What is a Carbon Footprint?

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Project	What is a Carbon Footprint?
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Executive Summary

This report has been commissioned by the Swedish Forest Industries Federation and Timcon to provide accessible definitions of the terms 'carbon footprint' and 'carbon neutral'. The report also introduces the standard processes and protocols used in calculating carbon footprints, and the final section gives an overview of the role of forests and wood products in the global carbon cycle.

Human induced climate change is now recognised by the global community as the greatest environmental threat of the 21st century. Countries, organisations and individuals alike are starting to take responsibility for making the emissions reductions necessary to stabilise global warming gases in the atmosphere.

A 'carbon footprint' is a measure of the greenhouse gas (GHG) emissions associated with an activity, group of activities or a product. The main reason for calculating a carbon footprint is to inform decisions on how to reduce the climate change impact of a company, service or product.

The term 'carbon neutral' refers to something with a carbon footprint of zero. 'Carbon neutrality' is normally achieved by first calculating a carbon footprint, then reducing emissions as far as possible, and finally 'offsetting' the remainder by purchasing emissions reductions 'credits' generated by external projects such as renewable energy schemes or forestry projects.

Wood products from sustainably harvested forests have a 'negative carbon footprint' meaning that they act as a carbon store. As trees grow they 'fix' carbon dioxide from the atmosphere by photosynthesis and it is stored as carbon within the organic matter that makes up the trees. An example study shows how the carbon footprints of buildings can be reduced by increased use of sustainably sourced timber acting as a long-term carbon store.

1.   What is a Carbon Footprint?

A 'carbon footprint' is a measure of the greenhouse gas emissions associated with an activity, group of activities or a product. Nearly everything that we do produces greenhouse gas (GHG) emissions either directly or indirectly; whether it be getting to work, watching TV or buying our lunch. The most important greenhouse gas produced by human activities is carbon dioxide. Direct GHG emissions sources are often easy to identify – for example burning fossil fuels for electricity generation, heating and transport.   It is sometimes less obvious that products and services also cause indirect emissions throughout their life-cycles.   Energy is required for production and transport of products, and greenhouse gases are also released when products are disposed of at the end of their useful lives.

1.1 Comparison of definitions

Although it has become a very popular term, there is currently there is no universal definition of a carbon footprint. Definitions vary in terms of which activities and greenhouse gases should be included within the scope of a carbon footprint assessment, and the level of detail. Carbon footprint methodologies range from simple online calculators to complex life-cycle analysis. Automated web-based calculators (for example the BP and BSkyB household calculators) tend to only cover carbon dioxide emissions. Some carbon footprint definitions recently researched by ISA (2007) also only mention carbon dioxide (Energetics, 2007; Global Footprint Network, 2007). Other definitions and methods include all Kyoto greenhouse gases and measure emissions in terms of 'carbon dioxide equivalents' (see box 1), for example Carbon Trust (2007).

1.2 Why work out a carbon footprint?

The increasing interest in 'carbon footprinting' comes as a result of growing public awareness of global warming. The global community now recognises the need to reduce greenhouse gas emissions to mitigate climate change. Countries, organisations and individuals alike are starting to take responsibility.

Businesses and services that are not currently regulated under the Kyoto protocol may wish to pre-empt future regulations, and may find marketing advantages in being 'green'. Calculating a carbon footprint can be a valuable first step towards making quantifiable emissions reductions. This in turn can lead to long term financial savings as well as reducing climate-change impact (Stern 2006).

Box 1: Greenhouse gases
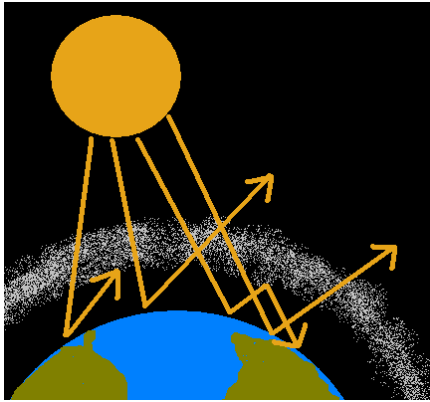
Greenhouse gases affect the ability of the earth's atmosphere to retain heat. Higher greenhouse gas concentrations in the earth's atmosphere cause global warming through this 'greenhouse effect'. The Kyoto protocol, which originated at the 3rd Conference of the Parties to the United Nations Convention on Climate Change in 1997, has identified six greenhouse gases whose atmospheric concentrations are strongly influenced by human activity. The most important of these is carbon dioxide (CO_2). The global warming potential (GWP) of each greenhouse gas can be expressed in CO_2 equivalents (see table). For gases with a high global warming potential, a relatively small emission can have a considerable impact.

Kyoto gas	GWP*	Example sources
Carbon dioxide (CO_2)	1	Burning fossil fuels
Methane (CH_4)	23	Cattle, landfill sites, leaks from disused mines, burning fossil fuels.
Nitrous oxide (N_2O)	296	Emissions from fertilised soils, burning fossil fuels.
Sulphur Hexafluoride (SF_6)	22,200	Leaks from electrical and electronics industries.
Perfluorocarbons (PFCs)	4,800 – 9,200	Electronics industries, fire extinguishers
Hydrofluorocarbons (HFCs)	12-12,000	Leaks from air conditioning and refrigeration systems. LPG storage.

*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 Source: IPCC (2001)

1.3 What has been assessed so far?

An increasing number of organisations and product manufacturers are assessing the carbon footprints of their operations, one-off events and products. Organisations range from charitable organisations like MercyCorps to commercial companies such as BSkyB, as well as small and medium sized enterprises. Product assessments have been conducted for a range of goods including electronics products, vehicles, and disposable goods. Some UK examples include Innocent smoothies, Walkers crisps, Louise Galvin hair care products and The Times newspaper.   The Carbon Trust has recently announced the intention of Coca Cola, Scottish & Newcastle, Cadburys, Halifax and the Co-operative Group to commit to carbon footprinting some of their products. Carbon footprints have also been calculated for construction projects, for example Sabban Property Investments (new-build luxury accommodation in the Middle-East), Caledonian Building Systems (modular steel framed construction) and Forestry Commission/ Self-build Scotland (largely timber-framed buildings). Footprinting of one-off events such as the EU's Greenweek events is also increasingly common.

Figure 1. Innocent Drinks assessed their supply chain

Figure 2. Sabban Property Investments assessed their 'Sabban Towers on the Pearl Qatar' development

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1.4 What does 'carbon – neutral' mean?

'Carbon neutral' is another popular term that is often not well understood. Something that is 'carbon neutral' has a carbon footprint of zero. An organisation, for example, that wants to reduce its climate change impact will usually first calculate its carbon footprint and then identify areas of its operations where emissions reductions can be made. Most of the time it will not be possible to reduce a carbon footprint to zero, and companies may choose to invest in projects that generate emissions reductions to 'offset' the emissions that they cannot reduce internally. Emissions reductions (also known as 'offset') are sold in tonnes of CO_2 equivalent and can come from a range of projects such as renewable technologies, energy efficiency projects, land-use change projects and methane capture.

2.   What does a Carbon footprint look like?

2.1 Protocols for Carbon Footprinting

The most widely recognised protocol for businesses and organisations is the WBCSD/WRI Greenhouse Gas Reporting Protocol. www.ghgprotocol.org The GHG protocol divides emissions sources into three 'scopes' according to level of responsibility where some indirect sources (eg. emissions from waste and subcontracted activities) are optional for reporting. The California Climate Action Registry General Reporting Protocol largely follows the GHG protocol, and ISO 14064 provides an international standard for organisations based on the GHG protocol www.iso.org.   Other   company-specific protocols, for example the CarbonNeutral protocol, also tend to refer to the GHG protocol. The GHG protocol works well for internal benchmarking but is not so well suited for comparisons of carbon footprints between   organisations   due   to   optional reporting of 'scope 3' activities.

For products there is not yet a published global   protocol   for   carbon   footprinting, although there are standards for Life-Cycle Analysis (ISO 14044 + ISO 14040). The ISO standards cover other environmental impact measures   such   as   acidification, eutrophication, photo-oxidant formation as well as greenhouse gases.   The Carbon Trust has produced a draft methodology for product carbon footprinting with the intention of developing a UK standard in partnership with Defra and BSI British Standards. The methodology is available for use but is still under development.   Currently it does not cover the retail or use phases of the life-cycle.

Figure 3. GHG Protocol
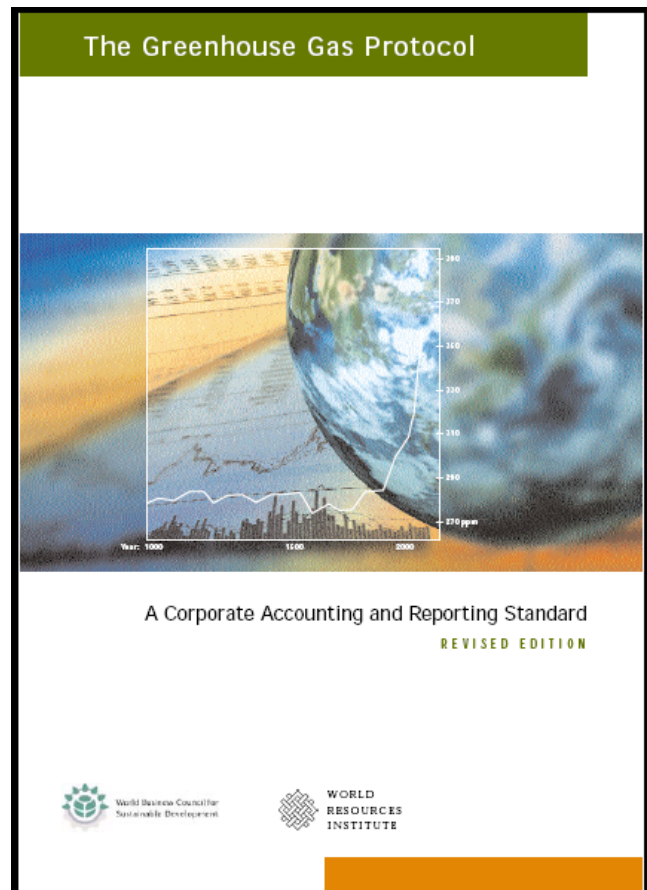
2.2 *Examples of Carbon Footprints*

The steps needed to work out a carbon footprint are different depending on whether the subject is an organisation or a product. Simplified examples of each are shown below.

Organisation: Carbon footprint of a business with 5 offices

A carbon footprint for an organisation is typically measured in tonnes of CO_2 equivalent per year. These emissions can be broken down by activity as shown in Figure 4 and Table 1 below.

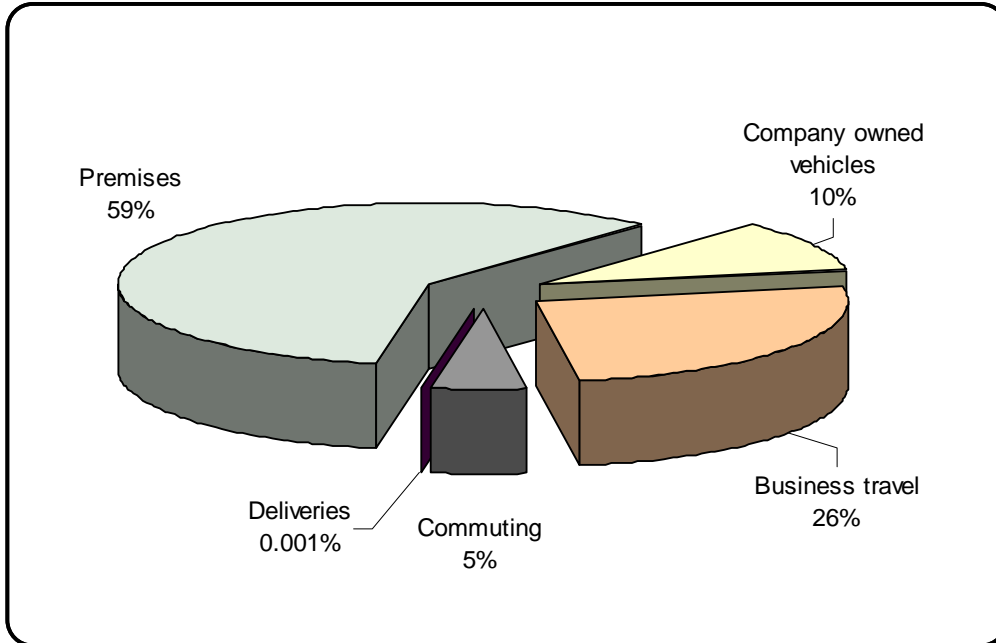*Figure 4. Carbon footprint Breakdown for a Business with 5 offices*

Table 1. Breakdown of company emissions by activity

Source of emissions	Equivalent emissions CO$_2$ (t/yr)	Proportion of total
Premises - electricity	2,342.4	40%
Premises - gas	394.3	7%
Premises - heating Oil	530.5	9%
Premises - Backup generators	1.6	0%
Premises - refrigerant loss	0.0	0%
Company owned vehicles - petrol cars	587.3	10%
Business travel - petrol cars	162.1	3%
Business travel - taxi hire	85.5	1%
Business travel - air travel	830.4	14%
Business travel - train travel	11.5	0%
Business travel - hotel stays	401.9	7%
Commuting - petrol car	206.9	4%
Commuting - motorcycle travel	7.3	0%
Commuting - train	37.6	1%
Commuting - bus	40.4	1%
Deliveries - van	3.7	0%
Premises - landfilled waste	191	3%
Total	**5,834**	**100%**

The basic steps required to calculate a carbon footprint for an organisation are as follows:

1. Establishment of the assessment boundaries:
   - Organisational
   - Operational
   - Greenhouse gases
2. Collection of data.
3. Calculation of emissions using appropriate emissions factors (see Box 2).

The *organisational boundary* can be defined in terms of ownership and/or control. A company may own several operations but only control a small number and may only wish to assess the operations that it controls.

The *operational boundary* for the example company is shown in Figure 5 below. Some organisations may choose to leave out some activities over which they have limited control (eg. Staff commuting, outsourced deliveries) as defined by the GHG protocol (see section 2.1).

In this example the *greenhouse gas* boundary includes CO$_2$, CH$_4$ and N$_2$O emissions arising from fuel combustion and CH$_4$ emissions from waste disposal to landfill. Sometimes companies may choose to conduct a simplified assessment concentrating only on CO$_2$ emissions.

Figure 5. Operational boundary for Business Carbon Footprint
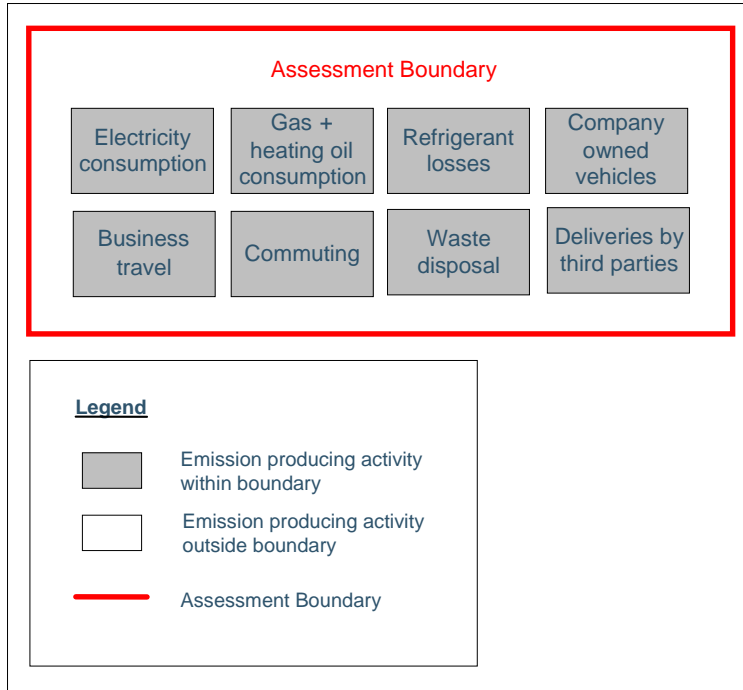
For most organisations it is possible to collect primary data for the majority of these activities, for example cubic metres of gas used per year, amount of fuel used by company cars, distance flown. In cases where good systems are not established, estimates and assumptions are sometimes made. These should be clearly stated when reporting greenhouse gas emissions as they affect the accuracy of the total carbon footprint estimate.

Standard emissions factors (see box 2) are available for all the above activities. Some have a greater or lesser degree of 'uncertainty' associated with them. The accuracy of a carbon footprint relies not only on the accuracy of data but also on the emissions factors. The International Panel on Climate Change (IPCC) provides a methodology for assessing uncertainty (IPCC 2007).

It is useful to report emissions by a standard unit for benchmarking purposes. For organisations a useful measure can be average annual emissions per employee (Table 2).

Box 2: Emissions factors

It is possible to measure actual greenhouse gas emissions associated with some activities such as industrial processes and transport. Emissions from, for example, cars, aeroplanes and electricity generation are well understood and documented. Standard 'emissions factors' have been calculated for these activities so that actual emissions do not always have to be measured, but can be calculated from other data – such as amount of fuel used. Emissions factors have also been derived for activities where it is not so easy to measure emissions – such as from agricultural and land use activities, although these factors are much more uncertain.

Table 2. Annual emissions per employee

Source of emissions	No. employees	Total CO$_2$ equiv. (t/yr)	Emissions per employee (tCO$_2$e/yr)
Total/average	**1,600**	**5,834**	**3.6**

Product: Carbon Footprint of The Times Newspaper

Product Carbon Footprints are commonly expressed either as 'cradle to gate' footprints, or 'cradle to grave' depending on the life-cycle stages included. The essential difference between assessment boundaries is shown in Figure 6.

Figure 6. Cradle to gate and Cradle to grave assessment boundaries

Cradle to Gate

Cradle to Grave
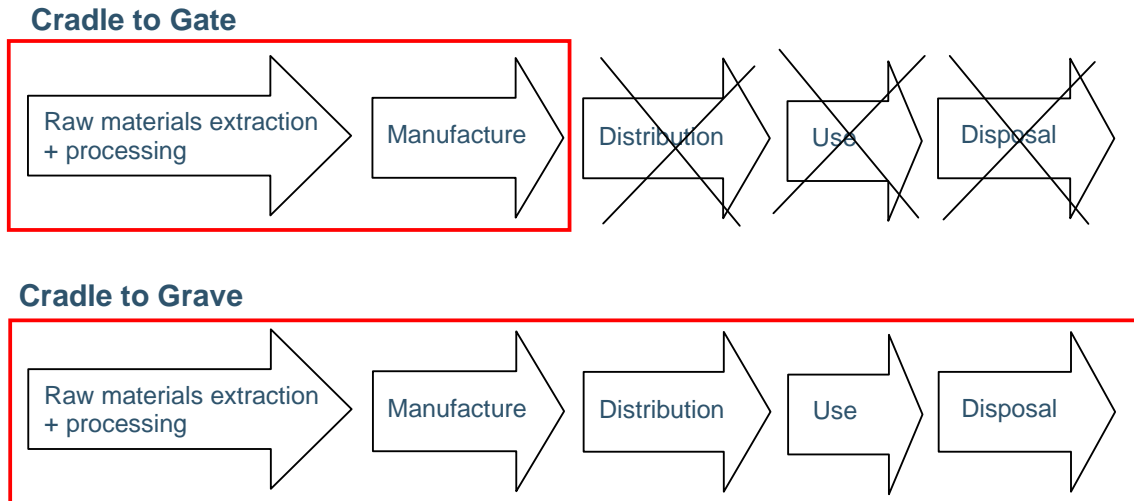
The basic steps required to calculate a carbon footprint for a product are as follows:

1. Analyse the materials and supply chain processes.

2. Build a supply chain map for the product.

3. Define the assessment boundaries (including the selection of greenhouse gases and the emissions sources which will be included).

4. Data collection

5. Calculation of emissions using appropriate emissions factors.

A supply chain map for The Times is shown in Figure 7 below. The 'Materials' stage applies collectively to extraction and processing of raw materials.

Figure 7. Newspaper supply chain map
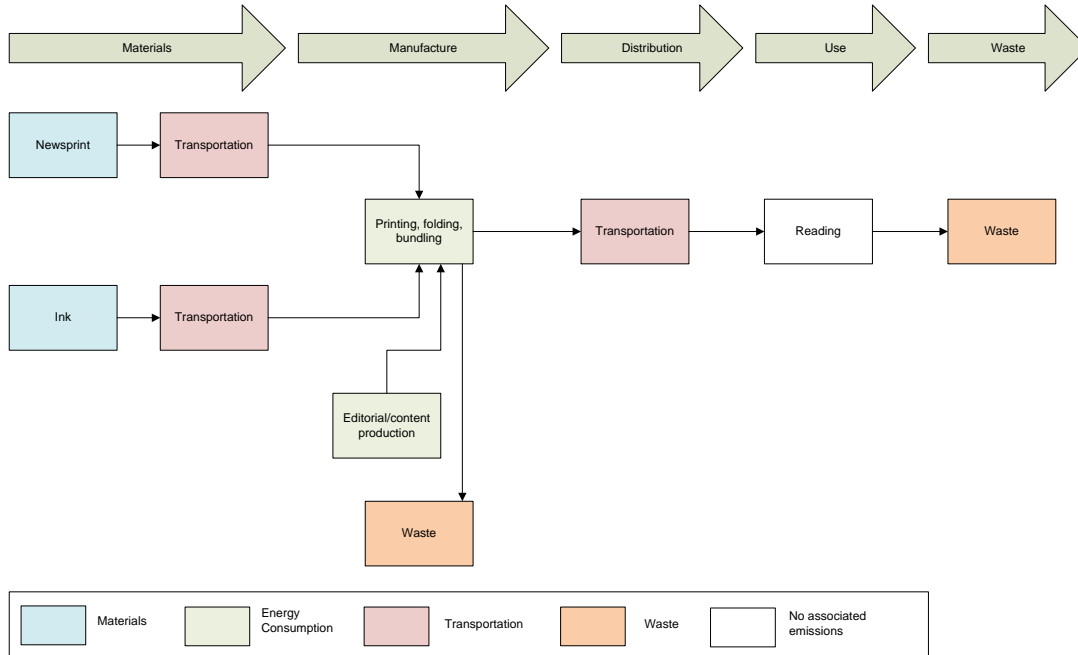
For product assessments multiple third parties are often involved in the supply chain map, and data collection becomes more difficult further down the supply chain, especially for the original extraction and processing of raw materials (for example manufacture of chemicals for ink and newsprint manufacture). For this reason published life-cycle analysis results for basic materials (such as papers, inks, plastics and construction materials) are often used in product carbon footprinting as 'secondary data' to estimate emissions associated with extraction and processing of raw materials, and primary data collection begins further up the supply chain.

In the case of The Times, the 'use' phase of the product life cycle has been excluded from the assessment boundary because there are no associated emissions. In the case of products that require energy for use (eg. electronics), or storage and preparation (eg. food) the use phase is often excluded due to variation between buyers and lack of control on the part of the product manufacturer. Similarly the disposal phase is sometimes omitted although this is generally considered less acceptable.

Product emissions are usually reported by unit of product. For The Times they are broken down by edition and by copy in Table 3. Figure 8 shows a breakdown of emissions by activity.

Table 3. The Times Carbon footprint by Edition and Copy

	Emissions per edition of The Times (tCO$_2$e)	Number of copies per edition	Emissions per copy of The Times (kgCO$_2$e)
Emissions (tree to end of life)	221.6	775,000	0.29

Figure 8. The Times Carbon Footprint breakdown by activity

Premises/
production
emissions
20%

Business travel
2%

Outgoing
deliveries
19%

End of life waste
30%

Incoming
deliveries
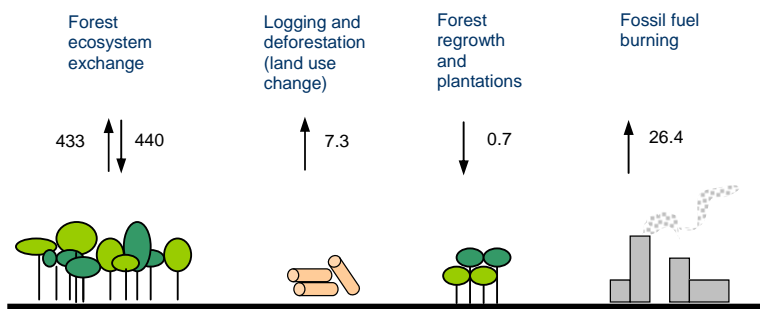4%

Materials (paper
and ink)
25%
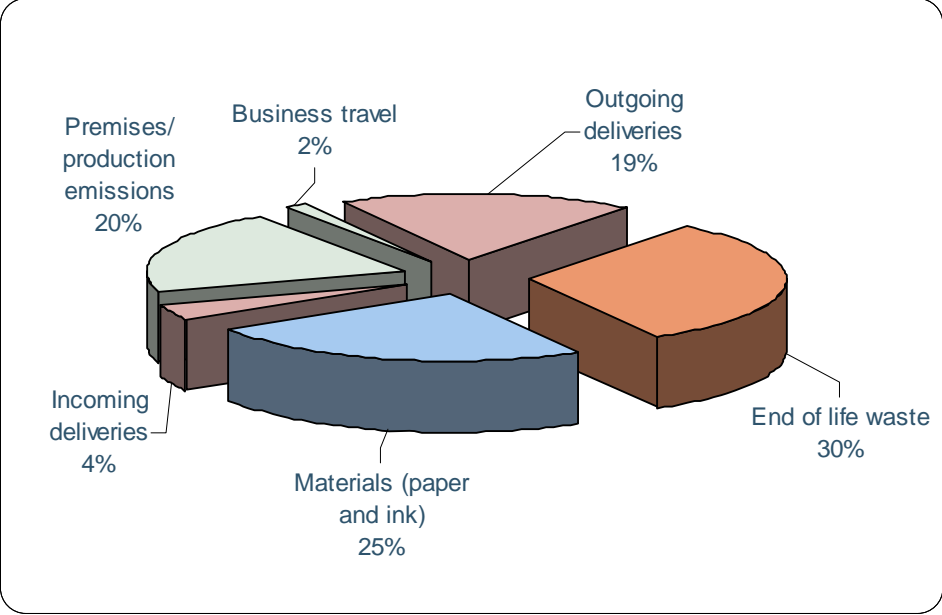
3. Wood and Carbon Footprints

3.1 Forests and the Carbon Cycle

As trees grow they 'fix' carbon dioxide from the atmosphere by photosynthesis and it is stored as carbon within the organic matter that makes up the trees.   Carbon dioxide is also released back into the atmosphere when trees die and decay or are burned for fuel or during deforestation. Global emissions from deforestation due to land use change are about 1.8 to 9.9 billion tonnes of carbon dioxide every year (averaged over the 1990s, IPCC 2007). However the amount of carbon dioxide being fixed by forests around the world is still greater than emissions from deforestation, so forests act as a net 'sink' for human-induced carbon dioxide emissions. Major CO_2 flows between land and atmosphere are shown in Figure 9 below.

Figure 9. Major Land-Atmosphere Flows (billion tonnes CO_2 per year)

Forest ecosystem exchange	Logging and deforestation (land use change)	Forest regrowth and plantations	Fossil fuel burning
433 440	7.3	0.7	26.4

About two thirds of human-induced emissions over the last two centuries have come from fossil fuel burning, and a third from land use change (deforestation and agricultural expansion). About 45% of these emissions have remained in the atmosphere. The remaining emissions have been absorbed by the oceans and forests which act as a crucial buffer modifying climate change caused by human activities (IPCC 2007).

3.2 Wood as a Carbon Store

If wood is not destroyed, the carbon that was fixed by photosynthesis can act as a long – term carbon store. This means that wood has a negative carbon footprint. Wood-based products such as paper and board packaging can also act as short-term carbon stores (Enterprise Europe 11, 2003). The increase in global population and economic activity since the 1980s has not been matched by increased industrial demand for wood (IIED/ECCM 2004). It is often thought that deforestation is associated with wood production. However, in reality, forest cover in Europe is currently increasing due to a favourable market for wood products. Deforestation mostly occurs in areas where agriculture is more profitable than wood production. Promoting sustainable forestry and wood products could help to fulfil the potential of forests to slow down climate change.

3.3 Carbon Footprints of Wood and Other Materials

Materials like plastic, metal and concrete all require a lot of energy for extraction of raw materials and manufacture. These materials all have positive carbon footprints. Wood has a negative footprint because of the carbon dioxide fixed by the original living tree. The emissions associated with harvesting, transporting and processing of wood products are small compared to the total amount of carbon stored in the wood. This means that even when energy use for harvesting, transport and processing are taken into account, wood still has a negative footprint. Comparing the carbon footprints for wood and non-wood products shows that using wood products saves greenhouse gas emissions. Some example footprints are shown in Table 4 and Figure 10 below. These are 'cradle to gate' as opposed to 'cradle to grave' figures.

Table 4. Cradle to Gate Carbon Footprints for Materials used in Construction

| Material	kgCO$_2$/tonne	Source	Year
Kiln dried timber	-1,200	Building Research Establishment	1999
Steel girders	2,400	EC Technical Steel Research (BRE method)	2002
Concrete columns + beams		ECCM (derived from Building Information Foundation, Finland)	2004
Injection moulded PVC	2,200	The Association of Plastics Manufacturers, Europe	2005
Roofing tiles	137	Building information foundation, finland	2004
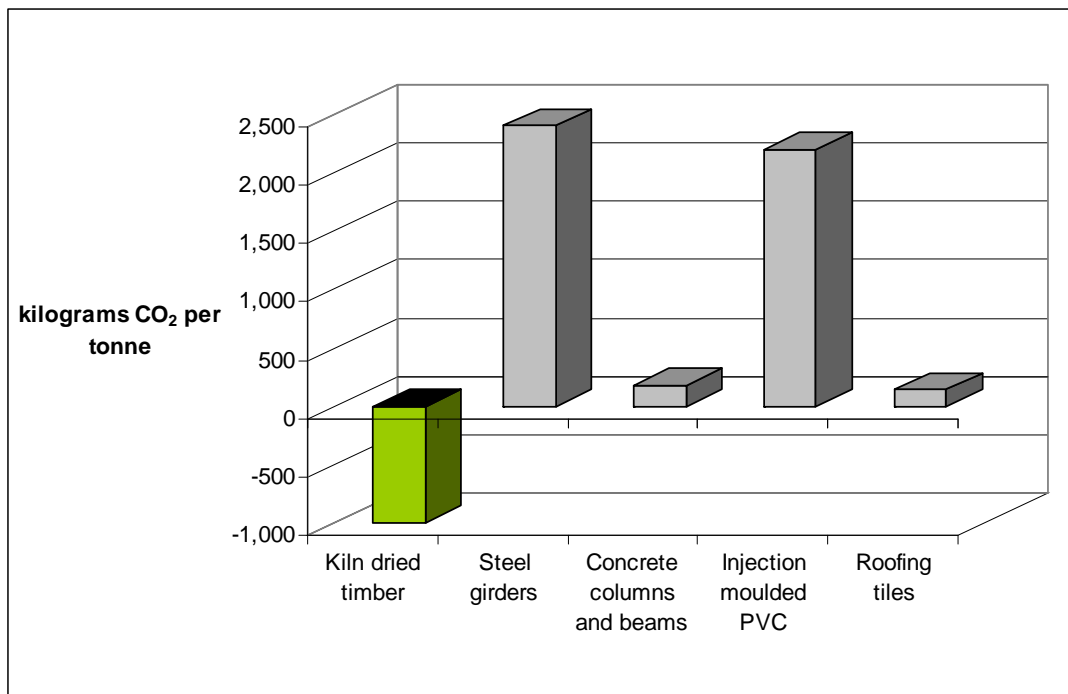
Figure 10. Graph of the cradle to gate carbon footprints for materials used in construction
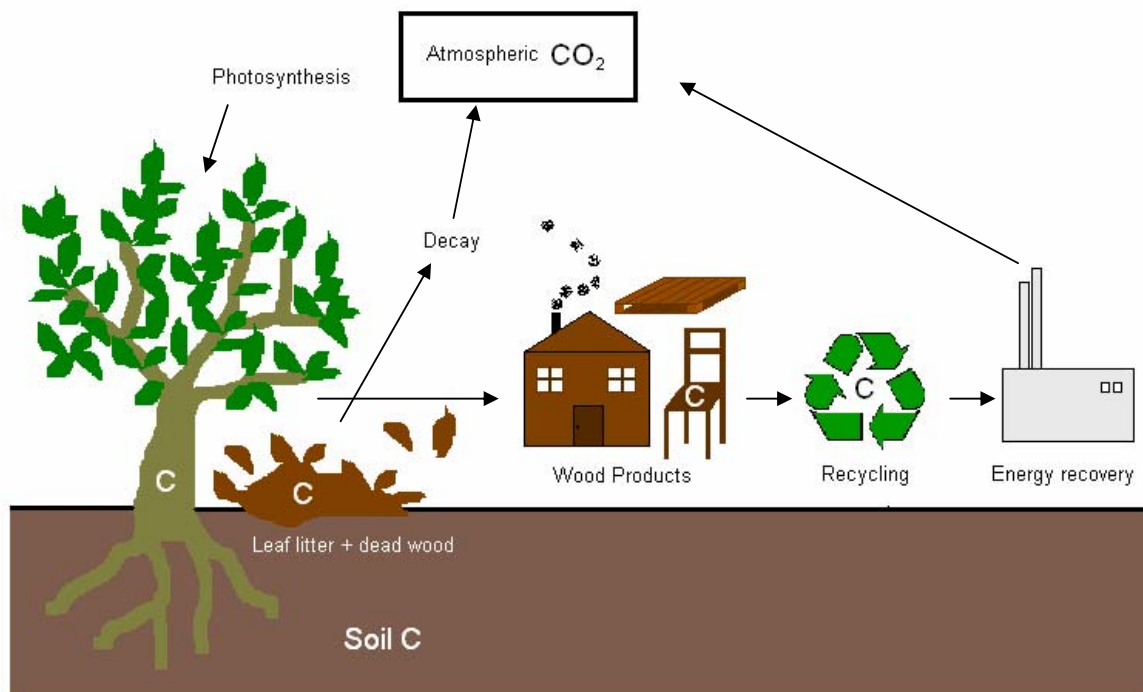
*C refers to stored carbon

Figure 11. Wood and the 'ideal' carbon cycle[1]

If wood is sent to landfill it decomposes to produce methane (a powerful greenhouse gas). However, only a small proportion of wood in landfill decomposes to produce methane, and the rest remains in the ground as a carbon store. It is much better to recycle waste wood by making it into other products such as chip-board. Finally, if it can no longer be recycled, wood can be burned for energy recovery, which can have the added benefit of displacing fossil fuels that might otherwise have been used (see Box 3).

Box 3: 'Fossil' and 'non-Fossil' Carbon

Earth's atmosphere currently contains about 78% nitrogen, 20% oxygen and 0.038% carbon dioxide along with trace amounts of other gases. Millions of years ago there used to be more carbon dioxide in the atmosphere which was extracted over a very long period of time through the growth, death and 'fossilisation' of plants and animals forming oil, coal and gas underground. Carbon in oil, coal and natural gas is referred to as 'fossil' carbon, and by burning these fossil fuels we contribute to a net increase in the current atmospheric concentration of CO_2.

Burning wood or biomass also releases CO_2 but if more trees are planted the CO_2 is then taken up again by photosynthesis as part of the carbon cycle so there is no net increase in atmospheric CO_2 concentration. Carbon in wood or biomass can be thought of as 'non-fossil' carbon.

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[1] In reality it may be that forests, timber and wood products are burnt, not for energy recovery, cycling carbon dioxide back in to the atmosphere.

3.4 A packaging (pallet) example

As a simple example of the negative climate change impact of wood products, the carbon footprint of a wooden pallet is shown below (cradle to gate including the product use phase, ECCM 2007). The figure shows a breakdown of the footprint by activity and it can be seen that the amount carbon stored in timber far outweighs emissions associated with harvesting, transportation and manufacturing. The net footprint of this pallet is -28 kilograms of CO_2 per pallet.

Figure 12. Carbon Footprint of a Wooden Pallet

EUR pallet (800 x 1,200)
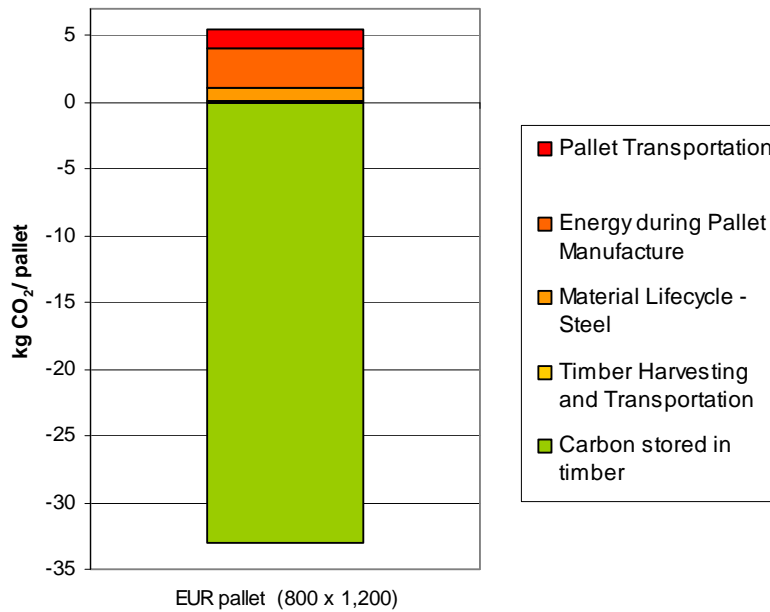
3.5 A Building Comparison

A study by ECCM for Forestry Commission Scotland shows the potential emissions reductions that can be made by increasing timber content in construction projects. Three buildings comparisons were conducted, considering carbon dioxide emissions associated with extraction and production of building materials; a two bedroom house, three bedroom house, and a block of flats. ECCM estimates that there could be up to an 86% reduction in carbon dioxide emissions associated with building materials if timber internal and external elements are specified wherever possible (Figure 13).

*Figure 13. GHG Emissions from Increasing Timber Content of Buildings*
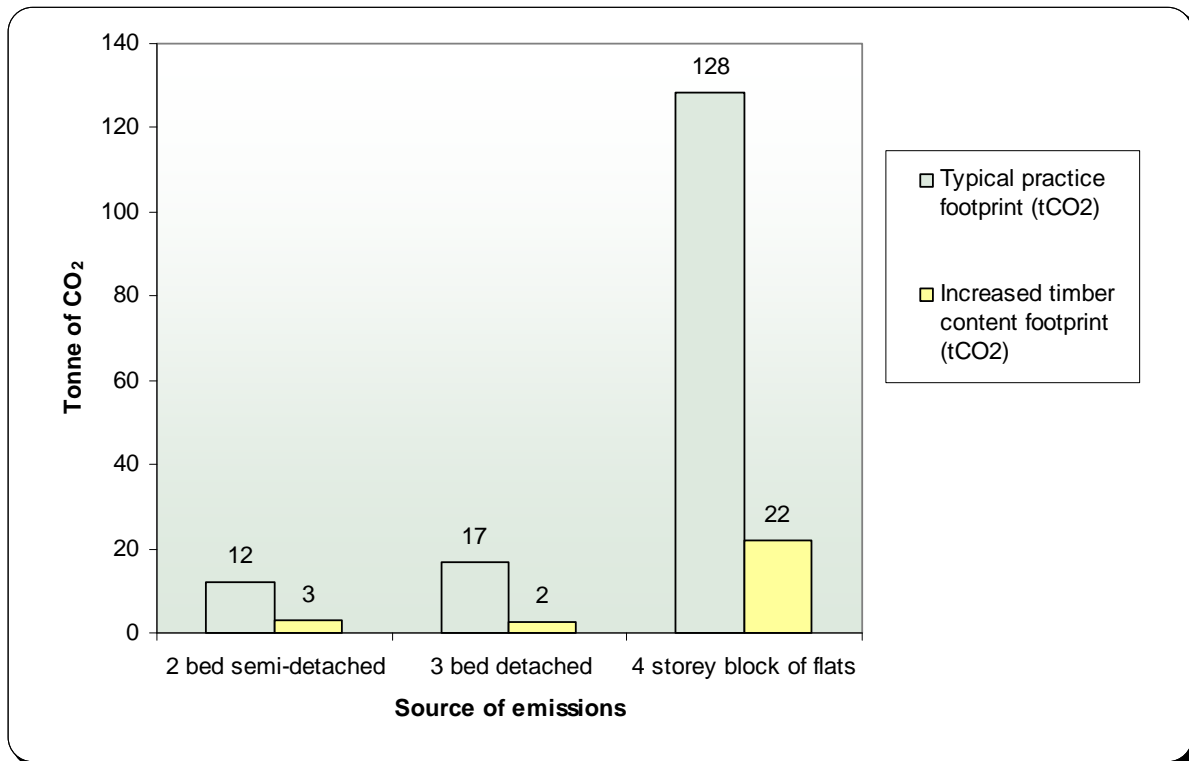
*Typical practice refers to a Scotland.

Table 5 and Figure 14 shows that an estimated 9.2 tonnes of CO_2 emissions can be saved by increasing the proportions of timber and other less GHG intense materials in a typical two bedroom semi-detached house. The table shows how these savings are broken down by building element.

Table 5. Possible GHG savings from using timber in a two bedroom Semi-detatched House.

Building element	Materials: Typical practice	Tonnes of CO_2	Materials: Increased timber content	Tonnes of CO_2	Tonnes of CO_2 savings
Foundations	Concrete	0.9	Concrete	0.9	0
Flooring	Hardcore, concrete slab, screed, chipboard, extruded polystyrene insulation	2.0	Hardcore, concrete slab, timber floor, EPS insulation	1.0	1.0
Ceilings	Plasterboard	0.2	Plasterboard	0.2	0
Joists	Timber I joists	-0.12	Timber I joists	-0.12	0
External walls	Timber frame, brick work, plywood sheathing, glasswool insulation and plasterboard	4.9	Timber frame, timber clad, panelvent board, cellulose insulation and plasterboard	-1.9	6.9
Internal walls	Timber frame and plasterboard	0.2	Timber frame and plasterboard	0.2	0
Stairs	Timber	-0.1	Timber	-0.1	0
Windows	Glass PVC frame	0.1 0.03	Glass Wooden frames	0.1 -0.02	0 0.04
Internal doors	Panel doors (chipboard)	-0.1	Panel doors (chipboard)	-0.1	0
External doors	PVC	0.1	Timber	-0.1	0
Roof	Timber rafters, rock wool insulation and Marley plain concrete (BRE element profile)	4.0	Timber rafters, rock wool insulation, felt, battens and clay tiles (BRE element profile)	2.9	1.0
Total	-	12.2	-	3.1	9.2

Figure 14. Possible GHG savings using timber in buildings.
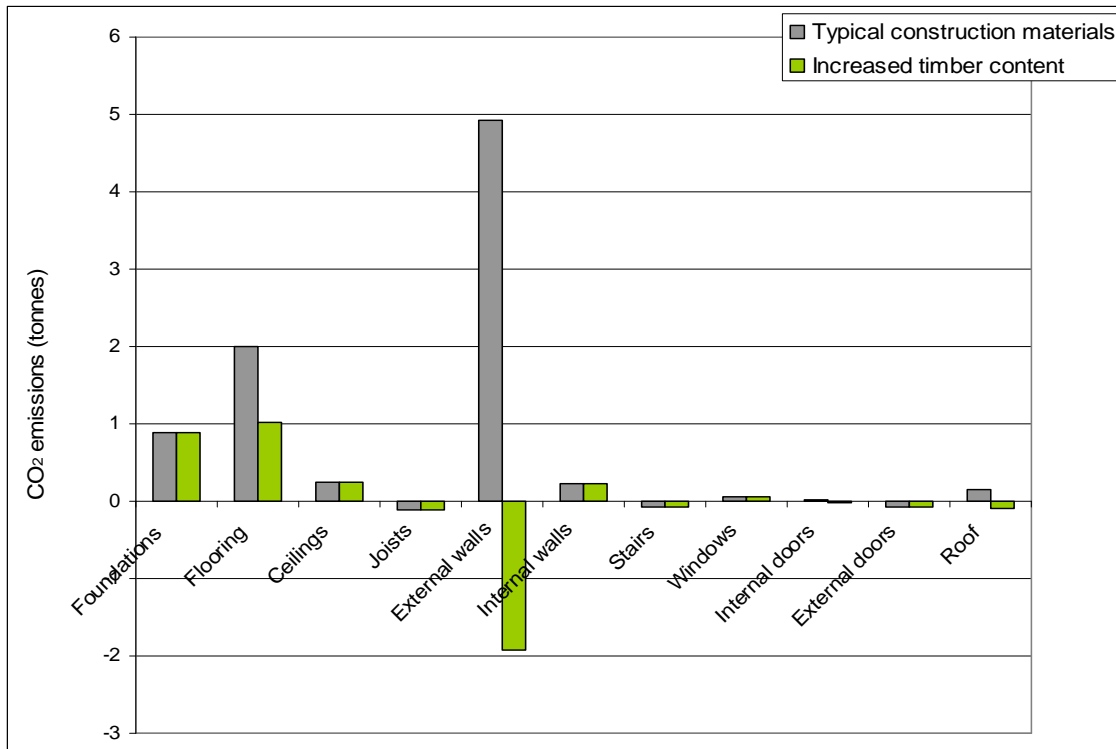
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Glossary

Carbon Dioxide Equivalent (CO$_2$e). 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).

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.

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$_2$**e**) e.g. Carbon dioxide has been designated a GWP of 1, Methane has a GWP of 21.

Greenhouse gases (GHG). The current IPCC inventory includes six major greenhouse gases. These are Carbon dioxide (CO$_2$), Methane (CH$_4$), Nitrous oxide (N$_2$O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF$_6$).

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.

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.

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