Ricardo
Energy & Environment

Use of North American woody biomass in UK electricity generation: Assessment of high carbon biomass fuel sourcing scenarios

Technical Report

Report for DECC
943/12/2014

ED 60674 | Issue Number 5 | Date 27/04/2016

Customer:

DECC

Customer reference:

943/12/2014

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Date:

27 April 2016

Ricardo-AEA reference:

Ref: ED60674- Issue Number 5

Executive summary

The objectives of the work

Large scale biomass electricity generation plants in the UK import wood pellets from around the world but particularly from North America. The UK Department of Energy and Climate Change (DECC) commissioned a study in 2014 to assess the potential impact of these imports on carbon emissions, which resulted in the development of the Biomass Emissions and Counterfactual (BEAC) model[1]. Stephenson and Mackay (2014) used the BEAC model to estimate the additional carbon impact of UK demand for pellets from North America, using a series of paired scenarios-and-counterfactuals from the model. Each scenario compares the carbon emissions from the supply and use of pellets to a counterfactual designed to represent what could have happened in the absence of UK pellet demand in forests in North America. Stephenson and Mackay (2014) identified a series of low carbon scenarios, which could supply the potential UK bioenergy electricity demand. It also, however, identified a number of potential scenarios that could result in high carbon emissions. The BEAC model does not indicate the likelihood of any of the scenarios.

In 2015 DECC commissioned Ricardo Energy & Environment to assess the likelihood of the high carbon scenarios identified in the BEAC modelling occurring in North America to meet demand for biomass in UK electricity generation between now and 2030. Specifically, the study aimed to:

- Develop an evidence base of qualitative and quantitative evidence on the likelihood of the selected BEAC biomass source scenarios associated with the highest greenhouse gas emissions.
- Analyse these data to provide DECC with a qualitative and quantitative assessment of the likelihood of each relevant scenario.
- Provide an assessment of the strength of the data/uncertainty associated with the results of the analysis.

Stephenson and Mackay (2014) identified 28 potential scenarios that could be associated with high net greenhouse gas (GHG) emissions (in comparison with coal or gas fired electricity generation) as a result of demand for pellets from the UK biomass electricity sector up to 2030. One scenario 22a, although low carbon, was also considered as it forms a pair with a scenario, 22b, that is high carbon. Eleven additional carbon scenarios that were not considered in Stephenson and Mackay (2014) but which were identified in the BEAC model as possibly having a high GHG intensity were also included in this study (total number 40) in order to understand if these scenarios might also be likely in the North American pellet supply chain.

Methodology

The likelihood that the high GHG emissions scenarios happen is determined not only by supply and demand, but also by a complex interplay of other factors influencing the North American forestry sector. The response of the forestry sector to demand for pellets is not straightforward but may depend on a number of drivers/constraints such as:

- the willingness and ability of the forest land managers to react to demand for fibre for pellets
- the impact of changes in demand for other forestry products (e.g. saw timber and panel board products)
- the location of the forest relative to pellet mills, a low carbon transport network and alternative forest product markets
- the general economic situation (including the value of land for alternative uses)
- the availability of equipment for harvesting and comminution
- regional and national regulations and
- the personal objectives of private landowners, particularly in the Southeast USA where private owned forest is a high proportion of the wood resource.

[1] https://www.gov.uk/government/publications/life-cycle-impacts-of-biomass-electricity-in-2020

In this study we used a number of sources to uncover evidence on both likelihood that a scenario could occur and any factors that would result in the scenario or constrain it. This evidence was provided by stakeholders in North America and the UK through responses to a questionnaire on the scenarios, by a literature review examining the factors that influence forestry in North America and by economic modelling of supply responses to pellet demand in Southeast USA:

- The questionnaire for stakeholders asked questions about the context of their understanding of pellet supply; about their opinion of how likely the scenarios are and how widespread they might be; and about factors that drive or constrain fibre supply for pellets.
- The literature review examined information on factors that might result in or constrain pellet supply in Canada and Southeast USA (including demand for other forest products; forestry practice, ownership, regulation and policy; economics/financial return; and reported pellet supply strategies).
- The modelling was done using a forest sector model developed to model forest resource in Southeast USA; the US Southeast Sub-Regional Timber Supply model (SRTS). This model is a recursive dynamic model. This means that it simulates forestry and bioenergy decisions by allocating resources across owners and sub-regions to clear the market for the current time period and then updates resource and market conditions between periods as it moves through time. Market simulations from a recursive dynamic model should be viewed as a likely market response to a policy and market shock based on current price effects.

In each of these activities we sought information not only on whether the high carbon scenarios are likely, but also on what factors are likely to influence the supply response to pellet demand. This enabled us to understand what the major drivers or constraints would be for each scenario. The evidence from these three sources was brought together in an analysis tool that considered firstly the evidence from the questionnaire of stakeholders and then added the evidence from the literature and SRTS modelling to provide an overall likelihood ranking for each scenario. The results are reported in depth in a Technical Report available with the analysis tool on the DECC web site.

Stakeholders approached

The number of people qualified with the broad range of experience and expertise required to understand the likelihood of the pellet supply scenarios is relatively small. Our project partners, Applied GeoSolutions (USA), Professor Robert Abt of North Carolina State University and Professor Tat Smith of University of Toronto identified the stakeholders for the questionnaire using their considerable knowledge of the forestry sector in their countries. This resulted in identification of 156 key stakeholders. Of these, 56 responded to the questionnaire (36%). These respondents represented the full range of the stakeholder groups in the North American pellet supply chain in the USA and most of the range in Canada (Canadian NGOs declined to participate).

The majority of people who responded to the survey had considerable experience: either they or their organisations had at least 5 years' experience in the field. These stakeholders included organisations involved in or representing the interests of forestry ownership and management; pellet production; pellet users; non-bioenergy wood users; government regulation (including Provincial level experts in Canada); senior academics; and NGOs (including trade associations and conservation organisations). Two types of stakeholders were represented by a relatively small number of respondents: non-bioenergy fibre users and environmental NGOs[2].

High carbon scenarios that the study found were the most likely

Of the 40 scenarios considered in this study, the respondents to the questionnaire considered 5 were considered likely or moderately likely (now or in the future). Four of these five are high carbon scenarios. These are given below along with their expected scale:

[2] There were only two organisations that were purely involved in non-bioenergy products, although six of the forestry sector organisations produced large quantities of non-bioenergy products. There were four NGOs.

- *4a[3] Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon*. The scenario was considered moderately likely now and more likely in the future. This scenario could be common in the vicinity of pellet mills.
- *5a Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon*. The scenario was considered moderately likely, but at low scale (i.e. that this will not happen very often or be relevant to a large part of the supply chain).
- It is worth noting that the majority of respondents commented that it is unlikely that coarse and fine residues would be extracted separately in both USA and Canada, as it is expensive to separate them.
- *14a Additional wood from intensively-managed pine plantation, in Southeast USA with harvesting every 25 years, against a counterfactual in the absence of pellet demand of a frequency of harvest at every 35 years, given the current low demand for saw timber*. The scenario was considered to be likely now by respondents, but there was no consensus or it was thought to be unlikely in the future. If the scenario happened it would not be widespread. Comments on this scenario qualified the responses received. The main issue was that intensively managed pine plantations would not be managed on a 35 year rotation as described in the counterfactual (trends in the US Southeast are for shorter rather than longer rotations, so the counterfactual is unrealistic. Additionally the financial return drops off significantly with longer rotation length). However, respondents thought that there is a possibility that additional harvest from plantations would be used in pellet production, for example, additional fibre could be taken from intensively managed plantations through changes to thinning regimes rather than rotation length though this was not a scenario in the earlier BEAC model. This would most probably happen through planting at higher density and introducing additional thinning early in the plantation growth.
- *30a Additional wood from the conversion of unmanaged forest into production in Southeast USA, against a counterfactual of the forest remaining unmanaged*. The scenario was considered likely now but there was no consensus in future, and it was thought that the practice would happen only at moderate scale, near to pellet mills. The definition used for unmanaged forest in our study was the UN Food and Agriculture Organisation (FAO) definition of unmanaged forest as 'forest without a management plan'. The vast majority of forest land in Southeast USA is 'managed' in that it is under the influence of human management for a land management objective, whether or not that objective includes harvest or not (Oswalt et al. 2014). A large proportion of naturally regenerated timberland is privately owned by families and very little of this comes under a management plan. These forest owners bring their timberland back into management at harvest and it was this situation that respondents thought could occur if the price for pellet fibre was sufficiently high enough. On the other hand our study found that it is extremely unlikely that land set aside for conservation would be brought into timber production, because many of these lands are legally protected from harvest. Respondents asked for a clearer definition of 'unmanaged' and said that family owned timberland could be regarded as 'under managed' rather than unmanaged.

The fifth scenario considered likely or moderately likely is scenario 22a, which has a negative GHG intensity over 40 years .

- *22a Additional wood from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 25 years, against a counterfactual of continued harvesting every 50 years, and leaving to regenerate naturally*. The scenario was considered likely but it would not be widespread. It was also identified as a potential pellet fibre supply scenario in the SRTS modelling. This scenario was included in the study as one half of a pair of scenarios, the other

[3] The scenario numbers are those used in the BEAC report (Stephenson and Mackay 2014).

being 22b, which has a GHG intensity greater than 200 kg CO2e/MWh over 40 years and where the harvest rotation is only 20 years. Scenario 22b was considered by respondents to be unrealistic for softwood raw timber use[4].

All other scenarios were considered unlikely or no consensus could be reached and it was agreed that they would not be very widespread. A large number of the respondents commented on some of the terminology used in the Stephenson and Mackay (2014), which they found ambiguous and said made interpretation of the likelihood of the scenarios difficult. Further detail on these scenarios is provided in this report, where we have also drawn attention to the terminology referred to above.

Key messages

In addition to the results for likelihood presented above, the key findings from the analysis of the scenarios are:

- The most likely sourcing strategies for fibre for pellets in Southeast USA are sawmill and pulpmill residues, forest residues (depending on their definition, as noted above), increased harvest of thinnings from plantations and additional roundwood used for fibre for pellets in USA (e.g. by increased harvest of pulpwood and diversion from other non-bioenergy supply). Increased harvest of thinnings from plantations is not considered in BEAC; and diversion from other non-bioenergy supply was only considered with indirect impacts outside of USA in our study, but the respondents to the questionnaire thought that this displacement would most likely be within the Southeast USA region. The use of residues is examined, but the wide differences in definition of residues needs to be considered.
- Responses to the questionnaire and results from the literature review in Canada indicated that for the foreseeable future pellet fibre supply will be derived from a combination of primary and secondary manufacturing co-products (e.g. sawdust) and possibly harvest of standing unutilized Annual Allowable Cut (AAC) at the same time as harvest for other more valuable forest products. Any forest derived supply strategy must be considered within the AAC as stated in Provincially approved management plans and within Provincial forest policy in Canada. Examination of the impact of pellet demand on the proportion of AAC utilized has not been quantified to date, and would be necessary to further quantify how pellet demand affects harvest for that assortment in addition to more valuable forest products.
- There was no consensus on 20 of the high carbon scenarios in Stephenson and Mackay (2014). The reason for the no consensus result was due to two issues: (i) important differences in how respondents interpreted the scenarios or (ii) the number of 'I don't know' responses that influenced the results. An example of (i) is the scenarios for the conversion of naturally regenerated forest to intensive pine plantations in Southeast USA, where there was no overall consensus on the likelihood of these scenarios in the future, even where (in the case of 22a) respondents said it sometimes happens now. With regards to (ii), our analysis assigned no consensus to scenarios where there were a high proportion of 'I don't know' answers (e.g. 6 out of 15 responses were 'I don't know'). One set of scenarios where 'I don't know' responses were important was Scenarios 19-21. These examined the displacement of pulpwood for pellet use, causing indirect impacts in land use change elsewhere. The most common response to these scenarios is that they are very unlikely, but the number of 'I don't know' responses has resulted in no consensus overall. For all of the no consensus scenarios

[4] From Stephenson and Mackay (2014): "owing to the increased growth rate, an intensively-managed Loblolly plantation that is harvested every 20 years, has a similar non-soil carbon stock to a naturally-regenerated Loblolly forest that is harvested every 50 years (Scenario 22b), whereas an intensively-managed Loblolly plantation that is harvested every 25 years, has a greater non-soil carbon stock than a naturally-regenerated Loblolly forest that is harvested every 50 years (Scenario 22a)."

if they were to occur it was thought that they would only occur at a very low level (i.e. they would not be a common strategy for pellet fibre supply).

- The remaining 15 high carbon scenarios with their counterfactuals identified in Stephenson and Mackay (2014) were not thought to be a realistic representation of forestry practice in North America by the forestry sector and therefore not representative of how increased pellet fibre would be sourced.
- With the exception of scenario 22a (explained earlier), the low carbon scenarios in BEAC were not tested in this study, but respondents to the survey and sources in the literature asserted that these represent the more likely sources of fibre for pellets.

Factors influencing fibre supply include:

- Those factors that influence fibre supply for pellets within a 50 mile radius of a pellet mill and close to transport hubs for Europe are the most important. These include drivers such as Government support for bioenergy; costs such as harvest costs, labour costs etc.; and constraints such as sustainability requirements. Each of these influence the financial return from pellet fibre and therefore the supply strategies that are feasible. The financial return from the main forest product, saw timber, is important in determining strategies for pellet supply. The recent recession has decreased demand for saw timber, which in turn has decreased the availability of sawmill co-product. Demand for small roundwood has not been affected by this recession to the same extent. This has resulted in increased demand for pulpwood from small roundwood, while at the same time decreasing availability of sawmill co-products and higher prices for pulpwood have been experienced in some regions. The impacts of this situation is discussed in detail in Chapter 6 of the report. However, the financial return from pellets *alone* is not sufficient to drive harvests either in Canada or Southeast USA. Strategies for fibre supply for pellets are thus likely to be integrated with general forest management and harvest for other forest products and will change as the overall economic situation develops (particularly changes in demand in the construction sector).
- Fibre price is the most significant cost in pellet production and this is a function of a number of variables:
  - The source of fibre for pellets (i.e. co-product versus small round wood)
  - The location of the fibre relative to the pellet mills. Location influences a number of other variables (such as transport costs, price of fibre etc.), so it is not possible to extrapolate from one region to another.
- Pellet fibre availability is a function of saw mill residue and small roundwood availability. In our questionnaire some respondents said that pellet production impacts the market of other wood products that rely on these feedstocks, but only moderately and a number of respondents said there was no impact. This is likely to be location dependent and responses may be influenced by location of the respondent and their own personal experience. Forest2 Markets (2015) recently examined this situation and found that “it is likely that price for pine pulpwood would have increased without incremental demand from pellets, especially when other factors such as supply restrictions and weather are taken into account”.
- The price that buyers are able to pay for the pellets will influence the supply strategy. In this study pellet producers identified that they could not afford a 20-30 per cent sustained increase in price of fibre over a period of months without having to reconsider their business model. This is supported by independent analysis (e.g. Pöyry 2014).

Important messages on the interpretation of BEAC are:

- The study exposed issues with the interpretation of some BEAC scenarios:
  - The BEAC analysis in Stephenson and Mackay (2014) does not explicitly consider the impact of economics, rather it models the greenhouse gas impacts of scenarios informed by a literature review and stakeholder engagement. BEAC scenarios

contain implicit economic assumptions by changing rotation length or converting land to plantations. Our work has shown that financial return (i.e. economics) is important in determining whether or not the scenario happens. Respondents to the questionnaire frequently commented that it might be possible for a scenario to occur in theory, but it would be unlikely in practice because it does not make economic sense based on the returns that pellets provide, their limited market compared to other forest products and the potentially limited period that demand for fibre for pellet production is expected to last. The use of changes in rotation as envisaged by Stephenson and Mackay (2014) was generally considered uneconomic by our survey respondents.

- The counterfactuals for a number of scenarios are difficult to prove. For example, scenarios 10-13 where changes in rotation age for naturally regenerated forests were suggested. Respondents said it is not possible to know how a forest would be managed in the absence of pellet demand. They also said it is not correct to assume that the forest would be harvested on a longer or shorter rotation. Faced with a better financial return from converting the land in some other way land owners in the USA may opt for different choices, which could also be valid counterfactuals.
- In Canada forestry laws and regulations have been negotiated over more than two decades and are designed with the intention of ensuring sustainable forest management. This continuing process provides the back drop to pellet supply strategies. Permitted harvest is determined as a balance of a number of objectives including economic return and social and environment objectives. Considerable time and resources are used to draw up agreed management plans. Canadian respondents to the questionnaire found some of the scenarios in BEAC difficult as they are contrary to the Canadian forest management process.
- Definitions are important and should not be open to interpretation, but we found respondents were defining some terms differently, particularly those for forest residues, managed/unmanaged land and ‘additional wood’.

In addition to the above our study also uncovered the following factors that influence of pellet impact:

- The small size of pellet markets both by volume and value compared to other forest product markets. These other markets give higher value or financial return than pellet markets and tend to dominate decisions about harvest and replanting/regeneration of forests. Pellet demand alone is therefore unlikely to drive forest stand rotation length or harvest choices. This was supported in all three evidence sources in this work.
- Much of the carbon and ecological impact of market demands on North American forests can be controlled through sufficient and appropriate approaches to and regulation of forest management.

The SRTS modelling included limitations as follows:

- The SRTS modelling runs included (of necessity) certain limitations and assumptions; e.g. the region studied, assumptions about pellet demand and assumptions related to recovery of the housing market etc. Restrictions on the modelled geographic area did not allow displacement of fibre supply to other neighbouring regions in the USA (‘leakage’). This resulted in a higher price for fibre than would have happened if leakage had been allowed. This is discussed in detail in Chapter 6 of the report.
- SRTS modelling also examined carbon impacts on a different basis to BEAC. In the SRTS modelling increased pellet demand was shown to have no impact on the overall negative carbon levels in the standing stock (it may even increase due to increased planting). However, it could lead to a switch from slower-growing naturally regenerating forests to faster growing pine plantations. This may cause other issues, including possible impacts on

biodiversity, water quality and landscape which it was beyond the study remit to examine. Further discussion of the modelling of carbon in SRTS is provided in Section 6.4 of the report.

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Appendices

Acknowledgements

The Authors would like to acknowledge the assistance of the following organisations in this study and the peer review:

Canada

NCASI, Forestry Innovation Investment, Tembec, Ontario Power Generation, Pinnacle Renewable Energy Inc, BC Ministry of Forests, lands and Natural Resource Operations, Rentech Inc, John Arsenault, Ontario Ministry of Natural Resources and Forestry, Québec Ministry of Forest Wildlife and Parcs, Natural Resources Canada, Forest Products Association of Canada, Shaw, Resolute FP Canada Inc, Groupe Savoie Inc, Peter Duinker of, Dalhousie University, FP Innovations, Wood Pellet Association of Canada, Weyerhaeuser Canada.

USA

Spatial Informatics Group LLC, F&W Forestry Services Inc, Oak Ridge National Laboratory, USDA Forest Service, C Galik of Duke University, Rayonier Inc., Roger Sedjo of Resources for the Future, NASCI, K Skog and K Abt of the US Forest Service, Hancock Natural Resource Group, CNJV., Society of American Foresters, Natural Resources Defense Council, Southern Environmental Law Center, Dogwood Alliance, MWV, Georgia Biomass LLC, Weyerhaeuser Company, RockTenn, CM Biomass NA, Fram Renewable Fuels L.L.C., US Industrial Pellet Association, Westervelt Renewable Energy, LLC., Enviva, The Earth Partners, National Alliance of Forest Owners, Plum Creek Timber Company, American Forest Foundation, Drax Biomass Inc (USA), S Ohrel of the US EPA.

The USDA and US EPA were represented by government experts who represent their own personal opinions and not official policy views.

UK

Drax Power Ltd. (UK), Lynemouth Power Ltd, MGT, Friends of the Earth.

We would like to thank IEA Bioenergy for their support of the webinars that were part of the expert review of this work and the Canadian Institute of Forestry for organising the webinars.

1 Background, Aims and Objectives

This report provides the results from a study of the sourcing of fibre for pellets in North America. It was designed to assess the likelihood of high carbon sourcing scenarios for pellet production in North America. These high carbon scenarios had been identified in modelling results obtained from the UK Department of Energy and Climate Change (DECC) Biomass emissions and counterfactual model ('BEAC') and reported in Mackay and Stephenson, 2014.

BEAC is a life cycle assessment (LCA) model developed to assess the greenhouse gas (GHG) emissions intensity and energy input requirements of a series of scenarios for biomass supply for energy in the UK. The BEAC modelling in Stephenson and Mackay (2014) examined carbon emissions from woody biomass supply from North America for electricity generation in the UK and showed that where bioenergy is sourced responsibly it produces lower carbon emissions than fossil fuels. The emissions limits examined in Stephenson and Mackay (2014) are defined in the UK Renewables Obligation (RO). Electricity from biomass that is subsidised by the RO must be proven to generate electricity with a maximum GHG emission intensity of 285 kg $CO2_e$/MWh from April 2014, and 200 kg $CO2_e$/MWh from April 2020 (DECC, 2013a). The European Union Renewable Energy Directive (RED) sets a methodology for calculating the GHG emissions from bioenergy supply on a life cycle basis. Under the RED methodology, as well as emissions from cultivation, harvesting, processing and transport of the biomass feedstocks, emissions from direct land use change (where the land use has changed category since 2008) and soil carbon accumulation from improved management of land. The BEAC study estimated all of these emissions but also included emissions from changes in carbon stocks of forests, foregone carbon sequestration, carbon debt and indirect impacts such as displacement effects.

Stephenson and Mackay (2014) concluded that in 2020 it may be possible to meet the UK's demand for solid biomass for electricity using biomass feedstocks from North America that result in electricity with GHG intensities lower than 200 kg $CO2_e$/MWh, when fully accounting for changes in land carbon stocks, forest carbon stocks, foregone carbon sequestration and indirect impacts. However, they also showed that there were other bioenergy scenarios that would be found to have GHG intensities less than 200 kg $CO2_e$/MWh by the RED LCA methodology, but that could lead to high GHG intensities (e.g. greater than electricity from natural gas and coal), when emissions from changes carbon stocks of forests, foregone carbon sequestration, carbon debt and indirect impacts such as displacement effects. The BEAC modelling identified 29 potential scenarios that could be associated with high net greenhouse gas emissions as a result of demand for pellets from the UK biomass electricity sector up to 2030. Eleven additional high carbon scenarios that were not considered in BEAC were also included in this study, taking the total number of scenarios examined to 40.

These scenarios were assessed in the BEAC analysis for carbon emissions, but Stephenson and Mackay (2014) did not examine whether they were *likely* to be the pathways by which the biomass would be supplied. For example, they did not look at the economics of the biomass supply and whether or not financial return would encourage the scenarios; nor were they able to do an in depth study of forestry practice in North America, including the drivers that dictate forest management.

The aim of our project was to assess the likelihood of these high carbon wood fuel sourcing scenarios occurring in North America between now and 2030 to meet demand for biomass in UK electricity generation. The core questions asked by this project concerned how likely it is that fibre is supplied in the way the scenarios suggest, either now or in the future; and, if it is likely, at what scale does this or might this happen (e.g. how much area might this cover, or how common might these practices be)? In addition the work examined how fibre for pellets might be obtained in future.

The project methodology is described in Chapter 2. The project was developed to provide a database of evidence on the likelihood of the high carbon BEAC scenarios happening, using three main sources of evidence: the literature, a questionnaire sent to representative key stakeholders in Canada, the USA, the UK and Europe, and economic modelling of forestry in the US Southeast. The results from this evidence base are provided (in summary) in Chapters 4-9. Additionally we have provided an Analysis Tool, an excel spreadsheet developed to analyse the results of the questionnaire and bring together all three elements of the evidence in one place. More detailed results including the comments made by stakeholders alongside their responses to the questionnaire are provided in Appendices 4 and 5. All results from the questionnaire of stakeholders are anonymised to protect respondent confidentiality.

Where stakeholder comments are attributed in this report, this is with the express permission of those individuals and organisations concerned.

1.1 The BEAC model

The BEAC model analysis in Stephenson and Mackay (2014) examines the greenhouse gas impact of scenarios for biomass supply for pellets in North America. Each scenario is compared to the modelled carbon emissions of a counterfactual designed to represent what would have happened in the absence of pellet demand in forests in North America. So the BEAC model comprises a series of paired scenarios-and-counterfactuals that examine the additional carbon impact of demand for pellets from North America for use in electricity generation in the UK. In some situations more than one counterfactual is available for comparison with the pellet fibre supply scenario. For example for the scenario that examined increased use of forest residues for pellet production, the counterfactual was developed to represent what would have happened to the forest residues in the absence of pellet demand. In this case the model allows a counterfactual in which the residues are burnt at the roadside, and an alternative counterfactual in which the residues are left in the forest. This enables modelling of GHG impact against two plausible counterfactuals which provide different results.

The scenarios in BEAC are shown in Table 1-1. They examine the sources of different types of wood that may be used to provide fibre for pellets. These are:

- saw sawmill co-products (with the potential to displace feedstocks for other non-bioenergy products),
- forest residues without an alternative market
- diseased wood
- additional harvest from naturally regenerated forest (through more intensive harvest or harvest on additional land),
- Roundwood (e.g. pulpwood) from existing plantations
- Wood for bioenergy displacing non-bioenergy uses, causing additional wood to be imported (in this case into Southeast USA)
- Additional wood harvest from establishing new plantations (energy crops and intensively-managed pine) on naturally-regenerated timberland in Southeast USA
- Additional wood harvest from establishing new plantations (energy crops and intensively-managed pine) on abandoned agricultural land.
- Conversion of naturally regenerated forest to plantation or short rotation coppice (SRC) and abandoned agricultural land converted to plantation or SRC.

The BEAC model only examines the additional impact of pellet demand. It assumes that all other demands on the forest will remain the same at a landscape level as in the absence of pellet demand and therefore does not model the carbon impact of other forest products for all scenarios. In addition if the counterfactual is that the forest would not be harvested as frequently in the absence of pellet demand BEAC models the carbon impact as the difference between the counterfactual of continued forest growth and harvest for pellets. This means that the counterfactual assumed is important as it also has a high impact on the outcome of the model. Further information on the development of BEAC is provided in Box 1-1 and here.

Box 1-1 Details on the development of the BEAC scenarios

In the BEAC model scenarios were constructed to represent North American woody feedstocks that are currently used for the production of woody pellets (e.g. pellets from saw-mill residues, beetle-killed trees, and pulpwood), as well as potential future scenarios that might conceivably occur if there is increased demand for biomass (e.g. pellets from wood derived from new, dedicated plantations). The model included a wide range of scenarios, including some that may not necessarily be likely; environmental, economic and social factors will all play a part in determining which of these scenarios could occur in the future. The intention was to shed light on which scenarios are potentially satisfactory (from the points of view of GHG intensity and energy intensity ratio - EIR) and which scenarios are potentially not satisfactory, so as to guide future policy decisions. A literature review was conducted to assess the likely available resource of each scenario by 2020, and the BEAC model was used to estimate the GHG intensity and EIR of each scenario, taking into account the counterfactual land use for each scenario, i.e. what the land would be used for if it were not used to grow the bioenergy feedstocks. Further information on the development of the scenarios is provided in Stephenson and Mackay (2014).

BEAC was developed by DECC to take into account factors that are not included in the Renewable Energy Directive (RED) (2009/28/EC) methodology for assessment of carbon emissions from bioenergy. These were carbon debt, changes in average carbon stock, foregone carbon sequestration and indirect impacts. A description of how these were included in available in Stephenson and Mackay (2014).

Table 1-1 Summary of BEAC scenarios as examined in Stephenson and Mackay (2014). The analysis in Stephenson and Mackay (2014) examined potential pathways and their impact on carbon, not whether or not these scenarios are likely. Thus the list below may contain scenarios or counterfactuals that may not be likely. The scenarios that are classed as high greenhouse gas (GHG) intensity are those that were shown to produce emissions >200kgCO2e/MWh andare the scenarios that were considered in this study.

No.	Scenario description	Counterfactual description	Low or High GHG intensity
1	(a) Saw sawmill co-products in Southeast USA (no drying) (b) Saw sawmill co-products in Pacific Canada (no drying)	Burn as waste (no energy recovery)	Low GHG
2	(a) Saw-sawmill co-products in Southeast USA; dry from 25 wt% to 10 wt% moisture. (b) Saw-sawmill co-products in Pacific Canada; dried from 25 wt% to 10 wt% moisture[5]		
3	(a) Saw-sawmill co-products in Southeast USA; dry from 50 wt% to 10 wt% moisture. (b) Saw-sawmill co-products in Pacific Canada; dry from 50 wt% to 10 wt% moisture		
4a	Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest	High GHG
4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.		
5a	Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon.		
5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.		
6a & 7a	Fine and coarse forest residues, removed from forests in Southeast USA, for 15 years only (then residues are left in the forest again).		
6b & 7b	Fine and coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).		
8	(a) Forest residues (both coarse and fine), removed from forests in Southeast USA, continuously over the time horizon. (b) Forest residues (coarse and fine), removed from forests in Pacific Canada, continuously over the time horizon.	Burn the residues at the roadside as a waste.	Low GHG

[5] In this context wt stands for weight and is a shorthand used to show the percentage moisture content on a weight basis.

No.	Scenario description	Counterfactual description	Low or High GHG intensity
9	Salvaged dead trees, which have been killed by mountain pine beetle in Pacific Canada.	(a) Leave in the forest. (b) Remove and burn at the roadside.	Low GHG
10a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	High GHG
10b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years	High GHG
11	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.	Continue harvesting the forest every 70 years	High GHG
12a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	High GHG
12b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years	High GHG
13a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA from every 70 years to every 60 years.	Continue harvesting the forest every 70 years	High GHG
13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated hardwood forest in Southeast USA every 70 years.	Reduce the rate of harvest compared to the harvest in the presence of pellet demand, to every 80 years	High GHG
14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Continue harvesting every 25 years	Reducing the frequency of harvest compared to the harvest in the presence of pellet demand, to every 35 years	High GHG
14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Increased demand for small roundwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest compared to the harvest in the presence of	High GHG

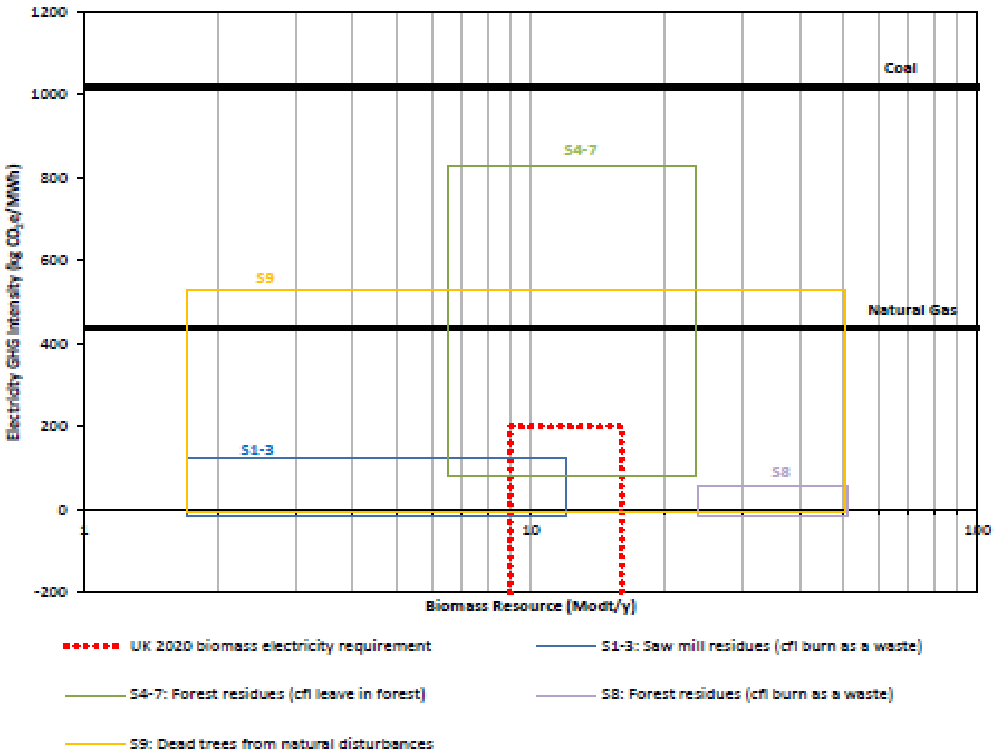
No.	Scenario description	Counterfactual description	Low or High GHG intensity
		pellet demand, to every 35 years	
15	15, 16, 17 = Same as Scenario 14, but with different counterfactuals.	Converted over 50 years to an even-aged naturally-regenerated pine forest that is harvested every 50 years.	Low GHG
16		Scenario 15,16 Converted over 25 years to a naturally-regenerated pine forest that is left to continuously sequester carbon, rather than harvested	Low GHG
17		Scenario 17: Converted over 25 years to agricultural land (e.g. cotton plantation).	Low GHG
18	Additional wood (in comparison to the counterfactual) from increasing the management intensity (and hence yield) of a pine plantation in Southeast USA that is harvested every 25 years (e.g. adopting optimal thinning practices and initial planting densities; Will et al., 2006).	Continue previous management regime	Low GHG
19	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in Southeast USA used for non-bioenergy purposes	High GHG
20	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah.	Pulpwood produced in Southeast USA used for non-bioenergy purposes	High GHG
21	Pulpwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.	Pulpwood produced in Southeast USA used for non-bioenergy purposes	High GHG
22a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Low GHG
22b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	High GHG
23a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	High GHG
23b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and	High GHG

No.	Scenario description	Counterfactual description	Low or High GHG intensity
		leaving to regenerate naturally	
24a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	High GHG
24b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years Conversion over 50 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	High GHG
25a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	High GHG
25b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 70 years.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	High GHG
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Southeast USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.	High GHG
27	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years	Abandoned agricultural land left to revert to temperate grassland	Low GHG
28	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land that was previously annually ploughed, to an intensively-managed pine plantation that is harvested (a) every 25 years, (b) every 20 years.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.	Low GHG
29	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land that was previously annually ploughed, to an intensively-managed pine plantation that is harvested (a) every 25 years, (b) every 20 years.	Abandoned agricultural land left to revert to temperate grassland	Low GHG

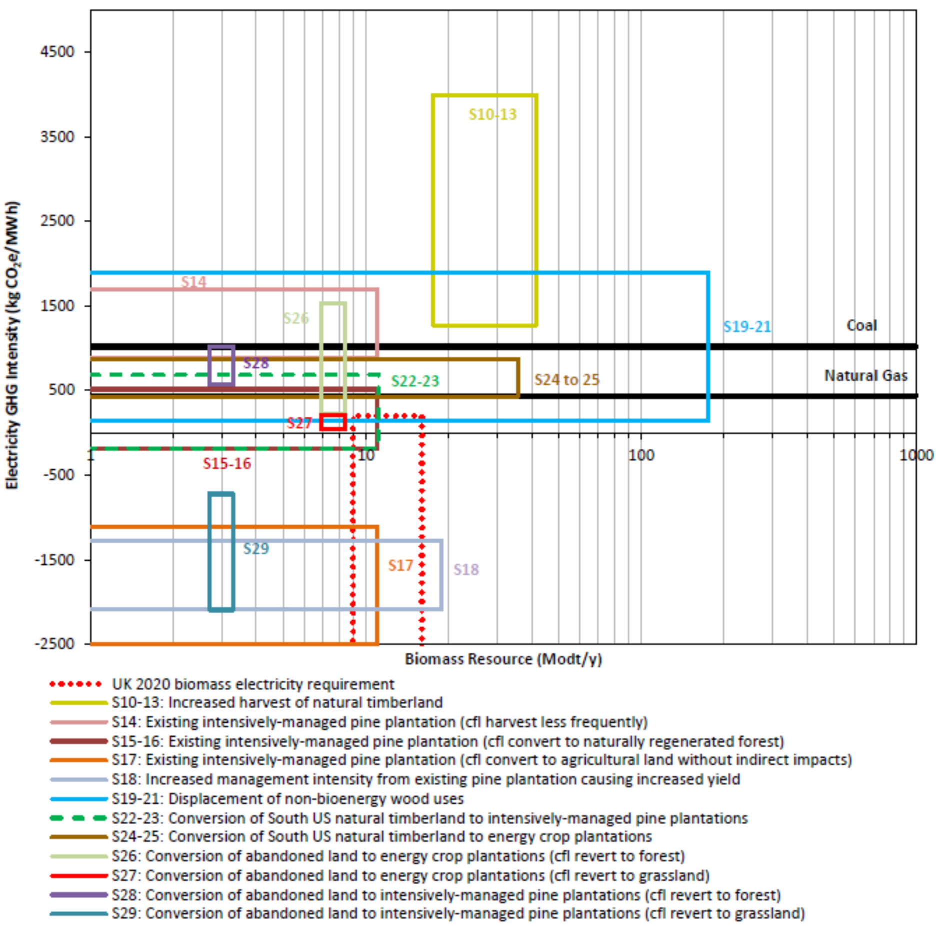
A summary of the results to the BEAC modelling is provided in Figure 1-1(a) and (b). This figure provides the results of the GHG intensity modelling over 40 years and allows comparison with the quantities of biomass required for the 2020 electricity requirement in the UK. From this diagram it is possible to see which scenarios have high carbon intensity. Results for the same scenarios but with analysis of GHG intensity over 100 years are provided in Appendix 2.

Figure 1-1 Summary of resource of North American roundwood and energy crops that may be available by 2020 and their GHG intensity over 40 years as modelled by BEAC Source: Stephenson and Mackay 2014. The figure below is taken from the Stephenson and Mackay (2014) report. The 's' numbers below refer to the scenarios examined in that report and listed in Table 1-1. Cfl: counterfactual

(a) Supply scenarios related to residue use



(b) Roundwood and energy crop scenarios assessed in BEAC



This study only examined those paired BEAC scenarios-and-counterfactuals where GHG intensity was high compared to coal or gas fired electricity generation. The scenarios and counterfactuals where carbon impact was lower than coal and gas fired generation are not included in this study, as they are not considered to be a threat to the carbon sustainability of the supply chain for pellet use to generate electricity in the UK. For example, the paired scenario-counterfactual in which forest residues are extracted for which the counterfactual is burning at the roadside is not examined as this was not a high carbon scenario. The high carbon scenarios identified by BEAC and referred to in this report are listed below by the scenario numbers given to them in BEAC and shown in Figure 1-1:

- **Scenarios 4-7: Forest residues that would otherwise have been left in the forest being used in pellet production.** The carbon impact of these scenarios is related to the type of residue used (the use of fine residues were analysed in BEAC to have a lower carbon impact than coarse residues), the climatic condition of the region where the residues are left, and the length of time over which the residues degrade.
- **Scenarios 10-13: Increased harvest of naturally-regenerated forest.** The BEAC counterfactual for these scenarios is continued harvesting at a lower rate, which results in a GHG emissions difference between the pellet demand scenario and the counterfactual. For these scenarios, different rates of harvest were modelled in the BEAC model by considering different times between harvests (rotation lengths). If the average rate of harvest of a set area of naturally-regenerated forest were to increase, the average time between harvests (rotation length) would decrease.
- **Scenario 14: Change in the use of wood grown in intensively-managed pine plantations from non-bioenergy to bioenergy uses** (if demand is low for non-bioenergy uses, these plantations might be used to produce pellets; the counterfactual alternative in Stephenson and

Mackay (2014) would be that they are harvested less frequently[6]). The BEAC model (Stephenson and Mackay 2014) assumed that in the absence of pellet demand the plantations would be harvested less frequently, such that less biomass material would be harvested, and more biomass material would be stored in the above-ground biomass of the forest. The BEAC study based this on evidence that this scenario was common after the recession, where fewer trees were cut, and the forest inventory increased. The BEAC study assumed it could also represent a scenario where initiatives encourage forest owners to extend their rotation length, in order to increase carbon storage. In this scenario the BEAC analysis resulted in higher carbon emissions in the presence of pellet demand due to greater harvest.

- **Scenarios 19-21: Displacement of non-bioenergy wood uses** i.e. US pulpwood going to the UK instead of the US paper industry. In the BEAC analysis it was assumed that this had an indirect land use change impact and that there was also a carbon impact resulting from longer distance transport of wood for used for non-energy purposes as a result of this displacement.
- **Scenarios 22-25: New plantations on naturally regenerated timberland in Southeast USA.** Scenarios 24 and 25 address the conversion of naturally regenerated timberland[7] to energy crops, whilst scenarios 22 and 23 address the conversion of naturally regenerated timberland to intensively managed loblolly plantations. In BEAC it is assumed that the counterfactual to these scenarios is continued harvesting of the forest for a mix of wood products (e.g. saw logs and pulpwood). Stephenson and Mackay (2014) discuss the differences in non-soil carbon in the plantations and energy crops compared to naturally regenerated timberland, saying that the non-soil carbon stock is greatest in naturally regenerated hardwood forest or an intensively managed plantation harvested every 25 years, but that non-soil carbon stock in SRC plantations is lower than naturally regenerated forest[8].
- **Scenario 26: Energy crops[9] grown on abandoned arable land.** Stephenson and Mackay (2014) analysis assumes that the additional wood created by scenario 26, in comparison to the counterfactual, is used for bioenergy. Any changes in carbon stock in the forest relative to the counterfactual are attributed to this wood output. Their analysis showed that the achieved yield of the plantation, and the foregone carbon sequestration, greatly affect the GHG intensity of the generated electricity. Stephenson and Mackay (2014) says: "electricity generated from energy crops that achieve a yield of 30 odt/ha/y has a lower GHG impact than electricity generated from energy crops with lower yields (5 to 15 odt/ha/y), assuming all other variables (e.g. fertiliser input) are constant, because the greater the amount of biomass which can be produced from the land, the greater the amount of energy which the life cycle GHG impact is divided by. If energy crops are grown on abandoned land that would otherwise revert to sub-tropical deciduous forest (Scenario 26), the foregone biomass growth dominates the life cycle, and the overall GHG intensity of biomass electricity is significant." Other scenarios where alternative land reversion is considered (e.g. to grassland) were not analysed in this study as their GHG emissions intensity was significantly lower.

We also examined additional scenarios 10P-13P: Increased harvest of plantation forest, and scenario 30[10]: on bringing unmanaged forests into production, in each of the key regions (Southeast USA, East Canada, Pacific Canada and Boreal Canada). These scenarios are shown in Table 1-2.

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[6] This is arguable and depends on the market for alternative uses for the biomass: if there is high non-bioenergy demand then the counterfactual could be harvest for an alternative use. In this work we have used the BEAC scenarios as described by Stephenson and Mackay (2014) in which they assume the conditions as described for the scenarios listed for the scenarios above. In the case of Scenario 14 Stephenson and Mackay (2014) examined the case where non-bioenergy demand is low, to mirror the situation as claimed by many pellet mill operators in North America. In our study we were often presented with alternative counterfactuals by respondents. The exact counterfactuals are important, differ with market conditions and could make significant differences to the outcome of the modelling.

[7] Stephenson and Mackay (2014) also referred to this as 'natural timberland'. The term is used to refer to those forests that are harvested every 50-70 years and left to naturally regenerate after harvest, and which have been routinely used in timber supply in the USA.

[8] From Stephenson and Mackay (2014): "owing to the increased growth rate, an intensively-managed Loblolly plantation that is harvested every 20 years, has a similar non-soil carbon stock to a naturally-regenerated Loblolly forest that is harvested every 50 years (Scenario 22b), whereas an intensively-managed Loblolly plantation that is harvested every 25 years, has a greater non-soil carbon stock than a naturally-regenerated Loblolly forest that is harvested every 50 years (Scenario 22a). The non-soil carbon stock in a naturally-regenerated hardwood forest that is harvested every 70 years, is significantly greater than in an intensively-managed plantation that is harvested every 20 years (Scenario 23b), and similar to in an intensively-managed plantation that is harvested every 25 years (Scenario 23a). For both scenarios 24 and 25, the non-soil carbon per unit area stored in an SRC plantation is significantly lower than that stored in a naturally-regenerated forest, as SRC is coppiced frequently (assumed here to be every 3 years), meaning that there is little time to accumulate large amounts of above-ground biomass."

[9] Energy crops are defined in Stephenson and Mackay (2014) as woody energy crops (such as short rotation coppice) and herbaceous energy crops (such as Miscanthus and switch grass). The energy grasses have achieved the higher yields cited above. In Scenario 26 Stephenson and Mackay investigated yields of short rotation coppice from the conversion of abandoned agricultural land of 5-30odt/ha/y.

[10] For the purposes of the present report, Scenario 30 – bringing unmanaged land into production – is not the same as Scenario 30 in the 2014 BEAC model. It is instead based on Scenario 33 in that model, which considers what happens when UK broadleaf forests are brought back into production to produce small round wood for the heat market (through production of wood chips). It is difficult to transpose this system directly into

Further details on these scenarios are provided in Appendix 1.

Table 1-2 Additional scenarios considered in this study

No.	Scenario description	Counterfactual description
10Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
10Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
11P	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Pacific Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
12Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
12Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 50%	Leave plantation in previous management
13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 20%	Reduced frequency of harvest with low demand for wood
30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Southeast USA	Forest remains unmanaged
30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged
30c	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Pacific Canada	Forest remains unmanaged
30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged

1.2 Objectives

The objectives of the project were to:

- Develop an evidence base of qualitative and quantitative evidence on the likelihood of the selected BEAC biomass source scenarios associated with the highest greenhouse gas emissions from the literature, from a questionnaire of stakeholders in the supply chain in North America and from modelling of the supply response to demand for fibre for pellets in Southeast USA
- Analyse this data to provide DECC with a qualitative and quantitative assessment of the likelihood of each relevant scenario between now and 2030 as a result of demand for biomass from UK biomass electricity generators.

North America. There are large areas of North American forest that are unmanaged but the term does not mean the same as in the UK and it is likely to have different meanings in the USA and Canada.

- Provide an assessment of the strength of the data/uncertainty associated with the results of the analysis.

The scope of the project was the use of biomass by the UK biomass electricity sector.

1.3 Demand

This study was designed to examine supply of fibre for pellets independent of demand. However, we have considered demand for the economic modelling in the USA. In addition respondents were asked to consider the impact of UK and European supply and current and planned pellet plants in their regions in their answers. Guidance on the quantities was provided on this basis. The guidance to consider European supply was because the bulk of exported North American pellet demand is currently used in Europe (EIA 2015a). Demand may also grow in North America itself and in Asia. Our study concentrated on regions that are important to European demand, i.e. regions with close proximity to suitable ports and where price enables the supply to be viable. This includes Southeastern USA, Easter Canada and Pacific Canada where pine beetle kill has resulted in the development of a pellet industry.

When modelling demand in the Southeastern USA we considered the operating and planned pellet plants that are likely to be built. This provided a supply similar to the projected demand from Europe. There is some speculation that US demand will increase. From information we consulted (e.g. EIA 2015, and 2016, Biomass magazine 2015, US EPA (2015)) the evidence is that US demand be spread across the USA. We assumed that the costs of transport would make it difficult for Southeastern USA to be a prime supplier for these markets and that they would source supply nearer to the demand.

2 Methodology

The methodology used three approaches to data gathering from North America and the UK:

- A questionnaire sent to stakeholders in the North American pellet supply chain that sought their opinion on the likelihood of the scenarios, the evidence that informs this opinion and information on key variables that drive or constrain the scenarios. This is described in Chapter 7.
- A literature review to provide evidence on key variables such as costs, constraints and forestry practice. This is described in Chapter 3.
- A modelling exercise using the Sub-regional Timber Supply (SRTS) model developed at North Carolina State University. This model is described in Chapter 6.

The work was undertaken by a team of four contractors: Ricardo Energy & Environment in the UK; Applied Geosolutions and their Subcontractor, Professor Bob Abt in the USA; and Professor Tat Smith of Toronto University in Canada.

2.1 Overview of methodology

Whether or not the BEAC high GHG emissions scenarios happen will be determined not just from an interaction between supply and demand, but also by other factors that influence the forestry sector in North America, such as: increased demand for pellets in the USA and Europe (including the UK) and the price that can be afforded by UK generators. The reaction of the forestry sector to demand for pellets will depend on a number of drivers or constraints and will not be straightforward. It will depend on factors such as:

- the willingness and ability of the forest sector to react to demand for fibre for pellets
- the impact of other demand for alternative products (e.g. saw timber)
- the general economic situation (including the value of the land for alternative uses)
- the availability of equipment for harvesting and comminution
- regional and national regulations and
- the timescale under consideration (we examined the timescale relevant to current UK market incentives for large scale electricity generation, i.e. to 2030 at the latest).

Some understanding of the complexity of the situation can be gleaned by considering a situation where there is an increased price for fibre as a result of pellet demand. This will make the production of fibre for pellets more attractive. However, production of fibre for pellets may be constrained by the impact of alternative, more financially attractive markets, lack of appropriate equipment or forestry standards and regulations. Additionally, there will be an interplay with transport availability and costs, so that the distance to the pellet mill or alternative markets may be important. An additional factor to consider is that foresters may manage considerable acreage, so they may react differently in different locations.

There are also pressures on price: in the UK the price the biomass electricity generators are willing to pay is limited by the level of incentives (i.e. the value per MWh). Finally, there may be interaction between the scenarios, which may be mutually dependent or exclusive, or impact on each other in different ways. For example, some scenarios may depend on the distance from the pellet plant and landowners may use different strategies to meet fibre demand depending on the transport distance. In other cases it may be feasible to decrease rotation and then convert what would previously have been naturally regenerated forest to plantation, given the right set of drivers.

To uncover the nuances of the situation we used a number of difference sources of evidence to understand what the response of the North American forestry sector might be to increased pellet demand from the UK and Europe. The evidence is provided by stakeholders in North America and the UK through their responses to the questionnaire, by a literature review and by the SRTS economic modelling focussed on Southeast USA. Within each of these evidence gathering exercises we sought information not only on whether the high carbon intensity scenarios are likely but also on what factors are likely to influence the supply response to pellet demand. For example in the questionnaire we asked questions on the factors that might encourage or prevent the scenarios occurring; and we asked supplementary questions on forestry practice, prices and regulation that influence the supply change. In the literature review we examined evidence regarding forestry in North America, what the major drivers are for forest products, current pellet production and the economics of pellet production where available. This enabled us to understand what the major drivers or constraints would be for each scenario.

The results have been exposed to expert opinion through presentation at webinars and through a formal peer review by experts in the field in North America and the UK.

The work was undertaken in four Tasks as shown in Table 2-1.

Table 2-1 Outline of project method

Task	Description	Deliverable
1	Define the methodology in detail, to agree the questions for the questionnaire and which stakeholders should be approached	Methodology report.
2	Data gathering: • Questionnaire for stakeholders in the North America pellet supply chain (including UK biomass generators), • Literature review • SRTS modelling • Production of evidence database	Data for final report
3	Data analysis: analysis of the likelihood of the high carbon BEAC scenarios happening, including a range of criteria that drive and constrain the scenarios.	Provision of data for Interim and final reports
4	Results presentation phase: ➢ Reports as indicated in the deliverables ➢ Excel Analysis Tool ➢ QA log ➢ Datasets for final report (non-attributable, for publication)	Interim report Final report Presentation for Webinar in Canada and USA Evidence Analysis Tool, with guidance

2.2 Task 1 Scoping the approach to research questions

The first phase of the work defined the issues that are relevant to each scenario and the questions to be asked in the study. This was done through:

- Identification of the key influences on each scenario, including (quantitative and qualitative) variables that might constrain the scenarios. Examples include:
  - price,
  - distance,
  - Federal or State harvesting and retention guidelines,
  - Canadian Provincial regulations
- Identification of key influences for the decision for all stakeholders in the bioenergy-pellet-power station supply chain.

The first stage in our analysis was extraction of factors that were thought to be important in influencing the likelihood of the scenarios. This was done by including the factors highlighted by Stephenson and Mackay 2014; and adding factors that the project team thought were important. Questions on these factors were then added to the list of questions to be asked about the scenarios. The preliminary list of questions developed from this exercise was piloted with a small number of key stakeholders who represented the range of stakeholders for the final survey and their comments were also taken into account, both to revise content and to improve routing of questions. One important consideration in developing the final list of survey questions was how to ensure that the questions would provide an unbiased evidence base, both by capturing the views of a range of experts from all sectors concerned with forestry and by ensuring that the questions are carefully phrased to reduce the potential for bias. To do this the project team consulted survey design experts and social researchers with Ricardo-Energy & Environment and at DECC.

The second part of this first phase of work was the identification of stakeholders for the questionnaire. This was done through the project partners. The project partners have considerable knowledge of the forestry sector in their countries and were able to use this experience to provide a list of 156 key stakeholders who are likely to be influential in or concerned about pellet supply from North America (including UK biomass generators), as well as having a good understanding of the way in which forests are managed in North America. There are a limited number of well-informed stakeholders with the knowledge to answer a detailed questionnaire on the BEAC scenarios. Of the 156 stakeholders contacted, 56 responded to the questionnaire – a response rate of 36%. A number of the people who did not answer the survey (particularly UK stakeholders) wrote to tell us that they felt their experience was not sufficient. It is not possible to provide information on the proportion of the relevant sectors in the regions covered, because this information is not readily accessible. However, although the number of respondents was not suitable for extensive statistical analysis we believe it provided representation of the important sectors in pellet production, including some of the most significant stakeholders.

The stakeholders who did respond included organisations involved in or representing the interests of: forestry ownership and management; pellet production; pellet users; non-bioenergy wood users; Government regulation; academia; and non-governmental organisations (including trade associations and conservation organisations). The breakdown of the respondents into stakeholder groups is shown in Chapter 8 on the questionnaire results.

This exercise in defining the research questions was also used to inform the scope of the literature review and the SRTS modelling.

2.3 Task 2 Data collection

The data collection is summarised schematically in Figure 2-1.

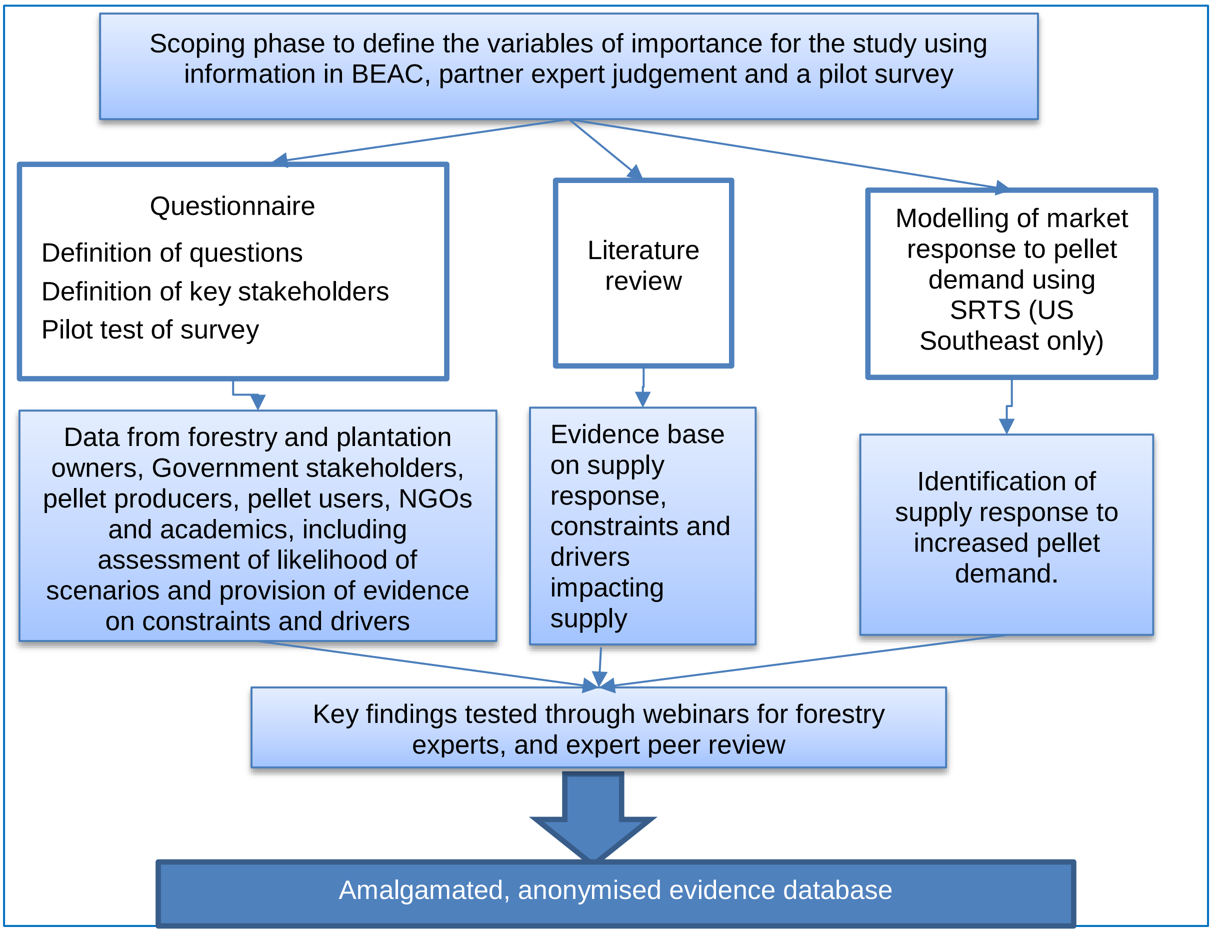
The methodology for these three approaches to evidence gathering was very different and, in some cases, complex. To make it easier to follow the methodology and results obtained from each type of evidence gathering we have structured the report in three sections:

- Chapter 3 describes the approach to the literature review. This is followed by Chapters 4 on USA and 5 on Canada that provide the literature review for these regions in the report.
- Chapter 6 describes the approach to the economic modelling of pellet supply in Southeast USA and provides a summary of the results to that modelling.
- Chapter 7 describes the methodology for data collection and analysis for the questionnaire of North American and UK stakeholders and provides a high level summary of results. This is followed by the results to the questionnaire in Chapter 8.
- The results for all sets of evidence are combined in Chapter 9

This is followed by a discussion of these results and conclusions in Chapter 10.

It can be seen in Figure 2-1 that economic modelling was only undertaken to support this work in Southeast USA which is the region most impacted by European pellet demand. This was important as BEAC does not use economic modelling. No economic modelling was undertaken in Canada, despite the significant pellet supply from Canada to the UK, because we did not find a Canadian model that was suitable for use in this work. However economic factors are included in the calculations of the Annual Allowable Cut (AAC) in Canada and we have included comments on the AAC in this report that refer to economic factors.

Figure 2-1 Schematic of method for data collection.



2.4 Validation of results

The evidence obtained through the three sources above has been reported in two ways. The first is this report. The second is an Analysis Tool that combines the results from the survey with the high level conclusions from the literature and the US modelling. Both of these have been subjected to peer review. The first peer review comprised a discussion of the results at webinars in North America. This allowed stakeholders in the North American pellet supply chain to have a review of the results and to comment on them from their experience. It opened up the work to a larger audience than the survey respondents (this audience was estimated to be over 800 for the Canadian webinar). The webinars were left on the internet for further feedback and comments for some weeks. The second stage of peer review comprised a panel of independent experts selected by UK Department of Energy and Climate Change (DECC).

- In Canada a webinar facilitated by Tat Smith was held by the CIF (Canadian Institute of Forestry). This workshop was held on 24th June and was supported by the International Energy Agency Bioenergy Agreement's Task 43. The webinar was open to members of CIF and publicised among forestry experts in Canada, including survey participants. The webinar is available[11]. We have considered comments received in the webinar and subsequently in this report.
- DECC's peer review was undertaken by key experts in the USA, Canada and UK.

[11] www.cif-ifc.org/wp-content/uploads/2015/06/CIF-IFC-webinar-slides_DECC-North-American-wood-pellet-survey-prelim-Canadian-results_24-June-2015.pdf and www.cif-ifc.adobeconnect.com/_a1112870713/p8syc4zm0l4/

3 Literature review: Methodology

Evidence was sought from the literature on the key variables that influence the likelihood of the scenarios. One thing that became clear very quickly was that few of the scenarios are envisaged in the literature. To overcome this we have examined policy and economic conditions (or other drivers or constraints) that may encourage or prevent the scenarios. This included evidence on the regulation of forestry, management of the forestry process and evidence on the economics of pellet production.

Note on the extent of the evidence in the literature review: The resources within this project were not sufficient to do a full rapid evidence assessment or scoping review such as those described in Collins et al (2014). Instead we evaluated the strength of the evidence as far as possible using the method outlined below. This means that detailed sources of evidence, such as management plans were not scrutinised, as time did not allow. The main sources of information was peer reviewed papers, Government data (e.g. statistics and regulations), trade body web sites (for statistics) and grey literature e.g. that published by NGOs, the industry and trade organisations, which is not peer reviewed. This allowed us to collect evidence on key issues of relevance to the likelihood of the high carbon scenarios in Stephenson and Mackay (2014), together with an indication of the strength of that evidence.

3.1.1.1 Evaluation of individual literature sources for strength of evidence and analysis

The literature was scrutinised against evaluation criteria using UK Government HM Treasury guidelines. The criteria used and examples for evaluation are provided in Table 3-1. Each source of literature was assessed for whether or not it included the criteria listed in Table 3-1. If it did include a large number of these criteria the evidence was regarded as good quality; if only a few of these criteria were satisfied the evidence was regarding as lacking and further evidence was sought. This was intended to cut out evidence not based on good quality data or based on a limited number of sites rather than general practice. If there were no sources that provided good quality evidence on a specific issue, then we have said that there is ‘no evidence’ or ‘evidence lacking’ for the issue in question. This is discussed in the next section on uncertainty.

Table 3-1 Criteria for assessing literature sources in terms of quality of evidence

These criteria were taken from UK Government Guidance (HM Treasury 2012)

Criteria for assessment	Example of how criteria can be evaluated
Findings	Credibility of findings from the literature source; how well the evaluation addresses the study’s original aims; the scope for drawing wider inference from the study; and the clarity of the basis of the evaluative appraisal.
Design	How defensible the study design is in terms of rationale, design and discussion of limitations.
Sample	How well defended is the sample design or target selection of cases? Is there a detailed profile of sample composition or case inclusion? Does the study describe the population of interest and how the sample relates to it? Is there a discussion of access and methods of approach?
Data collection	How well was the data collection carried out? Is the approach to analysis described? Is the context of the data sources described? Does the data collect allow description of multiple perspectives? Are outliers, negative cases or exceptions discussed? How well has detail, depth and complexity of the data been conveyed?
Reporting	How clear are the links between data, interpretation and conclusions; how clear and coherent is the reporting?
Reflexivity & neutrality	How clear are the assumptions/ theoretical perspectives/ values that have shaped the form and output of the evaluation?
Auditability	How adequately has the research process been documented? Is there a discussion of the strengths and weaknesses of data sources?

3.1.1.2 Treatment of uncertainty

Uncertainty in literature can be the result of two different factors:

1. Evidence or data may be lacking and as a result assumptions are made or data is provided from a limited dataset. For example there could be evidence on pellet use from one small site only, rather than on a regional basis; or evidence could be based on assumptions made about specific variables such as circumstantial evidence. Individual sources of literature based on such limited data would then not meet all of the criteria listed in Table 3-1, i.e. they would fail to meet the criteria for design or sample. If most of the literature on a particular issue is limited in this way then evidence on this issue is considered to be inadequate or inconclusive (see strength of evidence below).
2. There may be a lack of agreement within a dataset, represented by wide ranging results. For example, there may be lack of agreement on demand for pellets, depending on the assumptions used for pellet demand and how this will grow with time. The range of data is another indication of uncertainty for a specific issue and we have considered such data as inconclusive in the strength of evidence ranking below.

By examining the evidence in all pieces of literature on a specific issue an indication of uncertainty in the literature for that issue was obtained. This in combination with the amount of evidence and the extent to which that evidence covers the geographical area under investigation provided us with an indication of the strength of evidence. So, for example, regulation and legal requirements are certain (because they exist) and cover a wide area. This means that we can assign regulation a high strength of evidence. However, evidence on specific issues, such as the removal of forest residues from a particular type of forest or region may be less well documented in the literature and therefore the strength of evidence would be lower (e.g. ranked as inadequate or inconclusive). Another example is the economics of pellet production. Most of the evidence on this in the literature is based on modelling that makes assumptions about the price of the fibre for pellets. The assessment of these models would depend on the context of the model and the information provided on comparison with other data. The modelling may be of high quality, but the assumptions made may be based on less clear data: this may result in a downgrading of the data to inconclusive or inadequate.

3.1.1.3 Strength of evidence

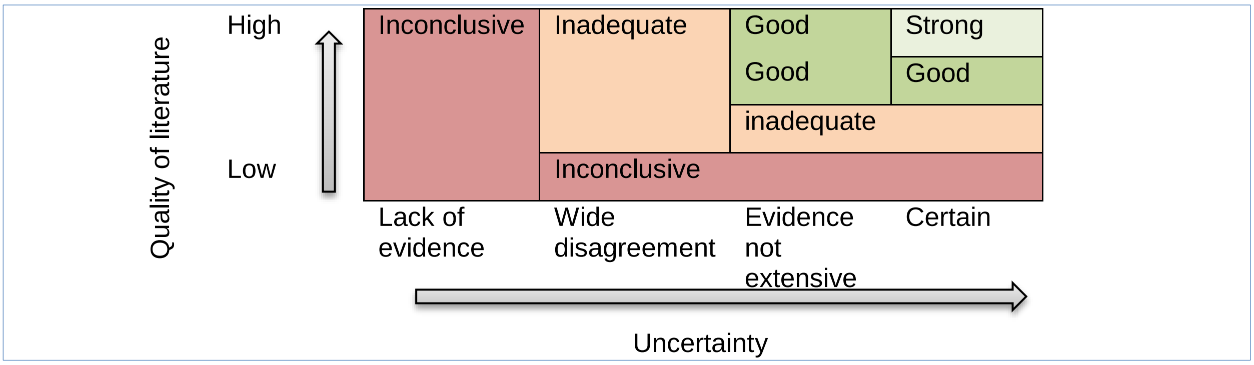
The assessment of the evidence from individual sources of literature was used together with the findings from all of the literature on a particular issue to provide an indication of the strength of the evidence on that issue (

Figure 3-1):

- Strong: literature evidence from sources that meet most of the criteria in Table 6 for most sources **and** good corroborative evidence across all sources of literature
- Good: Literature evidence meets most of the criteria in Table 6 for most sources, with good agreement between sources but there is limited evidence (limited by region covered or by the amount of evidence available)
- Inadequate: Literature does not include some of the criteria in Table 6 as evidence is missing or lacks some aspects of quality or neutrality and/or there is conflicting evidence presented by different sources
- Inconclusive: lack of evidence in the literature and/or many sources of literature lack a number of aspects of the criteria in Table 3-1.

These assessments are presented in the summary of evidence on the overview tab for each scenario in the Analysis Tool. The assessments are only related to the strength of evidence on a specific issues. In the case of the literature being ranked as inconclusive, this should be interpreted as meaning that more or better quality data or evidence is required, not that a scenario does or does not happen.

Figure 3-1 Assessment of strength of evidence in the literature: the strength of evidence is the combine scores as shown in the coloured blocks



The evidence reviewed is discussed in Chapter 4 for the USA and Chapter 5 for Canada by variable or issue that impacts the supply of fibre for pellets, e.g. ownership and regulation/governance, potential supply strategies, competing uses and economics. At the end of each of these chapters we have summarised the potential sources of fibre supply for pellets and the key factors that influence fibre supply, as well as what this means for the BEAC scenarios. In these chapters we have considered all sources of fibre for pellets, including the ones that had low carbon impact in BEAC, so were not included in this study. This enables us to put the potential supply in the BEAC high carbon impact scenarios into perspective.

We have used this summary to reach a view on whether the literature provides evidence that the BEAC scenarios are likely or not. If this evidence is inconclusive we have said so. These high level summaries are presented in Chapter 9 of this report, which brings all of the results together.

4 Overview of forestry in the United States

4.1 America's forest resource

Forests cover about 310 million hectares (766 million acres) of the United States' land area, totalling about 33% of the nation's land area (Oswalt et al. 2014). Forest land in the US is roughly evenly split, with 55% and 45% of forest land occurring west and east of the Central Plain, respectively (Oswalt et al. 2014) (Figure 4-1 shows the forest regions; Table 4-1 presents area of forest).

Figure 4-1 Forest Assessment regions of the US, as defined by the USDA Forest Service Forest Inventory and Analysis Unit. From Smith et al. (2004).

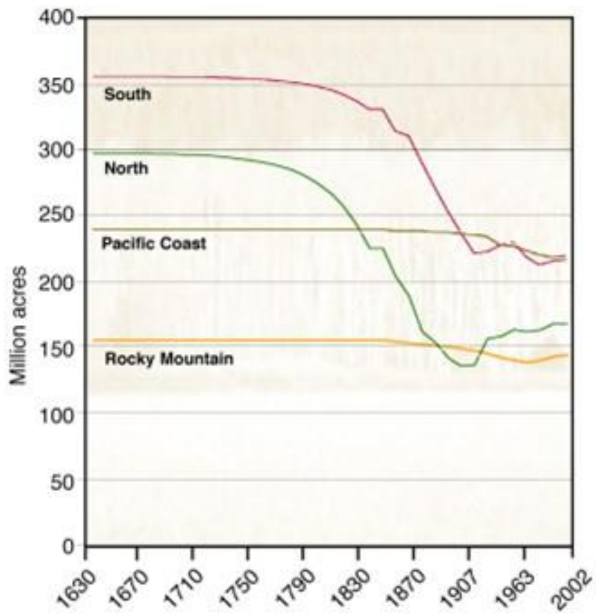
Of the 310 million hectares (766 million acres) of forest land, 211 million hectares (521 million acres) (roughly 68%) are defined as "timberland," meaning that they are capable of producing at least 1.38m^3 timber/ha/y (0.56 m^3 (20 ft^3) timber per acre per year) and not legally withdrawn from timber production (Oswalt et al. 2014).

Forest land area in the US has been reasonably stable for the last 100 years (Figure 4-2) following significant deforestation of the North and South in the 1800s, though recent years have seen a very slight increase in forest and timberland area in the North and South (**Table 4-1**).

Table 4-1 Forest land area in million acres, between 2007 and 2012 by region. From Oswalt et al. (2014).

Region	2007		2012	
	Forest	Timberland	Forest	Timberland
	Hectares (acres)			
North	70 (172)	66 (164)	71 (176)	68 (167)
South	95 (235)	83 (204)	99 (245)	85 (210)
Rocky mountains	53 (131)	30 (75)	54 (132)	29 (71)
Pacific coast	87 (214)	30 (75)	87 (215)	30 (73)
Total	305 (752)	208 (514)	310 (766)	211 (521)

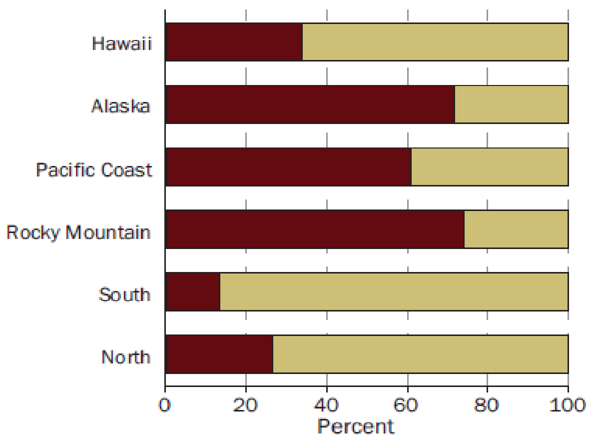
Figure 4-2 Trends in US forest area from the 1600's to 2002. From Smith et al. (2004).



4.1.1 Forest ownership in the US

The majority (58%) of forest land in the US is privately owned by individuals, families, Native American tribes, partnerships, corporations, non-governmental organisations, and other private groups. The remaining 42% of forest land is controlled by Federal, State, and local governments. This pattern varies across the country, with private ownerships dominating in the North and South (74 and 87% of forest land, respectively) and public ownerships dominating in the Rocky Mountains and along the Pacific Coast (74 and 61% of forest land, respectively) (Figure 4-3). The pellet export from the US to the UK comes largely from the US Southeast. For this reason this study concentrates on forestry practice in the US Southeast.

Figure 4-3 Forest ownership trends in the US by region (2012). Source: Oswalt et al. (2014).



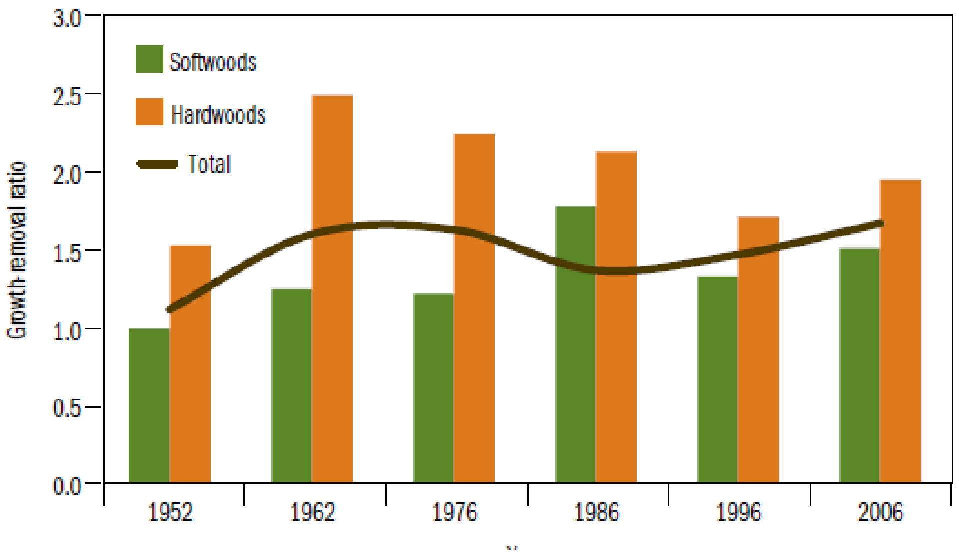
	North	South	Rocky Mountain	Pacific Coast	Alaska	Hawaii
	million acres					
Public	46.5	32.7	97.5	51.4	92.5	0.6
Private	129.1	212.0	33.8	32.9	36.1	1.2

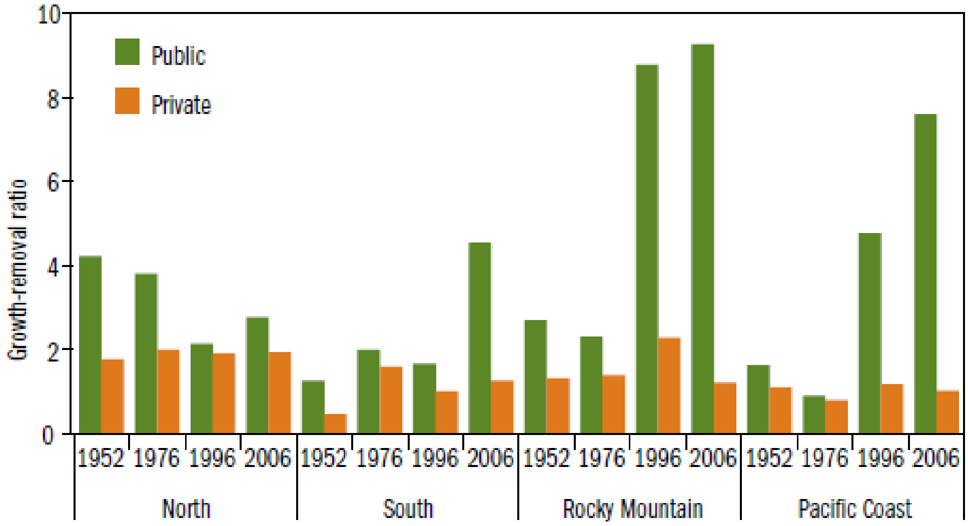
The US has an estimated 11 million private landowners. While 61% of these landowners own fewer than 4.05 hectares (10 acres), most (67%) of the private forestland in the US is in holdings of at least 40.5 hectares (100 acres). Twenty-two percent of private forest land is in holdings of at least 4,050 hectares (10,000 acres) and is owned by less than 1% of the owners. These are lands held by corporations or investment organizations and largely managed for commercial purposes (Oswalt et al. 2014). Private forests provide more than 90% of the wood and paper products produced by the US, compared with less than 2% provided by forests from public lands (Oswalt et al. 2014). Further information is provided on forest ownership and the factors that influence this in Section 4.3.2.

4.1.2 National timber growth and harvest trends

The ratio of net growth and growing-stock removals (G:R) is important because it measures the extent to which forest growth is outpacing harvest. A ratio < 1 indicates that harvests exceed growth on an annual basis, while a ratio > 1 indicates that growth is outpacing harvest. Forests in the US overall have a Growth:Removals (G:R) >1 (Figure 4-4), though we note that G:R is greater for hardwood forests than for softwood forests. This is because the traditional uses of hardwood are decreasing in the USA therefore these forests are growing more than they are being harvested (including regional reductions in harvesting hardwoods for fuels in the South and North regions (Smith et al 2009). In addition, G:R varies by ownership and by region, such that publicly-owned forests have a G:R ratio far in excess of 1 while the removals and growth are closer together for private forests (Figure 4-4). These graphs show how forest inventory has changed over the 50 year period to 2006. Even in the US Southeast, which produces a significant part of US forest products, the G:R ratio has been >1 in the past 30 or so years. Figure 4-4 also shows the cyclical nature of G:R ratios, which has important implications when looking at carbon stocks and means that caution should be exercised when looking at single points in time.

Figure 4-4 Growth: Removals for US softwood and hardwood forests through time (top) and broken down by ownership type and region (bottom). From Smith et al. (2009).





4.2 Domestic timber demand

4.2.1 Timber products

Timber removed from US forests is typically:

- sawtimber that goes to mills for processing
- residues (volume cut but not used) that do not otherwise have economic value and
- wood removed as a result of land clearing or pre-commercial thinning.

Removals from growing stock were relatively constant between 1996 and 2006, but as demand for sawtimber fell due to housing market slowdown during the recession, they declined sharply between 2006 and 2011, particularly in the US Southeast (Figure 4-5). Softwood harvests had declined by 16% and hardwood harvests by 20% in 2011 compared to 2006.

Once the wood is harvested, the majority of the timber goes to saw logs, with pulpwood and fuelwood being the next most important forest products. Although saw log production dropped sharply from 2006 (as stated above) the volume of other product types has remained reasonably stable (Figure 4-6). There has also been a decline in the US pulp and paper industry (Figure 4-7). However, the use of pulpwood (small roundwood) has remained important because of its increasing use in other products such as oriented strand board (OSB).

Even so, Figure 4-6 shows the continuing dominance of the US Southeast in US timber harvests. This dominance and its position on the Eastern seaboard is the main reason why UK (and European) pellet users are attracted to production in the Southeast USA.

Figure 4-5 Growing-stock removals (harvests) in the US by species group, region, and year, 1952-2011. From Oswalt et al. (2014). (Note: 1 billion cubic feet is 28 million cubic meters)[12]

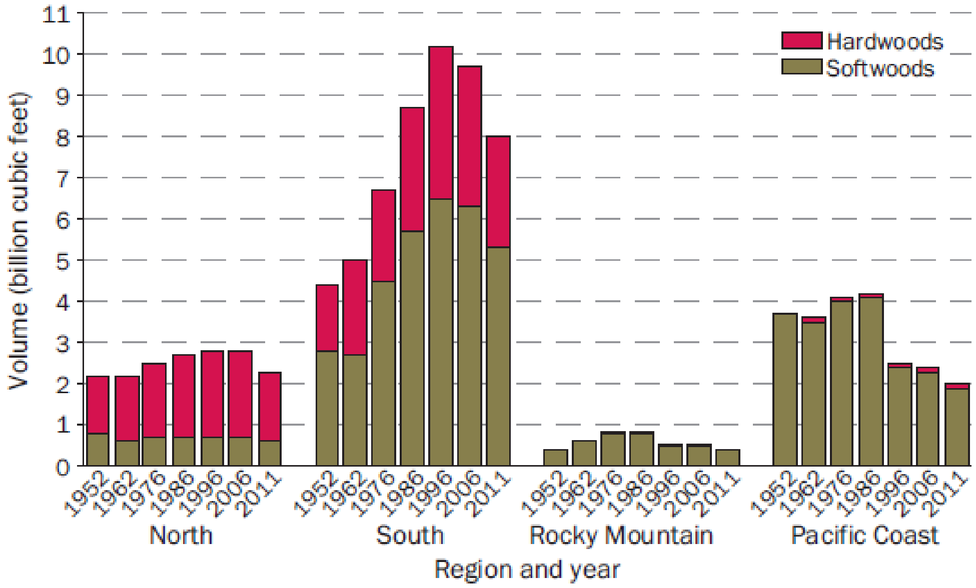
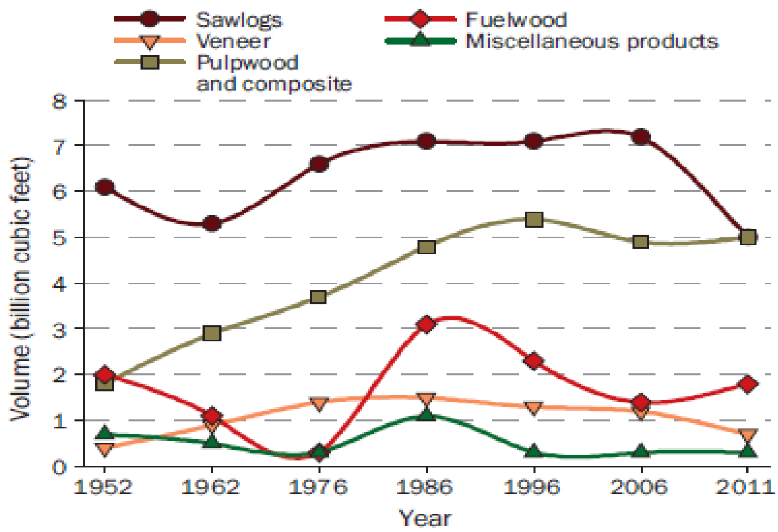


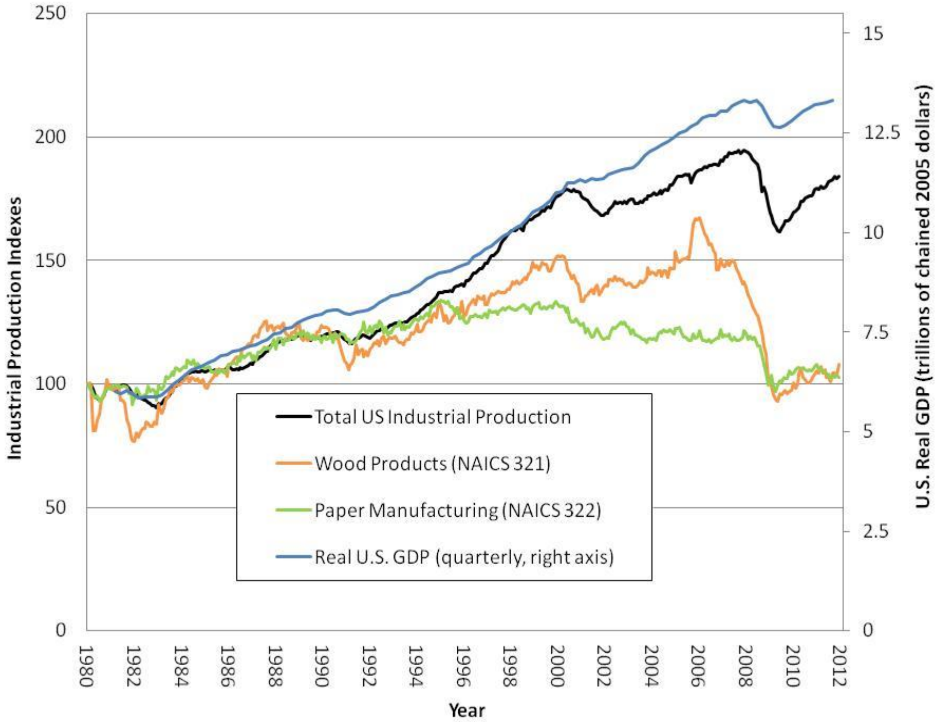
Figure 4-6 Trends in US production by primary product, 1952-2011. From Oswalt et al. (2014).

Note: fuel wood here refers to logs used for residential fuelwood, i.e. for use as fuel in homes.



[12] It is not easy to convert cu m of wood to tonnes. This is because the calculation is one that depends on density. Depending on species the density of wood varies considerably between 250kg/t to 1000kg/t.

Figure 4-7 Trends in the pulp and paper sector (as defined by industry NAICS codes) compared to real GDP from 1980 to 2012 (Jan 1980 = 100). From Woodall et al. (2012).

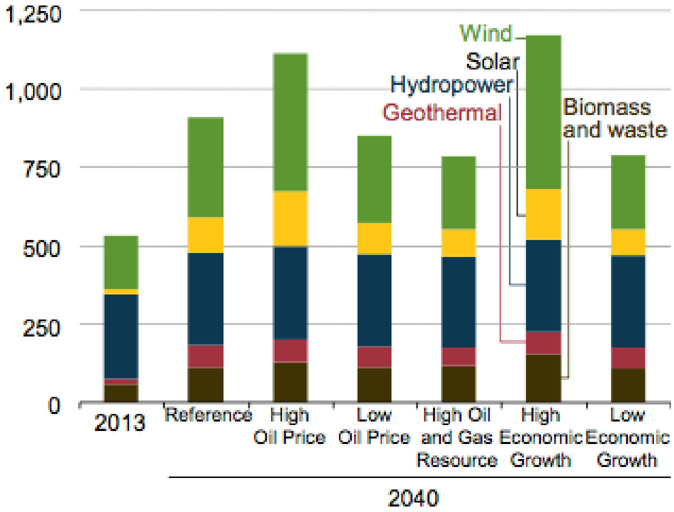


4.2.2 Wood bioenergy

Domestic demand for wood-based bioenergy has historically been very low in the US (Ince et al 2011). However, these domestic trends may change due to Federal and State-level requirements. At the State level, renewable portfolio standards (RPS) require that a portion of electricity be generated from renewable sources, whether solar, wind, or biomass. It is notable that the States making up the US Southeast do not have RPS (Union of Concerned Scientists 2013)

The level of domestic demand for bioenergy may also change depending on how States choose to treat biomass as they design state compliance plans for the Clean Power Plan. State plans are due to the USEPA in September 2016, but extensions until 2020 will be available for States needing extra time. Compliance obligations will begin in 2022. Overall, the US Energy Information Administration (EIA) (2015) predicts that renewable energy will be responsible for a third of new generation capacity through 2040, with biomass generation increasing by about 3.1%/year on average, primarily due to increases in coal co-firing (EIA 2015). This gradual increase in domestic bioenergy generation is not likely to affect the supply of wood to Europe, all else being equal, given the scale of projected European demand compared to the projected scale of domestic demand. Other renewable energy technologies are expected to meet larger shares of domestic demand for electricity (Figure 4-8).

Figure 4-8 Expected increase in renewable generation, 2040 (Results to modelling for six different scenarios. Units: billion kWh). From EIA (2015).



4.3 Forests in the Southeast US

4.3.1 Forest characteristics

As of 2007 the forests in the Southeast region of the US (Figure 4-9) accounted for 30% of the unreserved forest area and 27% of the total forest land nationwide (Smith et al. 2009). The most common prevalent forest type are loblolly-shortleaf pine stands, which cover 22.3 million hectares (55 million acres) (Smith et al. 2009) and longleaf-slash pine forests, which make up 19% of the southern pine land area (this type is being lost to fire and conversion to faster-growing loblolly-shortleaf pine plantations (see Box 4-1 for more information on these conversions), and is mostly concentrated in Florida and Georgia). In 2000, pine forest area was roughly half planted and half naturally regenerated (Figure 16). Oat-pine forests cover around 9.3 million ha (23 million acres). Forests consisting of mixed stands of oak, gum and cypress are found in wetter sites, and now total 8.1 million hectares (20 million acres) in the Southeast (these forests were once common in the Southeast but many have been lost through conversion of bottomlands to hardwood (Smith et al. 2009)).

The clearest trend in southern forest land area is the decline in natural pine stands with their replacement by planted pine stands (Figure 4-10, Wear et al. 2007). Pine plantations have expanded steadily, from practically none in the 1950s to more than 21.15 million hectares (30 million acres) in the late 1990s. Pine plantations account for about 16% of all timberland area in the Southeast (Wear et al. 2007). Since 2000, the acreage in new plantations has declined substantially (Figure 4-11). Box 4-1 expands on these trends and the reasons for them.

These forest types are important in the BEAC model: they represent significant timber resources and common forest types from which fibre for pellets might be extracted. BEAC also envisages scenarios in which naturally regenerated forest is replaced with intensive plantations in the US Southeast. These figures show that if this happens it is likely to be a continuation of a trend that has been happening in the US Southeast for the production of saw logs and pulp wood since the 1950s.

Figure 4-9 Map of Southeast USA showing forest cover types

(Source: http://www.fia.fs.fed.us/library/maps/docs/forestcover.pdf, accessed 2015)

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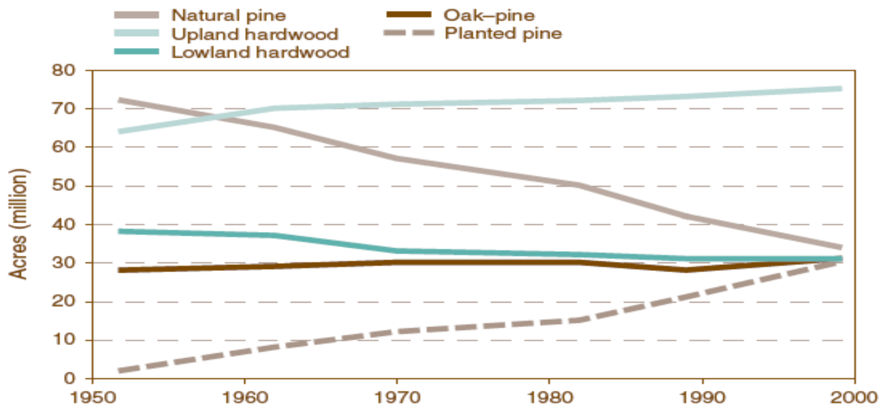
Figure 4-10 Area of forest types in the US Southeast. From Wear et al. 2007

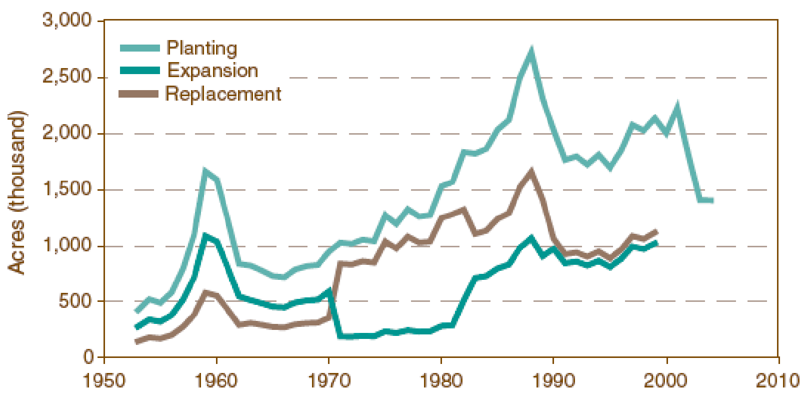


Box 4-1 Development of tree planting in the US Southeast from the 1940 (taken from Wear et al (2007)

"Planting in the Southeast appears to be strongly influenced by market signals, i.e., anticipated returns to the planting investment (see Newman and Wear 1993). However, it has also been influenced by governmental programs that reduce the costs of forest establishment for nonindustrial forest owners. Federal programs have encouraged tree planting on nonindustrial private forest lands with the objective of enhancing future timber supplies (for example, the Forestry Incentives Program) or achieving conservation objectives by planting agricultural fields (for example, the Conservation Reserve Program, or CRP). In addition, several States have employed similar tree planting programs for private landowners.

Tree planting in the Southeast grew from essentially none in 1945 to an average of between 1.5 and 2 million acres per year in the 1990s (Figure 4-11). The pattern of tree planting shows distinct spikes in the 1960s and 1980s corresponding to the Soil Bank and CRP tree planting programs, respectively. These programs were restricted to nonindustrial private forest lands. Except during these two periods, tree planting has been dominated by forest industry and concentrated on the 20 percent of timberland controlled by this ownership. In the period between the Soil Bank and CRPs, the industry share of planting rose to about 70 percent of the total. Since the CRP, industry planting has constituted about 50 percent of total planting."

Figure 4-11 Area of forest planted in the U.S. Southeast for forest area expansion and for replacement of harvested trees on existing forests, 1952-2005. From Wear et al. (2007).



4.3.2 Forest Ownership

4.3.2.1 Patterns of forest ownership

Private forest land owners in the US typically fall into one of two categories: industrial and non-industrial forest owners. Industrial forest owners are corporations and other private groups that own and operate primary wood-processing facilities. Non-industrial private forest (NIPF) owners include corporations, families, individual, and other private groups that do not own and operate primary wood-processing facilities. Family forest owners are a subset of this NIPF category; these are families, individuals, trusts, estates, and other unincorporated groups that own forest land (Butler 2008).

Different categories of forest land owners are likely to have different motives for owning forest land: thus, ownership patterns influence the likelihood of harvest and the likelihood of forest conversion to another non-forest use, as well as the type and frequency of management activity. In the Southern US, 58% of the forest land is owned by family forest owners, defined as non-industry, unincorporated forest land owners, while 28% of the forest land is owned by other private landowners (including both industrial and non-industrial) (Figure 4-12). Box 4-2 provides a profile of family owners of forest in the USA from 2006. This shows that timber production is a main motivation for only 10% of them; in 2006 the main reasons for harvesting related to maturity and improving quality of trees; and that in their five year plans harvest for commercial purposes (excluding firewood) was not a high priority.

It is worth noting that the proportion of land held by the “other private” category is higher in the Southeast (at 28%) than in any other US region: much of the land in Southern forests today is owned by incorporated private entities, whether industrial or not. Figure 4-13 shows how the share of ownership changed between 1945 and 2005.

Different categories of landowners, and even different landowners within a category will have multiple and varying reasons for owning forest land, so pellet demand is just one factor of many that influence the harvest of forests in the US Southeast (see drivers of forest harvest in Section 4.3.2.2below as well). This is important with respect to the BEAC analysis. It means that pellet demand is just one factor of many that influence the harvest of forests in the US Southeast. Proving that pellet demand alone is driving increased harvest would not be easy.

Figure 4-12 Distribution of forest ownerships in the US (selected data from Butler 2008, using survey data for 2006).

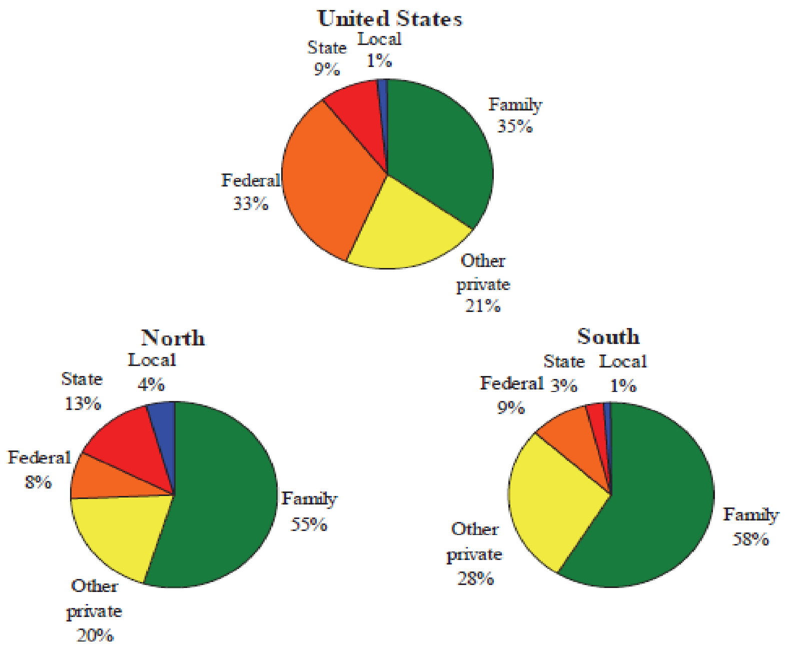
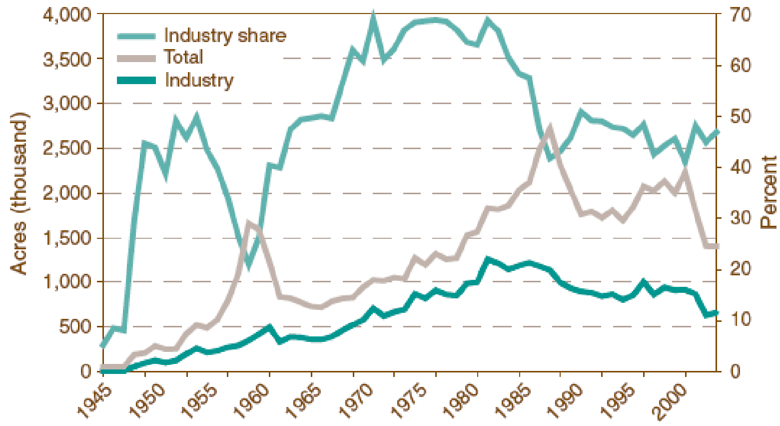


Figure 4-13 Acreage in industry owned and total plantations (left axis) and share of plantations in the US Southeast owned by Industry versus all other ownerships (right axis), 1945-2005. From Wear et al. (2007).

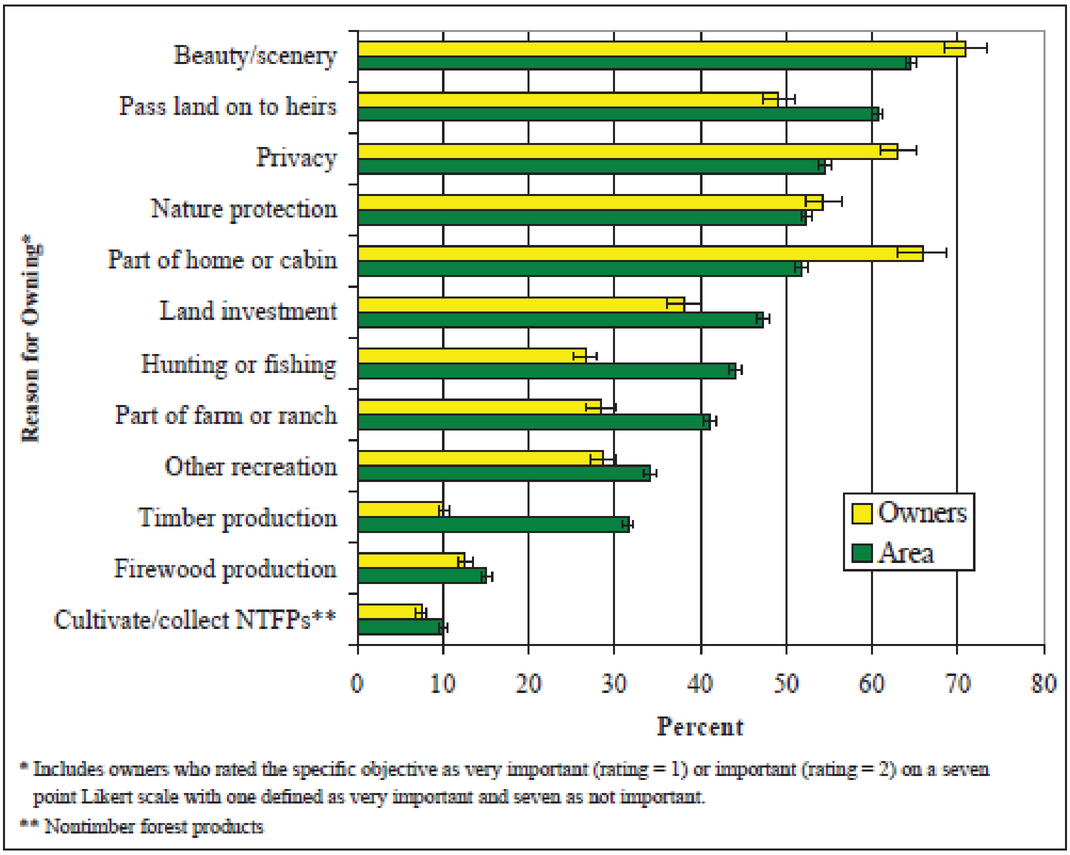


Box 4-2 Characteristics of family owners of small scale forest in USA (taken from Butler 2007)

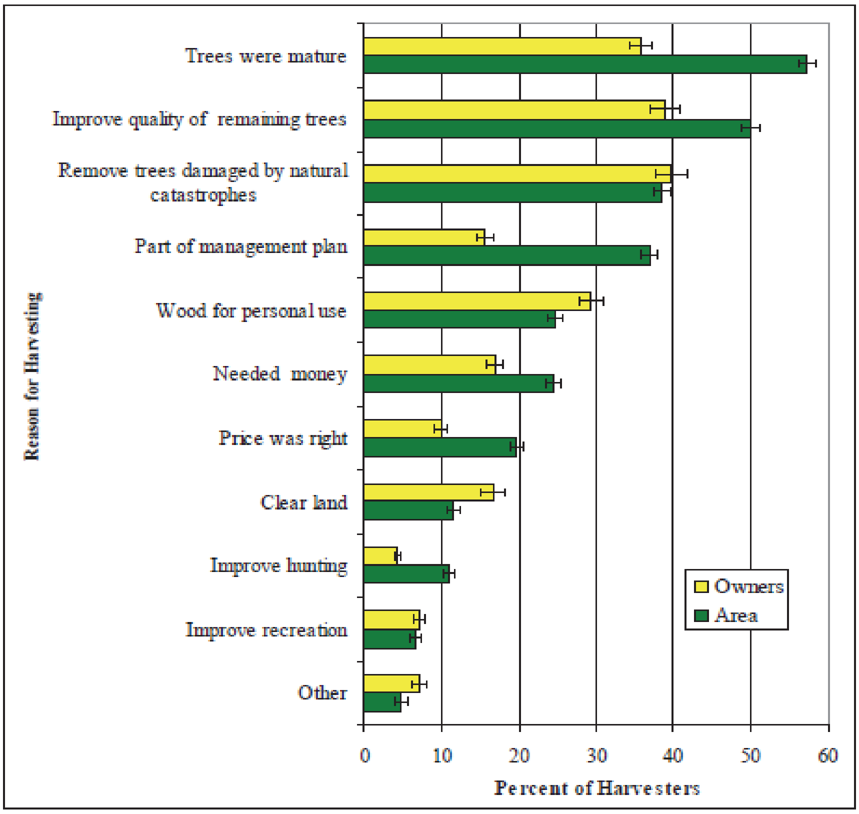
In the US Southeast family owners are a significant part of forest ownership (Figure 4-12). In Butler's 2006 survey 4% of these owners had a management plan (representing 17% of the forest area) and a further 15% sought professional advice (37% of forest area).

The following charts provide some background to the motives for family ownership of forest land in the USA. Note: Firewood refers to logs that are sold for home heating or campsites (USDA 2010)

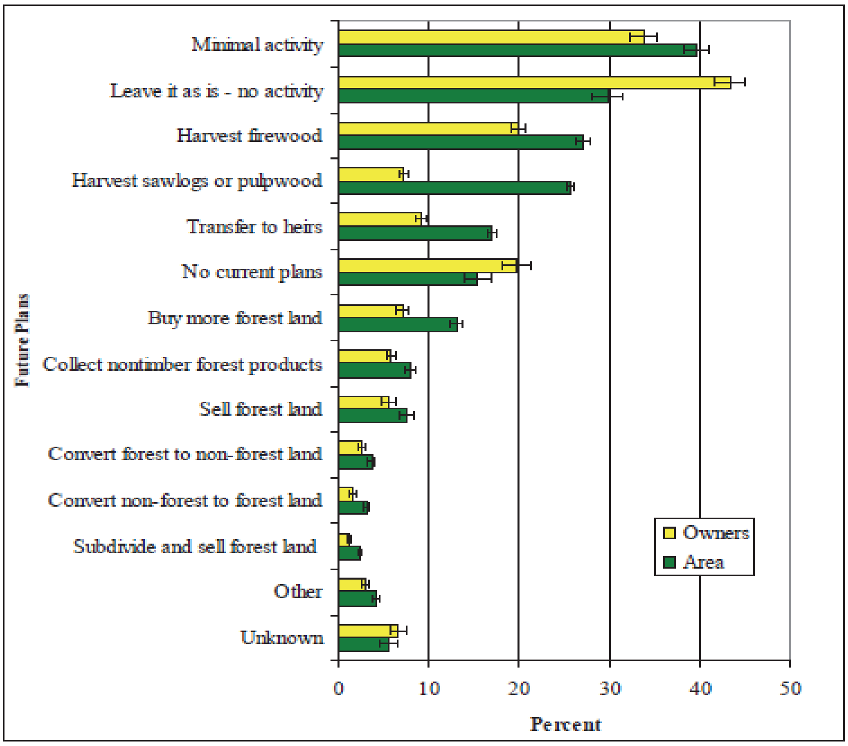
Reasons for ownership (USA family forest owners, 2006)



Reasons for harvesting (USA family forest owners, 2006)



Plans of family forest owners in USA (2006-11, surveyed in 2006)

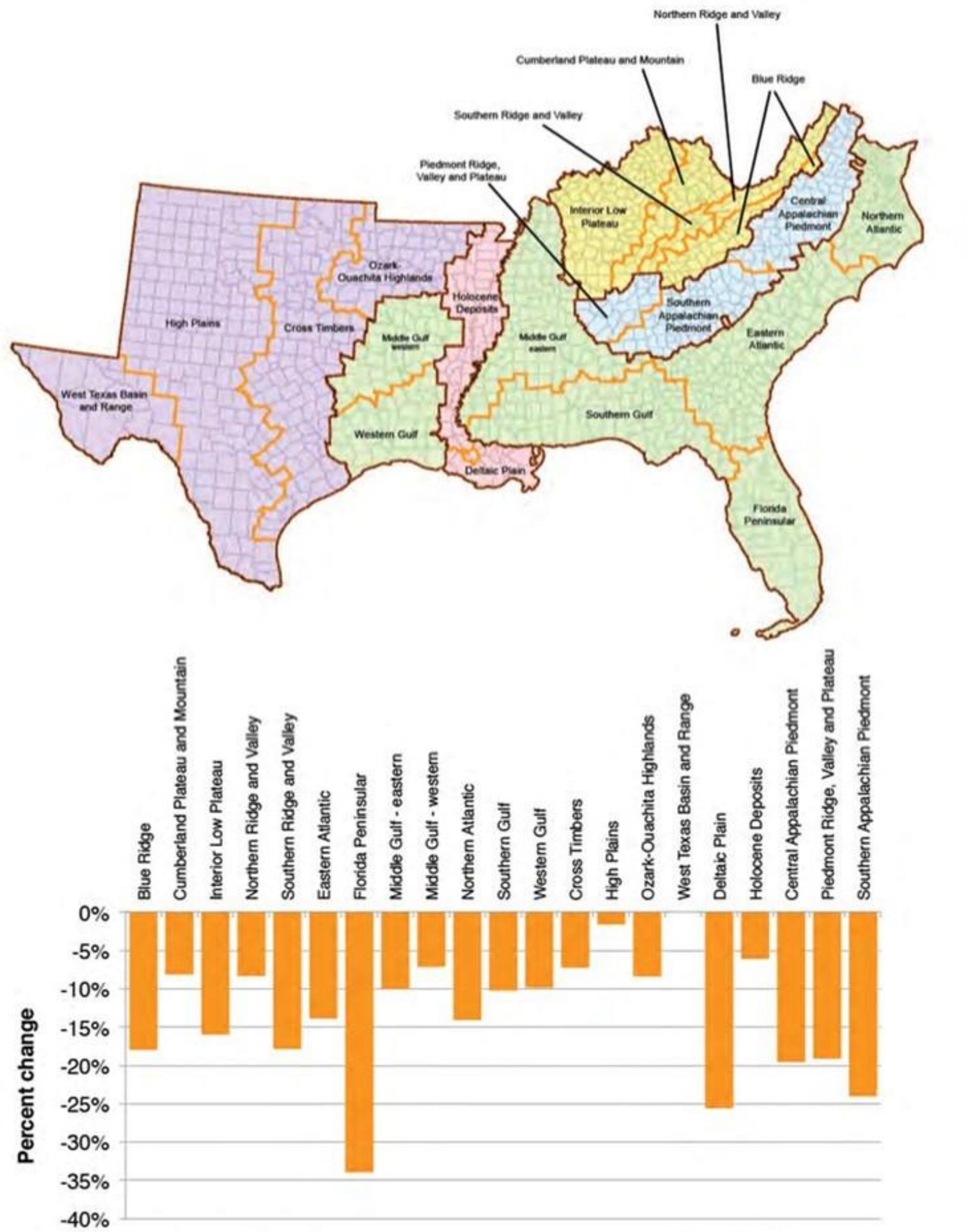


4.3.2.2 Drivers of forest harvest rates

In general, NIPF landowners are motivated by the revenue they can achieve from timber harvest. As a result, the price of timber is an important determinant of willingness to harvest (WTH) (Aguilar 2014). At the same time, a robust market for woody bioenergy would is likely to enhance the WTH of many landowners, especially those who i) are financially motivated, ii) consider management for certain habitats to be an important goal (and thus would not harvest under normal circumstances), and/ or iii) are sympathetic to the importance of global climate change (assuming the harvesting would result in low carbon energy). Thus a robust market for woody bioenergy would likely lead to added availability of woody biomass from managed forests (Gruchy et al. 2011, Joshi and Mehmood 2011). However, in order to realise a robust bioenergy market even at high prices, some education of small private landowners may be necessary. Research has found that many landowners are not aware of the additional revenue potentially available from harvest of woody bioenergy (Joshi et al. 2015), so it is not certain that this additional harvest would occur without an investment in education of landowners. A robust market for forest-related commodities will also help to keep forests intact and further enhance supply, as landowners who can realise revenue from timber might be more likely to choose to keep their land in forests rather than convert it to agriculture (Wear and Greis 2013).

Land conversion to urban uses is projected to be significant: future trends in population and income growth point to at least a doubling of developed land uses in the Southeast by 2060 (Wear and Greis 2013). Mondal et al (2013) confirmed these trends. Associated with this urbanization is a likely loss of forest land, ranging from 4.5 million hectares (11 million acres) (7%) to 9.315 million hectares (23 million acres) (23%), depending on expected effects of economic growth and market futures for timber prices (Wear and Greis 2013). Forest loss is expected to be most substantial in areas where urbanization is likely to be most intense, such as peninsular Florida and the Piedmont (Figure 4-14).

Figure 4-14 Predicted percentage change in forest land by Southern region, 1997-2060 based on intermediate Cornerstone B scenario (from Wear and Greis 2013). Cornerstone B is characterized by high population and income growth accompanied by decreasing timber prices and planting rates.

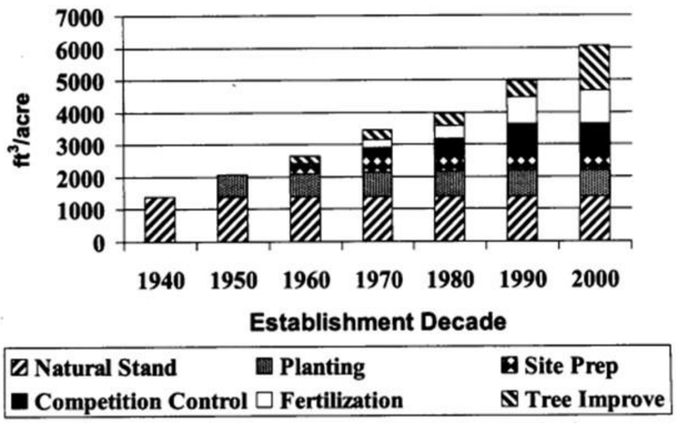


4.3.3 Forest management

4.3.3.1 Pine plantations

Forest management regimes in the Southeast differ depending on the type of forest. Planted pine stands are typically managed on an even-aged basis with rotation ages from 25-35 years (Dickens et al. 2014; Pöyry 2015). Evidence from the questionnaire is that a 25 year rotation is most common. There may or may not be an intermediate thinning (or two) before the stand is harvested and replanted. Southern pine plantations are among the most intensively managed forests in the world, with growth rates up to 400 ft^3 acre/ year ($28m^3$/ha/y), having achieved impressive gains in productivity over the last 50 years via extensive investments in genetic improvements and intensive fertilization (Fox et al. 2007, Figure 4-15).

Figure 4-15 Attribution of increased pine productivity improvements to various silviculture practices, 1940-2000. From Fox et al. (2007).



4.3.3.2 Natural hardwoods

Southern hardwood stands tend to be the result of prior land use rather than purpose planted for modern forest products. In many cases they have resulted from natural regeneration as agriculture was abandoned. Thus, while they may be harvested for timber today, they were rarely established on purpose by planting. Instead, southern hardwoods tend to be naturally regenerated, uneven-aged, and selectively harvested (Conner et al. 2004).

4.4 Projected timber supply

Timber supply is a function of price: as demand goes up, the price will increase as well and the amount of timber harvested will increase. If there is excess supply in the market, then the price will be likely to stay the same or decrease until the excess supply is used up and then the price will increase until supply is available to meet the added demand. The total supply of wood can be thought of as an interlinked system of various wood types, where sawtimber is the highest value product and is thus usually the main driver of the harvest decision. Pulpwood consists of smaller trees, which are more often used for bioenergy and typically fetch a lower price.

Projections of future timber, OSD, paper and pulp and biomass supply can vary substantially from one another, due to differences in methodology and assumptions about future policies, market demand and landowner response to policy and market drivers, such as changes in planting and harvest rates. Projections of standing stock based on current estimates of volume growth and projected demand in the wood products market (Nepal et al. 2012) estimate slight declines in hardwood inventory and slight increases in softwood inventory out to 2050 (Figure 4-16). Projections incorporating likely future demand from all wood sources anticipate a surplus of wood from the SE US in 2025 (Pöyry 2014, Figure 4-17).

Figure 4-16 Projected inventory in Southern softwood (left) and hardwood (right) forests by decade to 2050. Source: Nepal et al. 2012.

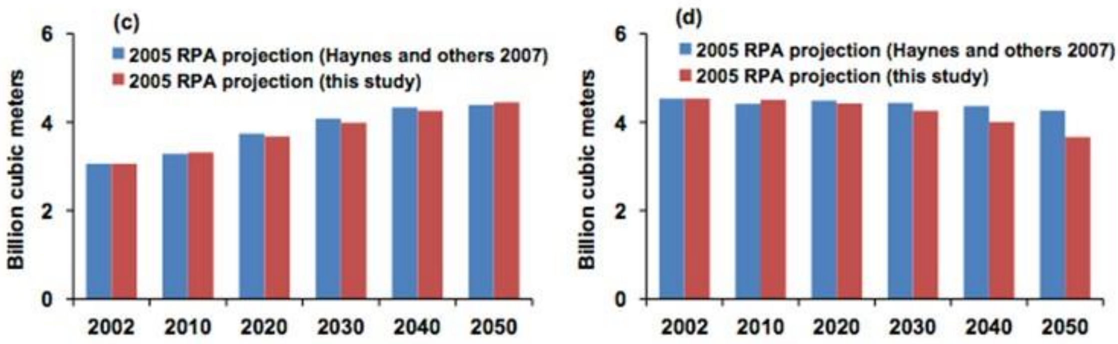
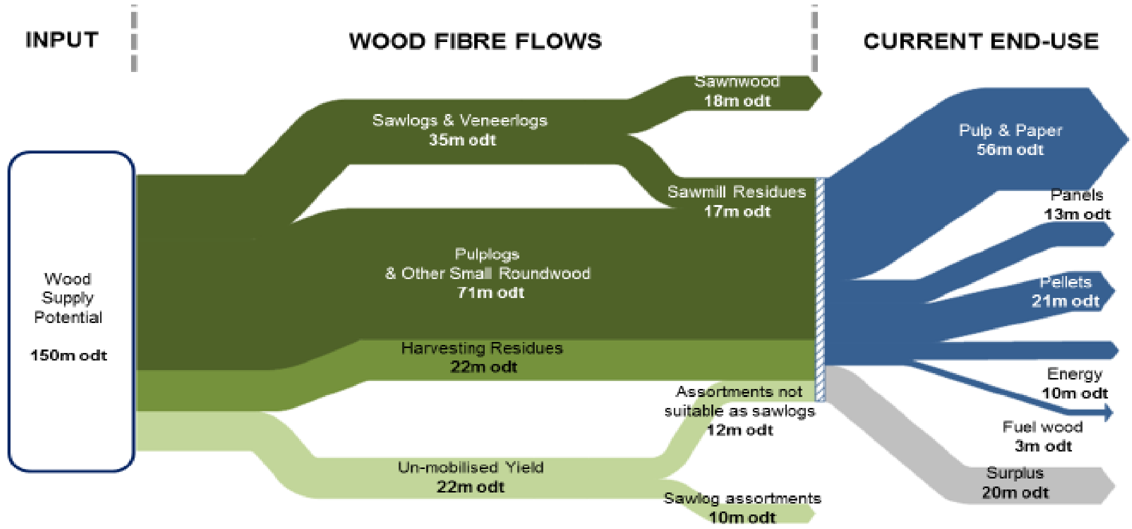


Figure 4-17 Projected flows of wood biomass by input and end use, 2025. Source: Pöyry 2014



It has to be noted that these are all projections based on assumptions about future markets. As shown in 4.3.3.2 there is an alternative view, which is that population and other pressures will result in increased urbanisation in some regions of the Southeast. This shows that there are a number of potential futures depending on the state of the economy and the wood sector and that some regions in particular may come under pressures from outside of the timber market.

4.4.1 Residues

4.4.1.1 Mill co-products

Mill co-products are defined as the residues from milling operations. These are linked to the supply of sawtimber because they are a profit-adding co-product of the milling process at sawmills and veneer/ plywood mills (Abt et al. 2014). Mill co-products are often completely utilised at the mills where they are generated either for energy or for board manufacture. Where they are not used they are waste products that would otherwise be left to decompose and are often used for pellet production.

4.4.1.2 Logging residues

Logging residues are the tree components remaining behind after the higher-value material is taken away, and are typically of little to no value in the sawtimber or pulpwood market. These residues can be recovered and used for energy purposes or for pellet production, but until recently few estimates existed of the amount of residue available and its recovery cost (Gan and Smith 2006). A key factor is the potential recovery rate of forest residues: different studies have used widely varying assumptions about the proportion of logging residues that can be recovered following harvest (BERC 2012).

An additional complication is the practical definition of logging residues: in some analyses, logging residues are lumped together with thinnings, making it difficult to distinguish between the residues, which would otherwise have been left to decay, and fuel or treatment thinnings, which would have otherwise been left standing (Forisk 2011). However, as the BEAC work shows, these two different counterfactuals would likely result in pellets with very different greenhouse gas impacts. Whether or not a forest landowner chooses to harvest logging residues associated with a sawtimber harvest depends on the market value of the residues, as well as the economic cost of conducting the recovery operation. The finer the residue, the more difficult and expensive the recovery operation because small pieces tend to be mixed with unmerchantable components like dirt and debris.

Gan and Smith (2006) report that logging residues from growing stock forests in the US might total 13.6 million tonne/ year, with about two-thirds of this potential in the Southeast and South Central regions. Galik et al. (2009) report that logging residues might total 5.9 million tonne / year in VA, NC, and SC alone. More recent assessments of supply report logging residue availability for the SE US between 13.9 million dry tons/y (BERC, 2012) and 28.4 million dry tons/y (Forisk, 2010)[13]. The USDA billion ton

[13] These estimates are equivalent to 12.5 million oven dried tonnes/y and 25.8 million oven dried tonnes/y.

study reported that logging residue availability might vary by a factor of 3 depending on biomass price (Department of Energy 2011).

Hoefnagels et al. (2014) analysed the price-dependent availability of residues including unmerchantable forest residues, pole mill residues and discarded pallets to conclude that it would be economically advantageous to produce pellets using these feedstocks at pellet prices between $82 and $100/ tonne (approximately £55 – 67/tonne or $74.5 – 91/ton), but we note that this price does not include transport costs. To put this into perspective spot price indices for Europe have been reported in the range £6-7.50GJ/tonne (£5.5 – 6.8/ton) (at the port, CIF) or around $150 to $190/tonne ($137 – 173/ton) over the past couple of years.

4.5 Guidelines for forest management

Forest management can be influenced by requirements in regulation or by voluntary management practices or certification. The extent and influence of these in the Southeast USA is described below.

4.5.1 Federal land management regulations

There are few, if any, Federal regulations for private lands that mandate particular harvest regimes or specify land management practices. Instead, landowners are required to abide by Federal and State environmental regulations that measure outcomes, specifically with respect to water quality or endangered species conservation. The pieces of legislation most relevant for private landowners in the US Southeast are:

- The **Clean Water Act** (North Carolina Forestry Association 2015) **-** sets the basic structure for regulating discharges of pollutants to waters of the United States. Federal regulations define wetlands as "…areas inundated or saturated by surface or groundwater at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. Wetlands are considered waters of the U.S. and are subject to federal regulations under the Clean Water Act. Ongoing forestry operations are exempt from obtaining a 404 dredge and fill permit provided that certain requirements are met. To maintain this permitting exemption, the forestry operation (1) must be established and ongoing; (2) must not change or convert the wetland to an upland; (3) must not change the use of the wetland where the reach and flow of waters are impaired. Change in use is generally defined as changing forest land to agriculture, or forest land to development or similar changes. Conversion to upland is also a change in use.
- The **Endangered Species Act of 1973 -** protects animal and plant species currently in danger of extinction (endangered) and those that may become endangered in the foreseeable future (threatened). It also provides for the conservation of ecosystems upon which threatened and endangered species of fish, wildlife, and plants depend, both through Federal action and by encouraging the establishment of state programs. Thus, landowners are required by law to maintain habitat for those species protected under the ESA.

Additional regulatory action at the Federal level may influence forest management activities indirectly, via markets and incentives (rather than directly through regulation of land management practices).

4.5.2 State-level land management regulations

Few protective regulatory policies in the US are specifically directed at managing private forests. Instead, as described above forest management is generally only affected when activities have the potential to impair water quality, air quality, or critical habitat for endangered species. While none of the States in the Southeast has a comprehensive forest management act, Florida and Virginia do have aggregated individual statutes that function together in a fairly comprehensive way. Florida's approach includes zoning and harvest notification at the county level, and BMPs for wildlife, water, and aesthetics at the water management district level. In Virginia, a seed tree law[14] is utilized in conjunction with voluntary best management practices (BMPs) and regulation of loggers. In Kentucky, the Forest

[14] Virginia's seed tree law stipulates that after a harvest event at least eight cone-bearing pine trees 14 inches or larger in diameter on each acre must be left uncut and uninjured. If a seed tree 14 inches in diameter or larger is not present on any particular acre, two of the largest diameter trees present must be left in its place. The seed trees must be left uncut for three years following the timber harvest. (Virginia Department of Forestry).

Conservation Act establishes guidelines for loggers and mandates BMPs (though it is not comprehensive). With those exceptions, few of the State-level regulatory policies directly address forestry and forest management (Granskog et al. 2008).

4.6 Best Management Practices (BMPs)

Forestry BMPs refer to systems or processes that are put in place to ensure that forest harvest practices ensure environmental integrity. Developed as a requirement to grant an exemption to silvicultural activities in the non-point source pollution permitting requirements of the Clean Water Act, BMPs are now common practice and 86% of timber operations nationwide use them (Kittler et al. 2012). Overall, they provide guidance on streamside management zones, forest roads, stream crossings, timber harvesting, and site preparation. When properly applied they can successfully mitigate the long-term water quality impacts of forestry activities. However, it is important to note that they are not always mandatory and enforcement of BMP practices is uneven (Kittler et al. 2012).

At least eight US states have developed voluntary biomass harvesting guidelines that are meant to guide practices to protect soil fertility, wildlife habitat, water quality etc. during harvest. Called biomass harvesting guidelines, these are typically focused on maintaining the amount of down woody material[15] (DWM) that can be sustainably removed without adversely impacting nutrient cycling and habitat (Kittler et al. 2012).

The only state where harvesting guidelines have been written into regulatory language are the harvesting rules adopted in Massachusetts, which must be followed for harvested biomass to be eligible for their Renewable Portfolio Standard (RPS)[16], in order to ensure appropriate levels of GHG reduction and efficiency associated with biomass energy. These mandatory guidelines place the following limits on qualifying biomass harvests: (1) biomass fuel can make up no more than 30 percent of a harvest by weight; (2) it must derive only from thinning and residues; (3) harvests must leave 75 percent of logging residues on good soils and all residues on poor soils; and (4) removals must not come from steep slopes, old growth, naturally down woody material, or cavity trees (Abt et al. 2014). Designing the rules in this way is intended to maintain soil fertility in the forest while also ensuring that only the woody material that would otherwise have been left to decompose is used for bioenergy.

Overall, since BMPs are not mandatory, enforcement is uneven. Although they are currently being used by the majority of landowners in their harvesting operations, BMPs are likely not to be a factor influencing the future availability of wood for pellets.

4.7 Forest certification

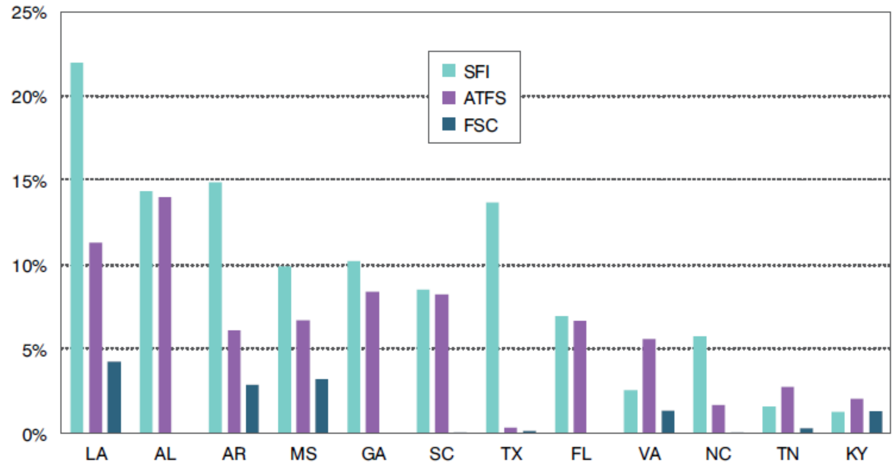
Forest land can be enrolled in third-party certification systems, such as Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), and American Tree Farm Systems (ATFS) certification. These programs are voluntary, and require landowners to pay a third-party certifier to verify that particular conditions are being met on their forestlands. Requirements and stipulations vary from program to program, but overall they are meant to ensure general compliance with a set of standard environmental practices. In southern states, up to 30% of forest lands are certified to one of these three standards (Figure 4-18). Kittler et al (2012) examined the existing EU import requirements for sustainability and the ways in which companies can reduce actual or perceived risks from sourcing fibre for pellets. According to their report 83% of forestland in Southeast USA was non-certified; 10% was certified through SFI, 6% through ATES and 1% though FSC. They describe four pathways that forest products in the US Southeast might take to achieve sustainability. Kittler et al (2012) considered the certification pathway as having the lowest sustainability risk, because conformance to it can be standardized. However the SFI, FSC, and ATFS systems in the US do not satisfy all of the European requirements, nor do they address the GHG emissions associated with particular feedstocks or forest

[15] This is used as an indicator of the health of forest ecosystems in the USA. It provides an estimate of "dead organic materials (resulting from plant mortality and leaf turnover) and fuel complexes of live shrubs and herbs. Specifically, components estimated by the DWM indicator are downed fine woody debris (FWD), downed coarse woody debris (CWD), litter, duff, fuel bed, slash piles, live/dead shrubs, and live/dead herbs (Woodall and Monleon 2007)

[16] Massachusetts' Renewable Portfolio Standard (RPS), like the RPS regulations in effect in other states, requires a certain proportion of the state's electricity to come from renewable energy. Electricity generators using qualified biomass are eligible for renewable energy certificates, or RECs (Massachusetts Government).

management regimes (Kittler et al. 2012, Abt et al 2014)[17]. This is why European industry has developed the Sustainable Biomass Partnership (SBP)[18]. Requiring more stringent certification of pellet fibre supply is likely to increase the price of fibre for pellets and could alter some supply strategies, depending on how the certification changes.

Figure 4-18 Proportion of private forestland enrolled in ATFS, FSC, and SFI certification, 2005. Source: Lowe et al (2011) cited in Kittler et al. (2012). Note that land can be certified under more than one scheme, so the total land certified may be less than the sum of the proportions under each scheme added together.



State abbreviations are as follows: AL Alabama, AR Arkansas, FL Florida, GA Georgia, KY Kentucky, LA Louisiana, MS Mississippi, NC North Carolina, SC South Carolina, TN Tennessee, TX Texas, VA Virginia.

4.8 Forest land conservation

Forests that are harvested for timber – whether owned by family forest owners or by industrial landowners – constitute an important economic engine for the region. Thus, a robust market for wood is critical for maintenance of forest cover in the region.

As described in Section 4.1, the softwood and hardwood forest types in the Southeast differ dramatically from one another, in terms of both ecological characteristics and typical harvest regimes. While upland hardwoods are the most abundant forest type in the southern US by acreage (Figure 4-10), projected increases in timber harvest are most likely to occur in the planted pine stands (Abt et al 2014, Galik and Abt 2015), where silviculture improvements have increased the productivity per acre in the last 50-60 years (Section 4.1).

The forests of the SE broadly experience a wet and humid climate with mild winters and little to no snow cover; these favourable climate conditions lead to forest productivity that is high compared to other US forests and forests at similar latitudes worldwide. This high productivity, combined with terrain heterogeneity, support a wide diversity of habitats and ecological associations (NWF, 2013). In the southeast US, then, the focus of attention for conservationists and environmental groups is the ecologically sensitive, diverse, and valuable hardwood forest, both upland and bottomland.

The mature hardwood forest ecosystem in the Atlantic Coastal Plain is home to numerous species of conservation concern. Some of these bird species are neo-tropical migrants that breed in the Atlantic Coastal Plain and spend winters in the Caribbean and Central and South America. Birdlife International has identified Important Bird and Biodiversity Areas (IBAs) worldwide, many of which are located in the SE US. Though large enough to support self-sustaining populations of key species, these areas are designed to be small enough to be conserved in their entirety. IBAs are good indicators of critical habitat for other wildlife species as well.

[17] Galik and Abt (2015) attempted to map areas of certificated acres in Southeastern USA but were unable to find up to date and comprehensive data except for FSC. We have not been able to produce a map of this area.
[18] http://www.sustainablebiomasspartnership.org/sbp-framework

The bottomland hardwood forests are also ecologically important and especially rare, and also provide critical habitat for certain bird species. For example, North Carolina bottomland hardwood forests provide habitat to 18 percent of the global population of Prothonotary Warbler, 14 percent of the global population of Yellow-throated Warbler, and 11 percent of the global population of Acadian Flycatcher (Southern Environmental Law Center, 2015).

The particular issue of conservation concern in the SE US is the loss of mature upland and bottomland hardwood stands to pine plantations. If we assume that any additional forest harvest to meet pellet demand comes from hardwood stands, then conservationists are concerned about the loss of those hardwood stands as critical habitat for wildlife. Alternatively, if we assume that additional harvest comes from pine plantations, then conservationists are concerned that hardwood forests will be lost. Conservationists are also concerned that the scenarios involved might have large-scale carbon implications. For example, increased harvest of natural forests (BEAC Scenarios 10-13) and conversion of natural forests to plantations (BEAC Scenarios 22-23) could in some circumstances be associated with high GHG emissions. These concerns do not constitute evidence that pellet demand causes any of these trends: further evidence is needed. It is also likely that the markets for all forestry products from hardwood stands will influence their harvest and subsequent reforestation and separation of the influence of pellet demand may be difficult.

The National Wildlife Federation (2013) conducted a site-level analysis of the areas around existing wood bioenergy facilities, in order to quantify the overlap between likely sourcing areas and forests of conservation concern. Each facility's footprint is different: the potential impact on wildlife may be positive or negative and depends on where the facility is located, what kind of wildlife species are being considered, and what kind of forest surrounds it.

4.9 Projected pellet demand from the UK and Europe

In order to project pellet demand from the UK and Europe for this project the modelling work done as part of this study (Chapter 6), we developed a bottom up approach to estimate pellet demand in Europe. This was based on power station announcements in the UK; for Europe, information was taken from Verhoest and Ryckmans (2012) and Hoefnagels and Junginger (2015). These data provided an estimate of UK demand for pellets from the USA of around 3.6 million tonnes in 2015, rising to an estimated 7-8.3 million tonnes by 2020 and then held steady to 2030. Additional European demand for pellets from the USA was estimated to be 4 million tonnes in 2015 rising to 9 million tonnes in 2030. This gives a total European demand in the region of 16 -17.3 million tonnes by 2030. Low demand figures were estimated assuming that only 70% of the planned conversion to biomass would occur due to changes in policy, difficulty in obtaining finance and increased sustainability concerns.

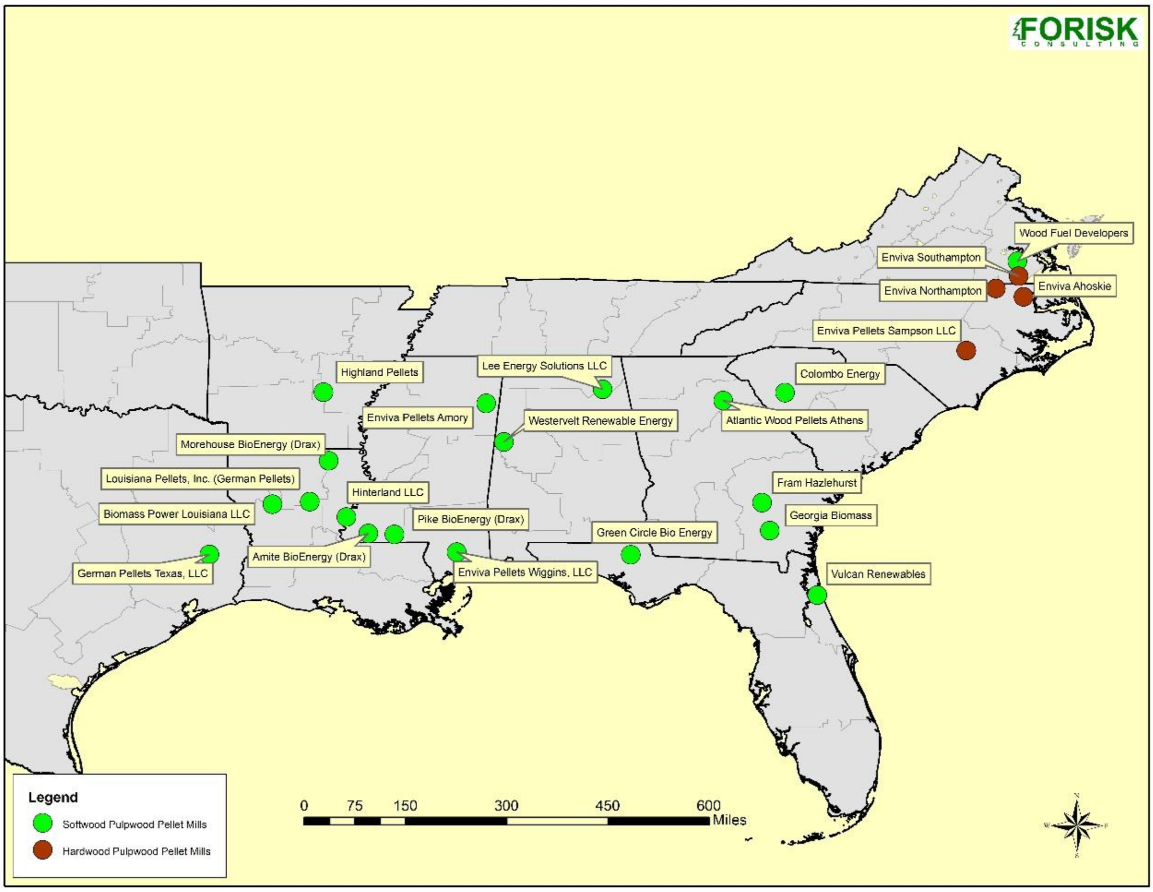
World Bioenergy Association (2014) calculated the biomass requirements for the accelerated deployment of renewables in Europe published by the European Renewable Energy Council in 2010. Their estimates are that it would be possible to import 16 Mtoe of pellets to Europe by 2030. This is equivalent to around 40 million tonnes of pellets, not all of which would come from the USA. The paper does not give details on where the imports would come from. Assuming that the USA, Canada, Russia and Brazil would all be part of this import market, we believe that it would be reasonable to assume that 50% of these pellets would come from the USA. This is equivalent to an optimistic maximum demand scenario of 20 million tonnes of pellets from the USA. In the USA Forest2Market (2015) examined demand from pellet plants in operation and construction in 2015. They concluded that there is a potential of 10.8 million tonnes of export pellets, which represents 25 million tonnes of wood fibre. This is higher than our estimates above, but of a similar order. Forest2Market (2015) say this fibre demand represents 1% of US Southeast pulpwood inventory and 0.3% of all US Southeast inventory. They contrast this to total removals in the US Southeast in 2014 of 250.2 million tonnes (3.3% of total inventory). Chapter 6 provides further details on the demand estimates used in our work.

4.10 Wood utilization for pellet production in the SE USA

Pellet demand is not distributed throughout the thirteen southern states. It is concentrated in the coastal plain to take advantage of intensively managed plantations or hardwood supply with short haul distances to ports. Figure 4-19 shows announced pellet mill locations as described by Forisk, LLC and Southern Environmental Law Center pellet facility databases. The impact of pellet demand is influenced by the spatial resolution of interest, which is shown on the map. This can be contrasted with the region of study for the SRTS modelling described in Chapter 6 (Figure 6-1), which provides a detail analysis of the forest resource related to market trends in the pellet study region. Overall, the rate at which timber harvest produces wood for pellets to meet UK and European demand will be a function of price, which will be demand-driven.

Figure 4-19 Operating and Proposed Wood Pellet Plant Location (source: FORISK, 2015)

This map shows pulpwood-using pellet plants (operating and announced) that pass viability screens (i.e. are "likely" to happen)



Information on wood used for pellets in Southeast USA comes from Drax's 2014 figures. This shows that the main resources used are saw mill residues, forest residues[19], storm salvage and thinnings. Projections of future supply come from modelling such as that by Abt et al (2014). In general wood for pellets in the UK (and Europe) comes from regions with good access to the coast (see for example the plants linked to Drax in Figure 4-19[20]). This is because the cost of transport/haulage in the USA is a significant part of the cost (Iriate and Fritsche, 2014, EIA 2014).

4.11 Wood pellet utilisation in the USA

Wood is not widely used in the US to generate electricity, because wood bioenergy producers cannot compete with traditional forest products manufacturers for feedstock, and because they cannot produce energy at a price competitive with low-cost energy sources such as natural gas (NAFO, 2013). It is technically possible for traditional coal-fired plants to co-fire with wood chips up to 10 or 15% (USEPA 2015a). These projects are traditionally implemented to reduce the GHG emissions associated with power generation, but the uncertainty surrounding EPA's accounting for biogenic carbon emissions

[19] Drax prepared these figures for OFGEM and use the OFGEM definition of residues: Branch wood, tops, bark and other residues (collected from forests at harvest, which can include other low grade wood). (Drax 2014)

[20] See also: http://biomassmagazine.com/articles/10423/drax-plans-another-mississippi-pellet-plant

makes the value of co-firing projects uncertain. The Clean Power Plan may incentivize additional co-firing projects, but incentives for these projects will be implemented on a state-by-state basis when states release their individual state compliance plans (US EPA 2015b). The extent of wood biomass utilization in the US (and therefore the extent to which domestic demand would limit the availability of pellets to the UK) is currently unknown, given the ongoing policy discussion related to accounting for biogenic GHG emissions from bioenergy as well as the incomplete status of state compliance plans.

Forest products is an important sector in the US economy. According to USDA it generates over US$2 billion/year in sales and accounts for 6% of the US manufacturing GDP (USDA 2015a). As a portion of the overall forest products industry, the marginal increase in wood demand for bioenergy to 2023 might range from 4-9% of the wood currently used by the forest sector (NAFO, 2013). The domestic demand for wood pellets is even lower, as pellets are not typically used in industrial settings in the US. Instead, pellets are occasionally used by consumers in residential settings as a convenient alternative to firewood.

4.12 Economics of pellet production

Wood pellets are produced via an industrial drying and manufacturing process by pellet producers at pellet production facilities, using raw wood as the feedstock. Value is added at each stage in the feedstock procurement, pellet production, and distribution process (Figure 4-20). Each of the stages can be broken down further into its component parts. For example, the delivery price of roundwood feedstock to the pellet facility is a function of the stumpage price (30% of the delivered price), harvesting cost (50% of the delivered cost), and transportation (20% of the delivered cost) (Qian and McDow 2013). At the pellet production stage, roughly 50% of the cost of the delivered pellets (to the port for export) is the cost of the feedstock, while 40% and 10% of the delivered pellet cost are attributable to the cost of pellet production and transportation to the port, respectively (Qian and McDow 2013). This is important in the consideration of the impact of increases in feedstock price on pellet production. Qian and McDow (2013) compiled estimates from the literature to quantify the gross margin of a pellet production facility using standard numbers for pellet production and feedstock costs in the SE, concluding that pellet production costs were roughly $122.91/ tonne (£4.82/GJ[21]). Using this set of assumptions, they concluded that the gross margin for a pellet production facility would be 20.7% for pellets delivered at $155/tonne (£6.1/GJ[22]) (Table 4-2).

[21] Assuming £17/GJ and $1.5/£
[22] £103/tonne assuming £1=$1.5

Figure 4-20 The wood pellet value chain (Source: Qian and McDow, 2013).

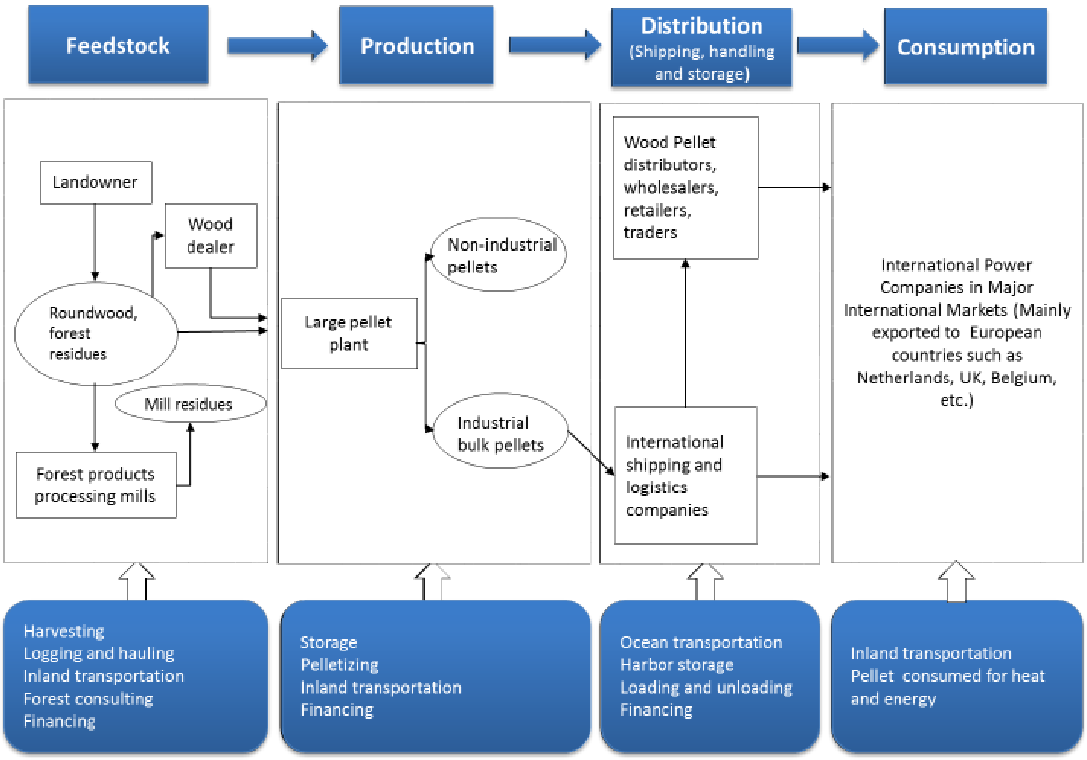


Table 4-2 Cost breakdown at pellet production facility. Source: Qian and McDow (2013)

		Assumptions ($)	Percentage of total cost (%)	low	high
Feedstock cost		64	52.1	50	70
Plant operation cost	Total cost	47.91	39	21.2	131.19
	Fixed cost	27.91	22.7	11.48	51.77
	Depreciation of assets	22.41	18.2	6.48	45.77
	Fixed Operation and maintenance cost	5.5	4.5	5	6
	Variable cost	20	16.3	9.64	79.42
	Energy	10	8.1	5.64	39.42
	Personnel	10	8.1	4	40
Delivery cost to ports		11	8.9	7	15
Direct production costs		122.91	100	78.12	216.19

FOB[23] wood pellet prices	155	130	160
Gross margin	20.7%		

4.13 Summary

The following summary examines the resourcing strategy for fibre for pellets in Southeast USA from the literature review alone. It summarises the findings of this Chapter on the feasibility of strategies required for the scenarios described in Stephenson and Mackay (2014).

Current supply strategies for pellet fibre in Southeast USA includes sawmill co-products, forest residues and small roundwood. Sawmill co-products are often committed to other markets or used at the sawmill, so their availability is limited. The current construction recession limits this further. Forest residues in their widest sense are used for pellet production at present (Drax 2015) and there is evidence of increased small roundwood harvest in response to pulpwood (including pellet) demand.

Logging residue harvest could increase to meet pellet demand, but the extent of residue availability depends on price. Landowners are motivated to harvest by price (Aguilar 2014) and there is evidence that higher prices would lead to additional wood being made available (Gruchy et al. 2011, Joshi and Mehmood 2011) – providing the landowners are aware of these opportunities (Markowski-Lindsay 2012). Additional wood harvest and processing would cause increased availability of logging and mill residues, as both types of residues are by-products of industrial use of wood (Section 4.4). Recent estimates of the tonnage of logging residues (tops and limbs that would otherwise have been left on the forest floor to decay) potentially available from Southern forests range from roughly ~10 million tonnes/year for the South Eastern and South Central regions (Gan and Smith 2006) to 28.4 million dry tons/y (Forisk, 2010). The USDA billion ton study reported that logging residue availability might vary by a factor of 3 depending on biomass price (Department of Energy 2011). Hoefnagels et al. (2014) concluded that it would be economically advantageous to produce pellets using certain residue feedstocks at pellet prices between $82 and $100/tonne (approximately £55 – 67/tonne or $74.5 – 91/ton) (lower than current European spot prices which recently ranged from $150-$190/ tonne ($137 – 173/ton)), but we note that this price does not include transport costs. We conclude that logging residues could be an important source of fibre for pellets to 2030, but we note that there is an upper limit on residue availability and that harvesting logging residues is expensive, so price will also be a factor.

The definition of logging residues influences their likely GHG Impact as well as their availability. The counterfactual for the residues is also important (for example, whether they are burnt on site or left to decay on the forest floor) and will influence CO_2 emissions. The approach of (for example) US EPA (2011) differs from the findings of Stevenson and Mackay (2014), which found that the GHG impact of residues was low if the residues would have otherwise been burned, but potentially higher for other counterfactuals depending on the size of the residues and climatic conditions. An additional complication is the practical definition of logging residues: in some analyses (e.g. Forisk 2011, Department of Energy 2011), logging residues (tops and limbs that are left on the forest floor after a harvest operation) are considered together with thinnings, making it difficult to distinguish between logging residues that would otherwise have been left on the forest floor to decay, and fuel or treatment thinnings, which would have otherwise been left standing.

Additional wood will likely be harvested from naturally regenerated forests. As described above, landowners are motivated to harvest by price and will thus be more likely to make wood available if demand (and thus the price) increases, providing they are aware of the income from bioenergy. Based on current pellet demand, naturally regenerated (predominantly hardwood) forests are being harvested for fibre for pellets, especially in the upland areas near existing pellet plants in North Carolina and Virginia (Drax 2014, Enviva 2015, Evans 2013). As long as these pellet plants continue operations, it is likely that they will continue to remove fibre from hardwood forests in their immediate vicinity. Any additional pellet plant capacity in regions adjacent to existing hardwood forests (Figure 4-19) would likely result in increased harvest from these forests. These harvests do not change the rotation length

[23] Note FOB refers to reference Free on Board prices, or the delivery price for wood pellets to traders or European utility buyers at US domestic ports

as pellet demand does not dictate this: they result in additional wood being taken from the forest at harvest, rather than being left as a residue. Naturally regenerated hardwood forests are typically managed using uneven-aged forest management, so rotation length is not a concept usually applied to these forest types. From our review of the economics of pellet production (4.12) it is important that the price is right. Transport distance will be an important factor in this. It is unclear from this whether pellet demand is sufficient to drive harvesting decisions. However as other timber products have a greater capacity to pay (Pöyry 2014) we suspect that the harvest decision is driven by these products and pellet demand will result in additional wood being taken at harvest.

Additional wood will also come from pine plantations. The acreage in planted pine has grown significantly in recent years and now accounts for roughly 16% of the total forest area in the Southeast (Wear et al. 2007). These forests are heavily managed (Fox et al. 2007) and are typically harvested on an even-aged basis with rotation ages between 25-35 years (Dickens et al. 2014; Pöyry 2015). These forests currently supply much of the timber for existing pellet operations (Abt et al. 2014) and planted pine stands are projected to be the largest source of supply for added pellet demand into the future (Galik and Abt 2015). We could find no information on whether or not rotation length is influenced by pellet demand, but it is likely that pellet fibre will come from thinnings (i.e. thinning of trees as the plantation develops) and from pulpwood when saw timber is harvested, rather than impacting rotation, which would decrease the value of the harvest of the product with the highest financial return (saw timber). Abt et al (2014) say that "increased pine harvest to meet pellet demand leads to increased investment (planting), which leads to inventory levels (over time) that are higher than under the baseline (i.e. baseline stumpage price and assumed non-bioenergy product demand)".

It is not likely that displacement of non-bioenergy uses would occur outside of the US. Aggregate demand for timber in the US is comprised of timber demand for sawtimber, composite, veneer, and pulp in addition to pellet and non-pellet bioenergy uses (Abt et al. 2014, Oswalt et al. 2014). The bioenergy components of this market (both pellet and non-pellet) are a very small portion of the total aggregate timber market (Forest2Market (2015) estimates pellet demand to be 0.3% of US Southeast inventory), and demand for some traditional timber products has been softening due to waning demand for paper products and slowdowns in the housing market (Abt et al. 2014, Woodall et al. 2012). Projections do indicate that announced pellet production capacity would account for more than 20% of the 2011 non-sawtimber harvest by 2020. However (Abt et al. 2014), suggest that increased pellet production will be a more noticeable component of the overall timber harvest going forward. However, pellet demand will not be likely to change the dynamics of sawtimber production unless the price of pellet feedstock causes pellet facilities to compete with traditional sawtimber uses. As a result, increased demand for pellets is not likely, in the short term, to cause increased harvest for non-bioenergy products to occur outside the US.

Pellet demand alone currently does not drive harvest. Of the pellet plants that are announced or currently in production (2005-2016), softwood pulpwood is the predominant feedstock source (Abt et al. 2014), followed by mill residues and hardwood pulpwood. As landowners can achieve much higher prices for sawtimber than for pulpwood (Pöyry 2014), the driver of harvest decisions is typically the sawtimber harvest, though the combined revenue from harvest of sawtimber and small roundwood could well influence the timing of a harvest decision. At current feedstock prices, however, it would not be an economical choice for landowners to harvest sawtimber-size trees solely to meet demand for pellets.

Short-rotation energy crops are not likely to be used to meet pellet demand. While there is evidence that short-rotation energy crops might be very well suited to the climate and landscape in the southern US (Zalesny et al. 2011), they are not in widespread use. Prices for these feedstocks would have to be substantial in order for landowners to choose to establish short-rotation energy crops rather than planted pine, for example.

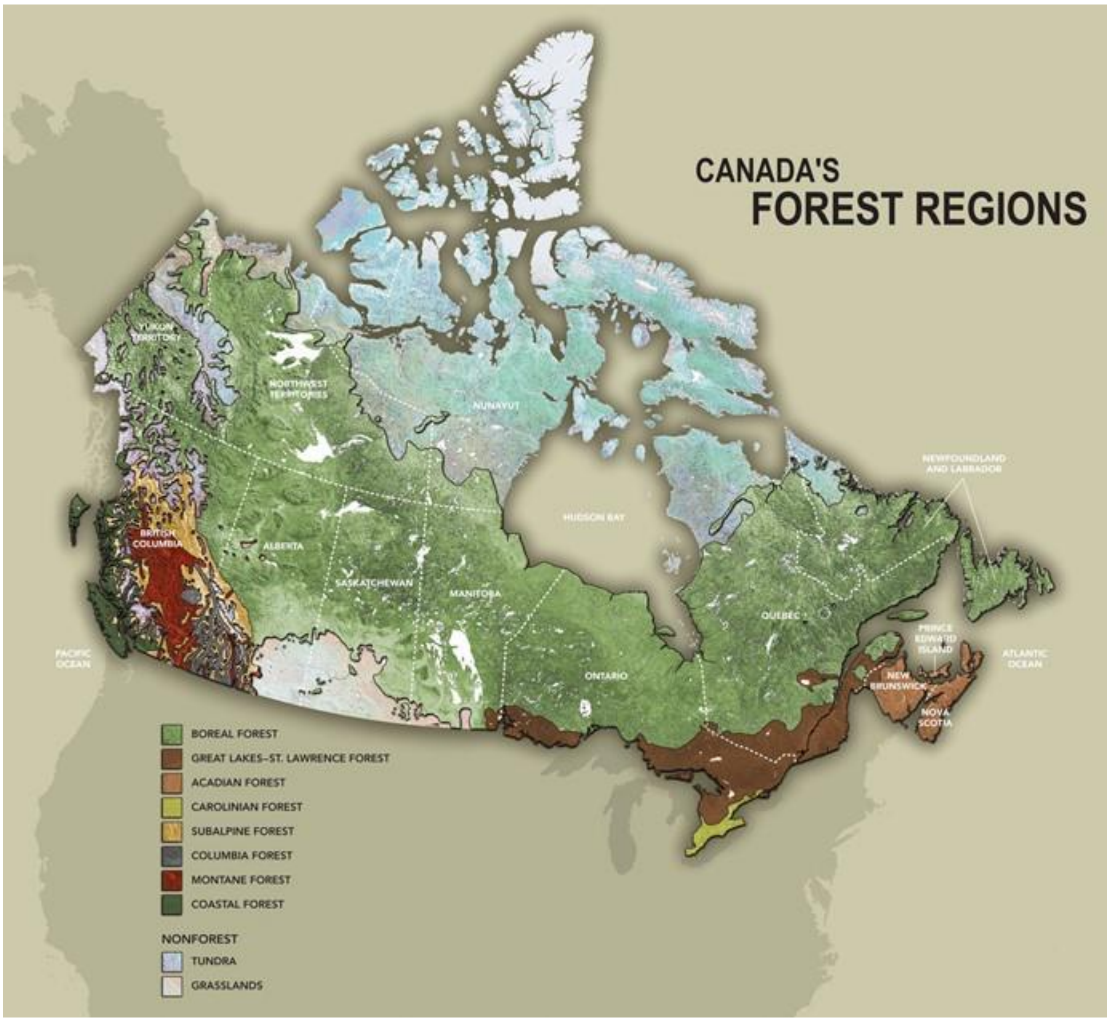
Whether or not unmanaged land will be brought into production depends on the definition of "unmanaged." The vast majority of the forest land in the southern US should be considered "managed" in the sense that it is under the influence of human management for a land management objective, whether that objective includes harvest or not (Section 4.1.1, Oswalt et al. 2014). Since there are very few restrictions on harvest aside from the regulatory restrictions associated with the Endangered Species Act or the Clean Water Act, private landowners could choose to harvest at any time. Thus, if the price for timber increases, it is likely that some landowners would indeed bring their forestland into timber production. On the other hand, it is extremely unlikely that land set aside for conservation would be brought into timber production, because many of these lands are legally protected from harvest.

5 Overview of Canadian forestry

5.1 Canada's forest resource

Canada's forest resource is estimated to be around 348 Mha (860 million acres, 38% of total land area), or 9% of the world's forest cover and 24% of the World's boreal forests; 64% of Canada's forests are softwood, 15% are hard wood and the remainder are mixed forests (Natural Resources Canada, 2014). The majority of Canada's forest is boreal, with some temperate forest (Figure 5-1).

Figure 5-1 Canada's forest regions (source: NRC)



The overall sustainable harvest level (set by the Annual Allowable Cut, AAC, which is based on detailed planning) currently determined for each Canadian forest is in total 227 Mm^3 per annum (8000million ft^3/annum). In reality, the actual harvest level declined from 2006-2012 and only 148 Mm^3 (0.6 Mha or 1.5 million acres of forest) were harvested in 2012, the lowest level in decades. However, in 2013, production of manufacturing timber and structural panels increased by 6-7% as a result of a recovery in the US housing market, while pulp production remained largely stable, helped by the weakness of the Canadian dollar; the forest industry's contribution to Canada's GDP in 2013 was $19.8 billion (Natural Resources Canada, 2014). Wood volume is expected to remain relatively unchanged as harvesting and natural disturbances (including fire and insect infestations) continue to be offset by forest regrowth and regeneration (Natural Resources Canada, 2014). Nearly three-quarters of Canada's forest area is in British Columbia (38%), Quebec (18%) and Ontario (15%) (Statistics Canada).

The BEAC report (Stephenson and Mackay 2014), is concerned with those regions that export to the UK, which it refers to as Pacific Canada, East Canada and Boreal Canada. It defines East Canada as Ontario, Quebec, New Brunswick, Nova Scotia, PEI, Newfoundland and Labrador, including all regions in Eastern Canada where export of pellets to the UK is relevant; but the large tracts of Boreal forest in East Canada were not considered explicitly in scenarios detailed in the report. British Columbia is in the Pacific North West (Pacific Canada), but the BEAC report did not explicitly investigate scenarios involving Boreal forest in this region.

5.2 Ownership/governance

Approximately 94% of Canada's forest belongs to the Crown and forest management is the responsibility of the provinces (Natural Resources Canada, 2014); the remainder is privately owned. Each province has its own forest legislation, regulations, standards (e.g. Government of Ontario, 2004) and programmes through which it allocates logging rights and management responsibilities through a "tenure" system.

Private forest companies, communities and individuals gain the right to harvest timber in Crown forests through timber tenures with the Provincial government, which specifies the annual level of harvest allowed over a set number of years. This is referred to as the Annual Allowable Cut (AAC) (Natural Resources Canada, 2014). A timber tenure can take the form of an agreement, licence or permit, a legally binding contract that provides the contract holder with specific rights to use public forests over a specific period of time, in exchange for meeting government objectives, including forest management obligations and the payment of fees (e.g. for stumpage). Longer term licences include Tree Farm Licences and Forest Licences, which can be up to 20-25 years. Tree Farm Licences allow exclusive rights to harvest timber and manage forests in a specified area; Forest Licences allow the right to harvest an allowable annual cut.

It is a requirement of timber tenures that forest management plans are drawn up by the private forest companies, communities or individuals concerned and approved by the Provincial government. These spatially-explicit plans must comply with provincial standards and can take considerable time and cost to develop. All areas harvested must be regenerated by natural or artificial means (i.e. by planting or seeding); less than half of harvested areas in Canada achieve full stocking according to provincial guidelines from natural regeneration (Natural Resources Canada, 2014). This means that artificial seeding and planting is commonly used to supplement natural regeneration. Forest management is audited annually[24] and tenures can be revoked by provincial governments at any time, if management is not consistent with that which has been agreed.

Canada's commitment to sustainable forest management has been set out in national forest strategies since 1992. Differences in forest legislation, regulations and standards between Provinces reflect the differing balance of stakeholder views, although Canadian Council of Forest Ministers (CCFM) have agreed upon common Criteria and Indicators of Sustainable Forest Management in Canada to provide national reports on progress towards sustainable forest management (CCFM, 2003). The framework is based on an approach that reflects: the need to manage forests as ecosystems in order to maintain their natural processes; "the recognition that forests simultaneously provide a wide range of environmental, economic, and social benefits to Canadians; the view that an informed, aware, and participatory public is important in promoting sustainable forest management; and, the need for forest management to evolve to reflect the best available knowledge and information" (CCFM, 2003). The CCFM is also involved with the Montréal Process, which includes 12 non-European countries covering 90% of the world's temperate and boreal forests who report on sustainable management of temperate and boreal forests.

The most recent number for total hectares of managed forests in Canada is 232 million hectares (573 million acres) (Natural Resources Canada, 2015a). The area of forest that is independently-certified as sustainably managed is 161 million ha[25] (397 million acres, 69% of total managed forest area) (Natural Resources Canada, 2014). The majority of forest products companies are now certified through the

[24] Most, if not all, Provinces conduct audits that are in addition to audits conducted for forest certification. For example, independent Forest Audits are required in Ontario to meet Crown Forest Sustainability Act (CFSA) requirements and Environmental Assessment Act approval. These Independent Forest Audits are undertaken every five years local forest sustainability by considering compliance with the CFSA, forest management plan, approved manuals and guides; the effectiveness of forest operations in achieving local FMP objectives and action plans to address previous audits' noted shortcomings; and, a licensee's compliance with the terms and conditions of the forest resources licence See: https://www.ontario.ca/laws/statute/94c25 and https://www.ontario.ca/laws/statute/90e18

[25] See www.certificationcanada.org website

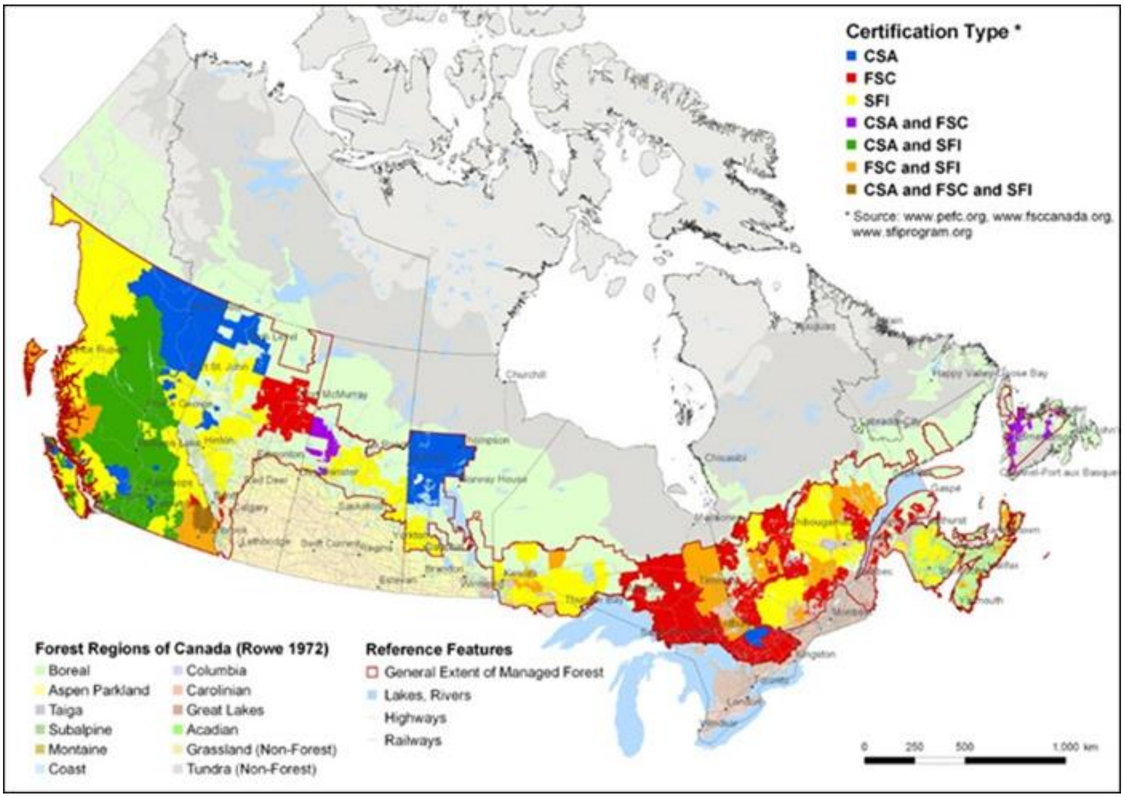
Canadian Standards Association (CSA), Sustainable Forestry Initiative (SFI) and Forest Stewardship Council (FSC). SFI has one standard for all of North America (2015-2019 Forest Management Standard). CSA has similar standards for all of Canada (CSA Z809 Sustainable forest management; CSA Z804 Sustainable forest management for woodlots and other small area forests). FSC has four regional certification standards in Canada: the National Boreal Standard; the Maritimes Standard; the British-Columbia Standard; and the Great Lakes St. Lawrence Standard (currently in draft form). Experience has shown that FSC standards differ in application from Ontario to Quebec. For example, higher standards have been set in Ontario than in Quebec. In Ontario, all areas holding tenures are certified, as is more than 79% of the Crown Forest Estate.

Growth rates of forest trees in many areas of Canada are slow, particularly in the boreal zone (Natural Resources Canada, 2014) and much of the area being managed is primary forest and is being felled for the first time. However, it is a requirement of statutory legislation, forest standards and certification, that areas of ecological importance, including ‘old growth’ have to be identified in forest management plans and managed accordingly. Defining Canadian old growth forests in a scientifically meaningful, yet operational and policy-relevant manner has proven challenging (Mosseler et al. 2003) and there is no accepted standard definition despite acceptance of the concept. The general extent of Canada’s managed forest estate and certified forests is shown in Figure 5-2. Twelve percent of Canada’s land area is set aside as provincial or national parks. Forest management seeks to emulate natural disturbance regimes.

Canada’s governance system in relation to forest management restrains potential for UK wood-pellet demand to have adverse impacts. The Canadian forest sector is relatively slow to respond to new markets and it is not possible to increase or change harvest regimes suddenly under normal circumstances[26]. Nevertheless, in relation to the AAC, the percentage that is harvested may change in reflection of market conditions; in many years it is well below the level set by provincial governments (Natural Resources Canada, 2014).

Figure 5-2 Canada’s managed forest estate and certified forests

(Source: http://certificationcanada.org/en/certification/certification-maps/\)



[26] One example where harvest regimes have been changed rapidly in response to abnormal circumstances is the harvest of pine-beetle diseased wood in British Columbia.

5.3 Potential implications of UK wood-pellet demand

Between 2003 and 2013 Canada's harvest of timber fluctuated between 117 and 208 Mm^3 (4131-7345 million ft^3) of timber annually (NRC, 2016). The average was 161 Mm^3 (5685 ft^3) and figures for 2013 were 152 Mm^3 (5367 ft^3). Only c.1-1.4% (1.7 M tonnes, 1.9 million tons) comprises wood pellets for export. The majority of wood pellet fibre for pellets (at least 88%) currently comes from sawmill co-products with < 12% supplied by harvest residues[27]. Wood pellet fibre is a relatively low-value commodity and, as such, demand for it does not currently drive forestry activity. Instead, it is a by-product of commercial forest management and timber conversion for high-value materials. Previous informal review by Canadian experts suggests that it is highly unlikely that UK wood-pellet demand will become an important driver of forest management in Canada, e.g. it is unlikely to be a determinant of the length of forest rotations, which will instead be driven by the slow rate at which marketable timber grows. However, if one assumes that UK wood-pellet demand could lead to a marginal uplift in the value of standing timber by allowing exploitation of otherwise unmarketable timber and forest residues, then there are really only two possible scenarios (or a combination of the two) that could follow:

1. Intensification of forest management within that proportion of the AAC that would already be destined for felling; or
2. An increase in the proportion of the AAC that would be felled with no significant change in the intensity of forest management operations.

The first scenario could demand an increase in harvesting of forest residues (and currently unmerchantable species). This would be constrained to varying degrees in different Provinces by statutory forest legislation and forest standards, as well as the often greater demands of a range of forest certification schemes. Currently, many Provinces, including Ontario, are not prescriptive about residues (Roach and Berch 2014). Nova Scotia is an exception, as it does not support whole-tree harvesting and prescribes retention of residues. In general, managed boreal conifer stands are clear felled. However, treatment of scattered, unmarketable broadleaves (e.g. aspen and birch) within the stands tends to be somewhat random. They can be cut down and left in situ, harvested and left trackside, or extracted with the main crop. Forest residues, including such broadleaves, are usually placed in piles and often burnt. This has negative consequences for carbon emissions and for the ecosystem. Stephenson and Mackay (2013) examined this counterfactual using the BEAC tool and showed that the use of these residues in pellets for electricity generation in the UK has low carbon impacts, similar to those associated with pellets from saw mill residues. In this study we do not examine these relatively low carbon scenarios. The study examines the impact of the use of residues that would otherwise be left to decay in the forest, which was associated with higher carbon impacts in the BEAC study.

In 2010, WWF and the Forest Products Association of Canada (FPAC) reported that most Provinces and certification schemes were considering whether their existing guidelines were sufficient to respond to the potential impacts of large-scale biomass harvesting; some had undertaken formal assessments, and some had produced new guidelines. All indicated that biomass harvesting must be conducted within their existing forest management policies and guidelines, which require some basic level of retention of woody debris in order to ensure long-term site productivity (Walto and Johnson, 2010).

The second scenario would demand felling of new areas specifically for wood-pellet production that would be (1) suited to higher-value products than wood pellets, or pulp and paper, or (2) of unmarketable quality for non-energy uses. The financial returns of these various options would probably not justify the required operations. It is noteworthy that Rentech Inc has signed a 10-year contract to supply Drax with approximately 0.4 M tonnes (0.44 Million tons) of pellets annually (from a wood-pellet plant that is being built at Wawa, Ontario, alongside Lake Superior). Rentech's associated tenure, which comprises a mix of previously unmanaged and managed forests and which will produce a number of products of which pellets is just one, is the largest ever granted by Ontario's Ministry of Natural Resources and Forestry (MNRF). It was originally intended to be used to produce jet fuel, but this did not happen. It has been estimated that harvesting, extraction and transport costs may be in the region of CA$150-200 per dry tonne, plus additional costs of shipping to the UK (see Box 5-1 for more detail).

[27] This is expert information. It is consistent with the findings of IEA bioenergy information (Ikonen and Asikainen, 2013).

5.4 Regional forest characteristics: Mountain pine beetle

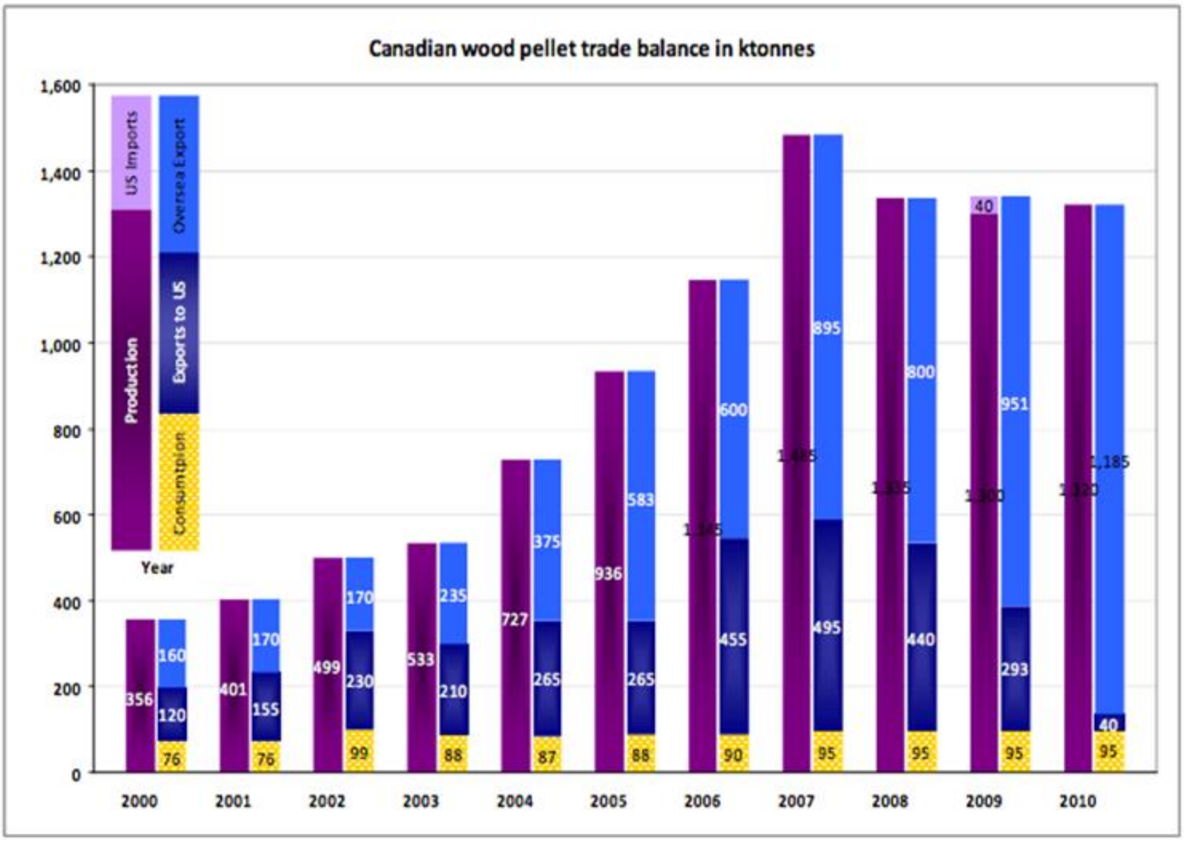
In order to understand how UK wood pellet demand might potentially affect forest management in central British Columbia, one must first understand how the mountain pine beetle epidemic has devastated 18 Mha (44 million acres) of forest and related forest dependent communities in that Province and how salvage logging has generated massive amounts of sawmill co-products (Natural Resources Canada). At its peak in 2007, 10 Mha (25 million acres) was affected (in total by this date) but this had declined to 3 Mha (7.4 million acres) by 2012 (Natural Resources Canada, 2014). It has been estimated that this has led to loss of more than 50% of merchantable pine (700-750 Mm^3), however, the outbreak is expected to have largely subsided in British Columbia by 2017 (Natural Resources Canada). The scale of devastation has challenged forest governance systems and the degree to which regulations have provided adequate safeguards during salvage operations. The AAC was increased to salvage pine beetle-kill stands and replace them with fully-stocked stands of commercial species, thereby promoting regeneration and active management. However, the scale of activity has raised questions about how to ensure all of the forests' values are maintained. There are potentially important implications for provincial government, for certification schemes, and in relation to the EU Renewable Energy Directive (i.e. in relation to Article 17(3), as although ecological processes have been significantly disturbed by the scale of pine beetle-kill, areas of high biodiversity value are likely to survive). Hence, there have been considerable concerns about the need to set aside natural retention areas in forest killed by mountain pine beetle instead of clear-felling everything. However, as these areas are vulnerable to fire the issue has been contentious. Harvesting of all pine-kill areas identified for clearance is likely to be completed within the next ten years, which will lead to a subsequent slump in the AAC and therefore availability of harvest residues. This could result in socio-economic pressures to extend clearance into natural retention areas. This could be beneficial in relation to climate change mitigation but could have serious consequences for biodiversity associated with ecologically important areas. Once areas of beetle-kill timber have been cleared, the likelihood is that the management of regrowth will be sustained. Benefits for climate change mitigation could result from a reduction in risk of wild fires, and because "in the long term, sustainable forest management strategies aimed at maintaining or increasing forest carbon stocks, while producing a sustained yield of timber, fibre, or energy from the forest, will generate the largest sustained mitigation benefit." (IPCC 2007 ch 9: Forestry, AR4, Group III).

5.5 Pellet production in Canada.

5.5.1 Pellet plants and exports

The Wood Pellet Association of Canada provides information on pellet production (Figure 5-3). As of 2014, Canada had 46 pellet plants with 3.23 Mt (3.6 million tons) annual production capacity. Of this, 1.7 Mt (1.9 million tons) were exported worldwide, of which around 1 Mt (1.1 million tons) were exported to the UK (Arsenault 2015, Statistics Canada, 2015). Typical moisture contents of wood pellets are around 10% (Hogan 2013).

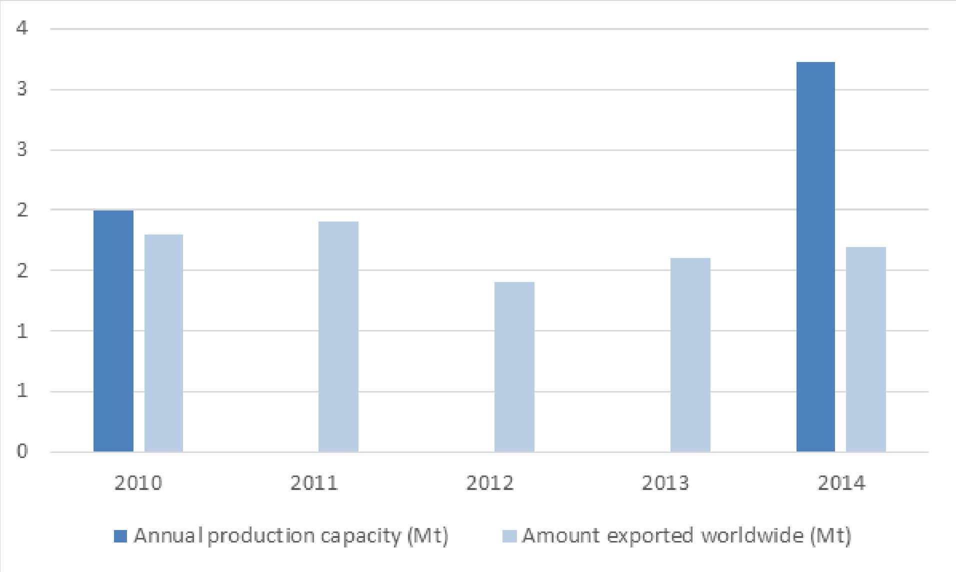
Figure 5-3 Wood pellet production in Canada 200-2010 (source: Wood Pellet Association of Canada, 2015)



However, there is annual variation in the export tonnage, ranging from 1.2 to 1.9 Mt (1.3 – 2.1 million tons) in recent years. In 2010, Canada's pellet plants operated at about 65% capacity, producing about 1.3 Mt (1.4 million tons) per year, 90% of which was exported, while in 2011 almost 1.9 Mt (2.1 million tons) of production was exported. In 2013, 1.6 Mt (1.8 million tons) of wood pellets were exported from Canada (Statistics Canada 2015[28]). The information on pellet production capacity and exports in the literature is provide in Figure 5-4.

[28] http://www5.statcan.gc.ca/cimt-cicm/searches-cherchers?lang=eng&searchStr=4401&refYr=2012&refMonth=7&freq=6&countryId=999&provId=1 Just under 0.9Mt went to the UK.

Figure 5-4 Annual production capacity and exports of pellets in Canada (note production capacity is shown only for those years where information was readily available)



British Columbia accounts for about 65% of Canadian production at present, while Alberta, Quebec, New Brunswick, Nova Scotia, and Newfoundland collectively account for 35%[29]).

Pellet plants in British Columbia tend to be large. An average British Columbia plant produces about 150,000 tonnes (165,000 tons) annually. Two new British Columbia plants are being built with a total annual capacity of 400,000 tonnes (440,000 tons).

Pellet plants in Eastern Canada tend to be much smaller, based on available fibre supply and different markets. Most have about 50,000 tonnes capacity; the two largest eastern plants produce 100,000 tonnes (110,000 tons) each annually. Rentech is commissioning a large plant at Wawa that will supply Atikokan co-firing plant in Canada and Drax in the UK (see Box 5-1)

Box 5-1 Rentech pellet plant development.

The Hawkins Wright 'Forest Energy Monitor' April 2014[30] noted that Rentech is currently building two pellet mills in Ontario (a 100,000 tonne/y (110,000 ton/y) mill at Atikokan); and a 450,000 tonne/y (495,000 tons/year) plant at Wawa, in commissioning). These investments are backed by a 10-year offtake contract with Drax for 400,000 t/y (440,000tons/year).

Rentech has provided figures from their forest management plant that show that the following percentage production for forest products: pellets 20%; saw logs 40%; and product sold on open market 30%. The remainder is pulp and veneer.

5.5.2 Sources of pellet feedstock: Mill Residues

Table 5-1 shows estimates for the production of sawmill co-products in Canada. Production does not equal availability as a considerable proportion of these co-products are already committed to in mill use or to other markets. This proportion is shown in the second column. These sources show quite a wide range of co-product production. This is because data is not readily available and has to be estimated from other sources (such as wood flow into and out of the mills). A wide range of assumptions are used in estimating the final figure, including assumptions for economics, competing uses and sustainability. This makes it difficult to provide one figure. In addition it is likely that there will be fluctuation between regions and over time, depending on the construction market. The figures in Table 5-1 indicate that less than 30% of the co-product produced is available for pellet production, some 1-10.8 million odt per year.

[29] For a map showing wood pellet plant locations see: http://www.pellet.org/images/CBM_Pelletmap2012FINAL.pdf accessed 7 August 2015
[30] http://www.hawkinswright.com/Bioenergy-Forest_Energy_Monitor-Back_issues accessed August 2015. Updates have been included from: http://biomassmagazine.com/articles/12294/rentech-reports-delays-at-atikokan-wawa-pellet-plants and from Rentech (personal communication).

More exact information on the sawmill co-product available for pellet production in Canada is needed.

Table 5-1 Estimates of sawmill co-products in Canada from various sources

Estimated annual production of saw mill co-products (million odt/y)*	Fraction of sawmill co-products already committed to energy generation and other products	Time period	Source of information	Comments
36.7 (1300 million ft^3 or 41.4million bone dry tons, bdt)	83%	1999-2010	Chen et al. (2013)	Analysis of wood flow in Canada. Estimates for co-product production and use are calculated from average annual wood consumed to produce solid wood products and data on the use of co-products for different sawmill and board mill products. A large proportion of the sawmill co-products are used for energy at the sawmill.
3-17 (3.3 – 18.7 million bdt)	70%	Review of literature estimates from 1980s to 2008.	Gronowska et al. (2009)	The range results from different constraints or assumptions in studies (e.g. whether or not economics, competing uses or sustainability are considered). The authors say the lower estimate is conservative (all competing uses are excluded). The high estimate results from an assumption that 50% of harvested round wood will become mill residues (and does not take competing uses into account).
15 (16.5 million bdt)	87%	2014	Pöyry 2014	Estimate for Western Canada only on basis of wood flow model
1.3-1.6 (1.4 – 1.8 million bdt)		2015	Illich Lama. Personal communication	For Ontario only
7.8 to 14.2 (8.6 to 15.6 million bdt)		2015	Personal communication, Kirsten Vice from National Council for Air and Stream Improvement (NCASI)	

5.5.3 Sources of pellet feedstock: logging residues

The WPAC has indicated that while the Southeast US industry is growing rapidly, British Columbia's pellet industry growth has stalled, due in large part to the lack of access to a cost-effective and predictable fibre supply; this has now become the biggest threat to the continued viability and growth of British Columbia's pellet industry (WPAC, 2013). As noted in section 5.4, lumber producers in British Columbia can harvest the entire forest stand, including the low grade residues, incorporating tops, branches, and low grade logs. WPAC report that frequently, if a pellet producer is unable to meet a primary tenure holder's price demands, the primary tenure holder simply burns the harvest residue. This issue is likely to arise, as Pöyry (2014) have estimated that the wood pellet industry has the lowest capacity to pay for wood fibre of all the current markets in Western Canada, at between US$37/odt and US$60/odt.

An analysis of wood pellet feedstocks in British Columbia suggests that although the mountain pine beetle outbreak was beneficial to the wood pellet industry in the short term due to AAC uplifts, in the long term it is unlikely to be beneficial (as the AAC is significantly reduced) (Lloyd et al., 2014). This is because the harvesting of affected stands with low proportions of saw-log quality trees is less economically attractive than the collection of harvest residues from stands with high proportions of saw logs. In the long-term, the mountain pine beetle outbreak will reduce the volumes of harvest residues available to wood pellet producers in British Columbia.

Some authors indicate that **logging residue** removal could be a key resource for energy. For example Tiffault et al (2014) say that residue removal levels are expected to increase over time as the feedstock production industry matures. As indicated in Section 5.4 it is likely that this will be moderated by the development of policies and guidelines that define practices and thresholds based on the ecological suitability of various ecosystems to sustain harvest residue removal.

5.5.4 Sources of pellet feedstock: Pulpwood[31]

In recent decades there has been a decline in pulp wood consumption in Canada. For example, Statistics Canada (2015) and the Quebec Ministry of Natural Resources that show a decline of pulp chips from 7.5 Mt per year in 2005 to 5.25 Mt in 2014, whilst pellet production levels have increased from 146,000t to 341000 t. This is a significant increase but less than the decline in pulp and paper fibre use. In a personal communication John Arsenault from the Quebec Wood Export Bureau has commented on this decline: he has observed a resultant shift from production of wood chips for pulp to its use for energy and pellets. This represents a dynamic switch between markets to provide fibre for pellets rather than increased harvest. Stephenson and Mackay (2014) acknowledge a trend in the use of pulpwood in Southeastern USA (quoting Forest2Market data). The BEAC tool models the use of pulpwood in a number of ways and Stephenson and Mackay (2014) discuss the importance of the various counterfactuals to the carbon impacts of its use. We were not able to find further evidence on the nature of these changes in Canada in the literature, but believe the situation does need further investigation in order to shed light on the counterfactual for pulpwood use and its carbon consequences.

5.5.5 Use of forest biomass for energy in Canada

A useful review summarising policies, legislation, regulations and guidelines, related to the harvest of woody forest biomass in Canada, is given by Roach and Berch (2014). This report provides an insight into the types of forest biomass currently used for energy in Canada. It is clear that this use is still in development and localised. The amount of wood used for energy is very low compared to the use of wood for other forest products sectors in Canada (see section 5.3). The report also provides a summary of the forest harvesting policy for each Province and Territory, which can include guidelines related to retention of forest residues and a recognition of the importance of the role of forest residues role for site and ecosystem sustainability. Roach and Berch (2014) also discuss the potential use of 'coarse woody debris' for ecological, silvicultural and other reasons as well as for energy. The detail on forest use for bioenergy in the regions relevant to BEAC is summarised below:

- British Columbia: local policy permits the use of forest residues. There are a number of companies in British Columbia using forest residues from harvesting to generate energy or

[31] Stephenson and Mackay (2014) define pulpwood as a sub-category of roundwood. The exact definition varies between different saw-mills. In Southeast USA, this consists of roundwood which has a small end diameter typically less than a saw log (5 - 8 inches), but greater than 2.5 inches (0.064 m) (also known as small roundwood in the UK), and low quality roundwood with dimensions of saw logs and chip-n-saw, that can't be used for sawn-timber.

make pellets. The main source of forestry wood used is roadside residues. These are used to generate electricity, for heat and power and to fire dryers for pellet production.

- Ontario: Has rules on what can and cannot be removed from sites and procedures for biomass allocation. A number of companies are using forest biomass or roadside residues in cogeneration. The report says that "only stands identified in existing forest management plans are utilised and in those stands any undesirable/unmerchantable trees can be taken, but green-tree retention guidelines still apply." Ontario Power Generation has converted Atikokan Power Station from coal to biomass wood pellets.
- Quebec: In 2012 the wood biomass sector was not well developed in Quebec, although there was a programme encouraging small scale local heating (i.e. conversion of institutional buildings from light oil to biomass).
- Newfoundland: "In response to a decline in provincial markets for pulpwood, Newfoundland's forest industry is starting to adapt by utilising smaller diameter trees (pulpwood and smaller), previously non-merchantable species, and dead wood to produce energy and energy-producing products… logging slash remains on site (as whole tree harvesting is not permitted in Newfoundland)." The report provides examples of forest products industry using wood pellets from sawmill co-products and unmerchantable trees[32]. It explains the origin of "energy wood" as by-products of traditional pulp or sawlog harvesting.
- Nova Scotia: Wood biomass is used in co-generation and in the forest products sector. Much of this wood is provided from sawmill and production co-products. There is a support programme for local community projects and under this forest biomass is limited to stem-only wood from non-merchantable trees (see footnote 35).
- New Brunswick: New Brunswick has a detailed policy on biomass harvesting. In 2010, the Province awarded eight allocations of Crown forest biomass to New Brunswick companies. The wood was sourced from forest biomass on a sustainable basis. This is used mainly for cogeneration in the pulp sector and for local heat.

Further guidance on regulations and practices relevant to biomass harvesting is provided in Walto and Johnson (2010).

5.5.6 Other information

Several large research projects are under way to speed up the development of torrefied[33] pellet production, both in Canada and Europe. Large-scale introduction of torrefied pellets was expected around 2014-2015, but has not materialised yet. While the torrefied pellet has some transportation and storage advantages over un-torrefied pellets, a sustainable business case is unclear in the long run, as are the GHG balance benefits of various drying and conversion and supply chain pathways.

5.6 Economics of pellet production

5.6.1 Cost of wood fibre production in Canada

Overview

Argus provides weekly, monthly, historic and forward data for spot wood pellet prices and prices for transport by sea of wood pellet from North America and Canada (Argus 2015). Prices are given FOB (free on board) which means the seller is responsible for all costs up to loading the goods on board a ship designated by the buyer. Information on current industrial wood pellet prices is summarised in Table 5-2.

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[32] The term unmerchantable is used with regard to trees that cannot be used for the main timber harvest at clear cut. In the Newfoundland example above, these are defined as small-diameter, off-species and dead trees. In this example, harvesting of these trees is done with saw logging, so entire stands of small-diameter trees are not being harvested (Roach and Berch 2014). Elsewhere in Newfoundland 'energy wood' is pulpwood plus small stems and off species.
Unmerchantable trees can simply be a species of no market value, but they are typically weak or small trees that could be diseased or deformed in some way that makes their use for timber not practicable. Depending on the management of the forest, the harvesting method and the availability of potential markets for poor quality wood these trees may be left in situ, cut and left to degrade in the forest, cut and burnt to enable regeneration of stronger trees or used for pellet wood if there is a local market. This is not an example of increased harvest rates, but additional use of the clear cut. It may be difficult to establish a counterfactual other than through historical practice. Therefore the carbon impact of the use of these trees is not straightforward.

[33] Torrefaction of biomass, e.g., wood or grain, is a mild form of pyrolysis at temperatures typically between 200 and 320 °C. Torrefaction changes biomass properties to provide a much better fuel quality for combustion and gasification applications.

Table 5-2 Industrial wood pellet price information (Source: Argus 2015)

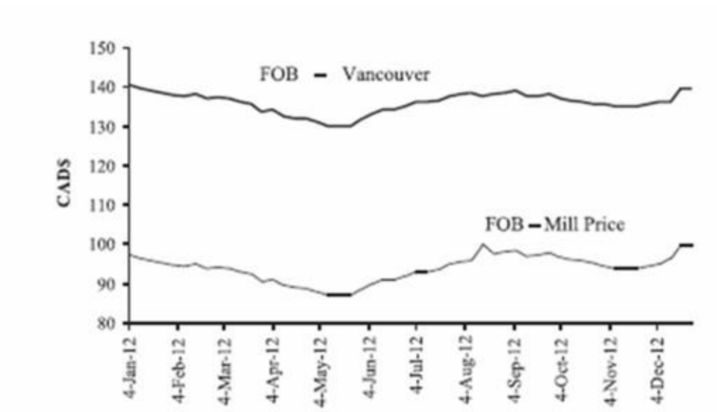
Note: the regions in the table do not precisely match those in our study, but do provide an indication of prices for North American pellets in 2015.

Product	Price January 15, £/GJ	Recent price range, £/GJ	Forward price 2018, £/GJ
Industrial pellet, fob SW Canada	5.6	5.1 to 5.6	6.3
Industrial pellet, fob NE USA	6.3		7.0
Wood pellet freight, Vancouver- ARA[34], 45kt	1.2		
Wood pellet freight, Mobile- ARA, 45 kt	0.7		
Wood pellet freight, Mobile- ARA, 25kt	0.8	0.8 to 0.9	

These are spot prices, but 95% of pellets for the power market are sold under bilateral contracts, a substantial proportion of which are long term contracts. Spot prices do not necessarily reflect these contract prices.

Currently there is little difference between Industrial and premium bulk pellet[35] prices. Prices are said to be volatile (Argus Biomass Markets), but historic data does not show a large variation (see Figure 5-5).

Figure 5-5 Wood pellet prices (C$/t) Source: Argus Biomass Markets 2012. Figure shows price delivered to Vancouver, and price at the mill gate which excludes transport to the port.



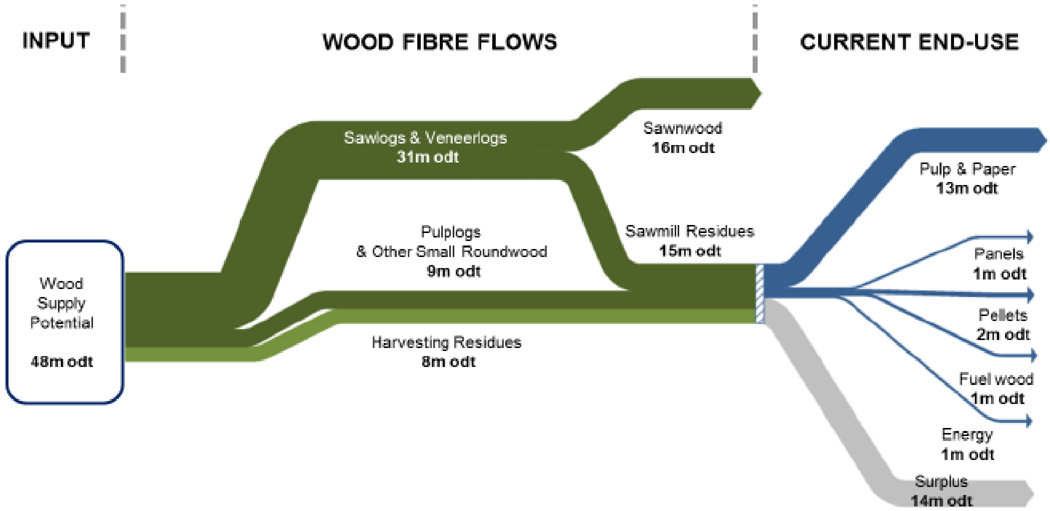
5.6.2 Western Canada

As indicated in Section 5.5 Western Canada (British Columbia) is currently the main pellet exporting area of Canada (AEBIOM 2013); the main source of pellet feedstocks is secondary residues from sawmill processing of logs from trees killed by mountain pine beetle (Lloyd 2014).

Pöyry (2014) points to the dominance of saw logs as a driver of timber demand in British Columbia, and offers the following current biomass wood flows (Figure 5-6). The market for these pellets has been Europe, but over the past year or so an alternative market in Korea and elsewhere in Asia has opened up for pellets for bioenergy from British Columbia (Roos and Brackley 2012, Biomass Magazine 2015).

[34] Amsterdam-Rotterdam-Antwerp area – a port and refining area in the Belgian-Dutch region. A cargo or barge of a refined product traded on a cost, insurance and freight (CIF) ARA basis means that ports within this area are covered in the cost. A cargo traded on a free-on-board (FOB) basis means the shipment can come from any of these ports.
[35] Industrial and premium pellets are different grades of pellets. Premium pellets are higher grade, producing less ash and having more consistent combustion. They are therefore better suited to small scale application.

Figure 5-6 Wood biomass flows in Western Canada in 2014 (source: Pöyry, 2013)



As indicated section 5.2 pulp and paper industries and the existing pellet industry in Canada operate primarily on sawmill co-products, with the harvesting residues currently largely unutilised by the pellet sector.

Table 5-3 summarises information on costs in Western Canada from the literature. As there is little information on the actual costs of these fibre sources, much of the data available is from trials or from estimates used in economic analysis.

Table 5-3 Information on wood fibre costs to the pellet mill from the literature

Wood fibre source	Delivered cost, £/GJ	References
Chips	2.3	AEBIOM 2013, Lloyd 2014
Sawdust/ shavings*	1.3	AEBIOM 2013
Bark*	0.2	AEBIOM 2013
Wood fibre from pine beetle killed wood (sawlogs still viable)	1.6	Lloyd 2014
Wood fibre from pine beetle killed wood (sawlogs not viable)	3.4	Lloyd 2014
Harvest residues	1.6	Lloyd 2014
Harvest residues from more remote areas	1.9	Lloyd 2014

** AEBIOM quote 'delivered value' which is thought to include a profit element*

5.6.3 Eastern Canada

In Eastern Canada, there is potential to expand pellet production (Deloitte 2008, Maure 2015). Estimated costs for wood fibre production in Eastern Canada are summarised in Table 5-4. Comparisons are indicative only, as estimates are made using different methods, with some values taken from current prices and some from modelling.

Current estimated costs of extracting residues or producing dedicated wood fibre for biomass from short rotation forestry (SRF) are at least as high as extracting roundwood/fibre for other purposes.

It should also be noted that Yemshanov (2015) discusses barriers to conversion of land to Short Rotation Forest production and concludes that prices 'significantly above current returns from agriculture' are required before land conversion is likely. The reluctance to convert from agriculture is based on lack of flexibility of land use due to the longer term forestry rotations and the lack of annual incomes from forestry. This is backed by a survey of farmers. Therefore the minimum price estimated from net present value (NPV) calculations alone is likely to be an underestimate.

Costs for extracting roadside residues are lower than standing whole trees (Ralevic, 2013). This is because there are additional costs in harvesting the unutilised standing trees that have to be borne by the biomass end user.

Relavic (2013) also gives much higher costs for harvesting residues from remote areas, due to longer transport distances and more difficult transport conditions. Maure (2015) states that costs for delivered wood can be much higher due to transport costs and assumes haulage cost of £0.6 /GJ (CA$8.53/m^3) for 100 km distance, but says transport costs can vary from less than £0.3 /GJ (CA$5/m^3) to greater than £1 /GJ (CA$15/m^3) depending on distance and road type.

Relavic (2013) uses two scenarios, one in which just roadside residues are extracted, and one in which roadside residues and unmarketable standing trees are harvested. These scenarios are relevant to BEAC since:

- The 'roadside residues only' scenario means only utilising primary residues for energy production that would have otherwise been burned at the roadside.
- The 'roadside plus standing trees' scenario involves harvesting standing unharvested standing trees plus the roadside residues that otherwise would have been burned at roadside.

He estimates that at current costs and target prices about 30% of the residues can be recovered economically from the 'roadside plus standing trees' scenario, and about 86% of the residues could be recovered economically for the 'roadside residues only' scenario[36]. Pre-piling of roadside residues is cost effective. (This is for existing logging operations in Ontario).

Table 5-4 Estimated costs for fibre production for pellets in Canada

Wood fibre source	Roadside cost, £/GJ	Delivered cost, £/GJ	Cost to recover all residues (even remote from mill), £/GJ	Reference
Residues from clearcut harvest (roadside residues only)		2.2 to 2.5	4.2	Ralevic 2013
Residues from clearcut harvest (roadside residues and unutilised standing trees)		4.1 to 4.3	5.9	Ralevic 2013
Roundwood	1.3 to 1.8	2.5 to 3.0		Maure 2015
Forest biofibre	1.7 to 2.2	2.5 to 3.0		Maure 2015
Forest slash at roadside	1.2 to 1.5	1.8 to 2.1	4.1	Maure 2015
Residues from clearcut harvest (roadside residues only)	3.5	5.4		Yemshanov 2014
Wood fibre from dedicated poplar SRF plantation	0.9 to 1.3 (harvest cost)	2.3 to 2.9		Yemshanov 2008
Fibre supply	2.2	3.2		Deloitte 2008

5.6.4 Summary of economics of wood pellet production

Deloitte 2008 estimated the following prices as averages in Canadian conditions (Table 5-5).

[36] Note that "standing unutilized AAC" is potentially an important source of biomass and relates directly to the 1st bullet on Section 5.3, but harvesting them has cost implications. These two scenarios and related cost data provide an important quantification of the cost consequences of bullet 1 in section 5.3. It points out that there are significant cost consequences of harvesting more trees to make energy products than currently demanded by traditional forest products markets.

Table 5-5 Estimated prices for pellet production in Canada

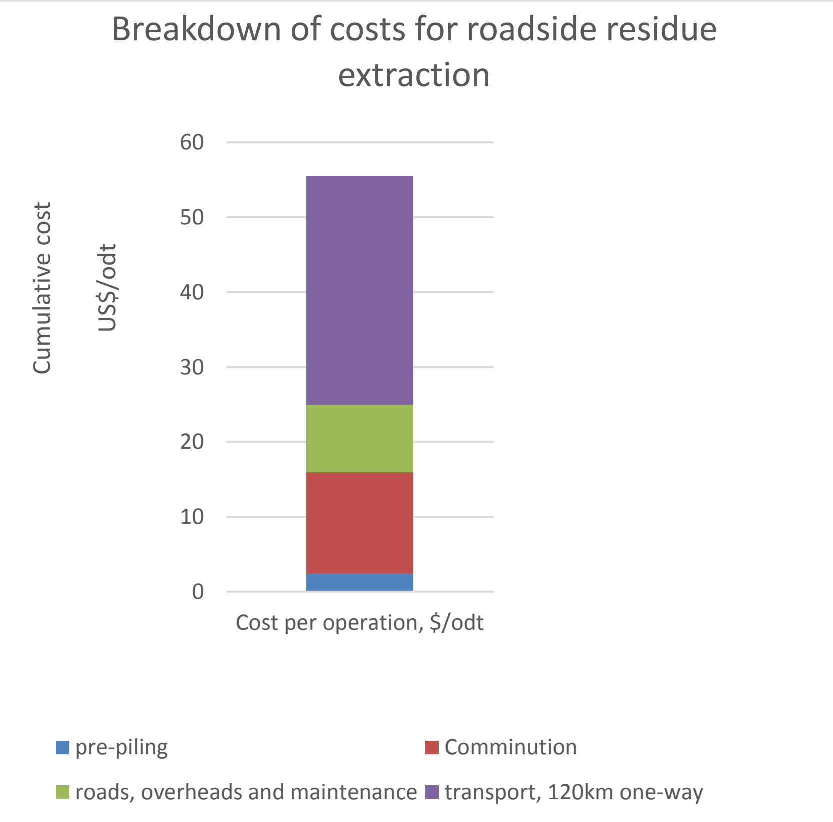
Prices are corrected for 2014.

	£/GJ (2014 prices)	References
Cost of fibre supplied to pellet mill	3.0	Deloitte 2008
Cost of pellet produced	6.0 to 6.7	Deloitte 2008
Of which fibre input cost	2.8 to 3.2	Deloitte 2008

The wood fibre costs are important for the overall economics of pellet production. These data are supported by Drax (2012), which estimates a pellet production process cost (excluding fibre supply) of about £3 /GJ.

The fibre costs are dependent on the region of Canada considered and the type of residue harvested, as described in the sections above, and are estimated to range from 1.6 to 3.2 £/GJ. In general, the costs are dominated by transport and comminution[37] costs, as illustrated in the data in Figure 5-7 from FP Innovations (Ryan 2015), using their BiOS model. This model has been developed to simulate all activities in the forest supply chain.

Figure 5-7 Costs extracted from presentation on supply chain management for bioenergy production (Adopted from Ryan 2015). Prices are Can$. They show the costs delivered to the pellet plant and what these costs are due to.



These costs can be compared on the one hand with the current value of wood pellets FOB[38] South West Canada of £5.6/GJ (CAN$ 145/t) to £6.3/GJ (160 CAN$/t).

[37] Comminution is the reduction of solid materials from one average particle size to a smaller average particle size, by crushing, grinding, cutting, vibrating, or other processes.
This term is commonly used in the harvesting residue utilization literature to describe a lot of processes designed to reduce the particle sizes for further processing.
[38] FOB: Free on Board –a measure of the cost of pellets at the port

It can also be compared with the Wood Paying Capacity of pellet mills in Western Canada, as calculated by (Pöyry 2014). This estimates that pellet mills have the ability to pay up to £2.6 to 3.1/GJ (71-85 US$/t) for wood fibre in 2014, rising to £2.9 to 3.4/ GJ (80 to 95 US$/t) in 2025.

These figures are summarised in Table 5-6, and show that wood pellet production in Canada has marginal commercial viability at current wood fibre costs and pellet prices.

Table 5-6 Costs for pellet production in Canada

	£/GJ (2014 prices)	References
Cost of fibre supplied to pellet mill	3.0	Deloitte 2008
Cost of pellet produced	6.0 to 6.7	Deloitte 2008
Of which fibre input cost	2.8 to 3.2	Deloitte 2008
Current and forward price for SW Canadian wood pellets	5.6 to 6.3	Argus 2015
Wood paying capacity of pellet mills in SW Canada, 2014	2.6 to 3.1	Pöyry 2014
Wood paying capacity of pellet mills in SW Canada, 2025	2.9 to 3.4	Pöyry 2014

These data suggest that saw logs and standing, un-utilised trees on harvest blocks are unlikely to be a viable source of wood fibre for pellet plants, but that roundwood, sawmill co-products and roadside residues are all potentially economic sources of wood fibre for pellet plants. This is based purely on economic costs and does not take forest regulations in the various Provinces into consideration.

5.6.5 Factors affecting costs/ prices of wood fibre and pellets

- Alum (2014) showed that improving forest inventory information can potentially improve profitability of forestry operations by up to 50%, and profitability of fuel logs by 25%. This is achieved by more efficient and timely supply of wood fibre to markets. However, this is likely to be difficult to achieve in practice.
- Yemshanov (2014) suggests that cost of residue extraction could be reduced by up to 35% if integrated harvesting methods were introduced, rather than the current model of a separate pass to collect and process roadside residues and possibly utilising standing unharvested trees.
- Recent evidence (Pöyry 2014) on wood pellet mill capacity to pay for wood fibre suggests that current small roundwood and residue prices would need to rise by only about 15% to 20% to make pellet mills unprofitable. Harvesting improvements to reduce costs would therefore be beneficial.
- Lloyd (2014) shows that harvesting Canadian wood purely for wood fibre for pellets is uneconomic. This has been investigated as a way to utilise pine beetle killed biomass, and it was concluded that substantial subsidies would be required to offset high harvesting costs.
- Prices that large-scale users are able to pay for pellets are influenced by power prices and subsidies in the power market; 95% of wood pellets are traded bilaterally, often under long-term contracts. Published prices are spot prices and do not reflect the whole wood pellet market.
- Transportation costs are a critical component of the total cost. The cost of transporting wood fibre to a pellet plant greatly influences delivered fibre costs, so pellet mills are sited close to an abundant source of low quality wood fibre, such as next to a sawmill. Transport of the pellets to a port, and subsequent long distance shipping costs influence the value obtained from the pellets. Pöyry (2014) used a modelling approach to suggest that by selling pellets to the Pacific Asian market rather than Europe, Western Canadian pellet producers can realise additional profit due to lower shipping costs.

5.7 Summary

The literature review covers the resource that may be available from forestry in Canada. It does not attempt to reproduce the conditions of BEAC scenarios directly but it does provide information on the wood fibre that could be used for pellets:

Sawmill residues are the most likely source of pellet fibre in Canada: There is strong evidence that the current main source of wood for pellets in Canada is sawmill co-products and wood from pine beetle kill in British Columbia (WPAC 2013, Chen et al 2013). Mackay and Stephenson (2014) show that carbon impact from the use of sawmill co-products is low. There are two export markets for these pellets: Europe and Asia. Pöyry (2014) suggests that the Asian bioenergy market would be of most interest to West Canada. This would mean that most export to Europe would come from East Canada. We suggest that modelling of biomass for pellets in Europe concentrates on potential practices in this region.

Competition with non-bioenergy producers: It is likely that sawmill co-products will continue to be a large source of pellet fibre in Canada for the foreseeable future (Arsenault 2015). Recovery of the construction market is likely to increase the availability of such residues. The extent to which there is competition between the panel board sector and the pellet sector is not clear from this review (the evidence in inconclusive). Johnston and van Kooten (2015) suggest that the price of industrial round wood would increase by 1% if pellet demand doubles and that the price of fibreboard would increase by between 1 and 7% (these are modelled global price increases). They suggest that the global production of roundwood and fibreboard would fall due to use of alternative products rather than production being displaced from Canada to other world regions. We suspect that where there are issues due to competition for wood fibre they will be localised and important regionally (there is no literature evidence on this): but Pöyry's capacity to pay (Pöyry 2014) suggests that panel board mills have a higher ability to pay. The implications of this are not clear: it could mean that pellet mills are situated away from pulpwood demand to decrease competition for resource (as they are unable to compete economically), but there we found no evidence in the Canadian literature on this point.

The **proposed sources of fibre for pellets** other than sawmill co-products are: **forest residues and unmerchantable wood** (which may be classed as forest residues depending on the definition used by foresters) (Relavic 2013). There is good evidence in the literature on the potential for use of these sources for wood pellets, but there is conflicting evidence in price analysis on its economic viability (Ryan 2015). The evidence indicates that transport distances and costs are important (indicating that use of residues may be local to pellet mills only). The use of this wood for pellets results in removal of additional carbon from the forest but its carbon impact depends on the counterfactual – how the residues would have been treated in the absence of pellet demand. Evidence in the literature is that residues are burnt or left to degrade, so it is not possible to generalise. Removal of forest residues is dictated by Provincial regulations, some of which control the removal of residues (these have been discussed in this chapter). We conclude that evidence on potential use of forest residues and unmerchantable wood is good, but there are factors that act to restrict this use, including transport costs and Provincial regulations.

One alternative resource that could be used for pellets is **small roundwood**, obtained through the extension of harvest (to meet the AAC). There is no evidence in the literature that this is happening at present but the economic analysis presented indicates that it could be economic (Maure 2015). The evidence on the economic feasibility of this strategy is good, but the extent of such practice is not clear (there is no evidence on this) and we suspect that the use of such resources may be local to pellet mills, restricted by transport costs.

The potential to take additional wood from forests is covered in the paragraphs above. In Stephenson and Mackay (2014) it is suggested that this would result in **rotation change**. The literature indicates that forest growth in Canada is slow. It takes a long time for a tree to reach a size suitable for saw timber. The AAC is set for saw timber demand, so forestry practice will be to continue to meet these rotation periods in order to achieve optimal harvest for saw timber. The proposed changes envisaged in Stephenson and Mackay (2014) of 20 to 50 year decreases in average rotation are not feasible, given this evidence. It is more likely that additional wood would be taken at harvest or by extending the harvest to meet the AAC[39] rather than taking wood from immature trees.

[39] For example, more roundwood could be taken from trees at harvest to meet pellet demand, necessitating harvest of a larger part of the AAC.

Short rotation forestry: Yemshanov (2015) discusses barriers to conversion of land to Short Rotation Forest production and concludes that prices 'significantly above current returns from agriculture' are required before land conversion is likely.

It is clear that there are dynamic links between demands for wood pellets, saw timber and particle and fibre board. Wood pellet manufacturing is highly dependent and integrated with the production of other primary wood products (Johnston and van Kooten 2015). An in depth review of all the relevant timber markets, their likely development and their interactions would be necessary to clarify these links and is beyond the scope of this review. However, we believe that the wood pellet prices are insufficient to drive harvests..

Economics: The review of economics of pellet production in this chapter shows that costs are not sufficient to drive harvest and probably will never be sufficient to drive harvest. There are ways to decrease the harvest costs for residues (Yemshanov 2015), but the introduction of these would have to be supported by a strong market for the product. It is not clear whether the current market for pellets is sufficient to stimulate this investment and the evidence we have used in this review is not adequate for us to be able to comment on potential cost reductions.

The highest costs in the supply chain relate to transport and preparation in the forest (chipping and moving the residues around). We have taken this to mean that pellet fibre supply strategies are likely to be local as well as being integrated with other forest product harvest. The evidence for this is circumstantial and based on the economic analysis section above.

6 Modelling of pellet demand in the Southeast USA: SRTS Methodology and background

As indicated in Chapter 4, the U.S. Southeast is a uniquely market driven forest economy in which 87 percent of timberland is privately owned. Private landowners are responsible for over 95 percent of timber supply. Financial returns to landowners have been shown to be the key driver determining the intensity and extent of forestland which competes in a largely *laisse faire* landscape mosaic interspersed with marginal agriculture. A long history of active markets and forest resource data (US Forest Service Forest Inventory and Analysis, USFS FIA) has led to an extensive literature of market and resource studies. These data provide the foundation for the Sub-regional Timber Supply (SRTS) model[40]. It uses published market elasticities and land use responsiveness to price and a detailed forest resource database to project market and resource responses to alternative demands. The market clearing price is determined for each product across sub-regions, ownership categories, and forest types. Similar models of other pellet supplying regions are not available.

The SRTS model has been used in this study because it provides this insight into the impact of economics on the supply response to pellet demand in the context of other wood consumers in the region. The BEAC analysis in Stephenson and Mackay (2014) does not explicitly consider the impact of economics, rather it models the greenhouse gas impacts of scenarios informed by a literature review and stakeholder engagement (see Figure 1-1). BEAC scenarios contain implicit economic assumptions by changing rotation length or converting land to plantations.

Thus SRTS is used to provide us with a view on how economics may impact the likelihood of some of the BEAC high GHG emissions intensity scenarios in the Southeast USA in a dynamic market. This complements the survey and literature data by allowing modelling of economic aspects of southern forestry that are important to the understanding of the impact of UK (and European) demand for pellets on this region.

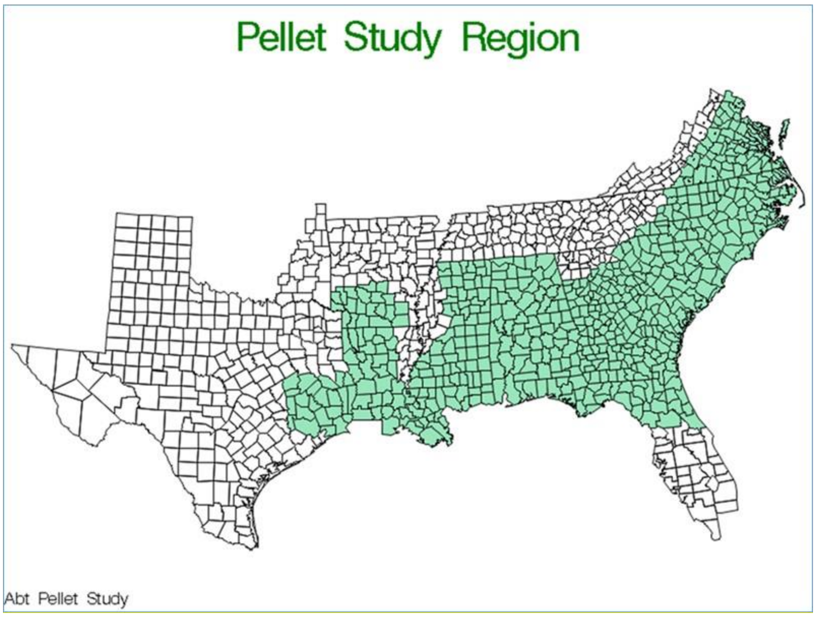
6.1 Background to SRTS modelling

Pellet demand is not distributed throughout the thirteen southern US states. It is concentrated in the coastal plain to take advantage of intensively managed plantations or hardwood supply with short haul distances to ports. The study region used in our modelling is based on the location of operating and announced pellet mill locations as described by Forisk, LLC databases (Figure 4-19). Figure 6-1 shows this region.

The impact of pellet demand is influenced by the spatial resolution of the analysis. For example a study focused on a 60 mile circle around each pellet plant would highlight the impacts concentrated around mills, while a southeast wide analysis would show diluted impacts since many regions, particularly those far from the coast and mountainous regions, would be unaffected by pellet demand. For this study a single region was run which included a contiguous area that included all operating and announced pellet mills at the time of study initiation. It excludes areas where pellet procurement is unlikely to occur based on current databases. As shown in Figure 6-1 this includes the mid-Atlantic, south-eastern, and western gulf coastal plain and piedmont survey units.

[40] For information on this model and how it is used, please see: http://research.cnr.ncsu.edu/sofac/

Figure 6-1 Pellet Study Region



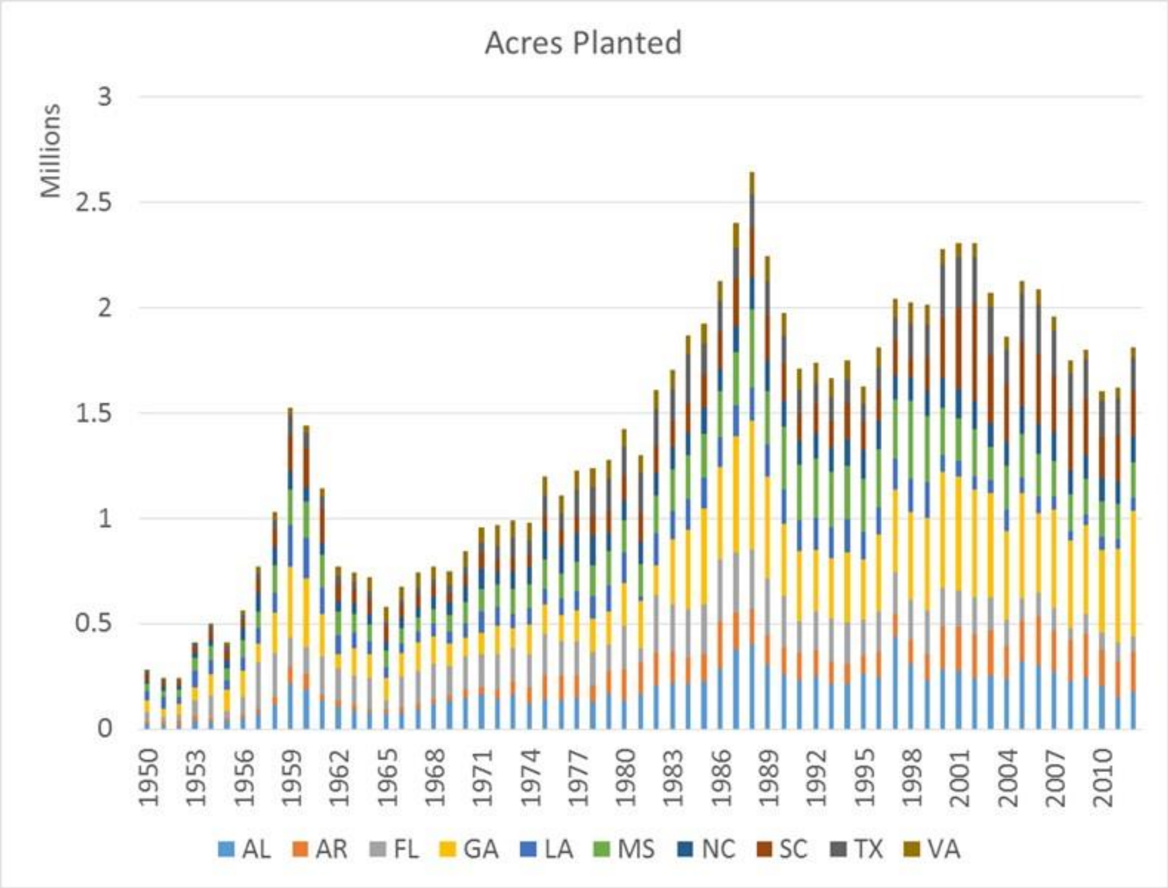
The U.S. forest resource situation was described in Chapter 4. This section provides a detailed look at the forest resource situation and market trends in the pellet study region.

The first 10 to 15 years of small roundwood supply is pre-determined by the existing age class distribution. After planting peaks in the 1950s (Soil Bank Program), the 1980s (harvest of 1950's plantings, Conservation Reserve Program) and the late 1990s (high prices) recent planting in the Southeast has declined (Figure 6-2). Further information on this planting is provided in Section 4.3.1and Box 4-1. These trends vary by region and determine the age class distribution of pine plantations. Figure 6-3 shows plantation age class distribution for the region and by state. For some states (e.g. Figure 6-3: South Carolina, Georgia and Mississippi) the number of acres in younger age classes are less than in the 25 year age class, where final harvest typically occurs. Though plantations are less than a quarter of the forest landscape, they account for over 75 percent of pine harvest in the pellet region. Pine pulpwood is usually harvested as part of a thinning operation before the age of 15.

The implication of this distribution is that although growth exceeds removals overall, the ingrowth (trees growing into a size class) for pine small roundwood is likely to be lower in coming years in some key market areas, i.e. for this specific age group growth will not exceed removals. Since final harvest is dependent on pine sawtimber prices and a final harvest is the precursor to most planting, a slow housing recovery could continue the reduced planting trend for several years.

Figure 6-4 shows the age class distribution by forest type. Note that in aggregate there is a moderate drop off in acres in the younger plantation age classes. Naturally regenerated stands are predominately in the over 50 age class, while pine plantations dominate the younger age classes. Though upland hardwoods are the most common forest type in the Southeast as a whole, the pellet study region includes more bottomland hardwoods than upland hardwoods. Lowland hardwoods is a forest type where most forested wetlands occur, but designation as lowland hardwood does not necessarily imply wetland hydrology. Figure 6-5 shows growth and removals for the 31 survey units included in the study. Growth exceeds removals for all forest types and both species groups. As shown in Table 6-3, 2011 removals are likely to be higher for pine pulpwood and lower for all other products than estimated in plot samples. Pine removals occur predominately in the 20-30 year age class, while hardwood removals are predominately in 50+ year old lowland hardwoods.

Figure 6-2 Pine plantation acres for States in the pellet region studied in this analysis (Source: Hernandez and Harper 2014).

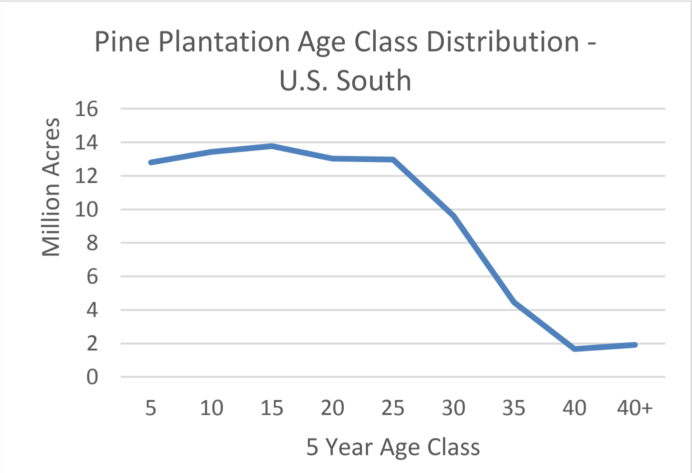


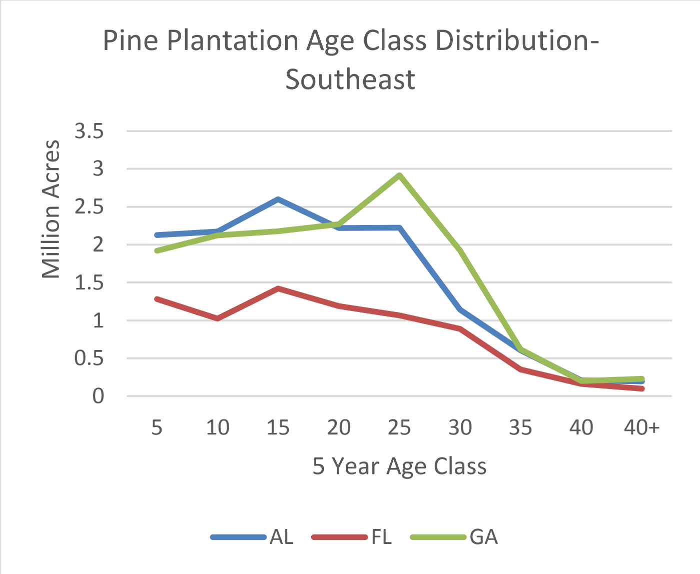
Key

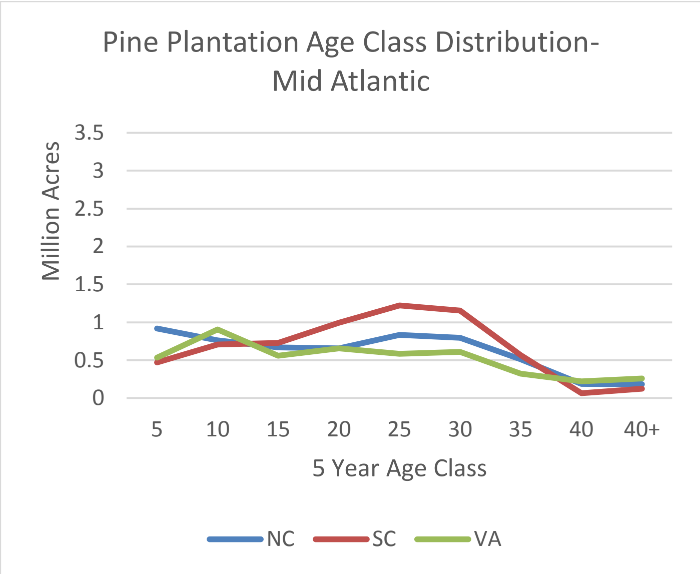
AL – Alabama; AR – Arkansas; FL – Florida; GA – Georgia; LA – Louisiana; MS – Mississippi; NC – North Carolina; SC – South Carolina; TX – Texas; VA – Virginia

Figure 6-3 Pine plantation age class distribution by region (From current inventory data, see

Table **6-1** for date of data)




Pine Plantation Age Class Distribution-Southeast
Million Acres
3.5
3
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
35
40
40+
5 Year Age Class
AL
FL
GA


Pine Plantation Age Class Distribution-Mid Atlantic
Million Acres
3.5
3
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
35
40
40+
5 Year Age Class
NC
SC
VA

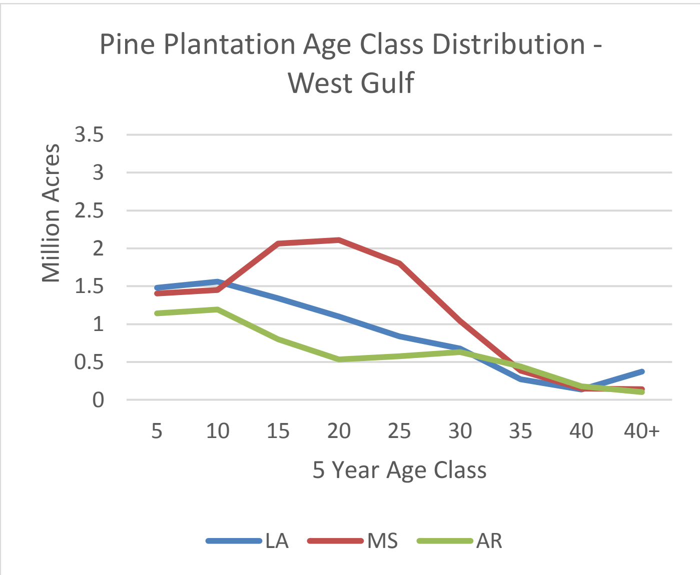

Pine Plantation Age Class Distribution - West Gulf
Million Acres
3.5
3
2.5
2
1.5
1
0.5
0
5
10
15
20
25
30
35
40
40+
5 Year Age Class
LA
MS
AR

Figure 6-4 Pellet region age class distribution (data version 28b – 2013, see Table 6-1**)**

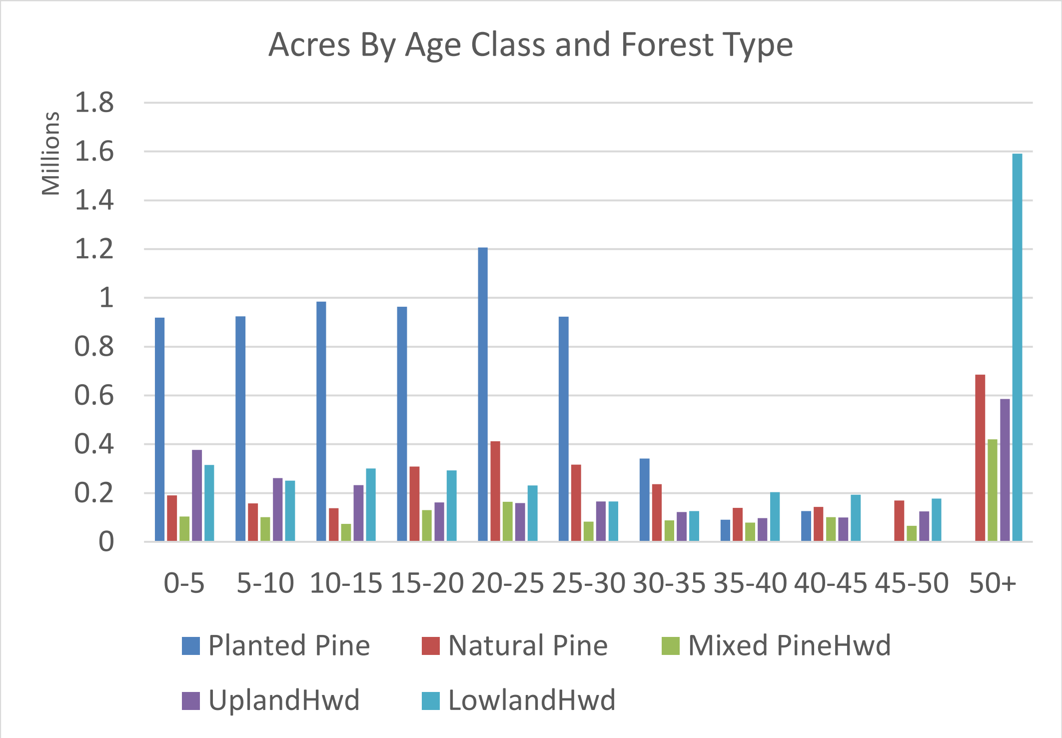
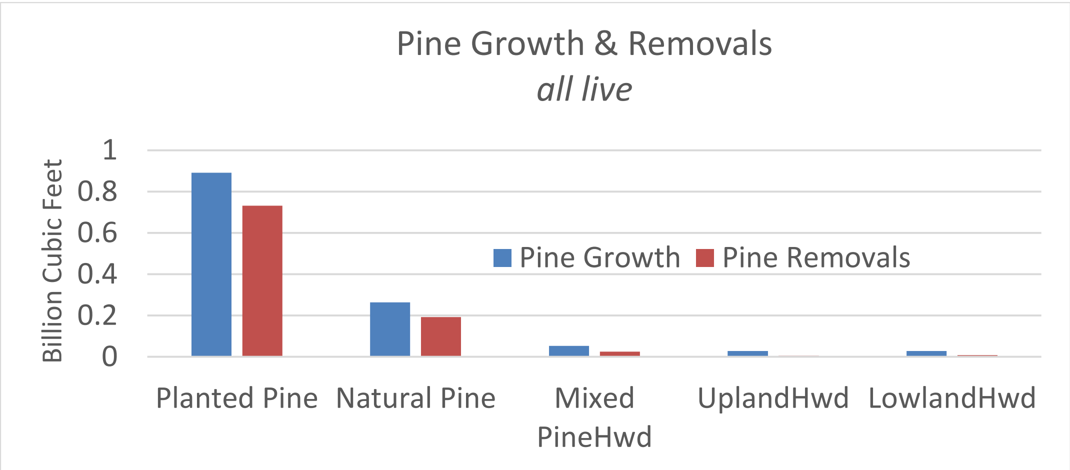


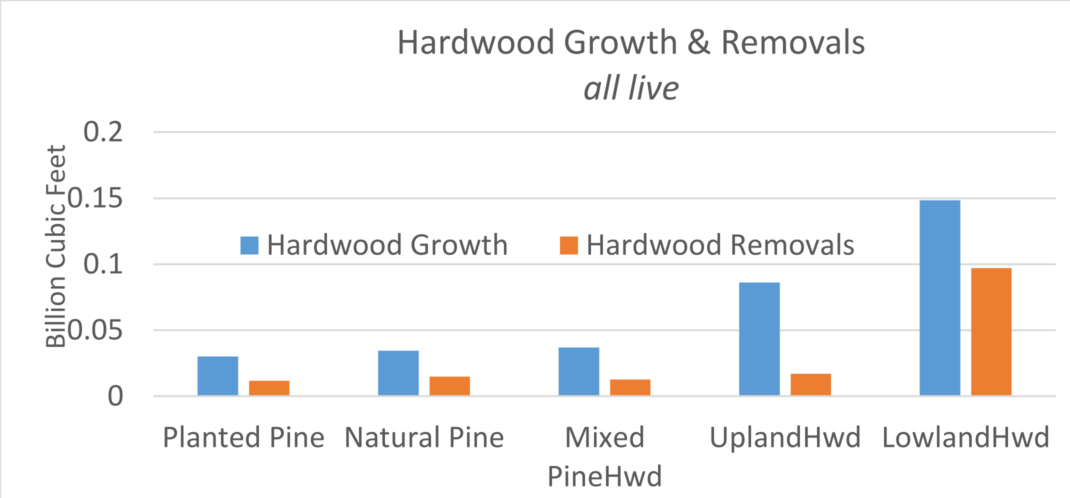
Figure 6-5 Pellet region growth and removals

(Note: all forest types include a mixture of pine and hardwood, including pine plantations, and therefore the graphs below show removals from all forest types)

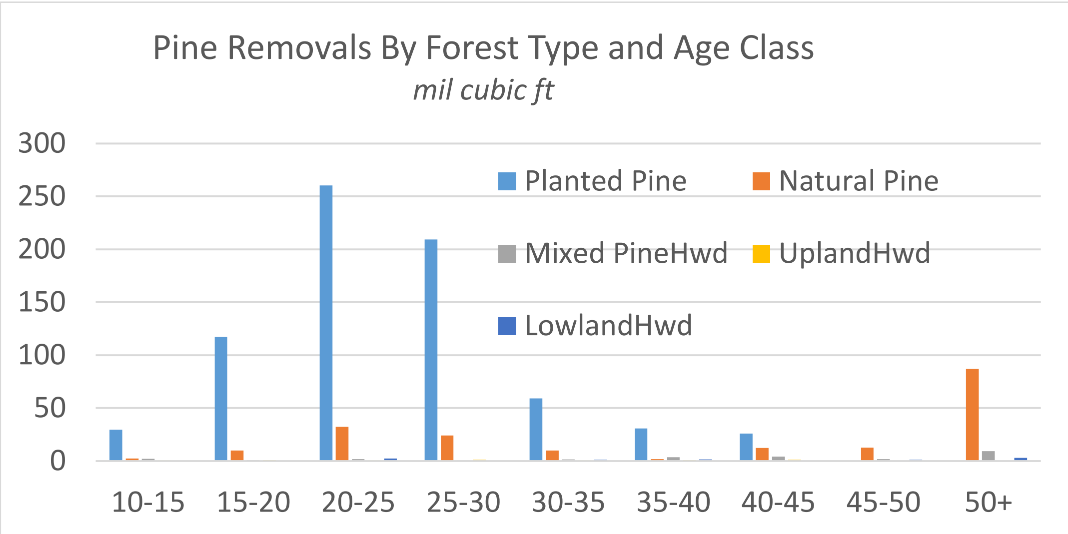
(a) Pine growth and removal



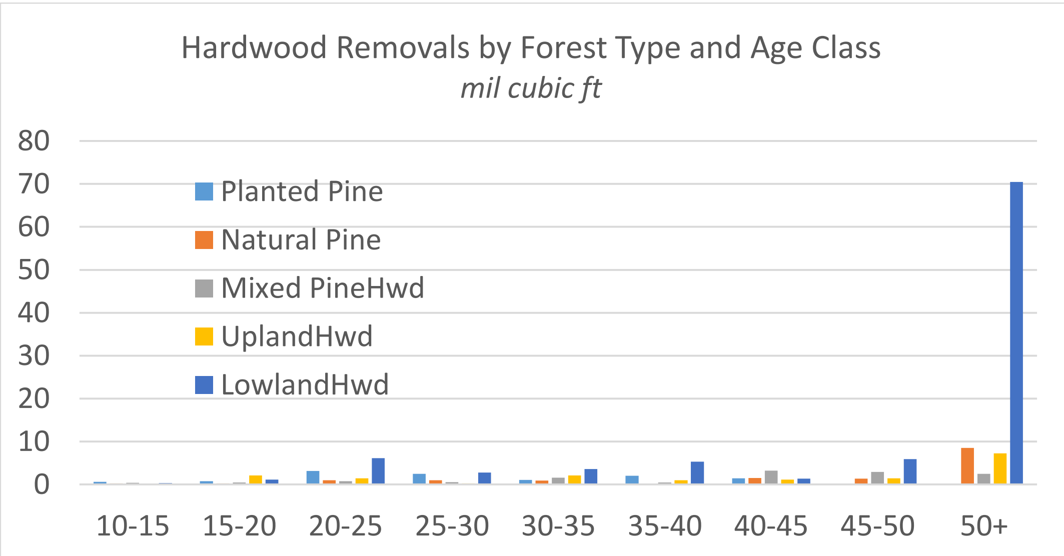
(b) Hardwood growth and removals



(c) Pine removals by forest type and age class



(d) Hardwood removals by forest type and age class



6.1.1 Wood consumption trends

The resource situation sets the supply context for projecting demand. As part of understanding the results projected by the modelling it is equally important to set the context for wood use by the existing forest products industry. In Figure 6-6 and Figure 6-7 large roundwood is the sum of sawtimber and veneer consumption with sawtimber dominating the category (81% in 2011). Small roundwood is the sum of pulp, composite, and other mill consumption which is dominated by pulp (84% in 2011). The impact of the housing recession on pine large sawtimber is shown in Figure 6-6, and at least some of the increase in pine pulpwood consumption during the recession is due to the reduced availability of sawmill co-products. Figure 6-7 shows that the recent south-wide increase in pine pulpwood consumption (by pulp mills) mirrors the loss of mill residues during the recession. Both figures (36 and 37) show that pine small roundwood consumption was at 16 year highs in 2011 reflecting recession impacts and a shift in mill capacity to pine based pulps (e.g. absorbents and packaging). This illustrates how housing recovery (and sawmill co-product availability) is a key determinant of how pellet demand for pine roundwood will affect markets. This shows how important market/economics is in terms of driving forest harvest; and the relationship between housing recovery and small roundwood consumption.

Figure 6-6 and Figure 6-7 also illustrate that, unlike pine, small hardwood roundwood demand shows a long term declining trend. Paper products that use hardwood pulp tend be in categories that are being displaced by electronic media (e.g., printing and writing papers). Some of this capacity, which traditionally used significant proportions of hardwood fibre, has been converted to pine only based products like absorbent pulp. As noted above, this is one component of the pine pulpwood consumption increase.

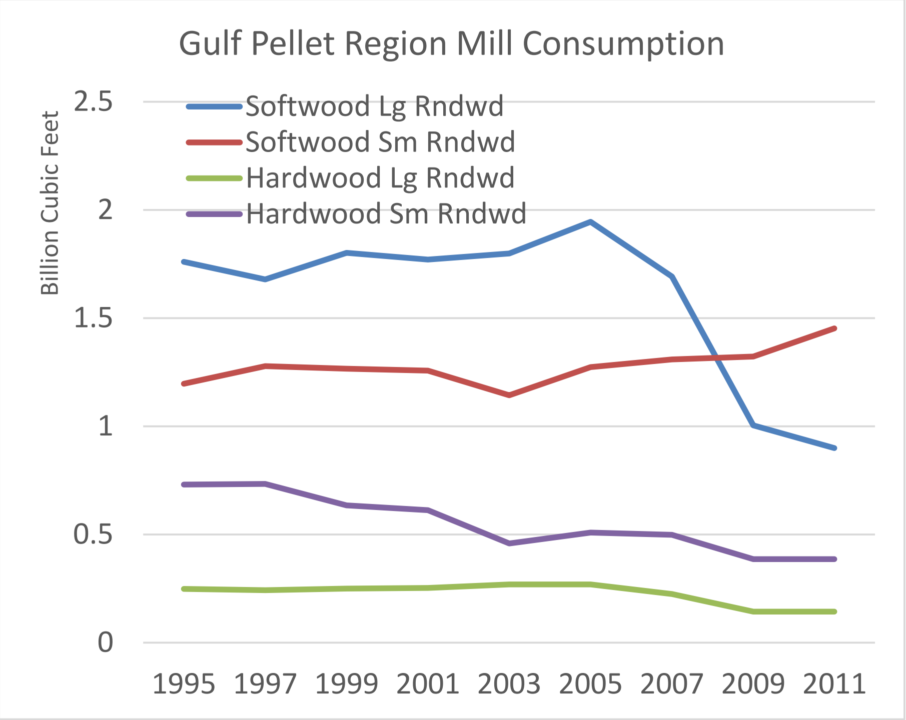
As shown in Figure 6-6, labelling hardwood pulpwood as “small roundwood” may not appropriate because lower grade and lower valued large roundwood may well be used for pulp, even though it is larger than the diameter given (>27.5 cm (11 in) dbh[41]). Further the tops, limbs, and other tree parts that are chipped for fibre uses constitute a larger component of hardwood harvest as compared to harvest at a relatively homogenous pine plantation.

[41] This definition is taken from the USFS FIA Timber Products Output (TPO) not from the DEAC definitions in Stephenson and Mackay (2014)

Figure 6-6 Wood consumption trends by species and size class and region. Source USFS TPO

Gulf region includes Alabama, Mississippi, Louisiana, Arkansas, Texas and northwest Florida
Atlantic region includes Virginia, North Carolina, South Carolina, Georgia and northeast Florida

SM: small; Lg: large. Large roundwood is sawtimber and veneer; small roundwood is the sum of pulp, composite and other mill consumption that is dominated by pulp.



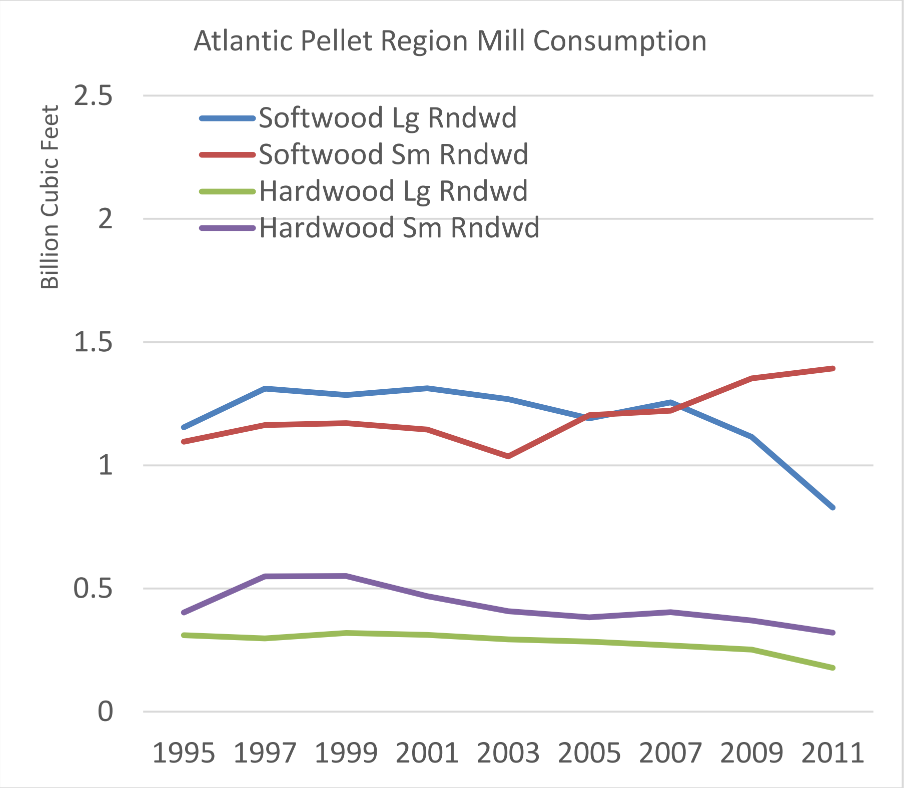
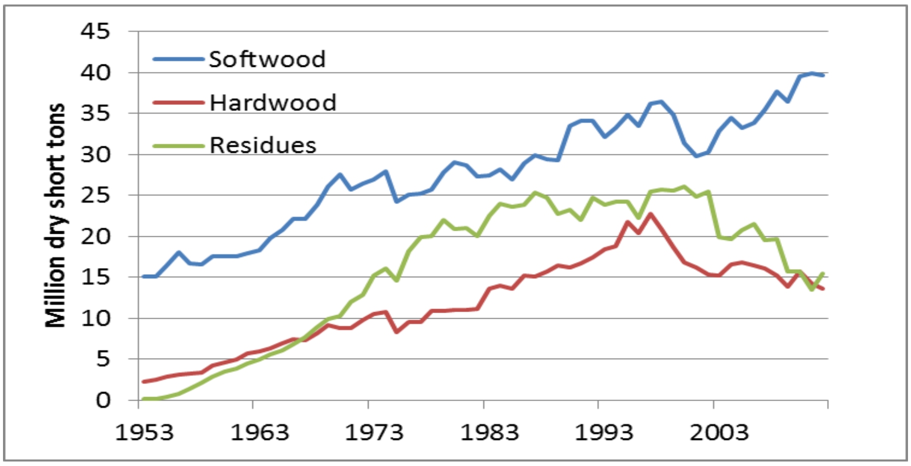


Figure 6-7 Pulpwood consumption by source, 1951-2012.



Sources for Figures 37 and 38: These data are derived from a series of Southern Pulpwood Production Reports, including Bentley and Cooper 2015, Bentley and Steppleton 2013 and 2011, Johnson and Steppleton 2011, Johnson et al. 2010, 2009 and 2008).

6.1.2 Summary of price trends[42]

Figure 6-8 shows nominal stumpage prices (standing timber price paid to landowner) over time for the U.S. Southeast. From the mid-1990s until the recession pine sawtimber prices were four to five times higher than pine pulpwood prices. As a result, southern pine silviculture has been driven by sawtimber. The key factor affecting current and future markets is the outlook for pine sawtimber prices after a 40 percent decline during the recession. As mentioned above, the reduction in lumber production also limited availability of sawmill co-products, which increased demand for pine small roundwood. Further, the lack of final harvest in anticipation of sawtimber price recovery continues the lag in planting for some regions.

This is the market context that led to the decision to examine pellet demand under two different pine sawtimber demand scenarios in this modelling section of the study. A robust recovery sets into motion a market dynamic that drives the system, including pellet impacts. A slow sawtimber market recovery means that pellet demand will be a more important driver of market dynamics mainly because the dominant driver (pine sawtimber) is in recession. In some areas with skewed plantation age class distributions, the price impact of continued scarce mill residues and additional demands on pine small roundwood could be significant.

It is important to note that although the pine sawtimber to pulpwood price ratio is at near historic lows (Figure 6-8) the rate of return for delaying harvest to reach sawtimber size is high. From an internal rate of return (IRR) calculation assuming the current 2.5 pine sawtimber price to pulpwood price ratio and a 10 percent per year stand growth rate, the landowner would be able to make over a 20 percent (nominal) annual return by delaying harvest 10 years for the stand to reach sawtimber size. For hardwoods, assuming a 4 percent biological growth rate and the current 2.8 sawtimber to pulpwood price ratio, the landowner would be able to make over a 9 percent (nominal) annual return by delaying harvest 20 years for the stand to reach sawtimber size. These rates of return reflect the compound effect of biological and price growth rates on the value increase over the period. Given the diversity of landowner objectives and local market conditions, some landowners are likely to harvest the current stand on a shorter rotation, while others will wait until pine sawtimber prices recover. The length of the next rotation would similarly be affected by local market conditions and expectations as the tree matures. So while current market conditions are more favourable to shortened rotations due to low sawtimber prices there is little financial incentive to do so. Even at double current Southeast wide pulpwood prices or yields, a 15 year rotation would not generate sufficient returns to financially justify forestland ownership at current land prices.

The last panel in Figure 6-8 shows the ratio of stumpage prices (landowner receipts) and delivered prices (mill expenditures). Since wood is expensive to harvest and transport pulpwood stumpage prices are typically less than one third of delivered prices. This is important in interpreting the modelled price

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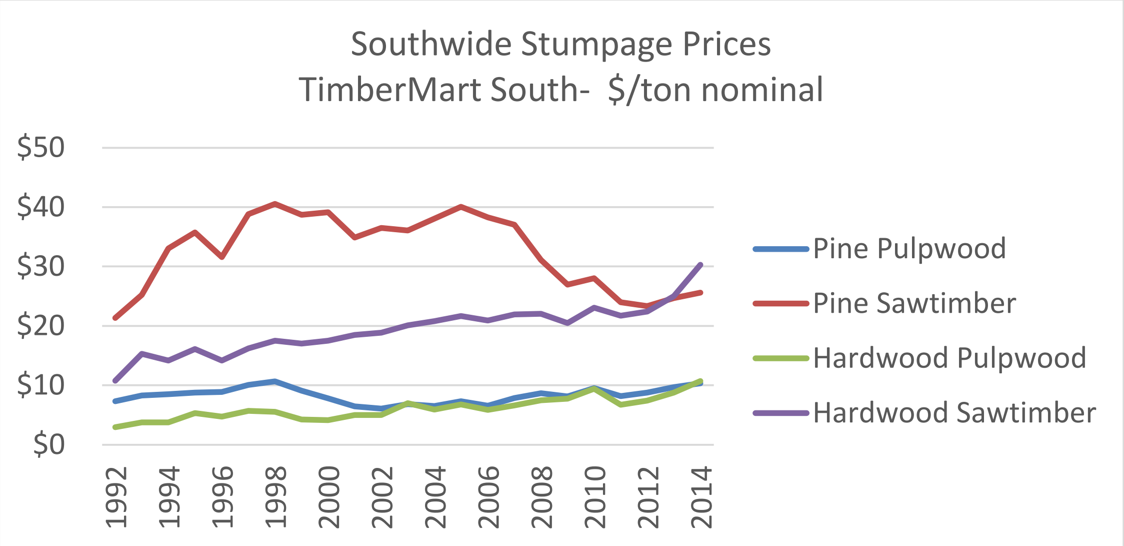
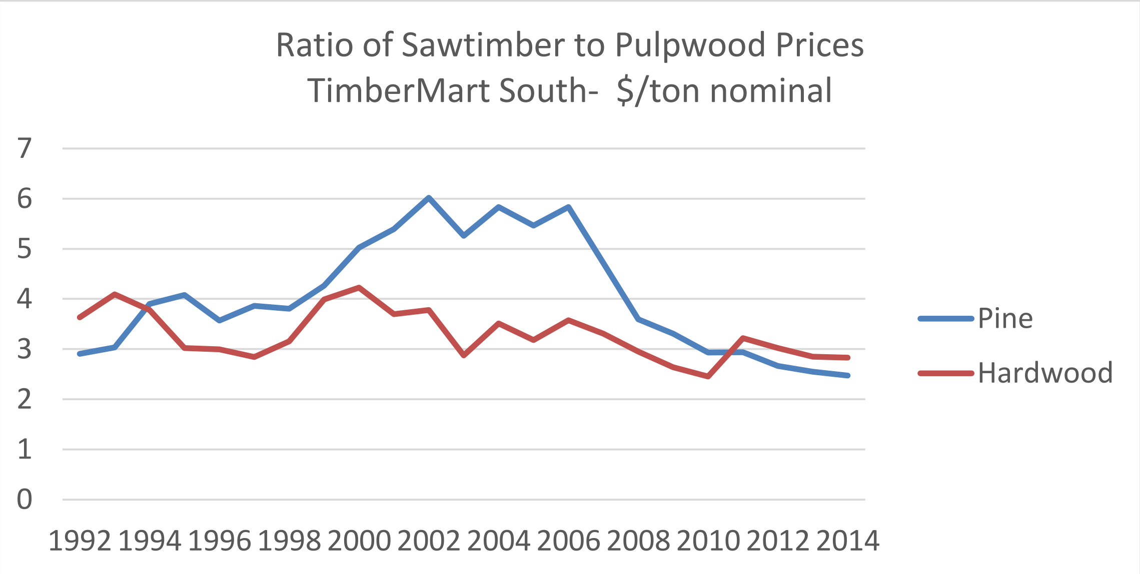
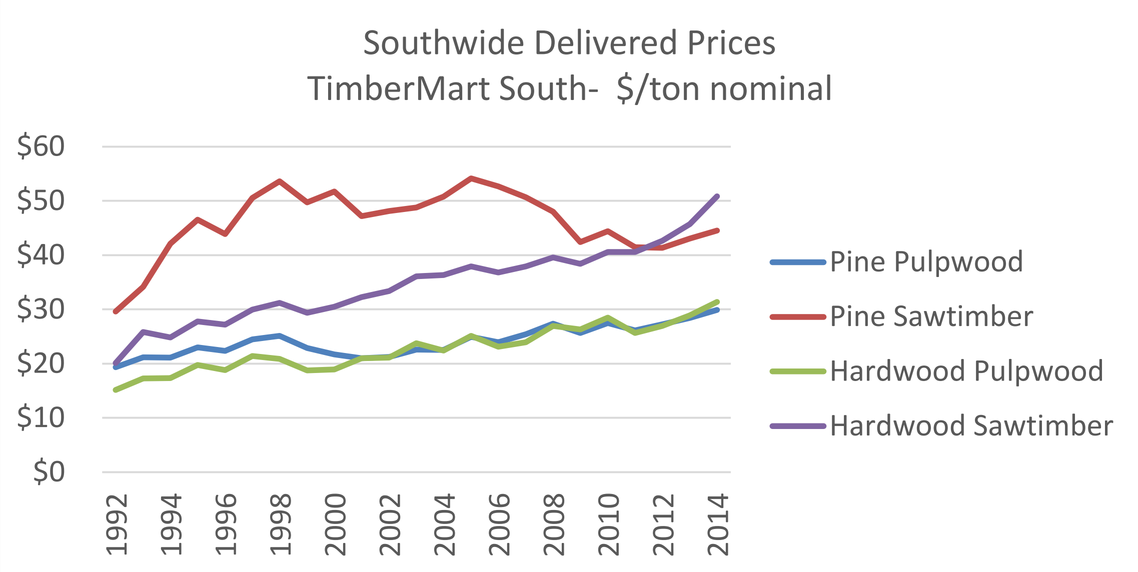
[42] Source: Timber-Mart South http://forestry.ces.ncsu.edu/historic-prices/

impacts. In SRTS, the price impacts reflect the change in the harvest trend relative to the inventory trend. If the harvest increase is higher (lower) than the inventory trend, prices rise (fall). The sensitivity of the price is determined by the price elasticity. In these simulations for pulpwood both the demand and supply price elasticities were inelastic (0.3). This implies that relatively large price changes are required to induce harvest change and is consistent with landowners growing timber primarily for sawtimber and pulpwood consumers being spatially constrained in the procurement operation. Though stumpage price effects may be significant, implied delivered price impacts are one quarter to one third in size.

Figure 6-8 Southern timber prices (1 metric tonne=1.1 ton)







6.2 SRTS modelling methodology

The following description of the SRTS model is taken from Galik et al (2015)[43]. The modifications to the model for this study is explained in the subsequent sections.

The SRTS model was developed to take advantage of detailed forest resource information and regional market parameters from the U.S. Forest Service's Forest Inventory and Analysis (FIA) database to estimate forest resource dynamics, harvest response, and market consequences at a sub-regional (e.g., multi-county) level (Abt et al., 2009; Prestemon and Abt, 2002). It models product demand as a function of product[44] stumpage price and demand shifts through time. The SRTS model uses constant elasticity functional forms (non-linear[45]). Product supply is modelled as a function of product stumpage price and inventory. The product price and harvest levels by product, sub-region, and owner are simultaneously determined in the market equilibrium calculations. In each year, the output from the market module is an equilibrium harvest by product for each region-owner combination. 'Product' modelled in this study is defined in the section on product definitions in 6.3.3. Inventory is the forest inventory in the region of study, also discussed in section 6.3.1. The inventory shift for the equilibrium calculation is estimated using empirically based growth derived from regional Forest Service data, harvest from the market equilibrium module, and land use change.

The model is a recursive dynamic model; therefore, it simulates forestry and bioenergy decisions in a way that allocates resources across owners and sub-regions to clear the market for the current time period and then updates resource and market conditions between periods as it moves through time. Hence, market simulations from a recursive dynamic model should be viewed as a likely market response to a policy and market shock based on current price effects. Though product demand and available inventory are key drivers of market outcomes, there are several other factors that will affect actual local market outcomes. These include market power (number of mills and landowners), timber supply agreements, fuel prices (affects economic procurement area), wet or dry weather (which affect logging conditions) and logging/trucking/rail constraints. The model attempts to capture long term trends in the broader market and does not include many factors that might affect short term regional variation.

Appendix 4 provides a list of literature that describes the development of this model, the assumptions and data used in the model and how it has been applied.

[43] Galik, et al. 2015.
[44] In this case the term 'product' refers to the final use of the wood (i.e. saw timber, pulpwood, pellets etc.) This is explained in more detail in Section 6.3.3
[45] This means that it assumes that the elasticity of specific market functions does not change.

6.3 SRTS Model Input for DECC Analysis

The section below describes the input data and assumptions for the SRTS modelling and the boundaries chosen in the modelling. The important ones are:

- The inventory data and the dates from which this is drawn
- The spatial scale chosen for this study represents a compromise between mill level assessments, which would show local resource impacts but ignore leakage effects, and south-wide or nation-wide assessments that reduce leakage, but add layers of assumptions and complexity beyond the scope of this analysis.
- The assumed product definitions
- The demand scenarios for pellets and current wood consumers in the region
- Assumptions on price responsiveness of product supply and demand, and their implications.

Further information on the source of data for variables is provided in the literature summary in Appendix 4.

6.3.1 USFS Forest Inventory and Analysis (FIA) Input Data

The forest resource data includes area (acres), volume (growing stock or all live, thousand cubic feet), growth (cubic feet per acre per year), and removals (including removals from land use change, thousand cubic feet). "All live"[46] volumes were used for this analysis because it includes "rough and rotten" volumes that are excluded from the definition of growing stock and that are important as a small roundwood source for pulp and pellet products. The FIA data is collected in a 5-7 year cycle. The current SRTS data version for these runs is 28b which corresponds with panel data up to 2013[47] for each state included in the analysis and an average measurement date of 2011. Table 6-1 shows the detailed data vintage of this dataset by state. Growth and removals are calculated as an annual average using the difference between the last two plot visits (from measurement data to previous measurement date). The 2011 removals were estimated as described in the "Adjusting FIA Removals to a 2011 Base Year" section below.

Table 6-1. USFS Forest and Inventory Analysis (FIA) data vintage used for this study Note: The dates are 'decimalised', i.e. 2011.5 will be midway through 2011

Inventory Dates for SRTS v28b Data				
State	**Compilation year**	**Average Plot Measurement Date**	**Average Previous Measurement Date**	**Average Date for Remeasurement**
Alabama	2013	2010.16	2004.07	2007.12
Arkansas	2013	2011.41	2005.69	2008.56
Florida	2013	2011.34	2004.99	2008.17
Georgia	2013	2011.17	2005.9	2008.54
Kentucky	2012	2010.86	2005.06	2007.96
Louisiana	2013	2009.96	2003.12	2007.45
Mississippi	2013	2009.89	2006.64	2008.91
North Carolina	2013	2010.21	2004.14	2007.21
Oklahoma	2013	2011.19	2008.15	2010.05
South Carolina	2013	2011.45	2006.46	2008.96
Tennessee	2012	2010.47	2005.76	2008.12
Texas	2013	2011.17	2006.03	2008.6

[46] That is, all living trees
[47] This means that 2013 is the most recent data of analysis. Some of the data was measured in previous years (after 2011), i.e. in the year shown in the second column of table 6.1.

Virginia	2013	2011.52	2006.53	2009.02

6.3.2 Regional Scope

Thirty one of the fifty eight southern survey units were included in this analysis. These were chosen because they cover the location of operating and announced pellet mills as described by the Forisk, LLC and Southern Environmental Law Center pellet facility databases. These data bases provide an indication of the development of pellet mills in the US Southeast, from which pellet supply to Europe will be drawn. As shown in Figure 6-1 this includes the mid-Atlantic, Southeastern, and western gulf coastal plain and piedmont survey units.

An important constraint in this analysis is presenting results at one spatial scale. Modelling at a smaller spatial scale (e.g. a single mill procurement circle) would better capture the concentrated local resource impacts, but impacts outside that circle (e.g. leakage) would be ignored. Modelling globally or nationally would reduce leakage from the modelled area, but would add complexity and uncertainty that were beyond the scope of this project. The spatial scope here reflects a compromise. It includes the entire Piedmont and coastal plain region in the southern U.S. within which pellet mills exist or are announced. Much of this area is outside the procurement zone of any pellet mill. By defining the region this way we include the resource impacts of potential displacement and spatial re-allocation of demand (leakage) within this broader zone.

Demand is price-responsive based on the elasticities described below. Higher prices lead to lower regional demand (and vice versa). So the model also does not force all of projected demand to be met within the region. However the model does not track market or resource impacts outside of the defined market.

Another consequence of this broader spatial scope is that concentrated local impacts around mills are not modelled. Since pine demand is 80% of the market and is distributed throughout the region, the pine impacts may have less spatial variation. For hardwoods, the current distribution of pellet demand is more concentrated and hardwood forests species and age structure differ more by region. The modelled set of projections does not provide insight into the spatial distribution of these localised impacts within the broader region.

6.3.3 Product Definitions

These simulations are based on four product categories; 1) pine small roundwood (aka pulpwood), 2) pine large roundwood (also known as sawtimber), 3) hardwood small roundwood, and 4) hardwood large roundwood. The breakpoint between small and large pine roundwood was 9 inches diameter breast height (dbh) for hardwood the breakpoint was 0.28m (11 inches) dbh. These definitions are consistent with USFS Forest Inventory and Analysis (FIA) sawtimber and non-sawtimber categories[48]. In addition to the size distinction, 15 percent of pine material in the large pine roundwood category was considered to be of insufficient quality or size (e.g. tops, limbs) to be used for sawtimber and was added to small roundwood volumes. For hardwoods, a 30 percent degrade to roundwood factor was used to reflect the higher residues due to tree form, species and grade found in the more diverse naturally regenerated hardwood forest.

Product definitions for this analysis did not change over time. In reality, product definitions are price sensitive. This is relevant since currently low sawtimber prices and high small roundwood prices means that trees that technically meet small sawtimber specifications may be more valuable in a small roundwood application. To the extent this resource is locally available it can increase effective supply and put an effective ceiling on pulpwood price increases. This has some implications for ingrowth into future sawtimber categories, but future sawtimber supply is not currently a concern.

6.3.4 Price responsiveness and land use change

In economics, elasticity measures the proportionate response of one variable to another. The demand price elasticity, for example, measures how quantity demand responds to a change in price. An elasticity of one would imply that a 1 percent change in price leads to a 1 percent change in quantity demand. If quantity responds less than proportionately demand is considered inelastic. The literature for the U.S. Southeast has consistently found demand-price and supply-price elasticities of stumpage to be

[48] BEAC used the same inventory data, but says that the definition of round wood varies between mills. It defines saw logs as a log with a small end diameter greater than 0.13 -0.2m (5-8 inches) and chip-n-saw as small saw logs and large pulpwood, with minimum diameters of 0.10 - 0.15 m (4 - 6 inches) and maximum diameters of 0.23 -0.41 m (9 - 16 inches). This is different to the FIA definitions used here, but of the same order.

inelastic. In these projections, demand-price elasticity is assumed to be 0.3 for pine and hardwood. While the demand price elasticity has been consistently estimated to be inelastic (<1), there is no empirical literature that represents this specific region, product definition, or emerging demands (pellets). These demand price elasticities were set to levels at the lower end of the responsiveness found in the literature (0.3 vs 0.5). This means that more of the resource impact was kept within the modelled region. This gives the advantage of giving a more conservative (higher resource impact) resource analysis, but allows higher regional price consequences.

The pine and hardwood supply price elasticity was assumed to be 0.3 for non-sawtimber to 0.5 for sawtimber. Supply – inventory elasticities were assumed to be 1 for pine and 0.7 for hardwoods (Pattanayak et al 2002; Beach et al. 2005). The former reflects an assumption that pine supply is proportional to inventory change, while hardwood supply is less than proportional to inventory change reflecting the fragmented nature and accessibility issues associated with hardwoods (e.g. lowlands and steep slopes). Reviews of relevant elasticity and land use studies are given in the SRTS literature section below.

Price responsiveness for wood input to pellet producers is unknown since the industry is emerging and there is no history of its responsiveness to price. Factor demand price elasticities depend on the importance of the factor in total cost, opportunities for using substitute products, and price responsiveness of the final product. There have been studies that estimate that pellet producers have limited ability to pay relative to other pulpwood products (Forisk, Pöyry), with some indications of a choke price (a price that cuts off demand).

One possible scenario is that pellet producers may not be price responsive in a narrow range of prices, but would exit the market when the choke price is reached across a wide region of their supply. However, once the production capacity is in place the decision to exit the market depends on future price expectations and the ability to cover variable costs. Since the pellet industry is expanding, location and feedstock choices are likely to respond to emerging wood input costs. Part of this is captured by the demand price elasticity which reduces regional demand as prices increase. The price projections below maintain current empirical pulpwood demand price relationships and should be interpreted cautiously.

Elasticities affect price and harvest impacts of demand changes (e.g. pellets) and directly affect potential GHG leakage. For this report leakage is defined as in Appendix E of the EPA Biogenic Carbon Accounting Framework (US EPA 2014) as an indirect source of biogenic CO_2 emissions associated with use of biogenic feedstocks[49]. Since this study is focused on the southern landscape, and land use change is an important part of the model results it is important to recognize the potential impact of indirect land use change (ILUC). The only way to capture leakage in a modelling context is to use global models that capture the dynamics across all sectors, markets, and resource use. The data to support this type of modelling varies across regions and sectors and seldom operate at a spatial scale relevant to questions raised in this study. The SRTS results include interaction with non-timber land and agriculture in the rural landscape. The specific model used is Hardie et al. (2000) but more recent work substantiates the importance of land rents[50] to land use change in the U.S. Southeast Lubowski et al. (2008). Since agricultural rents are exogenous to SRTS they were held constant for these runs. Since the projected rent changes in the model drive land use, it is important to understand ILUC in this application.

Much of the ILUC literature focuses on corn ethanol. In that application, using a row crop (corn) to produce ethanol is directly using high quality agricultural land in the most productive agricultural region for energy that might otherwise contribute to food supply. In this study increasing returns to forestland in the privately-owned market-based southern landscape will, under certain circumstances, expand the forest base relative to other rural land uses. Though the labels "timberland" and "agriculture" are often used, they don't capture the continuum of rural land uses including 2.4 million acres of idle cropland, 5 million acres of cropland pasture, 21 million acres of grassland pasture, and 31.3 million acres of cropland in the nine southern states (source http://www.ers.usda.gov/data-products/major-land-uses/.aspx, Texas was excluded). Since by definition the land converting to trees is either abandoned

[49] See also Galik and Abt (2015): "The inherent dynamics of the US Southeastern forest landscape make it difficult for a single-pellet purchaser to know for certain what the full GHG implications of his or her purchase will be absent the use of outside data or tools to assess the broader impacts. Complicating matters further, any significant addition of new bioenergy demand introduces the possibility of inter-regional shifts in patterns of biomass supply, also known as leakage. Although these shifts are expected to be small in this analysis given the magnitude of additional demand assessed, previous analyses have highlighted the potential significance of the phenomenon on a global scale (Frank et al., 2013)."

[50] Economic term for returns to landowners

(passively reverting) or based on rents (where cropland represents the highest rent) the acreage of non-timberland expansion does not directly translate into an area of productive agriculture expansion in another region.

6.3.5 Feedback between Pine Sawtimber Markets and Pine Small Roundwood Demand

As pine sawtimber markets recover from the recession there are both long and short term feedbacks to pine small roundwood demand. Since final harvest of sawtimber is the standard practice, its harvest coincides with planting the next rotation. Under standard silviculture practices the leads to availability of small roundwood due to thinning in 10-15 years.

An immediate effect on pine small sawtimber demand is the increased availability of sawmill co-products which are a superior substitute to pine small sawtimber for all markets that use pulpwood. The recent increase in recent pine small roundwood harvest is largely due to; 1) conversion of some hardwood based pulpwood demand to pine as mills reduce writing and printing paper capacity in favour of packaging and absorbent material fibre, and 2) the reduction in pine mill residue availability due to reduced output from pine sawmills. In this application non-pellet pine small roundwood demand is assumed to increase gradually. Mill residue availability was modelled assuming 30 percent feedback from increased pine sawmill consumption, which reduces pine small roundwood demand. Similar trends apply to a lesser extent to hardwood, which may be locally important. Since the price of hardwood sawtimber and pulpwood have been declining and represent a much small fraction of the total market, they were not explicitly part of the sensitivity analysis.

6.3.6 Demand Scenarios

The fundamental reason for the modelling portion of this study is to simulate the impact of increasing resource demands due to pellets. Unlike forest supply, which is largely determined by the existing age class structure for the next 10 to 15 years, demand for traditional forest products is especially uncertain as the U.S. economy recovers from a recession. Since the primary income source for landowners is pine sawtimber, it is clear that this market is key to the future of the resource. In addition pine pulpwood demand has increased in many areas while hardwood pulpwood demand is decreasing Southeast wide.

The marginal impact of pellets depends largely on this uncertain demand context of traditional products. To explore the sensitivity of pellet impact to the uncertainty of future markets, six scenarios were modelled to examine demand for non-saw timber when demand for saw timber is high and when it is low: 1) high pine sawtimber (PST) demand without pellets, 2) low PST demand without pellets, 3) high PST demand with low pellet demand, 4) low PST demand with low pellet demand, 5) high PST demand with high pellet demand, and 6) low PST demand with high pellet demand Table 6-2. In this way the analysis was used to understand the impact of pellet demand on non-sawtimber when sawtimber demand is high and when it is low. As discussed above this allows an understanding of the impact of the availability of an increased supply of sawtimber residues in a scenario where sawtimber demand is high. The levels of pine sawtimber demand used in the modelling are discussed below.

Table 6-2 Demand Scenarios

Base demand examines the situation when there is no pellet demand, both when there is high pine saw timber (PST) and low PST demand. The other scenarios examine the impacts of pellet demand on non-sawtimber demand in scenarios that consider high PST and low PST.

Scenarios	LABEL	Housing Starts – Pine Sawtimber Demand	Pellet Demand	Hardwood/Pine Pellet Split
1	Base High PST Demand.	High (USFS)	None	n/a
2	Base Low PST Demand.	0.5 x High	None	n/a
3	High PST Low Pellet	High (USFS)	Low	20% Hardwood
4	Low PST Low Pellet	0.5 x High	Low	20% Hardwood
5	High PST High Pellet	High (USFS)	High	20% Hardwood

6	Low PST High Pellet	0.5 x High	High	20% Hardwood

6.3.6.1 Pine Sawtimber Demand

Pine sawtimber (PST) demand trends were based on southern harvest projections underlying the USFS General Technical Report FPL-GTR-219 (Ince and Prekash, 2012). That study assumed a return to the long-run average of 1.09 million single family starts per year by 2020, then an increase of 0.4% per year after that. Housing starts represent the number of houses being built. Ince and Prekash (2012) projected that lumber imports would decrease, which with increased housing, lead to large increases in PST demand. Given the weak recovery of housing since 2010, this pine sawtimber demand was used as the "high" PST demand scenario. A "low" PST demand scenario was derived by lowering the annual growth rate of PST demand by 50 percent. This was simply chosen to bracket PST demand within a reasonable range.

Demand for other products (hardwood sawtimber and small roundwood for both species) were from the same study. Since these demands did not exhibit dramatic change and are less important as income sources, sensitivity analysis was not conducted on these product demands.

Figure 6-9 shows the traditional product demand scenarios.

6.3.6.2 Pellet Demand Scenarios

Unlike PST demand, the future of pellets is uncertain, mainly due to its dependence on EU and Member states (MS) renewable energy policies. In addition to the base case (no pellet demand) two pellet demand scenarios were developed guided by on Ricardo Energy & Environment's estimates in Box 6-1, information from Forisk LLC on pellet mills operating and in construction, and World Bioenergy Association (also discussed in Box 6-1). The figures used were a compromise of all of this data and do not match exactly the figures provided in Box 6-1. The low scenario assumed pellet consumption reaches 12 million tonnes[51] (13.2 million tons) of consumption by 2030 from the US Southeast. This is consistent with 5.6 million tonnes (6.2 million tons) pellet demand in the UK and 6.3 million tonnes (7 million tons) pellet demand in the rest of the EU. The high scenario assumes pellet consumption approaches 18 million tonnes over the same time period. This is consistent with 8 million tonnes (8.8 million tons) demand in the UK and 10 million tonnes (11 million tons) demand in the rest of the EU. Alternatively the low demand scenario could be interpreted as EU only and the high pellet demand scenario could be interpreted as EU plus UK demand. Figure 6-10 shows the wood consumption implications in millions of U.S. green tons of wood consumption.

Demand from the rest of the world was not considered. This is because only the EU has set in motion renewable energy policy that encourages large scale biomass pellet import at present. Although there are renewables targets in South East Asia (notably South Korea) that have resulted in pellet import into this region we have assumed that the distance between the US Southeast and Korea means that economic export to the region is not feasible. Although there is some indication that demand in the US may grow due to demand from co-firing we have assumed that this demand will be met by supply across the USA that will not impact greatly on the US Southeast. This is because there are forests across the USA and transport costs dictate that the co-firing sector will use supply close to its plants.

[51] Note: pellets will contain 7-10% moisture on a weight basis. The figures used for demand for pellet take moisture content of the pulpwood supply into account.

Box 6-1 Estimation of demand for biomass pellets from Southeastern USA

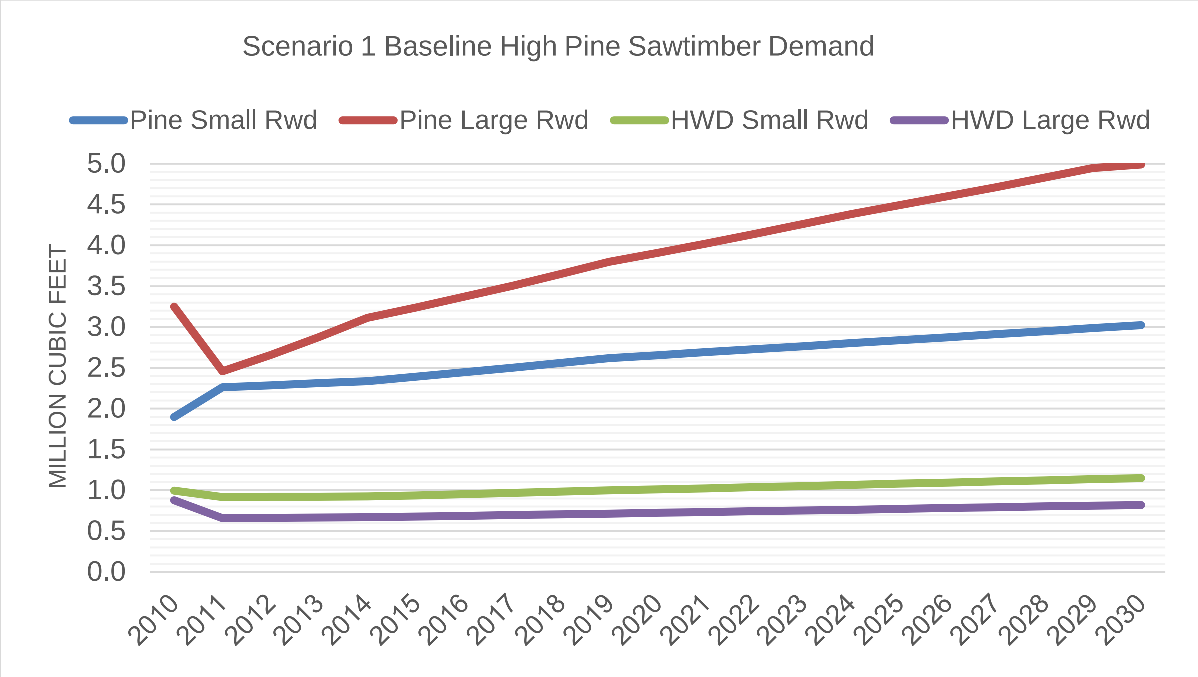
Ricardo Energy & Environment figures were developed from a bottom up approach for pellet use in the UK and Europe. This was based on power station announcements in the UK. For Europe information was taken from Verhoest and Ryckmans (2012) and Hoefnagels and Junginger (2015). This data provided an estimate of UK demand for pellets from the USA of around 3.6 million tonnes (4 million tons) in 2015 rising to an estimated 7-8.3 million tonnes (7.7-9.1 million tons) by 2020 and the held steady to 2030. Additional European demand for pellets from the USA was estimated to be 4 million tonnes (4.4 million tons) in 2015 rising to 10 million tonnes (11 million tons) in 2030. This gives a total European demand in the region of 16 -18.3 million tonnes (17.6 to 20 million tons) by 2030. Low EU (including UK) demand figures were estimated assuming that only 60% of the planned conversion to biomass would happen due to changes in policy, difficult in obtaining finance and increased sustainability requirements (which will add cost to pellet production).

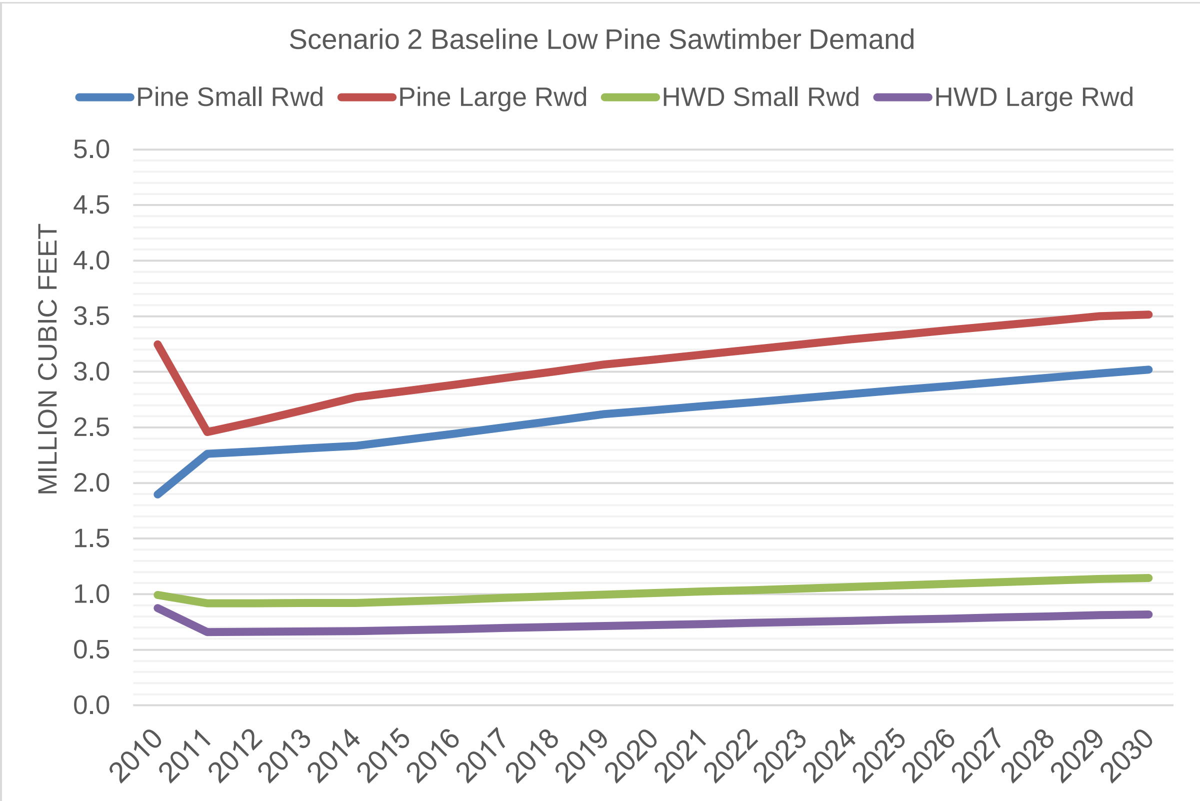
World Bioenergy Association (2014) calculated the biomass requirements for the accelerated deployment of renewables in Europe published by the European Renewable Energy Council in 2010. Their estimates are that it would be possible to import 16 Mtoe of pellets to Europe by 2030. This is equivalent to around 40 million tonnes of pellets, not all of which would come from the USA. The paper does not give details on where the imports would come from. Assuming that the USA, Canada, Russia and Brazil would all be part of this import market, we believe that it would be reasonable to assume that 50% of these pellets would come from the USA. This is equivalent to an optimistic maximum demand scenario of 20 million tonnes of pellets from the USA.

Comparing these two demand figures with figures for pellet plants in operation and construction provided in the text, it was decided to use a figure of 18 million tonnes (20 million tons) of pellets for high demand and just under 70% of this (12 million tonnes or 13 million tons) for low demand.

Figure 6-9 Traditional forest product demand scenarios

Units: million cubic feet. 1 cu ft. is 0.028m cubed [52].

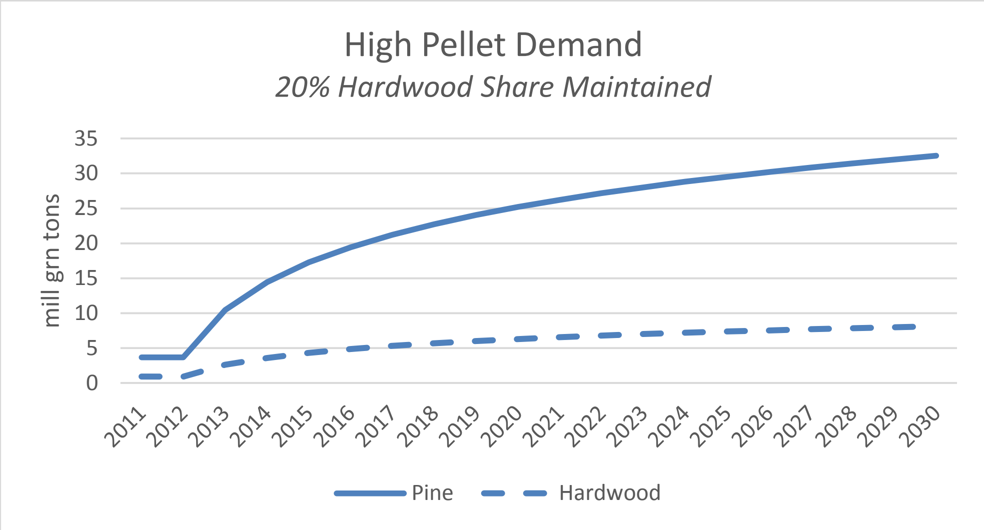


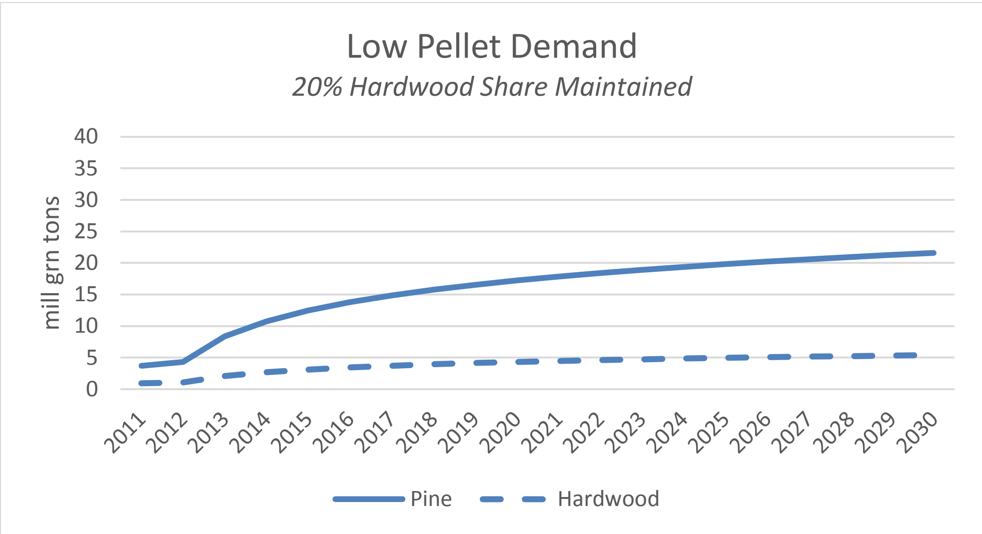


[52] It is not possible to convert the units to tonnes, as the inventory data is provided as cu ft and density of wood (i.e. weight per volume) depends on species.

Figure 6-10 Pellet demand scenarios

Units: million green tons. These include moisture content, i.e. represent harvested tons. I ton is 0.907 metric tonne.

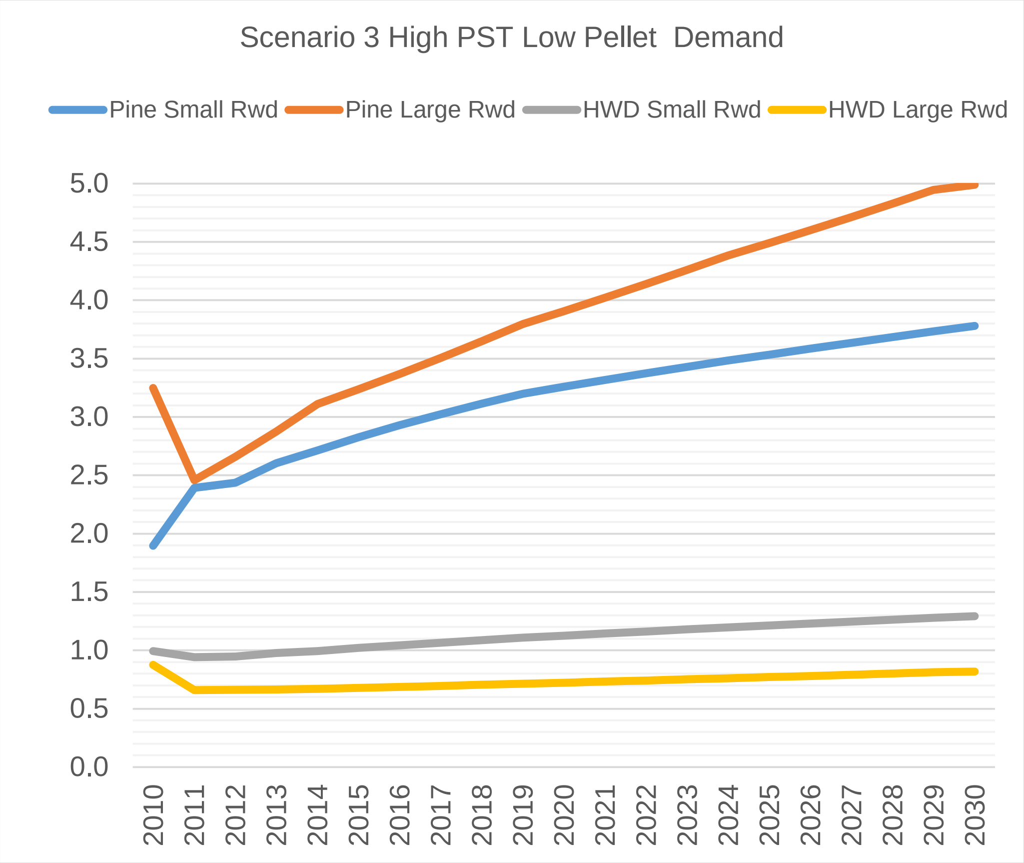


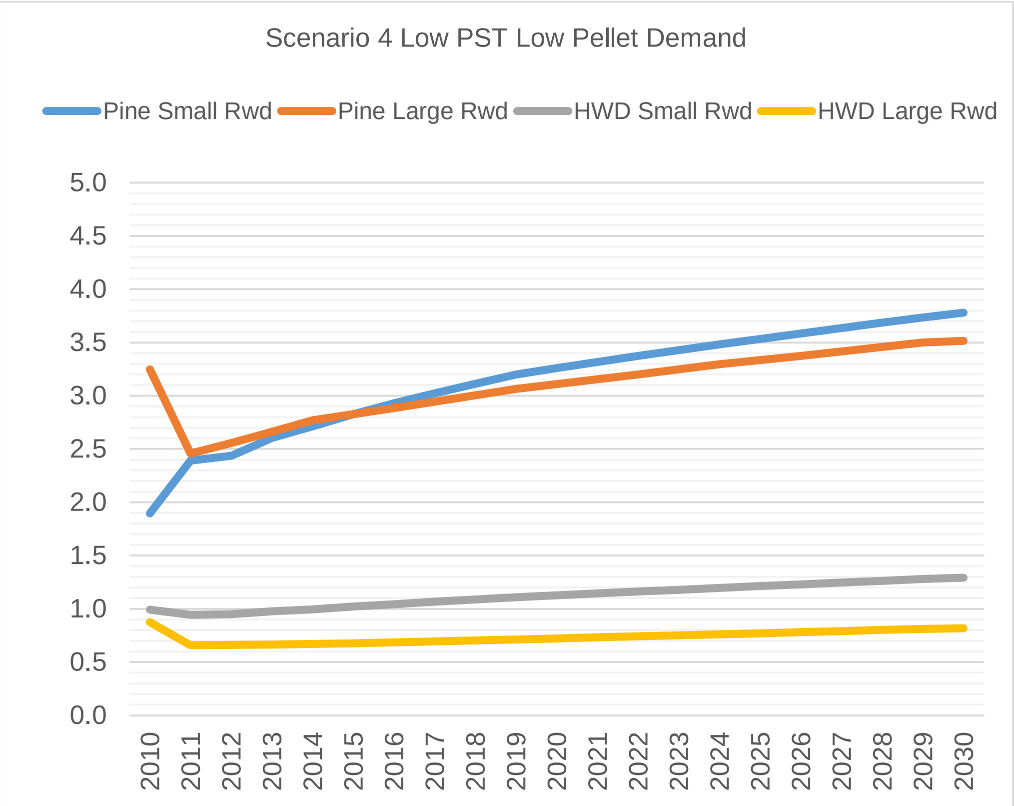


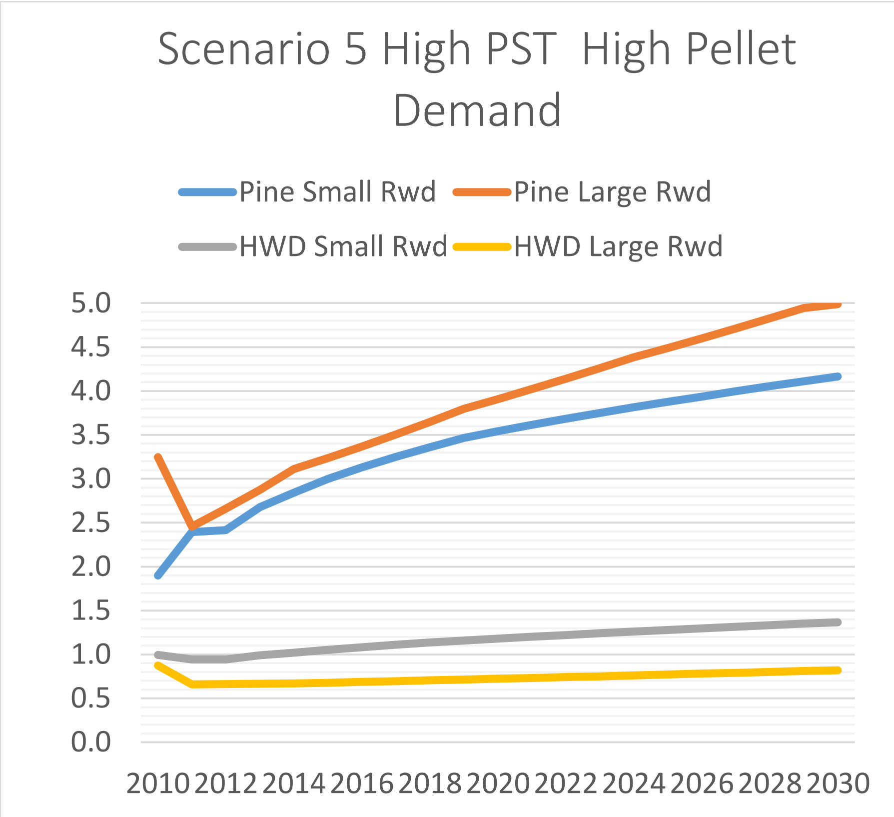
Pellet wood consumption was added to small roundwood demand by species group, yielding demand scenarios 3-6 as shown in Figure 6-11. The low pellet demand scenarios added an average of 22 percent to pine small roundwood demand and 12 percent to hardwood small roundwood demand over the projection period. The high pellet demand scenario increased small roundwood demand an average of 33 and 18 percent for pine and hardwood respectively.

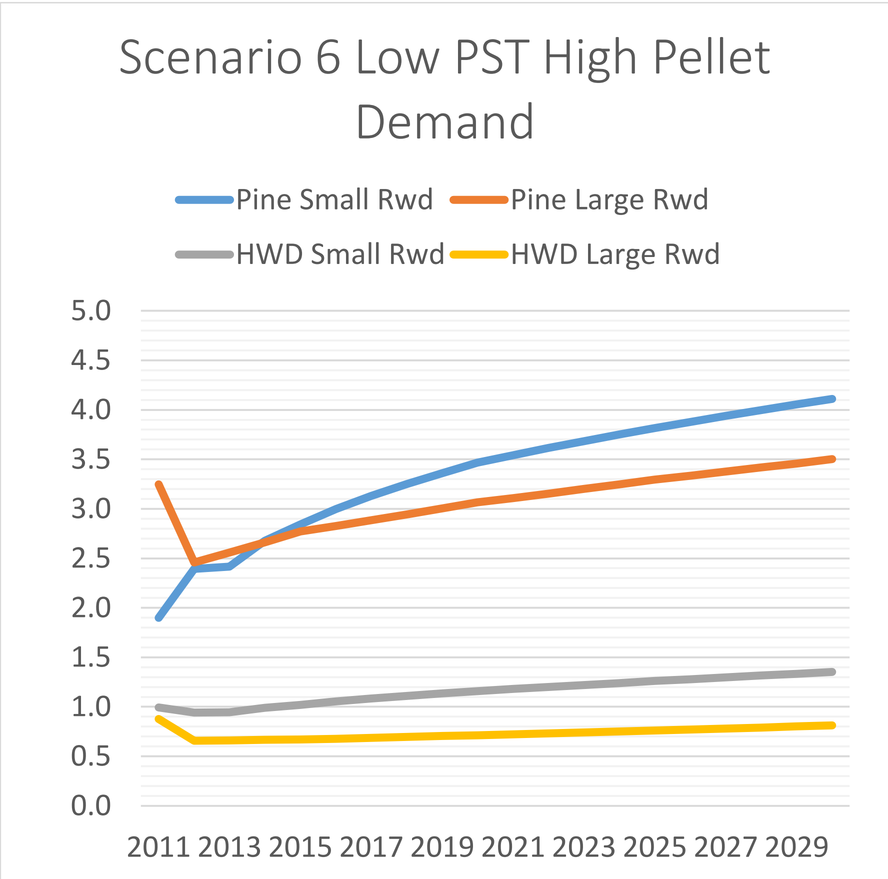
Figure 6-11 Combined pellet and pine saw timber (PST) demand scenarios. *(Scenarios relate to those listed in* **Table 6-2***)*

The axes on the left area indices compared to the year 2010.






Scenario 5 High PST High Pellet Demand
Pine Small Rwd
Pine Large Rwd
HWD Small Rwd
HWD Large Rwd
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010 2012 2014 2016 2018 2020 2022 2024 2026 2028 2030


Scenario 6 Low PST High Pellet Demand
Pine Small Rwd
Pine Large Rwd
HWD Small Rwd
HWD Large Rwd
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2011 2013 2015 2017 2019 2021 2023 2025 2027 2029

6.3.6.3 Adjusting FIA Removals to a 2011 Base Year

As shown in Table 6-1, the FIA plot data is collected over a five to seven year cycle. For variables based on remeasurement or volume change between survey cycles; e.g. growth and removals, estimates are calculated as an annual average between the current measurement date and the previous visit to the plot. Referring to the Georgia data in Table 6-3 for the panel ending in 2013, the average year plots were visited was 2011.17[53] and the average date that plots were previously visited was 2005.9. Thus the midpoint of the remeasured variables was 2008.5. For growth per acre by age class, using 2009 growth rates is probably not a problem. For removals, however, where the time span covered includes several years before the recession, it is problematic.

USFS FIA also conducts a census of mill consumption by product and county in odd years. This timber product output (TPO) database is used to adjust the starting point of the plot data to better reflect 2011 as follows. The TPO data for the years 2005, 2007, 2009, and 2011 for each of the 31 survey units is compiled by product. The average removals over this period correspond approximately to the period that the panel remeasurement data covers. The ratio of this average to the 2011 data provides an estimate of how the 2011 removals compare to the average removals over this period. Table 6-3 shows the average percent adjustment using the above procedure.

Table 6-3 TPO 2011 Removal Adjustment

TPO Removal Starting Point Adjustment	Pine Small Roundwood	Pine Large Roundwood	Hardwood Small Roundwood	Hardwood Large Roundwood
2011 Removals Relative to 2003-2011 Average	19%	-24%	-8%	-25%

Table 6-3 shows that for this region pine small roundwood removals were 19 percent higher in 2011 than the average of the 2005-2011 period. For all other products removals are lower in 2011, especially for large roundwood tied more directly to the housing market. The shift in removals from 2010 to 2011 shown in Figure 6-3 and Figure 6-11 reflect the implementation of the above adjustments. This aggregate shift is the sum of the individual survey unit adjustments applied to each product across the 31 survey units.

6.4 SRTS Modelling results

As described above, pellet demand is occurring during a convergence of high pine pulpwood demand related to recent planting trends and the lowest prices for the main rent driver (PST) in recent history.

Figure 6-12 shows projection results for pine pulpwood (PPW). The reference case (no pellet demand) shows the short run impact of increased mill residues on the market, as there is slight downward pressure on pine pulpwood prices in the **high PST** case even with flat initial demand for pine pulpwood (Figure 6-7). This is because sawmill co-product availability is tied to increases in saw timber consumption, so even in the reference case, sawtimber consumption recovery from the recession leads to increased residue availability. In addition, higher PST harvest leads to increased availability of cull material (this could be logging residues or low grade material) that meets some PPW demand. The increased harvesting and subsequent planting of pine plantations from higher PST demand also dampens the pellet price effect after 2020 as more acres are available for thinning. Nevertheless the current age class distribution (Figure 6-4) and the recent increase in PPW (pine pulpwood/roundwood) demand (Table 6-3) leads to projected price impacts in the pine pulpwood market. Assuming that stumpage is 30 percent of delivered price, the projected increase would range from 25 to 30 percent change in delivered price in the low pellet demand scenario and 40 to 50 percent change in delivered price in the high pellet demand scenario by 2025.

These results suggest that expected pellet demand will have price and harvest impacts in small roundwood markets. Figure 6-12 also shows that the pine pulpwood inventory differences are **greater between the low and high PST projections than they are between the low and high pellet demand projections**. High and low PST demand differences have similar impacts on PPW prices as the two pellet demand scenarios. High PST demand lowers consumption of pine pulpwood by providing

[53] As indicated above Table 6.1 this refers to a decimal year, i.e. 0.17 of the way through 2011.

offsetting mill residues. It also leads to increased final harvest which helps ameliorate the lack of planting in recent years discussed above. Increased pellet demand does lower 2030 pine pulpwood inventories relative to the no pellet scenario (3% and 5% for low and high pellet demand respectively), but it remains above pulpwood inventories with low PST demand. With low PST demand, the lack of final harvest continues the lower planting trend and inventories of pine pulpwood decline by 10%. In this case where pine sawtimber prices remain relatively low, the addition of pellet demand and its price effects result in increasing pine pulpwood inventory impacts by 2030.

Figure 6-14 shows that sawtimber markets are not likely to be affected by pellet demand other than pine small sawtimber as described above. The low pine saw timber demand scenario keeps prices essentially flat while the high demand scenario drives higher PST prices, which as the most important rent driver, affect land use change. Note that in the low PST demand high pellet demand scenario, stagnant PST prices and increasing PPW prices leads to a significant impact of PPW on forest rents[54]. Given that we are starting at a historical low in the PST to PPW price ratio (Figure 6-8), this combination continues a trend which we have not observed historically. So for example if PST prices dropped a small amount it would more than offset a similar scale PPW increase since PST prices are three times higher. However if PST prices are flat (Figure 6-14 middle row), a significant increase in PPW prices (Figure 6-12 pellet demand runs) means that PPW prices become more important to forest rent calculations. Hardwood sawtimber markets were not affected by PST demand scenarios, so only the high PST demand scenario is shown in Figure 6-13.

Figure 6-13 shows hardwood pulpwood market impacts. Since a higher proportion of hardwood pulpwood is the lower grade components of an older hardwood forest, there is less of an age class dynamic for hardwood pulpwood supply. Further, with the exception of a small area of eucalyptus plantations, there is not an intensive management response to hardwood demand. These factors lead to a relatively flat inventory trend, where the price effect is driven simply by the scale of demand relative to current removals. So high pellet demand leads to an increase in price and harvest but little effect on inventory. Recall that these runs assume that the current estimated proportion of hardwood pellet feedstock (20%) is maintained in the future. Announced capacity, however, is expected to be dominated by pine utilization (Figure 6-7). Though regional hardwood impacts could be overstated, these runs also spread the pellet demand impact over the study region (Figure 6-1). For pines this is not necessarily an issue, since demand is expected region wide. Hardwood impacts, however, could be concentrated around the pellet producers that utilize this resource[55].

Figure 6-14 shows that hardwood sawtimber markets are not likely to be affected by pellet demand. Pine sawtimber inventories increase significantly by 2030 in all scenarios, but increases in the pellet scenarios are 1% to 4% lower than the reference case. The low pine saw timber demand scenario keeps prices essentially flat while the high demand scenario drives higher PST prices, which as the most important rent driver, affect land use change. Note that in the low PST demand high pellet demand scenario, stagnant PST prices and increasing PPW prices leads to a significant impact of PPW on forest rents. Given that we are starting at a historical low in the PST to PPW price ratio (Figure 6-8), this combination continues a trend which we have not observed historically. So, for example, if PST prices dropped a small amount it would more than offset a similar scale PPW increase since PST prices are three times higher. However if PST prices are flat (Figure 6-14 middle row), a significant increase in PPW prices (Figure 6-12 pellet demand runs) means that PPW prices become more important to forest rent calculations. Hardwood sawtimber markets were not affected by PST demand scenarios, so only the high PST demand scenario is shown in Figure 6-13.

The above market dynamics are the drivers of the land use and forest carbon responses to increased pellet demand. Figure 6-15 shows that with **low PST** demand and no pellet demand timberland decreases slightly over the projection period to 2030, with a slight concentration in pine plantations. With pellet demand driving higher returns to timberland, there is an additional shift toward pine plantations. Note that the land use model linkage only estimates the net impact of timberland change. So while there is empirical evidence that timberland extent is price responsive, there is not an empirical basis for knowing the forest type composition of the resulting forest. For these projections pine plantations were assumed to be the most price sensitive component and therefore plantation acres increase faster when prices go up and decrease faster when prices go down. Lowland hardwoods were assumed to be least price responsive since they are associated with certain soil types. Change in the

[54] Economic term for returns to landowners

[55] Hardwood pellet demand is concentrated in North Carolina and Virginia, whereas pine pellet demand is distributed evenly throughout the region.

other naturally regenerated types (natural pine, mixed pine hardwood, and upland hardwood) were assumed to reflect the empirically based price sensitivity in the land use model (Parks et al 2000). When the projection shows the natural acres remaining stable but the proportion of timberland in plantations changing it is the net effect of less loss of natural forest to agriculture due to higher prices, which is offset by loss of natural forest to pine plantations which are more price sensitive.

The historical land use literature is based on a period where pine sawtimber was the dominant forest rent driver. In these runs (low PST with pellet demand) rents are influenced significantly by PPW prices. While the rent calculation takes into account the scale and timing differences of pulpwood and sawtimber, land use response driven by PPW in these scenarios should be interpreted cautiously. This is especially true given that the pellet industry response to higher prices is unknown. If the industry is more price responsive to increased wood costs or has a low choke price, then the price peaks projected here will not occur. For the high PST demand runs the marginal impact of pellet demand is small both because PST prices are higher, but also because they dampen pellet prices. These scenarios are more consistent with historical price relationships.

Land use change is one component of forest carbon dynamics, but the age class and forest type distribution of the forest inventory also affects forest carbon. In SRTS carbon estimates are based on projected volume by region, forest type, and age class. Above ground carbon pool estimates are derived from Smith et al. 2006 (FORCARB) and equations published in Foley 2009. Figure 6-15 shows that forest carbon increases over time, but additional pellet demand leads to a small (< .2%) decrease in 2030 relative to the no pellet demand scenario. In cases where housing does not recover quickly and pellet demand is high, the market impact of pellets becomes more pronounced. In terms of forest carbon the impact of added pellet demand in a low housing scenario was a (2%) increase in forest carbon by 2030. This is consistent with pellet rents being more important in a market with continued low pine sawtimber prices. In all cases forest carbon increased by more than 15% from 2011 to 2030.

Pine plantation extent increases as described above, but with low demand for PST and the current glut of sawtimber inventory, sawtimber inventories (pine and hardwood) continue to increase (Figure 6-14). In addition the shift of harvest to pine plantations reduces harvest pressure on natural stands so that average age of the natural stands continues to increase (Figure 6-16). So the combination of a larger component of the forest being in the fastest growing forest type and increasing inventories in the natural forest leads to carbon gains. Figure 6-16 shows decreases in the average age of plantations.

This is primarily due to an increase in harvest and planting which leads to larger young age component in the inventory relative to the current age distribution which is skewed toward older stands. Figure 47 also shows small (less than one year) decreases in the age of the naturally regenerated stands.

Figure 6-12 Pine pulpwood market results

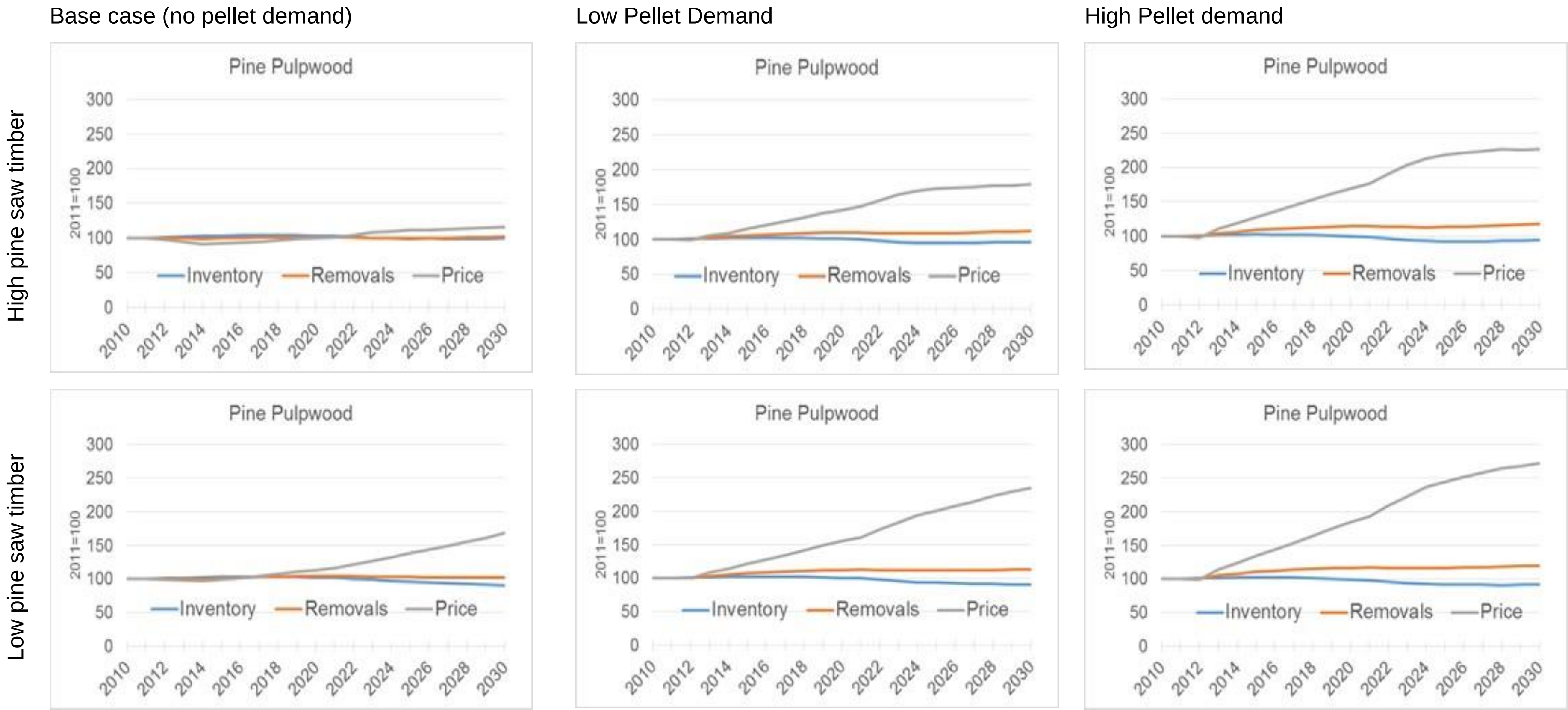


Figure 6-13 Hardwood pulpwood market results

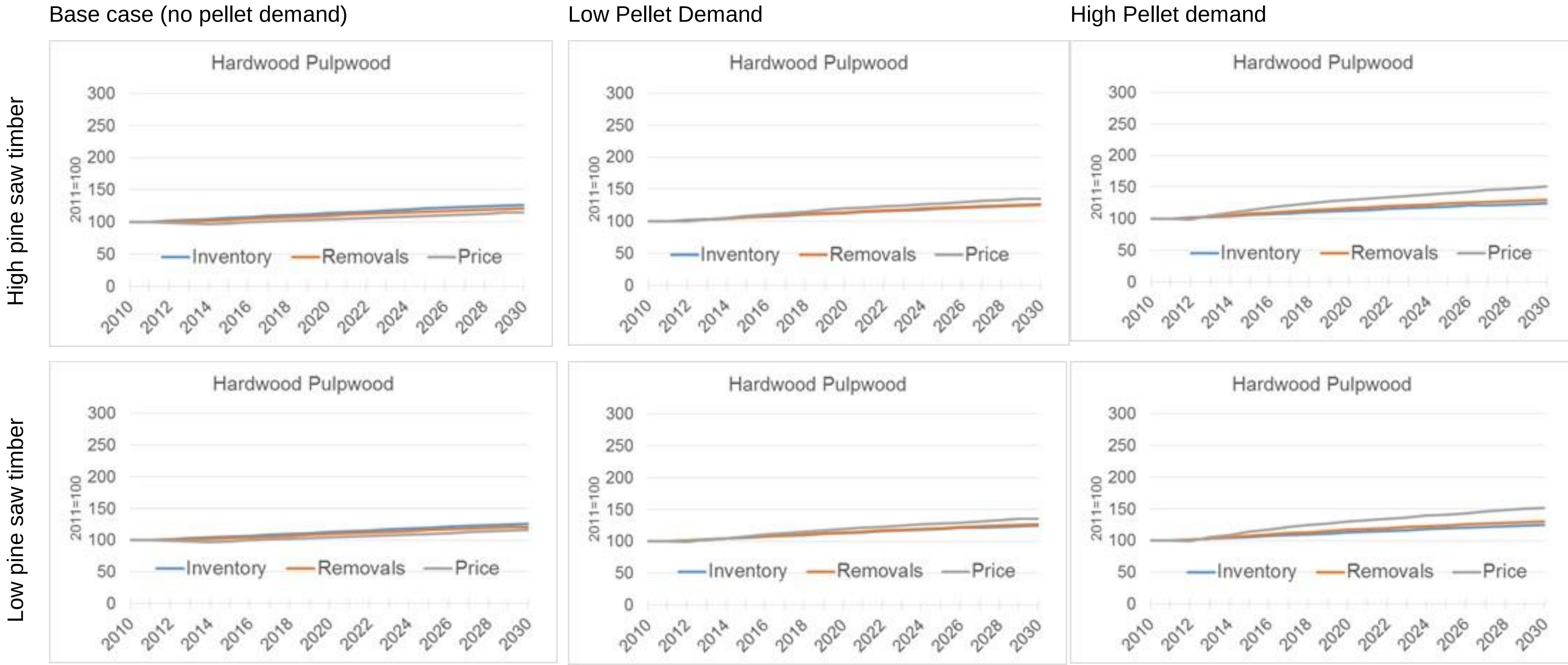
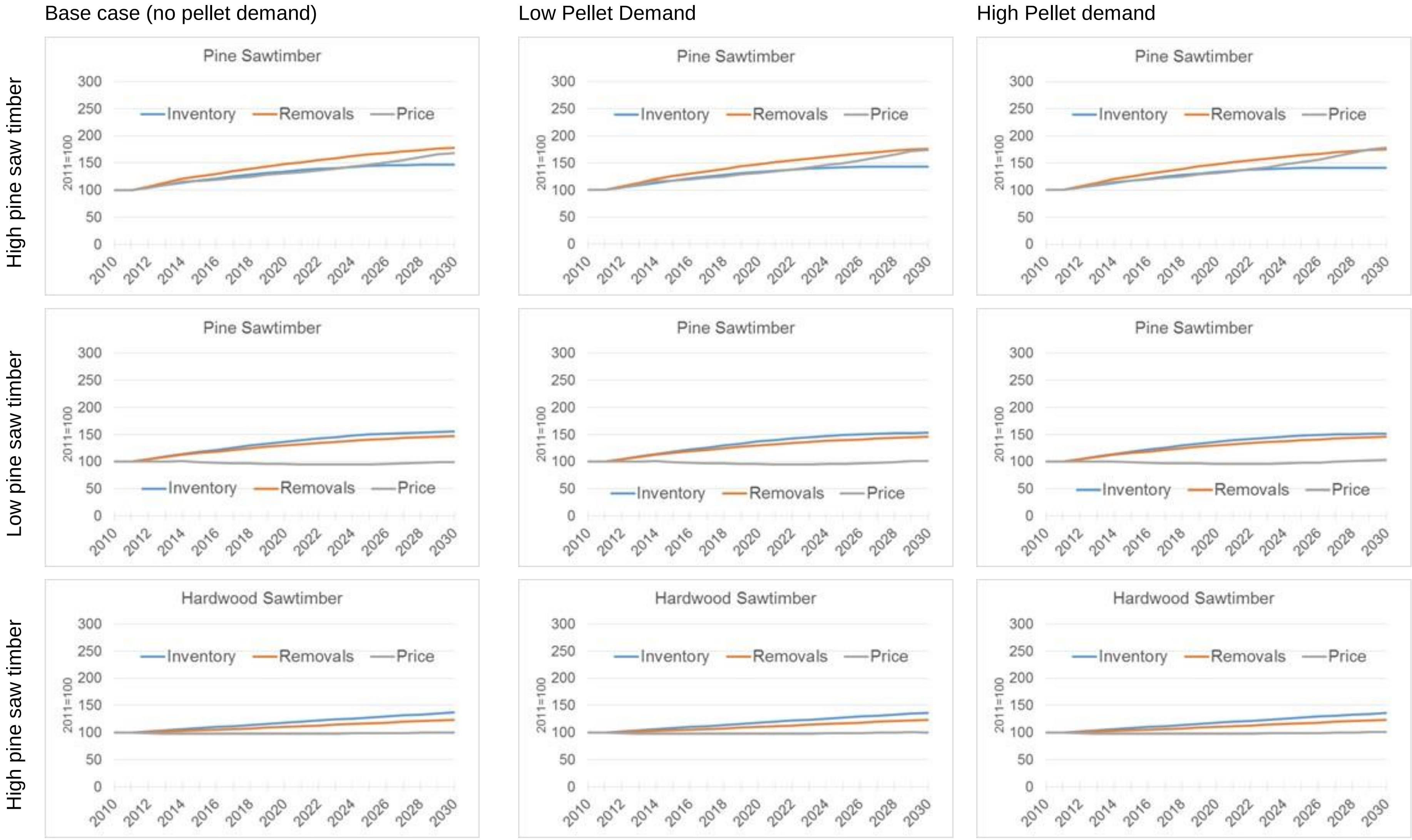
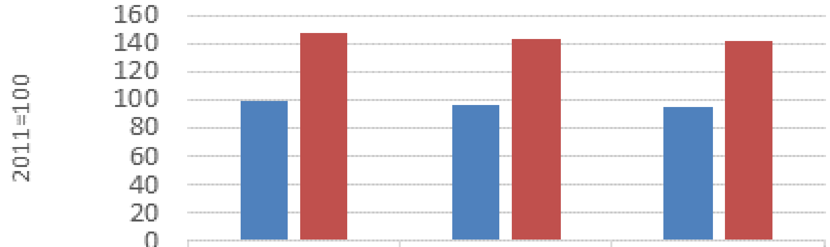


Figure 6-14 Saw timber market results (note: this presents the results for sawtimber changes, not pulpwood)



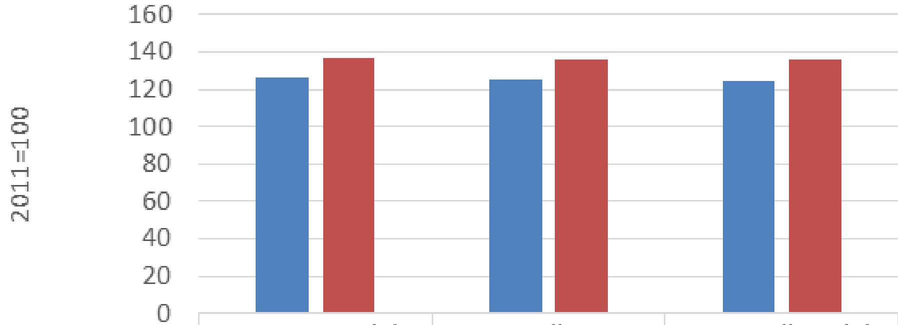
Figures for 2030 are:

2030 Pine Product Inventory - High PST Demand



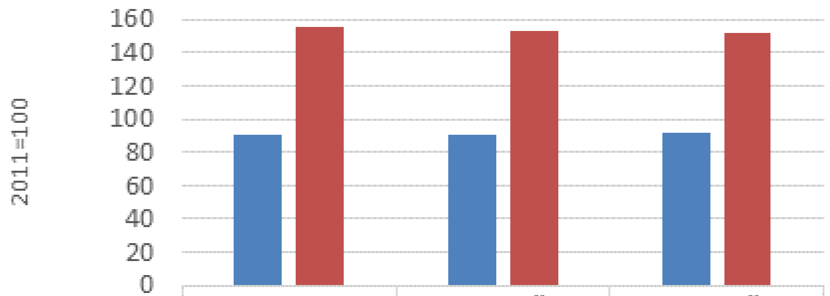
	2030 Base High	2030 Pellet Low	2030 Pellet High
Pulpwood	99.3	96.4	94.3
Sawtimber	146.9	143.1	141.1

2030 Hardwood Product Inventory - High PST Demand



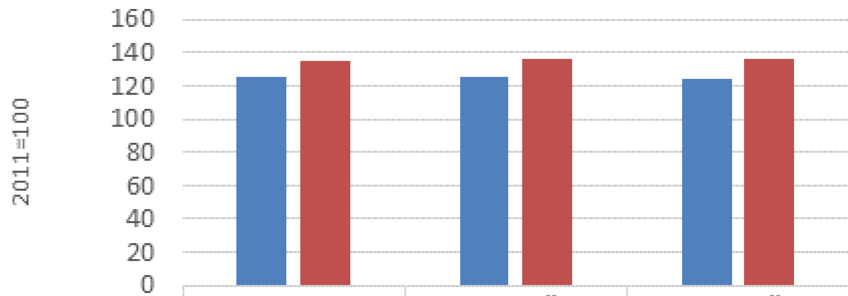
	2030 Base High	2030 Pellet Low	2030 Pellet High
Pulpwood	126.5	125.3	124.5
Sawtimber	136.8	136.4	136.1

2030 Pine Product Inventory - Low PST Demand



	2030 Base Low	2030 Pellet Low	2030 Pellet High
Pulpwood	90.8	90.47	91.5
Sawtimber	155.1	153.1	151.5

2030 Hardwood Product Inventory - Low PST Demand



	2030 Base Low	2030 Pellet Low	2030 Pellet High
Pulpwood	125.3	124.9	124.2
Sawtimber	135.5	135.9	135.6

Figure 6-15 Timberland and forest carbon by scenario

Base= no pellet demand; Figures for 2011 shown for comparison. Base low = low PST demand, Base high= high PST demand, Pellet low= low pellet demand; pellet high = high pellet demand.

Low pine saw timber demand

High pine saw timber demand

Timberland area

Forest Carbon

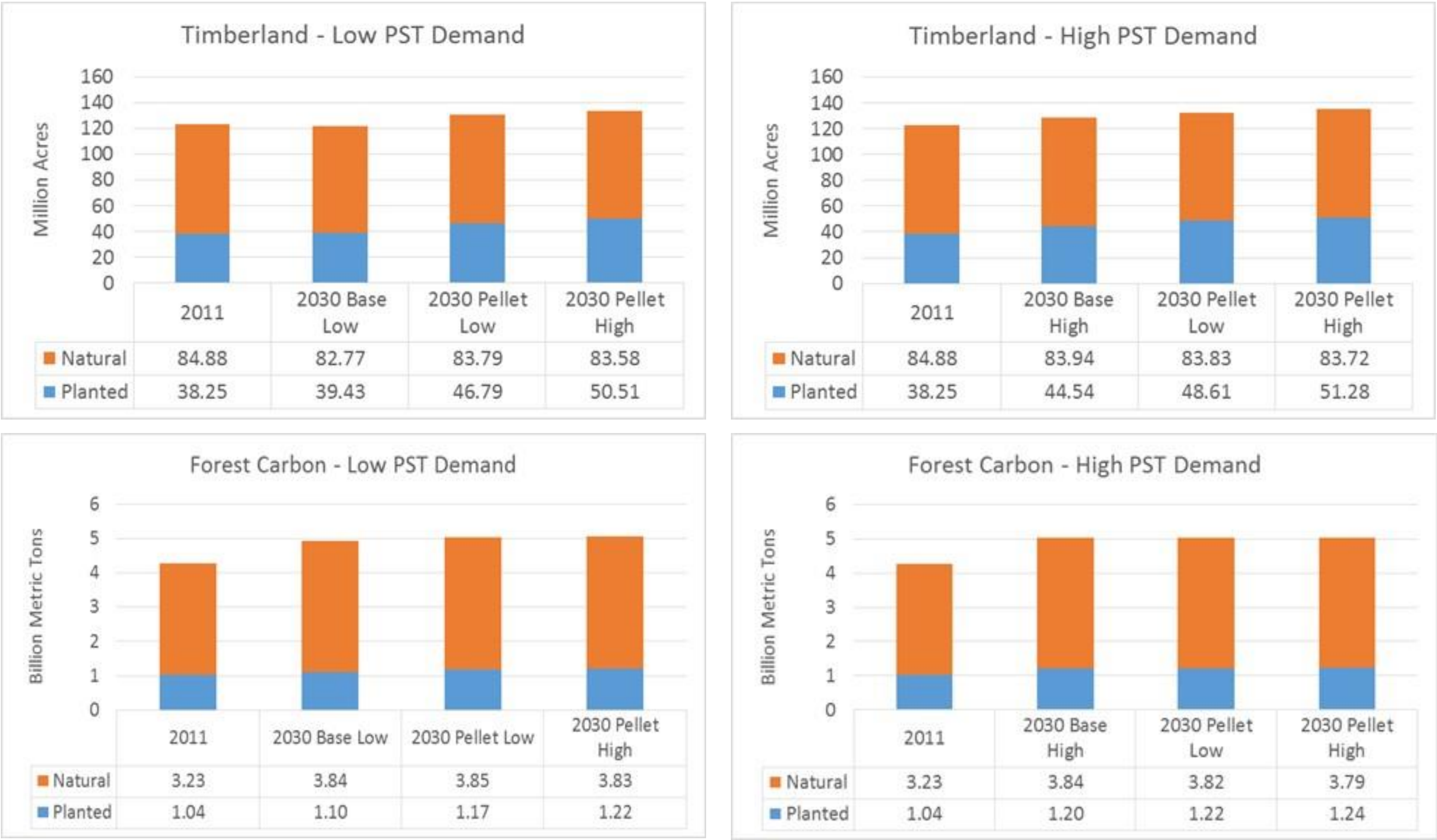
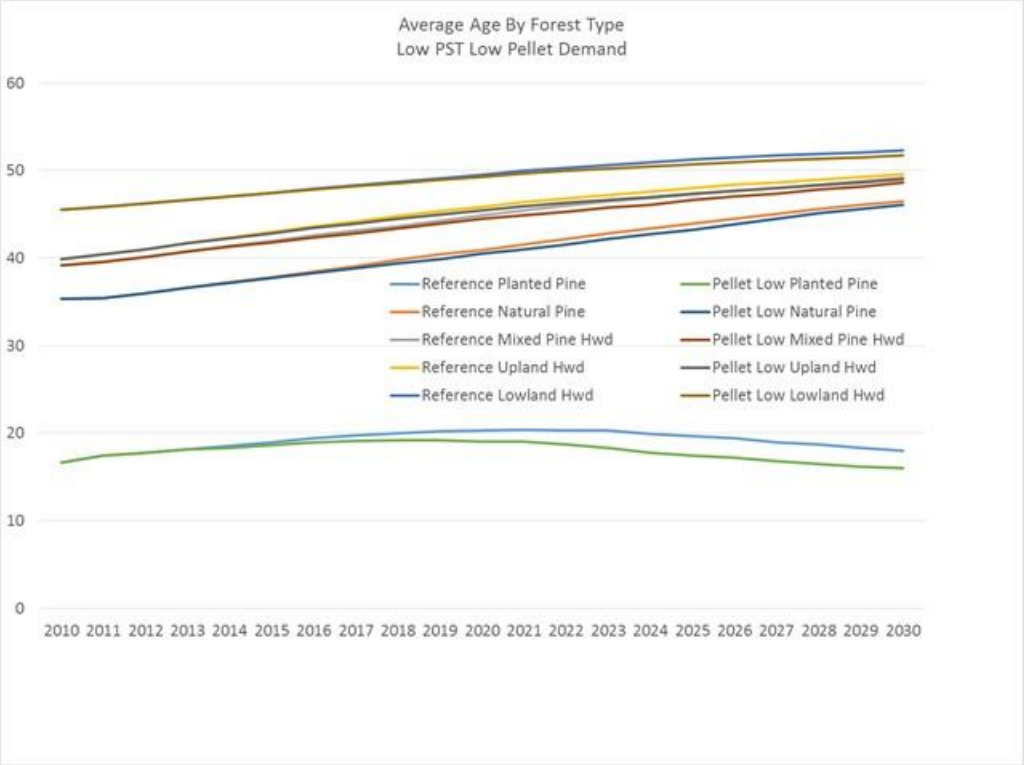
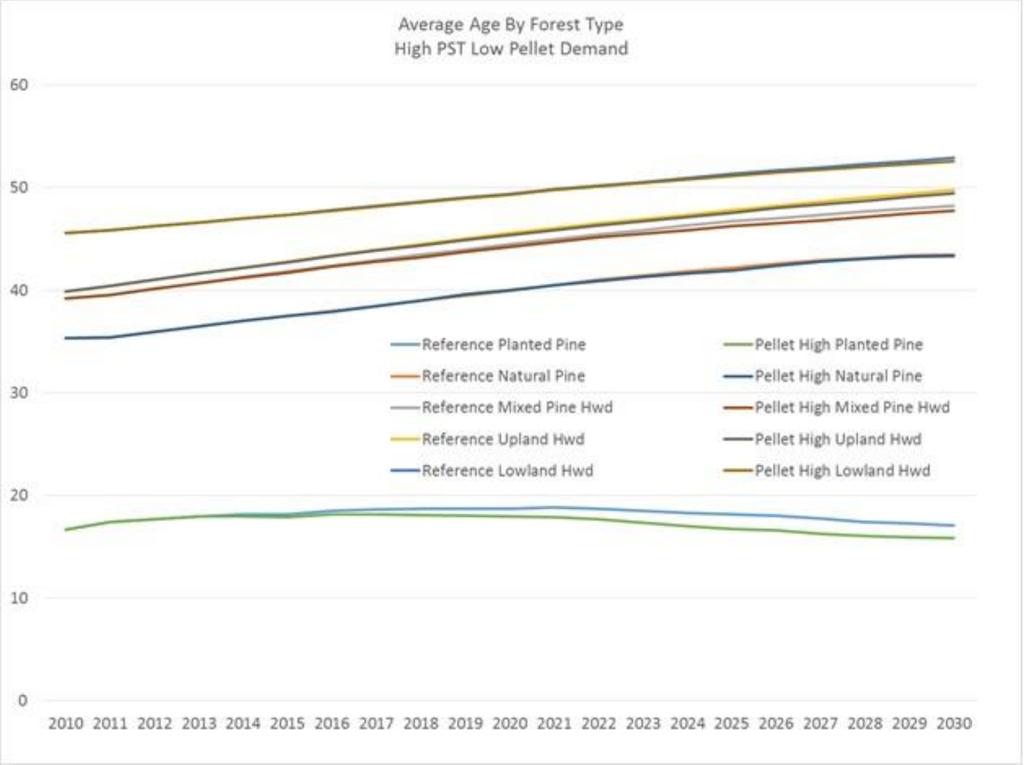
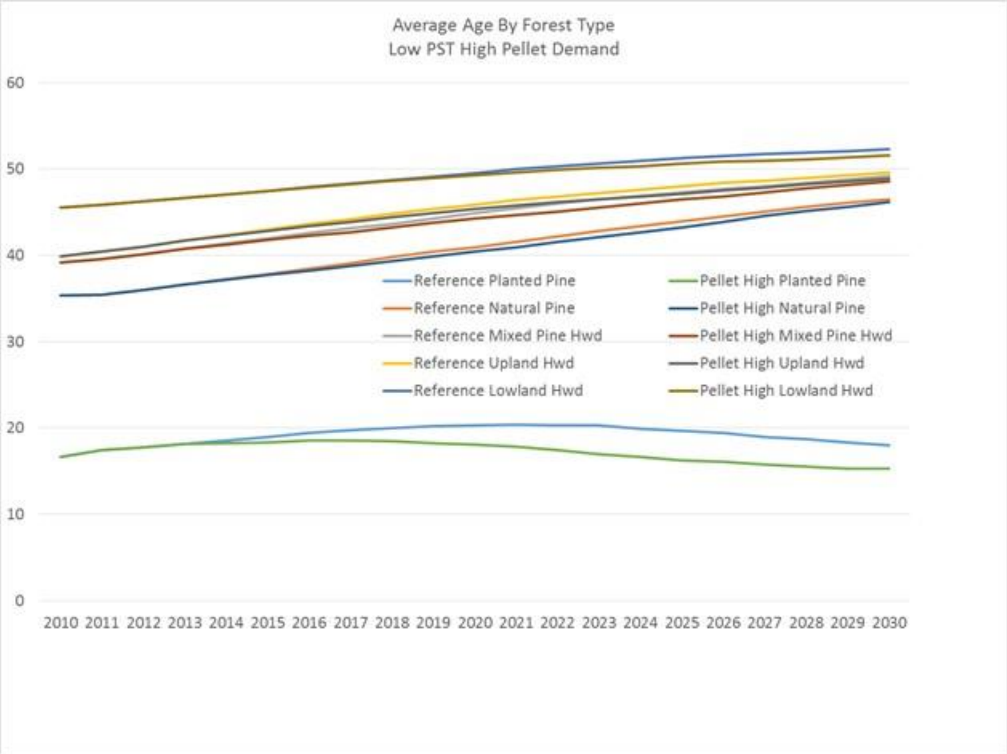


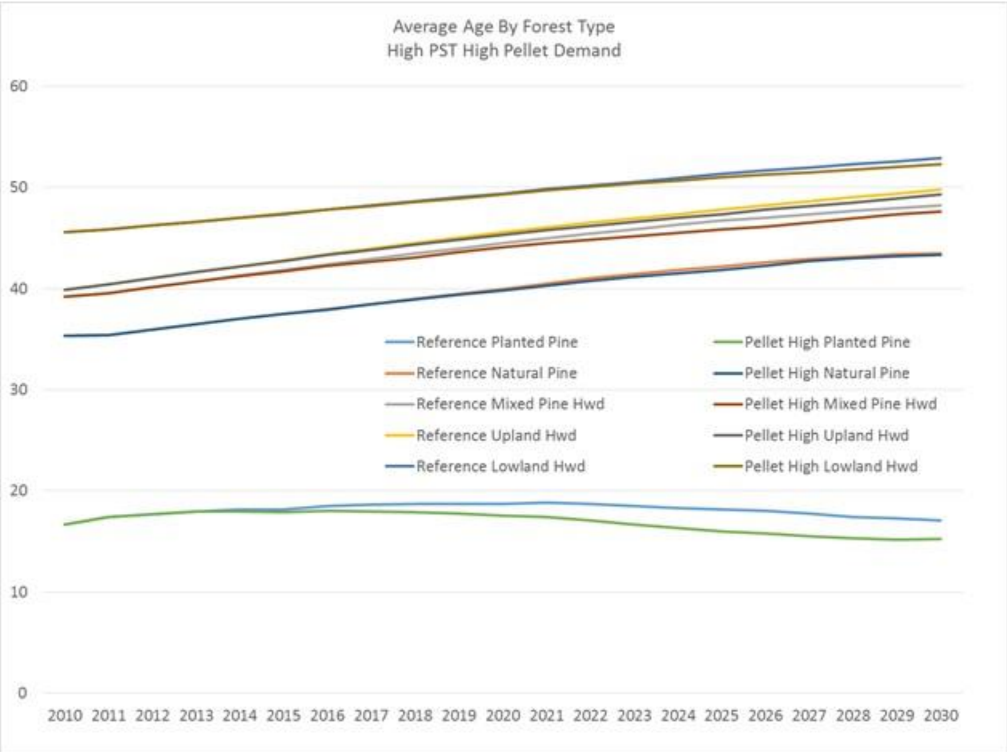
Figure 6-16 (a) Low pellet demand impact on average age by forest type



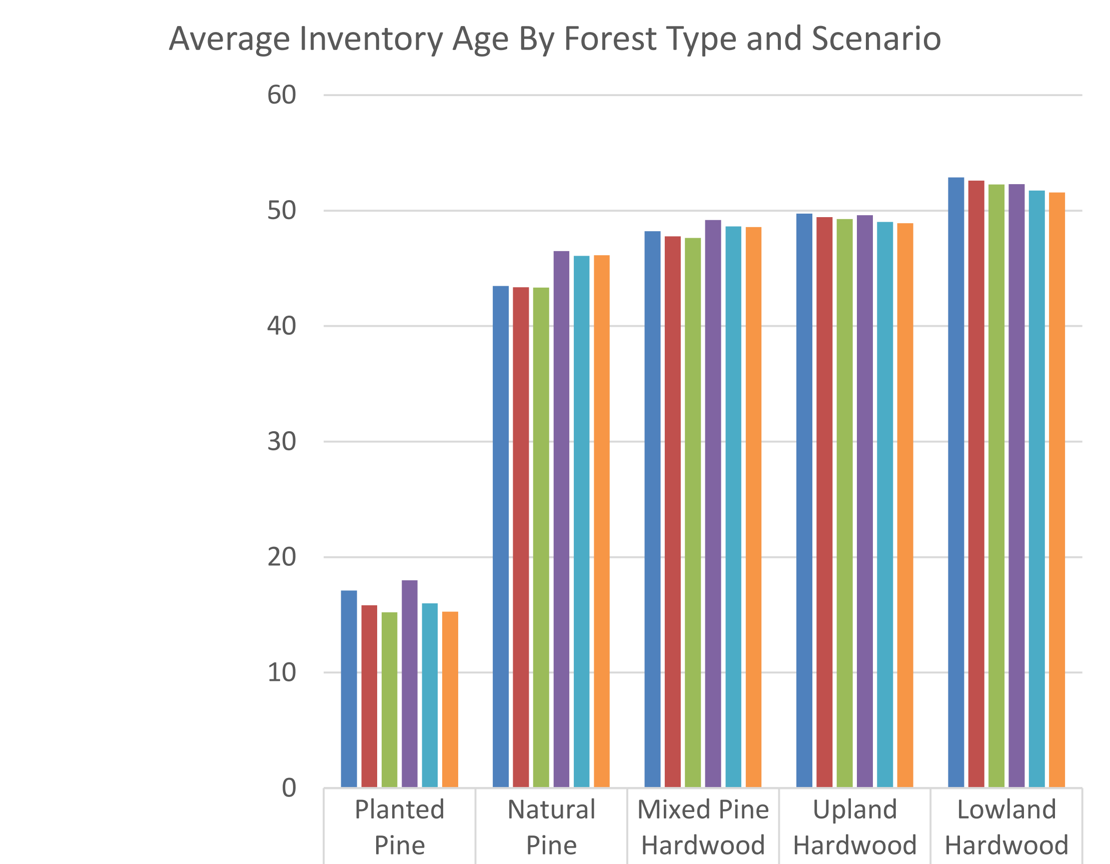


(b) High pellet demand impact on average age by forest type





(c) Average inventory age by forest type and scenario in 2030



	Planted Pine	Natural Pine	Mixed Pine Hardwood	Upland Hardwood	Lowland Hardwood
High PST No Pellet	17.1	43.5	48.2	49.7	52.9
High PST Low Pellet	15.8	43.4	47.8	49.4	52.6
High PST High Pellet	15.2	43.3	47.6	49.3	52.3
Low PST No Pellet	18.0	46.5	49.2	49.6	52.3
Low PST Low Pellet	16.0	46.1	48.6	49.0	51.7
Low PST High Pellet	15.3	46.1	48.6	48.9	51.6

6.5 Relationship to BEAC Scenarios

Market models are appropriate to estimate the likely outcomes of increased demand in the Southeastern U.S. It is a privately owned landscape producing more timber than any other single country. The same market driven dynamics that drive land use, management intensity, and harvest responses for multiple products simultaneously make it difficult to look at any one factor in isolation. In this application the market boundary was the area that includes existing and announced pellet facilities. Forest dynamics are based on empirical forest harvest, growth, and age class distributions to model all forest types based on existing utilization patterns. SRTS uses empirical land use models to estimate the impact of forest prices on forest composition and extent. The results vary over time and across regions. The outputs described here focus on 2030 outcomes at a regional scale.

The results discussed here should not be seen as forecasts of a most likely outcome. They represent an attempt to capture first order ecological and economic dynamics over a plausible range of demands to see how the system will respond to additional demand for one component of the forest. The result puts pellet demand in the context of current utilization of the forest. The result is not necessarily a change in rotation age but a pulse that is large enough to cause a price impact and a supply response. By increasing harvest of lower valued products it affects the extent and age class distribution of pine plantations. If the key market driver (PST) does not recover quickly, the marginal impact of this 'pulse' could be locally significant. Its importance to landowner rents (and pulpwood consumer costs) is higher in that scenario, but forest carbon increases. Small reductions in inventory age are shown for hardwoods and the effect is larger in the high pellet demand scenarios. The overall impact on regional natural forest carbon is a slight decline (Figure 6-15) but plantation forest carbon increases.

Since demand increases lead to larger price changes than harvest change (due to price inelastic supply) and forest extent is affected by returns to timberland, increased demand in the Southeast since the 1950s has been associated with increases in management intensity, reduced loss of timberland and increasing regional forest carbon stocks. These results show that in some scenarios pellet demand could contribute towards the continuation of that trend on a regional level, mainly due to increases in faster growing plantations, rather than non-forested rural land. There are at least three important caveats; 1) these relationships are stronger in pine markets than hardwood markets, 2) there is large variability in local market conditions (both supply and demand). Region-wide projections of a pine dominated increase in demand will not capture this local variability, and 3) Indirect (outside the market) carbon effects are not modelled.

BEAC estimates forest carbon adjustments of discrete paired scenarios primarily as changes in rates of harvest (modelled using rotation lengths) and differences in forest growth rates of different forest types in fully regulated forests. The forest area is fixed in each BEAC scenario and the implied spatial scale is the forest base required to supply a pellet mill.

SRTS results imply that the marginal impact of additional pine small roundwood demand can have an impact on markets. This is due to the current age class distribution of pine plantations and low pine sawtimber demand. If pine sawtimber prices and production stay low, then the small sawtimber price impact might be significant, but it also leads to supply responses that more than compensate for the direct harvest impact and actually increases forest carbon. In scenarios where housing returns to its traditional role as the dominant market driver, the rent impact of pellets are reduced and the increased harvest has a small negative impact (< 0.2%) on forest carbon in 2030.

SRTS projections focused on above ground carbon consequences of pellet demand. Land use change and more intensive forest management could have a variety of impacts that are policy relevant but not explored in this analysis.

7 Development of the questionnaire and methodology for analysis

This section describes the method used for analysing the results from the questionnaire for the questions asked on the likelihood of the scenario. The first part of the method describes the questionnaire. Section 7.2 describes the way in which the likelihood assessment is done, including the analysis of the self-assessed confidence scores:

Analysis undertaken	Section for method	Questions analysed in this way (see **Box 7-1** for list of questions
Analysis of the most common view	Section 7.2.1.1	1-5
Summary assessment of responses to each question	Section 7.2.1.2	1-7
Likelihood of the 'ranked' questions (i.e. those questions about factors that encourage or prevent the scenarios occurring)	Section 7.2.1.3	6 and 7
Analysis of respondents self-assessed confident	Section 7.2.2	10

7.1 Development of the questionnaire

The questionnaire was designed to allow stakeholders to provide views on the likelihood of the BEAC high carbon intensity scenarios occurring, and to provide evidence to support their views. The questionnaire was in three sections:

- Part 1 allowed the stakeholder to provide information on themselves and their organisation, their interest in the North American pellet supply chain, the region(s) they are familiar with and any context on the area in which they work. This provided us with context on their experience of the stakeholders and factors that might influence their responses. It allowed us to check that survey respondents covered all the relevant types of organisations and regions included in the BEAC scenarios.
- Part 2 asked direct questions on the scenarios and their likelihood, including the likelihood of the counterfactuals. The same or very similar questions were asked about each scenario. As the scenarios cover a range of very different situations different options had to be provided for some scenarios. Part 2 also included questions on definitions, where useful, to allow us to understand any differences between stakeholders or regions. It also included questions and allowed comment on the extent to which these scenarios may occur. Box 7-1 provides a list of Part 2 questions.
- Part 3 asked questions on the variables that were identified in the scoping phase of the study (Section 2.2) to be important in influencing the production of pellets and the likelihood of the scenario happening. These questions asked about variables such as prices, costs, management of forests and factors influencing these (e.g. regulation). Part 2 questions were asked as a series of questions for each type of stakeholder in the supply chain (i.e. for the forestry sector, pellet producers, pellet users, the non-bioenergy sector and other stakeholders with an interest in pellet production).

Stakeholders were asked to rate their self-assessed confidence in their answers for each scenario in Part 2 and at the end of each stakeholder section in Part 3 of the questionnaire. This gave us an indication of the confidence the respondent had in their own answers for each scenario and the Part 3 questions. The respondents were also invited to add references to any supplementary evidence they relied on in answering the questions.

This format of questioning was tested on a pilot group of stakeholders and their comments were taken into account in revising and delivering the final questionnaire.

Box 7-1 Questions asked on each scenario in Part 2 of the questionnaire

The questions asked on each scenario were as similar as possible (given the different nature of the scenarios). For each scenario the following questions were asked:

1. Is the counterfactual provided above an accurate description of what currently happens when there is no or low demand for fibre for pellets? Response options were: definitely not; sometimes; most of the time; yes, always; I don't know. Respondents were also asked if this is not what happens, please say what else happens to residues (e.g. burnt to reduce wildfire potential).
2. Are the practices described in the scenario already occurring? Response options were: definitely not; sometimes; most of the time; yes, always; I don't know.
3. (a) If your own land holding has been affected in the ways described by the scenario what percentage of your forest land do you think has been affected by this? (b) If you are familiar with a region and aware of changes in this region, please provide the name of the region with an indication of the percentage forest affected by it, with evidence to support this.
4. In the future (to 2030), if demand for fibre for pellets stays at the current level how likely do you think it is that these scenarios will occur (or continue to occur, if they already happen)? Response options were: very unlikely; unlikely; moderately unlikely; moderately likely; very likely; I don't know.
5. Assuming pellet demand increases in the future, what is the likelihood of the scenario (a) at current fibre prices; (b) if prices rise by up to 15 %; and (c) if prices increase by 30%. These levels of price increase were chosen because pellet producers indicated that they represented the increase in prices that would influence their business model.
6. Which of the following changes would encourage the practices described in the scenario to occur? Participants were asked to select up to three most important factors. Options given varied depending on the scenario but in general concerned: whether increased demand would result in sufficient financial return to warrant the change in practice; if changes in legislation could facilitate the practice; if changes in forestry incentives would ensure sufficient financial return to allow the change to take place; if the proposed change would increase the value of the land; if the proposed change would reduce vulnerability to diseases or pests; or another change not given that would facilitate the practices in the scenario (for the participant to specify).
7. Which of the following changes would prevent the practices described in the scenario from occurring in the future? Options given varied depending on the scenario but in general concerned: whether increased demand would not offer sufficient financial return to warrant the change in practice; if changes in legislation would prevent the practice; if the proposed change would increase vulnerability to disease or pests; if low roundwood demand in general results in greater haulage distances for the roundwood market; if other uses make the land value more attractive; or if something else would prevent the practices in the scenario (for the participant to specify).
8. Does the emergence of pellet demand in a housing recession increase or decrease the probability of the scenario happening?
9. Do you have any other comments on these scenarios that are not captured elsewhere?
10. Overall how confident are you in the answers provided? Options: somewhat confident, confident, and very confident. Please say why you rate your confidence at this level (free text)
11. What is your source of information in answering the questions about the scenarios?

Approach to bias

The number of stakeholders with an interest in the North American pellet supply chain is limited. In addition it includes groups that have specific vested interests, carrying the risk that stakeholders might provide answers that would bias the results, particularly in the more contentious areas of the study. For example, stakeholders may simply decide that a scenario was likely or unlikely depending on their overall view of or interest in pellet production; and groups of stakeholders with similar interests might collude together to increase the number of times a particular question is answered in a particular way. In addition there is a limited number of well-informed stakeholders, with the knowledge to answer a detailed questionnaire on the BEAC scenarios, which means that it is not possible to conduct statistical analysis of the results.

To overcome these issues the questionnaire was designed to use neutral language and not lead respondents to a particular answer or pre-judge their likely answers. It was targeted at the full range of stakeholder groups that may have an interest in the North American pellet supply chain in order to ensure that no one group could unduly bias the questionnaire results.

Method of delivering the questionnaire

Once the questions had been agreed they were transposed to SurveyMonkey. Individual stakeholders were informed of the questionnaire and asked if they would like to participate in the study. Those who agreed to participate were then given access to the web site containing the questionnaire and instructions on how to undertake the survey. This web site also contained background information on the study and on BEAC with a link to the BEAC model and report to aid their understanding of the BEAC scenarios.

7.2 Analysis of results from the questionnaire

7.2.1 Analysis Tool Overview

Analysis of the questionnaire was undertaken in two ways. The results to **Parts 1 and 3** of the questionnaire were summarised from SurveyMonkey and are reported in Appendix 6. These are also referred to in Chapter 8.

Part 2, covering the direct questions on likelihood was analysed in a spreadsheet tool (referred to as the Analysis Tool). This Analysis Tool examines the responses by stakeholder group and provides a summary of the results for the combined stakeholder groups. The Analysis Tool provides analysis of the responses to direct questions on the likelihood of each scenario and its associated counterfactual for each scenario in a 'likelihood' sheet (one for each scenario). It also presents **an overall summary for each scenario**, which combines these conclusions from the analysis of the questionnaire responses, with the high level conclusions from the literature review, the SRTS modelling (where applicable to the scenarios) and the comments received from stakeholders in the questionnaire that qualify their answers. In this way it allows comparison of all of the evidence compiled during the course of the study, and an overall view considering all of these sources to be established.

The questionnaire was intended to canvas expert opinion, and there is a relatively limited pool of stakeholder experts. The questionnaire was sent out to 156 respondents, and 56 responses were received and are analysed in the tool. The number of respondents commenting on any particular scenario was less than this because the scenarios are specific to particular regions and forest types, so respondents typically had experience or knowledge of only a subset of these. The number of responses for scenarios varied from 4 (in Boreal Canada) to 30 (in Southeast USA) and for some scenarios there was no response from some stakeholder groups. The stakeholders who were asked to complete the questionnaire are some of the top experts in issues and practices related to forestry in North America; however, the number such experts is very small in some regions of North America. This means that for some scenarios the number of people who could realistically answer the questions in an informed way was very small (5 or 6 people).

For this reason, **it has not been possible to conduct a comprehensive statistical analysis of the questionnaire results.** The analysis of the Part 2 questionnaire results has however been structured carefully so that the views of the different stakeholder groups are considered in a balanced way. Views of individual stakeholder groups are analysed separately and are then combined to provide an overview, based on the views of these groups, as expressed in the questions analysed. These summary assessments which seek to balance the views expressed stakeholder groups, clearly identify where views were so divergent, that no overall conclusion can be drawn.

In this way we have attempted to avoid bias caused by different numbers of respondents in each type of stakeholder group. Although we attempted to achieve a good response rate from stakeholders in each group, it is not possible for us to know what coverage we have in terms of percentage of the whole population of each group. For some stakeholder groups there were a limited number of respondents with knowledge of the sector. Therefore rather than using a most common view from all of the individual responses, we assessed the results in a way that presents the views of each stakeholder groups on an equal basis. The reason we felt that all stakeholder groups should receive equal weighting is that each group brings a different kind of experience and knowledge to the sector, all of which are important in understanding the likelihood of the scenarios. We did not want any of those views to be lost amongst the survey responses simply because there were not many forest managers operating in a particular region, for example.

Although we have provided a summary assessment on the likelihood of each question (as in Figure 7-2 below), these only provide an approximate indication of whether there is consensus across the stakeholders who responded to the question. We recommend that these summaries be read alongside the supporting comments and other evidence in order to gain a full understanding of the likelihood and complexity of the scenarios.

The responses to the questionnaire were analysed in the following steps:

1) For each stakeholder group, the results were analysed to produce a histogram showing the percentage of respondents giving each answer, including 'I don't know' as a response. This data was also used to identify the **most common view** of each stakeholder group. The methodology used to determine the most common view for each stakeholder group is described below (see 7.2.1.1.).
2) Weighted histogram: The results for each stakeholder group were then presented on a histogram that shows the percentage allocation of views within that stakeholder group. To do this each stakeholder group was allocated a sixth of the chart to represent its views. That sixth was then divided by the percentage views expressed for a particular question. So that if 100% of the stakeholder group said 'yes, always' when asked if a scenario happens then that is shown as 16.6% on the histogram (i.e. a sixth of 100). If 100% of all responses for all stakeholder groups were the same, then each histogram for each stakeholder group will be 16.6%, i.e. of equal size. If, on the other hand the stakeholder groups views were split between 'definitely not', 'sometimes' and 'I don't know' then their score is split accordingly on the chart. This provides a visualisation of the responses of each group without weighing them by the total number of responses given. It means that if a higher proportion of responses was received from one well represented stakeholder group it does not swamp the responses from a stakeholder group with fewer responses and with opposing views. The number of respondents as a proportion of the total number of stakeholders is not known; our approach ensures that the view of a particular group of respondents is not overlooked simply because there were not many experts in that group in a particular region. An example of these results is presented in Figure 7-1 and Table 7-1. The histogram allows the viewer to see both the distribution of response, but also which stakeholder groups are contributing to that response. *Note that the histogram will only add up to 100% for the scenarios where at least one respondent belonging to each of the six groups of stakeholders has provided a response.*
3) Summary assessment of responses: Finally, for each of the questions on the likelihood of each scenario and the accuracy of the counterfactual, a summary assessment of the responses to that question was created. This summary is an assessment based on the weighted histogram created for that question that shows the split of responses within each group of respondents (see Figure 7-2 for an example). Details of the methodology for this summary assessment are provided in Section 7.2.1.2.

More detail on specific aspects of the methodology are given in the sections below.

Figure 7-1 Example of the weighted histogram in the analysis tool *(Response to the question on whether the practices described in a hypothetical scenario are already occurring.*

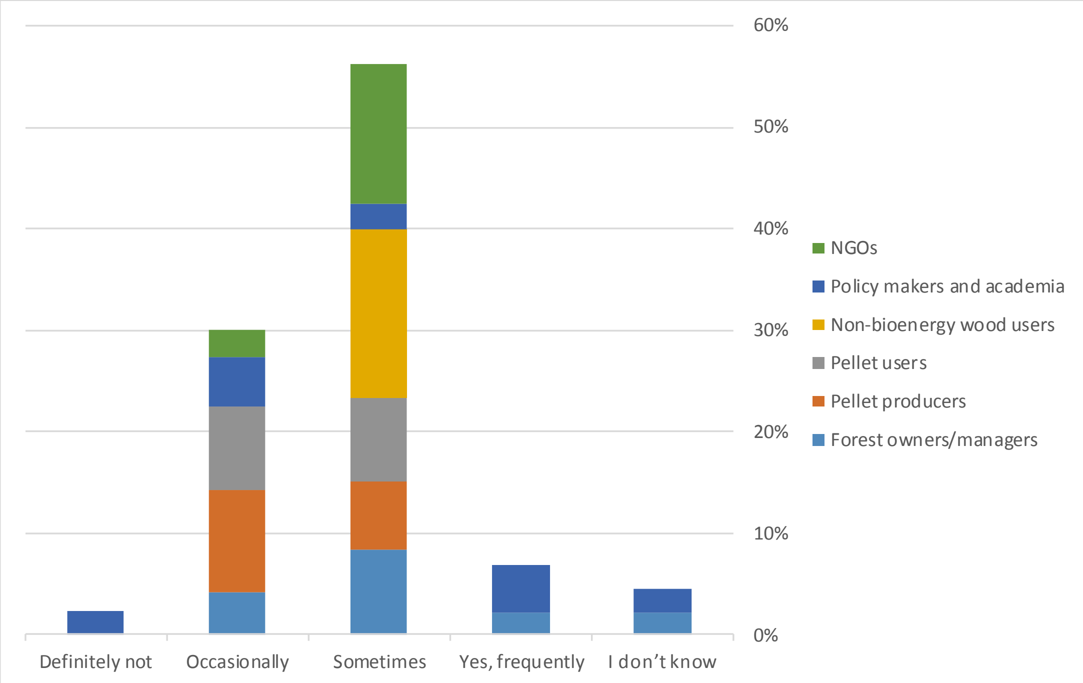


Table 7-1 Data used to produce weighted histogram (Responses to question 'Are the practices in the scenario already occurring?' for the same hypothetical scenario)

Responses to question							
Response	**Forest owners/ managers**	**Pellet producers**	**Pellet users**	**Non-bioenergy wood users**	**Policy makers and academia**	**NGOs**	**Total**
Definitely not	0	0	0	0	1	0	1
Occasionally	2	3	1	0	2	1	9
Sometimes	4	2	1	2	1	5	15
Yes, frequently	1	0	0	0	2	0	3
I don't know	1	0	0	0	1	0	2
Total	**8**	**5**	**2**	**2**	**7**	**6**	**30**

Total responses by percentage of each group.							
	Forest owners/ managers	**Pellet producers**	**Pellet users**	**Non-bioenergy wood users**	**Policy makers and academia**	**NGOs**	**Total**
Definitely not					2%		2%
Occasionally	4%	10%	8%		5%	3%	30%
Sometimes	8%	7%	8%	17%	2%	14%	56%
Yes, frequently	2%				5%		7%
I don't know	2%				2%		4%
Total	**17%**	**17%**	**17%**	**17%**	**17%**	**17%**	**100%**

Figure 7-2 Example of summary assessment of responses (For question 'Are the practices in the scenario already occurring?' for Scenario 13a)

Overall view from direct questions on likelihood	Sometimes
The majority view of stakeholder groups was that this scenario currently occurs sometimes, although a significant proportion thought it was less likely, rating it as only occurring occasionally	

7.2.1.1 Determining the most common view

The most common view is determined for questions: 1, 2, 4 and 5 in **Box 7-1** for each stakeholder group.

For each stakeholder group the response that received the most 'votes' is identified. It is possible that there may be more than one most 'common' response. For example, for policy makers responding to the question for a hypothetical scenario 'In the future (to 2030), if demand for fibre for pellets stays at the current level, how likely do you think it is that these scenarios will occur?' the responses are as shown in Table 7-2. In this case, three responses tied for maximum number of responses (each having two votes) so it is considered that there are three most common views – moderately likely, likely and very likely. If more than three responses tie for the maximum number of responses (for questions where there are six response choices plus 'I don't know'), then it is considered that there is no clear consensus on a most common response, and the tool reports "no clear consensus of the most common view". For questions where there are only four response choices (plus 'I don't know') then the tool reports "no clear consensus of the most common view" if more than two responses tie for the maximum number of responses.

Table 7-2 Data used to establish the most common view for a stakeholder group (For a hypothetical scenario)

Response	No.
Very unlikely	0
Unlikely	0
Moderately unlikely	0
Moderately likely	2
Likely	2
Very likely	2
I don't know	0
Total responses	**6**

A summary table of the most common views from each stakeholder group is also provided in the Tool. This summary table is created from the individual tables for each stakeholder group. In this summary table, if there was more than one 'most common view' in the stakeholder group, then these are only brought forward to the summary table only if they are 'adjacent in the list of responses (e.g. (moderately likely and unlikely), **and** none of the responses are "I don't know". If the responses are not adjacent in the list of responses (e.g. moderately likely and moderately unlikely), or one of the most common views was I don't know, then a most common view of 'no consensus' is recorded in the summary table.

7.2.1.2 Methodology for the summary assessment of each question

The methodology for doing the summary assessment for each question is based on the weighted histogram (described above). The process for assessing each question is as follows:

a) If more than 30% of the respondents according to the weighted histogram answered "I don't know" to a question, the overall assessment for that question is "No consensus." Note that this rule is applied first. If ≤ 30% of the respondents answered "I don't know", then the following rules are used to determine the overall assessment for that question. A differential of 30% was chosen to represent a reasonable proportion of respondents.

b) If the weighted histogram shows a clear majority of respondents are in agreement (> 50%), then the overall assessment for that question is the majority view. Comments are provided on the range of responses and also on the sample size if the sample size is small. >50% was chosen to represent a clear consensus on the issue.

c) If there is a most common view from the stakeholder groups, but less than a 50% majority (≤ 50%), the overall assessment for that question is the most common view, provided that the most common view received at least 20% more responses than the next most common view. Otherwise, the question is assessed as "No consensus." The cut-off of 20% was chosen because it represents a clear differential between the most common view and the rest of the views.

The exception to this is if the second most common view is adjacent to the most common view, in which case the assessment is given as xxx/yyy (e.g. "unlikely/moderately unlikely"), as long as the two options together add up to at least 50% of the weighted histogram. If the two adjacent most common views do not add up to at least 50%, the assessment is "no consensus." Comments are provided on the range of responses and the sample size.

This rule holds even if the assessment is therefore "Definitely not/sometimes." Although this combination of responses sounds inconclusive, the comments on the questionnaire indicate that respondents actually meant "rarely" or "very occasionally" when they answered "sometimes" (see Figure 7-1).

7.2.1.3 Likelihood of the factors that encourage or prevent scenarios

This analysis applies to questions 6 and 7 in **Box 7-1**, which

i) ask respondents to rank the top three factors which would encourage or prevent the scenarios occurring. Respondents are given a choice of 5 to 8 factors in each case, which differ slightly between the groups of scenarios, reflecting differences between the groups of scenarios.
ii) ask them how likely they think it is that these factors will occur (from six responses ranging from very likely through to very unlikely).

Respondents were asked to rank the top three factors, although in some cases respondents only ranked one or two factors.

These questions were asked only once for each group of scenarios[56]. In analysing these responses in the analysis tool we have only analysed the responses where the respondent provided a view on whether or not the scenario is occurring. This means that respondents who answered 'I don't know' to the question on whether the scenario is occurring are not included in the analysis of these questions on factors which encourage or prevent the scenario.

The analysis of the responses is done by stakeholder group. For each group a ranking score is calculated for each of the factors to allow identification of the top three factors. The score given for each rank is shown below:

- Responses ranked top (or 1) are allocated a score of 3
- Responses ranked second (or 2) are allocated a score of 2
- Responses ranked third (or 3) are allocated a score of 1

The overall score for factors that would encourage or prevent a group of scenarios is calculated as the sum of the number of responses for each rank times the rank score and divided by the number of respondents. This provides an overall score between 1 and 6. An example is shown below (Table 7-3) for a question where there were nine respondents.

The second part of this score was the ranking of how likely the change would be to happen. An average score for how likely the respondents considered any factor to be was calculated by:

1) Assigning a score to each of the potential responses from 1 to 6 for very unlikely (1) to very likely (6)
2) Multiplying the number of respondents assigning that response to the factor by the score
3) Dividing by the total number of responses to the question

[56] Scenarios were grouped by common characteristics in the survey, so for example, so for example Scenarios 4 to 7 are a group of scenarios that all refer to the removal of forest residues. The groups of scenarios are summarised in Appendix 1.

For factors that were ranked as important this allows us to calculate (on a range from 1 to 6) how likely respondents thought the change would be to occur, with 1 indicating very unlikely and 6 as very likely. A worked example is shown below (Table 7-4).

Table 7-3 Example of how the score for 'importance'' of a factor is calculated

Factor	No of responses ranking this first	No of responses ranking this second	No of responses ranking this third	Sum of no responses *rank score	Over-all score
A. Increased demand for fibre for pellets results a sufficient financial return	8	1	0	26	2.9
B. Changes in legislation or forest policy that facilitate this change in practice	1	4	1	12	1.3
C. Changes in forestry incentives that ensure a sufficient financial return to warrant the change	0	0	2	2	0.2
D. The proposed change increases the value of the land	0	2	1	5	0.6
E. The change results in a reduction in vulnerability to diseases or pests	0	0	0	0	0.0
F. Other (please specify)	0	1	0	2	0.2

Table 7-4 Example of how the average score for the likelihood of the factor is determined

Response	Score for response	No of respondents giving response	No of respondents * score for response
Very unlikely	1	0	0
Unlikely	2	1	2
Moderately unlikely	3	1	3
Moderately likely	4	2	8
Likely	5	2	10
Very likely	6	1	6
Sum		7	29
Average score			4.1

The results of the analysis on the ranking of the factors for each stakeholder group are then combined into an overall assessment. An equal weighting is given to each stakeholder group's views, the percentages of respondents in each stakeholder group who ranked the factor first, percentage who ranked it second and percentage who ranked it third are calculated. These percentages are then summed across all of the stakeholder groups. The percentages are then each multiplied by the appropriate ranking factor score as described above, and normalised to give an overall score for the importance of the factor. As in the individual stakeholder groups, this can vary from 0 to 3, with a score of 3 being achieved if all stakeholders in every group ranked the factor as the most important.

An average score is then calculated for how likely a factor is to occur by summing the likelihood scores for the factor from each stakeholder group and then dividing by the number of stakeholder groups who ranked the factors. This approach again gives an equal weighting to each stakeholder groups view.

This analysis allowed us to identify the top three factors that the respondents thought encouraged or prevented a group of scenarios happening and the likelihood that these factors would occur.

7.2.2 Respondents self-assessed confidence for all questions

For each group of scenarios, respondents were asked how confident they were in the answers they had provided, asking to quantify themselves as:

- Somewhat confident
- Confident
- Very confident

Each of these confidence levels was given a score:

- 1 for somewhat confident
- 2 for confident
- 3 for very confident

The overall 'self-assessed confidence' rating was then calculated by multiplying the number of responses at each confidence level, by the score for that confidence level, summing and then dividing by the total number of responses.

$$\frac{\sum (number\ of\ responses\ at\ confidence\ level\ ) \times (score\ for\ confidence\ level)}{total\ number\ of\ responses}$$

To ensure that 'I don't know' answers were not skewing results, this analysis only included the confidence ranking of respondents where at least one of their responses was different to 'I don't know' (i.e. respondents responding 'I don't know' to all questions analysed are excluded from the rating). The resulting score can vary from 1 (low confidence) to 3 (high confidence). When reporting the self-assessed confidence rating in the overview summary of the tool, the self-assessed confidence score was turned back into a confidence rating, using the same categories as in the survey of:

- 'somewhat confident' when the calculated confidence score is <=1.5
- 'confident' when the calculated score is >1.5 and <=2.5
- 'very confident' when the calculated score is >2.5

7.2.3 Uncertainty

Due to the qualitative and subjective nature of this survey, we have not been able to assess the uncertainty of the study statistically. However, we have captured two qualitative measures of uncertainty in our analysis of the questionnaire responses:

- Respondents were asked to provide a self-assessed confidence score to demonstrate how confident they were in the accuracy of their responses. The options for scores were low (1), medium (2) and high (3). These scores were averaged across all respondents and are summarised in the Analysis Tool for each scenario.
- For most questions "I don't know" was provided as a possible answer to the question. The number of "I don't know" responses has been summarised in the Analysis Tool. Where there was a high proportion of "I don't know" responses, the overall analysis of that question has been adjusted or determined to have "No consensus".

7.2.4 Summary of the findings in the Analysis Tool

The Analysis Tool also contains a high level summary of all of the findings from the likelihood analysis described above, the literature review and the SRTS modelling. This includes the number of responses to each question, the number of 'I don't know' answers, the self-assessed confidence rating (for survey responses), the strength of evidence rating (for evidence from the literature review) and the likelihood rating, together with a brief summary of comments or views. An example of part of a summary sheet is provided in Figure 7-3.

Figure 7-3 Example of part of a summary sheet in the Analysis Tool

Scenario 4a Coarse forest residues, removed from forests in South USA, continuously over the time horizon.

Summary of evidence on likelihood

Question	Evidence source	View	No of responses	No of don't knows	Don't knows as % of responses	Respondents self assessed confidence for all questions on scenario	Strength of evidence/confidence	Likelihood rating
The current situation								
Summary of evidence on likelihood	All	Likely. Extent of use not clear and dependent on definition of residues, proximity to pellet mill and the financial return. In some locations it may be very unlikely. Some harvest practices mean all non-merchantable wood is classified as 'residue'. Some States, Best Management Practices (BMPs) and certification schemes require that a proportion of logging residues be left in forest. In the future expansion of this use will depend on proximity to pellet mill, financial return and regulations or BMPs adopted. The financial return on the use of residues from forests for pellets is not sufficient to encourage changes in forest practice, so practice will be integrated into the management of forests for other products. There is some concern that demand for pellets is increasing the use of residues that would otherwise have been left in the forest in some regions. The counterfactual may be correct, but it will vary from location to location and may be difficult to prove.						
Are the practices described in the scenario already occurring?	Survey: question	The majority view of stakeholder groups was that this scenario currently occurs sometimes, although a significant proportion thought it was less likely, rating it as only occurring occasionally	30	2	7%			Sometimes
	Survey: comments	Residues, particularly coarse residues, are removed now, but the extent of removal is highly dependent on location, forest type, forest owner's objectives (including the need to reduce the costs of reforestation) and local markets for pulp, paper or wood fuel for power generation or for heating which is seasonal. Another factor that influences removal is the equipment available, e.g. having a chipper available and appropriate transport vehicles is important. This means that in the vicinity of a pellet mill or pulp mill that uses residues for power generation the residues may be removed but in most other locations they are not. In addition in a strong pulp wood market most of the 'coarse' grade residues would be used for this market. A number of respondents commented that the scale of removal of residues is small compared to the amount of residues generated (e.g. 10-20% or that the "large number of small producers simply don't bother with such 2nd order activities.")						
	Literature review	A number of sources in the literature say that logging residues are likely to be used as pellet fibre. The use will depend on the availability of sawmill residues, the harvest of saw logs and the amount that is practically and economically feasible to extract. The latter will depend on location/proximity to the mill.					Good	Sometimes
	SRTS modelling	It is not possible to use the SRTS model to provide a view on this scenario						
If it is occurring, what evidence is there about the scale it is occurring at?	Literature review	There is conflicting evidence of the extent of the use of forest residues and collection of logging residues has not been normal practice in SE USA. Some States, BMPs and certification schemes stipulate how much logging residue should be left in the forest. The literature does not differentiate between coarse and fine residues. Pellet mills have not said that they will use logging residues, but Drax has provided a figure for its use of 942,039t forest residues plus 164,410t of diseased wood & storm salvage from the USA in its 2014 biomass supply report (using Ofgem definitions). There is no indication if these are coarse, fine or mixed residues. Most concern has been expressed about the use of hardwood logging residues					Inconclusive	
	SRTS modelling	It is not possible to use the SRTS model to provide a view on this scenario						

Scenario 4a Coarse forest residues, removed from forests in South USA, continuously over the time horizon.

Summary of evidence on likelihood

Question	Evidence source	View	No of responses	No of don't knows	Don't knows as % of responses	Respondents self assessed confidence for all questions on scenario	Strength of evidence/confidence	Likelihood rating
The current situation								
Summary of evidence on likelihood	All	Likely. Extent of use not clear and dependent on definition of residues, proximity to pellet mill and the financial return. In some locations it may be very unlikely. Some harvest practices mean all non-merchantable wood is classified as 'residue'. Some States, Best Management Practices (BMPs) and certification schemes require that a proportion of logging residues be left in forest. In the future expansion of this use will depend on proximity to pellet mill, financial return and regulations or BMPs adopted. The financial return on the use of residues from forests for pellets is not sufficient to encourage changes in forest practice, so practice will be integrated into the management of forests for other products. There is some concern that demand for pellets is increasing the use of residues that would otherwise have been left in the forest in some regions. The counterfactual may be correct, but it will vary from location to location and may be difficult to prove.						
Are the practices described in the scenario already occurring?	Survey: question	The majority view of stakeholder groups was that this scenario currently occurs sometimes, although a significant proportion thought it was less likely, rating it as only occurring occasionally	30	2	7%			Sometimes
	Survey: comments	Residues, particularly coarse residues, are removed now, but the extent of removal is highly dependent on location, forest type, forest owner's objectives (including the need to reduce the costs of reforestation) and local markets for pulp, paper or wood fuel for power generation or for heating which is seasonal. Another factor that influences removal is the equipment available, e.g. having a chipper available and appropriate transport vehicles is important. This means that in the vicinity of a pellet mill or pulp mill that uses residues for power generation the residues may be removed but in most other locations they are not. In addition in a strong pulp wood market most of the 'coarse' grade residues would be used for this market. A number of respondents commented that the scale of removal of residues is small compared to the amount of residues generated (e.g. 10-20% or that the "large number of small producers simply don't bother with such 2nd order activities.")						
	Literature review	A number of sources in the literature say that logging residues are likely to be used as pellet fibre. The use will depend on the availability of sawmill residues, the harvest of saw logs and the amount that is practically and economically feasible to extract. The latter will depend on location/proximity to the mill.					Good	Sometimes
	SRTS modelling	It is not possible to use the SRTS model to provide a view on this scenario						
If it is occurring, what evidence is there about the scale it is occurring at?	Literature review	There is conflicting evidence of the extent of the use of forest residues and collection of logging residues has not been normal practice in SE USA. Some States, BMPs and certification schemes stipulate how much logging residue should be left in the forest. The literature does not differentiate between coarse and fine residues. Pellet mills have not said that they will use logging residues, but Drax has provided a figure for its use of 942,039t forest residues plus 164,410t of diseased wood & storm salvage from the USA in its 2014 biomass supply report (using Ofgem definitions). There is no indication if these are coarse, fine or mixed residues. Most concern has been expressed about the use of hardwood logging residues.					Inconclusive	
	SRTS modelling	It is not possible to use the SRTS model to provide a view on this scenario						
What percentage of your forest land do you think is affected?	Survey: comments	The use of residues for pellets was generally considered to be a minor part of the US forest inventory and forest products market.						
What percentages of a region do you think is affected?	Survey: comments	A small amount of residues is being used for pellet production because of the cost of transport, harvesting and utilisation technologies and the levels of conventional harvesting. The amount of pellet use is very small compared to the total forest inventory in the region.						
The future situation								
In the future (to 2030), if demand for fibre for pellets stays at the current level, how likely do you think it is that these scenarios will occur (or continue to occur, if they already happen)?	Survey: question	The most common view is that this scenario is moderately likely to occur in the future, although non-bioenergy wood users, and some forestry owners and managers, considered it to be very unlikely	27	3	11%			Moderately likely
	Survey: comments	Any increase in the use of forest residues for pellets will be dependent on location and price. Analysis of the market indicates that forest residues are not likely to be the only source of fibre for pellets. Additionally, the use of forest residues for pellet production is not likely to drive the market, which will be driven by saw timber demand or, in some circumstances, by pulpwood demand. The use of forest residues for pellet fibre is therefore part of and dependent on these markets. Some respondents said in the US South there is currently "heavy reliance on boles from new harvesting used for pellets." Other respondents said that the use of forest residues will only be on a small scale. Some respondents are concerned that the UK market has a cut off at 2027, which will impact investment in extraction of residues.						

8 Results to Questionnaire

8.1 Introduction

This Chapter contains the results to the questionnaire only. It is a high level summary. For further detail readers are directed to:

- The Analysis Tool, which contains the analysis of part 2 of the questionnaire on which the results provided here on likelihood are based
- Appendix 5, which provides the comments that were made on each question in part 2 of the questionnaire
- Appendix 6, which provides the results to parts and 3 of the questionnaire.

The high level review in this section combines the comments and results from the Analysis Tool. It is important to view these together because the comments provide many qualifications on the scores or ranks chosen by the respondents in the questionnaire. Among these there is a frequent comment that we offered a limited choice of response, e.g. we asked if a scenario is occurring now and provided a response options: definitely not, sometimes, most of the time, yes always or I don't know. The common comment is that respondents have selected sometimes, when they really meant occasionally or rarely but this option was not available. The Chapter below captures such comments.

This chapter contains context information on the participants in the questionnaire in Section 8.2 and then presents the answers on the questions dealing with likelihood of each group of high carbon impact scenarios. Information from Parts 1 and 3 of the questionnaire is drawn on where relevant in these sections. The 'grouping' of the scenarios is done as in Stephenson and Mackay (2014) i.e. along the lines of the type of fibre resource accessed in the scenarios.

8.2 Responses to the questionnaire: description of participants

There were 56 returns for the questionnaire. Respondents represented significant stakeholders in the pellet supply chain as shown in Table 8-1. It would appear from Table 8-1 that the views of non-bioenergy users were under-represented. Companies producing non-bioenergy forest products were invited to provide their views and we received views from a number of companies that produce non-bioenergy products, but most of these companies also produce pellets or provide roundwood for pellets and manage forests. The stakeholders who fall into this category have been classed in the forest owner or manager category, usually because they have said that this is the view they have used in completing the questionnaire.

Table 8-1 Breakdown of respondents by stakeholder type

Type of stakeholder	Number of responses
Pellet producer (PP)	13
Non-Governmental organisation (NGO)	6
Pellet users (PU)	6
Non-Bioenergy producer (NB)	2
Forest owner or manager (FO)	14
Public organisation (academic, government official) (PO)	15

Most respondents were from the USA and Canada. Many of the UK participants who were invited to respond felt their understanding of North American forest practice was insufficient to complete the questionnaire or to comment on the likelihood of the scenarios. This included a range of UK and European NGOs, financiers, academics, forestry experts and Trade Associations.

US respondents were drawn from large scale land owners, forest products companies, forest management, pellet producers, NGOs, trade associations, academic and Government with a strong interest in the US Southeast.

A number of US and Canadian respondents belonged to more than one stakeholder group. They were classified by the major interest that they demonstrated in the survey. This was particularly true of a number of large scale forestry organisations and some pellet producers: these organisations were also often involved in the production of forest products as well.

In the USA many of the respondents managed forests under certification (ATFS, FSC, SFI were mentioned by a number of respondents). Many of those who used product from forests obtained a significant proportion from certified forest.

Canadian respondents were drawn from Provincial Government, Trade associations, forest managers, pellet producers, pellet users and academia. NGOs in Canada declined to participate, as they felt their experience was not adequate.

Most of the respondents had been working in the area for more than 6 years, some for considerably more than this time. Even those who had much less experience worked for organisations with a track record in the area. This meant that participants drew considerably on expert judgement for their responses. However they also provided considerable evidence from the literature. This is listed in Appendices 4 and 5.

Respondents who were involved in the forest products supply and production chains provided figures for their main products by volume and value. From these figures the main products by volume or value produced by general forest products companies participating were saw timber and paper and pulp. However there were some companies for which pellets were the main product. In Canada respondents did not always provide figures for volume. Accepting that there is this omission, the total volumes that were provided were: 52.6 million m^3 wood for saw logs, 15.7 million m^3 for pulp chips and 100,000m^3 for pellets. Overall for respondents from Canada pellets represented between 0 and 5% of the volume they produced and the value of round wood for pellets was between 4 and 8% of the value of their other products (per tonne or m^3).

In the USA forestry respondents told us that pulpwood and sawtimber are their "primary value markets". In general saw logs represented between 50 and 75% of the volume of product; pulp wood represented the bulk of the remainder. Roundwood for pellets represented less than 3% of the volume harvested. The US Industrial Pellet Association said that for their members' pulpwood for paper and board still represented a major proportion of their market and that pellets represented around 20% of the market for their members.

We cannot say what percentage of the industry the respondents represent in their sector in North America, but they did include representatives of local companies and some of the largest forest products companies in North America and, in the USA, significant trade associations. In Canada respondents included Provincial Government officials who have an excellent oversight of the Canadian forestry sector and the way it is regulated.

Respondents included major pellet producers in Canada and USA and major pellet users in the UK. Pellet users from the USA and Canada were also included.

NGOs were mainly active in the US Southeast, but there was one UK NGO participant. No Canadian NGOs participated.

8.2.1 Forest Management

In addition to being asked about the likelihood of the high GHG intensity supply scenarios for pellets, Part 3 of the survey asked questions about factors that influence forest management. Table 8-2 presents a summary of responses. It can be seen that Provincial regulations, conservation requirements and the forest products industry are important in Canada and that State and Federal regulations and the forest products industry are important in the USA. These responses are in line with the evidence provided in the literature reviews (Chapters 4 and 5).

This means that these regulations will influence the way in which pellet fibre is supplied by the forestry sector. However, from the comments received it was clear that there is a range of views in the USA on whether the State regulations are adequate and what other factors are important. Examples are:

- "Most corporate landowners subscribe to forest industry certification standards - a key influence."
- "Most forestland in the Southeast lacks adequate mandatory regulations. More than 80% of forests are privately owned and logging operations are conducted with few restrictions and little oversight. Practices such as large-scale clearcutting, old-growth logging, wetland logging and the conversion of natural forests to plantations are mostly unregulated and are often practiced in sensitive habitats with little protection for species."
- "Government taxation has had a major influence on the structure of ownership and management as have state practice requirements/guidelines and in some places conservation requirements. Family landowners and some corporate owners may have additional conservation/ recreation goals that influence management."
- "Markets have a major influence on how forests, natural or planted, are managed and there is ample evidence that the presence of robust markets results in stable or increasing timberland acreage."

Table 8-2 Responses to questions 199-213 on the most influential factors (other than market) which influence decisions about the way forests and plantations are managed (in order of most to least influential)

	Southeast USA		East Canada		Pacific Canada		Boreal Canada	
(1 = most influential; 6=least influential)	**Rank: Naturally regenerated forest**	**Rank: Plantations**	**Rank: Naturally regenerated forest**	**Rank: Plantations**	**Rank: Naturally regenerated forest**	**Rank: Plantations**	**Rank: Naturally regenerated forest**	**Rank: Plantations**
State/Provincial regulations	1	2	1	1	1	1	1	1
Forest products industry	1	3	3	4	2	2	3	4
Conservation requirements	5	4	2	3	2	3	2	2
Federal Government policy or regulations	3	1	5	5	4	4	4	5
Other (specified separately)	4	5	4	2	5	5	5	3
There are no other factors that influence management decisions	6	6	6	6	6	6	6	6
answered question	**25**	**22**	**14**	**10**	**10**	**6**	**15**	**9**

8.3 Scenarios 4-7 High carbon scenarios for removal of residues

These scenarios concern the use of forest residues for pellet production (see Annex 1 for more detail). The counterfactuals are important to the carbon outcome. Where the counterfactual for the residues is to be burnt in the forest or at the landing or roadside, the outcome of the pellet supply-use chain is lower carbon impact and these scenarios have not been examined in this study. The counterfactuals examined here are listed in Table 8-3.

Table 8-3 Description of high carbon scenarios for the extraction of residues

Scenario	Description	Counterfactual
4a	Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest
4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
5a	Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest
5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
6a & 7a	Fine and coarse forest residues, removed from forests in Southeast USA, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest
6b & 7b	Fine and coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest

8.3.1 Definition and treatment of forest resides in the absence of pellet demand

Prior to being asked about the likelihood of the scenarios the participants were asked if they agreed with the BEAC definition of residues, shown in Box 8-1.

Box 8-1 Definition of forest residues given in BEAC

Fine forest residues: Tree tops, limbs, non-merchantable harvested trees and tree components, and downed trees which are left over from traditional timber harvesting. Includes pre-commercial thinnings. Diameter < 0.1 m.

Coarse forest residues: Tree tops, limbs, non-merchantable trees and tree components, and downed trees which are left over from traditional timber harvesting. Includes pre-commercial thinnings. Diameter > 0.1 m.

This definition does not include the removal of stumps

Almost all of the participants agreed in principle with this definition (33 of the 36 who answered this question). A large proportion (28 out of 36) said that fine and coarse residues are not managed separately. 33 respondents provided definitions of residues. Common comments were:

- “BEAC does not give an objective method of determining whether feedstock is ‘coarse forest residue’ or ‘pulpwood’. This is important as the calculations in BEAC depend on clear and accurate definitions.”
- “BEAC’s definition differs from the UK energy regulator (Ofgem) definition of forest residues in that Ofgem includes stumps and BEAC does not. In addition, BEAC includes non-merchantable trees (i.e. trees without an economically viable market), pre-commercial thinnings and downed trees – these are not included in the Ofgem definition.”
- Residues from forest operations include logging residues and pre-commercial thinnings (cut to improve the growth of remaining trees).

- Some participants said that 'non-marketable' trees are also regarded as forest residues. These are trees for which there is no current market (due either to their size or species).

An alternative definition was "all woody biomass left after logging operations except stumps". Further nuances from the USA were that "dead woody material that is on the site prior to harvesting is not considered a forest residue and is left in place per Best Management Practices (BMPs) for biodiversity." One comment included the following definition:

- "We define forest residues as tree tops, limbs, branches, leaves, and needles; diseased, rotten, or malformed trees unsuitable for sawmills, trees removed during pine plantation thinning; smaller diameter trees cleared during sawtimber harvests to avoid high-grading and clear the land for replanting or natural regeneration. It should be noted that the type of fibre considered residual material varies by location because of the presence and relative size of different markets. A market definition separating coarse and fine residues does not currently exist in the Southeast."

The full range of answers provided are given in Appendix 5.

The consequences of this disparity in definition of residues results in conflict between different stakeholder groups in the USA. The practice of clear cutting and subsequent inclusion of unmarketable trees as residues potentially for pellet production results in disagreement between stakeholder groups about the use of hardwood trees in pellet production and the origins of this fibre. The key issue here is: would normal harvest practices result in the felling of trees that are not marketable? Or would it leave these trees standing? If the latter, does pellet demand result in the felling of these trees and is this an additional carbon impact? Where it is common practice to clearfell it is clear that all trees in the stand would be cut, but if selective harvesting is practiced this may be an important consideration in carbon impact.

A universally accepted definition or understanding is required for forest residues so that the terminology of pellet-fibre use is understood and UK definitions match those used in countries of origin. This definition should take carbon impacts into account.

8.3.2 Comments on the counterfactual

In the absence of pellets all participants agreed that stumps would be left in the forest. Most said that residues are not landfilled. The most common practices are to leave residues at the roadside/landing site for natural degradation or to burn them at the road side. A proportion of residues are used for brash mats (to help movement of heavy machinery in the forest and to protect the forest floor) and a proportion must be left in the forest either because regulations/policy require this (Canada) or because BMPs, sustainability or State regulations require it, particularly for fine residues (USA). A detailed US comment is provided in Box 8-2. Other respondents pointed out that the counterfactual could also include urbanisation, which is a threat in some areas.

Box 8-2 Comment on how residues are treated at harvest in USA.

"Residues are generated at harvest. When roundwood tree stems are harvested and skidded to the loading deck, some residue is broken off and left on the forest floor. At the loading deck, if no market exists for residues, then residue piles will be generated. At this point, two circumstances may occur: The skidder may grapple the pile and spread some of the residue back across the forest, mostly on the skid trail. The skidder or a dozer will blade the residue to the edge of the deck, which clears the deck and creates a pile. At the loading deck, if a market exists (10-20 percent of the time), small residuals that cannot be loaded onto truck beds are generally chipped directly into trucks and used as boiler fuel for power generation at a mill or as a feedstock for pellets. In the absence of pulp or paper markets, tree tops, diseased and deformed trees, and small diameter roundwood with no other market demand that come down when a site is harvested for saw timber are loaded onto truck beds and delivered to pellet mills. Residues for pre-commercial thinnings are not usually collected and are left on the forest floor."

Thus the counterfactuals to extraction of forest residues for pellets are variable, depending on local circumstances and practice. The respondents to the questionnaire said it is not always easy to clearly understanding the counterfactual. One respondent commented that if pellet demand ceases to exist the counterfactual "will not be that forests would cease to be harvested and/or no residues would be used. In reality, the existing supply chain and infrastructure (could) attract another user of that product to the area."

8.3.3 Summary of comments on likelihood from the questionnaire

Table 8-4 summarises the views from the questionnaire. It includes a high level summary of the respondents view on likelihood, a summary of the respondents views on factors that would drive or prevent the scenarios (and how likely these are to happen) and a summary of the number of 'I don't know' responses. In addition to this respondents provided a view on their confidence in their answers. For this group of scenarios this self-assessed confidence score is 2.1, which signifies a degree of confidence on the part of the respondents. In these scenarios where there is no consensus this is because the views were either spread (sometimes from very unlikely to likely, e.g. scenario 5a, 6&7a) or there was a large proportion of 'I don't know' answers (e.g. scenario 5b and 6&7 b, question 1).

As well as responding to the questions and providing a score for each question respondents were also invited to comment on the question and to provide evidence to support their view. Representative comments are quoted to clarify the responses to the questions. Further detail on these comments is available in Appendix 5.

Scenarios 4 and 5 were generally thought to be moderately likely to likely in some circumstances, but the respondents did not think that they are commonly occurring in Canada and thought that they are occurring only on a localised basis in the USA. Scenarios 6 and 7 were not considered likely by the respondents.

The main comments on likelihood related to the fact that coarse and fine residues are not routinely separated. Participants could not understand what is meant by scenarios 6 and 7.

Comment on separation of coarse and fine residues were:

- This is technically difficult and probably would be costly to do. So although it might happen at times it is not common practice.
- Participants thought that it was more likely that coarse residues would be used. This is because fine residues are more likely to be intermingled with other debris such as soil and stones.
- Some residues are already used in boilers at pulp, paper and pellet mills.
- USA participants said that there are very few residues left after harvest of softwood plantations: so there is a need to differentiate by forest type.
- It is unlikely that fine and coarse residues would be extracted separately in Canada. One respondent said "fines can cause flashing in rotary dryers and are dangerous."

The confusion with scenarios 6 and 7 was because participants could not imagine a situation where this occurs. Typical comments were:

- forests are managed for saw timber production. Forest residues are a co-product of this process – they would only be taken (once) at saw timber harvest and then only if the price was sufficient. "Landowners are highly unlikely to change their management practices to produce more coarse residues".
- "Even if pellet demand goes away in 15 years, there will continue to be markets in some areas for fuel. Therefore the removal of residues will continue."
- "Because there is no difference between scenarios 4 and 5 and scenarios 6 and 7 in year one, we cannot determine whether or not these scenarios are occurring currently. Furthermore, any real incentive for these scenarios to occur are non-existent, as, even if pellet markets soften when subsidies expire, demand for these materials from other forest products manufacturers and non-pellet energy producers will continue."
- "There is a need for significant investment in equipment to extract residues from the forest. To do this in a forest for 15 years and then stop does not make commercial sense."

Table 8-4 Summary of views on scenarios 4-7 from the questionnaire for each question asked

(a) Overall view as assessed on basis of responses to questionnaire.

Scenario	Do described practices in scenario currently occur	How likely are these practices in the future if demand stays at current levels	How likely are these practices in the future if demand increases but price remains the same	How likely are these practices in the future if demand increases and price increases by 15%	How likely are these practices in the future if demand increases and price increases by 30%	Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?
4a	Sometimes	Moderately likely	Likely	Likely/Very Likely	Very likely	Most of the time
4b	No consensus	Moderately likely	No consensus	No consensus	No consensus	Sometimes/Most of the time
5a	Occasionally	Moderately likely	No consensus	No consensus	No consensus	Most of the time
5b	No consensus	Moderately likely	Very unlikely/unlikely	No consensus	No consensus	Sometimes
6a&7a	Definitely not	Moderately likely	No consensus	Unlikely	No consensus	Most of the time
6b&7b	No consensus	Moderately likely	No consensus	Unlikely	No consensus	Sometimes/ Most of the time

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
4a	Increased demand for pellet fibre	The costs of extraction decrease	Changes in forestry incentives	Insufficient financial return	Cost of extraction of residues too high	Other uses make land value more attractive
4b	Increased demand for pellet fibre	Changes in forestry incentives	The costs of extraction decrease	Insufficient financial return	Cost of extraction of residues too high	Changes in legislation and policy
5a	Increased demand for pellet fibre	The costs of extraction decrease	Changes in forestry incentives	Insufficient financial return	Cost of extraction of residues too high	Other uses make land value more attractive
5b	Increased demand for pellet fibre	Changes in forestry incentives	The costs of extraction decrease	Insufficient financial return	Cost of extraction of residues too high	Availability of logging capacity
6a&7a	Increased demand for pellet fibre	The costs of extraction decrease	Changes in forestry incentives	Insufficient financial return	Cost of extraction of residues too high	Other uses make land value more attractive
6b&7b	Increased demand for pellet fibre	Changes in forestry incentives	The costs of extraction decrease	Insufficient financial return	Cost of extraction of residues too high	Availability of logging capacity

(b) Data on the total number of responses and the number of 'I don't know' responses.

	Total no. of responses								Of which 'don't knows'						Of which 'don't knows'					
Scenario	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Factors that encourage	Factors that prevent	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual
4a	30	27	16	16	16	33	34	30	2	2	0	0	0	2	7%	7%	0%	0%	0%	7%
4b	15	15	6	6	6	25	17	15	6	2	1	0	0	0	40%	13%	17%	0%	0%	0%
5a	29	27	16	16	16	33	34	29	3	2	0	0	0	1	10%	7%	0%	0%	0%	3%
5b	13	13	6	6	6	25	15	13	7	2	1	0	0	0	54%	15%	17%	0%	0%	0%
6a &7a	28	26	16	16	16	33	33	28	4	2	0	0	0	0	14%	8%	0%	0%	0%	0%
6b &7b	15	5	6	6	6	25	16	15	7	0	2	2	2	1	47%	0%	33%	33%	33%	7%

Other comments were:

- Any change that happens in the use of forest residues will depend on the context, i.e. how close the location is to a pellet mill, the availability of a chipper, the backdrop of other economic and policy drivers and (in the US South) the motivation of the land owner.
- Some participants in the US are concerned about the "heavy reliance on boles from new harvesting used for pellets", but no evidence was supplied
- In the presence of increased demand and price for pellet fibre, participants thought that the "cost of removal coupled with the modest value of the residues" would not result in large increases in this practice. If the market reacted to increases in prices, this would result in downward pressure on prices in the longer term, so it was unlikely that pellet demand alone would result in rapid changes. Further US comments were that residues are an integral part of other markets and will be dependent on these markets; in Canada it respondents said that "there is already an excess of forest residues beyond ecological needs that is left behind now"

The scale of removal was thought to be low.

- The pellet market currently represents a very small proportion of the forest products industry (one statistic was "with 3.9 million tonnes of pellets produced for export (EU Statistics) and a max of 1.6 million m^3 of harvesting residues used, this represents just 0.015% of the inventory in the US Southeast.")
- In Ontario it was thought that around "2% of available residues" might be removed.
- The current harvest limits are not achieved in Canada, which some respondents think implies that harvest would be increased before forest residues are extracted.
- There was no overall consensus in Canada, as some Canadian respondents think that the only likely market for residues would be pellet demand. One respondent said that "timber supply reductions are forthcoming for the BC Interior and it is assumed that the removal of forest residues will become an increasingly important feedstock over time for pellet producers."

The use of forest residues as a raw material for pellet production was also commented on:

- "UK electric power plants need pellets made from "clean" chips for processing" *(no evidence of UK specifications was provided).*
- "Pellet producers typically don't like residues" *(again, no evidence of this was provided)*
- Some pellet producers cannot use more than 20% forest residues in their pellet production process. (*This is related to the design of pellet mills*).

8.3.4 Relevant comments from parts 1 and 3 of the questionnaire

The answers for these parts of the questionnaire and comments on them are provided in Appendix 6.

In Part 1 of the survey participants were asked what they thought the most **likely sources to provide fibre for pellets is**. The results indicated a wide variety of sources, but the use of **sawmill co-products** was chosen by 7 out of 16 respondents as was the **use of forest residues with bark** (Table 8-5a and c). The use of **thinnings and unmerchantable wood** was selected by 7and 8 respondents respectively.

When asked how pellet demand would be met in the long term, the top responses was to increase the use of forest residues (Table 8-5b). How the respondents defined forest residues is important, but these responses are an interesting contrast to the answers to the likelihood questions. The comments on these questions show that respondents see pellet fibre supply as part of another market, i.e. the higher value markets for saw timber or pulp and paper will likely drive forest management, but if there is a market for pellets and fibre can be produced cost-effectively then it will be part of an integrated supply chain. This is the basis for the potential use of forest residues. Planting new plantations is not likely to provide much additional wood by 2030.

Forest residues were thought to have more potential in Canada than in the USA. However, when asked (in Part 3, question 242) how much prices would need to change for fibre for pellets to encourage an increase in the use of forest residues, participants said that a large increase in price is needed (this response was given by 7 out of 12, 3 out of 6 and 6 out of 13 respondents in different Canadian regions). USA respondents thought other factors were equally important in dictating the removal of forest residues (such as a ‘critical mass of equipment capacity to handle roadside removals’). Comments included:

- “The price would have to persist at a higher level to encourage investments in the equipment needed.”
- “Currently, a majority of residues (that are) removed from the forest are used by the pulp and paper industry in boilers. Transportation and delivery costs can create an increase or decrease of residue removals. These would not be tied to the price or demand for pellets”

Pellet producers asked the same question also put coarse forest residues high on the list (after sawmill co-products and unmerchantable wood).

The second choice in Table 8-5b (diversion of non-bioenergy uses of pulpwood) will have displacement carbon impacts.

Table 8-5 Response to question on sources of wood used for pellets

(a) Current use

Sources used to provide wood for pellets	Response Count
Unmerchantable wood	8
Roundwood from coniferous plantations	8
Sawmill co-products	7
Forest residues with bark	7
Thinnings	7
Other (please specify)	6
Roundwood from naturally generated coniferous forest	5
Roundwood from naturally generated hardwood forest	5
Forest residues without bark	4
Roundwood from hardwood plantations	0
Short rotation coppice grown for bioenergy	0
answered question	**16**

(b) in the long term.

How pellet demand will be met in the long term (between now and 2030)	Total Score	Rank	
Increase use of forest residues	118	1	*most likely way of meeting pellet demand*
Divert pulpwood from non-bioenergy use	99	2	
Plant new plantations on abandoned agricultural land	66	3	
Other (*Comments provided*)	64	4	
Increase harvest by decreasing rotation length	62	5	
Convert naturally regenerated timberland to plantations	58	6	
Plant energy crops	47	7	*least likely way of meeting pellet demand*

answered question: 27			

(c) Pellet producers response on sources used for pellets now

Feedstocks most commonly used	Total Score	Rank	
Sawmill co-products	49	1	*most common feedstock used*
Unmerchantable wood	39	2	
Forest residues - coarse	37	3	
Commercial thinnings	32	4	
Pre-commercial Thinnings	25	5	
Forest residues - fine	24	6	
Roundwood from plantations – softwood	20	7	
Roundwood from naturally generated forest – softwood	14	8	
Roundwood from naturally generated forest - hardwood	13	9	
Roundwood from plantations – hardwood	4	10	
Short rotation coppice grown for bioenergy	3	11	*least common feedstock used*
answered question: 14			

(d) Answers to part 3 question on most likely sources of wood to be used for pellets

Most likely sources of wood if new sources were mobilised to meet fibre demand for pellets	**South east USA**	**East Canada**	**Pacific Canada**	**Boreal Canada**
1=most likely new source	*Rank*	*Rank*	*Rank*	*Rank*
Sawmill co-products	2	1	2	1
Forest residues would be extracted as part of operations at the roadside	5	2	1	2
Displacement of roundwood/pulpwood for non-bioenergy markets	4	3	3	3
Unmanaged wood would be brought back into management	1	4	5	4
The area of harvest of naturally regenerated forest would be expanded	10	5	6	5
Other (please specify below)	3	7	4	6
New plantations would be established from conversion of naturally regenerated forests	6	9	6	8
New plantations would be established on abandoned agricultural land	8	9	6	8
Energy crop plantations would be established	9	8	6	7
Current naturally regenerated forest would be harvested more frequently	7	6	6	8
answered question	**25**	**15**	**8**	**14**

8.3.5 Summary of responses on Scenarios 4-7 from the questionnaire

In summary the participants thought **Scenarios 4 and 5 were likely to happen as a result of pellet demand**, although there was a wide range of views, which meant that there was no consensus for a number of questions. The extent of the scenario occurring depended on the distance to the mill, other demands on the forest, regulations, BMPs (USA) and sustainability requirements. The extent of this practice was thought to be small, except in the vicinity of pellet mills. So, although there is a large theoretical forest residue resource, the extent of its extraction to meet pellet demand would be much lower.

The majority view was that scenarios 6 and 7 are unlikely. They would be difficult to prove because it would not be clear in the first years that extraction of residues would stop at year 15. In addition there were comments that residues are only taken at harvest, which is once at the end of the rotation.

It will be important to use the right counterfactual for removal of forestry residues, but it may be difficult to prove. The economics are likely to be marginal unless policy or bioenergy incentives are high. It is unlikely that coarse and fine residues would be separated, but, if this were to happen, it is likely that fine residues would be left in the forest. It is unlikely that pellet producers will want to rely entirely on this raw material; participants commented that a maximum of 20% forest residues could be used in pellet production and that UK pellet users require relatively clean material in pellets.

8.4 Scenarios 10-13

Table 8-6 Description of high carbon scenarios for the extraction of additional wood from naturally regenerated forest

Scenario	Description	Counterfactual
10a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years
10b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years
11	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.	Continue harvesting the forest every 70 years
12a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years
12b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years
13a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA from every 70 years to every 60 years.	Continue harvesting the forest every 70 years
13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated hardwood forest in Southeast USA every 70 years.	Reduce the rate of harvest to every 80 years

The first three of these scenarios (10-12) concern Canada. Scenario 13 concerns the Southeastern USA. They all examine the impact of **additional harvest by decreasing rotation of naturally regenerated forest in comparison to the counterfactual** (10: hardwood forest in East Canada, 11 and 12 coniferous forest in Pacific and boreal Canada respectively; 13: hardwood forest in Southeastern USA). In each scenario (a) assumes a larger decrease in rotation age (up to half in the Canadian scenarios) compared to (b). The counterfactuals for these scenarios is continued harvest at normal rotation except for Scenario 13 b, where the counterfactual is reduction in the harvest rate resulting in a longer rotation (80 years). The summary of results for these scenarios is provides in Table 8-7. This is a high level summary of the respondents view on likelihood, a summary of the respondents views on factors that would drive or prevent the scenarios (and how likely these are to happen) and a summary of the number of ‘I don’t know’ responses. In addition to this respondents provided a view on their confidence in their answers. For this group of scenarios this self-assessed confidence score is 2.2, which signifies a degree of confidence on the part of the respondents. In these scenarios where there is no consensus this is because the views were spread (sometimes from very unlikely to likely).

8.4.1 The likelihood of the counterfactual from the questionnaire

The counterfactual assumes that rate of harvest (modelled using 'rotation' periods) does not change in the absence of pellet demand in contrast to an increased rate of harvest (shorter rotation) in response to pellet demand, apart from Scenario 13b, where the counterfactual involves a reduced rate of harvest. Most of the participants commented that the counterfactual was more complex than this. What happens in the absence of pellet demand is determined in Canada by local regulations and the management plan agreed in the licence or tenure management plan. The rotation length of natural stands is driven by markets other than the pellet market. Currently the AAC is not exceeded in any Canadian province, so it is unlikely that rotation periods will be decreased as a result of pellet demand.

A number of respondents also suggested that the counterfactual could be different to that defined in these particular scenarios of BEAC, such as increased conversion to urban use or decreased harvest. It will depend on region, growth rate of forest and other market demands. Respondents said that it is not clear that the extraction of fibre for pellets impacts the rotation or harvesting period, as pellet fibre is only taken as part of an integrated forest products market. It will be difficult to determine if the extraction of additional fibre for pellets has changed the harvest period.

US respondents commented that forests are harvested at all ages, based on land owners' objectives. Financial return is usually an important consideration. This means that the more valuable saw log markets are likely to dictate harvest timing and fibre production for pellets will be a 'follower' of this market, so it will not dictate harvest timing. Typical average rotation periods vary widely and respondents said that they were not convinced that anybody could clearly distinguish between a 60, 70 or 80 year old hardwood stand. Many hardwood stands are multi-aged, since many have been partially harvested in the past to take out the best timber. This practice is less common now. Other respondents said it would be difficult to prove a change in rotation or to be certain of the counterfactual rotation period. A typical comment was "pellet markets are unlikely to affect the rotation age of naturally regenerated forests. The pellet market, like the paper market, makes use of the least valuable component of the forest stand and typically has little impact on harvesting decisions." Changing harvest period by 10 years or more is unlikely to be financially viable and the changes would probably be more subtle, i.e. 1-2 years. It was also pointed out that the counterfactual could also include urban land use, decreased harvest levels due to reduced market demand (similar to Scenario 13b) and increased impacts from forest health threats (e.g. disease and fire).

8.4.2 The Canadian scenarios 10a – 12b

In response to the question 'are these scenarios occurring now?' most Canadian respondents said definitely not or sometimes. Comments were: "In Canada the rate of harvest is independent of demand for fibre for pellets, as AAC is set by provincial governments related to production of primary products such as pulp and wood products." "Provincial law proscribes harvest of wood before maturity (90 years) on public land. We always follow the principle of the AAC for forest management. And the harvest practice is for high value product only". No change in forest management plans for fibre for pellet production were envisaged.

Respondents could not see this changing: "our actual AAC in Eastern Canada has been undercut for several years now" and "the tenure system does not encourage growing more wood and trees grow too slowly". It was also explained that AAC "is not connected to rates of harvesting, it's a much more complicated equation run by the provincial authorities."

When asked if there was anything that would encourage these scenarios to happen the most common response was an increase in demand in pellet fibre allowing sufficient financial return to encourage the scenario – but most respondents thought it was unlikely that this would happen. Conversely when asked what would prevent the scenario most respondents said insufficient financial return – and they thought that this was likely to be so. The agreed conditions for the AAC set forest management conditions and pellet demand is unlikely to change these. This is because saw timber and paper and pulp production

Table 8-7 (a) Overall view on scenarios 10-13 as assessed on basis of responses to questionnaire.

	Overall view as assessed on basis of responses to survey questions					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
10a	Definitely not	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Sometimes/Yes, always
10b	Definitely not	Very unlikely	Very unlikely	Very unlikely/unlikely	No consensus	Most of the time/Yes, always
11	Definitely not	Very unlikely/unlikely	Very unlikely	Very unlikely/unlikely	No consensus	No consensus
12a	Definitely not	Very unlikely	Very unlikely	Very unlikely	No consensus	Most of the time/Yes, always
12b	Definitely not/sometimes	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	No consensus	Most of the time/Yes, always
13a	Definitely not	No consensus	No consensus	No consensus	No consensus	Most of the time/Yes, always
13b	No consensus	No consensus	No consensus	Unlikely	No consensus	Most of the time/Yes, always

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
10a	Increased demand for pellet fibre	Low demand saw timber	Reduction in vulnerability to disease/pests	Insufficient financial return	Alternative market more attractive	Low pulpwood demand
10b	Increased demand for pellet fibre	Low demand saw timber	Reduction in vulnerability to disease/pests	Alternative market more attractive	Insufficient financial return	Low pulpwood demand
11	Increased demand for pellet fibre	Reduction in vulnerability to disease/pests	Low demand saw timber	Alternative market more attractive	Insufficient financial return	Changes in legislation or policy
12a	Increased demand for pellet fibre	Low demand saw timber	Reduction in vulnerability to disease/pests	Alternative market more attractive	Insufficient financial return	Low pulpwood demand
12b	Increased demand for pellet fibre	Low demand saw timber	Reduction in vulnerability to disease/pests	Alternative market more attractive	Insufficient financial return	Low pulpwood demand
13a	Increased demand for pellet fibre	Changes in forestry incentives	Changes in legislation or forest policy	Insufficient financial return	Alternative market more attractive	Changes in legislation or policy
13b	Increased demand for pellet fibre	Changes in forestry incentives	Low demand saw timber	Insufficient financial return	Alternative market more attractive	Changes in legislation or policy

(b) Data on the total number of responses and the number of 'I don't know' responses.

	Total no. of responses								Of which 'don't knows'						Of which 'don't knows'					
Scenario	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Factors that encourage	Factors that prevent	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual
10a	16	7	6	6	6	25	14	15	5	1	0	0	0	0	31%	14%	0%	0%	0%	0%
10b	15	7	6	6	6	25	13	14	5	1	0	0	0	0	33%	14%	0%	0%	0%	0%
11	13	6	5	5	5	24	10	12	5	0	0	0	0	0	38%	0%	0%	0%	0%	0%
12a	15	7	7	7	7	25	12	14	4	0	0	0	0	0	27%	0%	0%	0%	0%	0%
12b	15	7	7	7	7	25	12	14	4	0	0	0	0	0	27%	0%	0%	0%	0%	0%
13a	27	15	16	16	16	28	25	26	6	0	0	0	0	0	22%	0%	0%	0%	0%	0%
13b	26	15	15	15	15	28	25	25	6	0	0	0	0	0	23%	0%	0%	0%	0%	0%

are the markets that are considered in the AAC and the pellet market is too small and low value to be considered above these needs. Respondents did not think that economic conditions would allow a pellet producer to use wood from a mature forest in a way that resulted in a shorter rotation or additional harvest ("We are unaware of any scenario under which it would make economic sense for a pellet producer to utilize wood from a mature natural forest" and "increased demand likely will not affect harvest rotation"). However, a significant increase in traditional lumber markets would provide the financial incentive to increase harvesting and more residues would then be generated alongside this lumber. In addition in some Provinces the supply of wood exceeds current demand. Therefore it is more likely that existing supply within the AAC would be used to meet additional demand for fibre for pellets rather that a reduction in rotation.

One comment was "the way in which the scenarios have been built does not make sense. In reality, the dynamics at play are significantly more complicated than simply rotation time."

8.4.3 The US Scenarios: 13 a and b

When asked if the practices described in Scenario 13 are already occurring, the most common response was definitely not for scenario 13a and no consensus for 13b.

For scenario 13a there was a spread of views: 12 of 27 respondents said definitely not and five said sometimes. A number of these five said that by sometimes they meant rarely or occasionally. Six respondents said 'I don't know' and four said it is happening most of the time. A similar divergence was found in responses to 13b, but only 8 out of 26 answered definitely not and the same number answered sometimes. Five respondents said it happened most of the time. For this reason we have ranked this scenario as lacking consensus.

Understanding why there is divergence is related to how the scenario is understood by the participants in the survey. Most participants discussed the rotation length (which is directly related to rate of harvest of naturally regenerated forests) and discussed how financial returns influence harvest timing. However, one stakeholder group was mainly concerned with the harvest of naturally regenerated hardwood forests, which they think has increased due to pellet demand. This group did not concentrate on the changes in rotation length, just on increased harvest when the forest is cut.

The majority of respondents said that rotation lengths were unlikely to change significantly as a result of pellet demand, as pellet demand is not dictating harvest timing. Significantly decreased rotations were considered unlikely because saw log demand, which provides the best financial return, tends to dictate harvest decisions. Rotation lengths vary widely and are influenced by a number of factors including forest owner objectives. It would be difficult to prove any change as a result of pellet demand. Most respondents agree that a change of 10 years would be unlikely and that financial considerations are likely to constrain changes to 1-2 years at the most, for example:

"Pellet markets are unlikely to affect the rotation age of naturally regenerated forests. The pellet market, like the paper market, makes use of the least valuable component of the forest stand and typically has little impact on harvesting decisions. Sawtimber drives harvesting decisions. US Forest Service Inventory and Analysis data (FIA) data indicate the average age of hardwood removals is 54 years which is substantially different from the counterfactual and practices described above. The 10 year swings in rotation age included in the above scenarios would result in totally unrealistic amounts of wood being absorbed by the market. Even a 1-2 year swing in rotation age at any significant geographic scale would produce large volumes of wood. The scenarios are totally unrealistic".

Further greenhouse gas analysis investigating the impact of 1-2 year changes of rotation in Southeast USA naturally regenerated forests would therefore be beneficial. As indicated above respondents said that in naturally regenerated hardwood forests it is difficult to tell the age of the trees.

One stakeholder group did not mention rotation periods but commented on their concern that hardwoods were being harvested increasingly due to pellet demand: "current pellet demand is driving additional harvest of hardwood pulpwood including large trees that do not meet sawtimber specifications. Hardwood pulpwood in the Southeast is any tree, regardless of size or age that does not have a sawtimber market. Hardwood pulpwood demand in the Southeast has been steady since 2009. While pulp mill closures have reduced demand in certain areas, pellet demand is increasing harvesting well beyond the post closure status quo, and in the Virginia/North Carolina region where Enviva sources increasing pellet demand is projected to raise harvesting to levels where removals would exceed growth (Abt 2014a, Southern Environmental Law Centre 2015). However, since 2009, hardwood consumption for paper has remained stable, and is projected to remain stable over the next 5 years. The overall demand for hardwood pulpwood in the region is projected to increase by 5% over the next 5 years (Stephenson and Mackay 2014). It can be seen that the demand for hardwood paper feedstocks declined between 2008 and 2009; this was caused by closures of paper mills (22 out of an initial 100 paper mills closed in the US Southeast between 1990 and 2010 (Forisk 2014))". There is a need for further evidence to support this comment. The evidence provided indicates that the concern is about removal of residues and unmerchantable wood, not a concern about changes in rotation lengths. The respondents are concerned that the harvest is happening because of pellet demand and would not have happened in the area due to the decline in hardwood use for paper. The evidence that hardwood paper feedstocks declined is supported by the literature; evidence that pellet mills have moved into areas where pulp and paper demand has declined is also not in dispute. Further evidence on the impact of pellet demand on the harvest of hardwoods and the carbon impact of this harvest is required.

When asked what factors might encourage scenario 13 to occur, most US comments were that that it is unlikely that such specific scenarios will happen: "We are unaware of any scenario under which it would make economic sense for a pellet producer to utilize wood from a mature natural forest." "We do not believe the low value pellet market will drive harvesting decisions in naturally regenerated forests. And changes in rotation age described in the scenarios are totally unrealistic." "The key point here is the financial return and scale of demand. In theory, if the pellet sector could pay more than the saw mills for fibre, and the scale of demand was sufficiently large and long term, then it could influence rotation length. However, the reality is that the pellet sector cannot afford to pay and demand is limited both in terms of scale and timing."

However, one stakeholder group said that "Existing demand is already causing cutting of large trees often through clearcutting. Projected increased demand will just accelerate this practice in areas where pellet mills are located. There are no current or likely U.S. legal or policy changes that will slow this cutting pressure on these highly bio-diverse wetland forests. Pellet makers want clean chips, and boles, tops and large limbs are the easiest way to get the clean chip volume."

When asked what factors would prevent this scenario from happening most US respondents said that land owner objectives may include factors such as conservation, recreation or aesthetics and that "the paying capability of the wood pellet sector is not sufficient to drive this change *(in rotation length)*." One group of stakeholders said that "reduction or elimination of UK subsidies that will drastically alter the pellet business model and ensure an insufficient financial return so that premature harvesting is not economically feasible".

8.4.4 Other questions from the questionnaire

In addition to the questions on the scenario likelihood the questionnaire included a number of questions on factors that influence rotation period and supply of fibre for pellets. These provide further evidence that pellet demand does not influence rotation period:

1. How might pellet supply be achieved in the longer term? The option to increase harvest by decreasing rotation length was one of the lowest ranked options (Table 8-8). One comment was: "'Increase harvest by decreasing rotation length', but want to be very clear that the likelihood of decreasing final harvest age on most tracts is low though the average age of all harvested wood could decrease due to increased utilization of younger thinnings". So there may be an increase in use of thinnings, which would decrease average age of the whole stand, but mature trees would still grow to full maturity (full rotation) because of the importance of the saw timber financial return.
2. What are the most influential factors that decide the current rotation? Most responses were financial return from the saw log market is the major factor, followed by return from chip-n-saw and then financial return from pulpwood (Table 8-8). Comments were that this varies with time and location and that sustainability requirements are also influential. Comments from the USA included: "Varies over time and location; Sustainability of the forest is always a consideration" "Financial and land condition objectives of the owning entity, family, non-forest industry corporate, forest industry, government (Butler et al, 2007). Timber prices will be a factor but so will macro-economic conditions and land condition objectives" "Naturally regenerated forests are mostly hardwoods as pine occurs in plantations. These natural hardwoods are not managed on a regimented harvest schedule like pine is. Much of it can only be accessed in particularly dry weather. Therefore harvests are opportunistic and driven by sawlog prices along with weather and current economic circumstances" Rotation periods for naturally regenerated forest were given as: "Naturally regenerated forest - hardwood 35-80; naturally regenerated forest - softwood 35-60."

Table 8-8 Responses to a question on factors influencing rotation length

Most influential factors which decide the current average rotation or harvest timing in Southeast USA	Response Count for Naturally regenerated forest	Response Count for Plantation
Financial return from saw log market is the major factor influencing harvest timing.	17	18
Financial return from chip-n-saw and pulpwood demand is the major factor influencing harvest timing	6	8
Any of the above, the major factor has varied over time	8	6
Financial return from roundwood/pellet demand is the major factor influencing harvest timing	1	1
Licence conditions influence harvest timing more than market conditions	0	0
Other	13	7
answered question	**25**	**25**

3. For Canada the most influential factors that decide the current average rotation are licence conditions followed by financial return from the saw log market (Table 8-9) e.g. "Provincial legislation and approved forest management plans over ride; rotation determined by sustainable harvest based on the ecological/biological capacity of the forest" and "Our forests are directed by the Crown Forest Sustainability Act. Rotation or harvest timing would be influenced by the CFSA." Rotation periods were given as: "For spruce dominated upland forest units (includes balsam fir) the minimum operable age is generally set at 80 years with no upper age limit. For the lowland spruce forest units the minimum operable age is generally set at 100 years with no upper age limit. For jack pine the minimum operable age is generally set at 60 years with an upper limit of 135 years, for birch 70 years with an upper limit of 135 years, and for poplar 60 years with an upper limit of 135 years"

Table 8-9 Responses to a question on factors influencing rotation length in Canada (only results for East Canada are shown)

Most influential factors which decide the current average rotation or harvest timing in East Canada	Response Count for Naturally regenerated forest	Response Count for Plantation
Licence conditions influence harvest timing more than market conditions	8	4
Financial return from saw log market is the major factor influencing harvest timing.	6	4
Other (please specify)	4	4
Financial return from chip-n-saw and pulpwood demand is the major factor influencing harvest timing	2	2
Any of the above, the major factor has varied over time	1	1
Financial return from roundwood/pellet demand is the major factor influencing harvest timing	0	0
answered question	***14***	***10***

4. The questionnaire included a question on how changes in pellet prices affect management decisions on rotation length. Table 8-10 provides the responses to this. This shows that pellet prices were not the major influence management decisions on rotation. US and Canadian responses were different, which is not easy to see from Table 8-10. Canadians generally thought that Provincial regulations would be important. They commented that changes would "happen within the requirements of Provincial legislation and SFI certification." "Management decisions are moderately responsive to pulpwood/roundwood prices but pellet prices have no bearing on these decisions as the producers cannot afford pulpwood prices in the short term." In the longer term "expectations are critical for the decision to keep land in forest at all, but less important for short-term management choices of existing forests".

   US comments were that "BMPs in the southeast US are mostly voluntary, but still followed by roughly 90% of harvesting landowners"; "Such decisions are long-term decisions and will not be impacted by short term price changes"; "Forest management involves long-term decisions to maximize a return on investment. This is best achieved by planning for the highest value output – saw timber"; "it is possible that some small management decisions may change in response to a new market like pellets, but not decisions like harvest length or conversion to plantations. Some decisions influenced by this market may be things like the timing or number of thinnings." A number of respondents ticked 'other' in this question and said that this referred to the influence of long term market expectations, as forestry is a long term business.

Table 8-10 Responses to a question on how changes in pellet prices might influence rotation or harvest timing

How expected changes in pellet prices/pulpwood/round wood demand affect management decisions on rotation length/harvest timing or the replacement of naturally regenerated forests with plantations	Responses: Short term changes	Responses: Long term changes
Management decisions are not influenced by changes in pellet/pulpwood/roundwood prices	16	5
Management decisions are weakly responsive to changes in pellet/pulpwood/roundwood prices	9	19
State or Province regulations are an important influence on management decisions	11	11
Other (please specify)	13	13
Management decisions are moderately responsive to changes in pellet/pulpwood/ roundwood prices	3	9
Management decisions are very responsive to changes in pellet/pulpwood/roundwood prices	6	4
answered question	**37**	**38**

When asked what kind of price increase is needed to encourage an increase in harvest rate Canadians answered that this was irrelevant as the harvest rate is set by AAC calculations. US responses were that it would have to be a large increase in pellet prices (more than twice the current price) and that this was unlikely to happen. "Shorter rotations would produce smaller trees that are not suitable for sawn wood production. The pellet market could not afford to pay more than the saw log market. There is a substantial surplus of fibre to meet any increase in demand. A change in prices would not result in an increased harvest rate because pellet price does not drive this change, rotation length is driven by total crop economics. Response to increased demand is NOT decreased rotations."

8.4.5 Summary of Questionnaire Findings

Scenario 13 is one of the most controversial scenarios for the US. Whilst a large proportion of respondents concentrated comments on rotation periods as a measure of rate of harvest and said that these would not be influenced significantly by pellet demand (although changes of rotation of 1-2 years may be happening), one group of stakeholders was concerned about increased harvest of hardwood that they said is happening now as a result of pellet demand in the region of the hardwoods. It is not possible to reconcile these opposing views, because they concern different aspects of the harvest. They are different interpretations of the same scenario and result in different likelihood scores and an overall lack of consensus. Most comments concerned the way in which harvest of hardwood forests is driven by saw timber demand and that financial return on pellet fibre is not sufficient now and unlikely to be sufficient in the future to change this.

Scenarios 10-12: In Canada the respondents were more consistent: the scenario is not happening now and is very unlikely or unlikely to happen in the future. Rotation lengths and harvest timings are determined by Provincial AAC calculations, which are determined by many factors that do not include pellet demand. "The dynamics at play are significantly more complicated that simply rotation time." Pellets will be part of a larger market but will not drive the market. The counterfactual is more complex than assuming that all the rotation lengths will decrease. In Canada what happens in the absence of pellet demand is determined by local regulations and the management plan agreed in the licence or tenure management plan. Currently the annual allowable cut is not exceeded in Canadian provinces, so it is unlikely that rotation lengths will be decreased as a result of pellet demand.

8.5 Scenarios 10P – 13P

Scenario	description	Counterfactual
10Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
10Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
11P	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Pacific Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
12Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
12Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 50%	Leave plantation in previous management
13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 20%	Reduced frequency of harvest with low demand for wood

These scenarios concerned the **potential for increased harvest of plantations modelled by changing the rotation period**. The evidence collected for this study and reported in the Analysis Tool indicates that most of these scenarios are considered unlikely in the USA but there was no consensus in Canada. The latter was because the scoring was split between 'definitely not' and 'I don't know'. In fact there was a low response rate in Canada for this scenario and for some questions 50% of responses were 'I don't know'. Responses were often that the scenario does not occur now or that it may occur sometimes (but not very often). In general the scenarios were considered very unlikely in the future in Canada and USA. One reason for this lack of response and the number of 'I don't know' answers is because there are very few hardwood plantations in Canada or the USA and few conifer plantations in Canada.

The number of respondents who answered 'I don't know' reflects the difficulty that respondents had with these scenarios.

The evidence on scenarios 10P to 13P is provided in Table 8-11. Overall the self-assessed confidence score on the answers to these questions was 2.1, an indication that the respondents were confident in their answers.

Before answering questions on the likelihood of these scenarios participants were asked why they might do artificial regeneration of forests. The answers are very different in Canada compared to the USA. In Canada typical answers were:

- "Forest in Canada are regenerated through a combination of natural and/or artificial regeneration to produce ecologically appropriate stands. Natural or artificial regeneration is often supplemented by each other, e.g. natural regeneration with artificial seeding to fill in gaps and artificial regeneration with some naturals."
- "To fill the gaps in naturally regenerated forests and install forest on abandoned agricultural lands."

Artificial regeneration is related to compliance with regulations to ensure that natural diversity of the forest is achieved. In the USA typical comments showed how important financial return and rapid regeneration are:

- "Plantations are much more productive than artificial regeneration and supply the pulp and paper industry, but most plantations are also managed to provide higher value forest products such as sawtimber. Most plantations in the Southeast US are managed for multiple products and are not limited to rotation ages that would only produce pulpwood."
- "Faster and more predictable growth rate of the forest asset, easier thinning (evenly spaced stands), leading to higher and more predictable financial returns. Additionally, artificially regenerated pine forests, where thinning is performed and is economic, more closely resemble tertiary successional forests where fire was a common and frequent occurrence than in non-managed forests. This means that they actually have real and verifiable ecosystem benefits."

8.5.1 Summary of Canadian comments on scenarios 10P-12P

The definition of plantation is very important in Canada. Whilst artificial regeneration of forests occurs as described above a number Canadians commented that "we don't have hardwood plantations in Canada". Artificial seeding is practiced to ensure regeneration is appropriate in naturally regenerated forests. Biomass demand does not influence harvesting decisions due to the low value of biomass pellets. One respondent answered that future developments in tree genetics and processing technology are the factors that will drive down rotation periods.

The tenure system is likely to prevent the development of intensive plantations in Canada. When asked if increased pellet demand or increased prices for pellets would make a difference, comments reflected the requirements of regulation and the tenure system in Canada. It is likely that factors other than pellet demand will dictate forest management and changes. Rates of harvest are determined by Provincial authorities not the market and they take sustainable forest management into account. In general trees take time to mature and the "lumber market overrides the possibility that rotations would decrease to supply the pellet market."

8.5.2 Summary of comments on scenarios 13Pa and 13Pb

These scenarios concerned hardwood plantations, which are rare in Southeastern USA and the comments received and likelihood rankings reflected this. Comments on the counterfactual were that pellet demand will not determine the rotation periods of plantations, as the primary economic driver is saw timber. Plantation rotation is developed to maximise total revenue and economic return: "forests (plantation or naturally regenerated) are not managed for residues or low-value fibre, but are managed for high quality sawtimber. A low-value industry like pellets does not influence harvesting rates."

Table 8-11 Overall view on scenarios 10P to 13P as assessed on basis of responses to questionnaire.

Overall view as assessed on basis of responses to questionnaire						
Scenario	Do practices described in scenario currently occur	How likely are these practices in the future if demand stays at current levels	How likely are these practices in the future if demand increases but price remains the same	How likely are these practices in the future if demand increases and price increases by 15%	How likely are these practices in the future if demand increases and price increases by 30%	Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?
10Pa	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always
10Pb	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always
11P	No consensus	No consensus	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Most of the time/Yes, always
12Pa	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely/unlikely	Most of the time/Yes, always
12Pb	No consensus	Very unlikely	Very unlikely	Very unlikely	No consensus	Most of the time/Yes, always
13Pa	Definitely not	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always
13Pb	Definitely not/sometimes	Very unlikely/unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
10Pa	Increased demand for pellet fibre	Low demand saw timber	Changes in forestry incentives	Insufficient financial return	Market determined by saw log demand	Forest management not influenced by pellet demand
10Pb	Increased demand for pellet fibre	Changes in legislation or forest policy	Low demand saw timber	Insufficient financial return	Market determined by saw log demand	Changes in legislation or policy
11P	Increased demand for pellet fibre	Low demand saw timber	Change increases in value of land/changes in forestry incentives	Insufficient financial return	Market determined by saw log demand	Forest management not influenced by pellet demand
12Pa	Increased demand for pellet fibre	Low demand saw timber	Changes in legislation or forest policy	Insufficient financial return	Market determined by saw log demand	Forest management not influenced by pellet demand
12Pb	Increased demand for pellet fibre	Low demand saw timber	Changes in forestry incentives	Insufficient financial return	Market determined by saw log demand	Forest management not influenced by pellet demand
13Pa	Increased demand for pellet fibre	Low demand saw timber	Changes in forestry incentives	Market determined by saw log demand	Insufficient financial return	Forest management not influenced by pellet demand
13Pb	Increased demand for pellet fibre	Low demand saw timber	Changes in forestry incentives	Market determined by saw log demand	Insufficient financial return	Forest management not influenced by pellet demand

(b) Data on the total number of responses and the number of 'I don't know' responses.

Scenario	Total no. of responses								Of which 'don't knows'						Of which 'don't knows'					
	Current occurrence	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Factors that encourage**	**Factors that prevent**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**
10Pa	11	8	6	6	6	13	6	11	5	3	0	0	0	0	45%	38%	0%	0%	0%	0%
10Pb	8	8	6	6	6	12	5	8	4	3	0	0	0	0	50%	38%	0%	0%	0%	0%
11P	10	8	6	6	6	11	5	10	5	3	0	0	0	0	50%	38%	0%	0%	0%	0%
12Pa	9	8	6	6	7	10	5	9	4	3	0	0	0	0	44%	38%	0%	0%	0%	0%
12Pb	10	8	6	6	7	13	6	10	5	3	0	0	0	0	50%	38%	0%	0%	0%	0%
13Pa	17	15	16	16	16	13	11	15	4	1	5	5	5	0	24%	7%	31%	31%	31%	0%
13Pb	17	15	16	16	16	13	11	15	4	1	5	5	5	0	24%	7%	31%	31%	31%	0%

When asked if the scenario was already occurring, most respondents commented that there are insufficient hardwood plantations to tell: "plantation hardwood is so small that this change would generate an insignificant volume. 98.8% of all hardwood volume is naturally generated."

Future changes in demand or price are unlikely to change this: "Wood pellet prices will not drive this type of management decision. Even if pellet prices increased by significantly more than 30% to be on a par with sawlog prices, it would still make more sense to maximise volume production and harvest at the age of maximum mean annual increment or the point of maximum NPV (net present value). If demand and prices are sustained in the long term then forest owners would not need to change the rotation length, especially where there is a surplus of fibre. Premature harvesting may only occur in a small number of circumstances if the forest owner is in a distressed position and forced to harvest or if price increases are very temporary and owners want to make short term opportunistic decisions." In response to questions on whether there are factors that would enable the scenario comments were "extremely unlikely and the acreage and volume of hardwood plantation is so insignificant that it is irrelevant" and "we do not harvest or grow hardwood for pellets". One comment was: "The small amount of hardwood plantations that currently exist were planted experimentally by large industrial landowners. The practice was never officially adopted because the plantations did not end up being economically viable, and these forests are no longer being actively managed."

One group of stakeholders did consider that this type of change was possible. On factors that would prevent the scenario from occurring they commented "reduction or elimination of UK subsidies that will drastically alter the pellet business model and ensure an insufficient financial return so that premature harvesting is not economically feasible." This group of stakeholders provided this response to a number of scenarios.

In summary hardwood plantations are rare in the US Southeast so it is unlikely that these scenarios would have a great impact. Hardwood stands tend to have "more constraints from an environmental perspective and therefore it makes it a poor choice for focusing plantation investment."

Respondents commented that pellet fibre demand is also unlikely to have a great impact on softwood rotation. This is because rotation is driven by financial return, which is dictated by the highest value markets, not by pellet prices. This scenario would only be driven by policy changes or a much higher return on pellet fibre, neither of which was thought to be likely. The area of forest land impacted by this scenario is thought to be minimal.

Table 8-12 shows the answers to a Part 3 question on factors that influence harvest timing in the USA. From this it can be seen that the dominant view is that financial return from the saw log harvest is important. 'Other' factors include the objectives of the forest owners.

Table 8-12 Factors influencing harvest timing in the USA.

Most influential factors which decide the current average rotation or harvest timing in Southeast USA	Response Count for Naturally regenerated forest	Response Count for Plantation
Financial return from saw log market is the major factor influencing harvest timing.	17	18
Other	13	7
Financial return from chip-n-saw and pulpwood demand is the major factor influencing harvest timing	6	8
Any of the above, the major factor has varied over time	8	6
Financial return from roundwood/pellet demand is the major factor influencing harvest timing	1	1
Licence conditions influence harvest timing more than market conditions	0	0
answered question	**25**	**25**

8.6 Scenario 14

Scenario	Description	Counterfactual
14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Continue harvesting every 25 years	Reducing the frequency of harvest to every 35 years
14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Increased demand for pulpwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest to every 35 years

This scenario examines the harvest of additional wood from intensively managed pine plantations in Southeastern USA. 14(a) examines harvest continuing at 25 years; (b) examines a reduction to 20 years. The counterfactual is reduction of harvest frequency to 35 years.

8.6.1 Summary of comments from questionnaire

The evidence on this scenario is shown in Table 8-13. The responses to the counterfactual indicated that rotations for intensively managed softwood plantations in US Southeast vary from 25-45 years. Some respondents commented that rotations were around 25 years in their regions. Respondents thought that this could be shortened through productivity gains. **This means that the counterfactual of 35 years is unrealistic for part of the region.**

Rotation length is dictated by financial return from the saw timber markets and pellet demand is unlikely to influence this significantly (respondents said that at the most a change in rotation of 3-4 years either way would happen and only then if a significant change in prices occurs). Respondents did not think that the absence of pellet demand would result in longer rotation periods ("a lack of demand for small diameter roundwood would likely not cause an increase in rotation length. What would likely cause this is only a lack of demand in saw logs as landowners would likely delay final harvest"). A couple of respondents provided comments on financial modelling of the scenario[57]. These showed that decrease in rotation is likely to be of the order of 1-2 years at the most, but that the greatest impact would be on thinning. One respondent said there are several risks associated with no-thin regimes, including density induced mortality (lost volume), insect infestations, forest health decline, fire hazard, etc. Plus the inherent financial risk of managing for one or two end products rather than growing a tree that has multiple market options. For these reasons the scenario was considered unlikely. Comments included:

- "The pellet industry has no influence on the rotation for pine plantations. Sawtimber and other markets are the key drivers and the presence or absence of the pellet industry as a whole are not considered when making rotation decisions."
- "There is no reason to believe that a lack of pellets demand will cause rotation age to increase from where it is currently at."
- "Most landowners will time their harvest to maximize value regardless of demand for pellets, unless there are no other markets available. Housing recovery plays a wild card in that if housing does recover, increased demand for pulpwood sized material and clean chips due to the paper and paperboard market combined with pellets and Oriented Strand Board (OSB) will further destroy the small pine grow-drain in the Coastal SE USA."
- "The average rotation age or frequency of harvest in SE Georgia and NE Florida has been less than 25 years for the last 40 years. Frequency of harvest has been decreasing due to intensive management and increased genetic gain, long before anyone had heard of pellets in the US. The additional wood from intensively managed forests is grown for saw timber and is in no way related to pellet demand and has been changing for the last 50 years."

[57] For details on this modelling, please see appendix 4 in the comments listed under Scenario 14. This modelling has been performed using proprietary financial models used to determine optimal harvesting timing by large forestry companies.

Table 8-13 Overall view on scenarios 14a and b as assessed on basis of responses to questionnaire

	Overall view as assessed on basis of responses to questionnaire					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
14a	Most of the time	Unlikely	Unlikely	No Consensus	No Consensus	Definitely not/sometimes
14b	Definitely not/sometimes	Very unlikely/unlikely	Very unlikely/unlikely	Unlikely	No Consensus	Definitely not/sometimes

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
14a	Increased demand for pellet fibre	Shorter rotations yield greater financial return	Low demand saw timber	Market determined by saw log demand	Shorter rotation doesn't yield financial return	Insufficient financial return
14b	Increased demand for pellet fibre	Shorter rotations yield greater financial return	Low demand saw timber	Market determined by saw log demand	Shorter rotation doesn't yield financial return	Insufficient financial return

(b) Data on the total number of responses and the number of 'I don't know' responses

	Total no. of responses								**Of which 'don't knows'**						**Of which 'don't knows'**					
scenario	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Factors that encourage**	**Factors that prevent**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**
14a	20	15	15	15	15	12	18	17	0	1	1	1	1	0	0%	7%	7%	7%	7%	0%
14b	19	15	15	15	15	12	17	16	0	1	1	1	1	0	0%	7%	7%	7%	7%	0%

- "The frequency of harvest in managed pine plantations for many of the landowners/ managers we deal with is already around or lower than 35 years. Timberland of the largest landowners is on a 25-35 year rotation, depending on markets. No one has suggested to us that pellet demand will cause them to change the rotation lengths of the plantation, rather they have discussed increasing density of stands."
- "35 year rotations are longer than the current normal 25 year rotations in our area. Rotation age wouldn't increase. First, it is a misconception that all plantations are managed "intensively." Second, the purpose of intensively managed plantation pine is for the rapid growth of stem wood volume, particularly targeted for saw timber production. Decisions for rotation age are typically based on a Discounted Cash Flow (DCF) or Net Present Value (NPV) model with saw timber volume and saw timber price per unit being the main drivers behind future, discounted dollars. As such the price per ton of saw timber is the primary driver in moving rotation age targets. While smaller volume products such as pulpwood may have some impact, their volume is significantly lower than saw timber. As a result, a substantial price per unit change would be required to impact the DCF or NPV model output. In addition, studies have shown that forest productivity is higher than it has ever been, and that productivity will continue to improve, the result of better understanding of tree, soil and nutrient issues from one rotation to the next. As a result of these productivity increases, shorter rotation lengths are possible."

Asked if the scenario is occurring now a number of respondents commented that current rotations have increased in length due to the housing recession. They thought this situation would change only if the housing market picked up: the pellet industry has no influence on the rotation for pine plantations. A number commented that current rotations were in place for at least a decade before pellet demand existed.

Pellet demand is more likely to impact thinnings, perhaps by encouraging an additional thinning. This does not drive a decrease in rotation length: the driver of rotation length is the harvest of the final crop trees determined by the value of the trees to be harvested for high value products, as reflected in market prices, not the price of wood pellets.

Respondents to the questionnaire said that rotation length is more likely to change as a result of advances aimed at decreasing rotation period or in response to weaker demand in other markets. Representative comments were:

- "Market pressures continue to push for earlier harvest times (less than maximum annual increment), and increased use of OSB and other composite wood materials mean the large timber is less necessary. Mid-rotation economic returns from thinning for energy could actually economically enable lengthening of some rotations while increasing total productivity as rotations are pushed closer towards maximum annual increment."
- "Reduction in rotation age likely to happen given pellet demand"
- "All landowners would like to shorten rotations, strictly driven by financial drivers. But pellet demand will not decrease pine plantation rotation length. Additional wood will come as a result of greater plantation productivity. Rotation age will likely decrease as productivity increases."
- "1) The pulpwood component of a silvicultural regime does not drive changes to rotation length because it is the lowest value component. 2) Our forest productivity team ran multiple model runs to address this and other scenario 14 questions. This is a proprietary modelling tool that utilizes southern pine growth models in combination with financial discounted cash flow analysis to determine financially optimal silvicultural regimes. Site quality data from actual stands is input along with product specific pricing data and multiple iterations are executed by the model to determine the optimal regime. We use this model to inform the harvest planning process, updated in each geographic location every three years. For scenario 14, we used site data from a typical stand and BAU prices that result in a 25 year rotation, a fairly common situation for us. 3) The model was run with pulpwood stumpage pricing dropped to $5 to represent the counterfactual. $5 would be historically low for the Southeast and represents somewhat of a "break-even" price when depletions are accounted for. Depletions represent the "cost basis" of the pulpwood, i.e. the capital cost for the pulpwood component of having purchased or grown timber. Prices below $5 would therefore trigger other regime or land use changes (see below). The model resulted in the lengthening of rotation from 25 to 28 years the "bare land value" (BLV) was reduced by 14%. BLV represents "land rent" or the present value of the productive capacity of the land. Even in areas where pulpwood demand has significantly declined, we have

not utilized a $5 pulpwood price for harvest modelling. 4) The model run in #3 assumes two thins. At low prices such as $5, forest owners would reluctantly reduce to one thin or no thinning at all. When we modelled to one thin or no thin, the rotation age decreases to 19-23 with a much greater negative impact to BLV. There are several risks associated with no-thin regimes, including density induced mortality (lost volume), insect infestations, forest health decline, fire hazard, etc. Plus the inherent financial risk of managing for one or two end products rather than growing a tree that has multiple market options. Note that reduction of BLV ties directly to conversion to other uses. 5) Over the long term, management changes would be slow and variable as land owners change management based on their long term perception of the future. Management changes could include: - Landowners stop thinning - Trees begin to thin themselves naturally and mortality accelerates over time. - Some landowners harvest early to salvage their existing investment and begin a new regime - As stands are cut, planting occurs at lower densities - Innovation occurs for new forms of stocking competition control."

Scenario 14 b was less likely to occur and no evidence was provided in support of this scenario occurring. Most respondents thought it was unlikely because rotation length is driven by financial return in other markets. One respondent produced evidence to show that a significant increase in demand for pellets (>400%) and price (~50% increase) would be required to make this happen, which is unlikely; another that analysis changing saw timber and pulp demand showed that even in extremely favourable conditions for pellet fibre the change in rotation is likely to be two years at the most. Consequently a substantial price increase is needed for pellet demand to decrease rotations. This is because pellet fibre is currently a low value product and the financial return from its production is not sufficient to dictate rotation lengths.

Some respondents said that rotation lengths were decreasing as a result of other factors before pellet demand happened. In addition to comments above representative comments were:

- "An intensively-managed plantation, by definition, means a considerable investment in seedlings and management practices to support a return of value through sawtimber production. Pellet markets are unlikely to affect the financial return models in any significant to reduce rotation length by five years. This is not say that isolated instances of shorter rotation will not occur but it will not be a general practice."
- "This is not happening, or happening very rarely. Prices for pulpwood would need to be significantly higher to justify this change in management regime, some reports suggest that an increase of 200% would be required in pulpwood prices to make this option viable."
- "S14b: A much shorter rotation is unlikely to provide optimum NPV for the forest owners, regardless of a price increase in wood pellets. Growth rates would still be increasing at this age and the extra volume production gained by waiting another 5-10 years is likely to provide a much better return to the forest owner. Assuming that wood pellet demand and price increases are long term then the owner is much more likely to wait and maximise volume production than to harvest prematurely."
- "This happens rarely, only in small isolated pockets, primarily in the Coastal Plains; these harvests are what the industry considers outliers. They do not occur across the entire Southeast. Pellet demand, in general, will not be the cause of a reduction in rotation age of 5 years. If a Discounted Cash Flow (DCF) or Net Present Value (NPV) model were run, based on pulpwood price, the model would likely generate the same rotation length because of the lower volumes. At the most, it might reduce a rotation by two years. An analysis conducted by the National Alliance of Forest Owners and Forisk "concluded that forecast pine pulpwood prices in the Southeast in 2016 would have to increase from $11.47 per ton to higher than chip-n-saw prices of $17.09 per ton for landowners to be economically indifferent between a pulpwood-dominated forest and a sawtimber-dominated forest. Across the Southeast, bioenergy demand would have to increase 435% by 2016, from an expected 22 million green tons a year to 120 million green tons per year, for pine pulpwood prices to reach $17.09/ton*. This level of bioenergy demand in the region by 2016 is extremely unlikely. In comparison, the forest industry in the Southeast consumed 103.3 million green tons of pulpwood in 2010. Biomass energy wood use will have to be high enough for a sustained period to maintain high pine pulpwood prices to cause a shift in landowner behaviour. At the same time, competing higher-valued product prices would have to remain at prices low enough to incentivise switching from pulpwood to sawtimber rotations. Once established, these prices would have to remain economically feasible for over 23 years to incentivise multiple pulpwood rotations on the same

property. Overall, the analysis suggests that a significant shift from sawtimber to pulpwood rotations in the Southeast is highly improbable. (* Please note that these are stumpage prices, and not complete delivered fibre prices which would be much higher.)"

In summary most respondents said they have seen no evidence that this scenario is occurring. There were some comments that the scenario is happening in Georgia due to the concentration of pulp and paper mills in the area as well as bioenergy or pellet facilities. The evidence for this was drawn from the study by Evans et al (2013). Respondents thought that anything that encouraged the scenario was very unlikely to occur and that financial returns from other more attractive markets and alternative objectives for land owners are both likely to prevent a decrease in rotation from pellet demand.

8.6.2 Summary from questionnaire

There was no conclusive evidence that these scenarios occur or would occur in the future given higher pellet demand or price. Most respondents focused on the low financial returns from pellet fibre compared to other forest products, which means that pellet demand is unlikely to be a strong determinant of management decisions for intensively managed pine plantations. Evidence of the significant changes both in demand and return that would be required to alter this situation was presented. Respondents did not think that it was likely that these conditions would occur.

There were a number of comments that lower rotation lengths were witnessed prior to the increase in pellet demand, driven by the desire to increase productivity in general.

One set of comments that contradicted this, related to Georgia. In this region one group of stakeholders thought that the demand from paper, pulp and pellet mills in combination would impact management of plantations, making rotations change, but no evidence was provided to support the change in rotation length. These stakeholders quoted evidence on the demand for pulpwood in the area was provided from a study on forestry bioenergy in the region (Evans et al 2013). In this report two potential supply strategies from intensive plantations are speculated. One of these is increased thinning of intensive plantations. The impact of this on final rotation length of the plantation is not clear (the report is aimed at understanding wildlife impacts). The alternative strategy suggested is the conversion of forest to plantation. This is more relevant to scenarios 22 and 23 rather than 14. Neither of these strategies was confirmed by pellet producers.

8.7 Scenarios 19-21

Scenario	Description	Counterfactual
19	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in Southeast USA used for non-bioenergy purposes
20	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah.	Pulpwood produced in Southeast USA used for non-bioenergy purposes
21	Pulpwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.	Pulpwood produced in Southeast USA used for non-bioenergy purposes

These scenarios concern the use of pulpwood from Southeast USA causing an indirect impact of pulpwood for non-bioenergy purposes being produced elsewhere replacing forest or savannah in Brazil or naturally regenerated coniferous forest in Pacific Canada. The clear conclusion from the analysis is that these three scenarios are considered unlikely by respondents to the questionnaire. From the comments received this is because many respondents thought it was not possible to prove the connection between the two markets. The self-assessed confidence score for these scenarios was 2.3, which indicates that the respondents were confident in their answers. The 'no consensus' ranking for whether or not the scenarios are occurring now resulted from a split of 'definitely not' and 'I don't know' responses (e.g. 9 out of 15 said definitely not and 6 out of 15 for scenario 19).

8.7.1 Comments on these scenarios

The results for these scenarios are summarised in Table 8-14. In general **comments support the counterfactual**, although some respondents said that there is an excess of raw materials currently used for pellets and this material would otherwise not be utilised. The respondents said that the pulp industry in the USA has been consolidating for more than two decades, in response to changes in pulpwood demand. This is location dependent. The respondents said that in the absence of a non-bioenergy market for small roundwood (pulpwood) it is left in the forest. Two respondents commented that this means that the forest self-thins (through mortality) and can become unmanageable and vulnerable to alternative uses. Representative comments were:

- "There is an excess of raw materials currently used for pellets and this material would otherwise not be utilized"
- "….. increasing competition from foreign sources and weak pulp demand generally has meant the available market for this wood is pretty flat. The pulp industry in the US has been consolidating and contracting for 20+ years."
- "Yes, unfortunately we know that the combination of increased pellet feedstock demand, the age class distribution of inventory, and the inelastic supply response of land owners to a change in price have led to increased pellet feedstock prices and increased harvests in the U.S. Southeast (Lang 2014)."
- "There are times, in some locations, when the low demand for pulpwood results in it being left in the wood."
- "Currently pulpwood mostly goes to pulp and paper and OSB manufacturers, and for domestic energy use. Pulpwood that has no market to sell into is left in the forest."
- "Due to decline in traditional demand for pulpwood and increased forest productivity, sometimes thinning backlogs develop when there is no pellet demand. This leads to mortality through self-thinning rather than pulpwood production for non-bioenergy purposes."
- "Even if there are no pulpwood markets for pulp mills, there can be other non-bioenergy markets in the US. When a market exists for pulpwood, it is currently purchased by pulp and paper companies, OSB manufacturers and non-pellet domestic energy markets. When no market exists for pulpwood, however, it is left in the forest."

When asked **if the scenarios are currently happening** a number of respondent commented that pulp and paper fibre demand in the US is not related to pellet industry demand. Other comments were that the development of Brazilian pulp supply pre-dates the pellet industry in the US Southeast. The market for Brazilian pulp mills is different to that for Southeastern US pulp and the two are not connected.

Table 8-14 Overall view on scenarios 19-21 as assessed on basis of responses to questionnaire

	Overall view as assessed on basis of responses to questionnaire					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
19	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always
20	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes, always
21	No consensus	Very unlikely	Very unlikely	Very unlikely	Very unlikely	Most of the time/Yes always

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
19	Increased demand for pellet fibre	Low demand non-bioenergy products	Changes in forestry incentives	Insufficient financial return	Pellets cannot outcompete non-bioenergy products	Other uses increase land value
20	Increased demand for pellet fibre	Low demand non-bioenergy products	Changes in forestry incentives	Insufficient financial return	Pellets cannot outcompete non-bioenergy products	Other uses increase land value
21	Increased demand for pellet fibre	Low demand non-bioenergy products	Changes in forestry incentives	Insufficient financial return	Pellets cannot outcompete non-bioenergy products	Other uses increase land value

(b) Data on the total number of responses and the number of 'I don't know' responses

	Total no. of responses								**Of which 'don't knows'**						**Of which 'don't knows'**					
scenario	**Current occurrence**	**Future, demand at current levels**	**Future demand, increased same price**	**Future demand, increased price +15%**	**Future demand, increased price +30%**	**Factors that encourage**	**Factors that prevent**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future demand, increased same price**	**Future demand, increased price +15%**	**Future demand, increased price +30%**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future demand, increased same price**	**Future demand, increased price +15%**	**Future demand, increased price +30%**	**Counterfactual**
19	15	14	16	16	16	8	11	14	6	2	5	5	5	0	40%	14%	31%	31%	31%	0%
20	15	14	16	16	16	8	11	14	7	2	5	5	5	0	47%	14%	31%	31%	31%	0%
21	15	15	16	16	16	8	11	14	7	3	5	5	5	0	47%	20%	31%	31%	31%	0%

A number of respondents commented that it is not possible to know if this substitution is happening as there are many factors involved in depletion of the Brazilian rain forest, in particular agricultural pressures within Brazil. Evidence from USDA and Pöyry (2014) was drawn on to show that pulp demand in the US Southeast is expected to change, with a decline in pulp and paper demand. A number of comments said that there is no evidence that demand for pellets drives these changes:

- “Pulp and paper fibre demand in the US Southeast is not related to pellet industry demand or consumption.”
- “Lack of use or market access of US wood would lead to this... currently the causality here is opposite. Increases in southern hemisphere production are increasingly outcompeting US producers who have higher labour and land costs. For example, it is now cheaper to bring in roundwood from Chile/Brazil to Maryland, rather than harvest from Virginia (neighbouring State).”
- “I don't know and I doubt that anyone else can answer this question with any certainty. There are simply way too many other factors and issues involved in addressing the depletion of the Brazilian rain-forest. We do know that negatively impacting business in the United States can result in other regions out competing the US and driving US businesses off-shore.”
- “Conversions of rain forests are usually associated with agriculture. Conversion to plantations, if it occurs, is driven by global paper demand, not the bioenergy market. Many of the paper mills in the US Southeast that used hardwood have closed. In addition - “In July 2012 the USDA commissioned a study to assess the expected development of US forest inventory and growth rates across the entire US out to 2050, based on both historic data and growth rate modelling. This data showed that in the US Southeast, between 2014 and 2025, it is expected that available softwood volumes will increase by ~11%. Hardwood volumes are assumed to remain stable over the same period. As a result of this, the total wood supply potential in the US Southeast can be expected to increase by 10 million oven dried tonnes (odt), reaching 150 million odt by 2025. There is also expected to be a significant change in demand in this region. The pulp and paper sector is likely to see a decline in demand, due to a fall in demand for writing and newsprint papers which make up the large majority of production in this region. Balancing out this fall in demand are anticipated increases in demand from the wood based panels and wood pellets industries. The wood based panels industry is estimated to grow with a CAGR[58] of 5% out to 2020, but slowing down to only 1% CAGR by 2025. The wood pellet industry will also see a significant growth in demand of 15 million odt, with new pellet mill capacity being built to meet the increasing demand coming from Europe. Overall, due to the increase in supply and decrease in demand from the pulp and paper industry, there will continue to be a surplus of material in the US Southeast totalling 20 million odt. 12 million odt of this surplus will be from immobilised material, with the remainder mostly consisting of harvesting residues (Pöyry 2014).”
- “The demand for pellets will not affect Eucalyptus plantations in Brazil. The decision by pulp and paper to import Eucalyptus will be driven by logistics cost (harvesting, chipping, transportation). Conversion to Eucalyptus plantations will be driven by global demand of pulp and paper. Hardwood consuming pulp and paper mills in the US Southeast have almost all closed with only a couple remaining.”
- “In 2014, only 2% of our pulpwood production in the US Southeast was sold to pellet mills. This only occurred in areas where traditional demand for pulpwood had previously declined due to plant closures. Therefore, displacement due to pellet demand on our lands cannot already be occurring.”
- (In relation to scenario 20) “The demand for pellets will not affect Eucalyptus plantations in Brazil. The decision by pulp and paper to import Eucalyptus will be driven by logistics cost (harvesting, chipping, transportation)”
- (In relation to scenario 20) “Sometimes: Only in a peripheral manner, as the conversions are generally the result of increased demand for pulp and paper worldwide and the desire to increase productivity and profitability of these degraded lands.” (This comment was given by two respondents)

[58] Compound annual growth rate

In the case of displacement to Pacific Canada the following is a typical comment:

- "There is no evidence of any correlation of the use of pulpwood in the US Southeast to harvests in Pacific Canada. None whatsoever. The areas and products are too disjointed to have any type of impact. Harvest rates and rotation lengths in Pacific Canada will continue to be driven by sawtimber demand. Forest policy in Canada is driven by the Crown and any change will be difficult."
- "Theoretically, a rise in prices for pine pulpwood could displace softwood demand from USA to Canada over time. This would actually be a reversal of previous trends where Canadian mills closed and more opened in the US but it would not cause a reduction in rotation time. It would actually help stimulate a market in Canada for the pulpwood fraction of final harvests and sawmill co-products which have historically been piled and burned or incinerated in beehive burners."
- "The geographies and markets involved make this scenario most unlikely. While numerous factors can influence harvest rates, ultimately rotation length is determined by the governments in Canada."

When asked if this would change in the future many respondents commented that these scenarios are not likely to happen and repeated that there is no relationship between the Brazilian rainforest or forest in Pacific Canada and the pellet industry in the US Southeast. If US pulp supply was shifted due to pellet fibre demand then it would most likely be to neighbouring regions. "Conversion of rainforest is more likely to be to agricultural land"; "demand for bioenergy will not drive scenario 20 as conversions are generally the result of increased demand for pulp and paper worldwide and the desire to increase productivity and profitability of these degraded lands"; and in scenario 21 "the areas and products are too disjointed to have this type of impact." One respondent expressed concern that greater pellet demand might change this: "the greater concern is this scenario is more likely to happen if the subsidized pellet production increases as projected in the Southeast USA."

Most respondents did not think that anything would encourage these scenarios except for increased subsidies, which they considered unlikely to happen. "Removal of UK subsidies for pellets" would prevent the scenarios. However, for many respondents these scenarios did not make economic, practical or logical sense:

- "According to unpublished data from Forisk, 20 paper mills with a potential demand of 22.6 million tons of pulpwood were closed since 1998 in the US Southeast. We work with pellet producers to invest in the same locations where those closures previously took place. We prefer paper customers for pulpwood where demand continues to be healthy because they have the ability to pay higher prices according to our negotiation experience (and supported by analysis) - The productivity of our pine plantations has increased by 54% since 1998."
- "The USDA Economic Research Service did a report looking at actual indirect effects of US bioenergy production, which basically showed that the feared impacts some predicted for past policy were far overstated. The ISO technical committee developing a standard for Bioenergy Sustainability Criteria also looked at indirect impacts, and found no strong evidence that such were a major problem that had to be addressed."

8.7.2 High level summary of the questionnaire comments

Most respondents commented that there was no relationship between the pellet market in Southeast USA and the pulp and paper markets in Brazil and Pacific Canada and that causality for these scenarios would be difficult to prove. The trends in pulp and paper production in Brazil preceded pellet demand in Southeast USA by at least two decades. This market produces paper for different markets to the US Southeast. Any displacement of the US Southeast pulp and paper market is likely to be into neighbouring regions. Comments indicated that pulpwood demand changes have been happening for some time and are expected to continue. In part this is related to the costs of production of pulpwood and the fact that some pulpwood can be produced cheaper elsewhere; in part it appears to be related to a changing market for pulpwood. Pellet demand may be one of the pressure on pulpwood demand, but the most common respondents view is it will not be the only one. There was a mix of responses on this from the respondents: the most common view was that pellet markets cannot out compete other pulpwood markets, but one respondent thought that European 'subsidies' would result in higher pulpwood prices:

- "The European subsidies have already greatly increased costs of raw material for some U.S. paper and wood products facilities. For example, assuming that other market factors such as pulp/OSB production and the availability of residual sawmill chips remain unchanged, Forisk Consulting predicts average pine pulpwood stumpage prices across the Southeast could increase by 31 percent from 2014 to 2019 as a result of increased bioenergy demand, with 97 percent of the increase being pellet related. Forisk expects pine pulpwood use at pellet plants in the Southeast to increase from 4.9 million tons in 2014 to 16.9 million tons by 2019 – an increase of 245 percent. The share of pulpwood/chips, both pine and hardwood that will be used to make wood pellets, is expected to reach 10 percent in 2019, up from about 3 percent in 2013 and 4 percent in 2014."

Respondents could not provide any evidence of displacement of the pulpwood market as a result of pellet demand. A number of respondents said that the ability to pay for pellet producers was lower than for pulp and paper mills so this displacement should not occur. There may be localised effects around pellet mills, but we did not obtain any evidence of this.

Other comments were that these scenarios could be prevented by not subsidising the use of pellets for electricity generation in the UK.

8.8 Scenarios 22-25

Scenario	Description	Counterfactual
22a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
22b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
23a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
23b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
24a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
24b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years Conversion over 50 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
25a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally

These scenarios concern the conversion of naturally regenerated forest (coniferous forest in scenario 22, hardwood forest in scenario 23) to plantation or short rotation coppice (SRC) (coniferous forest in scenario 24, hardwood forest in scenario 25). The counterfactual is to continue with the normal harvesting practice (at 50 or 70 years), leaving the forest to regenerate naturally. A summary of evidence on these scenarios is provided in Table 8-15.

The counterfactuals are thought to be correct sometimes, although one stakeholder group (NGOs) said that they always happened and some other stakeholders answered definitely not or most of the time.

Respondents' confidence in their answers was high (score: 2.3).

8.8.1 Comments on the questionnaire responses about these scenarios

Commenting on the counterfactual respondents said the use of forests in the US Southeast is dynamic, depending on factors such as saw log market conditions, location and management decisions by family forest owners. However, conversion to plantation is not driven by pellet fibre considerations. Representative comments are:

- "Forest use in the Southeast is dynamic. Some new plantations are established. Other plantations are reverted to more natural regeneration patterns. In general, conversion to forest plantation is of far less concern than the much more common land use conversion to urban use."
- "The management of natural pine forest is not related to fibre demand from pellets. Rather it is for the production of saw timber and/or a multitude of other landowner objectives. Any conversion of a natural stand to plantation (or vice-versa) is also unrelated to fibre demand from pellets. Furthermore, the counterfactual assumes natural timber harvests are on a rotation of 50 years. FIA data suggestions the harvest age for natural pine is shorter: an average of 41 years. Forests owned by industrial land owners are already managed; non-industrial private landowners, however, cite many reasons for owning forest land, and timber production is one of the reasons for less than 20 percent (Butler et al, 2007)."
- "This answer is a struggle between definitely not and sometimes, absolutes being difficult to defend. However, the answer choices for this question are difficult to defend as they assume the pellet market always has an influence. As stated frequently in this survey, forest owners generally plan for an ultimate sawtimber harvest for highest return. Larger forest owners utilize plantations. Smaller forest owners, who likely own most of the natural stands cite many reasons for owning forest land, and timber production is one of the reasons for less than 20 percent. The odds of all pine being allowed to regenerate naturally are slim to none, given that pine plantations are decades old."

In response to whether or not Scenario 22a is occurring now respondents mainly said sometimes:

- "Econometric studies indicate increasing timber prices will influence conversion and expansion of forest area from agricultural area. Pellet demand would support this to the extent that it raises timber prices[59]."
- "Sometimes – but note that the coniferous forest that was harvested every fifty years was not likely a forest that was well managed or maintained for high carbon storage. The intensively managed forest likely has higher average carbon storage and greater production of all wood products. This would only happen in very odd pockets where all conditions were right."
- "Conversion of naturally regenerated forests to plantations has been happening since the 1940s. The landowner's decision to do this is based on many factors most of them financial to the landowner. The pellet demand has not affected this and won't in the future. Rotation age is determined by sawtimber markets and not pellet demand."
- "Sometimes - While there are conversions of natural timber to plantation timber (and vice-versa), it is difficult to quantitatively assess the percentage of acreage affected because of the specificity of the rotation ages suggested in the scenarios. In addition, not all plantations are intensively managed. Rotation age is currently - and will continue to be - determined by sawtimber markets. Currently, naturally regenerated coniferous forests in the Southeast USA are harvested at an average age of 41 years."

[59] No reference was provided for this but in other parts of the questionnaire we were referred to Professor Abt's work (see reference list in Appendix 5). For example, Galik and Abt (2015) looks at the impact of sustainability guidelines and forest market response in the assessment of EU pellet demand. This concludes: "Regardless of whether sustainability guidelines are applied, we find increased removals, an increase in forest area, and little change in forest inventory. We also find annual gains in forest carbon in most years of the analysis." Specifically this paper compared the impacts of restricting sourcing due to sustainability restrictions and found in this case plantation area increased compared to a situation when the restrictions from sustainability were not applied. They explain the results by saying that the increase in pellet demand leads to "an increase in forest rent, reducing the pressure on conversion of existing forests to some other, lower carbon use (e.g., agriculture)". However, this paper did not examine the additive pressures of timber price increase with increased pellet demand. See chapter 6 for further analysis of this situation.

Table 8-15 Summary of views for scenarios 22-25 from the questionnaire for each question asked

(a) Overall view as assessed on basis of responses to questionnaire.

	Overall view as assessed on basis of responses to questionnaire					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
22a	Sometimes	No consensus	No consensus	No consensus	No consensus	Sometimes
22b	Definitely not/sometimes	No consensus	No consensus	No consensus	No consensus	Sometimes
23a	Definitely not/sometimes	No consensus	Very unlikely/unlikely	No consensus	No consensus	Sometimes
23b	Definitely not/sometimes	Very unlikely/unlikely	Very unlikely/unlikely	No consensus	No consensus	Sometimes
24a	Definitely not	Very unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Sometimes
24b	Definitely not	Very unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Sometimes
25a	Definitely not	Very unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Sometimes
25b	Definitely not	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Sometimes

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
22a	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
22b	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
23a	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation

23b	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
24a	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
24b	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
25a	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation
25b	Shorter rotation yield better return	Increased demand for pellet fibre results In sufficient financial return	Change increases value of land	Shorter rotation does not give better return	Insufficient financial return	Changes in legislation

(b) Data on the total number of responses and the number of 'I don't know' responses.

	Total no. of responses								Of which 'don't knows'						Of which 'don't knows'					
scenario	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Factors that encourage	Factors that prevent	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual
22a	20	20	16	16	16	14	18	19	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
22b	19	20	16	16	16	13	18	19	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
23a	19	19	16	16	16	13	18	19	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
23b	18	19	16	16	16	13	18	18	0	0	0	0	0	0	0%	0%	0%	0%	0%	0%
24a	18	19	16	16	16	13	17	18	3	3	5	5	5	0	17%	16%	31%	31%	31%	0%
24b	18	20	16	16	16	13	17	18	3	3	5	5	5	0	17%	15%	31%	31%	31%	0%
25a	18	20	16	16	16	13	17	18	3	3	2	2	2	0	17%	15%	13%	13%	13%	0%
25b	18	20	16	16	16	13	17	18	3	3	2	2	2	0	17%	15%	13%	13%	13%	0%

In response to whether or not 22b is occurring now we were referred back to comments on Scenario 22 a, but most respondents also said a 20 year rotation is unrealistic for softwood saw timber use and this makes it very unlikely to happen:

- "A 20 year rotation is not realistic for softwood sawtimber use."
- "(This happens if we) include mixed hardwood/softwood (Oak/Pine) forest types in this category"
- "This type of rotation length is likely to be too short for the owner to maximise return on investment. Generally 25 years is optimum even on sites with the highest growth rates."

The extent of conversion was not clear from responses. Most respondents thought that scenarios 22 and 23 (conversion of naturally regenerated forests to intensive plantations) might be happening in localised areas. However, one respondent said that it was happening in 100% of the region: "Pine plantations have expanded steadily, from very little in the 1950s to more than 30 million acres in the late 1990s. Pine plantations now account for about 16 percent of all timberland in the Southeast. As of 2010, 82% of the Coastal Plain forest type – where pellet facilities are concentrated – was comprised of planted pine. The area of plantations is forecast to grow from 32 million acres to 43 million acres. This growth in plantations is most likely to occur at the expense of naturally regenerated pine forests – where declines are projected to be the greatest throughout the US South[60]."

For scenario 23a and b (conversion of hardwood forests to plantations) respondents said that this would be counter to certification conditions and would not be something practiced by large scale forestry. It might happen in upland hardwood areas, but it is difficult to quantify. It would be driven by saw timber market conditions, not pellet demand.

There were comments that this may happen if it includes mixed hardwood/softwood forest types (as above). It was thought that scenario 23 b was less likely to occur:

- "This decision is driven by sawtimber economics, not pellets. Our impression is that most of this type of conversion affects degraded, upland hardwood forest types."
- "Sometimes - The average rotation age for naturally regenerated hardwood forest is 54 years. Any stand with a rotation of 70 years is probably quite degraded, and is less ideal for carbon storage than a 25 year old pine plantation."
- "This would likely happen only rarely and then in situations with a highly degraded hardwood stand which must be clear cut, thus producing the opportunity, assuming soil and other conditions are compatible, to establish a pine plantation. Whether that plantation is then intensively managed with a 25-year rotation is up to the objectives of the particular forest owner."

For scenarios 24 and 25 (conversion of naturally regenerated forests to short rotation coppice, SRC) respondents said that SRC hardwood plantations are not planted in the US Southeast and would not provide sufficient returns to be attractive. In addition they would not meet the sustainability requirements for pellet use in Europe and are unsuitable for coal conversion or co-firing boilers:

- "As a general rule, short-rotation coppice is not planted in the Southeast US."
- "Only would occur if the SRC has much greater economic returns, and then still probably pretty rare. Don't know of it happening at any scale currently. Maybe some test plots at most."
- "There is no market for SRC at present in the wood pellet sector. SRC requires intensive management and therefore more expensive per tonne of fibre produced than conventional pulpwood. In a market where there is a substantial surplus of cheap pulpwood, where is the incentive to produce SRC and who would want to buy this? SRC also has undesirable properties that make it unsuitable for use in converted coal boilers."

In the future respondents saw no reason for change. Conversions for SRC were more likely from agriculture. Many respondents said that pellet demand does not offer sufficient financial return to enable these conversions, even if prices increase by 30%. This is due to the expense of conversion and the better return from saw logs. SRC plantations are not prevalent in the US Southeast and demand from Europe is not likely to result in conversion. Some respondents said that conversion to plantations is

[60] Wear and Greis (2013)

already happening in the US Southeast, but others said that this pre-dates pellet demand and is driven by saw log demand. This range of views is demonstrated in the following comments:

- "This practice is already occurring. Future increases in price will only make it all the more profitable."
- "Pellet demand is very unlikely to trigger the changes in 22a&b and 23a&b. The fibre needed for pellet production comes from the lowest valued component of harvested material. Even a significant increase in fibre prices is insufficient to change the management objectives of most landowners; sawtimber prices have a much greater influence on decision-making. Conversion decisions have been being made for decades, long before the advent of the pellet market. Conversion from natural pine to planted pine is expensive and conversion of hardwood to planted pine is even more expensive. Such decisions will be driven by the price trends for the more valuable portions of the stand, the sawtimber."
- "The counterfactual is not likely. It does not take 35 years to grow sawtimber in the Southeast in a properly managed forest, so harvest age is usually around 25 years. Any change in rotation lengths would be driven by the sawtimber market and sawtimber prices. The pellet industry is a small part of the overall forest industry in the Southeast US, and timber price changes are a result of multiple market dynamics. Even if pellet demand does increase prices, it would never be to the extent that it would cause a change in rotation length."
- "Scenarios 24 and 25: "These scenarios are implausible as SRC hardwood plantations are not prevalent in the US Southeast and are extremely unlikely to occur in the future"
- "Scenarios 22b, 23b: "20 years is likely to be too short a rotation to be able to maximise revenue, volume production and NPV."
- "Scenarios 22 and 23: "Most lands that are suitable for naturally regenerated hardwood forests are not suitable for pine plantations without significant cost (i.e. they are usually low lying bottoms which require bedding or similar land treatments) hence they are left as hardwood forests and grow into hardwood naturally. Existing softwood lands would be more intensively managed or degraded farm lands would be converted before conversion of hardwood forests was economically viable."

Considering what would encourage or prevent the scenarios, comments were that pellets are a minor income stream whose long term future is uncertain, and unlikely to drive changes. Any such changes could most effectively be prevented by reducing or eliminating UK subsidies.

There were also some general comments made in Part 3 of the survey that are relevant here. Asked how current prices need to change to encourage the conversion of naturally regenerated forest to plantation, the majority of respondents said a slight increase (10%) would encourage this. Comments were:

- "The investment to convert naturally regenerated forest to a pine plantation commonly exceeds $300/acre. Current prices for pulpwood do not create a return on investment that is high enough to justify the investment. Saw log pricing is required achieve the needed return."
- "There would be no conversion of naturally regenerated hardwood stands to plantation pine because the crop would not be eligible for Renewable Obligation support."

8.8.2 Summary of comments from the questionnaire on scenarios

Respondents said that the factors that drive the conversion of naturally regenerated forest to plantation relate to financial return, land owner objectives and the alternative land used (e.g. conversion to agriculture or to urban land). One respondent said that there are significant plantation areas in the Southeast USA and these are projected to increase. However, most respondents said that pellet demand would not drive this decision on its own as the return is not sufficient and unless there is a guaranteed stable market for a long period of time that results in large price increases. One respondent said that it was unlikely that naturally regenerated hardwoods would be converted to intensive plantations as the land is unsuitable and expensive to convert.

There was disagreement about how much this happens now. Most comments were it might happen (not driven by pellet demand) but only at a small scale. One comment was that forests are dynamic and that land will go in and out of plantation and naturally regenerated forest, depending on circumstances.

Comments on the establishment of hardwood short rotation coppice (scenarios 24 and 25) were that this is not happening in the US Southeast. The financial return is not sufficient to compete with alternative land uses.

8.9 Scenario 26

Scenario	Description	Counterfactual
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Southeast USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.

A summary of evidence on these scenarios is provided in Table 8-16. Respondents did not think that the counterfactual to this scenario was correct in most cases. They said that use of abandoned agricultural land is unrelated to pellet production and depends on landowner objectives. Abandoned agricultural land is most likely to revert to local vegetation (most likely pine or mixed forest), with only a small area having climatic conditions suitable for moist subtropical deciduous forest:

- “Abandoned agricultural land is coming back into agricultural production (due to increased agricultural commodity prices) or converting to urban. While historically this was true and much land came back into forestry, this trend is projected to decline and/or reverse in the next decade or two, particularly in the US Southeast.”
- "There should be a counterfactual for the natural conversion of abandoned agricultural land to natural pine forest. This forest type is more likely than a hardwood forest."
- “While the above may happen in rare cases if left for a long period, what is more likely is that the land reverts to scrubland for a short amount of time before moving to some other land use (forest, agriculture, development). Scrubland offers little sustainability benefits and the average carbon storage over this time period is not much higher than the agricultural land alone. But this cannot be linked to pellet demand or lack thereof alone.”
- “Sometimes or very rarely. However, subtropical, moist deciduous forest would only apply to a small portion of the Southeast USA. Most agricultural land in the Southeast USA would revert to coniferous forest. This counterfactual will only apply to a small portion of the Southeast USA. Only parts of Florida are currently considered subtropical.”
- “Land conversion is related to landowner objectives, depressed markets for timber products and agricultural markets.”
- “Whether or not agricultural land would be converted to forest depends upon a variety of factors that are hard to know going forward. What if agricultural prices increase? In Georgia, we are seeing some non-industrial landowners converting young pine plantations to blueberries because the blueberry demand is so high now. And 15-20 years ago, many farmers were planting Vidalia onions on their land vs. pine because the onion market was so strong...this has since changed. If all other variables-like saw timber and agricultural prices-were held constant, then the conversion of abandoned agricultural land to forests would be more likely during a recession."

When asked if the conditions in scenario 26 are already occurring, the majority of respondents said definitely not:

- “The planting of SRC hardwood is not an accepted practice in the Southeast US.”
- “Coppicing is generally not practiced in the SE US but there may be few landowner here and there experimenting with it. There are in the Southeast USA small acreages of miscanthus, cottonwood and eucalyptus; however, this is currently being planted for pulpwood production for the pulp and paper industry.”

Table 8-16 Summary of views of responses on Scenario 26 from the questionnaire for each question asked

(a) Overall view as assessed on basis of responses to questionnaire.

	Overall view as assessed on basis of responses to questionnaire					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
26	Definitely not/sometimes	Very unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Definitely not/sometimes

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
26	Increased pellet demand allows sufficient financial return	Changes in forest incentives	Changes in legislation or policy	Insufficient financial return	Other	Other uses increase land value

(b) Data on the total number of responses and the number of 'I don't know' responses.

	Total no. of responses								**Of which 'don't knows'**						**Of which 'don't knows'**					
scenario	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Factors that encourage**	**Factors that prevent**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**	**Current occurrence**	**Future, demand at current levels**	**Future increased demand, same price**	**Future increased demand, price +15%**	**Future increased demand, price +30%**	**Counterfactual**
26	12	10	16	16	16	7	9	12	0	0	1	1	1	0	0%	0%	6%	6%	6%	0%

- "If a landowner was not managing his agricultural land, we would not be likely to invest in a woody biomass crop. It is more likely this land would revert to forest."
- ""Even though saw timber demand is low during the recession and logging residue production is low, pulpwood is available at relatively low prices and those prices have not been sufficient to justify conversion of agricultural land to SRWC. An increase in saw timber production and availability of logging residue may further reduce the likelihood of development of SRC for pellet feedstock supply."
- We have discussed with some market players an interest in establishing short rotation crops on abandoned agricultural land, but the context is always domestic biofuels markets, not export pellet markets. Our interpretation of sustainability criteria that are developing in the EU is that these types of conversions will either not be allowed or are in a grey area. We understand from pellet companies that we do business with that they are not interested in this kind of material."

Respondents could not see this changing in the future even if demand and fibre prices increased:

- "Hardwood plantations are very expensive to establish and manage and there are few of them in the Southeast. It is very unlikely that pellet demand will cause an increase in the negligible southern acreage in hardwood plantation"
- "SRC hardwood plantations are not prevalent in the Southeastern US and are very unlikely to occur in the future"
- "SRC is not a desirable feedstock for wood pellet production, it is generally more expensive than pulpwood and residues and has undesirable chemical properties due to the very rapid growth rates. The very short term life span of wood pellet demand for EU utilities would not justify investment in SRC plantations, especially where there is a substantial surplus of conventional fibre."
- "Farmland would more likely be converted than timberland"

In response to questions on what would encourage or prevent this scenario from happening, respondents said that increased financial return or changes in incentives were required to encourage it, but that this was unlikely to happen. On the contrary, insufficient financial return and other uses that make the land more valuable would prevent it from happening. One comment was that "reduction or elimination of UK subsidies…would ensure insufficient financial return so the practice is not economically feasible."

In Part 3 of the survey, when asked what price would encourage this change, respondents said a price change would not encourage this practice – or only a very large price increase (up to 100%). One comment was that the UK RO was not sufficient incentive because long returns would be needed and the RO finishes in 2027, which is not long enough.

8.9.1 Summary

Respondents said that the conversion of abandoned agricultural land to SRC for pellet production is extremely rare to date in SE USA and is unlikely to happen for economic and practical reasons. In particular returns are unlikely to compete with alternative land uses, and the fibre produced is unsuitable for the technical specifications of industrial wood pellets. A number of respondents said that the counterfactual of reverting to natural moist semi tropical deciduous forest is unrealistic. Natural reversion is unlikely, and if it does occur it will more often be to the prevalent local pine or mixed forest.

8.10 Scenario 30

Scenario	Description	Counterfactual
30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Southeast USA	Forest remains unmanaged
30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged
30c	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Pacific Canada	Forest remains unmanaged
30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged

This scenario concerns bringing unmanaged forest back into management as a result of pellet demand. Unmanaged forest is defined using the FAO definition of forest without a management plan, so it excludes forest under conservation management. The counterfactual is to leave the forest unmanaged.

This scenario was split by region: 30a refers to the Southeastern USA, 30b-d refer to Canadian regions. A high level summary of evidence on scenario 30 is given in Table 8-17. Respondents' self-assessed confidence score for scenario 30a was 2.1, indicating that they had confidence in their answers. However for the Canadian scenarios 30b-d the self-assessed confidence score was 0.8 indicating that the respondents were much less confident. In these scenarios there were a greater number of 'I don't know' responses that contributed to the lack of consensus for the questions listed as no consensus in **Table 8-17**.

8.10.1 Scenario 30a - USA

Survey participants were asked if there is unmanaged forest in their region, why it is unmanaged. While a number of respondents said that they were unaware of any tracts of land that meet the definition of unmanaged forest, others responded along the following lines:

- "Landowner objectives, lack of financial capital and lack of markets."
- "Access is too limited, swamps, wetlands, etc."
- "Reasons vary – lack of market for product; landowner conservation objectives; hunting/recreation objectives; long term financial objectives."
- "Federal forests are largely unmanaged because of bureaucracy and litigation over active management. Many private forests are unmanaged because of owner's ignorance of forest management."
- "The forests in the SE US are comprised of small, private landowners. Many of these forests are family owned. When the forestland passes to the heirs, it is often clearcut and then not replanted due to the financial cost of replanting. Other family forests are often not managed for timber and may be managed for other purposes such as hunting, aesthetics and recreation. Other reasons may be the cost of management is too high, some areas are environmentally sensitive so are left as is and some areas may be too inaccessible to manage."
- "For the purpose of answering this question it is assumed that there is currently no active management and no current plan for future active management. By this definition there are unmanaged forest in each of the regions discussed in this survey. Generally speaking forests are not managed because the owner does not have the resources or motivation to invest in carrying out management. Where the owner chooses no physical intervention but does intend to harvest at some point in the future, then this can be considered a form of management, this could be considered an "under-managed forest" this type of forest could benefit from more activity (e.g. thinning, weed control, pest control, drainage, fertilisation, pruning etc.). Under-managed forests can be quite common in the US Southeast and are a potential source of thinnings and pulpwood, where markets are located within a reasonable transport distance."

Table 8-17 Summary of views from the questionnaire for each question asked on the likelihood of scenario 30

(a) Overall view as assessed on basis of responses to questionnaire.

	Overall view as assessed on basis of responses to questionnaire					
Scenario	**Do practices described in scenario currently occur**	**How likely are these practices in the future if demand stays at current levels**	**How likely are these practices in the future if demand increases but price remains the same**	**How likely are these practices in the future if demand increases and price increases by 15%**	**How likely are these practices in the future if demand increases and price increases by 30%**	**Is the counterfactual an accurate description of what happens in the absence of demand for fibre for pellets?**
30a	Sometimes	Moderately likely/likely	No consensus	No consensus	No consensus	Sometimes/Most of the time
30b	No consensus	Very unlikely/unlikely	Very unlikely	Very unlikely/unlikely	Very unlikely/unlikely	Sometimes/ Yes, always
30c	No consensus	No consensus	very unlikely/unlikely	Very unlikely/unlikely	very unlikely/unlikely	No consensus
30d	Definitely not	Very unlikely/Unlikely	Very unlikely	Very unlikely	Very unlikely/unlikely	Sometimes/Yes, always

Scenario	Top three changes which would encourage the practices described in the scenario to occur?			Top three changes which would prevent the practices described in the scenario occurring?		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
30a	Increased demand for pellet fibre provides sufficient financial return	Changes in forestry incentives	Increased demand for saw timber enables management of unmanaged forest	Insufficient financial return	Other uses make land value more attractive	Other / Low roundwood demand - longer haulage / Changes in legislation or policy
30b	Increased demand for pellet fibre provides sufficient financial return	Changes in forestry incentives	Increased demand for saw timber enables management of unmanaged forest	Insufficient financial return	Changes in legislation or policy	Low roundwood demand - longer haulage
30c	Increased demand for pellet fibre provides sufficient financial return	Increased demand for saw timber enables management of unmanaged forest	Changes in legislation or forest policy	Insufficient financial return	Low roundwood demand - longer haulage	Changes in legislation or policy
30d	Increased demand for pellet fibre provides sufficient financial return	Increased demand for saw timber enables management of unmanaged forest	Changes in forestry incentives	Insufficient financial return	Changes in legislation or policy	Low roundwood demand - longer haulage

(b) Data on the total number of responses and the number of ‘I don’t know’ responses.

	Total no. of responses								Of which 'don't knows'						Of which 'don't knows'					
Scenario	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Factors that encourage	Factors that prevent	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual	Current occurrence	Future, demand at current levels	Future increased demand, same price	Future increased demand, price +15%	Future increased demand, price +30%	Counterfactual
30a	18	17	15	15	15	17	13	18	2	2	0	0	0	1	11%	12%	0%	0%	0%	6%
30b	9	10	6	6	6	14	6	9	4	3	0	0	0	0	44%	30%	0%	0%	0%	0%
30c	4	5	6	6	6	12	2	4	2	3	0	0	0	0	50%	60%	0%	0%	0%	0%
30d	9	10	6	6	7	14	6	9	3	3	0	0	0	0	33%	30%	0%	0%	0%	0%

One thing that is clear from this is that 'unmanaged' forest needs careful definition that can be understood by all stakeholders. The respondents thought that undermanaged forest is more common in Southeastern USA and may be more likely to come back into management. Many respondents also said that most of the forest in the Southeastern USA is on land that was managed at some point. They said that most current forests in the area have regenerated over the past 100 years ("forests go in and out of forest management depending on the owner's management objectives"). The overall view was that the main motivation to bring these forests into management is financial. On public land it might be fire, insect or disease risk; on small private lands changes in management would be down to land owners' objectives.

Respondents said that the counterfactual would happen sometimes or most of the time, so that it is an accurate description at least some of the time. A number of respondents said that all forests in SE USA will come under management change at some time regardless of whether or not there is pellet demand:

- "There are very few acres of forest that will not be harvested at some point in the future, and the demand for pellets will have absolutely no effect on the management of the forest."
- "Pellet market would have little effect, if any, on whether these forests are managed."
- "Many of these forests will remain unchanged regardless of pellet fibre demand."
- ""It may remain unmanaged until it converts to agricultural or development land. Land will always *tend* to revert to its highest and best use in the a free market economy and this is rarely unmanaged forests"
- "All forests change. If the question is whether the forest remains unharvested, the answer would be sometimes. If the question means that the land remains unmanaged, that is most of the time but that is the same answer for when there is a pellet market.

Asked if the practices described in the scenario are happening the majority of respondents said that the practices are already occurring sometimes. However, the qualifications on this were important:

- "Other way around. More land is becoming unmanaged/unmanageable."
- "Land that is not a working forest in the Southeast is likely in a protected status that will likely not change."
- "Landowner objectives, stand improvement and stabilization in the saw log markets will drive this, not pellet demand. Unmanaged forests are sometimes being converted to managed forests. However, to tie this directly to pellet demand is not possible. This decision is more likely tied to landowner objectives for stand improvement and stabilization in the housing and saw timber markets."
- "This will likely happen on the margin but this also leads to a growing number of forest lands staying in forest versus being converted to other land uses."
- "Unmanaged forests are constantly being harvested throughout the Southeast. If by production, the questions means converted to managed stands, a pellet market is unlikely to have that much influence. Unmanaged/managed are personal decisions of the forest owner. Objectives changes as lives evolve or as new owners succeed to the property either by purchase or through inheritance."

If demand for fibre continues the scenario is moderately likely or likely to occur, particularly for *undermanaged* forests. The NGO stakeholder group said it was very likely to occur. At higher demand and high prices there was no consensus. Most respondents said that landowners who are not currently managing their forests are unlikely to begin to manage it or to be aware of prices. Any decision is more likely to be related to saw timber prices. There were a small number of respondents who said that this is already happening due to new demand from pellets and will increase with higher prices.

There was similar disagreement on the amount of land affected by the scenario. Some respondents said more that 70% of land; others that it was difficult to assess. Three respondents quoted figures on the number of family forest owners who have a management plan:

- "The Southeast is dominated by private ownership. Over 5 million private forest owners across the region hold 200 million acres of forest land, 86 percent of the total forest land area. On average, families and individuals own two out of every three acres of this private forest land. 59% of family forest owners own between 1 and 9 acres of forest land. One third of family forest land is owned by people who have never harvested and sold trees from their land. Only 3 percent of the family forest owners have a written management plan and only 13 percent have received forest management advice.[61]"

This shows the difficulty with the FAO definition and the difficulty respondents had in answering questions on the scenario.

The prime factor that would encourage the scenario was demand for pellets resulting in improved financial return, but respondents were uncertain about whether or not this would happen. They were more certain that insufficient financial return would prevent it happening. Other factors preventing it were suggested:

- "Lack of educational and incentive programs to encourage private landowners to manage their land more actively"
- "The pellet market is unlikely to drive any landowner decisions. Landowner objectives are very diverse ranging from timber income to aesthetics."
- "Markets for sawtimber and pulpwood are poor and offer no financial incentive to convert."
- ""Only 20% of landowners cite timber production as a reason to own forest land. There are many other factors considered when deciding to convert to forest land or bring unmanaged forests under management[62]".

8.10.1.1 Summary of results for scenario 30a from Southeastern USA

The definition of 'unmanaged' was felt to be unclear. Most forest land in Southeastern USA has been managed in the past and is likely to be managed again in the future. The timing of management depends on when financial returns are attractive for timber and pulpwood, and on a range of other user objectives for small scale private owners. The counterfactual was thought to happen sometimes, but a number of respondents felt pellet demand would have little or no influence on when a forest is brought back into management.

8.10.2 Scenarios 30b-d: unmanaged forest in Canada

As for the USA, Survey participants were asked if there is unmanaged forest in their region, why it is unmanaged. In Canada the main reasons given were remote access and distance from markets. Asked if the forests had been managed in the past respondents said yes, but not often and for most cases the answer was no. The main motivations to increase management of the forest would be social or financial. For example, it could be to provide "opportunities for First Nation communities".

Asked if the counterfactual was an accurate description of what happens in the absence of pellet demand respondents said yes, but emphasised the dynamic nature of forests and that such forest is likely to be remote. Pellets would likely not offer adequate financial return to convert these forests: "the forests are currently and will continue to change. The status quo is not on the menu of available options."

Asked if the scenarios are already occurring there was no consensus for East Canada and a number of 'I don't know' responses, but more consensus in Pacific and Boreal Canada that it was definitely not happening. Respondents said that they believe that it is the other way round: more land is becoming unmanaged (or unmanageable). Unmanaged forests are not managed for pellet production – other more valuable products would influence this, but the price of hardwood products is insufficient.

When participants were asked if the scenarios would occur in the future and at higher pellet demand and prices the most common responses for all regions were that this was unlikely. Respondents said that the amount of unmanaged forests in the regions was small and they did not expect it to be brought back into management because of pellet production. It is highly unlikely that anything would be put in place to encourage this practice and most likely that insufficient financial return would prevent it.

8.10.2.1 Summary of results for scenario 30a from Canada

Canadian respondents said that forests remain unmanaged because of remote locations and lack of proximity to markets. Pellet demand is unlikely to change this and the scenario was thought not to occur at present and to be unlikely to occur in the future, mainly because of lack of financial incentive.

[61] Wear and Greis 2013

[62] Butler et al 2007

8.11 Additional evidence provided in Part 3 of the survey.

8.11.1 Financial drivers

The survey also included questions on prices and financial drivers. Much of this information is regarded as confidential and respondents were either reluctant to provide it or provided it on a restricted access basis. However, some information was provided from Forest2Markets (Table 8-18) by a number of respondents. Respondents also commented that there is a wide geographical variation in prices, depending on location and quality of wood. Table 8-18 shows the higher value of sawtimber compared to pulpwood; and the high value of hardwood sawtimber. For contrast we have included data from Abt et al (2014) showing the results to analysis of breakeven stumpage prices for pellets in the UK (Table 8-20: note that the assumptions made in this are important, so the data is illustrative only).

Other survey questions provided information prices for fibre at the mill and the prices to UK users. Assuming 50% moisture content and £1=US $1.5 we have provided the summary in Table 8-19. This should be treated as an estimate. It provides an indication of prices to UK pellet users that are in line with those used in DECC recent analysis on the levelised cost of electricity from pellets (DECC 2013). Table 8-20 is shows for comparison.

Table 8-18 Average prices for pellet fibre over the past three years in the US South

Stumpage prices come from Forest2Market's Stumpage Price Database and delivered prices come from Forest2Market's Delivered Price database, which includes scale ticket information on eight million truckloads of delivered timber in the Southeast USA annually. This data is reproduced with permission from Forest2Markets [63]

Southeast USA - naturally regenerated	Answers	$/green ton	
	Range low	Range high	Av
Average range for stumpage price over past three years for naturally regenerated coniferous forest	10.58	33.24	21.93
Average range for pulpwood price over past three years for naturally regenerated coniferous forest	6.65	12.55	9.61
Average range for saw timber price over past three years for naturally regenerated coniferous forest	17.47	38.59	28.05
Average range for stumpage price over past three years for naturally regenerated hardwood	5.28	31.69	18.49
Average range for pulpwood price over past three years for naturally regenerated hard wood forest	5.35	12.91	9.14
Average range for saw timber price over past three years for naturally regenerated hardwood forest	24.33	42.7	33.53
Av price for wood from plantations	**Answers**	**$/green ton**	
	Range low	**Range high**	**Av**
Average range for stumpage price over past three years for intensively managed coniferous plantations	6.21	27.81	17.01
Average range for pulpwood price over past three years from intensively managed coniferous plantations	7.17	14.75	10.96
Average range for saw timber price over past three years from intensively managed coniferous plantations	12.75	34.51	23.63

[63] Note it is not possible to convert this to tonnes or £/GJ as the moisture content of the wood is not known. In the following table (Table 8.19) we have done this, but only by making assumptions that may not necessarily be accurate.

Average range for stumpage price over past three years from intensively managed hardwood plantations	2.29	21.8	12.04
Average range for pulpwood price over past three years from intensively managed hardwood plantations	5.19	12.9	9.03
Average range for saw timber price over past three years from intensively managed hardwood plantations	19.25	37.57	28.43

Table 8-19 Summary of prices for pellet production.

£/GJ	Low	high	Av
Softwood stumpage - natural regeneration	0.74	2.31	1.52
Softwood pulpwood - natural regeneration	0.46	0.87	0.67
Softwood stumpage - plantation	0.43	1.93	1.18
Softwood pulpwood - plantation	0.50	1.02	0.76
Softwood fibre for pellet	2.25	2.51	
Pellet mill price to UK pellet users (CIF)	6.27	8.24	
Hardwood stumpage - natural regeneration	0.16	1.51	0.84
Hardwood pulpwood - natural regeneration	0.37	0.90	0.64
Hardwood stumpage -plantation	0.16	1.51	0.84
Hardwood pulpwood- plantation	0.36	0.90	0.63
Hardwood fibre for pellet	2.11	2.60	
Pellet mill price to UK pellet users (CIF)	6.27	8.24	

Table 8-20 Analysis of break-even stumpage price (green US$/ton pulpwood, where additional profits were allocated to wood procurement proportional to other costs) source: in Abt et al 2014

Abt et al (2014) say: "To illustrate the importance of the Member State subsidies, we calculate a set of break-even prices for stumpage sourced from the U.S. Southeast based on assumptions regarding production, prices, and subsidies that we extracted from the literature and available databases for pellet consumers in the United Kingdom…. Based on the number of ROCs issued for a particular technology in a given year, the cost of coal, the energy content of coal, the energy content of wood pellets, and the value of ROCs both earned for and paid in lieu of complying with the generation requirements, we estimate a break-even price for pellets at which co-generators would be indifferent to using either wood pellets or coal. This assumes no additional costs are encountered in switching between fuels, either direct capital costs or indirect costs attributable to efficiency losses….. Using RISI-reported estimates of pulpwood required (2.24 green short tons/tonne of pellets) and the average proportion of delivered pellet price that is attributable to wood costs (0.354), and assuming that stumpage represents one-third of delivered costs, we calculate an estimated maximum stumpage price an energy producer would be willing to pay. Although there are other methods, we calculate these estimates using a baseline stumpage price (from RISI wood cost data) and then assume that all pellet price increases result in proportionally higher stumpage prices being paid (i.e., for every $1 of increased pellet price, total wood costs increase by $0.354, of which 33 percent is attributable to stumpage costs)." Converted on the basis above the lowest price (S11.21/green ton) is equivalent to approximately £0.24/GJ and the highest price ($18.09/green ton) to £0.39/GJ, which is lower than the prices in Table 8-19.

Type (and size) of power plant facility	2013–14	2014–15	2015–16	2016–17
Co-firing (low-range)	NA	NA	NA	NA
Co-firing (mid-range)	$11.21	$11.50	NA	NA
Co-firing (high-range)	$12.03	$13.98	$13.94	$13.68
Co-firing with CHP (low-range)	$12.85	$13.15	$14.76	$14.50
Co-firing with CHP (mid-range)	$15.33	$15.62	$15.58	$15.33
Co-firing with CHP (high-range)	$16.15	$18.09	$18.06	$17.80

NA indicates that even with the subsidy and penalties, pellets would not be preferred over coal for this size and type of power plant facility. CHP=combined heat and power.

One comment on the impact of pellet demand on prices was:

- "The European subsidies have already greatly increased costs of raw material for some U.S. paper and wood products facilities. For example, assuming that other market factors such as pulp/OSB production and the availability of residual sawmill chips remain unchanged, Forisk Consulting predicts average pine pulpwood stumpage prices across the Southeast could increase by 31 percent from 2014 to 2019 as a result of increased bioenergy demand, with 97 percent of the increase being pellet related. Forisk expects pine pulpwood use at pellet plants in the Southeast to increase from 4.9 million tons in 2014 to 16.9 million tons by 2019 – an increase of 245 percent. The share of pulpwood/chips, both pine and hardwood that will be used to make wood pellets, is expected to reach 10 percent in 2019, up from about 3 percent in 2013 and 4 percent in 2014." *(Note – estimates for pellet demand in Section 4.9 were 16-26M tonne by 2030).*
- An alternative comment was: "The current subsidy provided to pellet users is not high enough to provide a pellet price that would allow pellet manufacturers to outcompete paper. The capacity to pay of pulp and paper mills is significantly higher than the capacity to pay of pellet manufacturers[64]. In some cases, pellets are replacing abandoned markets rather than displacing them."

Table 8-18 and Table 8-19 provide a snapshot of the pellet supply chain draw from the past three years. Predicting how this might develop in the future is not straightforward. Abt et al (2014) summarising research on US timber markets say that "both timber supply and timber demand are relatively inelastic, meaning that small changes in demand or supply can result in sizable changes in wood price".

8.11.2 Costs in the pellet supply chain

The pellet supply chain includes a number of stages and players:

- The price for wood supply for pellets is made up of the costs of stumpage, harvest costs, transport, chipping or other treatment on site and the costs of any sustainability requirements associated with this supply.
- Pellet production costs include factors such as energy, labour costs and transport.
- Pellet users are at the end of the chain and are subject to pressures such as electricity prices in the UK, freight costs and exchange rate changes.

Asked to rank the factors that influence the market price of wood forestry respondents said that all of the options were likely to be important: market dynamics were considered particularly important, as was location. Respondents said many factors influence the pellet market: "in different geographies different factors will be the most influential or variable". Comments from the USA indicated that the housing recession is also influential for two reasons:

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[64] . Pöyry chart (Dovetail report), Iriarte, L. and Fritsche, U. 2014 Impact of Promotion Mechanisms for Advanced and Low- iLUC Biofuels on Markets. IEA Bioenergy, Task 40: Sustainable International Bioenergy Trade. http://www.bioenergytrade.org/downloads/t40-low-ilucpellet-august-2014.pdf

- The housing recession impacts saw timber demand and saw timber is an important driver of harvest. Respondents said pulpwood prices would have to increase by a very large amount (at least twice current levels) for pulpwood or pellet prices to drive harvest – but a number of respondents said that a price change would not result in increased harvest rates or that they thought the kind of price rises required were unlikely to happen.
- Residues from saw mills provide resource for pellets. So if the construction sector recovers there are likely to be more saw mill residues available for pellet production or for other forest products markets.

The Canadian respondents said that harvest rate is defined by AAC, but that the market for forest products also dictates whether the AAC is achieved.

Respondents in the USA said that stumpage was one of the greatest sources of variability, as was transport costs. Canadians were concerned about exchange rates (Table 8-21).

Table 8-21 Factors that influence the price that pellet mills charge

Factors which influence the price pellet mills charge UK pellet users	Response Count
The contract for fibre supply	11
Transport costs	10
other (please specify)	10
Currency exchange rates	9
Supply/demand for pulpwood	7
Sustainability costs	7
answered question	**16**

This shows the complexity of the supply chain and factors that influence prices of pellets to UK users. Understanding the impact of stumpage price increases alone is not sufficient to understand prices pellet producers pay. For example if stumpage prices increase and the other costs in the pellet supply chain remain the same, pellet prices could remain affordable, but if stumpage increases at the same time as labour costs and transport costs the affordability of the same change in stumpage price to pellet producers is very different. Perceived stability of the pellet market and long term contracts for fibre may influence decisions on where wood is sold, but opinion was split on how important this was. Some people thought this might be relevant, but only close to a pellet mill and the price has to be competitive. Respondents commented that forest owners do not generally sign long term contracts and there is no reason to suppose they would for pellets.

When pellet producers and users were asked which factors influence the price of North America pellets their answers also showed wide variation (Table 8-22). Although stumpage and competing demand for pellets also dominates this list there are a number of other influences. When asked about developments in the future this list did not change much: although the cost of regulations was thought to be more important in the future.

Table 8-22 Responses to Q 269: Main factors which influence the price for North American pellets

Main factors which influence the price for North American pellets	Number of respondents choosing this factor
Stumpage	9
Competing demand for pellets	8
Sea freight costs	8
Agreed indexing in long term contracts	8
Transport costs in North America	7
Currency exchange rates	7

Main factors which influence the price for North American pellets	Number of respondents choosing this factor
Competing demand for pellet feedstock by non-bioenergy sector	6
Regulation requirements	5
Comminution costs	2
Other (please specify)	4
Labour costs	3
Transport costs in UK	3
Port handling costs	3
Auditing and analysis costs	2
Insurance costs	2
answered question	**13**

The price of wood for pellets is important: it is a major cost in pellet production. Pellet producers were asked how much the price of softwood in the US Southeast needed to rise to make it too expensive for pellet production. There were few responses to this (10 in USA). Three respondents said a large increase (up to 100%), but the others thought the increase would be much lower. There were four comments that it would be between 10 and 30%. Four of 8 and 5 out of 10 Canadian respondents (in different regions) said an increase of less than 10% in fibre price would make it too expensive for pellet production.

Non-bioenergy users were asked if they were affected by demand for fibre for pellets over the past two years. The most common response (5 out of 9) was “no I am not affected by demand for pulpwood for pellets”. Only 1 respondent said he was affected and the effect had a moderate impact on his fibre supply (affecting more than 10% and less than 40% of the fibre supply). The impact was thought to be more important by more people in relation to saw mill co-products: 3 out of 9 thought there had been a moderate effect on fibre supply, although 4 out of 9 still said they were not affected by this.

Responses to this question included:

For USA

- “Comment from US: “The Forest Service recently released a report entitled, "Effect of Policies on Pellet Production and Forests in the U.S. Southeast " (Abt et al 2014). Findings include - Prices for pulpwood grade softwood in the coastal southeast will more than double by 2020 from where they would have been absent increases in bioenergy-related wood demand. Pellets are estimated to account for 73% of bioenergy-related wood demand in the coastal southeast during the projection period. Hardwood stumpage prices are projected to rise 34% by 2020 relative to where they would have been absent bioenergy demand. Further data from TimberMart South and Forisk clearly shows the upward price trend, of both stumpage and delivered pulpwood prices, vis-à-vis the trend of the Southeast U.S. demand for wood pellets – primarily for export to the UK. Timber Mart South Southeast US Pulpwood Stumpage prices and the relationship to wood consumption for pellet mills in the Southeast US shows a 25% increase in pine pulpwood stumpage prices since 2011 and a 60% increase in hardwood small roundwood stumpage prices. A more recent report from Forisk indicates that, assuming that other market factors such as pulp/OSB production and the availability of residual sawmill chips remain unchanged, average pine small round wood stumpage prices across the Southeast could increase by 31 percent from 2014 to 2019 as a result of increased bioenergy demand, with 97 percent of the increase being pellet related.”
- “The difference between delivered prices for sawtimber and pulpwood is unusually low due to the recent housing recession. Also, the inclusion logging and transportation costs in delivered prices masks the difference in the stumpage value of these products. Landowners make decisions based on stumpage prices. As the housing market recovers the value of saw logs will increase and the volume of sawmill co-products will increase, lowering the price of pulpwood and restoring the traditional price differential between the two products.”
- “None of the wood purchased by our pellet mill is suitable for production at our saw mill.”

For Canada

- "Board manufacturers, cardboard paper plants, dryers, biomass power plants and pellet mills all compete for sawmill co-products in Eastern Canada."

8.11.2.1 Summary

These responses emphasise the complexity of the pellet supply and that a number of factors influence the financial return from pellet supply. It is not easy to calculate a price ceiling for pellet fibre in North America as this depends on a number of factors. From the survey responses a number of important points emerged:

- Fibre price is a major cost in pellet production and this is a function of a number of variables
- Fibre price for pellets is not sufficient alone to drive harvest
- The impacts of a number of variables on pellet prices are location-dependent. So it is not possible to extrapolate from one region to another
- Pellet producers say they cannot afford a 10-30% sustained increase in price without having to reconsider their business model.
- Pellet fibre availability is a function of saw mill residue availability and pulpwood. Pellet production impacts the market of other wood products that rely on these feedstock, but only moderately and for a number of respondents there was no impact.

These findings are also reported in the literature and some of them are supported by the SRTS modelling.

8.11.3 Additional comments received on the questionnaire

There were a number of additional comments on the questionnaire from people who did not participate but sent in comments:

- Some respondents did not like the notion of 'likelihood' in relation to the scenarios, on the basis that nobody has ground for projecting likelihood of scenario outcomes
- The survey was complicated - too complicated for many stakeholders, particularly those who did not have the resources to complete it
- No consideration was given to the use of biomass that could be used for other long-lived products rather than bioenergy.
- The evolution of the paper industry has not been considered in the survey: "With the decline of this industry over the last decades there has been a very large reduction of pulp wood consumption, a reduction of more than the increase of pellet production or its most realistic forecasts." (This respondent also said: data obtained "Statistics Canada and the Quebec Ministry of Natural Resources show a decline of pulp chips from 7.5 Million tonnes (8.4 million tons) per year in 2005 to 5.25 Million tonnes (5.8 million tons) in 2014 whilst pellet production levels have increased from 146,000 metric tonne (161,000 tons)) to 341,000 tonnes (376000 tons), an important growth but far less than the decline in pulp and paper fibre use…. I therefore believe that saying that increasing the production of wood pellets in Canada might reduce carbon stocks is a counterfactual that omits the local market realities and should not be considered as probable in your report. The proper counterfactual for Quebec and most of Canada should be that pellet production increases will be through increased use of sawmill residues, with chips formerly destined to the pulp industry becoming increasingly part of those residues.")
- "Note for Sawmill residues, there are two types - 1) "clean" residues or chips suitable for making paperboard and 2) "dirty" residues or chips (fuelwood) suitable for bioenergy use…. (the forest products industry) uses major quantities of wood for energy. So not only are pellet manufacturers competing with traditional users of pulpwood for making paperboard, pellet mills are also competing with and using "biomass" material that is traditionally used by the pulp and paper industry for energy that greatly improves the energy efficiency of the industry. The forest products industry is a leader in the production of renewable energy. More than 65 percent of the on-site energy needed to produce paper products is derived from carbon-neutral biomass fuel. Carbon-neutral biomass materials include spent pulping liquors, bark, wood, wood scraps, wood by-products, and process residuals."

- "We appreciate your endeavour to elicit input from the US conservation community. There are substantive concerns over the use of woody biomass both from the perspective of carbon accounting and from the perspective of increased pressure to conservation areas of concern to us, both designated Important Bird Areas and other high value forestlands such as bottomland hardwoods. These issues are of concern to us both as climate policy solutions and as landscape management issues."

8.12 High level summary of overall likelihoods

Table 8-23 presents a high level summary of the results showing which scenarios are considered unlikely and which are either potentially likely or where there is no consensus from the responses to the questionnaire. These results show that the scenarios where there is some likelihood or there is a lack of consensus are:

- The **use of forest residues** (scenarios 4a and 5a) (depending on the definition of forest residues and the financial return from pellets); this is considered more likely in the USA than Canada (where there was no consensus), so only the US scenarios were ranked likely. The extent of this scenario depends on location and definition of residues. In Southeast USA the use of forest residues could be significant near pellet mills but not common over the whole of the Southeast. In Canada this practice is also only likely in the vicinity of pellet mills, but it was not thought to be as likely as in the USA and was thought to be likely to be slow and modest in development. Respondents did not think that coarse and fine residues would be separated, but if they were then it was more likely that coarse residues would be used. This is important because the BEAC tool indicates higher carbon impact from coarse than from fine residues. In the questionnaire it was clear that a large number of the stakeholders regarded residues as any part of the forest that has no economic value at the time of harvest. This means that unmerchantable trees, branches and any small wood not used for other purposes are included in this definition and could be used in pellet production. Regulations in both the USA and Canada could restrict the amount of residues removed (although this is less likely in the USA). Removal of residues may be controlled through sustainability certification and Best Management practices (BMPs) in Southeast USA. Both Canadian and US stakeholders thought saw sawmill co-products would increase if timber demand increases and that this would decrease the need for other residue use (although it may also be mirrored with increased use at the mills). This was supported in the literature and in SRTS modelling. A number of literature studies indicated that the use of forest residues is marginally economic, although location with respect to the pellet mill is key.
- **Additional wood from intensively managed coniferous plantations** in Southeast USA (providing the rotation length is not shortened, Scenario 14a) was considered moderately likely/ likely.
- **Additional harvest from the conversion of naturally regenerated forest in Southeast USA to an intensively managed pine plantation harvested** every 25 or 20 years: for these scenarios there was a wide spread of answers in the survey. Scenario 22a in which a naturally regenerated coniferous forest currently harvested at 50 years is converted to a plantation harvested at 25 years was thought to happen sometimes now, although there was no consensus to the questions on the future and the impact of increase pulpwood price, with responses split across the range unlikely to likely. The practice was considered definitely not or 'sometimes' happening currently for scenarios 22b-23b that considered shorted rotations for the pine plantations (22b and 23b) and conversion of a longer lived naturally regenerated hardwood forest (scenarios 23). However 'sometimes' was qualified in the survey comments to mean occasionally or rarely. For these scenarios there was a lack of consensus on the questions regarding future changes resulting from the wide spread of answers.
- **Bringing unmanaged wood into management** (scenario 30a). For the USA this was thought to sometimes occur currently and was moderately likely/likely in the future with no consensus on the impact of higher pulpwood prices. This result was due to the wide spread of responses to the questions on the scenarios. For Canada there was a no consensus rating overall for questions on the current situation and in the future due to the large proportion of 'I don't know' answers to some questions (e.g. in Boreal Canada 2 out 4 respondents said 'I don't know'; and in East Canada 4 out of 9 respondents said 'I don't know').

- There was a range of views on US scenarios where **additional wood is removed from naturally regenerated hardwood**, resulting in changes in rotation (scenarios 13a and b). 12 out of 27 and 9 out of 26 said the scenario was definitely not happening now, and a number of respondents answered sometimes to this scenario, but qualified this by saying sometimes meant rarely or occasionally. One stakeholder group (4 respondents) thought the additional harvest of these woodlands as a result of pellet demand was likely, and there was a lack of consensus in other stakeholder groups. There was a lack of consensus in some Canadian regions to these scenarios at higher prices (scenarios 10b and 12b).
- There was a lack of consensus on current use of **additional wood from plantations** in Pacific Canada and Boreal Canada (scenarios 10P to 12P), resulting from a low level of respondents, with a relatively high level of 'I don't know' answers (e.g. 4 or 5 respondents out of 7 or 8 answered 'I don't know' to the question about the scenario occurring now). These scenarios were considered unlikely in the future.
- For the scenarios considering **displacement of wood used for non-bioenergy**, resulting in the indirect effect of this wood being produced elsewhere (scenarios 19-21) there was a lack of consensus to the question on whether or not these scenarios are happening now, resulting from the large proportion of 'I don't know' returns. For scenarios 19, 20 and 21 6, 7 and 7 out of 15 respondents respectively said 'I don't know'; the majority of the rest said it is definitely not happening.

For some scenarios respondents ranked the scenarios likely but commented that this was because they thought that they may occur sometimes, but which they meant rarely, so the scope is small. Other scenarios are in this category because there are problems with the definition of important terms in the scenario, so there is disagreement about whether or not a scenario is unlikely because different stakeholders have interpreted the scenario differently (e.g. scenario 30 on bringing unmanaged woodland into management in the USA came into this category).

The Analysis Tool and the summary of the comments on the answers to survey questions provide the full data for these assessments and show the breakdown for different stakeholder groups. In this survey the comments from the stakeholders were important. We have presented the full range of comments in Appendices 4 and 5.

The comments made by the stakeholders who completed the questionnaire are important in qualifying these findings. There are many nuances, mainly relating to the scope of the practice, but also related to costs, prices, location, the integration of pellet supply into higher value markets and forest management practices. In Canada the application of forest regulations and calculation of annual allowable cut (AAC) is an important determinant of the likelihood of the scenarios. In the USA financial return and land owner objectives were thought to be important by many stakeholders, but a number of stakeholders (including forest sector stakeholders, pellet producers and users and public sector stakeholders) also stressed compliance with Best Management Practices (BMPs), regulations and sustainability certification was important in large scale supply strategies. Any pellet fibre supply strategy should conform to these requirements.

There were also issues with definitions. Terms such as forest residues mean different things to different stakeholders. This has influenced their views on likelihood. The use of 'average rotation length' to as a parameter to represent rate of harvest has also caused a problem, particularly for naturally regenerated forest (e.g. in Scenarios 13a and b, which examine additional harvest in US naturally regenerated hardwood forests resulting in shorter average rotations). This is because it is difficult to determine the age of forests naturally regenerated so long ago. An alternative parameter to the use of rotation length (e.g. area harvested per year) to represent rate of harvest in these forests is important in these scenarios, as some stakeholder groups consider that these scenarios are happening (i.e. there is additional harvest), if the specification for rotation period is ignored. More detail on this is provided in section 8.4.

A summary of the likelihood of pellet demand driving the high carbon scenarios from BEAC is provided in Table 8-23.

Table 8-23 High level summary of the results of the analysis of the questionnaire responses on the likelihood of pellet demand driving the high carbon scenarios from BEAC: the rows that are presented in grey are those that are consistently considered to be unlikely from the evidence in the survey. The rows in black are those where pellet demand is likely to drive the scenario or there is no consensus.

Scenario number	Description	Counterfactual	Potential Scale
Likely scenarios			
4a	Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest	High[65]
14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Continue harvesting every 25 years *(Note: Likely now but unlikely or no consensus in the future.)*	Reducing the frequency of harvest to every 35 years *(Note: The counterfactual was thought to be wrong by most of the respondents).*	Low[66]
22a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Low[67]
30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Southeast USA *(Note this was regarded as likely now, with no consensus in the future)*	Forest remains unmanaged	Medium[68]
Moderately likely scenarios			
5a	Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest	Low[69]

[65] Depends on the definition of forest residues in Southeastern USA.
[66] Although additional wood is likely to be sourced from intensively manged pine plantations and is likely to be a high source of pellet fibre, respondents told us that the counterfactual was incorrect, so on a strict assessment the use of fibre from this scenario is low.
[67] This is an interpretation that is strictly assessed against the scenario as it stands. Respondents said that it was unlikely that pellet demand would drive this change. However, it is likely that pellet fibre will come from pine plantations, so once converted they could be a medium to high source of pellet fibre.
[68] This depends on the interpretation of unmanaged wood. A number of respondents thought that private woodland could come under this classification and therefore on harvest would become managed. However, it was not so clear that pellet demand is driving this harvest.
[69] Respondents commented that they were less likely to separate coarse and fine residues and to use fine residues

Scenario number	Description	Counterfactual	Potential Scale
No consensus scenarios			
4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest	Low[70]
5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest	Low[71]
6a & 7a	Fine and coarse forest residues, removed from forests in Southeast USA, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest	Low
6b &7b	Fine and coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest	Low
13a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA from every 70 years to every 60 years.	Continue harvesting the forest every 70 years	Not possible to say[1]
13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated hardwood forest in Southeast USA every 70 years.	Reduce the rate of harvest to every 80 years	Not possible to say[72]
10Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 50% (*Note: unlikely in future*)	Leave plantation in previous management	Low[73]

[70] Respondents commented that they thought that residue use was promising, but needs investment and would not be a major part of pellet fibre use.
[71] Some respondents said the use of fine residues would be likely to cause explosions at the pellet mill.
[72] This depends on the interpretation of scenarios 13a and b. It is likely that pellet fibre will come from additional harvest of naturally regenerated hardwood forest, as Enviva are sourcing from these woods, but it is not clear what proportion of overall pellet fibre will come from this source.
[73] This is on the basis that respondents told us that plantations are rare in Canada

Scenario number	Description	Counterfactual	Potential Scale
10Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 20% (*Note: unlikely in future*)	Leave plantation in previous management	Low
11P	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Pacific Canada by decreasing the rotation period up to 20% (*Note: unlikely in future*)	Leave plantation in previous management	Low
12Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 50% (*Note: unlikely in future*)	Leave plantation in previous management	Low
12Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 20%	Leave plantation in previous management	Low
19	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest. (*Note: no consensus to unlikely, influenced by the number of 'I don't know' responses*)	Pulpwood produced in Southeast USA used for non-bioenergy purposes	Low[74]
20	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah. (*Note: no consensus to unlikely, influenced by the number of 'I don't know' responses*)	Pulpwood produced in Southeast USA used for non-bioenergy purposes	Low
21	Pulpwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.	Pulpwood produced in Southeast USA used for non-bioenergy purposes	Low

[74] For this and 20, 21 respondents told us that pulpwood is unlikely to be displaced in this manner.

Scenario number	Description	Counterfactual	Potential Scale
	(*Note: no consensus to unlikely, influenced by the number of 'I don't know' responses*)		
22b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Low
23a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	Low
30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged	Low
30c	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Pacific Canada	Forest remains unmanaged	Low
Unlikely scenarios			
10a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	
10b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 80 years	Continue harvesting the forest every 100 years	
11	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.	Continue harvesting the forest every 70 years	

Scenario number	Description	Counterfactual	Potential Scale
12a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	
12b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years	
13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 50%	Leave plantation in previous management	
13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 20%	Reduced frequency of harvest with low demand for wood	
14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Increased demand for pulpwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest to every 35 years	
23b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	
24a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	
24b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	

Scenario number	Description	Counterfactual	Potential Scale
	hardwood plantation that is coppiced every 3 years Conversion over 50 years		
25a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	
25b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 70 years.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Southeast USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.	
30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged	

9 Discussion of the results from all evidence

This chapter brings all of the evidence on the likelihood of the scenarios together. It provides a high level summary of each scenario comparing the evidence from the literature review, the SRTS modelling (where relevant) and the questionnaire.

9.1 Scenarios 4-7

Scenario	Description	Counterfactual
4a	Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest
4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
5a	Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest
5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
6a & 7a	Fine and coarse forest residues, removed from forests in Southeast USA, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest
6b & 7b	Fine and coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest

Table 9-1 presents a high level summary of the results for scenarios 4-7, together with a summary description of the scenarios. The results to the questionnaire indicate that scenarios were considered to be likely or moderately likely to happen by respondents, although there was no consensus in the questionnaire for a large number of questions on pellet supply in the future and at higher prices. Only the removal of coarse residues in Southeast USA was considered likely across the range of questions currently and in the future. The removal of residues in Pacific Canada and fine residues in Southeast USA was considered moderately likely in the future. The removal of residues for a defined period (scenarios 6 and 7) was generally considered unlikely in both the USA and Canada, but there were questions where there was no consensus (mainly because of the number of 'I don't know' responses).

This evidence is supported in the literature reviews, which show that forest residues are a potentially important resource for pellet fibre, but that investment in extraction technologies and adequate financial return is required for the extraction of forest residues.

We could find no information on scenarios 6 and 7 in the literature review.

Both in the response to the questionnaire and in the literature it was clear that forest residues are a small part of the pellet supply at present in Canada and will continue to be a small part of pellet supply in the future. The situation was not so clear in the USA, because it depended on the definition of forest residues. Currently a large proportion of the supply to Drax from the USA is from forest residues, according to Drax's own information).

The SRTS modelling could not assess these scenarios.

One important issue for this scenario was the definition of forest residues. It was clear that the term 'forest residues' means different things to different stakeholders and that this influenced their views on likelihood. There needs to be some consideration of the different 'fractions' of residues and their carbon impacts.

Respondents also commented on the counterfactuals. In Canada it is common to burn residues at the roadside, as part of fire control. In the USA the treatment of residues is less clear. In both regions a fraction of residues will frequently be required to remain in the forest to meet local regulation or sustainability requirements. Therefore the counterfactual is likely to be a mix rather than one specified option. Proving that one practice rather than another would have happened may prove to be contentious.

Table 9-1 Overall summary of evidence on Scenarios 4-7

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
4a	Use of coarse forest residues in Southeast USA.	Evidence from all sources is that this scenario is likely.	Respondents said the extent of use of coarse forest residues is not clear and is dependent on how respondents define residues, the proximity of the site to pellet mills and the financial return from their removal. The opportunity to remove residues was not thought to be large except near pellet mills. In some locations it may be very unlikely.	Leave all residues in the forest: Questionnaire respondents thought the counterfactual is correct most of the time, but it will vary from location to location and may be difficult to prove.	Some respondents classify all non-merchantable wood as 'residue'. This means that any wood that does not have an immediate market is classed as residues, including diseased or poor growth trees. In some States in Southeast USA Best Management Practices (BMPs) and certification schemes require that a proportion of logging residues be left in the forest. In the future expansion of the use of logging residues will depend on proximity to pellet mill, financial return and regulations or BMPs adopted. The literature provides supporting evidence of use (or potential use) of forest residues, although the cost of extraction and transport is important (see chapter 4). Financial return on the use of residues from forests for pellets is not sufficient to encourage changes in forest practice, so their removal would only happen in circumstances where it can be integrated into the management of forests for other products. Some respondents are concerned that demand for pellets is increasing the use of residues that would otherwise

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
					have been left in the forest in some regions.
4b	Removal of coarse forest residues.	Generally there was no consensus from survey results, although literature indicates it may happen sometimes, i.e. it is possible that it may happen.	All sources indicate removal of residues from forests in Pacific Canada is not extensive at present (less than 10% of forest residues and much less in some Provinces). The extraction of fine and coarse residues separately is not thought to be common in Canada, nor easy to do. Respondents said it is more likely that coarse residues would be extracted if they are extracted separately.	Leave all residues in the forest: Respondents thought that the counterfactual is an accurate representation of what might happen sometimes, depending on location and Provincial regulations (some Provinces have guidelines on forest residues, see the Canadian literature review, Chapter 4).	There is conflicting evidence in response to questions about the extraction of residues for pellets in the future at increased demand and prices. This is likely to be dependent on proximity to pellet mill, financial return and equipment available. There is evidence of marginal return on the use of forest residues for pellets at present in the literature.
5a	Use of fine forest residues in Southeast USA.	Overall evidence is that this is moderately likely to occur but would not be extensive (i.e. it would only happen in a small number of places and/or at a small scale). There was a lack of consensus in respondents to the questionnaire on how this would develop in	Respondents said the extent of use of fine forest residues is not clear and is dependent on how respondents define residues, the proximity of the site to pellet mills and the financial return from their removal. It was thought that fine forest residues were less likely to be used than coarse forest residues, because of the risk of contamination and the difficulty in separating coarse and fine residues. This is important because	Leave all residues in the forest: The counterfactual may be correct, but it will vary from location to location and may be difficult to prove.	The literature does not provide any evidence that coarse and fine residues would be collected separately.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
		the future or at higher prices.	BEAC shows a higher carbon impact from the use of coarse residues. The extent of use and potential issues are as for 4a.		
5b	Removal of fine forest residues.	There was no overall consensus on this scenario in the questionnaire responses – there was a lot of uncertainty, including 'I don't know' responses from the forestry sector. Where a view was expressed it was thought to be unlikely.	Respondents said the extent of use of fine forest residues is not clear and would be dependent on the proximity of the site to pellet mills and the financial return from their removal. One respondent said that fine forest residues will not be used for pellet production as they are an explosion hazard. In Canada Provincial regulations on their removal are also important, although removal is allowed in Pacific Canada (see Chapter 4).	Leave all residues in the forest: The counterfactual is thought to be an accurate description sometimes, but will be dependent on location and Provincial regulations	It was thought that fine forest residues were less likely to be used than coarse forest residues, because of the risk of contamination and the difficulty in separating coarse and fine residues. This is important because BEAC shows a higher carbon impact from the use of coarse residues. The extent of use and potential issues are as for 4b.
6a&7a	Use of forest residues for a set period in Southeast USA.	Moderately likely now, but with a degree of uncertainty. At higher prices in the future there was no consensus.		Leave all residues in the forest: The counterfactual is thought to be accurate most of the time, but will be dependent on location and may be difficult to prove.	No evidence on the scenario in the literature. Responses to the questionnaire demonstrated confusion about this scenario, concerning "why extraction of pellets would be stopped after 15 years" or "how we would know in year 1 that extraction will only go on for 15 years."
6b&7b	Removal of residues for a limited period.	In the questionnaire there was no consensus on whether these scenarios happen	There was no evidence on the scenario in the literature.	Leave all residues in the forest: The counterfactual may be an accurate description some of the time, but will be	Respondents to the questionnaire commented that "the use of forest residues for pellets is low in Canada (less than 10% of coarse and less

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
		now due to a high degree of uncertainty. At higher prices in the future there was no consensus		dependent on location and may be difficult to prove.	than 5% of fine residues)" and "residues can only be removed once, at harvest, which makes the concept of removal over 15 years difficult."

9.2 Scenarios 10-13

Scenario	Description	Counterfactual
10a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 50 years.	Continue harvesting the forest every 100 years
10b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years
11	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.	Continue harvesting the forest every 70 years
12a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years
12b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years
13a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA from every 70 years to every 60 years.	Continue harvesting the forest every 70 years
13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated hardwood forest in Southeast USA every 70 years.	Reduce the rate of harvest to every 80 years

The main view on these scenarios was that although additional harvesting of naturally regenerated forests may occur in response to pellet demand it would not drive significant changes in rotation length. The reason for this is that rotation length is driven by the highest value product. Both the literature and the questionnaire indicated that rotation length is not a straight forward concept for naturally regenerated hardwood forests in Southeast USA. A summary of findings from all of the evidence is provided in Table 9-2.

Table 9-2 Overall summary of evidence on Scenarios 10-13

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
10a	Additional wood from naturally regenerated hardwood, East Canada.	The finding of the questionnaire is that this scenario is very unlikely to occur. Achieving additional harvest by increasing the rate of harvest of a forest (leading to a change of rotation length) is unlikely to be driven by pellet demand.	We could find nothing in the literature that supports this scenario based on the proposed rotation change. However, it is possible that additional wood could be taken at harvest. This wood is classified as forest residue or unmerchantable wood (Roach and Berch 2014), which would otherwise have been felled and left in the forest at harvest in Ontario. It is likely that such wood would only be used in the vicinity of pellet mills and that financial return from its use makes it unlikely to be used at scale. We could find no policy that supports this scenario. The financial return from pellets is unlikely to support the scenario.	Continue harvesting the forest every 100 years: The counterfactual is considered by respondents to the questionnaire to be accurate some of the time, but it is likely to depend on region and local regulations as well as agreed management plans.	Questionnaire respondents said that changing the rotation length by halving it is unlikely in Canada as trees are slow growing and would not be suitable for saw timber, which is the major forest product driver. Respondents said that the annual allowable cut (AAC) set by Provincial Government includes consideration of harvest, but is a complex equation of many other factors as well. Respondents thought that poor financial return would be an important factor in preventing this scenario happening. Respondents said that currently AAC is not exceeded in Canada so it is unlikely that rotation lengths or harvest rate increase would be driven by pellet production; instead additional harvest may happen by extending the AAC harvested.
10b	Additional wood from naturally regenerated hardwood, East Canada but under a different rotation to 10a.	The findings of the questionnaire is that this scenario is very unlikely to occur, although there was no consensus at higher fibre prices.		Continue harvesting the forest every 100 years.	Comments on this scenario are the same as for Scenario 10a (but note the lower decrease in rotation in this scenario).

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
11	Additional wood from naturally regenerated conifer forest in Pacific Canada.	Respondents to the questionnaire said this scenario was unlikely or very unlikely to occur, except at higher prices, where there was no consensus. (There were only 6 respondents to this question).	The literature indicates that current bioenergy in British Columbia uses sawmill co-products and forest residues (Roach and Berch 2014). There was no evidence from the literature that harvest would be extended in response to demand for pellets.	Continue harvesting the forest every 70 years.	Comments on this scenario were similar to scenario 10a.
12a	Additional wood from naturally regenerated conifer forest in Boreal Canada, resulting in short rotation.	Respondents to the questionnaire said this scenario was unlikely or very unlikely to occur, except at higher prices where there was no consensus. For some questions there were only 7 responses.	There is no evidence in the literature to support this scenario. There is no policy that supports this scenario. The financial return from pellets is unlikely to support the scenario.	Continue harvesting the forest every 100 years: The counterfactual is difficult to determine as Provincial Regulation will determine what happens in the absence of pellet demand. Currently AAC is not exceeded in Canada so it is unlikely that rotation lengths or harvest increase would be driven by pellet production. The counterfactual is accurate some of the time, but is more complex than assuming that all the rotation length will decrease. It is likely to depend on region and local regulations as well as agreed management plans.	Achieving additional harvest by increasing the rate of harvest of a forest (leading to a change of rotation length) is unlikely to be driven by pellet demand. Changing the rotation length by halving it is unlikely in Canada as trees are slow growing and would not be suitable for saw timber, which is the major forest product driver. The AAC set by Provincial Government includes consideration of harvest, but is a complex equation of many other factors as well.
12b	Additional wood from naturally regenerated	Respondents to the questionnaire said this scenario was unlikely or		Continue harvesting the forest every 100 years:	Comments as for 12a, but note that the proposed decrease in rotation is shorter in this scenario.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
	conifer forest in Boreal Canada, resulting in a decreased average rotation.	very unlikely to occur, except at higher prices where there was no consensus.			
13a	Additional wood by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA resulting in decreased rotation.	Respondents to the questionnaire said that this scenario was not occurring now but there was no consensus on the future or on increased pellet fibre prices. Respondents did not think that the proposed rotation changes would happen. 12 out of 27 respondents said the scenario was definitely not happening now, and a number of respondents answered sometimes to this scenario, but qualified this by saying sometimes meant rarely or occasionally. One stakeholder group (4 respondents) thought the additional harvest of these woodlands as a result of pellet demand was likely, and there was a lack of consensus in other stakeholder groups. The concept of rotation was thought to be		Continue harvesting the forest every 70 years: The respondents thought that the counterfactual is accurate most of the time, although it is not easy to define rotation length for naturally regenerated forest in Southeast USA.	As noted by the respondents the concept of a rotation age does not apply to most naturally regenerated forests. In SRTS projections, 20 percent of pellet demand was defined to be hardwood. Applying this level of demand across the region led to a very small reduction in average age of the inventory relative to the no pellet demand counterfactual. This is partially due to increased harvest of older hardwood stands where most hardwood harvest occurs. It is also due to the resulting increase in younger hardwood stands so that the average age decreased. This is not directly comparable to the BEAC discrete shift in from one fixed rotation age to another. This does better reflect how hardwood forests are managed in the region. The SRTS results suggests a small change in the age class structure of the hardwood resource.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
		particularly difficult for hardwoods and this was confirmed in the literature review.			
13b	Additional wood by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA compared to longer rotation in counterfactual.	No consensus.	Nine out of 26 respondents said the scenario is definitely not occurring now and five said sometimes. A number of these five said that by sometimes they meant rarely or occasionally. Six respondents said 'I don't know' and four said it is happening most of the time.	Reduce the rate of harvest compared to the harvest in the presence of pellet demand, to every 80 years: The respondents thought that the counterfactual is accurate most of the time, although it is not easy to define rotation length for naturally regenerated forest in Southeast USA for the reasons above.	The concept of rotation was thought to be particularly difficult for hardwoods and this was confirmed in the literature review. The SRTS modelling results and the evidence on scale is as for 13a. The comments relating to tracking in 13a also apply here.

9.3 Scenarios 10P-13P

Scenario	description	Counterfactual
10Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
10Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
11P	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Pacific Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
12Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 50%	Leave plantation in previous management
12Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 20%	Leave plantation in previous management
13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 50%	Leave plantation in previous management
13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 20%	Reduced frequency of harvest with low demand for wood

Most importantly we received comments both from Canada and the USA that hardwood plantations are rare. In Canada respondents said that artificial seeding of forests occurs to ensure that the right species mix is achieved to reach management objectives for licences. In the USA intensive plantations are more common, but generally these are coniferous. A summary of findings from all of the evidence is provided in Table 9-3.

Table 9-3 Overall summary of evidence on Scenarios 10P-13P

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
10Pa	Additional wood from increase in harvest of hardwood plantation in East Canada, resulting in a shorter rotation.	Responses to the questionnaire lacked consensus on the occurrence of this scenario now (5 out of 11 respondents said 'I don't know') but it was thought to be very unlikely in the future or at higher pellet fibre prices.	The respondents and literature both suggest that intensive plantations are not common in Canada.	Leave plantation in previous management: The counterfactual was considered to be accurate most of the time.	Artificial seeding is used to ensure appropriate regeneration of managed forests. This could be considered a type of plantation, but such plantations will be slow growing (taking 60-80 years to mature) and cutting rotation length significantly would impact on the value of the saw timber. For this reason and because pellet demand is not a consideration in the determination of the AAC this scenario is unlikely. Financial return from pellets will not drive this scenario; regulation would prevent it.
10Pb, 11P, 12Pa and 12Pb	Additional wood from increase in harvest of hardwood plantation in regions in Canada resulting in shorter rotations.	Respondents to the questionnaire provided no consensus on the occurrence of these scenarios now (4 out of 8, 5 out of 10 and 4 out of 9 respondents who answered 'I don't know') but it was thought to be very unlikely in the future or at higher pellet fibre prices.		Leave plantation in previous management.	See 10Pa for comments.

9.4 Scenario 14

Scenario	Description	Counterfactual
14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Continue harvesting every 25 years	Reducing the frequency of harvest to every 35 years
14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Increased demand for pulpwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest to every 35 years

The overall summary of evidence on this scenario is presented in Table 9-4. The counterfactual was not thought to be correct by the respondents to the survey, but they did think that additional wood would be harvested from plantations in response to pellet demand at current rotations. This additional wood could come from thinnings or from pulpwood at harvest. Carbon modelling of the impact of this thinning would be useful.

Table 9-4 Overall summary of evidence on Scenario 14

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
14a	Additional wood from intensively-managed pine plantation, in Southeast USA, harvesting at 25 years.	The overall assessment was that it is unlikely in the future at current prices and only becomes likely at higher pulpwood prices.	The majority of respondents to the questionnaire felt that the practices were occurring now (so the counterfactual is not accurate). Survey respondents thought that scale was minimal at present. Evidence from the literature indicates that pellet production is only financially viable when there are incentives for bioenergy.	Reducing the frequency of harvest compared to the harvest in the presence of pellet demand, to every 35 years: The counterfactual was not thought to be accurate as rotation length is already around 25 years and it is unusual to have a 35 year rotation for intensively managed softwood plantations in the Southeastern USA.	There is good evidence from the literature review, SRTS modelling and survey that pellet demand will affect harvest from intensively managed softwood plantations in Southeastern USA but it is not likely to drive a change in rotation length. In other words there will be additional harvest due to pellet demand (often envisaged to be increased thinning or additional small roundwood being diverted to pellets), but final rotation for intensively managed plantations will not change, except in response to the saw timber market (see Chapter 4). Optimal rotations are set by a combination of the saw timber market and owner objectives. Financial return from pellets is unlikely to change this. Scale is not easy to determine as local conditions will influence harvest patterns. In regions where there is demand for sawtimber, small roundwood and pellets harvest patterns may be affected by the total

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
					market demand, but this is not likely to be a common situation.
14b	Additional wood from intensively-managed pine plantation, in Southeast USA, reducing rotation to 20 years.	Responses to the survey indicate that this is not occurring now and is unlikely in the future (becoming less unlikely at higher pulpwood prices).	Scale is not easy to determine as local conditions will influence harvest patterns, but it was thought to be minimal by most survey respondents. Evidence from the literature indicates that pellet production is only financially viable due to incentives.	Reducing the frequency of harvest compared to the harvest in the presence of pellet demand, to every 35 years: The counterfactual was not thought to be accurate as rotation length is around 25 years and it is unusual to have a 35 year rotation for intensively managed softwood plantations in the Southeastern USA.	There is good evidence from the literature review, SRTS modelling and survey that pellet demand will affect harvest from intensively managed softwood plantations in Southeastern USA but it is not likely to drive a change in rotation length. In other words there will be additional harvest due to pellet demand (often envisaged to be increased thinning or additional small roundwood being diverted to pellets by forestry stakeholders), but final rotation for intensively managed plantations will not change, except in response to the saw timber market (see Chapter 4). Rotation length is unlikely to be reduced to 20 years as a result of pellet demand. Optimal rotations are set by the saw timber market and owner objectives. Financial return from pellets is unlikely to change this.

9.5 Scenarios 19-21

Scenario	Description	Counterfactual
19	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in Southeast USA used for non-bioenergy purposes
20	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah.	Pulpwood produced in Southeast USA used for non-bioenergy purposes
21	Pulpwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.	Pulpwood produced in Southeast USA used for non-bioenergy purposes

Both the literature and the respondents to the questionnaire show that it is difficult to find direct evidence of displacement outside of the USA. Oliver (2013) says that conditions in Amazonia are not conducive to the commercial production of timber for the international market. Transport distances are very long and infrastructure is poor. The literature review indicated that displacement of non-bioenergy uses outside of the USA are not likely to occur. Aggregate demand for timber in the US is comprised of timber demand for sawtimber, composite, veneer, and pulp in addition to pellet and non-pellet bioenergy uses (Abt et al. 2014, Oswalt et al. 2014). The bioenergy components of this market (both pellet and non-pellet) are a very small portion of the total aggregate timber market, and demand for some traditional timber products has been softening due to waning demand for paper products and slowdowns in the housing market (Abt et al. 2014, Woodall et al. 2012). Projections do indicate that announced pellet production capacity would account for more than 20% of the 2011 non-sawtimber harvest by 2020. However (Abt et al. 2014), suggest that increased pellet production will be a more noticeable component of the overall timber harvest going forward. But pellet demand will not be likely to change the dynamics of sawtimber production unless the price of pellet feedstock causes pellet facilities to compete with traditional sawtimber uses. As a result, increased demand for pellets is not likely, in the short term, to cause increased harvest for non-bioenergy products to occur outside the USA. However, SRTS modelling has shown that spill over or leakage can occur into neighbouring regions (Abt et al 2014). This shows that there can be external effects within the USA, but that the complexity of proving these in other countries is beyond this work. The results are summarised in Table 9-5.

Table 9-5 Overall summary of evidence on Scenarios 19-21

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying comments
19	Small roundwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Responses to the questionnaire indicated a high level of uncertainty that this is occurring now (6 out of 15 responses were 'I don't know') but consensus was that it is very unlikely in the future.	There is no evidence that this is happening in the literature.	Pulpwood produced in Southeast USA used for non-bioenergy purposes: The counterfactual is an accurate description most of the time.	Respondents thought financial incentives from pellet demand are not sufficient to drive this change.
20	Small roundwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land.	Responses to the questionnaire indicated a high level of uncertainty that this is occurring now (7 out of 15 responses were 'I don't know') but consensus was that it is very unlikely in the future.	No evidence that this is happening from the literature.	Pulpwood produced in Southeast USA used for non-bioenergy purposes: The counterfactual is an accurate description most of the time.	Respondents thought financial incentives from pellet demand are not sufficient to drive this change and said Brazilian paper and pulp production predates pellet demand in Southeastern USA.
21	Small roundwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada.	Responses to the questionnaire indicated a high level of uncertainty that this is occurring now (7 out of 15 responses were 'I don't know') but there was an overall consensus was that it is very unlikely in the future (with a significant proportion of 'I don't know' responses).	There is no evidence that this is happening from the literature.	Pulpwood produced in Southeast USA used for non-bioenergy purposes: The counterfactual was felt to be an accurate representation most of the time.	Respondents thought that financial incentives from pellet demand are not sufficient to drive this change and that pellets cannot out compete non-bioenergy products. A number of questionnaire respondents said there was no connection between paper and pulp production in Pacific Canada and Southeastern USA.

9.6 Scenarios 22-25

Scenario	Description	Counterfactual
22a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 25 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
22b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
23a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
23b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
24a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
24b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years Conversion over 50 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
25a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally

Table 9-6 presents a high level summary of the results for scenarios 22-25, together with a summary description of the scenarios. This group of scenarios examine the potential change from naturally regenerated forest to intensively managed plantations (22 and 23) or to short rotation coppice (or other energy crop) (scenarios 24 and 25). There was more consensus on the latter: short rotation coppice (or other energy crops) are not currently grown at any scale in Southeastern USA and it was thought that this would not be likely in the future. There was no evidence to the contrary in the literature: most information on energy crops dealt with potential changes and indicated that the economics would not drive their planting for bioenergy without financial support.

For scenarios 22 and 23 there was less consensus. This was mainly the result of a split in opinion on the amount of conversion of naturally regenerated forest to intensive plantations and the driver for this conversion. Whilst most of the respondents thought that this did not happen very often and would not be driven by pellet demand, a small number (4 out of 19 respondents) commented that it was a common occurrence. The literature review indicated that the change is possible, but it would not be driven solely by pellet demand as the economics are not sufficiently attractive (e.g. see Pöyry 2014). The only scenario that was considered to be likely, at least sometimes, by the respondents to the questionnaire was 22a, in which naturally regenerated coniferous forest is converted to softwood plantation with a 25 year rotation. However, there was no consensus on this in the future and at higher prices for fibre. Most respondents still thought that sawtimber demand is the dominant driver for conversion to plantations, but there was no clear view on the extent of the influence of pellet demand in combination with sawtimber.

SRTS modelling results showed that the situation is related to changes in demand for all pulpwood. The modelling is based on empirical (historical) trends in which saw timber demand was higher than pulpwood demand (prices were 5 times than of pulpwood). However, the current situation is different to the historical situation as the sawtimber to pulpwood price is about half (2.5) of historical ratios. Even in these circumstances the results show that pine sawtimber remains the primary driver. However, in the SRTS runs where there is high pellet demand and low housing demand the analysis shows increasing pulpwood prices (doubling again) and no recovery of sawtimber prices. Under these circumstances SRTS modelling showed that historical trends continue (i.e. that sawtimber demand still drives conversion). However, it also showed that under these circumstances it is possible for pellets to have an impact. In the model runs undertaken for this study the response was kept within the region and no ‘leakage’ to neighbouring regions allowed. Bob Abt acknowledges that this leads to a higher than expected pellet impact on prices. These runs show that under these circumstances (i.e. with this set of assumptions) the impact of pellet demand on conversion to plantations could be more important that he would expect based on historical data. Even so a doubling of pulpwood prices is not currently sufficient to justify the cost of timberland conversion. In addition it is important to consider the timescale of market incentives for pellets in Europe. Conversion to plantation would need to yield additional return before 2027 for UK incentives to have an impact.

The scale of this impact from pellet demand requires further investigation, but our conclusion from the majority of responses to the questionnaire and the SRTS modelling is that it is not high and would occur in a situation where sawtimber demand does not recover.

Our overall conclusion is that conversion of naturally regenerated forest to intensively managed plantation may happen sometimes, but that most of this conversion would be influenced by sawtimber prices. However, pellet demand may be an additional driver sometimes, particularly at continued increased pulpwood prices relative to sawtimber prices. The extent of the influence of pellet demand is not clear from the modelling or the literature, but the economics of pellet production imply that it would be localised to the pellet mills as the cost of transport is likely to impact regions further from the pellet mills. We also conclude that the conversion of land to energy crops and short rotation coppice in particular is not likely in the near future and would not be driven by pellet demand.

Table 9-6 Overall summary of evidence on Scenarios 22-25

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
22a	Additional wood from the conversion of naturally regenerated coniferous forest in Southeast USA (harvested every 50 years) to intensive pine plantation (harvested every 25 years).	The overall evidence is that this is likely to happen sometimes at present, but there was no consensus in the future or on the impact of higher demand and prices.	Respondents said that the extent of conversion of naturally regenerated coniferous forest to intensive coniferous plantation is determined by local saw timber, small roundwood demand, agricultural commodity markets and owner objectives, rather than solely pellet demand. One respondent said that the cost of conversion is considerable and pellet fibre prices do not offer sufficient return. There was also a comment that most of the lands suitable for conversion have already been converted.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally: The counterfactual is an accurate description sometimes. Forest inventory (FIA) data was quoted by respondents to the questionnaire as evidence that rotation lengths average 41 years, shorter than that suggested in the counterfactual.	The rotation length will be determined by saw timber demand, not pellet demand. Financial return from pellet production is unlikely to change this now or in the future. SRTS modelling shows that under certain circumstances (small roundwood) prices could have an impact on conversion of naturally regenerated forests to plantations. The difference between housing demand scenarios had a bigger impact on conversion than pellet demand. But, the scenarios where housing demand remained low and pellet demand was high increased the influence of pellet demand on management intensity. For this to happen the price of small roundwood has to be relatively high compared to saw timber. This is a situation that has not been seen historically but current price differences between pine small and large roundwood are at historical lows. Continued low large roundwood demand and high small roundwood demand would delay return to historical price relationships. However, discounted cash flow analysis results in the modelling section indicate that even if small

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
					roundwood prices double they would not be sufficient to justify the current cost of timberland conversion. The questionnaire responses indicated that a doubling of small roundwood prices would impact pellet producers business plans, so this is an unlikely but not impossible situation.
22b	Scenario as for 22a, but with shorter rotation plantation.	The responses to the questionnaire were definitely not or sometimes occurring now, but respondents commented that by 'sometimes' they mean rarely or occasionally, so the overall rank could be regarded as 'rarely'.	The extent of conversion of naturally regenerated coniferous forest to intensive coniferous plantation is determined by local saw timber, small roundwood demand, agricultural commodity markets and owner objectives, rather than solely pellet demand.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally: The counterfactual is an accurate description sometimes. Forest inventory (FIA) data provides evidence that rotation lengths average 41 years, shorter than that suggested in the counterfactual. This would mean that the carbon implications are not as high as suggested in Stephenson and Mackay (2014).	There was no consensus on the future or higher prices. The rotation length will be determined by saw timber demand, but a 20 year rotation is unlikely. Financial return from pellet production is unlikely to change this now or in the future. SRTS modelling results are as for scenario 22a. However, there was no evidence from the modelling on the shorter rotation length.
23a	Additional wood from the conversion of naturally regenerated hardwood forest in Southeast USA to	The responses to the questionnaire were definitely not or sometimes occurring now, but respondents commented that by	Respondents said that the extent of conversion of naturally regenerated hardwood forest to intensive plantation is determined by local saw timber, agricultural commodity markets and	Continue harvesting the forest every 70 years, and leaving to regenerate naturally: The counterfactual is an accurate description sometimes, although the	SRTS modelling results are for scenario 22a. However, the majority of land conversion to pine plantations comes from natural and mixed pine-hardwood forests due to site conditions.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
	intensive pine plantation.	'sometimes' they mean rarely or occasionally, so the overall ranking could be regarded as 'rarely'. There was no consensus in the future, with stakeholder groups split in opinion between unlikely or very unlikely and very likely.	owner objectives, rather than pellet demand.	concept of 'rotation' does not apply to naturally regenerated hardwood forests. Evidence in the literature is that conversion to plantation would be driven by sawtimber demand, not pellet demand (see Chapter 4).	
23b	As for 23a, but with shorter rotation plantation.	The responses to the questionnaire were definitely not or sometimes occurring now (14 out of 16 responses). Respondents commented that by sometimes they meant rarely or occasionally, so the ranking could be regarded as 'rarely'. The questionnaire indicated that the scenario is unlikely or very unlikely in the future, but there was less consensus at higher fibre prices.	The extent of conversion of naturally regenerated hardwood forest to intensive plantation is determined by local saw timber, agricultural commodity markets and owner objectives, rather than pellet demand. A rotation length of 20 years is unlikely.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally: The counterfactual is an accurate description sometimes, although the concept of 'rotation' does not apply to naturally regenerated hardwood forests. Evidence in the literature is that conversion to plantation would be driven by sawtimber demand, not pellet demand.	SRTS modelling results are for scenario 22a. However, the majority of land conversion to pine plantations comes from natural and mixed pine-hardwood forests due to site conditions.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
24a	Conversion of naturally regenerated coniferous forest to short rotation coppice (SRC).	The responses to the questionnaire were definitely not occurring now and unlikely in the future. Financial return from pellets unlikely to drive this change.	There is little short rotation coppice (SRC) in Southeastern USA and evidence from the survey and literature indicates that it is unlikely that this will change.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally: The majority view in the survey was that the counterfactual is an accurate description sometimes, although for naturally regenerated pine FIA data indicates rotation length is on average 41 years.	SRTS does not model SRC.
24b	As for 24a, but with gradual conversion over 50 years.	The responses to the questionnaire were definitely not occurring now and very unlikely or unlikely in the future. Financial return from pellets are unlikely to drive this change.	There is little short rotation coppice (SRC) in Southeastern USA and evidence from the survey and literature indicates that it is unlikely that this will change.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally: The majority view in the survey was that the counterfactual is an accurate description sometimes, although for naturally regenerated pine FIA data indicates rotation length is on average 41 years.	SRTS does not model SRC.
25a	Conversion of naturally regenerated hardwood forest to short rotation coppice (SRC).	The responses to the questionnaire were definitely not occurring now and very unlikely/unlikely in the future. Financial return from pellets unlikely to drive this change.	There is little SRC in Southeastern USA and evidence from the survey and literature indicates that it is unlikely that this will change.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally: The majority view in the survey was that the counterfactual is an accurate description sometimes.	SRTS does not model SRC.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
25b	As for 25a, but with gradual conversion over 70 years.	The responses to the questionnaire were definitely not occurring now and very unlikely/unlikely in the future. Financial return from pellets unlikely to drive this change.	There is little short rotation coppice (SRC) in Southeastern USA and evidence from the survey and literature indicates that it is unlikely that this will change.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally: The majority view in the survey was that the counterfactual is an accurate description sometimes.	SRTS does not model SRC.

9.7 Scenario 26

Scenario	Description	Counterfactual
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Southeast USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.

The scenario results are summarised in Table 9-7.

Table 9-7 Overall summary of evidence on Scenario 26

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
26	Conversion of abandoned agricultural land to SRC.	Respondents to the questionnaire said that this scenario is either definitely not occurring or sometimes occurring now. They qualified this by saying that 'sometimes' means rarely or occasionally, so the overall rank could be regarded as 'rarely'. Respondents thought it is very unlikely in the future The main reason for the opinion that this is unlikely in the future is that the financial return on pellets is sufficient to drive this change and would not compete with the return on planted pine for saw timber. The literature does not provide any evidence to contradict this.	Low	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest: The counterfactual was not considered accurate in most locations in Southeastern USA.	Conversion of agricultural land is not modelled in SRTS.

9.8 Scenario 30a-d

Scenario	Description	Counterfactual
30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Southeast USA	Forest remains unmanaged
30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged
30c	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Pacific Canada	Forest remains unmanaged
30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged

This scenario concerns bring unmanaged forest into management. Unmanaged forest was considered to be forest without a management plan. The results to the questionnaire indicated different situations in the USA and Canada. This is because of the difference in forest ownership and motives on the part of the owners. This was supported by the evidence in the literature. In the USA a large proportion of timberland in Southeastern USA is owned as small parcels of land by family owners. These families have a variety of reasons for owning their land, many of which are unrelated to harvest value. Only 4% of these small scale owners have a management plan (Butler 2007), so strictly speaking a large quantity of potential timberland in Southeastern USA is unmanaged according to the definition used. However, given the right circumstances this land could come under management (harvest), often driven by personal motives. The need to maximise return means that saw timber demand will drive this interest. However, the use of residues or unmerchantable wood may by in response to pellet demand, although there is insufficient information in the literature to confirm this. It seems that examination of the use of unmanaged forest for pellets needs to be defined on a regional basis with appropriate modelling for the regional system most vulnerable to being brought back into management.

In the Canadian State owned situation the evidence is that it is unlikely that unmanaged forest will be brought back into ownership. We did not find evidence in the literature that demonstrated that this scenario is or would occur. On the contrary the evidence is that the land is too remote or difficult to access for harvest to be a viable option. This evidence is summarised in Table 9-8.

Table 9-8 Overall summary of evidence on Scenario 30

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
30a	Bringing unmanaged forest into management.	Responses to the questionnaire indicated this scenario is sometimes occurring now but there was no consensus on the future (views were widespread).	The responses to the questionnaire and the literature indicate that there are two types of forest that may be affected by this scenario: a) forests that are legally protected from harvest, via conservation easements or wetland or wilderness designation or similar, and b) forests that are owned by family forestland owners because they like owning forestland (for aesthetic or other purposes). Neither category is being harvested now, but category a) are legally protected and will not be harvested under any circumstances, while category b) are the forests that might come into production if the price increases enough (or if ownership changes) (see Chapter 4).	Forest remains unmanaged: The counterfactual is thought to be an accurate description sometimes, but there were difficulties in agreeing with it because management will depend on forest owner objectives, which would determine what happens in the absence of pellet demand. There was little information on bringing private small scale forest back into management in the literature but surveys of small scale owners confirm the results to the questionnaire (in fact a number of respondents quoted these surveys).	The lack of consensus in the questionnaire reflected a lack of consensus on the meaning of the term unmanaged forest. This was defined as “forest that has no management plan”. From the responses to the questionnaire there is a possibility that sawtimber demand would drive harvest (management) of these forests but there is no evidence that pellet demand would. There was no evidence from SRTS modelling on this scenario.
30b and 30c	Bringing unmanaged forest into management in East and Pacific Canada.	Responses to the questionnaire indicated no consensus now and that this scenario is very unlikely in the future.	The literature indicates that these scenarios are definitely not occurring now. It is unlikely that unmanaged forest would	Forest remains unmanaged: The counterfactual is considered by respondents to be an accurate	The no consensus view is influenced by the small number of responses and the high proportion of 'I don't know' responses to the questionnaire.

Scenario	Description	Likelihood	Extent	Counterfactual	Qualifying Comments
			be brought back into production as a result of pellet demand because AAC is not achieved in many regions in Canada (see Chapter 5). It is more likely that this would be exploited before management of unmanaged forests is considered.	description sometimes; the majority of unmanaged forest is remote and with little infrastructure in Canada.	
30d	Bringing unmanaged forest into management in Boreal Canada.	Responses to the questionnaire indicated that this scenario definitely does not occur now and is very unlikely in the future.	The literature indicates that this scenario is definitely not occurring now (see Chapter 5).	Forest remains unmanaged: The counterfactual is an accurate description sometimes; the majority of unmanaged forest is remote and with little infrastructure in Canada.	It is unlikely that unmanaged forest would be brought back into production as a result of pellet demand because the AAC is not achieved in many regions in Canada. It is more likely that this would be exploited before management of unmanaged forests is considered.

10 Discussion and conclusions

This section discusses the evidence on the likelihood of scenarios similar to the high carbon scenarios identified in Stephenson and Mackay (2014) collected from the survey, the literature and the modelling conducted in this study. It examines factors that might influence the interpretation of the evidence, draws conclusions on the results and provides key messages on the application of the BEAC model and on potential supply strategies.

10.1 Discussion of methodology and its impact on interpretation of evidence

The evidence provided needs to be qualified by the following:

- Literature: Few of the scenarios are envisaged in the literature. However, the literature does cover policy, economic conditions and potential forest management responses that may encourage or prevent the scenarios. The conclusions we have drawn from the literature are therefore necessarily indirect and rely on our interpretation. The literature review was limited by the scope of the work. In market driven economies (i.e. in Southeast USA in this study) a further in-depth review of the economics of pellet production would provide useful insight. In the more highly regulated Canadian forestry sector a comprehensive review of management plans could provide more insight into potential management responses to increased pellet demand.
- Stakeholders: There are a relatively small number of stakeholders who are qualified or experienced enough to comment on the scenarios. These do not make up sufficient numbers to allow statistical analysis. Instead we have relied on qualitative assessment of their views of the scenarios in the questionnaire (for our methodology see Chapter 7). Having completed this study of all of the high carbon intensity scenarios in Stephenson and Mackay (2014) further exposure of its results on the likely pellet supply strategies was undertaken in a webinar in Canada, which supported the strategies identified. A similar webinar in the Southeast USA is recommended.
- Interpretation of results in the questionnaire: In interpreting the results to the questionnaire we have attempted to avoid bias caused by different numbers of respondents in each type of stakeholder group. Although we attempted to achieve a good response rate from stakeholders in each group, it is not possible for us to know what coverage we have in terms of percentage of the whole population of each group. For some stakeholder groups there were a limited number of respondents with knowledge of the sector. Therefore rather than using a most common view from all of the individual responses, we assessed the results in a way that presents the views of each stakeholder group on an equal basis. The reason we felt that all stakeholder groups should receive equal weighting is that each group brings a different kind of experience and knowledge to the sector, all of which are important in understanding the likelihood of the scenarios. We did not want any of those views to be lost amongst the survey responses simply because there were not many forest managers operating in a particular region, for example. Chapter 7 discusses this methodology in more detail.
- Impact of interpretation of scenarios on the results: In some cases the scenarios as described in Stephenson and Mackay (2014) are open to interpretation and nuances are important. We provided limited options for scoring the likelihood. Respondents pointed this out and qualified the scores they provided with comments, which are an important part of the evidence. For example, when asking if the scenarios are currently occurring we provided the responses definitely not, sometimes, yes always, most of the time and I don’t know. Respondents criticised the lack of a response such as ‘rarely’. Often they selected ‘sometimes’ but qualified this by saying that the scenario may occur occasionally or rarely so ‘definitely not’ was not the correct response, but neither was ‘sometimes’.
- Respondents’ interpretation of BEAC scenarios: The BEAC scenarios examined in this study were limited to those that showed high carbon impacts. The aim of this project was to identify if any of these high carbon scenarios (or similar types of scenarios) might happen in reality. This was difficult for some stakeholders to assess, because some of the practices described in

the scenarios did not make economic or technical sense to them and they had difficulty understanding what the scenario meant or they felt some other action was far more likely. In places this has influenced their responses to the questionnaire. In these cases we have taken the approach of reporting their comments to demonstrate the difficulty in interpreting the scenarios.

- Terminology: BEAC estimates forest carbon adjustments of discrete paired scenarios primarily as changes in rates of harvest (modelled using rotation lengths) and differences in forest growth rates of different forest types in fully regulated forests. Some stakeholders found this concept difficult. Some participants thought that additional harvesting may happen as a response to pellet demand but it is not likely to change rotation lengths because these are determined by higher value (saw-timber or paper and pulp) markets. Many respondents believed that pellet demand will not change this. In the case of naturally regenerated forests it is not easy to determine the rotation period and, in the USA, these forests are not managed on a constant rotation basis. This meant that the forestry sector respondents tended to focus on the rotation lengths mentioned in scenarios concerning naturally regenerated forests, rather than whether or not additional harvest is happening. Other stakeholder groups concentrated on additional harvest rates. The important issue of additional harvest was therefore difficult to assess using the questionnaire results.
- SRTS modelling: The SRTS modelling used in the Southeast US is partial equilibrium modelling, i.e. supply responses are modelled by introducing changes (in this case pellet demand) and allowing the modelled system to reach a new equilibrium. There are a number of limitations to the SRTS modelling as used in this study.
    - Equilibrium modelling is expensive and interpretation is time consuming, so we were only able to do a limited number of runs
    - The model was developed to show how inventory may change (and forest types and age distributions), not to model scenarios such as those provided in BEAC
    - Indirect impacts are not considered in the model
    - The region of study was fixed as the region influenced by pellet mills, which means that neither local impacts nor US South-wide impacts (such as leakage) were modelled.
    - There were limitations in the input data: demand was based on best available data, but there has been no comprehensive study on pellet demand that we could draw on; some of the variables, such as price elasticity, were estimated because there is insufficient empirical data to draw on; and the region of study will affect the results (too small and it will be influenced by proximity to the pellet mills, too large and the impact of pellets will be diluted).
    - The pellet industry response to higher prices is unknown. If the industry is more price responsive to increased wood costs or has a low choke price, then the price peaks projected in this study will not occur.

  Chapter 6 discusses the importance of the context of resource and consumption, the development of the SRTS model over the past decade and the current historically unique situation in saw timber demand. In undertaking this study we were able to draw on the considerable experience of the US team to associate the SRTS model results to the scenarios and in accessing their experience of past analysis using this model.
- Sensitivity of outcomes and risks to key factors related to forestry and wood use: We were unable to conduct sensitivity analysis in this work. However, there are important variations that may impact GHG outcomes, such as age class and forest type distribution in the forest inventory. These will critically influence the GHG impacts. We were unable to cover these in this study but further analysis into understanding and managing the sensitivity of outcomes (in terms of GHG emissions) to critical factors related to forest characteristics, management and wood use would be useful.

10.2 Discussion of results

10.2.1 High level results

The evidence gathered in this study indicates that **15** out of 40 of the high carbon scenarios identified in BEAC (and the additional scenarios examined) are **not occurring and are not likely to occur** in the future, even with high pellet demand or higher fibre prices. For these scenarios there was good agreement between the respondents that they are unlikely now or in the, although some respondents did answer ‘I don’t know’. There was no evidence from the literature that these scenarios occurred.

There was **no consensus** for a further **20** out of the 40 scenarios, as a result of a wide spread of answers or because there were a relatively high number of ‘I don’t know’ responses.

Two out of the 40 scenarios were considered **likely now and in the future**; **three** of the scenarios were considered **likely or moderately likely now but with less consensus for the future** or at higher fibre prices. These five scenarios are:

- Scenario 4a and 5a: The removal of coarse and fine residues (respectively) in Southeast USA. Scenario 4a was thought to be more likely than 5a
- Scenario 14a: Additional wood from intensively managed coniferous plantations in Southeast USA (but not on a shortened rotation)
- Scenario 22a: Additional harvest from the conversion of naturally regenerated forest in Southeast USA to an intensively managed pine plantation harvested every 25 years
- Scenario 30a: Bringing unmanaged wood into management – this is not the use of designated forests, but the harvest of family owned small scale woodland that is not subject to a management plan.

Further details and caveats for all of the likelihood ratings are provided in section 8.12.

Four of these five are high carbon scenarios. The exception is scenario 22a, which has a negative GHG intensity over a 40 year period. This was included in the study as one half of a pair of scenarios, the other being 22b, which has a positive GHG intensity over 200 kg CO2e/MWh and where the harvest rotation is only 20 years, compared to 25 years for 22a. Scenario 22b was considered by respondents to be unrealistic for softwood raw timber use.

Of these five, four were considered to be likely to contribute only at a low scale to pellet supply. Scenario 4a was the only scenario considered to contribute a potentially high supply of pellet fibre. All supply is likely to be local to pellet plants, depending on transport costs. This is confirmed in SRTS modelling. Leakage or spill over into other areas may happen as a result of local displacement of other uses of this fibre, although most pellet plant owners told us that they chose to develop their plants areas where other pulpwood demand is low or decreasing.

Many of the counterfactuals were considered to be accurate at least sometimes and often most of the time or always in the responses to the questionnaire. Some counterfactuals were thought not to be occurring because the rotation length is not representative (it is too long). For some potential pellet supply strategies there are a number of counterfactuals, each of which have a different carbon impact (a number of which are modelled in the low carbon impact scenarios in BEAC). In these cases proving what the real counterfactual is may be difficult.

Other pellet fibre supply strategies were suggested and nuances on the scenarios are important. These are discussed below.

There was often a significant difference between the responses from the USA and Canada to the questionnaire because of the major differences in the way that the forestry sector in Canada is regulated compared to the market-orientated forestry sector in the Southeast USA. The slower tree growth in Canada compared to Southeast USA also probably accounts for differences in responses. This demonstrates that it is not possible to extrapolate conclusions on pellet supply strategies and responses to demand from one region to another and that the context for market and regulatory environment are important. Results are discussed separately for the two countries because of this.

A key factor that affects the likelihood of the scenarios is the regulation of forest in **Canada,** including the setting of the Annual Allowable Cut (AAC). This is discussed in Chapter 5. Essential elements are that calculations are based on financial return of high value products, conservation requirements (as set by local regulations), carbon stock and the socio-economics. Pellet demand is low compared to other forest products in Canada and it is unlikely to change AAC. The AAC sets a limit on harvest that has not been achieved for some years. Additionally current forest inventory in Canada is due to planting and regeneration of forests some time ago; pellet demand was not considered in this regeneration and it has not driven current trends.

In the **Southeast USA** financial return is important in motivating harvest and is highest from saw timber. Evidence is presented in Chapters 4 and 8 that saw timber return is significantly higher than pellet financial return. Consequently pellet demand is unlikely to be the sole driver of rotations or harvest: it is likely to be integrated into other supply chains (e.g. through increased planting resulting in increased thinning). Pellet demand may influence management decisions in Southeast USA, but it will not be the main driver of harvest timing.

SRTS modelling results showed that the impact of pellet demand is dependent also on whether or not the construction market recovers. The impact of high and low pine saw timber projections was greater than the impact of high and low pellet demand. This market context is important. The current US market situation is unique historically. It has resulted in a situation in which the ratio of sawtimber: pulpwood prices is at an historical low (2.5:1 compared to a more typical 6:1). If pulpwood demand continues to increase but sawtimber demand does not improve then the SRTS modelling (as it was undertaken on this study[75]) shows that the impact of demand for small roundwood could become more important than would be expected based on history, particularly in the vicinity of pellet mills. The caveat is that under 'normal' circumstances (i.e. normal as experienced historically) changes in price of a low value product (such as pellets) would not drive a harvest decision. It will always, however, be a contributing factor. As discussed in Chapter 6, the larger than normal impact of pulpwood prices does not make pellet demand the "driver" of harvest, but it is likely to be a more important as a contributor than would normally be expected.

The SRTS modelling showed that there was a likelihood that naturally regenerated forest land would be converted to pine plantation and it supported the finding that the response to high pellet demand is not likely to change rotation age. We have interpreted this as support for scenario 22a.

The SRTS modelling also provided a perspective on the overall regional carbon impact of pellet demand. The forest carbon results showed that pellet demand has a small negative or positive impact depending on the strength of the pine sawtimber market.

In both regions pellet markets are small compared to other forests products markets. In Canada most fibre for pellets comes from saw mill co-products and only a small amount of pellet fibre supply (<5%) comes from roundwood or other forest wood. In the USA the proportion from forests is larger, but saw mill co-products remain significant. Drax (2015) reported 80% of their pellet fibre came from forest residues, thinnings and storm salvage in 2014 and that around 16% came from saw mill co-products and sawdust. However, if saw timber demand recovers the availability of saw timber residues will increase and an increased proportion may be used for pellet fibre. For the Drax (2015) figures the definition of residues is important; this finding was supported in our questionnaire and influenced responses to Scenario 4a.

The current forest inventory in Southeast USA is a result of historic trends: it takes time to grow trees (even fast growing plantations) and these forests were planted before pellet demand rose to current levels. Inventories are higher now that they have been for some time, which is due in part to increased planting to meet forest product demand (US EPA 2013, Smith et al 2010)[76]. The development of intensive plantations in the Southeast USA means that this region is dominant in the forest products market. These plantations were developed to supply the pulp and paper and fibre board sectors, as well as saw timber and these markets are still the major driver for their planting. Currently, forest inventory data in the Southeast US indicates that growth exceeds removals for all forest types and regions. The increase in forest inventory has happened simultaneously with the abandonment of agricultural land as returns from agriculture decreased. However, land owners are likely to consider long term financial return when replanting after harvest and as agricultural commodity prices or urbanisation pressures increase these may become viable alternatives. There is some evidence from

[75] That is without a leakage response, by which demand shifts to regions outside the modelled area. This resulted in high predicted pulpwood prices.

[76] There are many reasons for the size of the current inventory: (i) The existence of publically owned natural forests that produce little timber and therefore have large Growth:Drain ratios (Smith et al., 2010). The area of reserved forest doubled between 1953 and 1997 (USDA, 2001). (ii) Tree planting and conservation efforts in the 1970s and 1980s (US Environmental Protection Agency, 2013); (iii) The movement of agricultural land from the East to the Mid-West since the 1950s, resulting in marginal agricultural land in the East reverting to forests (Smith et al., 2010; Fernholz et al., 2013; USDA, 2012). Overall, the total US forest land area increased by 4% between 1987 and 2007 (Smith et al., 2010). (iv) The age distribution of US forests. Significant areas of forest had not yet reached their equilibrium carbon storage in 2010, and were therefore continuing to grow. However, the new forests which have been established on the previous agricultural land in the East are now approaching maturity, therefore growth is slowing down (USDA, 2012); (v) Increased wood recycling and increasingly efficient wood processing techniques, reducing the wastage of wood. US saw-mills have reduced the amount of wood incinerated as a waste from 41 - 45% in 1940 to less than 1% in 2005 (Fernholz et al., 2013); (vi) Increased productivities, and hence wood outputs from intensively-managed plantations, reducing pressure on other forests (Fernholz et al., 2013; US Environmental Protection Agency, 2013); (vii) Decreased harvest during the recession (Ince and Prekash, 2012); (viii) A diverse wood industry resulting in it being economically competitive for private land owners to grow trees (Fernholz et al., 2013).

the questionnaire and the literature that in the Southeast USA a more robust market for forest-related commodities (including pellets) will increase the value of the land from forestry and reduce the likelihood that private land will be sold and converted to another land use. The literature (Butler et al 2007, 2008) also provides evidence that landowner objectives are diverse and include aesthetics, inheritance and conservation, making generalisations about management of forest in the Southeast USA difficult.

Inventory data for the Southeast USA indicates that pine removals currently occur predominately in the 20-30 year age class, while hardwood removals are predominately in 50+ year old lowland hardwoods.

This study found that there are concerns by some stakeholders that conservation impacts have not been fully considered in Southeast USA. In particular bottomland hardwood forests are ecologically important. Further work is needed to understand impacts in wetland habitats and habitats that are important to biodiversity (such as Important Bird and Biodiversity Areas discussed in Chapter 4).

There is no evidence from this study that pellet demand alone drives the harvest of these forests: but it may result in increased harvest rates in combination with other forest product demand (the evidence from the questionnaire and literature is not clear on this). The evidence from both the stakeholder questionnaire and the literature is that pellet demand does not decrease rotation in comparison to the counterfactual by 10 years or greater in the way that Stephenson and Mackay (2014) models. If it impacts rotation smaller changes in average rotation are more likely. Further work is needed to understand the extent of these impacts.

10.2.2 High level summary of the results on likelihood for each scenario

10.2.2.1 Canadian scenarios

Scenarios 4b, 5b, 6b, 7b,

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario – evidence from questionnaire	Potential scale of use	Literature evidence
4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest	No consensus	Low[77]	May occur sometimes
5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest	Likely	Low	No evidence to support this
6b & 7b	Fine and coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest	No consensus	Low/none	No evidence to support this

Where respondents to the questionnaire thought scenarios 4b and 5b to be occurring or to be likely in the future it was at a small scale and localised to the pellet mill, because of the small margin associated with the use of forest residues for pellets. Both the questionnaire and literature said this was related to the need for investment in equipment and transport costs. There is an important finding in BEAC that extraction and use of fine forest residues has less carbon impact than coarse residues. However, most Canadian respondents thought it highly unlikely that residues would be extracted separately and provided evidence that fine residues are not suitable for pellet production (explosion hazard). There is evidence in the literature evidence that extraction of forest residues must comply with Provincial regulations and some Provinces do not allow removal of forest residues, although in Pacific Canada it was thought that residues are a promising source of fibre for pellets. All likelihood is related to location as the marginal return means that the supply would have to be close to a pellet mill. There was no evidence that scenarios 6 and 7 would happen or that it would be easy to know in year one that the residues would only be removed for 15 years. Respondents agree that the counterfactual is an accurate representation of what might happen sometimes, depending on location and Provincial regulations.

[77] For 4b and 5b: This will depend on proximity to mill, the need for investment in harvesting equipment and the financial return from pellets

Scenarios 10-12

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potential scale of use	Literature evidence
10a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	Unlikely		No evidence to support these
10b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years	Unlikely		
11	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.	Continue harvesting the forest every 70 years	Unlikely		
12a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 50 years	Continue harvesting the forest every 100 years	Unlikely		
12b	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in boreal Interior-West Canada from every 100 years to every 80 years.	Continue harvesting the forest every 100 years	Unlikely		

There is difficulty in determining average rotation for naturally regenerated forest in Canada, which influences responses to these scenarios. Forests in Canada are slow growing, taking up to 100 years to mature, as indicated in the counterfactuals. So cutting rotation dramatically from 100 to 50 years would mean that the trees would not be mature enough for saw timber, whilst cutting rotation from 100 to 80 years was also considered unlikely. The forestry sector could not envisage large changes in rotation length but also did not suggest smaller changes either. As saw timber financial return is an important driver in the calculation of the Annual Allowable Cut (AAC) this means that these kinds of BEAC scenarios are unlikely or very unlikely to occur. There was no evidence from the literature to support the scenario. It may be feasible that additional harvest may occur, in that more unmerchantable wood may be extracted from the forest. However, it is difficult to understand whether or not this wood would have been left standing in the absence of pellet demand. It is likely that this will be dependent on licence conditions and regulations.

The counterfactual was also difficult to agree, as Provincial Regulation determines what happens in the absence of pellet demand. Currently AAC is not exceeded in Canada, so it is unlikely that rotation lengths or harvest increase would be driven by pellet production. The counterfactual is thought to be accurate some of the time, but respondents told us that it is more complex than assuming that all the rotation length will decrease. It is likely to depend on region and local regulations, as well as agreed management plans.

Scenarios 10P – 12P

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potentia l scale of use	Literature evidence
10Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 50%	Leave plantation in previous management	Unlikely		No evidence to support these
10Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in East Canada by decreasing the rotation period up to 20%	Leave plantation in previous management	Unlikely		
11P	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Pacific Canada by decreasing the rotation period up to 20%	Leave plantation in previous management	Unlikely		
12Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 50%	Leave plantation in previous management	Unlikely		
12Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a conifer plantation in Boreal Canada by decreasing the rotation period up to 20%	Leave plantation in previous management	No consensus		

Forests in Canada can be artificially seeded to ensure that the right species mix is encouraged and to fill in gaps in naturally regenerated forest. Such artificial plantations would be slow growing and decreasing the rotation would not yield economically viable saw timber. However, most questionnaire respondents thought that intensive plantations were not common in Canada and the scenarios were unlikely. Financial return from pellets would not be sufficient to encourage this scenario and it is likely that regulation would prevent it. We could find no evidence on the use of plantations for pellet fibre in Canada in the literature.

Scenarios 30b-d

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potentia l scale of use	Literature evidence
30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged	No consensus		
30c	Additional wood (in comparison to the counterfactual) from the	Forest remains unmanaged	No consensus		

	conversion of unmanaged forest into production in Pacific Canada					
30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged	Unlikely			

The questionnaire respondents showed a lack of consensus on Scenarios 30b-c. The most common views were very unlikely or unlikely because unmanaged forest in Canada is remote with a lack of infrastructure and it would be difficult to find a financially attractive market. There were also a number of 'I don't know' responses. Scenario 30d was thought to be unlikely for similar reasons. There was no evidence in the literature that Canada is considering bringing unmanaged forest into management, as the AAC is not currently met.

10.2.2.2 US scenarios

Scenarios 4a, 5a, 6a and 7a

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario	Potential scale of use	Literature evidence	SRTS Modelling
4a	Coarse forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest	Likely	High[78]	Likely	
5a	Fine forest residues, removed from forests in Southeast USA, continuously over the time horizon.	Leave all residues in the forest	Moderately likely. No consensus for some questions	Low[79]	No evidence	
6a & 7a	Fine and coarse forest residues, removed from forests in Southeast USA, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest	No consensus	Low	No evidence to support this	

Respondents said that scenarios 4-5 are occurring at least sometimes and likely to occur in the future, albeit at a localised or small scale. There is an important finding from the US survey comments that the definition of forest residues varies (see Box 10-1). If we are to understand the carbon implications of this scenario then the definition of forest residues must be understood and reflected in modelling. The literatures shows that some States, Best Management Practices (BMPs) and certification schemes require that a proportion of logging residues be left in forest. In the future expansion of this use will depend on proximity to pellet mills, financial return and regulations or BMPs adopted. This is supported in the literature (Aguilar 2014, Gruchy et al 2011, Joshi and Mehmood 2011, Hoefnagels et al. 2014). Fine forest residues are more likely to be left in the forest because of contaminants and debris associated with them. In the USA NGOs are concerned that once there is a market for bioenergy, everything will be called a "thinning residue" and will thus be considered a residue and counted as having zero emissions.

There was no consensus on Scenarios 6 and 7, by the respondents to the questionnaire because of the number of 'I don't know' responses - although the overwhelming view (when expressed) was that they were unlikely. The survey exposed confusion about this scenario and why extraction of pellets would be stopped after 15 years or how we would know in year 1 that extraction will only go on for 15 years. There was no evidence that these scenarios would occur in the literature.

[78] Extent depends on the definition of forest residues in Southeastern USA
[79] Respondents commented that they were less likely to separate coarse and fine residues and to use fine residues

Box 10-1 The need for clarity on the definition of residues.

BEAC distinguishes residues based on size (greater or less than 10 cm), and says that the larger residues have a greater GHG impact because of their size. However, there is another distinction that is also meaningful with respect to GHG emissions: whether or not the tree would have been left standing but for the bioenergy harvest. This is difficult to define, because a pre-commercial thinning might be associated with sawtimber harvest (so the trees would not have been left standing, since harvesting them is a by-product of timber stand improvement), but if the market for bioenergy is robust, then these pre-commercial thinnings will eventually be valuable on their own. If they become the prime motivator for the harvest, then they should not be called "residues." Different residues are likely to have different carbon impacts, so need to be categorised further, not just by size.

Scenario 13

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potential scale of use	Literature evidence	SRTS Modelling
13a	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in Southeast USA from every 70 years to every 60 years.	Continue harvesting the forest every 70 years	No consensus	Not possible to say[80]	Some evidence to support this	Some evidence to support this, but only small changes in rotation (1-2 years)
13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting of a naturally-regenerated hardwood forest in Southeast USA every 70 years.	Reduce the rate of harvest to every 80 years	No consensus			

In the USA rate of harvest and rotation periods are set by the financial return and this is determined predominantly by the highest value product (saw timber): so pellet demand is not the main driver in determining this. Many of the respondents said these scenarios were not happening because the rotation periods would not change so significantly as a result of pellet demand. However, there was some evidence that additional harvest is occurring in some hardwood forests on a regional basis in the vicinity of pellet mills.

Some stakeholders are particularly concerned about bottomland hardwoods. Our study uncovered this concern in relation to these scenarios, but not how pellet demand is impacting the harvest of these woodlands. In the literature the study by Evans et al (2013) highlights both potential impacts and benefits from pellet demand; and it discusses the key values and vulnerabilities of these landscapes. Tracking the use of roundwood from their harvest might provide clarification of the impact of pellet

[80] This depends on the interpretation of scenarios 13a and b. It is likely that pellet fibre will come from additional harvest of naturally regenerated hardwood forest, as Enviva are sourcing from these woods, but it is not clear what proportion of overall pellet fibre will come from this source

demand. However in itself this would not be enough to understand the impact of pellet demand. There is a general need to understand a number of things about the whole forestry system, such as owner motivation to harvest, the factors that put pressure on land use and those that help to maintain the forest and the role that pellet demand has in driving any of these. We suspect that pellet demand will be one of a number of pressures: and it may have positive as well as negative impacts. From our literature survey, bottomland hardwoods may not be replanted after harvest, but it is not clear what prevents reforestation and we suspect that a multiplicity of factors are important here as well, not least the economic value of alternative uses of the land or the cost of reforestation. Further work is required to clarify additional harvest strategies to understand how they should be modelled to clarify carbon impacts.

The SRTS modelling sheds some light on this as it indicates that there is a local impact with slight overall reductions in the regional average age of natural forests when pellet demand is present. To shift rotation length would require that price differences between high and low value markets are permanently and significantly shifted. This means that changes in the high-value market will be more important to this outcome than changes in the low-value markets (i.e. saw timber would need to decrease in value and pulpwood increase relatively). There are further complicating factors. Lowland hardwoods in Southeast USA are some of the highest value forests in the USA. This means that their value is high compared to the price that can be paid for pellet fibre, so this would suggest that pellet demand alone would not drive changes in the harvest timing in hardwood forests (although it may influence the management of the forest). The literature shows that these forests were used for paper and pulp that has now withdrawn from the area. Pellet producers moved in to take advantage of the regions where non-bioenergy producers moved out. It is not clear whether or not pellet demand has therefore caused additional harvest, (although if the treatment of these forests in the absence of pellet demand is no harvest, then it would have resulted in additional harvest compared to this counterfactual, but it is difficult to assign the lack of harvest to lack of pellet demand alone as we have said above: the financial return from pellets is not sufficient in itself to drive this harvest).

There is no consensus on this in the questionnaire responses: some respondents say that if pellet demand were not there then the counterfactual would be another use of the pulpwood; others that the counterfactual is no harvest. We have concluded that this scenario requires more investigation and more evidence on the impact of pellet demand on hardwood harvest, particularly that the harvest of these forests for pellet fibre is economically plausible and over what region the impact would be experienced. However, it is also important to note that this is a relatively minor part of the pellet fibre in Southeast USA and it is unlikely that pellet demand alone causes the impacts that result in the concerns expressed.

Scenarios 13Pa and 13Pb

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potenti al scale of use	Literature evidence	SRTS Modelling
13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the rotation period up to 50%	Leave plantation in previous management	Unlikely		No evidence to support this.	No evidence to support this.
13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in Southeast USA by decreasing the	Reduced frequency of harvest with low demand for wood	Unlikely			

	rotation period up to 20%					

Hardwood plantations are rare in Southeast USA and financial return from pellets would not be sufficient to change this.

Scenario 14a and b

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potenti al scale of use	Literature evidence	SRTS Modelling
14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Continue harvesting every 25 years	Reducing the frequency of harvest to every 35 years	Likely now and unlikely or no consensus in the future. The counterfactual was thought to be wrong by most of the respondents	Low[81]	Some evidence providing financial incentives are sufficient	Likely
14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in Southeast USA. Increased demand for pulpwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest to every 35 years	Unlikely			

Scenario 14a was considered to be occurring now, but unlikely in the future at current prices and only becoming likely as prices increase. Questionnaire respondents thought that the counterfactual was not accurate as rotation length is already around 25 years and it is unusual to have a 35 year rotation for intensively managed softwood plantations in the Southeast USA. Strictly speaking this makes the scenario unlikely, as it is modelled. However, there is evidence that additional wood will be sourced from intensively managed pine plantations and we have included the 'likely' rating from the respondents to reflect this.

There was evidence from the literature review that additional wood will come from pine plantations (e.g. Abt et al 2014). SRTS modelling also shows that pellet demand will affect harvest from intensively managed softwood plantations in Southeast USA, but it is not likely to drive a change in rotation length. This is because optimal rotations are set by owner objectives and it is more likely that sawtimber returns will drive changes in rotation. Evidence from the literature indicates that pellet production is only financially viable due to incentives for renewable energy, but that the return from pellets is much lower than that of saw timber. In regions where there is demand for sawtimber, pulpwood and pellets harvest patterns may be affected by the total market demand, but this is not likely to be a common situation.

Scenario 14b was thought to be unlikely as a 20 year rotation does not produce saw timber at optimal value.

Scenarios 19-21

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario -	Potential scale of use	Literature evidence	SRTS Modelling

[81] Although additional wood is likely to be sourced from intensively manged pine plantations and is likely to be a high source of pellet fibre, respondents told us that the counterfactual was incorrect, so on a strict assessment the use of fibre from this scenario is low.

			evidence from questionnaire			
19	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in Southeast USA used for non-bioenergy purposes	No consensus to unlikely, influenced by the number of 'I don't know' responses	Difficult to prove	No evidence to support this.	No evidence to support this
20	Pulpwood from Southeast USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah.	Pulpwood produced in Southeast USA used for non-bioenergy purposes				
21	Pulpwood from Southeast USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.	Pulpwood produced in Southeast USA used for non-bioenergy purposes				

Scenarios 19-21 (displacing bioenergy markets elsewhere) were considered unlikely by questionnaire respondents, mainly because the markets in the different regions were not thought to be linked and because the trends toward hardwood plantations in Brazil pre-date pellet demand by more than a decade. Most of the respondents did not answer the questions on these scenarios or answered 'I don't know'. The causes of shifts in bioenergy markets are complex and beyond this study, but there are indications in the literature that they were occurring before pellet production and are related to a number of local and international factors (see discussion in Chapter 9).

Scenarios 22-25

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potential scale of use	Literature evidence	SRTS Modelling
22a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Likely	Low[82]	Evidence that this can happen, but driver for conversion is saw timber. Pellets will add margin and may be part of	Likely, given the right financial environment

[82] This is an interpretation that is strictly assessed against the scenario as it stands. Respondents said that it was unlikely that pellet demand would drive this change. However, it is likely that pellet fibre will come from pine plantations, so once converted they could be a medium to high source of pellet fibre.

	harvested every 25 years				the driving force for change	
22b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	No consensus	Low		Likely – (support for conversion to plantation, not for rotation period)
23a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	No consensus	Low	Not likely because the local conditions are not right	No evidence
23b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	Unlikely			No evidence
24a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Unlikely			SRC not in model

24b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in Southeast USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years Conversion over 50 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally	Unlikely			
25a	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	Unlikely			
25b	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in Southeast USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes 70 years.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally	Unlikely			

The responses to the questionnaire indicated that pellet demand may drive Scenario 22a now and in the future: although there was less consensus on future development. Respondents said that the extent of conversion of naturally regenerated coniferous forest to intensive coniferous plantation is determined by local saw timber, pulpwood, agricultural commodity markets and owner objectives, rather than pellet demand alone. The rotation length will be determined by saw timber demand. Financial return from pellet production is unlikely to change this now or in the future. Questionnaire respondents thought that the counterfactual is an accurate description sometimes. FIA data was quoted as evidence that rotation lengths average 41 years, shorter than that suggested in the counterfactual. In other words this was another scenario where there was disagreement on the counterfactual which may have influenced responses.

Conversion of naturally occurring softwood forest to pine plantation was thought to be one strategy for pellet fibre supply in the literature, although the extent of this is not clear. SRTS modelling also supported this (see Chapter 6).

The other scenarios in this group (22b-25) are generally thought to be unlikely. Respondents to the questionnaire did not think that SRC would be planted for pellet demand in Southeast USA because conversion would cost too much and financial return would be insufficient. There was no evidence in the literature to counter this. There is some dissent on scenario 23, if a hardwood forest is cleared, once the timber is harvested it is possible that the highest value use of the land would be in planted pine. However, there is no literature evidence that this is happening.

Scenario 26

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potential scale of use	Literature evidence	SRTS Modelling
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Southeast USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.	Very unlikely		Unlikely	Not modelled

Scenario 26 was also thought to be unlikely because of the lack of SRC planting in Southeast USA and the cost of establishment. Respondents thought that a number of alternative scenarios on abandoned agricultural land were more feasible, such as the planting of alternative higher value agricultural commodities or urbanisation.

Scenario 30a

Scenario	Description	Counterfactual	Consensus on pellet demand driving scenario - evidence from questionnaire	Potential scale of use	Literature evidence	SRTS Modelling
30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Southeast USA	Forest remains unmanaged	Likely now and no consensus in future	Medium[83]	Likely on the basis of a wide definition of unmanaged forest (i.e. to include 'under-managed forest')	Not modelled

The view of the questionnaire respondents on Scenario 30a depended on their interpretation of the definition of unmanaged land. The questionnaire defined unmanaged forest as that which has no management plan, using the UN Food and Agriculture Organisation definition. In Southeast USA this is not straightforward as many family - owned forests do not have management plans. Whether or not these would constitute unmanaged forests was not clear: they are likely to have been managed at some time in the last 100 years. Respondents said that family owned forest land of this type is frequently brought back into management when it suits the landowners' objectives (and referred to e.g. Oswalt et

[83] This depends on the interpretation of unmanaged wood. A number of respondents thought that private woodland could come under this classification and therefore on harvest would become managed. However, it was not so clear that pellet demand is driving this harvest.

al 2014). So for this scenario it may be worth making distinctions between a) forests that are legally protected from harvest, via conservation easements or wetland or wilderness designation or similar, and b) forests that are simply owned by family forestland owners because they like owning forestland or for other reasons. Neither category is being harvested now, but category a) are legally protected and will not be harvested under any circumstances, while category b) are the forests that might come into production if the price increases enough. Literature evidence presented in Chapter 4 supports this.

10.2.3 Cost reduction

Recent evidence from the literature on wood pellet mill capacity to pay for wood fibre suggests that current small roundwood and residue prices would need to rise by only about 15% to 20% to make pellet mills unprofitable (see Chapters 4 and 5). This is supported in our study. Harvesting improvements to reduce pellet fibre costs would therefore be beneficial.

The literature suggests that the cost of residue extraction could be reduced by up to 35% if integrated harvesting methods were introduced, rather than the current model of a separate pass to collect and process roadside residues and possibly utilising standing unharvested trees. This investment will only happen if there is a stable and sustained market for pellets – at least one that allows for a return on investment in the machinery. The Nordic countries in Europe have invested in biomass energy and have a strong market for the fibre. They have decreased costs of supply using integrated harvesting. However, their energy situation is very different to Canada and the USA. Such integrated harvesting methods would increase the potential for use of residues from the forests, given regulatory constraints on the use of this source of fibre.

10.3 Application of BEAC

There are some messages from this work on the application of BEAC:

- The BEAC analysis in Stephenson and Mackay (2014) does not explicitly consider the impact of economics, rather it models the greenhouse gas impacts of scenarios informed by a literature review and stakeholder engagement. BEAC scenarios contain implicit economic assumptions by changing rotation length or converting land to plantations. Our work has shown that financial return (i.e. economics) is important in determining whether or not the scenario happens. Respondents to the questionnaire frequently commented that it might be possible for a scenario to occur in theory, but it would be unlikely in practice because it does not make economic sense based on the returns that pellets provide, their limited market compared to other forest products and the potentially limited period that demand for fibre for pellet production is expected to last. The use of changes in rotation as envisaged by Stephenson and Mackay (2014) was generally considered uneconomic by our survey respondents.
- The counterfactuals for a number of scenarios are difficult to prove. For example, scenarios 10-13 where respondents said it is not possible to know the exact age of a forest or how it would be managed in the absence of pellet demand. Respondents said it is not correct to assume that the forest would be harvested on a longer or shorter rotation. Faced with a better financial return from converting the land in some other way land owners in the USA may opt for different choices, which could also be valid counterfactuals.
- In Canada forestry laws and regulations have been negotiated over more than two decades and are designed with the intension of ensuring sustainable forest management. This continuing process provides the back drop to pellet supply strategies. Permitted harvest is determined as a balance of a number of objectives including economic return and social and environment objectives. Considerable time and resources are used to draw up agreed management plans. Canadian respondents to the questionnaire found some of the scenarios in BEAC difficult as they are contrary to the Canadian forest management process.
- Definitions are important and should not be open to interpretation, but we found respondents were defining some terms differently, particularly those for forest residues, managed/unmanaged land and ‘additional wood’.

10.4 Conclusions

10.4.1 Supply strategies

The results to the questionnaire and the literature suggest the most likely supply strategies (aside from saw mill residues, which were not included) were:

- the use of forest residues (however they are defined) and of thinnings
- roundwood will be used for pellets when there is no alternative higher value market (our evidence is that coniferous plantations in Southeastern USA is a potentially an important source for pellet fibre). This was confirmed in SRTS modelling.
- The questionnaire responses and SRTS modelling indicated that naturally regenerated forests could be converted to pine plantations. SRTS modelling shows that a shift to harvest of pine plantations reduces the pressure on natural stands.
- In Southeast USA respondents said that in the presence of financially viable sustained demand for pellet fibre one likely supply strategy is to plant more trees for thinnings in plantations and to do two sets of thinnings rather than one.
- Respondents also thought diversion of non-bioenergy pulpwood to pellets would occur. It was not clear what form this displacement would take. In some cases pulpwood demand is decreasing in some areas and pellet supply may take over as other demand slips; in other cases non-bioenergy pulpwood demand may move to neighbouring areas[84].
- The questionnaire responses exposed concern that additional harvest was being taken from hardwoods in Southeast USA, but overall there was no consensus on these scenarios. This was thought not to be adequately represented in BEAC. The evidence in the literature on this was limited and further evidence is required.

Our evidence for Canada shows that saw mill residues will remain important but additional harvest, integrated with harvest for non-bioenergy products and the use of logging residues were seen as being the most likely supply strategies. This is summarised in Table 8-23.

Overall the most likely supply strategies are those that can be integrated with other high value product supply chains, requiring little change or investment. This is because pellets are regarded as a low value product that improves margins but does not drive forest practice. In the longer term this might change if the pellet market increases, but not at current levels or prices. Investment in the pellet supply chain requires sustained demand, a stable policy environment and relatively low price fibre. Modelling of the pellet supply chain requires a more in depth understanding of the response of pellet producers to higher prices.

10.4.2 Additional Key messages

From the survey responses a number of important points emerged:

- Fibre price is a major cost in pellet production and this is a function of a number of variables
- Fibre price for pellets is not sufficient alone to drive harvest, but it will be most influential in areas close to pellet mills
- The impacts of a number of variables on pellet prices are location-dependent. So it is not possible to extrapolate from one region to another
- Pellet producers say they cannot afford a 20-30% sustained increase in fibre price over a period of months without having to reconsider their business model.

[84] This is a strange conclusion in the face of evidence that pellet mill's capacity to pay is less than that of non-bioenergy demand. We can speculate that it is because pellet demand to supply Europe is situated in the Eastern coastal plain near strategic ports; whereas non-bioenergy demand may supply local or regional markets and could source elsewhere. So in areas where stumpage increases non-bioenergy demand may have more flexibility to take supply out of the area. However, further evidence is required. For the purposes of this study it is important to understand how this displacement takes place and to where.

- Pellet fibre availability is a function of saw mill residue availability and pulpwood. Pellet production impacts the market of other wood products that rely on these feedstocks, but only moderately and a number of respondents thought there was no impact.
- For Southeast USA the motivation of family forest owners to harvest are important. Their motivation for ownership of the forest and their alternative potential actions may result in additional counterfactuals not considered in BEAC.

These findings are also reported in the literature and some of them are supported by the SRTS modelling.

For Canada, the factors that are considered in setting the AAC as stated clearly in Provincially approved management plans and according to Provincial forest policy are important. From the responses to the questionnaire, it seems clear that for the foreseeable future pellet fibre supply will be derived from a combination of primary and secondary manufacturing by-products (e.g. sawdust) as well as possibly harvest of standing unutilized AAC at the same time as harvest for other more valuable forest products. Examination of the impact of pellet demand on the proportion of AAC utilized has not been quantified to date, and would be necessary to further quantify how pellet demand affects harvest for that assortment in addition to more valuable forest products. In any case, Provincial forest policy requires that any trees harvested for wood pellet feedstock must fall within the AAC as defined in Provincially approved management plans and audited operations. There is essentially no potential for pellet demand alone to alter the way the AAC is determined.

Unmanaged forest: Our experience with the issues over definition of unmanaged forest and the use of unmanaged forest has led us to believe that this needs to be defined in relation to regional forestry practice in LCA analysis. The aim of such modelling should also be considered, i.e. whether it is about bringing forest that has never been managed into management or if it is about bringing under-managed forest back into management. Whilst the former systems may have designated status and some protection, the latter may not. However, bringing under-managed forest back into management may not necessarily be a bad thing if it goes hand in hand with objectives to improve the health of the remaining trees and takes biodiversity objectives into account as well. In this case the counterfactual will need to be carefully considered. It may not be leaving the forest un- (or under-) managed. If it is normal practice in a region to bring undermanaged forest back into management at harvest, then a legitimate counterfactual might be harvest of the forest without taking additional wood for pellets (i.e. leaving the residues in place).

Issues with life cycle assessment: This study has exposed problems that are common to life cycle assessment in an area as complex as forestry. Data provided for these models always relies on past history and projections of the future: this limits their usefulness in understanding the way a new product would interact with current markets. However, LCA such as BEAC are useful in defining where potentially high emissions may be expected and allowing development of strategies to avoid such situations. The important point is that foresters and the forest products market must understand the scenarios and that they are a necessary component of their development. Likewise carbon is not the only impact and experts with a clear understanding of other impacts and how to avoid them (e.g. on biodiversity, water or local socio-economic conditions) are important partners in the development of pellet supply strategies.

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Appendices

Appendices 5 and 6 are supplied as separate documents.

Appendix 1 - Summary of BEAC scenarios examined in this study

Table 11-1 Summary of scenarios for UK bioelectricity from North American Wood Pellets, as presented in the BEAC report

The table below lists all of the BEAC scenarios. In our data gathering exercise we are not examining all of these scenarios. The ones that had relatively low carbon emissions are not included in this study and they are shown in grey.

Scenario Number	Feedstock used for pellets	Counterfactual				
Woody residues						
Sawmill Co-products (definition in BEAC: Fine residues: Saw dust, wood flour, shavings and bark, produced as by-products of primary and secondary processing mills; Coarse, chippable residues (Saw-mill slabs and edgings, produced as by-products of primary and secondary processing mills.)						
1	a) Saw-mill residues in South USA; no drying. (b) Saw-mill residues in Pacific Canada; no drying.	Burn as a waste (no energy recovery).				
2	(a) Saw-mill residues in South USA; dry from 25 wt% to 10 wt% moisture. (b) Saw-mill residues in Pacific Canada; dry from 25 wt% to 10 wt% moisture.					
3	(a) Saw-mill residues in South USA; dry from 50 wt% to 10 wt% moisture. (b) Saw-mill residues in Pacific Canada; dry from 50 wt% to 10 wt% moisture.					
Forest residues Definition of forest residues in BEAC: <u>Fine forest residues</u>: Tree tops, limbs, non-merchantable harvested trees and tree components, and downed trees which are left over from traditional timber harvesting. Includes pre-commercial thinnings. Diameter < 0.1 m (Fritsche et al., 2012). <u>Coarse forest residues</u>: Tree tops, limbs, non-merchantable trees and tree components, and downed trees which are left over from traditional timber harvesting. Includes pre-commercial thinnings. Diameter > 0.1 m (Fritsche et al., 2012). This definition does not include the removal of stumps *Note: in all of these removal of coarse forest residues results in a larger GHG intensity that removing fine woody debris.*						
			Conditions	Additional tonnes removed (odt/y)		
					Scenario	Counterfactual

4	(a) Coarse forest residues, removed from forests in South USA, continuously over the time horizon.	Leave all residues in the forest.	40 years	40	0
			100 years	100	0
	b) Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.		40 years	40	0
			100 years	100	0
5	(a) Fine forest residues, removed from forests in South USA, continuously over the time horizon.		40 years	40	0
			100 years	100	0
	(b) Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.		40 years	40	0
			100 years	100	0
6	(a) Coarse forest residues, removed from forests in South USA, for 15 years only (then residues are left in the forest again). For example when analysed over a time horizon of 40 years, this involves the removal of residues for the first 15 years, then leaving the residues in the forest for the last 25 years of the time horizon.		40 years	40	0
			100 years	100	0
	(b) Coarse forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).		40 years	15	0
			100 years	15	0
7	(a) Fine forest residues, removed from forests in South USA, for 15 years only (then residues are left in the forest again).		40 years	15	0
			100 years	15	0
	(b) Fine forest residues, removed from forests in Pacific Canada, for 15 years only (then residues are left in the forest again).		40 years	15	0
			100 years	15	0
8	(a) Forest residues (both coarse and fine), removed from forests in South USA, continuously over the time horizon. (b) Forest residues (coarse and fine), removed from forests in Pacific Canada, continuously over the time horizon.	Burn the residues at the roadside as a waste.			
Dead Trees from Natural Disturbances					

<table>
<tr><td>9</td><td>Salvaged dead trees, which have been killed by the mountain pine beetle in Pacific Canada.</td><td>(a) Leave in the forest.
(b) Remove and burn at the roadside.</td><td colspan="3"></td></tr>
<tr><td colspan="6">Roundwood and Energy Crops
Definitions in BEAC:
Roundwood comprises <u>saw logs</u> (usually defined as a log with a small end diameter greater than 5 - 8 inches (0.13 - 0.20 m)); <u>Chip-n-saw</u> (small saw logs and large pulpwood, with minimum diameters of 4 - 6 inches (0.10 - 0.15 m) and maximum diameters of 9 - 16 inches (0.23 -0.41 m)); and <u>pulpwood</u> (roundwood which has a small end diameter typically less than a saw log (5 - 8 inches), but greater than 2.5 inches (0.064 m) (also known as small roundwood in the UK), and low quality roundwood with dimensions of saw logs and chip-n-saw, that can’t be used for sawn-timber).</td></tr>
<tr><td colspan="6">Increased harvest of Naturally-Regenerated Forests (BEAC definition: Productive forests that are of natural origin; these forests regenerate naturally through seeding, root suckers, or stump sprouts from existing trees.)
Note for these scenarios it is assumed any change in wood harvest is due to bioenergy demand that that use of wood for non-bioenergy remains the same.</td></tr>
<tr><td colspan="3" rowspan="2"></td><td rowspan="2">Condition</td><td colspan="2">Average wood production over time horizon (odt/ha/y)</td></tr>
<tr><td>Scenario</td><td>Counterfactual</td></tr>
<tr><td rowspan="4">10</td><td rowspan="2">Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated hardwood forest in East Canada (a) from every 100 years to every 50 years</td><td rowspan="4">Continue harvesting the forest every 100 years.</td><td>40 years</td><td>3.068</td><td>1.664</td></tr>
<tr><td>100 years</td><td>2.610</td><td>1.664</td></tr>
<tr><td rowspan="2">(b) from every 100 years to every 80 years.</td><td>40 years</td><td>2.044</td><td>1.664</td></tr>
<tr><td>100 years</td><td>1.992</td><td>1.664</td></tr>
<tr><td rowspan="2">11</td><td rowspan="2">Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated conifer forest in Pacific Canada from every 70 years to every 50 years.</td><td rowspan="2">Continue harvesting the forest every 70 years.</td><td>40 years</td><td>5.537</td><td>4.386</td></tr>
<tr><td>100 years</td><td>4.910</td><td>4.386</td></tr>
</table>

12	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated **conifer forest** in **boreal Interior-West Canada** (a) from every 100 years to every 50 years	Continue harvesting the forest every 100 years.	40 years	2.501	1.526
			100 years	1.888	1.526
	(b) from every 100 years to every 80 years.		40 years	1.830	1.526
			100 years	1.715	1.526
13	(a) Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a naturally-regenerated **hardwood forest** in **South USA** from every 70 years to every 60 years.	(a) Continue harvesting the forest every 70 years.	40 years	1.668	1.508
			100 years	1.563	1.508
	(b) Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated **hardwood forest** in **South USA** every 70 years.	(b) Reduce the rate of harvest to every 80 years.	40 years	1.508	1.508
			100 years	1.508	1.508
Existing Intensively-managed Plantations (BEAC definition: An area where trees have been planted, especially for commercial purposes) Note BEAC says: Intensively-managed plantations in South USA are used to produce saw logs, chip-n-saw and pulpwood. The thinnings, smaller diameter sections of the final harvested trees, and low-quality logs are used for pulpwood, and the larger, high-quality trees are used for chip-n-saw and saw logs.					
			Time horizon	**Average wood production over time horizon (odt/ha/y)**	
14	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in South USA.	14: Reducing the frequency of harvest to every 35 years.	40 years	5.931	4.608
			100 years	5.931	4.608
			40 years	6.183	4.608
			100 years	5.917	4.669

15	(a) Continue harvesting every 25 years, (b) Increased demand for pulpwood results in the rotation length reducing to 20 years. 15, 16, 17 = Same as Scenario 14, but with different counterfactuals. Scenario 14 also assumes low demand for wood. It assumes that any additional wood created in this scenario is used for bioenergy and that there is no difference between the amount of non-bioenergy wood between the scenario and its counterfactual.	15: Converted over 50 years to an even-aged naturally-regenerated pine forest that is harvested every 50 years.			
16		16: Converted over 25 years to a naturally-regenerated pine forest that is left to continuously sequester carbon, rather than harvested.			
17		17: Converted over 25 years to agricultural land (e.g. cotton plantation).			
18	Additional wood (in comparison to the counterfactual) from increasing the management intensity (and hence yield) of a pine plantation in South USA that is harvested every 25 years (e.g. adopting optimal thinning practices and initial planting densities; Will et al., 2006).	Continue previous management regime (medium-intensity management practices, harvested every 25 years).			
Displacing Non-Bioenergy Wood Uses This set of scenarios examine a situation in which demand for pulpwood increases, which could result in pulpwood which would otherwise be used for non-bioenergy purposes being used for pellets instead. The displaced wood product might then instead be imported, which would result in indirect GHG consequences in that region. Currently the main importers of wood into the USA are: Canada, Brazil, Chile, and China. The scenarios below examine a range of potential indirect changes resulting from higher demand for fibre for bioenergy.					

			Time horizon	Average wood production over time horizon (odt/ha/y)	
19	Pulpwood from South USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in South USA used for non-bioenergy purposes.	40 years	28.125	0
			100 years	29.250	0
20	Pulpwood from South USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah (IEA, 2011).		40 years	18.75	0
			100 years	19.50	0
21	Pulpwood from South USA, causing indirect impact of increasing the harvest rate of naturally-regenerated coniferous forest in Pacific Canada, from every 70 years to every 50 years.		40 years	5.537	4.386
			100 years	4.910	4.386
New Plantations Replacing Naturally-regenerated Forests in South USA **It is assumed that additional wood created in these scenarios in comparison to the counterfactual is used for bioenergy.**					
			Time horizon	**Average wood production over time horizon (odt/ha/y)**	
22	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in South USA that is harvested every 50 years, to an intensively-managed pine plantation that is harvested (a) every 25 years,	Continue harvesting the forest every 50 years, and leaving to regenerate naturally.	40 years	3.771	1.795
			100 years	5.056	1.795
	(b) every 20 years.		40 years	4.281	1.795
			100 years	5.157	1.795
23	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in South USA that is	Continue harvesting the forest every 70 years,	40 years	3.742	1.508
			100 years	5.054	1.508

	harvested every 70 years, to an intensively-managed pine plantation that is harvested (a) every 25 years	and leaving to regenerate naturally.			
	(b) every 20 years		40 years	4.278	1.508
			100 years	5.156	1.508
24	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated coniferous forest in South USA that is harvested every 50 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes (a) 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally.	40 years	10.821	1.795
			100 years	10.328	1.795
	(b) Conversion over 50 years		40 years	5.795	1.795
			100 years	8.398	1.795
25	Additional wood (in comparison to the counterfactual) from the conversion of a naturally-regenerated hardwood forest in South USA that is harvested every 70 years, to an SRC hardwood plantation that is coppiced every 3 years. Conversion takes (a) 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally.	40 years	10.902	1.508
			100 years	10.361	1.508
	(b) 70 years.		40 years	4,366	1.508
			100 years	7.557	1.508
New Plantations on Abandoned Agricultural Land BEAC assumes this agricultural land is abandoned owing to relocation of agriculture or its degradation from intensive use. It is assumed that the additional wood created by the bioenergy scenario, in comparison to the counterfactual, is used for bioenergy, and any changes in carbon stock in the forest relative to the counterfactual are attributed to this wood output.					
26	Additional wood (in comparison to the counterfactual) from the conversion of abandoned	Abandoned agricultural land left to revert to sub-			

	agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from South USA. SRC yields of: (a) 5 odt/ha/y (b) 10 odt/ha/y (c) 15 odt/ha/y (d) 30 odt/ha/y.	tropical, moist, deciduous forest.	
27	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land in USA that was previously annually ploughed, to an SRC hardwood plantation that is coppiced every 3 years. Assumed exported to UK from Northeast USA. SRC yields of: (a) 5 odt/ha/y; (b) 10 odt/ha/y; (c) 15 odt/ha/y; (d) 30 odt/ha/y.	Abandoned agricultural land left to revert to temperate grassland.	
28	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land that was previously annually ploughed, to an intensively-managed pine plantation that is harvested (a) every 25 years, (b) every 20 years. Assumed exported to UK from South USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.	
29	Additional wood (in comparison to the counterfactual) from the conversion of abandoned agricultural land that was previously annually ploughed, to an intensively-managed pine plantation	Abandoned agricultural land left to revert to temperate grassland.	

	that is harvested (a) every 25 years, (b) every 20 years. Assumed exported to UK from Northeast USA.		
Additional scenarios being examined in this survey. These scenarios are similar to those in BEAC, but are not included in the BEAC report			
Increased harvest rate of plantation forests (as for Scenarios 10-13 in the BEAC model but for plantations)			
10P	Increased rate of harvest of hardwood plantation in East Canada by (a) halving the rotation period (b) cutting the rotation by a short period.	Leave plantation in previous management	
11P	Increased rate of harvest of conifer plantation in Pacific Canada by (a) halving the rotation period (b) cutting the rotation by a short period.		
12P	Increased rate of harvest of conifer plantation in Boreal Canada by (a) halving the rotation period (b) cutting the rotation by a short period.		
13P	Increased rate of harvest of hardwood plantation in South USA by (a) halving the rotation period (b) cutting the rotation by a short period.	(a) Leave plantation in previous management (b) Reduced frequency of harvest with low demand for wood.	
Bring unmanaged forests into production Unmanaged forest is defined as forest for which no deliberate planning decision has been made currently or in the future. Management includes 100% conservation and sustainable forest management, including harvest of forest products.			
Scenario 30a	Bring unmanaged forest into production in South USA	Forest remains unmanaged	
Scenario 30b	Bring unmanaged forest into production in East Canada		

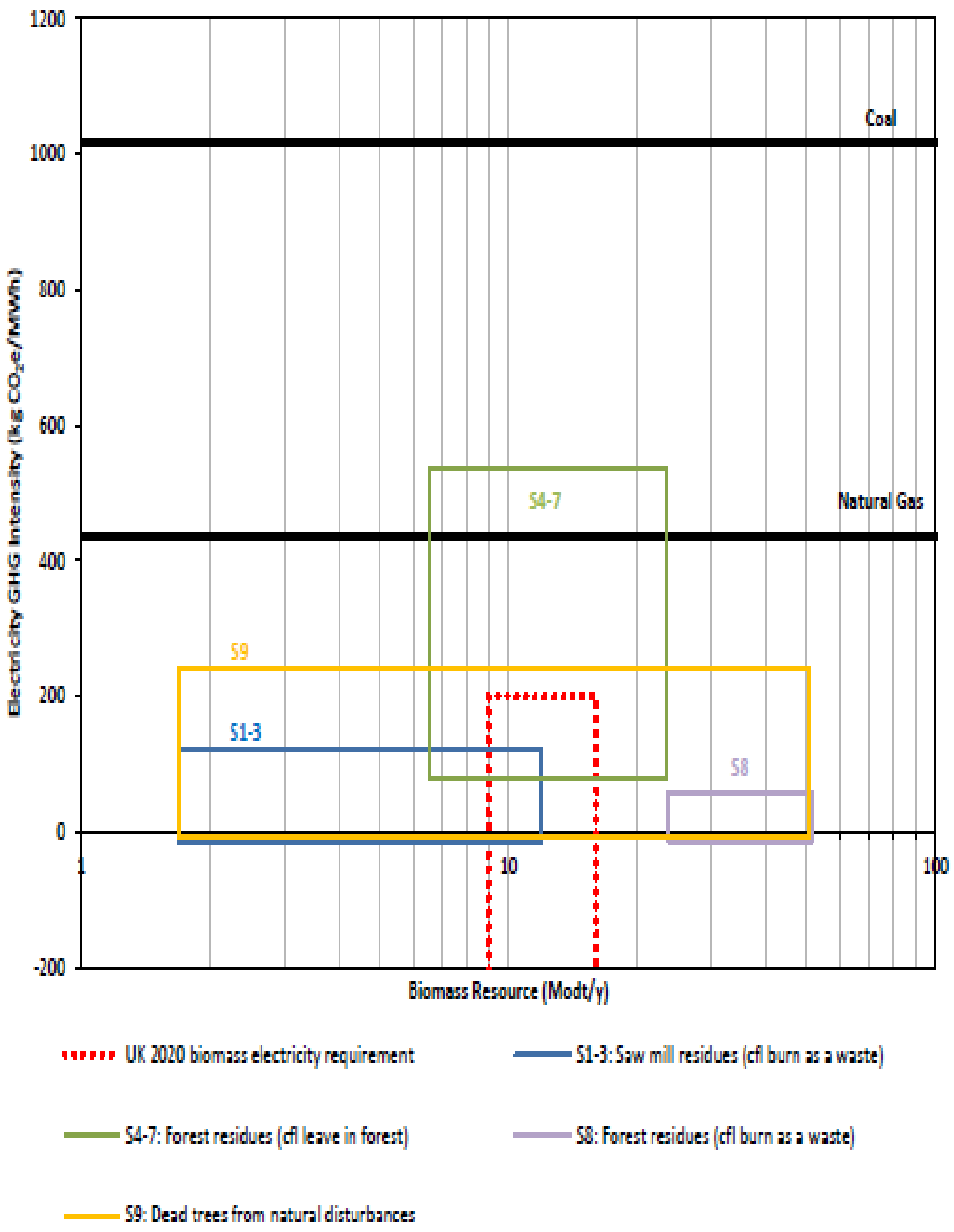
Scenario 30c	Bring unmanaged forest into production in Pacific Canada		
Scenario 30d	Bring unmanaged forest into production in Boreal Canada		

Appendix 2 Summary of results from BEAC

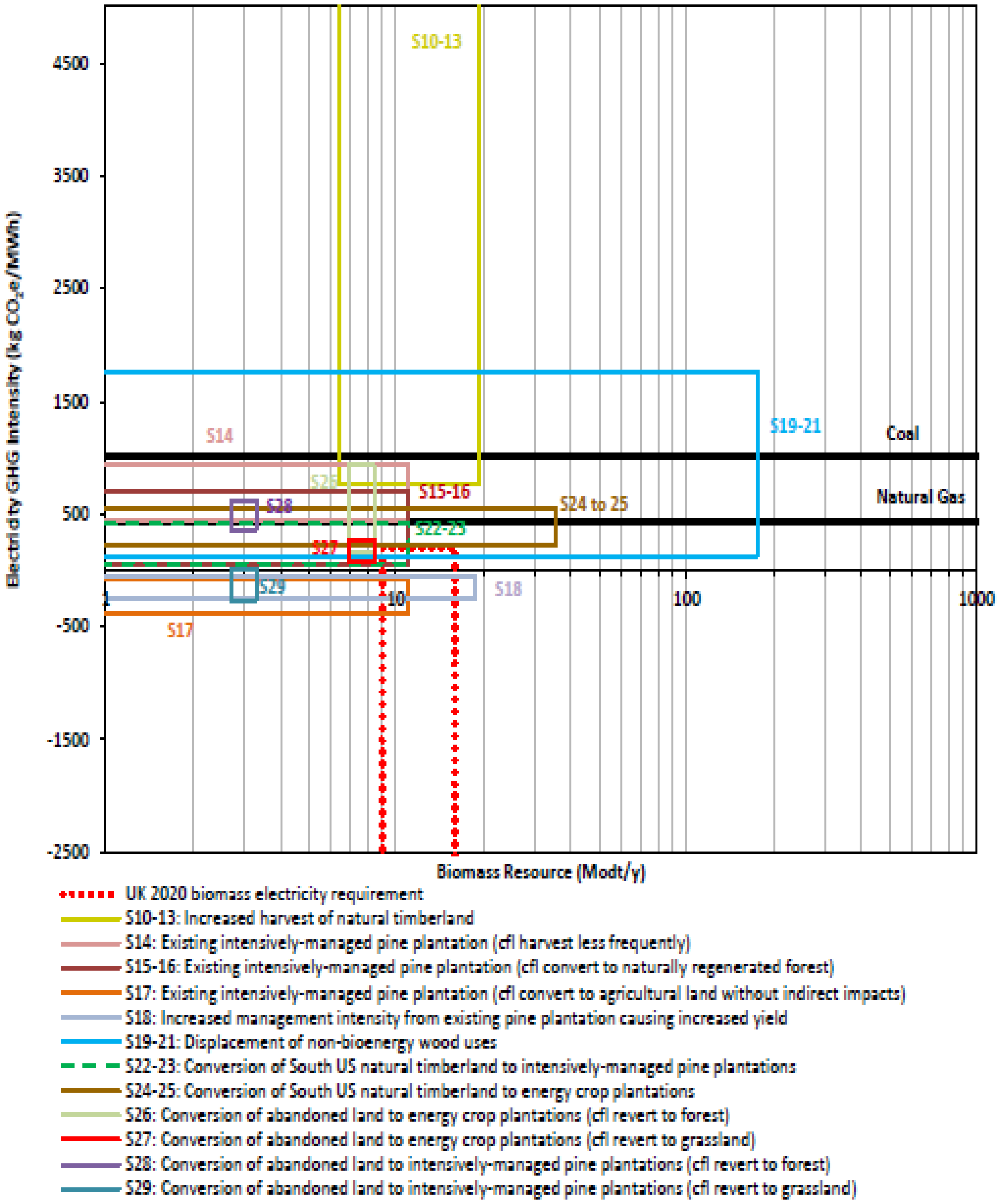
The following graphs present the results for the GHG intensity over 100 years for the BEAC scenarios (source: Stephenson and Mackay 2014).

Figure 11-1 Summary of resource of North American woody residues that may be available by 2020 and their GHG intensity over 100 years. Cfl: counterfactual**.**

(a) scenarios for the use of residues



(b) the remaining scenarios



Appendix 3 Conversion factors for biomass fuels

The conversion factors below are for biomass fuels in Nova Scotia and are taken from MacQarrie and Hudson (2013). They are not representative of other forest areas but do provide an indication of the relationship between the different units used in this report. Note: conversion between m^3 and tonnes will depend on moisture content and density. Different species produce wood of very different densities. This is discussed in UNECE (2009).

Chips

For mixed softwood species, one green tonne of primary fuel chips times 1.167 equals 1.167 cubic metres of solid wood ($1\ t \times 1.167\ m^3/t = 1.167\ m^3$)

For mixed hardwood species, one green tonne of primary fuel chips times 0.963 equals 0.963 cubic metres of solid wood ($1\ t \times 0.963\ m^3/t = 0.963\ m^3$).

Sawmill Co-products

For mixed softwood species, one green tonne of sawmill chips times 1.269 equals 1.269 cubic metres of solid wood ($1\ t \times 1.269\ m^3/t = 1.269\ m^3$).

For mixed hardwood species one green tonne of sawmill chips times 1.070 equals 1.070 cubic metres of solid wood ($1\ t \times 1.070\ m^3/t = 1.070\ m^3$).

For mixed softwood species, one tonne of sawdust equals 1.269 cubic metres of solid wood.

For mixed hardwood species, one tonne of sawdust equals 1.070 cubic metres of solid wood

Appendix 4 Literature related application of SRTS to this study

The following sources provide more information on how the model has been applied, the assumptions made in the model and sources of data. Full references are provided in the reference section.

SRTS Model Applications

Modelling of effect of bioenergy demand, policies, projections of southern timber supply and the market and greenhouse gas implications of forest biomass use: Abt et al (2012); Abt et al (2014); Abt et al (2010a); Abt et al (2009); Abt, et al (2010b); Galik & Abt, (2012); Chudy et al (2013); Galik et al (2009).

Public Agency Applications of the Model

US Forest Service (1988) South's Fourth Forest: Alternatives for the Future. Forest Resource Report No. 24. The initial grant to construct sub-regional modelling in the U.S. South was from the US Forest Service to develop state level projections for this project. This resulted in a USFS Award for "developing the first usable system for state-level projections". All state level analyses were based on the modelling framework that evolved into the SRTS model platform.

Southern Forest Resource Assessment. SRTS was used is the timber market model for the 2002 USFS Southern Forest Resource Assessment. Described in Chapter 14 of Wear & Greis (2002) David N. Greis, John G., eds. 2002. And also published in: Prestemon, & Abt. 2002.

Wear & Greis. 2013. The Southern Forest Futures Project: Technical Report. General Technical Report SRS-178. Chapter 10. Forest Biomass-Based Energy. pp. 213-260. SRTS was used as the modelling platform for evaluating the potential impact of bio-based demand on the southern forest resource.

Abt et al (2014) Effect of policies on pellet production and forests in the U.S. South.

US EPA Regional Vulnerability Assessment: Schaberg & Abt. (2004).

US Dept. of Energy: SRTS is being used to parameterize county level projections in the Polysys model and as a foundation for a description of the potential impact of bioenergy on the southern resource for the DOE 2016 Billion Ton Update.

State of Florida: Rossi, et al (2010). Woody Biomass for Electricity Generation in Florida: Bioeconomic Impacts under a Proposed Renewable Portfolio Standard (RPS) Mandate. Final Report to the Florida Department of Agriculture and Consumer Services, Division of Forestry. 99p.

State of South Carolina: Abt et al (2013). South Carolina's Forest Resource: A 20/15 Program Assessment.

Empirical Literature used to parameterize SRTS

Supply Elasticities: Pattanayak et al (2002); Beach et al. (2005)

Demand Elasticities: Abt & Soeun. (2003).

Forest Carbon Calculations: Smith et al. (2006).

Underlying equations for the above carbon calculations are from: Foley (2009)

Land use Response to Forest Rents: Hardie et al. (2000); Lubowski et al. (2008).

Model modifications since the publications above

There has been one minor change to the model since its use in the recent USFS General Technical Report SRS-202, "Effect of Policies on Pellet Production and Forests in the U.S. South, Southern Research Station; December 2014. The harvest targets for the oldest age classes have been modified to react to increasing accumulation of volume in those age classes. This is particularly true of pine plantations where the planting boom of the 1980s and the housing recession have led to higher projected volumes in that age class in the next 20 years. The model was modified to raise the target harvest intensity in the oldest age class proportional to the build-up in inventory relative to the FIA starting point. Sensitivity analysis suggest that this has little impact on market results but does reduce the build-up in older age classes over time.

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