Annex B Assessment Methodology

Introduction

This Annex sets out the methodology which was developed to support the lifecycle assessment of greenhouse gas emissions for the NPF4 proposed and alternative National Developments.

Definitions and terminology

Emissions sectors

The assessment is structured around the six emissions sectors of transport, electricity, buildings (heat), industrial, manufacture and construction processes, waste and land use, land use change and forestry (LULUCF). These emissions sectors reflect the sectors included in the Update to the Climate Change Plan 2018-2032, but exclude agriculture as being outside of the scope of the proposed and alternative national developments. Negative Emissions Technologies (NETs) are included for the assessment of the Industrial Green Transition Zones, which is the only national development for which this sector is relevant.

Emissions sources considered include those set out in the Climate Change (Scotland) Act 2009, as amended ('the Climate Change (Scotland) Act'). This created a statutory framework for greenhouse gas (GHG) emissions reduction in Scotland and set targets for reduction in emissions of the seven Kyoto Protocol Greenhouse Gases compared to the 1990/1995 baseline level. This "basket" of seven GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

CO2 equivalent

CO_2e is the measure used to compare the emissions from various greenhouse gases on the basis of their global warming potential (GWP) by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

Embodied carbon is the total greenhouse gas (GHG) emissions (often simplified to "carbon") generated to produce materials and also applies to the materials and processes required for construction of a building or structure. The embodied carbon of re-use or recycling some materials can be less than the embodied carbon of producing new material from new raw materials.

Carbon is also stored in materials such as wood, which can be released by burning or decomposition, leading to the release of carbon dioxide.

Positive and negative effects

Within the assessment framework, the terminology 'positive effect' refers to reduced emissions relative to the baseline. The term 'negative effect' refers to an increase in emissions relative to the baseline. Within the assessment framework it is clear where both positive and negative effects occur in relation to a sector emissions source. For example, a potential National Development (pND) which both increases traffic levels in one area, but also implements infrastructure to support low carbon travel in another. The final column of the assessment framework makes a judgement (with an associated confidence level) about the net GHG balance in relation to that sector. The final

summary of overall effects draws conclusions on the balance of GHG emissions between the different sectors.

Lifecycle stages

The assessment considers emissions from different stages of the lifecycle of a National Development. Lifecycle stages include 'baseline' which captures any existing sources of emissions or any sequestration and storage that could be affected by the development. For example, for a road improvement pND the baseline is the current road which may be subject to congestion issues, and the associated vehicle emissions. The baseline for a new freight rail route would be the existing road traffic emissions of the freight transport, and also the emissions associated with the current existing land use. Construction related emissions are more significant for developments which utilise carbon intensive materials such as concrete and steel. Operational emissions are likely to occur over the longest timeframe - during the operation of the development. In many cases, the operational life of a pND is unknown, so assumptions have been made as appropriate.

Finally, the assessment has made assumptions around decommissioning. It is acknowledged that there is a high degree of uncertainty over the decommissioning phase of development, and that different assumptions will apply to different development types and locations. This includes the approach to infrastructure removal or the level of site restoration at the end of the development's lifespan. Where appropriate, restoration to the equivalent of green field condition has been assumed to allow comparison across the pNDs. It is acknowledged that future use of a site may be lower or higher intensity in the future.

Direct and indirect effects

The assessment table identifies both direct and indirect effects. Direct effects are those that arise as a direct result of the development, such as the generation of additional traffic movements from a new development. Indirect effects are those that arise because of the development, typically through enabling actions. For example, research and development for renewable energy may enable further renewable energy development.

Embodied energy

Detail on the definitions of embodied energy are set out in McAlinden (2015)[1]. This defines 'embodied energy' as "the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service" (Cleveland & Morris, 2009). The different ways of defining embodied energy commonly include cradle-to-gate, cradle-to-site, and cradle-to-grave. For the purposes of the assessment, we will use a cradle to grave approach, as the assessment framework includes the decommissioning phase of development.

The document notes that the definitions are given for energy but are equally valid when considering embodied carbon (dioxide) emissions. Subtleties in correctly measuring embodied carbon include the sequestration of carbon within building materials such as timber, and the emission (or sequestration) of carbon dioxide through chemical

[1] McAlinden, B., (2015) Energy Briefing Sheet: Embodied Energy and Carbon. Institution of Civil Engineers. [online] Available at: https://www.ice.org.uk/knowledge-and-resources/briefing-sheet/embodied-energy-and-carbon [Accessed 15/4/2021]

reactions during the production of materials such as cement and the lifetime use of materials such as in the carbonation of concrete.

A cradle-to-grave approach includes the following:

- Initial embodied energy: the energy required to initially produce the building/structure. It includes the energy used for the abstraction, the processing and the manufacture of the materials of the building/structure as well as their transportation and assembly on site [construction].

- Recurring embodied energy: the energy needed to refurbish and maintain the building/structure over its lifetime [operation].

- Demolition energy: the energy necessary to demolish and dispose of the building/structure at the end of its life [decommissioning].

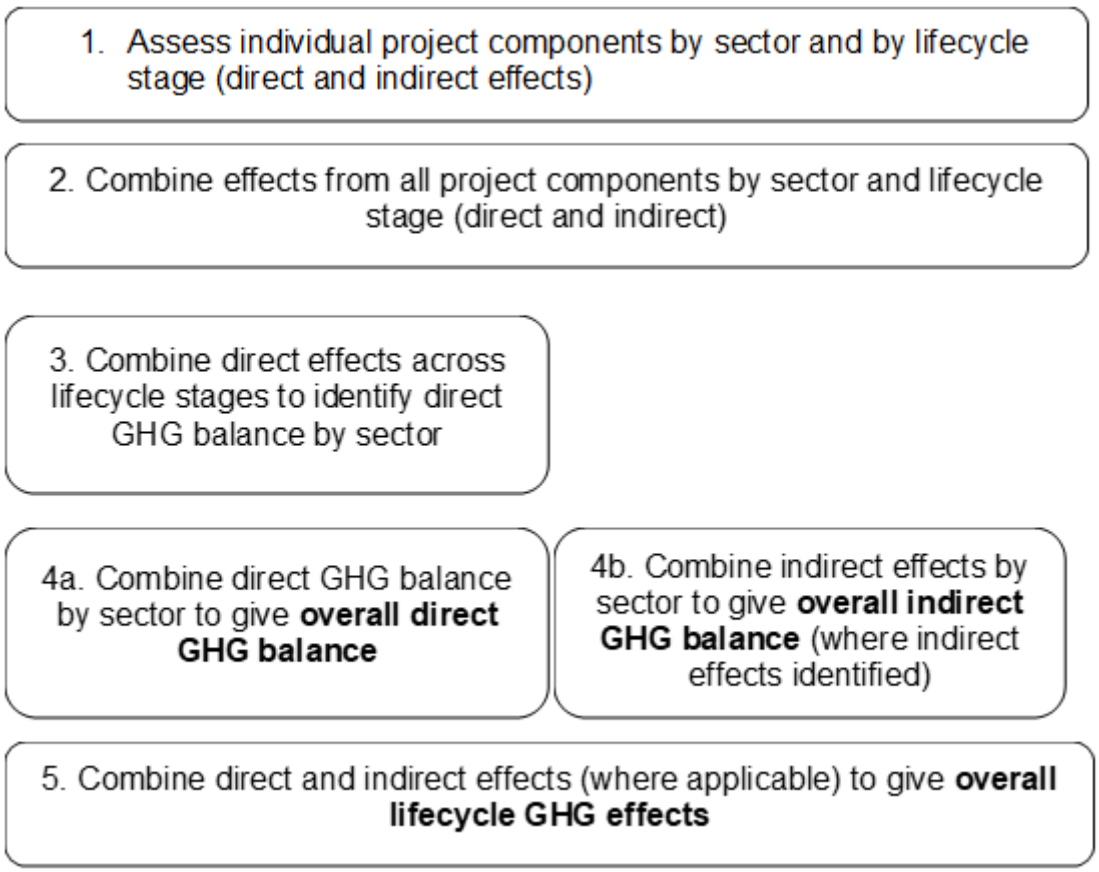
Cradle to grave embodied energy does not include the operational energy or carbon emissions of using the product/building, which is captured in other rows of the assessment framework.

Methodology

Introduction

This section provides an overview of the methodology applied to the assessment process. The stages in this process are summarised in Figure B.1 overleaf, and described in more detail in the following sections. The assessment is based on the proposed national development description and supported by assumptions.

Figure B.1: Assessment stages



Overview of methodology stages

Stage 1

Many of the proposed national developments comprise a number of distinctly different components (e.g. rail infrastructure, industrial development, low carbon energy generation), each of which is likely to have a very different profile of lifecycle GHG emissions. Where this is the case, the assessment is broken down to allow assessment all of the constituent parts. An assessment is undertaken for each of these components, before they are combined to provide an overall picture of the projects GHG effects. Each assessment stage, and the final combined summary are structured as Table B.3.

It should be noted that projects and their components vary considerably in the level of detail available. The assessment has been based on descriptions provided by the Scottish Government. Where project components are high level, the assessment is necessarily broad in nature. The project descriptions should be read alongside the information provided in NPF4. It is acknowledged that more detailed proposals for some pNDs have been published elsewhere, but for reasons of certainty and consistency, the assessment has been limited to the components defined by the SG.

The assessment firstly identifies the nature and scale of the effect for each project element, by sector and lifecycle stage. This is scored using the following system, as illustrated in Table B.1:

Table B.1: Project element scoring

Key
Significant negative (increases emissions)
Minor negative (increases emissions)
Negligible negative (increases emissions, several negligible effects could combine in the summary table)
Negligible positive (increases emissions, several negligible effects could combine in the summary table)
Mixed negligible (both increases and reduces emissions at a negligible scale)
Mixed (both increases and reduces emissions at a minor scale)
Minor positive (reduces emissions)
Significant positive (reduces emissions)
No effect

An example of the assessment table which applies this scoring system for each project element is illustrated in Table B.3.

Direct effects on emissions

The assessment framework allows the consistent consideration of direct GHG emissions or savings associated with each proposed National Development (pND). This framework distinguishes between different sources of emission (e.g. transport, heating) and different lifecycle stages (e.g. construction, operation).

The framework allows recording of embodied carbon, reflecting the potential for significant amounts of carbon to be embodied in existing structures and materials required for construction, and for the energy use in their production and manufacture. This also allows the 'flow' of carbon to be distinguished in the assessment framework, so that the balance between an initial investment in infrastructure which achieves a long term flow of low carbon activity can be identified. Most infrastructure projects will result in initial carbon emissions from construction, followed by much lower carbon emissions from operation. For renewable energy projects the assessment will include GHG emissions savings over the lifetime of the project as they displace energy generated by fossil fuels.

Indirect effects on emissions

It is recognised that some of the pND include developments which are demonstrator projects will support future roll out of a new technology, or they are projects that enable other low carbon activities, such as enhancements to the transmission network to carry renewable energy. Indirect emissions effects are also identified in the assessment table in relation to the operational phase of development. These are quantified where appropriate in terms of:

- extent (local, regional, national);
- duration (short, medium, long term),
- if the development enables other low carbon activity (such as improvements to grid infrastructure supporting renewable energy development); or
- if the development has a multiplier effect, for example through research and development or demonstration.

Direct emissions and indirect emissions are each reported in a separate section of the conclusions before being drawn together to identify the overall effect.

Predicting GHG effects

Assessment of the likely type and scale of emissions or emission savings draws on published information about GHG emissions associated with different types of development. The level of available information varies considerably between types of emission and also stage of development, which is reflected in the assessment. Equally, where information on the pND is imprecise, it may be necessary to consider a range of emission scenarios. Where no information is available, judgements are based on professional judgement and clearly indicated as such.

Assessing significance

Having identified, calculated or estimated the likely GHG emission effects of each pND component, across each emission type and lifecycle stage, the next stage is to assess their significance.

To assist in this process, we have defined a series of emissions benchmarks based on the sectoral carbon reduction pathways to 2032 set out in the 2020 Climate Change Plan update (CCPu), and updated in 2021. It is recognised that the emissions are projected to decrease over time, and therefore in the future a smaller decrease in emissions contributes a larger proportion of the reduction. The benchmark of 2021 is therefore used to provide a static figure against which all reductions can be assessed, to remove the uncertainty around future targets which may be subject to change. So, for example, the emission reductions resulting from a proposed waste development would be considered in terms of its contribution to the reductions in emissions required from the waste sector up to 2032.

Recognising that these scales of change are somewhat abstract and that predictions may be challenging for some development types and emission sources, we developed a series of benchmarking examples to guide assessors' decisions.

All emissions, either positive or negative have been given equal weighting within the assessment framework in order to allow judgements to be made on the overall balance of GHG emissions.

For example, in terms of buildings, the CCPu has set a requirement for the sector to reduce emissions from 7.6 $MtCO_2e$ in 2021 to 2.6$mtCO_2e$ by 2032, a reduction of 5.0 $MtCO_2e$. The corresponding scales of effect, and benchmarking examples, would be as shown in Table B.2:

Table B.2: Benchmarking

Scale of effect	Change in emissions	Tonnes CO_2e	Benchmark #1	Benchmark #2
Minor	<1%	<50,000 tonnes	eq to emissions to up to 2,500 homes	replacement of up to 8,800 conventional boilers
Moderate	1-5%	up to 250,000 tonnes	up to 12,500 homes	up to 44,500 boilers
Major	5-10%	up to 500,000 tonnes	up to 25,000 homes	up to 88,000 boilers
Super	10%	>500,000 tonnes	>25,000 homes	>88,000 boilers

A fuller set of benchmark examples is provided in Table B.8.

Where information is provided on the likely scale of change in GHG emissions for a pND, this was factored into the assessment. However, due to the high level nature of

the potential and alternative national development descriptions, this information is typically very broad.

Table B.3 is repeated for as many elements of the proposed or alternative national development as required. For some projects with a less complex scope only a single assessment table is required before moving to Stage 2.

Table B.3: Example assessment table

Development	Sub-category	Source of emissions	Baseline	Stage of development				Uncertainty
				Construction	Operations (direct)	Operations (indirect)	Decommissioning	
NAME	SUB CATEGORY	**Transport**		*Explanatory text for positive or negative effect and scale of effect*	*Explanatory text*	*Explanatory text*	*Explanatory text*	*Explanatory text*
		Electricity			*Explanatory text*	*Explanatory text*		
		Buildings/Heat						
		Industrial, manufacture and construction processes		*Explanatory text*				
		Waste		*Explanatory text*	*Explanatory text*		*Explanatory text*	
		LULUCF						
		Negative Emissions Technologies (if applicable)						

Stage 2

The Stage 1 assessment is then followed by a summary table which combines all project components to identify the balance of effect by sector, by lifecycle stage. The main body of the summary table is illustrated in Table B.4 below.

Table B.4: Example summary table (excluding final column)

Summary of significant effects from all project components including cumulative effects.	**Baseline**	**Construction/ establishment**	**Operation (direct)**	**Operation (indirect effects not included in GHG balance by sector)**	**Decommissioning**
Transport		*Overall combined transport **construction/establishment** GHG emissions for **all project components***	*Overall combined transport **operation (direct)** GHG emissions for **all project components***	*Overall combined transport **operation (indirect)** GHG emissions for **all project components***	*Overall combined transport **decommissioning** GHG emissions for **all project components***
Electricity					
Buildings (heat)					
Industrial, manufacture and construction processes					
Waste					
LULUCF					
Negative Emissions Technologies ((if applicable)					

Stage 3: Assessment of effects by emissions sector

The next step was to draw conclusions about the overall impact of a pND on GHG emissions. Firstly, where relevant, it was necessary to combine the assessments for individual project components to build a picture of the overall emissions effects of the National Development as currently proposed.

As illustrated in Table B.6: Process for identifying GHG balance by sector (direct effects), the summary table draws conclusions on the combined direct effects across construction/establishment, operation and decommissioning by sector. The overall GHG balance is identified as positive or negative, (see the final column of Table B.6), and the scale of that effect is related to the benchmarking for that sector using the colour coding shown in Table B.5 below. The benchmarking relates to the quantity of 2021 emissions reductions by 2032, and is explained in more detail in the section on 'Assessing significance'.

The next step was to draw conclusions about the overall impact of a pND on GHG emissions. There are two stages to this. Firstly, where relevant, it was necessary to combine the assessments for individual project components to build a picture of the overall emissions effects of the National Development as currently proposed. Secondly, taking account of the scale and significance of effects on emissions at different lifecycle stages, and the duration of lifecycle stages, professional judgement was used to draw conclusions about the overall impact of the development in question. Due to variations in the level of information underpinning the assessment a qualitative approach was used.

Assessment of emissions against the 'Negative Emissions Technologies' sector is only included where this is relevant to the proposed National Development.

Table B.5: Benchmarking score colour codes

Overall effect colour codes (positive)	Overall effect colour codes (negative)
Minor	Minor
Moderate	Moderate
Major	Major
Super	Super
Neutral	Neutral

Table B.6: Process for identifying GHG balance by sector (direct effects)

Summary of significant effects from all project components including cumulative effects.	Baseline	Construction/ establishment	Operation (direct)	Operation (indirect effects not included in GHG balance by sector)	Decommissioning	GHG balance by sector (direct)
Transport						Overall judgement on direct GHG balance by sector related to benchmarking
Electricity						
Buildings (heat)						
Industrial, manufacture and construction processes						
Waste						
LULUCF						

Stages 4a, 4b and 5: Judgements about overall effect

The next step was to draw conclusions about the overall effect of a pND on GHG emissions. There are two stages to this. Firstly, where relevant, it was necessary to combine the assessments for individual project components to build a picture of the overall emissions impacts of the National Development as currently proposed. Secondly, taking account of the scale and significance of effects on emissions at different lifecycle stages, and the duration of lifecycle stages, professional judgement was used to draw conclusions about the overall impact of the development in question. Due to variations in the level of information underpinning the assessment a qualitative approach was used.

Following the sector by sector combination of effects, summary text is provided for direct effects, indirect effects and the overall summary of effects.

The summary of effect identifies whether effects are net positive (decrease emissions) or net negative (increase emissions). The overall summary draws together effects across different emissions sectors and takes both direct and indirect effects into account. This conclusion is based on the detail provided at the time of the assessment, and the conclusion may be subject to change depending on the nature and detail of the projects taken forward. The overall summary of effect for each proposed national development may include a range of potential impacts on greenhouse gas emissions. This reflects the uncertainties associated with the detail of the proposed national developments, the scale of potential effects, and uncertainties around the implementation of new technologies. The assessment detail identifies the approximate scale of increase or decrease in emissions in qualitative terms, which may range from low to very high.

This information on overall effects is presented beneath the summary table, as illustrated in Table B.7:

Table B.7: Process for identifying summary GHG balance for direct, indirect and overall effects

Summary of direct lifecycle GHG effects	Describes the overall direct lifecycle GHG effects, noting the confidence level related to effects for each sector. The overall effect is identified as net positive or negative.
Summary of indirect lifecycle GHG effects	Describes the overall indirect lifecycle GHG effects. The overall effect is identified as net positive or negative.
Summary of overall lifecycle GHG effects	Describes the overall effect, combining direct and indirect effects. Identifies the scale of the effect, which may be a range depending on uncertainties associated with the national development. The range used is from low, medium, high to very high. The summary attributes a confidence level to the scale and / or nature of the effect.
Additional mitigation and enhancement	Describes suggested mitigation and enhancement.

Mitigation and enhancement

The final step was to consider, for each pND, whether any of the identified sources of GHG emissions could be mitigated or whether there is scope to enhance carbon reductions. The use of the detailed assessment framework allowed this part of the process to focus in on those aspects of developments where additional measures could result in the greatest GHG savings.

Where a pND identifies any project related mitigation, this was reflected in the assessment, but was identified as mitigation identified by the developer, and a level of uncertainty is attributed to this proposed mitigation. LUC also identified mitigation and enhancement and this was identified as 'additional mitigation and enhancement'.

Cumulative effects across all pND

Finally, cumulative effects across all pND were assessed, bringing together the environmental effects from all of the summary tables by emissions sector. The assessment framework allows judgements to be made across the sectors in terms of sources of emissions. The narrative text reflects on the balance of emissions and reductions between the sectors, drawing out where there are shifts in emissions sources between the below sectors:

- Transport
- Electricity
- Buildings (heat)
- Industrial, manufacture and construction processes
- Waste
- LULUCF.

Table B.8: Benchmarking and examples (benchmarked against 2021 emissions reductions by 2032[2])

Sector (reduction from 2021 to 2032)	Significance rate	% required emission reduction	tonnes CO2e	benchmark #1	benchmark #2
Agriculture (1.5mtCO2e reduction)	Minor	<1%	<15,000 tonnes		
	Moderate	1-5%	75,000 tonnes		

[2] See Appendix C: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/pages/17/

Sector (reduction from 2021 to 2032)	Significance rate	% required emission reduction	tonnes CO2e	benchmark #1	benchmark #2
	Major	5-10%	150,000 tonnes		
	Super	0.1	>150,000 tonnes		
Electricity (6.3mtCO2e reduction)	Minor	<1%	<63,000 tonnes	carbon savings from up to 28 2MW turbines[3]	
	Moderate	1-5%	315,000 tonnes	carbon savings from 140 2MW turbines	Shell St Fergus 318k tonnes
	Major	5-10%	630,000 tonnes	carbon savings from 278 2MW turbines	Grangemouth CHP 702k tonnes
	Super	0.1	>630,000 tonnes	carbon savings from >278 2MW turbines	Peterhead PS 2m tonnes
Industry (5.8mtCO2e reduction)	Minor	<1%	<58,000 tonnes	Aberdeen papermill 64k tonnes	
	Moderate	1-5%	290,000 tonnes	15 Dundee tyre factories @20k tonnes	
	Major	5-10%	580,000 tonnes	Blue Circle at Dunbar 573k tonnes	
	Super	0.1	>580,000 tonnes	Peterhead PS 2m tonnes	
Waste (0.8mtCO2e reduction)	Minor	<1%	<8000 tonnes	up to 18150 fewer tonnes household waste to landfill	

[3] Compared with grid mix generation: https://www.gov.scot/publications/calculating-carbon-savings-wind-farms-scottish-peat-lands-new-approach/pages/13/

Sector (reduction from 2021 to 2032)	Significance rate	% required emission reduction	tonnes CO2e	benchmark #1	benchmark #2
	Moderate	1-5%	40,000 tonnes	90,000 fewer tonnes household waste to landfill	
	Major	5-10%	80,000 tonnes	181,250 fewer tonnes household waste to landfill	
	Super	0.1	>90,000 tonnes	>181,250 fewer tonnes household waste to landfill	
Transport (3.7mtCO2e reduction)	Minor	<1%	<37,000 tonnes	up to 12,250 fewer cars[4]	up to 310 fewer HGVs[5]
	Moderate	1-5%	up to 185,000 tonnes	61,250 fewer cars	1500 fewer HGVs
	Major	5-10%	up to 370,000 tonnes	122,500 fewer cars	3,100 fewer HGVs
	Super	0.1	>370,000	more than 122,500 fewer cars	more than 3,100 fewer HGVs
Buildings (5mtCO2e reduction)	Minor	<1%	<50,000 tonnes	eq to emissions to up to 2,500 homes[6]	replacement of up to 8,800 conventional boilers[7]
	Moderate	1-5%	up to 250,000 tonnes	up to 12,500 homes	up to 44,500 boilers
	Major	5-10%	up to 500,000	up to 25,000	up to 88,000

[4] Based on data from https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020, medium sized car, 10,000 miles pa

[5] Based on data from https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020 for HGV travelling 100,000 miles pa

[6] Based on average house emissions of 20 tonnes CO2e pa

[7] http://www.heatingandventilating.net/heat-pumps-performance-and-carbon-saving

Sector (reduction from 2021 to 2032)	Significance rate	% required emission reduction	tonnes CO2e	benchmark #1	benchmark #2
			tonnes	homes	boilers
	Super	0.1	>500,000 tonnes	>25,000 homes	>88,000 boilers
LULUCF (1.8mtCO2e increase in sequestration)	Minor	<1%	up to 18,000 tonnes	up to 67ha mature broadleaf	up to 107ha mature conifer[8]
	Moderate	1-5%	90,000 tonnes	333ha mature broadleaf	535ha mature conifer
	Major	5-10%	180,000 tonnes	667ha mature broadleaf	1071 ha mature conifer
	Super	0.1	>180,000 tonnes	>667ha mature broadleaf	>1071 ha mature conifer

[8] https://www.forestresearch.gov.uk/documents/983/fcin048.pdf