Forestry Commission Scotland Greenhouse Gas Emissions Comparison - Carbon benefits of Timber in Construction



A report by the Edinburgh Centre for Carbon Management Ltd.

August 2006

DOCUMENT CONTROL

Title	Forestry Commission Scotland - Greenhouse Gas Emissions Comparison - Carbon Benefits of Timber in Construction
Report number	ECCM-EM-196-2006
Report status	1.3
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Background

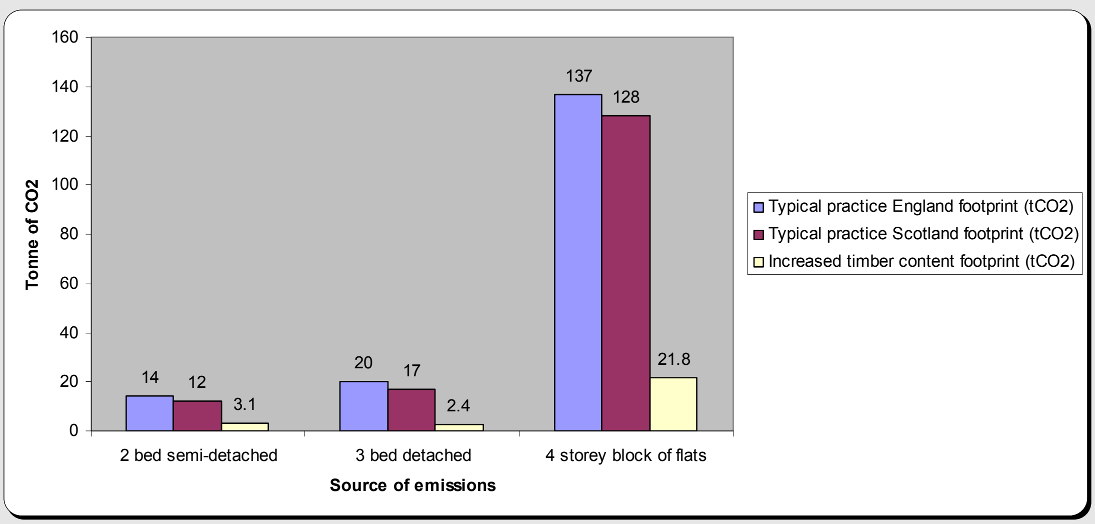
This assessment compares the greenhouse gas (GHG) emissions arising from the embodied energy[1] of a variety of different building materials that could be used in the construction of a 2 bed semi-detached house, a 3 bed detached house and a 4 storey block of flats. In addition this study quantifies the potential GHG benefits of increasing the timber content of the 3 types of accommodation.

The impact of transport on the overall GHG balance of timber is also assessed by comparing a range of hypothetical supply chains.

Summary of Emissions – Building Materials Assessment

ECCM estimates that, indicatively, there could be up to an 86% reduction in the GHG emissions associated with the embodied energy of building materials if timber internal and external structural elements and fittings are specified wherever possible rather than typical practice Scottish building materials.

For the purposes of comparison, examples of each house type using typical *English* building materials are also included; please see Appendix IV for details.



Summary of Emissions – Timber Transport Assessment

ECCM estimates that the two least carbon intensive methods of sourcing sawn timber for a company operating in the UK are by transporting it by train or by 44 tonne (28 tonne payload) lorry from a locally grown source.

[1] Embodied energy is the energy used during the 'cradle to gate' lifecycle of the material (extraction and manufacturing / processing)

Scope and Methodology

The assessment methodology follows the guidelines provided by the World Business Council for Sustainable Development (WBCSD) Greenhouse Gas Protocol.

The assessment boundary of this study includes the GHG emissions associated with the embodied energy of a range of different building materials that may be used in the construction of a 2 bed semi-detached house, a 3 bed detached house and a 4 storey block of flats.

For the transportation of timber, this study focuses on fuel combustion emissions from timber transported by ship (small and large), train and lorry (44 and 60 tonne) from Canada, Scandinavia, Eastern Europe and the UK.

1. Introduction

1.1 Background

Climate change presents a serious challenge for responsible business leaders in the 21st century. Most scientists now agree that rising atmospheric concentrations of greenhouse gases (GHGs), particularly carbon dioxide (CO_2), threaten to have severe impacts on food production, natural ecosystems and human health over the next 100 years. Industrialised and rapidly industrialising countries are the main sources of greenhouse gases. However, the greatest impacts will be felt by people in developing countries, particularly those in low lying coastal regions and marginal agricultural areas.

Figure 1. Flooding in Bangladesh

In response to the threat of climate change, the Kyoto Protocol was adopted in December 1997. Under the Protocol, industrialised countries have a legally binding commitment to reduce their collective greenhouses gas emissions by at least 5% compared to 1990 levels by the period 2008-2012. Russia ratified the Kyoto Protocol on 18th November 2004 and as a result it came into force on February 16th 2005.

Figure 2. Kyoto Ratification -The UN Secretary General Kofi Annan receives Russia's instrument of ratification. Allowing the Kyoto Protocol to enter into force in early 2005. Picture taken from http://unfccc.int/2860.php.

The UK ratified the Kyoto Protocol in May 2002 as part of a joint ratification by European Union countries. The UK commitment is for a 12.5% reduction in Kyoto greenhouse gases, however the UK Government has pledged to reduce CO_2 emissions by 20% of their 1990 level by 2010. Total UK GHG emissions for 2003 for all sources (fossil fuel combustion, industrial processes and land use change and forestry) were 665 800 000 tonnes of CO_2 equivalent, 13.4% below 1990 levels (UNFCCC, 2003). The 2003 UK Government's Energy White Paper set an aspiration for the UK to reduce carbon emissions by 60%, and create a low carbon economy by 2050.

National governments and the EU are taking a variety of steps to reduce GHG emissions including the introduction of emissions trading schemes, voluntary reduction and reporting programs, carbon or energy taxes, and regulations and standards on energy efficiency and emissions. Increasingly, companies will need to understand and manage their GHG risks in order to maintain their license to operate, to ensure long-term success in a competitive business environment, and to comply with national or regional policies aimed at reducing corporate GHG emissions (WBCSD/WRI 2004).

Materials used in construction have widely varying amounts of greenhouse gases associated with their extraction, refining, manufacture or processing and delivery. The production of cement and steel alone account for over 10% of global, annual greenhouse gas emissions. As new buildings become more energy efficient, the emissions associated with materials make up a greater proportion of their total climate change impact.

Planners, developers, architects and builders are becoming more aware of the climate change impacts of construction materials and are increasingly including climate change considerations in their selection of materials for building projects.

2. Assessment Methodology

2.1 General Procedure

The assessment methodology used here follows the reporting principles and guidelines provided by the Greenhouse Gas Protocol published by the World Business Council for Sustainable Development and the World Resources Institute (WBCSD/WRI Protocol).

In line with the WBCSD/WRI Protocol, ECCM have used the following procedure to undertake this study:

1. Establishment of the assessment boundaries (including the selection of: greenhouse gases and project boundaries).
2. Calculation of emissions using appropriate conversion factors.
3. Analysis of results.

The assessment procedure and a summary of results are presented in the main text of the report. A detailed description of emissions calculations and associated assumptions are presented in Appendices II and III.

A glossary of climate change terms is found in Appendix I.

2.2 Greenhouse Gases - Overview

An assessment such as this can include all six greenhouse gases covered by the Kyoto Protocol. The six Kyoto gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexaflouride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs).

The global warming potential (GWP) of each greenhouse gas may be expressed in CO_2 equivalents (see Table 1). For those gases with a high global warming potential, a relatively small emission can have a considerable impact.

Table 1. The global warming potential of the Kyoto gases

Kyoto gas	GWP*
carbon dioxide (CO_2)	1
methane (CH_4)	23
nitrous oxide (N_2O)	296
sulphur hexaflouride (SF_6)	22,200
perfluorocarbons (PFCs)	4,800 – 9,200
hydrofluorocarbons (HFCs)	12 - 12,000

*Note: the ‘global warming potential’ of a gas is its relative potential contribution to climate change over a 100 year period, where CO_2 =1 (see Glossary for a full definition). Source: IPCC (2001).

2.3 Greenhouse Gases

This assessment covers the CO_2 emissions arising from the embodied energy of building materials and from transport fuel combustion. CH_4 and N_2O factors have not been included in this assessment as conversion factors are not available for all materials that have been assessed as part of this study, and their relative contribution to overall GHG emissions will be small.

2.4 Scope of Assessment

The scope of this study encompasses the embodied emissions of a selection of construction materials and the emissions arising from a range of different modes of timber transport.

This study does not consider or compare the varying lifetimes of different construction materials, and the impact that this may have on the lifetime carbon footprint of the building.

In addition, the carbon benefits of increasing timber in construction illustrated in this report relate to new buildings only. This report does not seek to recommend replacing existing buildings with increased timber content alternatives.

2.5 Reporting Approach

ECCM does not base its emissions assessments on direct measurement of emissions, but on estimates of material and energy consumption (principally weight or volume of fuel, but also weight or volume of waste and material) from which estimates of emissions can be derived, by the application of relevant conversion factors (i.e. amount of CO_2 produced per unit of fuel consumed). This approach is considered the most pragmatic, since the quantity of key greenhouse gases produced in most combustion and manufacturing processes is well understood. However, the certainty of waste emission estimates is lower, but direct measurement is rarely a realistic option.

The validity of all estimates depends on the accuracy, relevance and completeness of the data and on the conversion factors used. ECCM's approach is to set out as clearly as possible all the assumptions and conversion factors used, so that the report is as transparent as possible and the estimate of emissions is founded on 'best evidence'.

ECCM is guided by the precautionary principle. Where there is any doubt over activities undertaken, or where there is a choice of published figures available for calculating greenhouse gas emissions, a conservative 'worst case' scenario is assumed, unless otherwise specified.

2.6 Emission factors

Emissions factors for the lifecycle of building materials were taken from standard data provided by the UK Building Research Establishment (BRE), the Finnish Building Information Foundation and the European Plastics Industry and applied where appropriate.

In order to establish the tonnes of CO_2 emitted from fuel consumption default conversion factors were applied. These were taken from ‘Environmental Reporting: guidelines for company reporting on greenhouse gas emissions’ published by the UK government (DEFRA 2005).

3. Data

3.1 Data Sources

The quantities and dimensions of construction materials, upon which the emissions calculations were based are not taken from actual architects specifications. Rather they are estimates created by ECCM based on previous carbon footprinting projects and standard structural engineering reference works (See references).

The previous carbon footprinting projects can not be named for reasons of confidentiality.

3.2 Data Assumptions

All assumptions underlying the emission calculations are detailed in Appendices II - IV.

4. Results

Building materials comparison

ECCM have detailed a range of potential building materials that may be used in the construction of a 2 bed semi-detached house[2], a 3 bed detached house and a 4 story block of flats and have calculated the GHG emissions associated with each. These are presented in Appendix II.

In order to illustrate the GHG reductions that can be achieved by increasing the timber content of a 2 bed semi-detached house, a 3 bed detached house and a 4 story block of flats, ECCM have presented a *'typical building materials (Scotland)'* scenario and an *'increased timber content'* scenario for each of the accommodation types. These are shown in Tables 2-7 below[3].

2 bed semi detached –building materials comparison

Typical materials (Scotland)

Building material	**Tonnes of CO_2**
Foundations	
Concrete	0.9
Flooring	
Hardcore, concrete slab, screed, chipboard, extruded polystyrene insulation	2.0
Ceilings	
Plasterboard	0.2
Joists	
Timber I joists	-0.12
External walls	
Timber frame, brick work, plywood sheathing, glasswool insulation and plasterboard	4.9
Internal walls	
Timber frame and plasterboard	0.2
Stairs	
Timber	-0.1
Windows	
Glass	0.1
PVC frame	0.03
Internal doors	
Panel doors (chipboard)	-0.1
External doors	
PVC	0.1
Roof	
Timber rafters, rock wool insulation and Marley plain concrete (BRE element profile)	4.0
Total	**12.2**

Table 2. 2 bed semi-detached – typical materials (Scotland)

[2] It is assumed that a semi detached complex is composed of two dwellings sharing one wall. Only one dwelling has been assessed in this study.
[3] The emissions associated with the roof are calculated using BRE 'element profiles' which includes emissions from embodied energy of the frame, insulation and roof tiles.

Increased Timber content

Building material	Tonnes of CO_2
Foundations	
Concrete	0.9
Flooring	
Hardcore, concrete slab, timber floor, EPS insulation	1.0
Ceilings	
Plasterboard	0.2
Joists	
Timber I joists	-0.12
External walls	
Timber frame, timber clad, panelvent board, cellulose insulation and plasterboard	-1.9
Internal walls	
Timber frame and plasterboard	0.2
Stairs	
Timber	-0.1
Windows	
Glass	0.1
Wooden frames	-0.02
Internal doors	
Panel doors (chipboard)	-0.1
External doors	
Timber	-0.1
Roof	
Timber rafters, rock wool insulation, felt, battens and clay tiles (BRE element profile)	2.9
Total	**3.1**

Table 3. 2 bed semi-detached – increased timber content

3 bed detached – building materials comparison

Typical materials (Scotland)

Building material	Tonnes of CO_2
Foundations	
Concrete	1.7
Flooring	
Hardcore, concrete slab, screed, chipboard, extruded polystyrene insulation	1.9
Ceilings	
Plasterboard	0.4
Joists	
Timber I joists	-0.59
External walls	
Timber frame, brick work, plywood sheathing, glasswool insulation and plasterboard	8.4
Internal walls	
Timberframe and plasterboard	0.27
Stairs	
Timber	-0.1
Windows	
Glass	0.1
PVC frame	0.06
Internal doors	
Panel doors (chipboard)	-0.02
External doors	
PVC	0.1
Roof	
Timber rafters, rock wool insulation and Marley plain concrete (BRE element profile)	4.5
Total	**16.8**

Table 4. 3 bed detached – typical materials (Scotland)

Increased Timber content

Building material	Tonnes of CO_2
Foundations	
Concrete	1.7
Flooring	
Hardcore, concrete slab, timber floor, EPS insulation	0.7
Ceilings	
Plasterboard	0.4
Joists	
Timber I joists	-0.59
External walls	
Timber frame, timber clad, panelvent board, cellulose insulation and plasterboard	-3.3
Internal walls	
Timber frame and plasterboard	0.3
Stairs	
Timber	-0.1
Windows	
Glass	0.1
Wooden frames	-0.04
Internal doors	
Panel doors (chipboard)	0.0
External doors	
Timber	-0.1
Roof	
Timber rafters, rock wool insulation, felt, battens and clay tiles (BRE element profile)	3.3
Total	**2.4**

Table 5. 3 bed detached – increased timber content

4 storey block of flats – building materials comparison

Typical materials (Scotland)

Building material	Tonnes of CO_2
Foundations	
Concrete	4.7
Flooring	
Hardcore, concrete slab, screed, chipboard, extruded polystyrene insulation	39.9
Ceilings	
Plasterboard	2.3
Structural Steel	
Steel	15.44
External walls	
Brick outer leaf with block internal leaf, glasswool insulation and plasterboard	32.1
Internal walls	
Timber frame and plasterboard	8.7
Stairs	
Concrete	1.1
Windows	
Glass	0.3
PVC frame	0.29
Internal doors	
Panel doors (chipboard)	-0.4
External doors	
PVC	0.6
Roof	
Timber rafters, rock wool insulation and Marley plain concrete (BRE element profile)	23.4
Total	**128.3**

Table 6. 4 storey block of flats – typical materials (Scotland)

Increased Timber content

Building material	Tonnes of CO_2
Foundations	
Concrete	4.7
Flooring	
Hardcore, concrete slab, timber floor, EPS insulation	1.0
Ceilings	
Plasterboard	2.3
Joists	
Timber I joists	-3.17
External walls	
Timber frame, timber clad, panelvent board, cellulose insulation and plasterboard	-9
Internal walls	
Timber frame and plasterboard	8.7
Stairs	
Concrete	1.1
Windows	
Glass	0.3
Wooden frames	-0.18
Internal doors	
Panel doors (chipboard)	-0.4
External doors	
Timber	-0.4
Roof	
Timber rafters, rock wool insulation, felt, battens and clay tiles (BRE element profile)	17.3
Total	**21.8**

Table 7. 4 storey block of flats – increased timber content

For the purposes of comparison, examples of each house type using typical *English* building materials are shown in Appendix IV.

The savings that can be achieved by increasing the timber content in the 3 types of house are illustrated in Table 8 and Figure 3 below.

Type of building	Typical practice Scotland footprint (tCO_2)	Increased timber content footprint (tCO_2)	Difference (tCO_2)	Percentage saving (%)
2 bed semi-detached	12.2	3.1	9.2	75%
3 bed detached	16.8	2.4	14.4	86%
4 storey block of flats	128.3	21.8	106.5	83%
Average	-	-	-	**81%**

Table 8. Building materials carbon footprint comparison

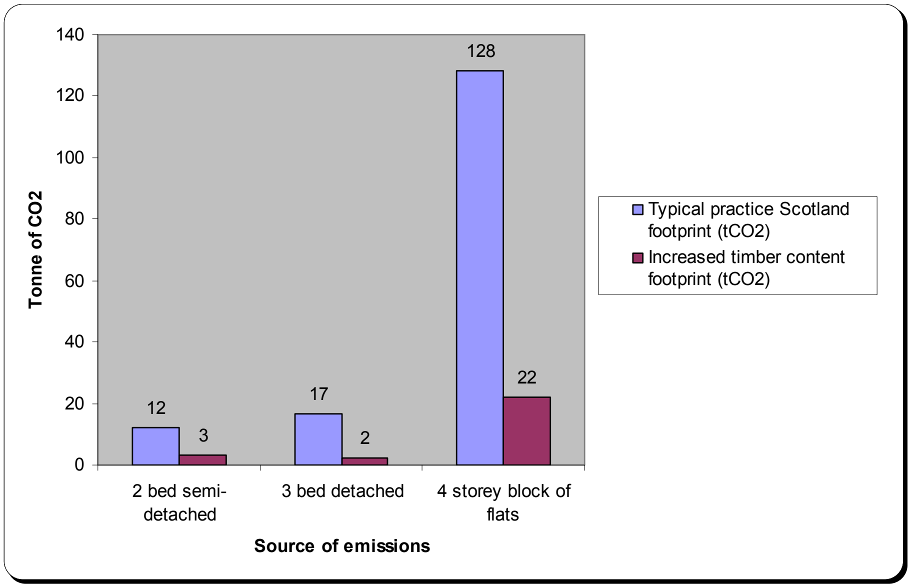


Figure 3. Building materials carbon footprint comparison

Timber transport

In order to quantify the contribution of transport to the GHG balance of timber, ECCM calculated the emissions that would be associated with UK, Swedish, Canadian and Latvian sawn timber supply chains. The GHG emissions arising from a variety of modes of transport were quantified. These include small and large boat, train and 44 tonne (28 tonne payload), and 60 tonne (40 tonne payload) lorries. The resulting matrix and all assumptions used are shown in Appendix III.

To illustrate the savings achieved by sourcing local sawn timber and using the most fuel efficient mode of transport, ECCM created four example routes by which timber is transported. These are presented in Tables 9-13.

Example journey - Sweden to Scotland	**Methods of transport**	**Total tCO_2 per tonne transported**
Vaxjo - Gothenburg - Newcastle - Perth	60 tonne lorry, large ship, 44 tonne lorry.	0.038

Table 9. Timber transportation emissions – Sweden to Scotland

Example journey - Latvia to Scotland	**Methods of transport**	**Total tCO_2 per tonne transported**
Gulbene - Riga - Newcastle - Perth	Train, small ship, 44 tonne lorry.	0.128

Table 10. Timber transportation emissions – Latvia to Scotland

Example journey - Canada to Scotland	**Methods of transport**	**Total tCO_2 per tonne transported**
Shawinigan - Montreal - Liverpool - Perth	44 tonne lorry, Large ship, 44 tonne lorry	0.134

Table 11. Timber transportation emissions – Canada to Scotland

Example journey - Scotland (locally sourced)	Methods of transport	Total tCO2 per tonne transported from origin to Perth
Fort William - Perth	44 tonne lorry	0.007

Table 12. Timber transportation emissions – Scotland (locally sourced)

Of these routes, the least carbon intensive route for a company operating in the UK is from a UK supplier transporting by 44 tonne (28 tonne payload) lorry.

Transporting timber by train is not always an option. However, of all modes of transport assessed as part of this study, trains have the lowest associated GHG emissions. ECCM have compared the emissions associated with sawn timber transported from Crianlarich to Chirk by train and by 44 tonne (28 tonne payload) lorry to illustrate this, and the results are presented in Table 13 below.

Source of emissions	Emissions Metric kg CO_2/tonne.km	Tonnes of CO_2/tonne of
Crianlarich - Chirk		
Road freight (44 tonne articulated lorry)	0.04	0.021
Train freight	0.03	0.015

Table 13. Timber transportation emissions – Rail and 44 tonne lorry comparison

Timber milling efficiencies will vary from country to country and this will impact on the overall carbon footprint of sawn timber. This is however beyond the scope of this assessment.

5. Analysis of Results

For all building types that have been assessed as part of this study, GHG emissions associated with the embodied energy of construction materials are lower if the timber content is increased. This study has demonstrated that, indicatively, it is possible to achieve up to an 86% reduction in GHG emissions by increasing the amount of timber specified in buildings.

Figure 4. As trees grow, they sequester carbon from the atmosphere giving them a negative carbon intensity.

These emissions reductions are achieved as timber is used to replace building materials that have high carbon intensity such as concrete and steel. These materials have high GHG emissions associated with extraction, refining, processing and manufacture.

Wood has a negative carbon intensity because while a tree is growing, carbon is sequestered and stored, meaning that CO_2 is taken from the atmosphere, rather than being emitted into it during production of the material. It should be noted that emissions reductions resulting from the use of timber in construction will only be achieved if the timber is taken from a sustainably managed source.

This study has shown that it is possible to reduce GHG emissions associated with construction materials by incorporating wood in to buildings wherever possible. To further reduce emissions, it should also be considered where the timber is sourced from. This study has shown that timber that is sourced locally has the lowest associated GHG emissions.

Figure 5. Timber transported by lorry

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Appendix I

Glossary

Glossary

Carbon Dioxide Equivalent (CO_2e). The universal unit of measurement used to indicate the global warming potential (GWP) of each of the 6 Kyoto greenhouse gases. It is used to evaluate the impacts of releasing (or avoiding the release of) different greenhouse gases.

Climate change. A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods (Source: United Nations Framework Convention on Climate Change).

Control. The ability of a company to direct the operating policies of a facility or organisation. Usually, if the company owns more than 50% of the voting interests, this implies control. The holder of the operating licence often exerts control, however, holding the operating licence is not a sufficient criteria for being able to direct the operating policies of a facility or organisation. In practice, the actual exercise of dominant influence itself is enough to satisfy the definition of control without requiring any formal power or ability through which it arises.

Direct emissions. Emissions that are produced by organisation-owned equipment or emissions from organisation-owned premises, such as carbon dioxide from electricity generators, gas boilers and vehicles, or methane from landfill sites.

Equity share. The percentage of economic interest in/benefit derived from an organisation.

Global warming The continuous gradual rise of the earth's surface temperature thought to be caused by the greenhouse effect and responsible for changes in global climate patterns (see also Climate Change).

Global Warming Potential (GWP) The GWP is an index that compares the relative potential (to CO_2) of the 6 greenhouse gases to contribute to global warming i.e. the additional heat/energy which is retained in the Earth's ecosystem through the release of this gas into the atmosphere. The additional heat/energy impact of all other greenhouse gases are compared with the impacts of carbon dioxide (CO_2) and referred to in terms of a CO_2 equivalent (CO_2e) e.g. Carbon dioxide has been designated a GWP of 1, Methane has a GWP of 21.

Greenhouse gases. The current IPCC inventory includes six major greenhouse gases. These are Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF_6).

IPCC. The Intergovernmental Panel on Climate Change. A special intergovernmental body established by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO) to provide assessments of the results of climate change research to policy makers. The Greenhouse Gas Inventory Guidelines are being developed under the auspices of the IPCC and will be recommended for use by parties to the Framework Convention on Climate Change.

Indirect emissions. Emissions that are a consequence of the activities of the reporting company but occur from sources owned or controlled by another organisation or individual. They include all outsourced power generation (e.g. electricity, hot water), outsourced services (e.g. waste disposal, business travel, transport of company-owned goods) and outsourced manufacturing processes. Indirect emissions also cover the activities of franchised companies and the emissions associated with downstream and/or upstream manufacture, transport and disposal of products used by the organisation, referred to as product life-cycle emissions.

Kyoto Protocol. The Kyoto Protocol originated at the 3rd Conference of the Parties (COP) to the United Nations Convention on Climate Change held in Kyoto, Japan in December 1997. It specifies the level of emission reductions, deadlines and methodologies that signatory countries (i.e. countries who have signed the Kyoto Protocol) are to achieve.

Appendix II

Emissions Calculations and Assumptions – Building materials

Appendix III

Emissions Calculations and Assumptions – Timber transportation

Appendix IV

Emissions Calculations and Assumptions – Typical English Building Materials