Ricardo Energy & Environment

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

Methodology guide to analysis tool

Report for DECC
943/12/2014

Customer:

DECC

Customer reference:

943/12/2014

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27 April 2016

Ricardo-AEA reference:

Ref: ED60674- Issue Number 1

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1 Introduction

This guide describes the analysis tool for the study 'Use of North American woody biomass in UK electricity generation: Assessment of high carbon biomass fuel sourcing scenarios' carried out by Ricardo Energy & Environment for DECC. The aim of the study was to assess the likelihood of a number of scenarios for the source of fibre for pellets in North America, which the analysis by Stephenson and Mackay (2014) using DECC Biomass emissions and counterfactual model ('BEAC') indicated could have high carbon consequences. This analysis tool should be viewed in conjunction with the main Technical Report that provides a full background to the study, the methodology used, and the results. The main report is available on the DECC website.

2 Overview

The analysis tool summarises the evidence on the likelihood of the high carbon scenarios in Stephenson and Mackay (2014). The evidence was collected using three approaches to data gathering

- 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.
- A literature review to provide evidence on key variables such as costs, constraints and forestry practice.
- A modelling exercise using the Sub-regional Timber Supply (SRTS) model developed at North Carolina State University.

Each scenario analysed is given a number (S4a, S4b etc.) in line with the numbering used in Stephenson and Mackay (2014). The scenarios analysed, their counterfactuals (i.e. what is assumed to happen in the absence of demand for pellets)[1], their numbers and the part of the analysis tool in which they appear in is given in Table 2.1 below. The analysis tool was split into four parts to ensure that the workbook file sizes did not become too large.

For each of the high carbon scenarios considered in the analysis tool, there is:

- An **'overview'** sheet which summarises the evidence from all of the different sources
- A **'likelihood'** sheet which provides details of the analysis of the response to questions in the questionnaire which directly asked about the likelihood of scenarios. The methodology used in the likelihood sheet is explained further in Section 3 of this guide
- A **'comments**' sheet, which summarises the additional comments that users made in responding to these direct questions
- A **'literature review'** sheet summarising the evidence from the literature review

For scenarios where the SRTS model can provide evidence on the scenario there is also:

- A **'SRTS model'** sheet'

In order to aid navigation through the workbook, as all information from the questionnaire comments, literature review, and SRTS model sheets is replicated in the overview sheets, these sheets have been hidden. Users may unhide them in the normal way, by right clicking on any tab, selecting unhide, and then clicking on the sheet they wish to unhide.

A fuller description and analysis of the evidence from each source, including references which were examined as part of the literature review is given in the following sections of the Technical Report:

- **Questionnaire comments**: Chapter 8
- **Literature review**: for the USA, Chapter 4 and in particular the Summary in Section 4.7; for Canada, Chapter 5 and in particular the Summary in Section 5.7
- **SRTS modelling:** Chapter 6

[1] A concise description of the scenarios Is given in Appendix 1 of the Technical Report, and a full description in Stephenson and Mackay (2014), which is available at https://www.gov.uk/government/publications/life-cycle-impacts-of-biomass-electricity-in-2020,

Table 2.1 High carbon scenarios and their location in the tool.

Part of analysis tool	Scenario No.	Scenario description	Counterfactual description
Part 1	4a	Coarse forest residues, removed from forests in South USA, continuously over the time horizon.	Leave all residues in the forest
Part 1	4b	Coarse forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
Part 1	5a	Fine forest residues, removed from forests in South USA, continuously over the time horizon.	Leave all residues in the forest
Part 1	5b	Fine forest residues, removed from forests in Pacific Canada, continuously over the time horizon.	Leave all residues in the forest
Part 1	6a & 7a	Fine and coarse forest residues, removed from forests in South USA, for 15 years only (then residues are left in the forest again).	Leave all residues in the forest
Part 1	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
Part 2	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
Part 2	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
Part 2	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
Part 2	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

Part of analysis tool	Scenario No.	Scenario description	Counterfactual description
Part 2	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
Part 2	13a	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.	Continue harvesting the forest every 70 years
Part 2	13b	Additional wood (in comparison to the counterfactual) generated by continuing harvesting a naturally-regenerated hardwood forest in South USA every 70 years.	Reduce the rate of harvest to every 80 years
Part 2	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
Part 2	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
Part 2	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
Part 2	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
Part 2	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
Part 2	13Pa	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in South USA by decreasing the rotation period up to 50%	Leave plantation in previous management

Part of analysis tool	Scenario No.	Scenario description	Counterfactual description
Part 2	13Pb	Additional wood (in comparison to the counterfactual) generated by increasing the rate of harvest of a hardwood plantation in South USA by decreasing the rotation period up to 20%	Reduced frequency of harvest with low demand for wood
Part 3	14a	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in South USA. Continue harvesting every 25 years	Reducing the frequency of harvest to every 35 years
Part 3	14b	Additional wood (in comparison to the counterfactual) from intensively-managed pine plantation, in South USA. Increased demand for pulpwood results in the rotation length reducing to 20 years.	Reducing the frequency of harvest to every 35 years
Part 3	19	Pulpwood from South USA, causing indirect impact of Eucalyptus plantation replacing Brazilian rainforest.	Pulpwood produced in South USA used for non-bioenergy purposes
Part 3	20	Pulpwood from South USA, causing indirect impact of Eucalyptus plantation replacing Brazilian abandoned degraded pasture land, which would otherwise revert to tropical savannah.	Pulpwood produced in South USA used for non-bioenergy purposes
Part 3	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.	Pulpwood produced in South USA used for non-bioenergy purposes
Part 3	22a	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 every 25 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
Part 3	22b	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 every 20 years.	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
Part 3	23a	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 intensively-managed pine plantation that is harvested every 25 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally

Part of analysis tool	Scenario No.	Scenario description	Counterfactual description
Part 3	23b	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 intensively-managed pine plantation that is harvested every 20 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
Part 3	24a	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 3 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
Part 3	24b	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 over 50 years	Continue harvesting the forest every 50 years, and leaving to regenerate naturally
Part 3	25a	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 3 years	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
Part 3	25b	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 70 years.	Continue harvesting the forest every 70 years, and leaving to regenerate naturally
Part 4	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 South USA.	Abandoned agricultural land left to revert to sub-tropical, moist, deciduous forest.
Part 4	30a	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in South USA	Forest remains unmanaged
Part 4	30b	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in East Canada	Forest remains unmanaged

Part of analysis tool	Scenario No.	Scenario description	Counterfactual description
Part 4	30c	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Pacific Canada	Forest remains unmanaged
Part 4	30d	Additional wood (in comparison to the counterfactual) from the conversion of unmanaged forest into production in Boreal Canada	Forest remains unmanaged

3 Methodology used for analysis of questionnaire responses

3.1 Overview of methodology

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 3.3 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 3.1 for list of questions
Analysis of the most common view	Section 3.3.1.1	1-5
Summary assessment of responses to each question	Section 3.3.1.3	1-7
Likelihood of the 'ranked' questions (i.e. those questions about factors that encourage or prevent the scenarios occurring)	Section 3.3.2	6 and 7
Analysis of respondents self-assessed confident	Section 3.3.3	10

3.2 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 3-1 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 3-1 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.

3.3 Analysis of results from the questionnaire

3.3.1 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 the main report in Appendix 6.

Part 2, covering the direct questions on likelihood was analysed in 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 South 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 3.2 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 3.2.1.1.).
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 3.1 and Table 3.1. 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 3.2 for an example). Details of the methodology for this summary assessment are provided in Section 3.3.1.3.

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

Figure 3.1 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.*

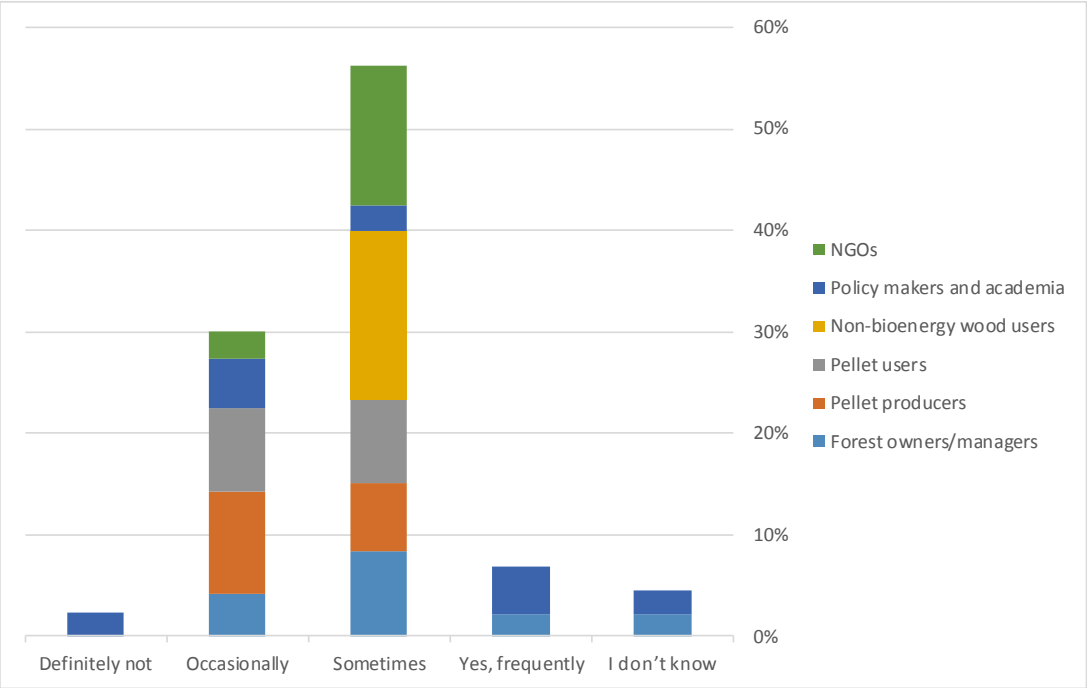

Table 3.1 Data used to produce weighted histogram (Responses to question 'Are the practices in the scenario already occurring?' for the same hypothetical scenario)

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 3.2 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	

3.3.1.1 Determining the most common view

The most common view is determined for questions: 1, 2, 4 and 5 in Box 3.1 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 3.2. 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 3.2 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.

3.3.1.2 Likelihood ratio assessment

The likelihood ratio assessment is done for questions concerning the future likelihood of the scenarios (questions 4 and 5 in Box 3.1). It evaluates whether a scenario is likely or unlikely based on the ratio of responses rating the scenario as likely (to some degree) or unlikely (to some degree). It was used as an initial screening assessment to help identify scenarios where particular care should be taken in making the summary assessment as initial indications were that the scenario might be likely. As the likelihood ration assessment was only considered a crude indicator however, the ranking it suggested was not taken into account in the summary assessment which was done using the methodology described below (Section 3.3.1.3)

The first step in the likelihood ration assessment is to calculate for each stakeholder group the percentage of total responses within the group falling into each of these three categories:

- Likely responses: “moderately likely“, “likely”, and “very likely”
- Unlikely responses: “moderately unlikely”, “unlikely”, and very unlikely.
- “I don’t know” responses.

An overall weighted percentage of responses in each of these three categories is then calculated by summing the percentages from each stakeholder group and dividing by the number of stakeholder groups responding. This is illustrated in the worked example below (Figure 3.3).

The weighted percentages are then used to determine whether a scenario is ‘likely’, ‘unlikely’ or there is no consensus according to the.

a) If the weighted % of “I don’t knows” is >=0.5 it is considered that there is no likelihood consensus.

b) If the weighted % of unlikely responses is zero it is considered that the scenario is clearly likely to happen.

c) If the weighted % of likely responses is zero it is considered that the scenario is clearly unlikely to happen.

The likelihood ratio is calculated where there is no direct clear view on the likelihood and represents the weighted % of likely responses over the weighted % of unlikely responses. The likelihood ratio is then analysed to determine whether there is a clear consensus of the likely responses over the unlikely responses by considering the cases below:

a) If the likelihood ratio greater than 2, it is considered that most of the responses are within the likely group hence the scenario is likely to happen

b) If the likelihood ratio is less than 0.5, it is considered that most of the responses are within the unlikely group hence the scenario is unlikely to happen

c) If the likelihood ratio is between 0.5 - 2, it is considered that there is no clear consensus on likelihood for that scenario and requires looking into the histogram to determine the overall likelihood.

These criteria are summarised in Table 3.3.

Table 3.3 Criteria used to determine the likelihood ‘ratio’ assessment

‘I don’t knows’ percentage	‘Likely’ percentage	‘Unlikely’ percentage	Ratio of likely to unlikely percentages	Likelihood ‘ratio’ assessment
> 50%	Any	Any	Any	No consensus on
<50%	=0%	>50%	Any	Unlikely
	>50%	=0%	Any	Likely
	>0%	>0%	>2	Likely
			>=0.5 and <= 2	No consensus
			<0.5	Unlikely

Figure 3.3 Worked example of calculation of weighted percentages used for likelihood 'ratio' assessment

Response	Very unlikely	Unlikely	Moderately unlikely	Moderately likely	Likely	Very likely	I don't know	Total
Forest owners/managers	1	1	0	5	0	1	0	8
Pellet producers	0	0	0	3	0	0	1	4
Pellet users	0	0	0	0	0	0	0	0
Non-bioenergy wood users	2	0	0	0	0	0	0	2
Policy makers and academia	0	0	0	2	2	2	0	6
NGOs	0	0	0	5	0	0	1	6

↓

Group responses into three categories

↓

	Likely	Unlikely	I don't know	Total
Forest owners/managers	6	2	0	8
Pellet producers	3	0	1	4
Pellet users	0	0	0	0
Non-bioenergy wood users	0	2	0	2
Policy makers and academia	6	0	0	6
NGOs	5	0	1	6

↓

Convert number of responses to percentages

↓

Stkeholder group	Likely	Unlikely	I don't know	Total
Forest owners/managers	75%	25%	0%	100%
Pellet producers	75%	0%	25%	100%
Pellet users				
Non-bioenergy wood users	0%	100%	0%	100%
Policy makers and academia	100%	0%	0%	100%
NGOs	83%	0%	17%	100%

↓

Divide each percentage by number of stakeholder groups who responded (5)

↓

Stkeholder group	Likely	Unlikely	I don't know	Total
Forest owners/managers	15%	5%	0%	20%
Pellet producers	15%	0%	5%	20%
Pellet users				
Non-bioenergy wood users	0%	20%	0%	20%
Policy makers and academia	20%	0%	0%	20%
NGOs	17%	0%	3%	20%

↓

Sum percentages to give combined weighted percentages

↓

Stkeholder group	Likely	Unlikely	I don't know	Total
Combined weighted percentages	67%	25%	8%	100%

3.3.1.3 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 3.1).

3.3.2 Likelihood of the factors that encourage or prevent scenarios

This analysis applies to questions 6 and 7 in Box 3.1, 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[2]. 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 (**Error! Reference source not found.**) 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

[2] 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.

3) Dividing by the total number of responses to the question

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 3.5).

Table 3.4 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 3.5 Example of how the score for 'likelihood'' of a factor is calculated

	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.

The score is then turned into a likelihood rating using as shown in Table 3.6.

Table 3.6 Likelihood rating for score of X

Likelihood score	Likelihood rating
x<1	Very unlikely
2>x>=1	Unlikely
3>x>=2	Moderately unlikely
4>x>=3	Moderately likely
5>x>=4	Likely
x>=5	Very likely

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.

3.3.3 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

3.3.4 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".

3.3.5 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 3.4. The evidence from each of these sources was then combined into an overall summary of evidence on the scenario.

Figure 3.4 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	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.						

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