Feasibility study on sustainability criteria and the effect of wood pellet demand on forest carbon stock

Part B Report: Feasibility Study

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Disclaimer

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

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1 Executive Summary

This report forms the second part of a project designed to understand whether it is possible and feasible to quantify what impact UK biomass sourcing has had on forest carbon stock in the US, Canada and Europe and further to ascertain how a different set of sustainability criteria could impact on predicted forest carbon stocks.

In the first part (Part A) a comprehensive review of existing relevant literature was performed to identify previous approaches to modelling forest carbon and identify key insights and difficulties encountered in the studies, approaches to modelling and limitations, and main causes of variability in conclusions. Details of the literature review, and its results and findings may be read in the Part A report, with a summary of key insights presented in Section 3 of this report. A review of the various possible approaches to addressing the questions posed by BEIS are discussed in Section 4.

The literature review, presented in the Part A report, arrived at a number of insights and conclusions. Based on further consideration of the findings it is concluded that:

- A modelling approach is the most appropriate methodology for assessing the short-term and long-term impacts of different scenarios relevant to actual and possible biomass energy policies which includes examining the impact of policies that deprioritise use of biomass for energy.
- A robust methodology needs to be designed for constructing the scenarios that will provide the basis for parameterising forest sector carbon accounting models.
- Several candidate methodologies exist for the construction of scenarios, which require further evaluation.

With regard to the possible methodologies for constructing scenarios, it is further concluded that:

- A methodology based principally on the analysis of data on forest biomass use by the wood-processing and biomass energy sectors (by feedstocks) is unsuitable for further development and evaluation as a central study methodology on its own. However, insights and understanding into relevant wood biomass supply chains, gained from these data sources (where available), are likely to form a very important supporting component of any methodology.
- The application of economic models is undeniably of considerable value as a means for analysing potential systematic changes in the forestry, wood biomass and energy sectors in response to possible and actual bioenergy policies. However, economic modelling would appear to be most appropriately applied when providing evidence and insights as a supporting component of any methodology.
- Suitably designed stakeholder consultation (with clearly defined objectives) needs to form a component of any methodology and in addition the possibility for using this approach as the central methodology.
- Methodologies involving the formulation of a set of stated assumptions or based on “real-life” case studies should be further elaborated and assessed for their potential as a primary methodology.

Informed by the results of the literature review, a generic structure for any full-scale study of the effect of wood pellet demand on forest carbon stocks, and any potential influence of defined sustainability criteria, was developed. The development and evaluation of specific methodological options forms the main content of Part B of this project. The options considered are:

1. Region-focussed stakeholder-led assessment

2. Installation-focussed case study assessment
3. Assumptions-based assessment.

In addition, the option of not proceeding with a full-scale study was suggested in the Part A report, given the many uncertainties and technical difficulties identified in the literature review, and consequently this has also been assessed as a fourth option alongside the three others identified above. Option 4, considered in this report, involves undertaking an assessment based on existing available data and scientific evidence and understanding. Alternatively, under Option 4, no further action could be taken.

These four options have been considered for possible full-scale studies to address the questions originally posed by BEIS. The suggested methodology for each option, including tasks involved and resource requirements, likely duration and costs, are described Sections 5 to 8. Each section concludes with a qualitative assessment of the effectiveness of each option, divided into the ability of each methodology to address the four questions, and the extent to which other key desirable characteristics are achieved, including transparency and acceptability by the community. The assessments for all four options are summarized in Table ES1.

Table ES1 Summary of effectiveness of study options

Criterion	Maximum points allocation	Option 1	Option 2	Option 3	Option 4
BEIS Q1 (current impact)	15	12	10	6	10
BEIS Q2 (sustainability scenario)	15	10	10	6	10
BEIS Q3 (maximising sustainable supply)	15	7	0	15	6
BEIS Q4 (wider relevance)	10	5	3	3	5
Transparent	10	9	10	10	5
Understandable	10	8	10	10	5
Data available	10	8	5	8	4
Wide acceptance	5	4	3	2	2
Transferrable	5	4	4	4	3
Wider applications	5	3	2	3	5
Total	**100**	**70**	**57**	**67**	**55**

Note: Option 4 considers the case of not proceeding with a full-scale study. The option considered here involves undertaking an assessment based on review of existing available data and scientific evidence and understanding. Alternatively, under Option 4, no further action could be taken; this case cannot be assessed in the same way as the options above.

The assessment tables in Sections 5 to 8, summarized in Table ES1, provide an overview of how each option performs against the different aspects of relevance to the full-scale study under consideration, including the effectiveness of each option in addressing the four principal questions posed by BEIS. Although a helpful summary, it is stressed that these assessments, and in particular the total scores for each option, have their limitations and are not appropriate for making a mechanistic selection of an option.

The analysis of the four methodologies, summarized in Table ES1, indicates that there is no clearly identifiable "best" approach, but that each has different strengths and weaknesses. A number of features may be observed about the assessments in Table ES1:

- Each option can be seen to be stronger or weaker in addressing each of the four principal questions. Hence it is likely that different study options may be selected, depending on which question is seen as most important to address. None of the options is assessed as scoring more than two thirds of possible marks across the four principal questions.

- Three of the options score quite highly for transparency and understandability, whilst one scores half marks.
- With regard to the criterion considering the likelihood of the study results and conclusions gaining wide acceptance, two options score more than half marks, and two score less than half marks.
- All of the options score reasonably highly for transferability of the methodology (not necessarily the results) to other geographical regions or situations.

It should be stressed that the above assessments are qualitative and based on the judgments of the study team, drawing on the information provided in this report.

The assessment of options suggests that the duration of a full-scale study would be longer than a year, and potentially up to 40 months, and range in cost from around £250k to £830k, depending on the option selected, the number of regions or case studies included, and certain details of the methodology employed (e.g. number of models applied).

Consideration could be given to a research programme consisting of a combination of the assessment method options described in this report. One possible example might consist of the following four elements:

1. A further critical assessment could be made of the currently available evidence and scientific understanding. The findings could then inform how the subsequent elements of the programme may be taken forward.
2. Assumption-based assessments could be made, with the aim of gaining an understanding of the variable impacts of forest management practices and woody biomass feedstock utilisation for bioenergy. These assessments could be used to validate or otherwise refine a set of enhanced sustainability criteria for application to forest bioenergy sources.
3. Assumption-based assessments could also be made for the purpose of estimating potentials for maximum sustainable supply of woody biomass from different regions for use as an energy feedstock.
4. Region-focused or installation-focused case-study assessments could be undertaken to provide evidence for the sustainability (in terms of forest carbon) of forest bioenergy sources being supplied to the UK.

An alternative programme might involve proceeding with assumption-based, region-based and/or case-study assessments, then undertaking a critical assessment of these alongside other relevant studies for the purpose of verification.

2 Background

This report forms the second part of a project designed to understand whether it is possible and feasible to quantify the impact UK biomass sourcing has had or could have in future under a revised set of sustainability criteria, on forest carbon stock in the US and Europe. The objective would be to ascertain whether:

- current biomass sustainability criteria are adequate to conserve forest carbon stocks, and further,
- whether it is possible to determine what the impact of alternative sustainability criteria would be on forest carbon stocks, and
- how this would affect available sustainable biomass supplies into the future.

BEIS are keen to understand whether current sustainability criteria, or potential future changes to these (through RED II or other policy revisions) are robust enough to prevent undesirable forest management scenarios or practices occurring.

BEIS recognises the difficulties and complexities associated with attempting to define if any changes in forest management practices have occurred as a result of sourcing feedstocks for biomass, where this has occurred and at what scale, as well as how this might affect forest carbon cycling.

BEIS currently requires an understanding whether it is feasible to assess bioenergy policy impacts on carbon stocks in forests from which biomass could be imported into the UK, and if so, to gain an understanding of the costs of a programme of work capable of delivering an assessment against the criteria referred to in the above bullet points.

2.1 Project team

The project team brought together a mix of highly experienced analysts from NNFCC Limited and Forest Research with experience in both bioenergy technologies, feedstocks, sustainability, forest management and forest carbon accounting.

2.2 Scope

The key focus of interest to BEIS is quantifying impacts of bioenergy sourcing on forest carbon stock changes. In this context, it must be recognised that the provision of forest biomass for energy may have other impacts related to carbon balances that do not involve impacts on forest carbon stocks. For example, demand for bioenergy may lead to the diversion of existing forest biomass production from alternative end uses. Equally, there may be situations where harvesting biomass from forests for use as energy may lead to reductions in forest carbon stocks, but for which the net impact on greenhouse gas (GHG) emissions is a net saving, when the full system life cycle is considered. Given the project brief, consideration of such issues is out of scope in this study. However, any analysis developed from the proposed approaches could form part of a more comprehensive assessment of GHG emissions in the wider forest-based economy and/or energy sector. In short, forest carbon stock is only one part of the story, but this is the focus for this analysis.

The key questions of interest to BEIS are:

1. What effect has the supply of wood pellets to UK power stations had on the forest carbon stocks in SE USA, Canada and Europe?

2. How would the situation with forest carbon stock have been affected if alternative sustainability criteria had been in place?
3. How can we maximise the sustainable yield and what are the risks and challenges of doing this? How will that change in the future?
4. How applicable would any conclusions be to other areas of potential forest biomass supply?
5. An estimate of the possible costs of a full-scale study. How long would it take?

No specific emphasis was placed on choice of temporal boundary, with the aim of assessing the potential for development of a flexible methodology adaptable to meet a wide range of research questions of interest relating to trade-off between management for short-term or long-term objectives.

Choice of spatial boundary has a significant impact on the ease of assessment. The adoption of a narrow system boundary (i.e. focussing on the forest area supplying a specific pellet mill) may make the task simpler, but there is still an innate difficulty in determining the specific areas of forest directly involved in biomass feedstock supply. Alternatively, assessing forest carbon stock impacts more widely can be complicated and subject to greater uncertainty. Some questions may be simpler to answer with a narrower scope. The role of spatial boundary was considered in identifying the 'best' approach for addressing BEIS assessment needs.

In terms of key countries of supply, the USA, Canada and Europe were defined as the key regions of focus for the work.

In defining the most promising approaches to address the specific questions raised by BEIS, the pros and cons of differing approaches are highlighted.

2.3 Part A – literature review

The first part of the work involved a review of existing literature by Forest Research, addressing the agreed scope and objectives. A key aim was to identify previous approaches adopted to model forest carbon, addressing the following in particular:

- Geographical scope
- Types of forest species, systems and management considered
- Approaches and rationale adopted in defining counterfactuals
- Identification and construction of scenarios
- Types of feedstock considered to use as bioenergy
- Representation of land use change
- Spatial scale
- Assessment methodologies applied
- Representation of forest carbon stocks/biogenic carbon
- Timescales
- Key insights and difficulties encountered in studies, including key causes of variability, difficulties encountered in data acquisition and stakeholder engagement, and approaches to modelling and limitations.

The quality and relevance of sources was scored and recorded, with key comments and scores collated in an Excel work sheet. This was used to compile simple metrics associated with the review of the scope of papers and key insights. The full review is available separately. A total of 350 relevant papers were identified and the most relevant sifted down to 68 papers selected for detailed assessment.

Specific attention was paid to reviewing approaches used to define scenarios for biomass sourcing and counterfactual cases, as well as approaches to estimating and presenting results for carbon impacts.

This report builds on the key findings of the review.

3 Key findings from the literature review

In summary the key overarching findings of the review support conclusions of other and earlier reviews, that studies of the impact of using forest resources for bioenergy on forest carbon stocks lead to very variable results. However, this variability is systematic and reflects choice of feedstock, forest management scenario(s), and counterfactual forest management (what would have happened otherwise), amongst other factors rather than the result of uncertainties.

In short there is no lack of understanding or published results that limits the addressing of questions of interest to this study; the difficulty arises from the complexity involved in accurately representing the dynamics of forest systems around the world as well as how forest products markets respond to changes in feedstock demand as a result of the introduction of increased demand for biomass pellets. However, it is possible to identify and classify types of intervention and sourcing situations into those that are more or less likely to occur and pose high or low risk of unsustainable sourcing practice.

Analysis of previous studies (and associated methodologies) that have looked to address the impact of biomass sourcing on forest carbon stocks highlighted the following key issues for consideration in any follow-up study.

3.1 Terminology

There is a need to standardise nomenclature and provide a clear definition of each wood category referenced. This has been a problem confounding comparison of results between published studies. This finding raises the question as to whether it may be possible to propose an unambiguous and consistent list of terms and definitions, as well as the prospects for its widespread acceptance and adoption by stakeholders.

3.2 Transparency

To facilitate peer review of the relevance of the assessment and to permit wider utilisation, approaches, assumptions and as far as is practicable data used should be clearly identified and publicly available. The results and conclusions of any study are fundamentally linked to the assumptions made.

3.3 Modelling

A great variety of different types of model have been used, depending on the study, ranging from simple equations, taken as representing the essential characteristics of tree growth, through forest sector carbon accounting models to large-scale models of the forestry sector (and wider land use) and of wood processing chains.

The range of modelling approaches applied in studies, and the inconsistencies in their outputs, can make it difficult to compare or synthesise the results of different studies, for example when undertaking a meta-analysis of study results.

Methods based on the application of models have a number of important advantages:

- Generally, models can work with available data.
- Scenarios should be straightforward to represent
- Model results can be integrated into life cycle assessments of full-chain GHG balances

- The projection of forest carbon stocks and sequestration into the future is usually an essential feature of the functionality of relevant models.
- Simple model results can be used for illustrative purposes to support the transparency and understandability of concepts and more complex model calculations
- In principle, models can be applied to different geographical regions, given adequate parameterisation

However, relying on models also has several potential weaknesses:

- Model results rely on the robustness of model design and calibration and the flexibility and detail with which models can represent scenarios for forest management and wood utilisation
- As with the application of any modelling system in any context, the principle of "garbage in, garbage out", applies. Significant errors can occur in model calculations if data inputs and parameter settings are poorly or incorrectly specified. This includes situations in which a model is applied outside the limits of the applications for which the model has been designed.
- Some models are very complex and calculations can be difficult to follow. It is important for stakeholders to be able to "trust" model simulation results, but this is not always achieved when model calculations lack transparency due to their complexity or because of underlying assumptions that are not obvious to stakeholders.

Extending models of current behaviour, particularly through use of economic modelling, to examine impacts of an increased demand for biomass needs careful examination to ensure assumptions and relationships remain applicable when a new market driver is introduced. A potential inherent weakness is that economic models may contain relatively simplified representations of forest management changes in response to economic drivers. Greater use of sensitivity analysis could increase confidence in their results.

3.4 Choice of forest management scenarios and counterfactual cases

These are critical factors in comparative analysis of impacts on forest carbon stocks. The value of any study is underpinned by transparency regarding the choice of scenario(s) and counterfactual(s), including the selection of region and forest type, management practices, feedstocks, and spatial and temporal scales. The details of the "with-bioenergy" scenarios and counterfactual scenarios investigated in studies range from the realistic to the implausible, and the extent to which an individual study may be of value in a particular situation will depend upon the specific choice of "with-bioenergy" and counterfactual scenario(s), Owing to the wide range of forest management practices, wood feedstocks, assumptions and methodologies represented in these studies, this is not surprising. As discussed in Section 3.5, it is very difficult to use the scenarios presented in published studies alone as a basis for specifying the most likely forest management activities and patterns of wood utilisation.

3.4.1 Provisional characterisation of scenarios

The specification for the literature review included a requirement to identify scenarios for forest management and feedstock use relevant to the supply of woody biomass for utilisation as an energy feedstock, and their counterfactuals, in the geographical regions of primary interest to this project, i.e. Europe, Canada and the USA. Whilst noting the difficulties highlighted above, Part A included a tentative statement of proposed scenarios, informed by published studies as far as possible, but also relying on the experience and judgement of the report authors. These define key forest management activities and feedstock types and the anticipated relevance of such factors for forest carbon impacts, as well as providing a subjective assessment of the importance of, and confidence in inclusion of each suggested aspect of management actions as part of a given scenario.

For each country of interest, forest management and feedstock sourcing activities were selected to characterise three possible scenarios:

1. "With bioenergy" - i.e. a scenario representing current practice with existing bioenergy policies
2. "Counterfactual" or "baseline" - likely practice in the absence of a demand, or reduced demand, for bioenergy
3. "Refined criteria" or "enhanced sustainability" – scenario(s) in which sustainability criteria attached to bioenergy sources are refined in accordance with management changes to try and reduce the risk of detrimental impacts on forest carbon stocks (e.g. as proposed in Matthews et al., 2018).

While the authors recognise that such recommendations are speculative, they provide a range of likely scenarios that could be taken into consideration when designing a future study.

Questions that follow include how to assess the prevalence of different forest management systems and how forest management might change, and to what degree, in the presence and absence of biomass sourcing. There are a number of possible approaches to address these questions, described further in section 3.5 .

The range of relevant scenarios illustrates how there are likely to be multiple forest management activities and wood feedstocks involved in any set of actions in supplying biomass energy, and that forest management responses are likely to be complicated and vary within a region. Additional responses related to upstream forest product sectors and feedback effects add a further layer of complexity.

The approach adopted in Part 1 to define scenarios provides a method to document and demonstrate the assumptions made about forest management response to biomass demand and demonstrate the degree of confidence held in assumptions to inform review and support discussion, particularly where these underpin modelled assessments.

3.4.2 Dealing with land-use change

Very few studies have taken account of the likelihood of land-use change associated with the utilisation of forest harvest residues and by-products for bioenergy. It would seem reasonable to assume that the presence or absence of regional demand for woody biomass for use as an energy feedstock could lead to an expansion or contraction of the forest area within the region.

While studies representing a static forest area could be making a critical simplification, this could be valid in some situations, for example in regions where forestry is strongly regulated and land available for afforestation is limited.

Given the uncertainties, Part 1 of this study suggests a precautionary approach might be appropriate, assuming a fixed forest area as the default situation. In geographical regions where the possibility of land-use change is considered important, this could be explored in scenarios as part of a sensitivity analysis, informed by stakeholder dialogue over the likelihood of anticipated modelled changes in land use against stakeholder experience.

3.5 Informing sourcing and counterfactual scenarios

The review in Part A identified five approaches to devise and 'populate' scenarios to ensure as far as possible they reflect the most likely realities of forest management and any changes resulting from biomass sourcing within a target region, namely:

1. Making assumptions about forest management activities and wood feedstocks involved in scenarios.
2. Applying economic models in conjunction with large-scale forest sector models to simulate as best as possible the forest management activities and wood feedstocks involved in scenarios.
3. Utilising forestry sector information on the consumption of woody biomass for use as an energy feedstock and inferring forest management practices from these.
4. Undertaking case studies involving actual wood-processing facilities and investigating the use of wood feedstocks in their supply chains, and the management of the forest areas involved.
5. Consulting with stakeholders within a relevant region to try to establish the forest management practices and wood feedstocks most likely to be involved in biomass sourcing scenarios and how management would otherwise proceed in the absence or presence of increased demand for biomass.

The strength and weaknesses of each approach were reviewed. Each had its own specific attributes, but no one approach was demonstrably better than all others. The drawbacks of the different approaches may be summarised as follows:

1. Using feedstock supply data from the pellet sector alone was seen to have specific weaknesses. It was felt that much of the data required would not exist or would be of questionable quality or reliability. No data would be available for counterfactual scenarios. There are also difficulties in linking such data to the forest management practices involved in the supply of feedstocks.
2. Weaknesses affecting economic models may limit their usefulness (e.g. limited transparency, difficult to understand, reliant on implicit assumptions, high uncertainty).
3. Relying on case studies would give very discrete results that may not be reflective of the wider region or general practice.
4. Relying on assumptions alone may just add to the existing body of research without adding clarity on situations that reflect the reality of forest management practices in regions of biomass supply.
5. Stakeholder consultation relies on the ability to identify an appropriate range of participants and gain consensus of view, which can be difficult.

Reliance on sectoral data as the main approach was deemed to be unsuitable as an approach in its own right as a result of too many specific weaknesses. Similarly, relying on economic modelling as the principal approach for assessment was considered problematic. However, both approaches could well be of value in supporting roles as part of an assessment methodology. In all cases some degree of stakeholder engagement would be required to 'ground truth' scenarios and modelled outputs.

3.6 Modelling carbon impacts

Overall, forest carbon models were considered to have most advantages out of the possible approaches for evaluating temporal as well as contemporary impacts of forest management on carbon cycling in forest systems subject to a range of different management practices. However National Forest Inventory data in particular, as well as other relevant data sources have a role in supporting or informing carbon modelling.

Relevant models have been developed by a number of organisations and examples applicable in the geographical regions of interest to this current project include (not an exhaustive list):

- CARBINE developed in the UK
- CO2FIX originally developed in the Netherlands
- EFISCEN developed in Finland and the Netherlands
- CBM-CFS developed in Canada
- FORCARB2 developed in the USA, with regional variants
- FVS developed in the USA, with regional variants
- GLOBIOM in conjunction with G4M developed in Austria.

In principle, any of these models could be applied to assess forest carbon stocks and sequestration, and the potential impacts on these as a result of forest management and wood utilisation to supply woody biomass for use as an energy feedstock.

The models listed above are based on similar scientific principles and methodologies. Hence, they tend to have similar strengths and weaknesses, although with some notable differences. A comprehensive critical review of forest carbon accounting models (and other models of relevance to this project) would require significant effort but may be worth considering. Below, some key features of the selected models listed above are summarised. This assessment is based on the publicly available documentation for the models and on information provided for three of the models in a review paper by Kim et al. (2015).

In Table 3.1, details are given about the geographic regions in which each of the models have been applied and the spatial scales at which each model is most appropriate for application. Table 3.2 summarises the types of forest represented in the models, and how this representation is implemented. An assessment is also given in the table of the detail with which forest management practices and patterns of wood utilisation are represented in each model. For GLOBIOM-G4M, the information in Tables 3.1. and 3.2 relates to the G4M model, which is a relatively simple forest model incorporated into the GLOBIOM global-scale, multi-sectoral economic model, which includes a representation of land use based on grid squares.

It should be noted that all of the above models are mainly applicable to “high forest”, as opposed to the modelling of other land types with tree cover, such as parkland, coppice managed for production of small poles or land with scattered unproductive trees.

Table 3.1 Summary of regions and scales of application for selected forest carbon accounting models

Model	Regions where applied	Scales represented
CARBINE	Europe, Russia, Canada, USA, Brazil, Oceania, Japan	Stand, Landscape, National
CO2FIX	75+ countries in boreal, temperate and tropical regions	Stand (Landscape version available as CO2LAND)
EFISCEN	Europe, Russia	Landscape, National
CBM-CFS	Canada, Russia, Europe	Stand, Landscape, National
FORCARB2	USA, Canada	Landscape, National
FVS	USA	Stand, Landscape
G4M	Global	National, Global

Table 3.2 Summary of representation of forest types, forest management and wood utilisation in selected forest carbon accounting models

Model	Forest types	Forest management	Wood utilisation
CARBINE	Internal growth model representing 16 forest species, in combination with multiple growth rates. The user needs to describe stands or landscapes in terms of these. Calibrated for UK, requires “species mapping” (reliant on assumptions) when applied to tree other species in other regions.	Includes a dynamic growth model representing a range of thinning practices and felling rotations. Rough representation of uneven-aged forests.	Detailed representation of potential raw wood feedstocks (branch wood, small roundwood, sawlogs, bark, stumps and roots). Detailed modelling of the allocation of wood to a range of end uses (e.g. structural timber, panels, fuel).

Model	Forest types	Forest management	Wood utilisation
CO2FIX	Requires the user to supply information on the development of growing stock for a given stand. Has been extended to represent stands consisting of multi-species cohorts.	Generic representation of harvesting as thinnings and fellings. Allows a range of felling rotations.	Detailed representation of potential raw wood feedstocks. Detailed modelling of the allocation of wood to a range of end uses.
EFISCEN	Requires the user to supply information on growing stock and increment describing the forests in a given region (typically National Forest Inventory data).	Generic representation of harvesting as thinnings and fellings. Allows a range of felling rotations.	Optional module: Generic representation of potential raw wood feedstocks. Generic modelling of the allocation of wood to a range of end uses.
CBM-CFS	Requires the user to supply standard tables representing the growth of stands or forests in a given region	Generic representation of harvesting as thinnings and fellings. Allows a range of felling rotations.	Generic representation of potential raw wood feedstocks. Generic modelling of the allocation of wood to a range of end uses.
FORCARB2	Requires a separate large-scale forest forecasting system to provide inputs about the development of forests in a given region	Generic representation of harvesting as thinnings and fellings. Allows a range of felling rotations.	Generic representation of potential raw wood feedstocks. Detailed modelling of the allocation of wood to a range of end uses.
FVS	Requires bespoke calibration for tree species and growth rates of stands or forests in a given region	Includes a dynamic growth model representing a range of thinning practices and felling rotations. Potentially very detailed representation of thinning and felling practices.	Not represented.
G4M	Includes a generic growth model representing a wide range of growth rates. The user needs to describe stands or landscapes in terms of the distribution of relevant growth rates.	Generic representation of harvesting as thinnings and fellings. Allows a range of felling rotations.	Generic representation of potential raw wood feedstocks. Generic modelling of the allocation of wood to a range of end uses.

4 Review of approaches to address BEIS questions on bioenergy pellet demand impacts on forest carbon stock

The analysis undertaken in the literature review, presented in the Part A report and discussed in outline in Section 3 above, provides the basis on which to now develop and evaluate methodologies for addressing the objectives of this project (see Section 2.2).

It is certainly possible to assess the impact of changes in forest management on forest carbon dynamics, and the relationships between forest biomass growth and losses, forest management and forest carbon stocks and rates of sequestration are well known. That is not the most difficult aspect. The difficulty arises in ensuring that the representativeness of scenarios developed for describing on-the-ground forest management practices in response to demand for biomass for pelleting (and possible counterfactual scenarios), including the adequate reflection of the range of possible forest management decisions. The remaining related difficulty lies in understanding or predicting how forest management might change in the future, particularly in response to differing sustainability criteria.

All this inevitably means that scenario modelling needs to form the basis of any assessment and the key requisite is ensuring the scenarios represent realistic and likely forest practices as far as possible, how these might change under different (defined) situations, as well as identifying the most relevant supply regions and forest types involved.

The main methodologies for scenario construction have already been identified in Part A and have been listed in Section 3.5. A preliminary assessment of the suitability of these methodologies was also included in the Part A report; each has some associated issues as also noted in Section 3.5.

Based on these assessments, it is concluded that:

- A modelling approach is the most appropriate methodology for assessing the short-term and long-term impacts of different scenarios relevant to actual and possible biomass energy policies (which includes examining the impact of policies that deprioritise use of biomass for energy).
- A robust methodology needs to be designed for constructing the scenarios, to be used as a basis for parameterising forest sector carbon accounting models.
- Several candidate methodologies exist for the construction of scenarios, which require further evaluation.

With regard to the possible methodologies for constructing scenarios, it is concluded that:

- A methodology based principally on the analysis of data on forest biomass use by the wood-processing and biomass energy sectors (by feedstocks) is unsuitable for further development and evaluation as a central study methodology. However, insights and understanding into relevant wood biomass supply chains, gained from these data sources (where available), are likely to form a very important supporting component of any methodology.
- The application of economic models is undeniably of considerable value as a means for analysing potential systematic changes in the forestry, wood biomass and energy sectors in response to possible and actual bioenergy policies. However, economic modelling would appear to be most appropriately applied when providing evidence and insights as a supporting component of any methodology.
- Suitably designed stakeholder consultation (with clearly defined objectives) needs to form a component of any methodology and in addition the possibility for using this approach as the central methodology.

- Methodologies involving the formulation of a set of stated assumptions or based on “real-life” case studies should be further elaborated and assessed for their potential as a primary methodology.

Regardless of methodology, the presumption is made that three scenarios should be constructed for the purpose of making the assessments of interest, as already identified in the Part A Report given in Section 3.4.1. For clarity these are repeated below:

1 “With bioenergy” - i.e. a scenario representing current practice with existing bioenergy policies
2 “Counterfactual” or “baseline” - likely practice in the absence of a demand, or reduced demand, for bioenergy
3 “Refined criteria” or “enhanced sustainability” – scenario(s) in which sustainability criteria attached to bioenergy sources are refined in accordance with management changes to try and reduce the risk of detrimental impacts on forest carbon stocks (e.g. as proposed in Matthews et al., 2018).

The inclusion of a counterfactual scenario representing a baseline in the absence of a demand for bioenergy permits the scenarios representing current bioenergy use and representing possible future bioenergy use regulated by refined sustainability criteria to be assessed against this common baseline. Hence, it is possible to assess the impacts on forest carbon stocks innately associated with each of the bioenergy scenarios and to compare these with one another. If no baseline scenario is defined, it is still possible to assess the impacts of one bioenergy scenario relative to the other, but it is not possible to assess the impacts of the two bioenergy scenarios independently.

These conclusions suggest a generic structure as shown in Figure 4.1 for any full-scale study of the effect of wood pellet demand on forest carbon stocks, and any potential influence of defined sustainability criteria.

The development and evaluation of specific methodological options forms the main content of Part B of this project and is presented in the ensuing sections of this report.

The options considered are:

1. Region-focussed stakeholder-led assessment
2. Installation-focussed case study assessment
3. Assumptions-based assessment.

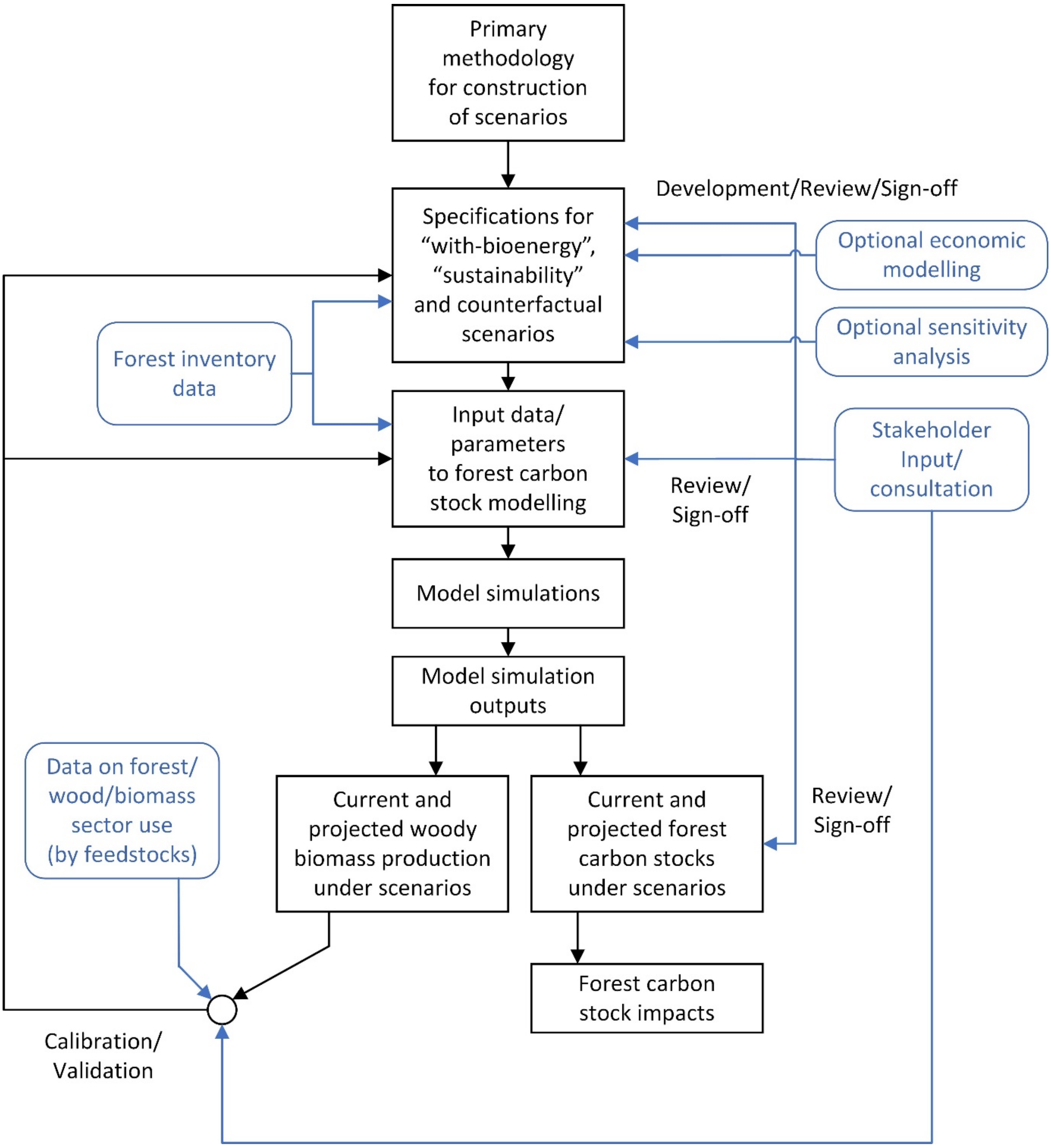

Figure 4.1. Suggested generic structure of methodology for a full-scale study of the effect of wood pellet demand on forest carbon stocks

The Part A report concluded by noting that the option of not proceeding with a full-scale study should also be considered, given the many uncertainties and technical difficulties identified in the literature review. Hence, this is also assessed as a fourth option alongside the three options identified above.

The assessments of the four options discussed above are presented in the following sections of this report:

- Option 1 – Region-focussed stakeholder-led assessment (Section 5)
- Option 2 – Installation-focussed case study assessment (Section 6)
- Option 3 – Assumptions-based assessment (Section 7)

- Option 4 – Not proceeding with a full-scale study (Section 8).

Each option is assessed systematically according to the following scheme:

- Methodology – an outline description of the structure and methods likely to be employed in the study, consisting of the main tasks, procedures and entities involved and their interrelationships, including a diagrammatic illustration
- Materials/data/tools required – the main types of materials, data and tools required to carry out the study, including a brief consideration of any implications in the event that key resources may not be available
- Staff requirements – a list of the staff resources (including types of role, expertise and skills) likely to be required to carry out the study
- Stakeholder inputs – the suggested composition and role(s) of stakeholders required for the study
- Duration – an estimate of the likely time required to carry out the study; this is based on the judgement of the authors of this report
- Cost – an estimate of the likely costs of the study; this is based on notional day rates for staff resources and estimates of costs for materials, data and tools, as judged by the authors of this report
- Key strengths and weaknesses – a qualitative assessment of the key strengths and weaknesses likely to be associated with the study approach
- Effectiveness – partially informed by the assessment of strengths and weaknesses, a qualitative assessment of the likely effectiveness of the study in addressing the objectives set by BEIS, covering a range of criteria as listed in Table 4.1, including the first four questions listed in Section 2.2. (The fifth question in the list, concerned with study duration and cost, is addressed above.) As also shown in Table 4.1, each criterion is allocated a maximum number of points such that the maximum score for effectiveness that can be allocated to a study option is 100.

The possibility may be noted of applying a combination of the optional methodologies discussed in this report. Brief consideration is given to this possibility in Section 9.1.

Some clarification is appropriate of the basis for estimating project costs. The main costs estimated are those associated directly with the staff time of the study team, for which a notional day rate has been assumed. Total staff costs have been estimated by combining the assumed day rate with estimates for the project duration and assumptions about productive time of researchers spent on the project over its life cycle. Costs associated with overheads, infrastructure, consumption of materials and travel associated with the project have not been estimated explicitly but are assumed to be covered within the assumed staff day rate.

Table 4.1 Criteria for assessment of study effectiveness

Criterion	Basis of assessment	Maximum points allocation
BEIS Q1 (current impact)*	In the judgement of the authors of this report, the effectiveness of the study in addressing the question posed by BEIS, “What effect has the supply of wood pellets to UK power stations had on the forest carbon stocks in SE USA, Canada and Europe?”	15
BEIS Q2 (sustainability scenario)*	In the judgement of the authors of this report, the effectiveness of the study in addressing the question posed by BEIS, “How would the situation with forest carbon stock have been affected if alternative sustainability criteria had been in place?”	15
BEIS Q3 (maximising sustainable supply)*	In the judgement of the authors of this report, the effectiveness of the study in addressing the question posed by BEIS, “How can we maximise the sustainable yield and what are the risks and challenges of doing this? How will that change in the future?”	15
BEIS Q4 (wider relevance)*	In the judgement of the authors of this report, the effectiveness of the study in addressing the question posed by BEIS, “How applicable would any conclusions be to other areas of potential forest biomass supply?”	10
Transparent	An assessment of the extent to which the methods of the study and any calculations or results would be openly apparent for review and checking by stakeholders.	10
Understandable	An assessment of the extent to which non-expert stakeholders should be able to follow the study methods and understand how the results have been produced.	10
Data available	An assessment of the likelihood of the data needed to undertake the study being readily available and suitable for use without major processing or analysis.	10
Wide acceptance	An assessment of the likelihood that the results and conclusions of the study would gain wide acceptance amongst stakeholders or otherwise would be defendable by BEIS	5
Transferrable	An assessment of the suitability of the study methodology for application in other geographical regions or different situations involving the use of woody biomass as an energy feedstock.	5
Wider applications	An assessment of whether the study methodology or results would be relevant for addressing other questions or for other research or policy applications.	5
TOTAL score		**100**

* Note: For BEIS Questions 1 to 4, this includes an assessment of “tractability”, i.e. the likelihood that the question can be addressed by the methodology without encountering major obstacles and, if these obstacles are encountered, the extent to which it might be practical to address them.

Costs have also been included to support the involvement of stakeholders, as specified for each option. An annual cost of £5k per stakeholder has been assumed. This is taken to represent an honorarium paid to each stakeholder to encourage engagement in the study, whilst also covering any expenses, potentially including significant costs for travel and accommodation. An alternative approach would be to reimburse stakeholders for any expenditure explicitly incurred as a result of their participation in the study. The details are of course entirely a matter for an authority commissioning a study to decide.

5 Option 1 – Region-focussed stakeholder-led assessment

5.1 Objective and methodology

5.1.1 Objective

Under this option the objective is to estimate actual and/or potential impacts on forest carbon stocks arising from the management of forests within a defined geographical region, associated with relevant scenarios for the supply of woody biomass for use as an energy feedstock.

5.1.2 Methodology

The principal methodology employed for the development of scenarios is stakeholder engagement and consultation. A schematic diagram of the methodology is shown in Figure 5.1. The rationale for including significant stakeholder input is that this provides insight into the behavioural characteristics of forest owners and how they are likely to respond to changing circumstances, which is often difficult to predict through modelling exercises and expert review alone. For example, individual forest owners are best placed to comment on how or whether they may change species when considering replanting and the key information that would influence changes in harvesting behaviour. There are commonly time lags affecting management changes which reflect this wider influence of behavioural change. Utilising input form stakeholders helps to incorporate these wider impacts in the round when comments on likely responses to changing drivers to increase or decrease interest in biomass supply are discussed.

5.1.3 Tasks

Task 1: Identify a relevant geographical region – this is likely to be geopolitically defined, e.g. a country, province, state, county or similar, which is considered to be relevant to the supply of woody biomass for use as an energy feedstock in the UK. Target geographical regions may be selected by BEIS, informed by advice from stakeholders including information from pellet end users to identify the relevant supplying regions.

Task 2: Assess the quantity of woody biomass being supplied to the UK from the region; this may be based on relevant forest/biomass sector data (where available), informed by expert stakeholder judgement if required. Also assess how the quantity of woody biomass supplied to the UK may change in the future under the scenarios specified by BEIS (baseline, current bioenergy, enhanced sustainability); this will be determined by stakeholder input.

If considered appropriate/desirable, economic modelling could also be applied (or results from existing relevant economic studies could be reviewed) to inform the construction of projections of woody biomass production from the region under the specified scenarios. The resultant projections and underlying information and assumptions should be documented and reviewed by the stakeholder group.

Task 3: Characterise the current composition of forest areas in the region according to relevant factors, e.g. tree species, growth rates, soil types, tree/stand ages, ownership types, current management (and intended management). This will involve assessing and analysing relevant forest inventory data and

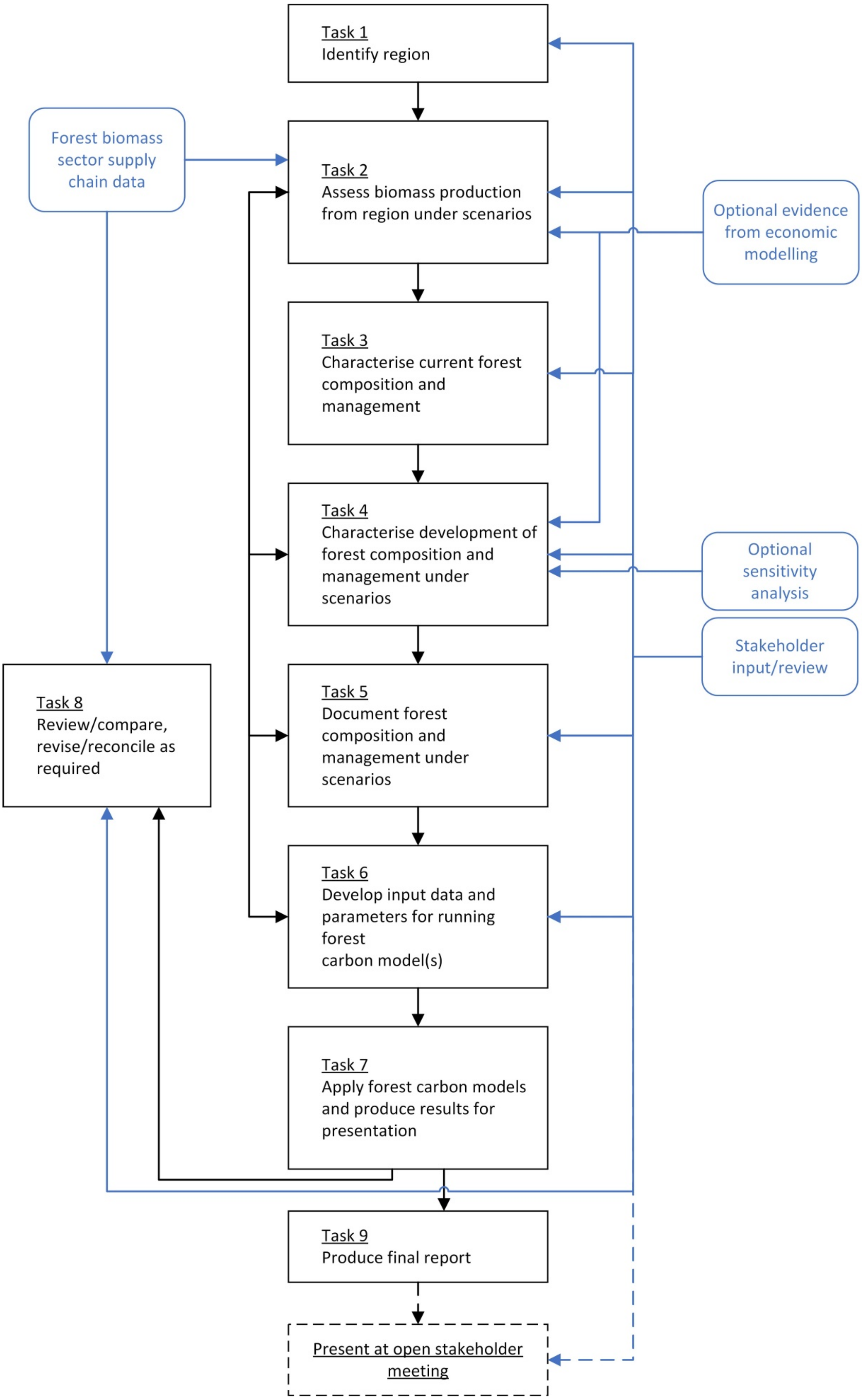

Figure 5.1 Schematic diagram of Option 1 study methodology

other relevant forest information sources (e.g. yield tables), where these sources are available, supplementing these as required with assumptions derived from consultation with stakeholders.

Task 4: Characterise the likely development of forest composition in the region under the scenarios defined by BEIS (baseline, current bioenergy, enhanced sustainability). Data sources such as national forest inventories can be referred to when characterising the current forest composition in the region in terms of tree species, growth rates, tree age distributions and (possibly) some aspects of forest management. However, it is also important to characterise which specific forest areas within a region are (or may be) involved in supplying biomass for use as an energy feedstock, e.g. which specific tree species might be involved. It is also important to consider how management of forest areas for bioenergy production might affect future species composition (e.g. as a result of one tree species being planted in place of another one when restocking harvested stands). These aspects will be determined principally by stakeholder input but possibly informed by economic modelling, where such models include a sufficient representation of the forest sector. The application of economic modelling may be of particular relevance if dynamics of land-use change (afforestation and forest loss) are considered relevant for representing in scenarios, to inform stakeholder discussions and the formulation of assumptions.

Task 5: Document the information on forest composition and management in a report. Submit the report for review by stakeholders and revise as necessary.

Task 6: Develop data and parameters for use as inputs to a suitable forest sector carbon accounting model (or more than one of them for cross-validation). Document the data and parameters and demonstrate how these are derived from the information on forest composition and management under the specified scenarios developed in Tasks 4 and 5. Revise as necessary following stakeholder review.

Task 7: Apply the forest sector carbon accounting model(s) to produce simulations and results for the development of forest carbon stocks, for each of the specified scenarios (baseline, current bioenergy, enhanced sustainability). Process the results into a form suitable for presentation to stakeholders and wider communication; this includes estimating impacts on forest carbon stocks obtained by comparing results for bioenergy scenarios with those for the baseline scenario, and with each other.

Task 8: If necessary, repeat Tasks 2 and 4 to 7 iteratively, making revisions as necessary, to ensure consistency in the outputs and outcomes of the various tasks. For example, the biomass supply simulated by the forest sector carbon accounting model(s) in Task 7 may require reconciliation with, or calibration against the estimated quantities suggested by the outcomes of the assessments in Task 2. Stakeholders may have an important role in “reality-checking” the overall outcomes of Tasks 2 and 4 to 7 and advising on modifications as necessary. The option of carrying out a sensitivity analysis may be pertinent at this stage, with the aim of building confidence in the study results in providing robust evaluations of the specified scenarios whilst also characterising likely ranges and/or uncertainties associated with results.

Task 9: Document the methods, results and conclusions of Tasks 2 to 8 in a final report, submit for review by stakeholders, amend as necessary and obtain sign-off.

Task 10 (optional): Present findings of the study at an open stakeholder meeting, supported by the study stakeholder group.

5.1.4 Representation of forest areas

The approach taken to representing the composition and management of forest areas in Tasks 3 and 4, the associated modelling in Tasks 6 and 7, will depend on two factors:

1. The completeness and accessibility of data describing forest composition and management (e.g. the data available from forest inventories and management plans)
2. The views of the stakeholder group involved in the study, particularly with regard to how model results are to be presented and understood more widely.

Essentially, subject to the above there are three possible approaches:

1. Selection of a set of exemplar stands of trees, designed to represent key component of forests in the region, with associated stand-scale modelling of forest carbon stocks
2. Selection of a set of exemplar forest types, to represent key component of forests in the region, with associated modelling based on theoretical populations formed of stands of each of the exemplar forest types, with notional age distributions
3. Representation of the actual composition of forest areas at the landscape scale, based on best available sources of forest information (e.g. forest inventory data) and associated modelling at the landscape scale.

The use of theoretical populations of stands or individual exemplar stands benefits from requiring less data input, and being easier to model, but concurrently the outputs are of less value to the wider regional situation and will tend to overlook wider temporal and landscape effects. The choice of approach based on forest stand or landscape scenarios and outputs can be put to stakeholder review to improve the reliability of the final outputs. Depending on the outcome of discussions with the study stakeholder group, any of the above methods may be applied in the study, or some combination, for example stand-scale modelling to assist with transparency and understandability and landscape-scale modelling to estimate impacts on forest carbon stocks representative for the region in relation to projected levels of biomass supply.

5.2 Materials, data and tools required

The main requirements for this study option are:

- Good meeting facilities for face-to-face meetings with stakeholders (possibly in the UK or abroad or both); this is an essential requirement for the study
- Relevant sources of forest biomass sector supply chain data for the region of interest, to the extent that they exist and are accessible; if not available, this may be mitigated to an extent by more extensive stakeholder consultation
- Relevant data on current forest composition and management (see Section 5,1.4); if not available, this may be mitigated to an extent by more extensive stakeholder consultation
- Access to (and the capacity to apply) one or more forest sector carbon accounting model(s); this is an essential requirement for the study
- If considered to be a desirable element of the project methodology, access to (and the capacity to apply) a relevant economic model of the forestry, wood industry and/or biomass sector(s) applicable for the study region
- Computing facilities for the storage of data and results and for running numerically intensive model simulations, with associated QA and QC processes,

5.3 Staff requirements

The indicative requirements for staff directly deployed to work on the study (not necessarily full time) are:

- Project leader
- Experienced and credible facilitator for stakeholder engagement; alternatively, this individual could be appointed independently of the study team (see Section 5.4)
- At least one expert on the forest sector and biomass supply chains
- At least one expert in applying the forest sector carbon accounting model(s) applied in the study
- Manager and curator of study data sources, results and other products, including version control
- Staff member responsible for ensuring QA and QC.

In addition, if economic modelling were to be considered a desirable option for the project methodology, there would be the following staff requirements:

- At least one expert on economic modelling applied in the forestry/wood industry/biomass sector(s)
- At least one expert in applying the economic model applied as part of the study.

It may be noted that one or more individual team members could possibly take on more than one of the roles described above. One staff member amongst the above would take on the role of rapporteur for the stakeholder group (see Section 5.4.2).

5.4 Stakeholder inputs

For this study option, stakeholder engagement and inputs form the central element of the methodology for scenario development. Hence, the functions and consequent composition of the study stakeholder group are particularly important.

5.4.1 Stakeholder functions

The study stakeholder group would be required to fulfil the following functions:

- Confirming the geographical scope of the specified study region(s) in Task 1
- Assisting with the assessment of biomass production from the region(s) under the specified scenarios in Task 2, subject to any evidence available in the form of forest biomass sector supply chain data
- Taking a major role in characterising current and future forest composition and management in the region(s) under the specified scenarios in Tasks 3, 4 and 8 (see subsequent discussion)
- Reviewing and signing off the documentation of forest composition and management under scenarios in Task 5
- Reviewing and signing off the input data and parameters for running forest carbon model(s) in Task 6 as consistent with the defined and documented scenarios from Task 5
- Carrying out a "reality check" on the study results and overall outcomes in Task 8 and advising on modifications or refinements to scenarios or modelling as required
- Reviewing and signing off the final study report produced in Task 9, seeking amendments if required

- Supporting the presentation of the study and its findings at an open (wider) stakeholder meeting in Task 10 (assuming this option is taken up).

5.4.2 Composition of stakeholder group

The suggested composition of the study stakeholder group is given in Table 5.1. The group is relatively large, for two reasons:

1. To ensure that all relevant areas of expertise are included
2. To demonstrate openness and permit the representation of a diversity of stakeholder interests.

Table 5.1 Suggested composition of stakeholder group

Stakeholder role	Number
Facilitator (study staff or independent, see Section 5.1.3)	1
Forest owners, forest owner representative organisations and/or forest management companies within the region	2
Wood industries within the region (pellets/non-pellets)	2
Environmental NGOs active within the region	1
UK or European environmental NGO	1
BEIS representative (optional)	1
Forest sector researcher, ideally active within region	1
Environmental scientist/ecologist, ideally active within region	1
UK forest sector/biomass supply chain researcher (study staff member, see Section 5.3)	1 or 2
Rapporteur (study staff, see Section 5.3)	1
Total	**12/13**

5.4.3 Conduct of business

It is envisaged that the decisions, recommendations and any actions of the study stakeholder group would be taken on the basis of consensus; achieving anything less than this could compromise the credibility and ability to defend the results and conclusions (see Section 5.4.4). The deliberations of the stakeholder group would remain confidential until the study has concluded. However, afterwards, members of the stakeholder group should be free to discuss the proceedings, in the interests of openness.

The critical contribution of the stakeholder group is in developing and specifying the details of the scenarios for biomass production and consequent forest management to be modelled as part of the study (see Tasks 2 to 5 and 8 in Section 5.1.3, notably Task 4). The process for achieving this is envisaged as involving the following steps:

Step 1 – Providing advice to the study team during the collation of sources of relevant information and evidence (Tasks 2 to 5).

Step 2 – Reviewing and assessing the importance and usefulness of sources of information and evidence; this may include working with economic modellers to develop supporting evidence and insights with regard to the possible evolution in the actions of forests owners, in particular in terms of decisions about forest management (Tasks 2 to 5).

Step 3 – Advising on, reviewing and commenting on the characterisation of forest areas in the study region(s), including current forest management activities; this may also include an assessment of confidence or uncertainties attached to estimates of forest composition and management (Task 3).

Step 4 – Identifying different ways in which forest management may be different or may change under the specified study scenarios (baseline, current bioenergy, enhanced sustainability), including assessing the likelihood of different types of management (change). As above, this may include working with economic modellers to develop supporting evidence and insights with regard to the possible evolution in the actions of forests owners, in particular in terms of decisions about forest management. In addition, recommendations could be made on the uncertainties that should be attached to different types of change in forest management activity, notably with regard to their likelihood (Task 4).

Step 5 – Reviewing the documentation of the above process produced by the study team, advising on corrections, modifications or refinements if required and signing off a report describing the outcomes, including details of the scenarios (Tasks 5 and 6).

Step 6 – Contributing to the iterative improvement of the scenarios as required (Task 8).

5.4.4 Process in the event of disagreement amongst stakeholders

According to the process envisaged, individual stakeholders do not need to abandon specific agendas that they may represent or support when approaching discussions of the stakeholder group (in fact the proposed composition of the stakeholder group recognises the need to reflect the diversity amongst such agendas in society). Nevertheless, the success of this study methodology depends crucially on the willingness of all members of the stakeholder group to contribute openly and objectively to the development of the study scenarios and to strive to achieve consensus. Stakeholders would also be expected to adhere to a similar culture in all other activities and any communications related to the study,

The possibility must be considered that an important disagreement may remain within the stakeholder group at some critical stage of the deliberations and which proves to be impossible to resolve, despite best efforts. In such circumstances, there could be two possible responses:

1. Abandon the study, document what was done including the nature of the disagreement and the basis of the decision to close the study down
2. Continue with the study but develop alternative scenarios reflecting the disagreement. Model all scenarios and consider the differences in estimated impacts. Discuss the disagreement and the reasons for it openly in the final report, and comment on the implications for the estimate derived for carbon stock impacts.

5.4.5 Appointment of stakeholders

There would appear to be two possible ways to appoint members of the stakeholder group:

1. BEIS and the study team identify relevant individuals and invite them to participate
2. BEIS issues a call for stakeholder group members. Individuals apply by submitting letter of application, a CV and a statement showing how they meet certain selection criteria (to be defined).

It may be appropriate to pay an honorarium to stakeholder members to secure their active participation in the study.

5.5 Duration

The estimated duration of the study depends on the number of regions specified for study. Indicative estimated study durations are:

- 18 months (1 region)
- 24 months (2 regions over the same period)
- 36 months (up to 4 regions over the same period).

It may be noted that the possibility exists to proceed with an initial study of up to 2 regions. The performance of this study could then be assessed, with the option of proceeding with a further study or studies in the event of a successful outcome and there being sufficient interest in further work.

5.6 Cost

The estimated directly incurred study team costs depend on the number of regions specified and whether more than one region is studied over the same period. Indicative costs on this basis are shown in Table 5.2.

Table 5.2 Estimated costs directly incurred to support work of study team

Regions studied	Estimated cost (£k)
1 region (1 carbon model)	325
1 region (2 carbon models)	375
2 regions studied in succession (1 carbon model)	650
2 regions studied in succession (2 carbon models)	750
2 regions studied over the same period (1 carbon model)	435
2 regions studied over the same period (2 carbon models)	500
4 regions studied over the same period (1 carbon model)	650
4 regions studied over the same period (2 carbon models)	750

The costs for securing the co-operation from the study stakeholder group, if considered necessary, are estimated at between £70k to £130k, per region studied, depending on the basis of the payment.

5.7 Key strengths and weaknesses

The key strengths and weaknesses of the study option are listed in Table 5,3.

Table 5.3 Summary of key strengths and weaknesses of study option

Strengths of approach	Weaknesses of approach
Once relevant region is identified regional forest management organisations, universities and NGOs active in the region can be identified to facilitate engagement. Provides a regional-scale assessment of impacts. Can work with available forest and biomass sector data (although the more data that is available, the better). Modifying the scenarios allows some examination of sensitivity. If stakeholder sign-off is obtained, should provide a credible assessment of the impacts of UK bioenergy policy on forest carbon stocks in the region, under the specified scenarios.	Complex - needs significant data processing and integration and interpretation of stakeholder views to provide the inputs to models. Needs a significant body of stakeholders to co-operate to provide a meaningful and coherent information for the construction of scenarios for the region of study. Some or all stakeholders may be reluctant to co-operate, in particular to endorse the study outcomes. It may prove impossible to achieve consensus amongst stakeholders. Need for significant consultation extends project duration and adds to costs.

5.8 Assessment of effectiveness

Table 5.4 presents the qualitative assessment of the effectiveness of the study option.

Table 5.4 Qualitative assessment of effectiveness of study option

Criterion	Qualitative assessment	Score
BEIS Q1 (current impact)*	Provided that the stakeholder groups all support the study outcomes, this option should provide a credible assessment for the regions studied. Stakeholders can support modelling efforts in cases where	12

	data are limited. Disagreement within stakeholder groups could increase the uncertainty associated with study results, and in the extreme case could compromise the study. The study results would only be directly applicable for the specific region(s) studied.	
BEIS Q2 (sustainability scenario)*	As above but requires extrapolation from current forestry practice and wood supply chains to a hypothetical situation under the scenario considered in this question.	10
BEIS Q3 (maximising sustainable supply)*	The methodology in this study option could be applied to assess the maximum possible supply of biomass from a specified region, for use as an energy feedstock, allowing for specified sustainability criteria. Hence, the study should be able to inform understanding of how the maximum estimated yield of biomass within a region depend on the specified sustainability criteria. The question of assessing risks and challenges associated with realizing this potential would appear to be a policy analysis question with a different scope to that of this study.	7
BEIS Q4 (wider relevance)*	As noted above, the study results would only be directly applicable to the specific region(s) studied. However, it may be possible to comment on where similar outcomes might be expected in other regions of the world, noting that this may be uncertain.	5
Transparent	Provided that the documentation is sufficient, the basis for the construction of scenarios, and for the development of model simulations, should be completely open.	9
Understandable	Provided the transparency criterion is met, it should be straightforward to follow how the scenarios have been constructed. The way in which results for forest carbon stocks have been modelled for very large regions may not be immediately apparent but could be explained in a supporting discussion and backed up with some simple example stand-scale model simulations, if considered necessary.	8
Data available	Reasonable data are available for regions within the USA, Canada and Europe, with some exceptions. There will be limited data available in many other regions. The study methodology takes account of limitations in data by stressing the possibilities for gaining understanding of forestry in the region through stakeholder engagement and by employing simplified modelling approaches if needed.	8
Wide acceptance	Provided that the selected stakeholder group is willing to endorse the findings of the study, there is a good chance that the conclusions could gain wide acceptance. In the event of an unresolved disagreement amongst stakeholders, if BEIS decides to continue with the study, there is a reasonable chance of being able to defend the study conclusions, as long as the engagement with the stakeholders is managed well, i.e. openly acknowledging any disagreements and reporting any implications for uncertainties in results.	4
Transferrable	The methodology could be applied in other geographical regions or situations but this is very dependent on being able to identify and engage with strong and well-informed stakeholder groups.	4
Wider applications	In principle a stakeholder-led methodology could be adapted to address related applications, e.g. more complete LCA of bioenergy supply chains and non-energy biomass products. The approach could also be extended to cover aspects of policy development by BEIS (e.g. further refinement of sustainability criteria).	3
TOTAL score		**70**

6 Option 2 – Installation-focussed case study assessment

6.1 Objective and methodology

6.1.1 Objective

Under this option the objective is to estimate actual and/or potential impacts on forest carbon stocks arising from the supply of wood to a single processing facility (e.g. a wood pellet mill), or possibly a group of relevant associated wood processing facilities, associated with relevant scenarios for the supply of woody biomass for the production of wood fuel.

6.1.2 Methodology

The principal methodology employed for the development of scenarios is a case study approach, focussed around the specified facility, or group of facilities, identifying the key feedstock suppliers and forest owners who would then be targeted to identify management practices and possible relevant counterfactual approaches (likely alternative management responses) under different or changed circumstances. The scenarios derived for the case study would then provide the inputs to the assessment of forest carbon dynamics in a similar way to that described for Option 1 in Section 5. However, given that the scenarios are developed for a case study based on forest areas identified directly as supplying specified wood processing facilities, the need for extensive stakeholder input is reduced compared to study Option 1. A schematic diagram of the methodology is shown in Figure 6.1. A key requirement is the willingness of a processing facility to engage with the study and provide relevant data which could pose a significant challenge to any project team.

6.1.3 Tasks

Task 1: Identify a relevant installation, or group of installations, to form the basis for a discrete case study. Examples might involve a wood pellet producing facility, operating in isolation from other installations, or such a facility operating as part of a larger installation, such as a combined sawmill and wood pellet mill. Another possibility might consist of a small group of wood processing facilities operating in close proximity, such as a wood pellet mill, sawmill and paper mill with closely overlapping catchments in terms of forest areas supplying biomass to them. Critical consideration in selecting the subject(s) for the case study are:

- A clear relevance to study objective (i.e. supply of woody biomass to the UK for use as an energy source),

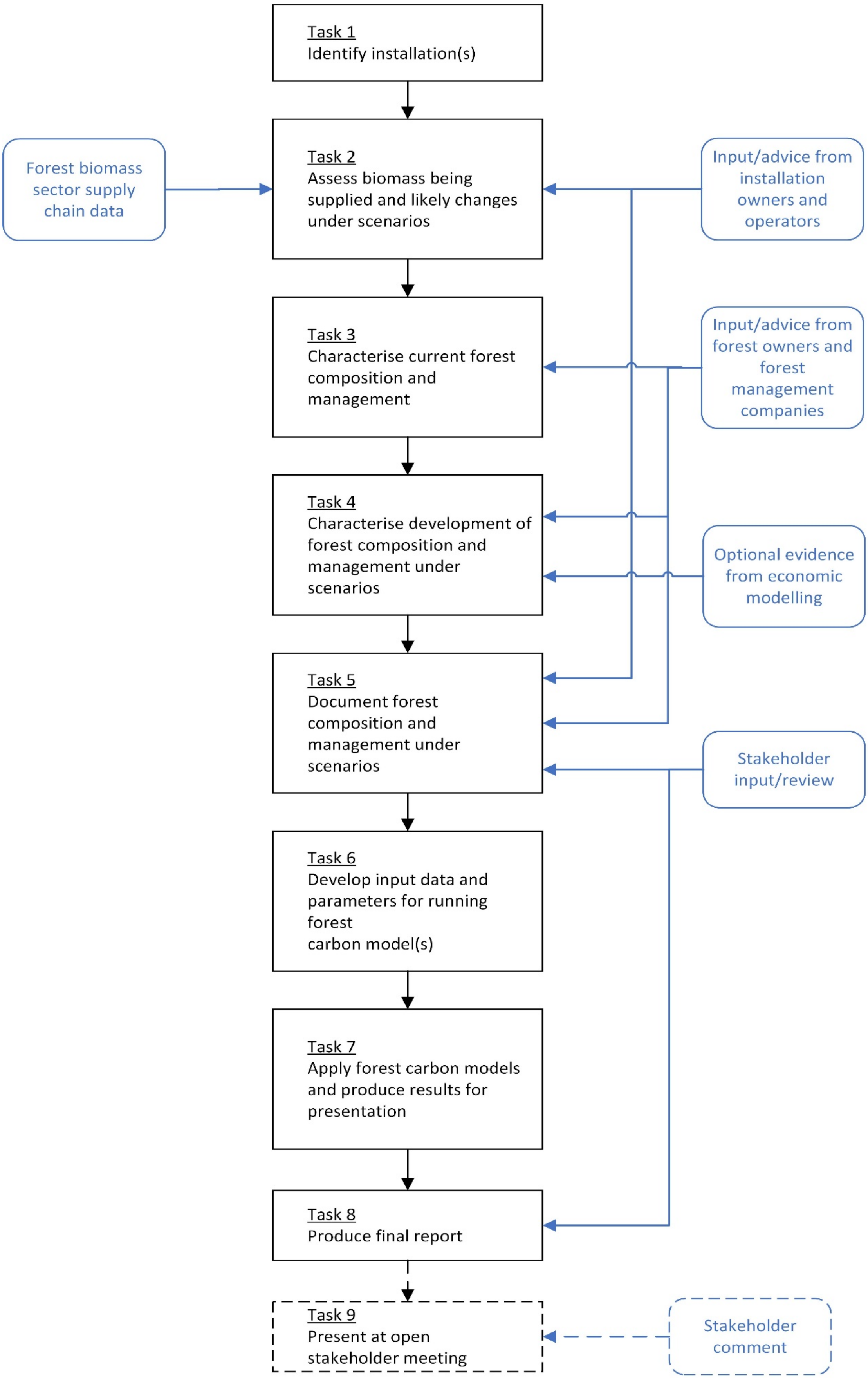

Figure 6.1 Schematic diagram of Option 2 study methodology

- In the case of a group of facilities, close association in terms of relying upon common and/or interrelated forest resources for biomass supply
- Strong interest and willingness from the companies owning and running the facility or facilities to co-operate in undertaking the case study.
- The process for identifying and approaching suitable installations for study would need to be determined by BEIS in discussion with the study team.

Task 2: Assess the quantity of woody biomass being supplied to the installation(s); this should be based on data for the relevant wood processing facilities. For transparency, this means that the installation(s) need to be willing to share the relevant information openly. In addition, working with the operators of the installation(s), identify the types of forest areas involved in supplying woody biomass, including characterizing the types of feedstocks consumed. Also assess how, in the judgment of the installation operators, existing utilization of forest resources and feedstocks would be likely to change under a counterfactual scenario, and a scenario in which enhanced sustainability criteria were to apply. The resultant information and assumptions should be documented and reviewed by the study stakeholder group (see Section 6.4).

Task 3: Characterise the current composition of forest areas in the biomass supplying catchment for the installation(s), according to relevant factors, e.g. tree species, growth rates, soil types, tree/stand ages, ownership types, current management (and intended management). This will involve assessing and analysing relevant forest inventory data and other relevant forest information sources (e.g. yield tables), where these sources are available, supplementing these as required with assumptions derived from consultation with stakeholders. Forest owners and forest management companies within the catchment form an important group of stakeholders, since the possibility exists to consult them about how forest areas have been managed in actual practice to supply biomass feedstocks to the installation(s). If at all possible, a sample of forest owners and forest management companies should be contacted to provide relevant information and advice.

Task 4: Characterise the likely development of forest composition in the catchment under the scenarios defined by BEIS (baseline, current bioenergy, enhanced sustainability). Ideally this should be determined principally by consultation with the installation operators and a contact group of forest owners and forest management companies in the catchment (see Task 3). If the necessary level of engagement with local actors cannot be achieved, then input will need to be sought from forestry experts with knowledge of the region (e.g. forest owner organizations and forestry researchers). Possibly, this exercise could be informed by economic modelling, where such models include a sufficient representation of the forest areas within the catchment. The application of economic modelling may be of particular relevance if dynamics of land-use change (afforestation and forest loss) are considered relevant for representing in scenarios.

Task 5: Document the information on forest composition and management in a report. Submit the report for review by a stakeholder group (see Section 6.4) and revise as necessary.

Task 6: Develop data and parameters for use as inputs to a suitable forest sector carbon accounting model (or more than one of them for cross-validation). Document the data and parameters and demonstrate how these are derived from the information on woody biomass consumption by the installation(s) and the development of forest composition and management under the specified scenarios developed in Tasks 4 and 5.

Task 7: Apply the forest sector carbon accounting model(s) to produce simulations and results for the development of forest carbon stocks, for each of the specified scenarios (baseline, current bioenergy, enhanced sustainability). Process the results into a form suitable for presentation to stakeholders and wider communication; this includes estimating impacts on forest carbon stocks obtained by comparing results for bioenergy scenarios with those for the baseline scenario, and with each other. The option of carrying out a sensitivity analysis may be pertinent at this stage, with the aim of building confidence in the study results in providing robust evaluations of the specified scenarios whilst also characterising likely ranges and/or uncertainties associated with results.

Task 8: Document the methods, results and conclusions of Tasks 2 to 7 in a final report and submit for review by stakeholders. Amend in the light of comments from stakeholders. However, it is not necessary to obtain the approval or sign-off of stakeholders.

Task 9 (optional): Present findings of the study at an open stakeholder meeting, supported by the participating installation owners and operators and forest owners and forest management companies, as appropriate.

6.1.4 Representation of forest areas

The discussion in the description of study Option 1 regarding the representation of forest areas (Section 5.1.4) also applies here. In addition, it should be noted that the possibility may exist under this study option of working with data of direct relevance to the supply of the woody biomass feedstocks consumed by the installation(s), where these exist and can be made available by the installation operators or relevant forest owners and forest management companies.

6.2 Materials, data and tools required

The main requirements for this study option are:

- Relevant sources of data on forest biomass consumption by the installation(s) under study; this is an essential requirement for the study
- Relevant data on current forest composition and management (see Section 6,1.4); if not available, this may be mitigated to an extent by consultation with regional experts
- Access to (and the capacity to apply) one or more forest sector carbon accounting model(s); this is an essential requirement for the study
- If considered to be a desirable element of the project methodology, access to (and the capacity to apply) a relevant economic model of the forestry, wood industry and/or biomass sector(s) applicable for the study region
- Computing facilities for the storage of data and results and for running numerically intensive model simulations, with associated QA and QC processes,

6.3 Staff requirements

The indicative requirements for staff directly deployed to work on the study (not necessarily full time) are:

- Project leader
- At least one expert on the forest sector and biomass supply chains
- At least one expert in applying the forest sector carbon accounting model(s) applied in the study
- Manager and curator of study data sources, results and other products, including version control
- Staff member responsible for ensuring QA and QC.

In addition, if economic modelling were to be considered a desirable option for the project methodology, there would be the following staff requirements:

- At least one expert on economic modelling applied in the forestry/wood industry/biomass sector(s)
- At least one expert in applying the economic model applied as part of the study.

It may be noted that one or more individual team members could possibly take on more than one of the roles described above.

In addition to the staff directly involved in delivering the study, the active participation of the following groups is essential:

- The owners and operators of the installation(s) being studied
- At least some representatives of forest owners and forest management companies involved in supplying feedstocks to the installation(s).

6.4 Stakeholder inputs

For this study option, stakeholder engagement takes two forms:

1. The active participation in the case study by installation owners and operators and representatives of forest owners and forest management companies (see Section 6.3)
2. The involvement of stakeholders external to the study, who review and comment on key stages in the development of the case study.

The following discussion is concerned with the second group of stakeholders.

6.4.1 Stakeholder functions

The study stakeholder group would be required to fulfil the following functions:

- Towards the conclusion of Task 2, reviewing and commenting on the documentation of the analysis of feedstock consumption by the installation(s), including the assessment of how consumption might change under a counterfactual scenario, and a scenario involving enhanced sustainability criteria
- Towards the conclusion of Task 5, reviewing and commenting on the documentation of forest composition and management under scenarios
- Towards the end of Task 8, reviewing and commenting on the final study report
- Participation in the discussion of the case study and its findings at an open stakeholder meeting in Task 9 (assuming this option is taken up).

6.4.2 Composition of stakeholder group

In addition to those directly participating in the case study, it is suggested that there should be a minimum of four stakeholders, representing key viewpoints and areas of expertise, as shown in Table 6.1.

Table 6.1 Suggested composition of stakeholder group

Stakeholder role	Number

Owners and operators of installation(s) and forest owners and forest management companies participating in the case study	-
Environmental NGOs active within the region	1
UK or European environmental NGO	1
Forest sector researcher, ideally active within region	1
Environmental scientist/ecologist, ideally active within region	1
Total	**4**

6.4.3 Conduct of business

Under this study option, stakeholders are effectively independent of the study team. They are free to comment on the development of the study, particularly documentation and the findings, including recommending changes to documentation and reports. However, the approval of all stakeholders is not essential and the stakeholders do not sign off the final report.

The study team should transparently and systematically document their responses to any comments or suggestions made by stakeholders. A response should consist of:

- A clear indication of whether the comment or suggestion is accepted, accepted with modification or rejected
- In the case of acceptance in some form, documentation of the action taken; in the case of rejection, a supporting justification.

6.4.4 Appointment of stakeholders

The discussion of the appointment of stakeholders included in the description of study Option 1 (see Section 5.4.5) also applies here.

6.5 Duration

The estimated duration of the study depends on the number of case studies covered. Indicative estimated study durations are:

- 16 months (1 case study)
- 22 months (2 case studies over the same period)
- 28 months (3 case studies over the same period).

It may be noted that the possibility exists to proceed with an initial single case study. The performance of this study could then be assessed, with the option of proceeding with a further case study or studies in the event of a successful outcome and there being sufficient interest in further work.

6.6 Cost

The estimated directly incurred study team costs depend on the number of case studies specified and whether more than one case study is undertaken over the same period. Indicative costs on this basis are shown in Table 6.2.

Table 6.2 Estimated costs directly incurred to support work of study team

Cases studied	Estimated cost (£k)

1 case study (1 carbon model)	320
1 case study (2 carbon models)	365
2 case studies in succession (1 carbon model)	640
2 case studies in succession (2 carbon models)	730
2 case studies over the same period (1 carbon model)	435
2 case studies over the same period (2 carbon models)	500
3 case studies over the same period (1 carbon model)	555
3 case studies over the same period (2 carbon models)	635

The costs for securing the co-operation from the study stakeholder group, if considered necessary, are estimated at between £20k to £40k, per case study.

It is assumed that installation owners and operators, and forest owners and forest management companies would contribute time to the case study as support in kind.

6.7 Key strengths and weaknesses

The key strengths and weaknesses of the study option are listed in Table 6,3.

It may be particularly noted that a case-study methodology should provide a robust assessment of actual practices and impacts associated with providing wood feedstock to a specified installation such as a wood pellet mill supplying the UK. However, the main strength of such a methodology is in its retrospective assessment of practices that have occurred in the specific catchment of a specific installation. The methodology is less suited to assessing what would happen in the case of an increased drive to supply bioenergy, as this may involve other installations in addition to those being studied and a more extensive catchment area than covered in the study.

Table 6.3 Summary of key strengths and weaknesses of study option

Strengths of approach	Weaknesses of approach
Should provide a robust assessment of actual practices and impacts Provides results with a strong audit trail to supporting evidence and information Relatively straightforward to determine the study scope (i.e. focussed on a specific actual installation or installations) Reduced need for stakeholder input to scenarios and outcomes The basis of the study on tangible subjects (i.e. an actual installation or installations) should assist with transparency and understandability	Less suited to assessing what would happen in the case an increased demand for bioenergy Reliant on disclosure of consumer and supplier information, and a willingness to allow this information to be made public Installations owners and sufficient numbers of forest owners may not be willing to co-operate to gain a reliable picture of feedstock use and forest management practices The process of working with installation owners and operators, and forest owners and forest management companies, including data gathering and analysis, is likely to be resource-intensive The results will only be applicable for the installation(s) studied and may not hold more generally, e.g. within a particular geographical region. May need to focus on a number of different plants/regions to gain a broader insight

6.8 Assessment of effectiveness

Table 6.4 presents the qualitative assessment of the effectiveness of the study option.

Table 6.4 Qualitative assessment of effectiveness of study option

Criterion	Qualitative assessment	Score
BEIS Q1 (current impact)*	Provided that co-operation can be secured from installation owners and operators, and forest owners and forest management companies, this option should provide a credible assessment for the installations studied. It is assumed that this co-operation includes willingness to openly share relevant data. Disagreement from stakeholders can be mitigated by the strength of the audit trail to information underlying the study results. The study results would only be directly applicable for the specific installation(s) studied. General results would only be obtained by carrying out a number of case studies within each region.	10

BEIS Q2 (sustainability scenario)*	As above but requires extrapolation from current forestry practice and wood supply chains to a hypothetical situation under the scenario considered in this question. In this study option, the approach to extrapolation has the advantage of being based on the judgements of actual practitioners.	10
BEIS Q3 (maximising sustainable supply)*	The methodology in this study option cannot be readily applied to assess the maximum possible supply of biomass from a specified region, for use as an energy feedstock. The question of assessing risks and challenges associated with realizing this potential would appear to be a policy analysis question with a different scope to that of this study.	0
BEIS Q4 (wider relevance)*	As noted above, the study results would only be directly applicable to the specific installation(s) studied and may not even be generally representative for the region in which it is based. However, it may be possible to comment on where similar outcomes might be expected within this region, and in other regions of the world, noting that this may be uncertain.	3
Transparent	Provided that the information sources can be shared publicly, the basis for the construction of scenarios, and for the development of model simulations, should be completely open.	10
Understandable	Provided the transparency criterion is met, it should be straightforward to follow how the case studies have been carried out. The way in which results for forest carbon stocks have been modelled for a large region of forest, forming a catchment, may not be immediately apparent but could be explained in a supporting discussion and backed up with some simple example stand-scale model simulations, if considered necessary.	10
Data available	The data required should be available, but only if co-operation can be secured from installation owners and operators, and forest owners and forest management companies.	5
Wide acceptance	Provided that an audit trail can be demonstrated to a real installation, real forest areas, and clear evidence in support of related forest management practices, there is a good chance that the conclusions could gain wide acceptance. Even if the findings of the study meet with opposition from some quarters, BEIS should be able to defend the findings given a strong audit trail to the supporting evidence. A contention that the case study may not be representative of wider practices in a region may be harder to refute.	3
Transferrable	The methodology could be applied to installations in any geographical region, but this is very dependent on being able to identify and engage with a strong community of installation owners and operators and forest owners and forest management companies.	4
Wider applications	In principle a case study methodology could be adapted to address related applications, e.g. more complete LCA of bioenergy supply chains and non-energy biomass products. The approach could also be extended to cover aspects of policy development by BEIS (e.g. acceptability to practitioners of proposals for refined sustainability criteria).	2
TOTAL score		**57**

7 Option 3 – Assumptions-based assessment

7.1 Objective and methodology

7.1.1 Objective

Under this option the objective is to estimate the potential impacts on forest carbon stocks arising from the supply of woody biomass to the UK for energy, depending on a range of assumptions for the key parameters, to fully express the variety of possible forestry practices and forest carbon stock impacts.

7.1.2 Methodology

The methodology employed for the development of scenarios involves defining a large set of assumptions describing different scenarios for possible forest management practices involved in supplying woody biomass for use as an energy feedstock along with associated counterfactual scenarios. Scenarios for biomass supply would be classified depending on their consistency with different levels of sustainability criteria. The scenarios thus developed would then provide the inputs to the assessment of forest carbon dynamics in a similar way to that described for Option 1 in Section 5. The results of the modelling scenarios would be ranked according to the magnitude of impacts on forest carbon stocks (e.g. very negative, moderately negative, neutral, moderately positive etc.). Consultation could then be held with stakeholders to assess the likelihood of the various scenarios. It may be noted that this methodology was followed to an extent in the study of Stephenson and MacKay (2014). What is proposed here is a more complete and systematic study with associated stakeholder inputs, possibly covering more geographical regions. A schematic diagram of the methodology is shown in Figure 7.1.

7.1.3 Tasks

Task 1: Identify a relevant geographical region – this is likely to be geopolitically defined, e.g. a country, province, state, county or similar, which is considered to be relevant to the supply of woody biomass for use as an energy feedstock in the UK. Target geographical regions may be selected by BEIS, in discussion with the study team, taking into account information from pellet end users to identify the relevant supplying regions.

Task 2: Assess the quantity of woody biomass being supplied to the UK from the region; this may be based on relevant forest/biomass sector data (where available). Otherwise, the study team may need to make a judgement about this, informed by advice from external experts if required. Also assess how the quantity of woody biomass supplied to the UK may change in the future under the scenarios specified by BEIS (baseline, current bioenergy, enhanced sustainability); this will be determined by BEIS in discussion with the study team. The resultant projections and underlying information and assumptions should be documented and reviewed by the stakeholder group (see Section 7.4).

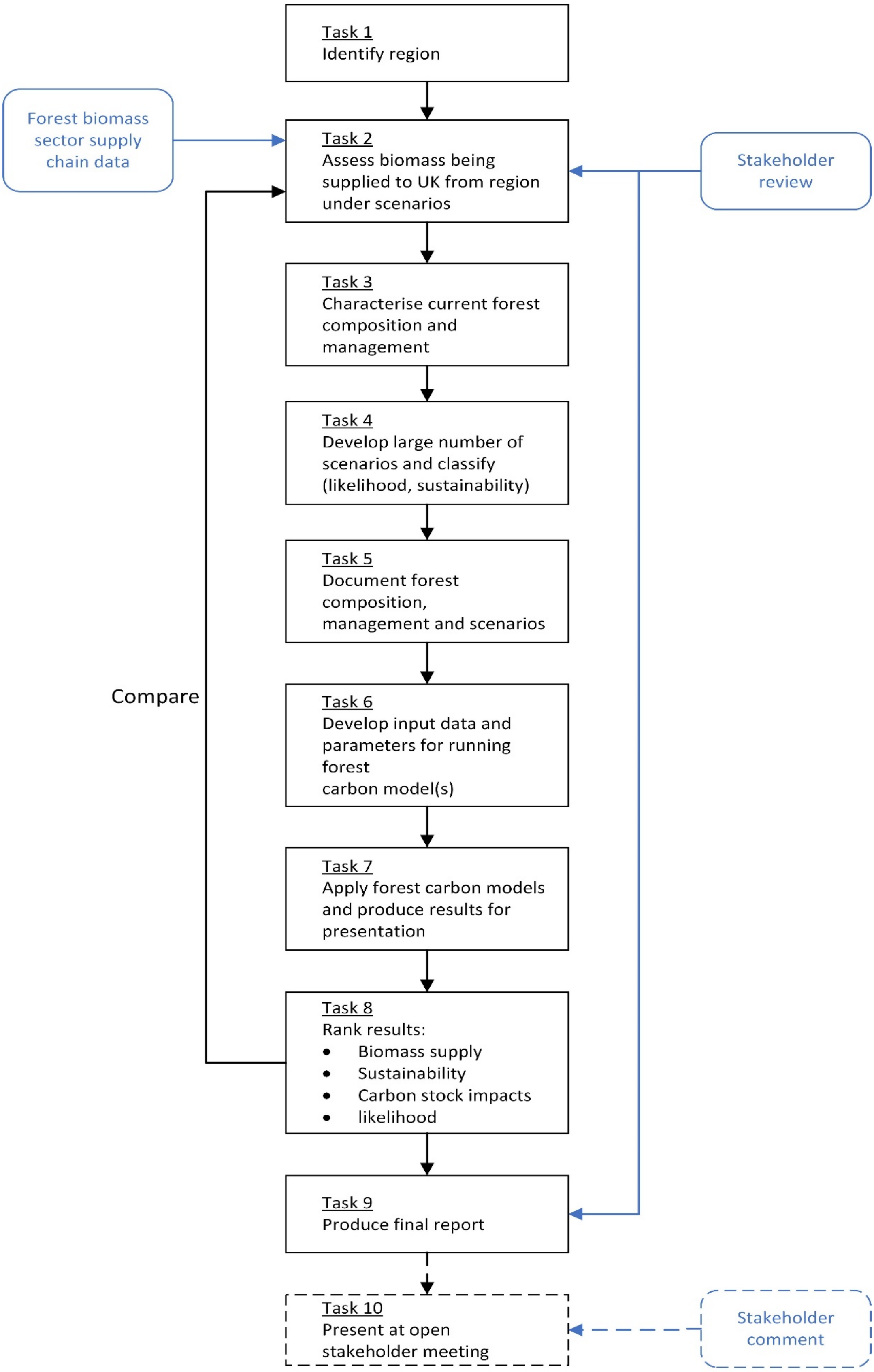

Figure 7.1 Schematic diagram of Option 3 study methodology

Task 3: Characterise the current composition of forest areas in the region according to relevant factors, e.g. tree species, growth rates, soil types, tree/stand ages, ownership types, current management (and intended management). This will involve assessing and analysing relevant forest inventory data and other relevant forest information sources (e.g. yield tables), where these sources are available. Gaps in information should be addressed by developing a relevant set of assumptions, including making simplifications e.g. with regards to the representation of forest areas, based on the judgement of the study team.

Task 4: Develop a large number of scenarios by defining different sets of assumptions about possible forest management practices involved in supplying woody biomass as an energy feedstock along with associated counterfactual scenarios. The different sets of assumptions should cover a wide range of possible forest management practices related to bioenergy production. Classify the resultant scenarios for biomass supply according to their consistency with different levels of sustainability criteria. Also classify the scenarios according to an assessment of the likelihood of each scenario actually occurring.

Task 5: Document the information on forest composition and management scenarios in a report. Submit the report for review by a stakeholder group (see Section 7.4) and revise as necessary.

Task 6: For each of the assumption-based scenarios, develop data and parameters for use as inputs to a suitable forest sector carbon accounting model (or more than one of them for cross-validation). Document the data and parameters and demonstrate how these are derived from the information on forest composition and management under the specified scenarios developed in Tasks 4 and 5.

Task 7: Apply the forest sector carbon accounting model(s) to produce simulations and results for the development of forest carbon stocks, for each of the specified assumption-based scenarios. Process the results into a form suitable for presentation to stakeholders and wider communication; this includes estimating impacts on forest carbon stocks obtained by comparing results for bioenergy scenarios with those for the counterfactual scenario. Results should also be produced for the magnitude of potential biomass supply associated with the different scenarios.

Task 8: Rank the results obtained for the various scenarios in terms of:

- The level of potential biomass supply associated with the scenario
- The consistency of the scenario with specified sustainability criteria
- The direction (positive, negative, neutral) and magnitude of forest carbon stock changes associated with the scenario
- The assessment of likelihood of each scenario actually occurring.

The level of potential biomass supply associated with each scenario should also be compared with the levels of supply identified in Task 2.

Task 9: Document the methods, results and conclusions of Tasks 2 to 8 in a final report and submit for review by stakeholders. Amend in the light of comments from stakeholders. Particular attention should be paid to views expressed by stakeholders on the likelihood of different scenarios. However, it is not necessary to obtain the approval or sign-off of stakeholders.

Task 10 (optional): Present findings of the study at an open stakeholder meeting, providing an opportunity for comment/input from members of the stakeholder group (see Section 7.4).

7.1.4 Representation of forest areas

The discussion in the description of study Option 1 regarding the representation of forest areas (Section 5.1.4) also applies here, with the exception of the reference to stakeholder consultation.

7.2 Materials, data and tools required

The main requirements for this study option are:

- Relevant sources of forest biomass sector supply chain data for the region of interest, to the extent that they exist and are accessible.
- Relevant data on current forest composition and management (see Section 7,1.4); if not available, this may be mitigated to an extent by consultation with regional experts
- Access to (and the capacity to apply) one or more forest sector carbon accounting model(s); this is an essential requirement for the study
- Computing facilities for the storage of data and results and for running numerically intensive model simulations, with associated QA and QC processes,

7.3 Staff requirements

The indicative requirements for staff directly deployed to work on the study (not necessarily full time) are:

- Project leader
- At least one expert on the forest sector and biomass supply chains
- At least one expert in applying the forest sector carbon accounting model(s) applied in the study
- Manager and curator of study data sources, results and other products, including version control
- Staff member responsible for ensuring QA and QC.

It may be noted that one or more individual team members could possibly take on more than one of the roles described above.

7.4 Stakeholder inputs

For this study option, the main purpose of stakeholder engagement is to obtain comments and views on key stages and outputs of the study, with the aim of strengthening the discussion, findings and conclusions in the final report.

7.4.1 Stakeholder functions

The study stakeholder group would be required to fulfil the following functions:

- Towards the conclusion of Task 2, reviewing and commenting on the documentation of the assessment of biomass production from the region(s) under the specified scenarios, subject to any evidence available in the form of forest biomass sector supply chain data
- Towards the conclusion of Task 5, reviewing and commenting on the documentation of forest composition and management under the assumption-based scenarios

- Towards the end of Task 9, reviewing and commenting on the final study report, in particular taking a view on the way in which forest carbon stock impacts have been classified and the likelihood of different scenarios actually occurring
- Participation in the discussion of the case study and its findings at an open stakeholder meeting in Task 10 (assuming this option is taken up).

7.4.2 Composition of stakeholder group

It is suggested that there should be a minimum of nine stakeholders, representing key viewpoints and areas of expertise, as shown in Table 7.1.

Table 7.1 Suggested composition of stakeholder group

Stakeholder role	Number
Forest owners, forest owner representative organisations and/or forest management companies within the region	2
Wood industries within the region (pellets/non-pellets)	2
Environmental NGOs active within the region	2
UK or European environmental NGO	1
Forest sector researcher, ideally active within region	1
Environmental scientist/ecologist, ideally active within region	1
Total	**9**

7.4.3 Conduct of business

Under this study option, stakeholders are effectively independent of the study team. They are free to comment on the development of the study, particularly documentation and the findings, including recommending changes to documentation and reports. However, the approval of all stakeholders is not essential, and the stakeholders do not sign off the final report. If an open stakeholder meeting is held at the end of the study, stakeholders may actively participate and can freely express their own views.

The study team should transparently and systematically document their responses to any comments or suggestions made by stakeholders. A response should consist of:

- A clear indication of whether the comment or suggestion is accepted, accepted with modification or rejected
- In the case of acceptance in some form, documentation of the action taken; in the case of rejection, a supporting justification.

7.4.4 Appointment of stakeholders

The discussion of the appointment of stakeholders included in the description of study Option 1 (see Section 5.4.5) also applies here.

7.5 Duration

The estimated duration of the study depends on the number of regions specified for study. Indicative estimated study durations are:

- 14 months (1 region)

- 28 months (2 regions over the same period)
- 40 months (up to 4 regions over the same period).

It may be noted that the possibility exists to proceed with an initial study of up to 2 regions. The performance of this study could then be assessed, with the option of proceeding with a further study or studies in the event of a successful outcome and there being sufficient interest in further work.

7.6 Cost

The estimated directly incurred study team costs depend on the number of regions specified and whether more than one region is studied over the same period. Indicative costs on this basis are shown in Table 7.2.

Table 7.2 Estimated costs directly incurred to support work of study team

Cases studied	Estimated cost (£k)
1 case study (1 carbon model)	255
1 case study (2 carbon models)	291
2 case studies (1 carbon model)	506
2 case studies (2 carbon models)	582
3 case studies over the same period (1 carbon model)	723
3 case studies over the same period (2 carbon models)	832

The costs for securing the co-operation from the study stakeholder group, if considered necessary, are estimated at between £45k to £90k, per region.

7.7 Key strengths and weaknesses

The key strengths and weaknesses of the study option are listed in Table 7,3.

Table 7.3 Summary of key strengths and weaknesses of study option

Strengths of approach	Weaknesses of approach
Relatively simple to model by comparison to other approaches. Scenarios are formulated by lead team so work can progress relatively quickly Gives insights into sensitivity of outcomes to variations in forestry practices Could further inform development or refinement of sustainability criteria Gives an indication of biomass potentials associated with different scenarios (hence by implication under different sustainability criteria) Simpler to explain and present	Potentially very large number of assumption-based scenarios would need to be modelled – presenting computing and data management burden Not clear how representative results are of on-the-ground situation without forest manager/wider stakeholder engagement (results may be challenged) May reinforce the notion that forest carbon stock impacts are uncertain Results may reinforce perceptions of stakeholders; may prolong debate rather than assist with convergence of understanding Tends to focus on specific and simplistic scenarios and impacts (one management practice represents all) Any later insights gained in review could lead to a need to repeat parts of the analysis (though the impact on time for computer modelling should be relatively short)

7.8 Assessment of effectiveness

Table 7.4 presents the qualitative assessment of the effectiveness of the study option.

Table 7.4 Qualitative assessment of effectiveness of study option

Criterion	Qualitative assessment	Score
BEIS Q1 (current impact)*	This option does not provide a definitive answer to this question since many possible outcomes will be suggested by the results, depending upon the assumptions made. However, an indication of the best possible answer to the question may be provided, as long as it is possible to identify a group of scenarios that are considered "most likely" to be involved in supplying biomass to the UK.	6
BEIS Q2 (sustainability scenario)*	As above.	6
BEIS Q3 (maximising sustainable supply)*	This option addresses this question very well, provided it is possible to classify the various modelled scenarios with respect to their consistency with different sustainability criteria, and that estimates of the associated biomass availability are generated as part of the modelling.	15
BEIS Q4 (wider relevance)*	The study results would only be directly applicable to the specific region(s) studied. However, it may be possible to comment on where similar outcomes might be expected in other regions of the world, noting that this may be uncertain.	3

Transparent	Provided that the documentation is sufficient, the basis for the construction of scenarios, and for the development of model simulations, should be completely open.	10
Understandable	Provided the transparency criterion is met, it should be straightforward to follow how the scenarios have been constructed. The way in which results for forest carbon stocks have been modelled for very large regions may not be immediately apparent but could be explained in a supporting discussion and backed up with some simple example stand-scale model simulations, if considered necessary. It will be important to explain and justify how the likelihood of different scenarios has been assessed and how the consistency of scenarios with certain sustainability criteria has been determined.	10
Data available	There are less stringent requirements for data associated with this option because the methodology relies strongly on assumptions. However, modelling can be strengthened where data are available.	8
Wide acceptance	Provided that the assumptions and the modelling approach are clearly explained and justified, there is a good chance that the conclusions reached regarding the sensitivity of forest carbon stock impacts to different forest management scenarios will gain acceptance. It seems probable that there will be ongoing debate, and possibly dispute, about the likelihood of different scenarios actually occurring. However, this could be viewed as making at least some progress in the debate about forest carbon impacts arising from bioenergy supply to the UK.	2
Transferrable	The methodology can be applied in other geographical regions, noting that simplifications may be required in cases where data on the composition of forest areas in a region are limited.	4
Wider applications	In principle this methodology could be adapted to address related applications, e.g. sensitivity analysis in complete LCA of bioenergy supply chains and non-energy biomass products. The approach is very relevant to some other aspects of policy development by BEIS (e.g. further refinement of sustainability criteria).	3
TOTAL score		**67**

8 Option 4 – Not proceeding with new study

If a decision is taken not to proceed with a full-scale study of the impacts on forest carbon stocks arising from the supply of wood to the UK for use as an energy source, the question then arises as to what "not proceeding" might involve. One possibility might be to take the decision to take no further action, other than to rely on the outputs of ongoing research and development being pursued elsewhere. Alternatively, "not proceeding" might involve further efforts to actively assess the current evidence based and scientific understanding on the subject, to address the questions originally set by BEIS as far as possible. This latter option is considered below.

8.1 Objective and methodology

8.1.1 Objective

Under this option the objective is to critically assess currently available evidence and scientific understanding to provide the best possible answers to the four principal questions posed by BEIS, specifically:

1. What effect has the supply of wood pellets to UK power stations had on the forest carbon stocks in SE USA, Canada and Europe?
2. How would the situation with forest carbon stock have been affected if alternative sustainability criteria had been in place?
3. How can we maximise the sustainable yield and what are the risks and challenges of doing this? How will that change in the future?
4. How applicable would any conclusions be to other areas of potential forest biomass supply?

8.1.2 Methodology

The principal methodology employed for undertaking this assessment is a review undertaken by a group of researchers with relevant knowledge and expertise. Additionally, some key pieces of currently unpublished evidence could be made more generally available. A schematic diagram of the methodology is shown in Figure 8.1.

A useful precursor to this would be to review existing studies to identify why and how studies have come to their particular conclusions to identify the best studies and approaches to adopt going forward.

8.1.3 Tasks

Task 1: Decide which region(s) will fall within the scope of the review – these are likely to be geopolitically defined, e.g. countries, provinces, states, counties or similar, which are considered to be relevant to the supply of woody biomass for use as an energy feedstock in the UK. This decision is best taken by BEIS, possibly, in discussion with leading members of the review group (if already appointed), taking into account information from pellet end users to identify the relevant supplying regions.

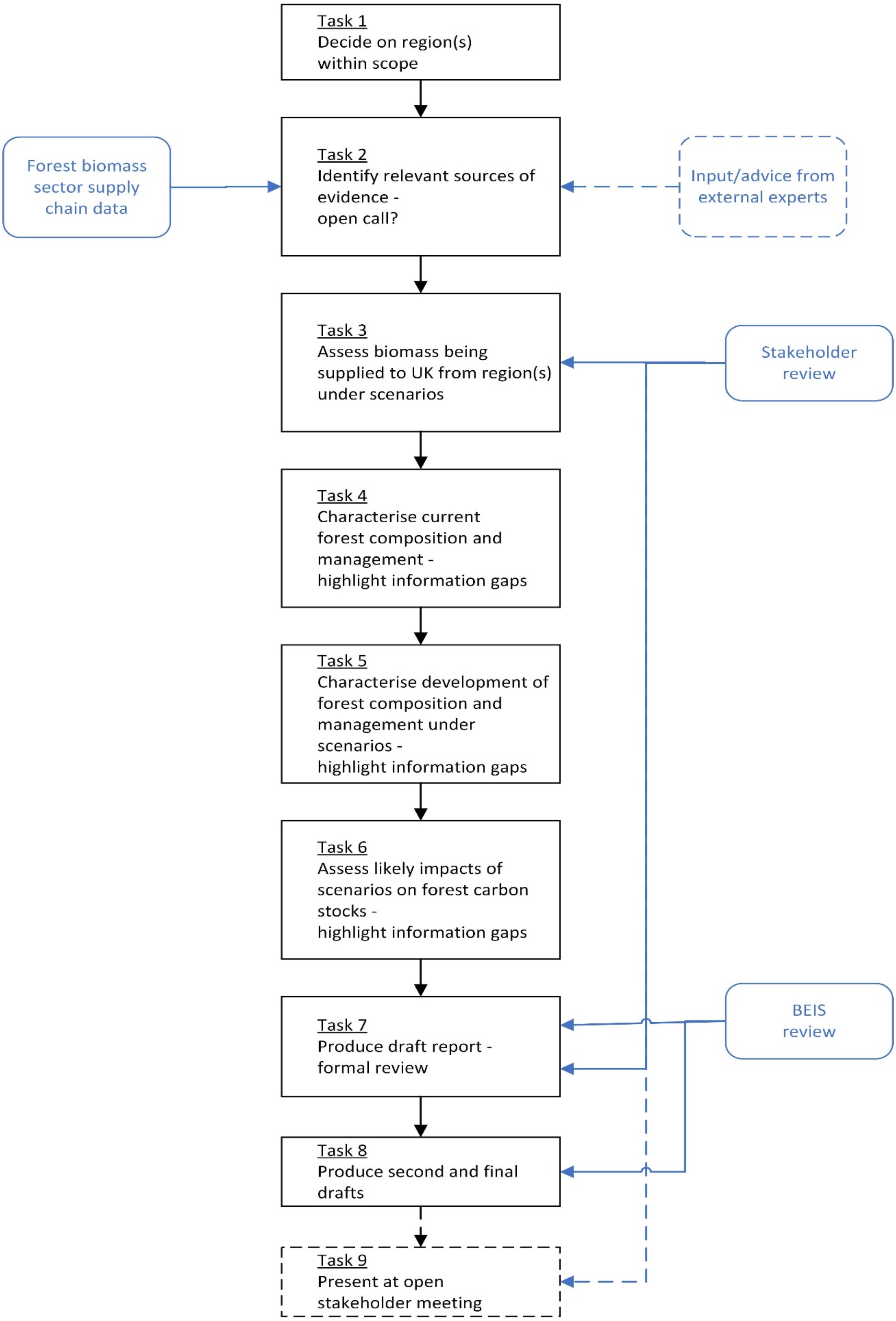

Figure 8.1 Schematic diagram of Option 4 study methodology

Task 2: The review group should identify all relevant sources of evidence, in the form of data and scientific studies, of relevance to addressing the questions of interest to BEIS. The possibility should be considered of issuing a formal call for evidence and papers.

Task 3: The review group should assess the quantity of woody biomass being supplied to the UK from the region; this may be based on relevant forest/biomass sector data (where available). Otherwise, the study team may need to make a judgement about this, informed by advice from external experts if required. The review group should also assess how the quantity of woody biomass supplied to the UK may change in the future under the scenarios specified by BEIS (baseline, current bioenergy, enhanced sustainability). The resultant projections and underlying information and assumptions should be documented and reviewed by stakeholders (see Section 8.4).

Task 4: Based on the available evidence, the review group should characterise the current composition of forest areas in the region(s) according to relevant factors, e.g. tree species, growth rates, soil types, tree/stand ages, ownership types, current management (and intended management). This will include assessing and analysing relevant forest inventory data and other relevant forest information sources (e.g. yield tables), where these sources are available. Gaps in information should be highlighted.

Task 5: The review group should characterise the likely development of forest composition and management in the region(s) under the scenarios defined by BEIS (baseline, current bioenergy, enhanced sustainability). This will be determined by critical assessment of the evidence available in data sources and relevant scientific literature. Gaps in information should be highlighted.

Task 6: For each of the scenarios developed in Task 5, the review group should make an assessment of the likely impacts on forest carbon stocks in response to the forest management practices associated with each scenario. The review group should also make an assessment of how forest carbon stock impacts vary depending on different types of forest management practice. These assessments will be derived from a critical review of the evidence available in data sources and relevant scientific literature. Gaps in information should be highlighted.

Task 7: The review group should prepare a draft report presenting the assessments in Tasks 4 to 6. The report should be submitted for review by BEIS and then circulated for wider review.

The assessment, findings and conclusions of the report should be developed by the review group on the basis of achieving at least consensus amongst the group members. In the event of a significant disagreement between review group members, all reasonable efforts should be made to find a resolution, otherwise the disagreement should be reported and discussed openly.

Task 8: The review group should prepare a second draft of the report prepared in Task 7, having responded to comments, as appropriate. The second draft should be submitted for review by BEIS and any comments received should be taken into account in a final report. The report should then be published.

Task 9 (optional): The review group should present the findings of the study at an open stakeholder meeting, providing an opportunity for comment, and for the review group to respond.

8.2 Materials, data and tools required

The main requirements for this study option are:

- Good meeting facilities for face-to-face meetings of the review group (possibly in the UK or abroad or both); this is an essential requirement for the study
- Relevant sources of forest biomass sector supply chain data for the region of interest, to the extent that they exist and are accessible; if not available, this may be mitigated to an extent through consultation with regional experts
- Relevant data on current forest composition and management; if not available, this may be mitigated to an extent through consultation with regional experts
- A compilation of relevant scientific studies, notably on impacts on forest carbon stocks arising from forest management activities
- Computing facilities for the storage of information sources and versions of reports with associated QA and QC processes,

8.3 Staff requirements

The main staff requirement is for fully participating members of the review group, with some supporting staff members:

- Either a Chair, or two Co-chairs of the review group
- Between four and nine review group members (to give a total membership of between 6 and 10)
- Manager and curator of data sources, published studies and report versions, including version control and QA where relevant.

It is envisaged that participants of the review group would not be working full time during the life cycle of the review.

8.4 Stakeholder inputs

There is no formally appointed stakeholder group for this study option, The role of stakeholders is to comment voluntarily on the assessment report produced by the study. It is desirable to have input from stakeholders representing a range of viewpoints, including the forest and biomass industries, environmental NGOs and the scientific community.

8.4.1 Conduct of business

Under this study option, stakeholders are entirely independent of the assessment being carried out in the study. They are free to comment on the assessment report, including recommending changes to wording and findings and their justification. However, the approval of stakeholders is not essential and the stakeholders do not sign off the final report.

The study team should transparently and systematically document their responses to any comments or suggestions made by stakeholders. A response should consist of:

- A clear indication of whether the comment or suggestion is accepted, accepted with modification or rejected
- In the case of acceptance in some form, documentation of the action taken; in the case of rejection, a supporting justification.

The details of the comments (suitably anonymised) and the responses, should be made publicly available.

8.4.2 Appointment of stakeholders

Stakeholders are not formally appointed to a group but a call should be issued, inviting stakeholders to offer comments on the draft assessment report.

8.5 Duration

The estimated duration of the study is between 18 and 24 months, depending on the scope of the review (number of regions, detailed terms of reference). The critical path is the time required to thoroughly review the evidence, notably relevant scientific literature, to establish the basis for any findings and conclusions. The time required to write the assessment report, and manage the process of reviewing it, is also likely to be significant.

8.6 Cost

The directly incurred costs for the review group are estimated to be between £370k and £810k, depending on the number of review group members, the number of regions specified and the detailed terms of reference.

8.7 Key strengths and weaknesses

The key strengths and weaknesses of the study option are listed in Table 8,3.

Table 8.3 Summary of key strengths and weaknesses of study option

Strengths of approach	**Weaknesses of approach**
The study follows a reputable model (i.e. IPCC assessment reports) Some of the analytical methods employed for the literature review in Part A of this study could be employed and extended The assessment report could be regarded as authoritative if a credible review group is appointed and at least consensus is achieved If carried out effectively, the review of scientific literature could help to clarify the root courses of apparent disagreements between different published studies The study can be carried out with existing available information sources The assessment process is clearly defined and is not dependent on new modelling which may prove intractable	Potentially limited by the varying levels of transparency in existing available information sources There may be important forest management practices and/or wood supply scenarios that are not sufficiently covered in published studies Limited by issues identified in the Part A report for this study (e.g. ambiguous terminology, variable basis for constructing scenarios, variable system boundaries) The basis of the assessment comes down to the judgement and arguments of the review group, rather than being based on a systematic numerical analysis of defined regions, installations or scenarios, referring to best available data sources The credibility of the study report could be compromised simply by a group of eminent scientists issuing a statement disagreeing with it

8.8 Assessment of effectiveness

Table 8.4 presents the qualitative assessment of the effectiveness of the study option.

Table 8.4 Qualitative assessment of effectiveness of study option

Criterion	Qualitative assessment	Score
BEIS Q1 (current impact)*	This option provides an answer to this question, to the extent possible based on existing available data and scientific findings, as judged by a review group. The process for achieving this is clearly defined but may be limited by information gaps and areas of uncertainty identified by the review group, and possible disagreements between review group members.	10
BEIS Q2 (sustainability scenario)*	As above.	10
BEIS Q3 (maximising sustainable supply)*	As above, but likely to be dependent on a smaller number of studies presenting multiple scenarios.	6
BEIS Q4 (wider relevance)*	As above.	5
Transparent	The process by which the review group has made its assessment should be transparent, but the assessment itself is likely to be limited by potential lack of transparency in some sources of evidence referred to in the review.	5
Understandable	It should be possible for the process by which the review group has made its assessment to be understood by stakeholders, but potential lack of transparency in some published studies referred to in the review, or obscure but important features in methods employed in published studies, may make some aspects of the assessment difficult to explain.	5
Data available	By definition the data required are available, since the review is of existing, available evidence. However, the likelihood exists that the review would highlight important data gaps.	4
Wide acceptance	The study follows a reputable model (i.e. IPCC assessment reports). The assessment report could be regarded as authoritative if a credible review group is appointed and at least consensus is achieved. However, the basis of the assessment comes down to the judgement and arguments of the review group, rather than being based on a systematic numerical analysis of defined regions, installations or scenarios, referring to best available data sources. Also, the credibility of the study report could be compromised simply by a group of eminent scientists issuing a statement disagreeing with it.	2
Transferrable	The review methodology could be applied to other regions or situations, provided that sufficient sources of evidence exist for assessment, and relevant experts can be appointed to the review group.	3
Wider applications	The review methodology could be applied to other questions or applications, provided that sufficient sources of evidence exist for assessment, and relevant experts can be appointed to the review group.	5
TOTAL score		**55**

9 Discussion and conclusions

9.1 Discussion

In the preceding sections of this report, four options have been considered for possible full-scale studies to address the questions originally posed by BEIS. The methodology, including tasks involved and resource requirements, likely duration and costs, have been suggested for each option, concluding with a qualitative assessment of the effectiveness of each option. The assessments for all four options are summarized in Table 9.1.

Table 9.1 Summary of effectiveness of study options

Criterion	Maximum points allocation	Option 1	Option 2	Option 3	Option 4
BEIS Q1 (current impact)	15	12	10	6	10
BEIS Q2 (sustainability scenario)	15	10	10	6	10
BEIS Q3 (maximising sustainable supply)	15	7	0	15	6
BEIS Q4 (wider relevance)	10	5	3	3	5
Transparent	10	9	10	10	5
Understandable	10	8	10	10	5
Data available	10	8	5	8	4
Wide acceptance	5	4	3	2	2
Transferrable	5	4	4	4	3
Wider applications	5	3	2	3	5
Total	**100**	**70**	**57**	**67**	**55**

Note: Option 4 considers the case of not proceeding with a full-scale study. The option considered here involves undertaking an assessment based on review of existing available data and scientific evidence and understanding. Alternatively, under Option 4, no further action could be taken; this case cannot be assessed in the same way as the options above.

The assessments in Table 9.1 can be used to compare the relative strengths and weaknesses of the options with regard to the different aspects of relevance to the full-scale study under consideration, including the effectiveness of each option in addressing the four principal questions posed by BEIS. However, it should be stressed that these assessments, and in particular the total scores for each option, are not appropriate for making a mechanistic selection of an option. This is because the results are very dependent on the relative weights (i.e. maximum points allocation) assigned to each criterion. This means, for example, that a study option could completely fail to address one of the questions, but potentially still have a high total score.

A number of features may be observed about the assessments in Table 9.1:

- Each option can be seen to be stronger or weaker in addressing each of the four principal questions. Hence it is likely that different study options may be selected, depending on which question is seen as most important to address. None of the options is assessed as scoring more than two thirds of possible marks for all four principal questions.
- Three of the options score quite highly for transparency and understandability, whilst one scores half marks.
- With regard to the criterion considering the likelihood of the study results and conclusions gaining wide acceptance, two options score more than half marks, and two score less than half marks.
- All of the options score reasonably highly for transferability of the methodology (not necessarily the results) to other geographical regions or situations.

It should be stressed that the above assessments are qualitative and based on the judgments of the study team and experience gained from the Part A review.

In terms of study duration, the assessment of options suggests that all of the options would take longer than a year to carry out, and potentially up to 40 months, depending on the option selected, the number of regions or case studies included, and certain details of the methodology employed (e.g. number of models applied). Estimated costs for a full-scale study range from around £250k to £830k, depending on the same factors.

Consideration could be given to a research programme consisting of a combination of the assessment method options described in this report. One possible example might consist of the following four elements:

- Firstly, a further critical assessment could be made of the currently available evidence and scientific understanding, with the aim of providing the best possible answers to the four principal questions posed by BEIS, as described in Section 8. This would build on (and hopefully improve upon) earlier reviews of literature and evidence, to obtain provisional answers to the BEIS questions. The exercise could also identify lessons that can be learned from earlier studies and reviews, building on what has already been concluded in the Part A Report of this project. These various findings could then inform how the subsequent elements of this programme may be taken forward.
- Secondly, assumption-based assessments could be made, with the aim of gaining an understanding of forest management practices and woody biomass feedstock utilisation for bioenergy that are consistent (or not consistent) with limited or positive impacts on forest carbon stocks and sequestration. It may be pertinent to extend such assessments to consider the full GHG impacts of complete forest bioenergy chains. These assessments could be used to validate or otherwise refine a set of enhanced sustainability criteria for application to forest bioenergy sources. The findings could be used as a basis for defining enhanced sustainability criteria and also defining scenarios for forest management and biomass feedstock utilisation reflecting their adoption.
- Thirdly, assumption-based assessments could also be made, in conjunction with the sustainability criteria developed in the preceding element, for the purpose of estimating potentials for maximum sustainable supply of woody biomass from different regions for use as an energy feedstock.
- Finally, region-focused or installation-focused case-study assessments could be undertaken to determine the impacts of UK bioenergy policy on forest carbon stocks in important regions or associated with major wood pellet manufacturers supplying the UK with bioenergy. The impacts of introducing enhanced sustainability criteria could also be assessed, in terms of impacts on forest carbon stocks and also potential biomass availability. Such assessments could serve as an evidence base for the sustainability (in terms of forest carbon) of forest bioenergy sources being supplied to the UK.

In the case of this example, there are some dependencies amongst the four elements listed above. If it is considered important to establish the best possible understanding before proceeding with further research, the first element must be carried out in advance of the other elements. The remaining three elements can be carried out in parallel to some extent, but the fourth element requires a set of enhanced sustainability criteria to be defined before it can be completed. This depends on the successful outcome of the second element. Whilst the example research programme outlined above may be regarded as comprehensive, it relies on all four assessment options described in this report and there would appear to be few opportunities for cost savings through efficiencies arising from complementarity or scale. Based on the cost estimates for individual options presented earlier, the approximately estimated cost of an ambitious research programme, consisting of the four elements above applied across several geographical regions, is £3.1M.

An alternative programme might involve proceeding with assumption-based, region-based and/or case-study assessments, then undertaking a critical assessment of these alongside other relevant studies for the purpose of verification.

9.2 Conclusions

The literature review for this study, presented in the Part A report, arrived at a number of insights and conclusions which are provided in that report. Based on further consideration of the findings of the literature review in Part B of this study it is concluded that:

- A modelling approach is the most appropriate methodology for assessing the short-term and long-term impacts of different scenarios relevant to actual and possible biomass energy policies (including the deprioritising of biomass energy).
- A robust methodology needs to be designed for constructing the scenarios, to be used as a basis for parameterising forest sector carbon accounting models.
- Several candidate methodologies exist for the construction of scenarios, which require further evaluation.

With regard to the possible methodologies for constructing scenarios, it is further concluded that:

- A methodology based principally on the analysis of data on forest biomass use by the wood-processing and biomass energy sectors (by feedstocks) is unsuitable for further development and evaluation as a central study methodology. However, insights and understanding into relevant wood biomass supply chains, gained from these data sources (where available), are likely to form a very important supporting component of any methodology.
- The application of economic models is undeniably of considerable value as a means for analysing potential systematic changes in the forestry, wood biomass and energy sectors in response to possible and actual bioenergy policies. However, economic modelling would appear to be most appropriately applied when providing evidence and insights as a supporting component of any methodology.
- Suitably designed stakeholder consultation (with clearly defined objectives) needs to form a component of any methodology and in addition the possibility for using this approach as the central methodology
- Methodologies involving the formulation of a set of stated assumptions or based on “real-life” case studies should be further elaborated and assessed for their potential as a primary methodology.

The development and evaluation of specific methodological options has been presented in this report. The options considered are:

1. Region-focussed stakeholder-led assessment
2. Installation-focussed case study assessment
3. Assumptions-based assessment.

The Part A report concluded by noting that the option of not proceeding with a full-scale study should also be considered, given the many uncertainties and technical difficulties identified in the literature review. Hence, this has also been assessed as a fourth option alongside the three options identified above. Option 4, considered in this report, involves undertaking an assessment based on existing available data and scientific evidence and understanding. Alternatively, under Option 4, no further action could be taken.

The four options have been developed and discussed in this report. The methodology, including tasks involved and resource requirements, likely duration and costs, have been suggested for each option, concluding with a qualitative assessment of the effectiveness of each option.

The assessments can be used to compare the relative strengths and weaknesses of the options with regard to the different aspects of relevance to the full-scale study under consideration, including the effectiveness of each option in addressing the four principal questions posed by BEIS.

A number of features may be observed about the assessments of the options as covered in the discussion in Section 9.1.

The assessment of options suggests that the duration of a full-scale study would be longer than a year, and potentially up to 40 months, and range in cost from around £250k to £830k, depending on the option selected, the number of regions or case studies included, and certain details of the methodology employed (e.g. number of models applied).

It is possible, and may be desirable, to combine options to address a range of information and evidence needs if sufficient financial resource is available (see Section 9.1 for example).

10 References

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