels et al., 2014).

The decrease in sawtimber harvest also causes an upward pressure on pulpwood prices, as many markets using pulpwood are also able to use residue chips from sawmills. When there is less sawtimber harvesting, there are also less processing residues, so these markets move to the next available low value material, pulpwood. Increased competition in this area then increases the price of pulpwood, causing a convergence in the prices of pulpwood and sawtimber, as shown in figure 5.9.

Without markets for saw timber, forest management would seem more unlikely, as thinning operations are costly, so without the incentive of a better financial return on the final crop, forest owners would be unlikely to make this investment in their forest. Commercial thinning, where there is a market for the material, can provide an interim revenue for the land owner and improve the final stem diameter of the stand (Watson et al., 2013). However, pre-commercial thinning has a greater cost to the forest owner, with a less certain return on this investment and it is less likely that the harvested stems will have a market, therefore pre-commercial thinning is not a comment practice in the US South (Watson et al., 2013). Unmanaged forests tend to have higher risks for wildfires and attack from pests and disease, and so a lack of sustainable forest management could lead to decreasing values of ecosystem services in the forest. An example of this is the pre-commercial thinning cost sharing exercise in Virginia as a mechanism for controlling the spread of the Southern Pine Beetle (Watson et al., 2013).

6.4.2 Potential for wood pellet markets to encourage final felling

Figure 5.9 showed an increase in pulpwood prices following the introduction of the market for wood pellets. It would be of serious concern if pulpwood prices increased to a high enough level where there could be a potential for stands with sawtimber grade material to be harvested for fibre for wood pellets.

However, the conclusions in section 5.3.2 show that a 63% increase in the price of pine pulpwood only led to an increase in removals of 26%. Even more interestingly, hardwood pulpwood prices have increased dramatically, by 160% and yet total harvesting of hardwood pulpwood has decreased by 27%. This is of specific interest as it appears that harvesting of pulpwood is less responsive to price than sawtimber, as sawtimber harvesting can be clearly correlated against sawtimber pricing, as shown in figure 4.6. It is likely that there is less sensitivity to pulpwood prices, as the value is lower than saw timber.

Some studies have suggested that a forest owner's 'willingness to harvest' is also a factor here, as some forest owners may be unwilling to harvest the forest they have owned and managed to the end of its rotation solely to energy markets (Aguilar et al., 2014). This is also a point of interest to the UK government, and as such is one of the reporting requirements under the 'profiling data', asking generators under the Renewables Obligation to report on the proportion of forests which were felled solely for energy markets.

Clearly there is a price associated with harvesting, so the value of the pulpwood would need to be sufficient to at least cover the cost of the harvest and to generate a sensible return for the forest owner. This value is almost impossible to quantify, as cost to harvest will vary significantly depending on the size and type of the stand, the region and other variables. The additional value which the forest owner may require is also difficult to quantify. It would seem unlikely that a forest owner would be satisfied with breaking even on the harvesting costs, as owning a forest more decades (likely up to 30 years for many southern pine plantations) can be considered an investment and a return on that investment will be expected. However, in certain cases, it may be that a forest owner chooses to harvest their stand for personal reasons, such as raising the funds for a child to go to college, or paying for a wedding. In these cases, the forest owner may be willing to harvest their stand at a lower cost, as the liquidation of the asset to raise funds is their key aim. Understanding the minimum price energy markets would have to offer to incentivise forest owners to harvest entire stands for energy is not an objective of this study, as other studies have shown that forest owner willingness to harvest an entire stand for energy is low and these decisions are not simply based on economic incentive, but also consider environmental impacts and the management objective of the forest (Aguilar et al., 2014; Joshi et al., 2013)

6.4.3 Potential for wood pellet markets to encourage integrated harvests

A more likely consequence of lower sawtimber pricing and increased pulpwood prices is an increased potential for integrated harvesting, rather than harvesting for pulpwood. Studies showing forest owners are unlikely to fell an entire stand for energy also show that owners are more likely to consider an integrated harvest – where a stand is felled and sold into multiple markets (Aguilar et al., 2014). If there is a significant market for traditionally lower value timber (pulpwood for paper, OSB or energy), combined with lower prices for sawtimber, the forest owner may choose to harvest their stand and sell sawlog grade material to a nearby sawmill, some material to chip-n-saw and lower value material to energy markets.

When a stand is harvested and material is sold to multiple markets, it is possible that the incremental value of the pulpwood for energy markets makes the total return on the harvest more economical for the forest owner. In this case, the additional value from the wood pellet market could be the difference between choosing to harvest the stand or not. Although, as discussed earlier there are multiple components of harvesting decisions, many of which are not related to economic drivers, which suggests that a small additional contribution to the final value from the wood pellet market may be unlikely to change the harvesting decision of forest owner.

However, as described in section 5.5.1, in some cases harvesting low quality material is advised by forestry guidelines. If the remaining trees are low quality and unsuitable for sawmilling, then if these trees are left growing, they may seed and the next rotation on the stand will be lower quality material which will not be suitable for sawmilling. In these cases, the economic incentive of the value of selling the wood fibre for wood pellets is unlikely to be the driver to harvest.

6.4.4 Potential for biomass markets to encourage forest management

The introduction of a market for lower quality material could appear to be at odds with the production of sawtimber grade material, however the two can be symbiotic. The production of higher value timber should take higher preference to forest bioenergy, not only because of the higher economic value of the material, but due to the inherent carbon benefits of sawlog grade material. High quality harvested wood products have the potential to be used as a long terms carbon sink, locking up carbon in construction or furniture for numerous decades.

The literature suggests this would be a positive impact of forest bioenergy and data suggests that there has already been an increased uptake of forest management in the US South as the markets for low value wood fibre have increased (Dorning et al., 2015). The areas of timberland undergoing thinnings, salvage cuttings or other mid-rotation treatments in 2005 was 10.5 million acres, which then increased by 18% to 12.4 million acres in 2010 (Hodges, 2012). It is shown in the literature that during this period of depressed sawtimber prices, the potential for other harvesting helped allow the forest owner to delay the harvest of sawlog grade material and receive some income from their stand by thinning and selling pulpwood to other markets (Hodges, 2012).

6.4.5 Implications of the findings of the impact of markets

Without a demand for lower value wood products, forest management would likely look very different. If the production of sawtimber were still the primary management objective, it is likely that a plantation would be planted at a lower density compared to a managed forest. In a managed forest, higher planting density forces the crop to grow tall and straight, with a thinning operation which then allows the trees to increase stem diameter. Without an anticipated thinning operation, a high planting density would result in tall thin trees, which would be highly unlikely to meet the minimum tree diameter required for sawmills. By planting the trees at a lower density, the trees are wider apart and thus more branched and are less likely to be accepted by sawmills due to the high frequency of knots. In this scenario, there would be lower overall carbon compared to a managed forest with a demand for lower value wood products and there would be a lower proportion of saw logs in the stand. If the quality of the final harvested wood product is lower, it is less likely to be used as a long term carbon store (construction, or high quality wood furniture) suggesting that the final harvested wood products would have a shorter half-life, decreasing the total carbon sink impacts of the stand. Therefore there is a potential for well controlled markets for forest biomass to have dual benefits, through displacing fossil fuels with bioenergy, improving carbon sequestration in the stand through management and improved stored carbon in final harvested wood products.

Data interrogated in this study suggests that the introduction of a new demand for wood fibre for pellets is not likely to incentivise forest owners to harvest forests in the South East United States. However, the literature suggests that a demand for lower quality wood fibre can have a positive impact on forest health through encouraging more active forest management. Sustainable forest management should encourage forest owners to manage their forest for the maximum benefit across a number of stakeholders. Forest thinning can have multiple positive benefits on forest health, including; improved biodiversity in the forest, improved recreational values, increased rates of carbon sequestration and increased stem diameter leading to increased value of the final harvest. If a demand for forest bioenergy can provide the economic incentive to carry out forest thinning where this may not otherwise have taken place, this can have multiple positive impacts on the ecosystem services of the forest.

If a market for forest bioenergy does encourage forest management, particularly thinning activities, then the impact should be monitored in a proactive way. There are known to be benefits to the production of sawlogs from thinning activities, but not every stand will benefit from this activity. As mentioned earlier, poorly planned thinning could have significant negative impacts. Proactive measurement of the impacts of this additional measurement and pre-emptive training and guidance for forest owners on when, how and if to thin their forest would be beneficial to ensure that all ecosystem services are considered in these forest management decisions.

7. Conclusion

To keep global temperature increases below a 2°C increase above pre-industrial levels, the need to decarbonise the energy sector and increase renewable energy generation is a key goal for society. Energy derived from wood currently makes up 46% of total renewable energy generation across Europe, predominantly through wood chip, but since 2009 the use of wood pellets for energy has increased significantly. The European market for wood pellets comprises 87% of total global wood pellet production and in 2014, European consumption was 20.5 million tonnes. Although significant volumes of wood pellets are traded between European countries, 50% of global wood pellet production is currently generated outside the EU.

Chapter 4.1 of this study shows that countries with higher natural resource availability of forest biomass are more likely to have a higher reliance on bioenergy. Some European countries, such as Latvia and Estonia, are able to maximise their forest bioenergy output, with a higher reliance on bioenergy compared to the European average, but have also been able to sustain an export trade in wood pellets, suggesting that higher levels of forest biomass mobilisation could be achieved in other countries. The facilitation of biomass trade could incentivise the use of biomass which is currently unused in its country of origin and simultaneously support countries with a lower natural resource availability of forest biomass in meeting their renewable energy targets.

A new export market for wood pellets in the US South has developed in response to this demand for renewable energy in Europe. In the years between 2009 and 2014, the US emerged as a major producer of wood pellets, providing 20% of European wood pellet demand. In the US South, pellet plants are distributed to concentrate in regions with active forest industries, showing that the wood pellet industry is dependent on other, higher value wood product industries. Harvesting of wood for pellets is significantly lower than the assumed fibre demand for wood pellets, suggesting that 40% of this demand is met through processing residues from sawmills, reducing the direct impact on the forest, as shown in Section 5.1. This use of processing residues and the physical location of new pellet plants close to other wood processing industries suggests a connection between by-product availability and wood pellets.

Total harvesting in the US South has increased since the introduction of the market for wood pellet fibre in 2009, however, the additional harvesting of woody biomass for wood pellets in 2014 accounted for only 2.4% of the total harvesting in this region, so trends cannot be easily identified or attributed to this new market. The US South has experienced significant levels of change over the last decade, following the economic recession which severely impacted levels of sawtimber harvesting, as shown in figure 5.4. The introduction of the wood pellet market in 2009 coincided with the beginning of the recovery of the sawlog market and as such, harvesting of higher value wood products has continually increased in the years since 2009, as shown in section 5.1.

Demand for wood products clearly plays a key role in harvesting patterns and decisions to harvest. Section 5.3 shows a clear increase in the price of pulpwood between 2011 and 2014, correlating directly to the introduction of the market for wood pellets. Historically, changes in pulpwood prices can be correlated to the introduction of new markets for this material and therefore increased competition. Another example of this is the increase in pulpwood prices during the 1990s, due to the introduction of the OSB market, which created an additional demand over and above the pulp and paper market, increasing competition and raising prices.

Patterns in harvesting are more sensitive to price changes in sawtimber than in pulpwood, due to the higher relatively price of sawlogs compared to pulpwood. In the example of hardwood pulpwood, prices increased by 160%, but harvesting increased by only 3%. As a higher value product, it appears that markets are driven by sawtimber demand and the new market for wood pellets is unlikely to incentivise final felling of forest stands. It would appear to be more likely that the presence of a wood pellet market providing an income stream for lower value wood fibre could encourage integrated harvests, where material is sold into multiple markets, or to encourage forest management interventions, such as pre-commercial thinning, which would normally not be economically attractive to a forest owner.

The use of biomass plays an important role in decarbonising energy industries and the facilitation of biomass trade could ensure a more equal distribution of natural resources and better ensure that the resource is sourced sustainably. The analysis in this study suggests that more forest biomass could be sustainably mobilised, but this is likely to be through stronger markets for higher value wood products increasing the availability of residues, as the economic incentive of wood pellets alone would likely not be enough to drive significant change in harvesting patterns.

7.1 Limitations of the study

This study is limited to look only at wood pellet trade, and recognises that significantly larger volumes of wood chip are used for energy generation. This study was also limited to consider only the current European demand for wood pellets, rather than considering a projected future demand and the possible impacts of this. The trends shown in this study for harvesting patterns and fluctuations in pricing are limited to a desk-based assessment, as data on this scale (the US South) would not be possible to collect as part of an individual study.

This study concludes that if the demand for wood pellets increased three-fold, total harvesting would still be within levels of harvesting which have been achieved in the years prior to 2005 and would still be below the annual forest increment in the US South. This finding is limited to the assumption that all other markets in the regions remain stable, as it is not currently expected for any new markets to emerge with competing demands in the US South.

Much of the data used in this study is publicly available information, and there can be risks associated with the accuracy of such data. Much of the data in Chapter 4 relies on data from Eurostat, which although is the most complete dataset available which pulls together all European activity, there are can be some concerns about the completeness of the data. Under Eurostat, trade which falls below a certain threshold is not required to be reported, so in the example of trade data on wood pellets, smaller volumes of traded pellets may not be captured here.

7.2 Recommendations for Further Work

Bioenergy provides a significant proportion of European renewable energy and wood pellets are only a small component of all solid biomass. This study was limited to focus on wood pellets, rather than wood chip, as wood pellets are a key energy carrier for larger scale electricity generation, specifically when bioenergy is imported. However, substantial volumes of wood chip are used for energy across Europe, which is worthy of attention. A study assessing the sustainability of wood chip used for energy should first identify the source of the material used, specifically to understand if extra-EU sources are used in this market.

This study focussed particularly on the United States as the major pellet producer globally, however the data shows that other countries are beginning to increase production and export of pellets. In less well-regulated regions, risks to sustainability of biomass increase and therefore newer, developing sources of wood pellets should not be ignored. Russia and Canada are both locations which are net exporters of wood pellets and both are regions with vast areas of forest (Eurostat, 2016a; FAO, 2010b). Canada has strong regulatory control surrounding its forest resource, with the majority of forested areas state owned and covered by the Canadian Standards Association, a certification scheme endorsed by PEFC (Programme for the Endorsement of Forest Certification) (PEFC Canada, 2016). Russia holds more area of forest than any other country, but has a far higher risk perception rating than other countries, and so would be worthy of assessment (FAO, 2010b).

This work was limited to consider only the current levels of demand for wood pellets across Europe and therefore a key area for potential further study is an assessment of the potential future demand for wood pellets, not only across Europe, but globally.

With a better insight into future levels of demand, more robust conclusions can be made about potential risks of rising demand for bioenergy. Quantification of potential future demand would first require an assessment of the renewable energy policies in place in each member state, to understand the target for renewable energy generation post-2020. An understanding of each country's renewable energy action plan would then be necessary, to understand to what extent bioenergy factors into future renewable energy generation. This study focussed on the example of the United Kingdom as the largest importer of pellets, which appears to suggest that future development of wood energy is limited. Similar policy assessment across Europe would be valuable to understand potential future European wood pellet demand.

Another area highlighted which justifies further work is an investigation into why some European countries are able to utilise their forest area to a higher level. This is worthy of investigation, as if more countries were able to sustainably mobilise more bioenergy domestically, importing requirements for wood pellets would be reduced. Latvia and Estonia are good examples of countries which have high proportions of forested area, but have a higher than average reliance on bioenergy to meet their renewable energy targets. These countries are both exporters of wood pellets. Initial comparison of the revenue generated from the forest area does not suggest that these countries have a more active forest industry compared to other European countries, so an investigation into the harvesting practices of these regions could provide important case studies of sustainable mobilisation of forest biomass.

Section 6.3.1 discussed the concern that pulpwood prices could rise to a level where it becomes economically viable for a forest owner to harvest their stand purely for the bioenergy markets. Although other studies have suggested that forest owners' willingness to harvest for energy markets would be low, it would be valuable to carry out further work to quantify the value pulpwood prices would have to reach in order to incentivise felling an entire forest stand (Aguilar et al., 2014; Joshi et al., 2013; Junginger, 2014).

Certain outliers would need to be excluded from this investigation, for example, forest stands with poor quality species or planting which would be unlikely to sell into the sawtimber market should not be assessed in this context. This work could canvas harvesting companies in the US South to find an average cost to harvest a stand using set parameters, such as size of the stand, species, age of the stand, location. This information would be a helpful indicator of the potential for energy markets to influence harvesting decisions. Once the cost to harvest has been identified (and therefore the breakeven point of the harvest), this study would then need to incorporate an assessment of forest owner's willingness to harvest the land for energy and the profit margin required to encourage this behaviour. This could be achieved by carrying out workshops and interviews with land owners.

Section 6.3.2 outlines the potential for markets for forest biomass to encourage forest management and suggests that this is already happening in the US South. A recommendation for further work would be to consider the potential impact on ecosystem services of increasing forest management. Where a forest management approach can have benefits to one ecosystem service, it can be detrimental to another and it seems that more could be done to understand and quantify these trade-offs (Duncker, 2012). Where a 'trade-off' is necessary for a particular forest management approach, this trade-off should be weighed against the valuation of the different ecosystem services (Duncker, 2012). Ecosystem services will have different assigned values in different forests. For example, the value of recreational services in a natural managed forest in a national park would be higher than the same service in a plantation forest where the primary objective is timber production. Similarly, if you consider the value of watershed protection, which has an important role to play in minimising soil erosion, regulating the flow of water and absorption of nutrients, watershed protection in a riparian forest located close to drinking water sources would be given valued very highly, compared to an urban forest not located near any water sources (Mercer et al., 2011a).

Further work to assess the impacts of increased forest management on ecosystem services would focus on thinning as the management intervention with the largest impact and would first need to take case studies of forests and first value the ecosystem services in each case, using a recognised method of valuation. An assessment would then need to be carried out in each case study, showing the quality of each ecosystem service before thinning takes place, following a thinning intervention and at the end of the rotation. Clearly, such an assessment would require the time taken for a full rotation to test. A more efficient way of testing would be to take case studies with similar set parameters; species, elevation etc. but at different stages in the rotation.

8. References

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