Guide to PAS 2050

How to assess the carbon footprint of goods and services

CARBON TRUST

defra
Department for Environment Food and Rural Affairs

BSI
British Standards

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Introduction

Climate change and product carbon footprints

'Carbon footprint' is a term used to describe the amount of greenhouse gas (GHG) emissions caused by a particular activity or entity, and thus a way for organisations and individuals to assess their contribution to climate change. Understanding these emissions, and where they come from, is necessary in order to reduce them. In the past, companies wanting to measure their carbon footprints have focused on their own emissions, but now they are increasingly concerned with emissions across their entire supply chain.

Supply chain GHG emissions, which include those associated with processes not controlled by the company itself, can be measured at either the company level or the level of an individual product. There are benefits to both company- and product-level supply chain emissions assessment; however, PAS 2050 and this guide focus on product-level emissions only.

This guide uses 'product' to refer to both physical products (i.e. goods) and service products (i.e. services) throughout; any differences related to services are highlighted in the text. Appendix II describes two examples of service carbon footprint assessments.

Measuring the carbon footprint of products across their full life cycle is a powerful way for companies to collect the information they need to:

- Reduce GHG emissions
- Identify cost savings opportunities
- Incorporate emissions impact into decision making on suppliers, materials, product design, manufacturing processes, etc.
- Demonstrate environmental/corporate responsibility leadership
- Meet customer demands for information on product carbon footprints
- Differentiate and meet demands from 'green' consumers

This guide explains how to assess GHG emissions of an individual product, either a good or a service, across its entire life cycle – from raw materials through all stages of production (or service provision), distribution, use and disposal/recycling – in accordance with the method specified in the BSI Publicly Available Specification 2050:2008, or 'PAS 2050'.

PAS 2050 background

PAS 2050 is a publicly available specification for assessing product life cycle GHG emissions, prepared by BSI British Standards and co-sponsored by the Carbon Trust and the Department for Environment, Food and Rural Affairs (Defra). PAS 2050 is an independent standard, developed with significant input from international stakeholders and experts across academia, business, government and non-governmental organisations (NGOs) through two formal consultations and multiple technical working groups. The assessment method has been tested with companies across a diverse set of product types, covering a wide range of sectors including:

- Goods and services
- Manufacturers, retailers and traders
- Business-to-business (B2B) and business-to-consumer (B2C)
- UK and international supply chains

PAS 2050 can deliver the following benefits:

- For companies, it can provide:
  - Internal assessment of product life cycle GHG emissions
  - Evaluation of alternative product configurations, operational and sourcing options, etc. on the basis of their impact on product GHG emissions
  - A benchmark for measuring and communicating emission reductions
  - Support for comparison of product GHG emissions using a common, recognised and standardised approach
  - Support for corporate responsibility reporting
- For customers (if companies choose to communicate their product footprints), it provides:
  - Confidence that the life cycle GHG emissions being reported for products are based on a standardised, robust method
  - Greater understanding of how their purchasing decisions impact GHG emissions

The term 'product carbon footprint' refers to the GHG emissions of a product across its life cycle, from raw materials through production (or service provision), distribution, consumer use and disposal/recycling. It includes the greenhouse gases carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), together with families of gases including hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).[1)]

Guide objectives, scope and structure

While PAS 2050 provides a standard method for assessing a product carbon footprint, this guide will help businesses to implement the standard by offering specific and practical guidance. It is not a replacement for PAS 2050 and should always be used alongside PAS 2050.

This guide aims to:

- Enable companies of all sizes, and from all industries, to assess the life cycle carbon footprint of their products and to identify emission reduction opportunities
- Share best practices, tools and frameworks for calculating product-level GHG emissions and prioritising opportunities to reduce emissions

PAS 2050 and this guide focus exclusively on GHG emissions created during a product's life cycle. They do not consider any other potential environmental,

[1)] See the IPCC (Intergovernmental Panel on Climate Change) publication, *Climate Change 2007: The Physical Science Basis* and PAS 2050 Annex A for a full list of gases.

Section I
Start-up

This section covers the important initial steps that ensure PAS 2050 implementation is fast, effective and that its results support decision making.

Setting objectives

The usual aim of product carbon footprinting is to reduce GHG emissions; however, organisations may have specific goals within that overall aim. Defining and agreeing the specific objectives for the product-level GHG assessment up-front creates the foundation for an efficient and effective process by:

- Enabling effective product selection to generate more useful findings at the end of the assessment,
- Providing direction on the scope, boundaries and data to be used in calculating the footprint, and
- Informing the choice of verification method which may be needed.

PAS 2050 can be applied with different levels of rigour, depending on how the footprint will be used. At a high level, PAS 2050 can be used to guide an internal assessment, such as identifying emissions 'hot spots', i.e. where to focus action to reduce GHG emissions across a product's life cycle. However, this approach does not result in carbon footprint information that can stand up to third-party verification and is not appropriate for external claims. If the goal is to certify and communicate the product footprint to customers, then it will require more precise analysis. Comparisons across product carbon footprints – or the same product over time – can only be achieved by using consistent data sources, boundary conditions and other assumptions across products and having the footprint results independently verified.

Verification is important to consider when the product carbon footprint is communicated either:

- internally within the company (e.g. different subsidiaries reporting to corporate level in a consistent way to assess carbon performance); or
- externally, to business customers or consumers, to inform purchasing, portfolio choice or other decisions

During the objective-setting process, and the footprinting process in general, it is helpful to include people across different areas within the company. The individuals selected will depend on the size of your organisation; see overleaf for an example of particular functions that could be involved. Smaller organisations may not have individual representatives for each area but should ensure that these perspectives are recognised during the start-up phase.

Who should be involved?

In a larger organisation internal participants could include, where applicable, representatives from:

- Senior management
- Environment/corporate social responsibility (CSR)
- Marketing/communications
- Production
- Procurement/supply chain
- Logistics
- Energy
- Finance/performance management
- Analysts[1] who will lead the carbon footprint calculations

[1] Many companies hire third-party consultants to perform the product carbon footprinting analysis. The decision depends on weighing internal resource availability and expertise against the costs of an external provider.

Product carbon footprinting does not require a full-time commitment from all stakeholders, but rather:

- initial agreement on the objectives,
- input throughout the process (e.g. help with data collection), and
- discussion of results and next steps

The level of commitment depends on the individual's role and the complexity and/or number of products selected for carbon footprinting.

Agreeing the objectives will help determine the size of the ongoing project team. If the goal is to test the method on one product but eventually roll it out to others, then it may be more effective to involve a wider set of people across the organisation – and supply chain – from the beginning. Similarly, if more than one product is to be tested this may impact on how the data is collected and formatted. It could be prudent to standardise your data collection methods and analysis in order to allow consistency in the way you present results.

It is useful to assemble this team for a series of introductory and scoping workshops to discuss these and other start-up issues as described below.

Key considerations during start-up phase

- Why product carbon footprinting? What are the objectives and expected outcomes?
- Based on these objectives, what criteria should be set for product selection?
- What products could meet those criteria?
- Who are the key supplier contacts?
- What resources and budget can be given to the project?
  - e.g. external consultants vs. in-house resources and expertise
- What governance/decision making structure will guide the project?
- How long will it take?
- Who is responsible for what, and what will they deliver?

Choosing products

When choosing products to footprint, it helps to set overarching criteria based on goals for the project, and then to identify which products best meet those criteria. Product selection criteria should fall directly from the objectives agreed at the beginning of the project, and are a key component of defining the scope – how many products, types of product, different sizes of product, etc.

Key questions to consider when selecting products include:

- Which products are likely to yield the largest emission reduction opportunities?
- Which comparisons are most relevant to the company's GHG reduction strategy? For example, comparisons across:
  - Product specifications
  - Manufacturing processes

social and economic impacts (e.g. biodiversity, water use, labour standards and other product impacts).

The method described in PAS 2050 can be used to assess the life cycle GHG emissions of any type of product:

- Business-to-consumer (B2C) goods, where the customer is the end user;
- Business-to-business (B2B) goods, where the customer is another business using the product as an input to its own activities; and
- Services that can be either B2C or B2B

This guide explains how to apply PAS 2050 in each of these circumstances but focuses on a typical consumer good. Any differences between this B2C application of PAS 2050 and B2B goods or services is highlighted in the text. A summary of the differences can be found in Appendix I.

This guide is structured in the following sections:

1. Start-up

Setting objectives

Choosing products

Engaging suppliers

2. Product footprint calculations

Step 1: Building a process map

Step 2: Checking boundaries and prioritisation

Step 3: Collecting data

Step 4: Calculating the footprint

Step 5: Checking uncertainty (optional)

3. Next steps

Validating results

Reducing emissions

Communicating the footprint and claiming reductions

- – Packaging options
- – Distribution methods
- Which products are most important from a differentiation or competitive perspective?
- Which brands/products are most aligned with potential emission reductions and marketing opportunities?
- How willing and/or able are suppliers to engage?
- What impact could the footprint analysis have on key stakeholders?
- How much time and resource can be committed to the footprinting analysis?

Once the product is chosen, the next step is to specify the functional unit (see PAS 2050 Section 5.8[2)]). A functional unit reflects the way in which the product is actually consumed by the end user (e.g. 250 ml of a soft drink, 1,000 hours of light from a light bulb, one night's hotel stay), or used as an input by a B2B customer (e.g. 1 kg sugar).

Defining the functional unit is a very important step in calculating a carbon footprint. The functional unit can be thought of as a meaningful amount of a particular product used for calculation purposes.

The functional unit is important since it provides the basis for comparison and, if desired, communication of results. It may be easier to do the actual analysis using a larger unit (e.g. a sheet of aluminium vs. a soft drink can). This is possible as long as the relationship between this unit of analysis and the functional unit is clearly understood, so that it can be converted back to the functional unit at the end of the analysis.

When choosing a functional unit there may be no single right answer, however it should be a unit that is easily understood and can be used by others. Often industry-specific guidance already exists in other standards, such as the functional units for nutritional information on food products.

[2)] Throughout this guide where specific sections of PAS 2050 are referenced, these refer to the 2008 version of PAS 2050.

Services note: Defining the functional unit is particularly important when calculating the carbon footprint of services.

- What do customers believe they are purchasing?
- What quantity of service is representative?
- What does the company want to compare the footprint against?
- What might customers want to compare against?

Engaging suppliers

Engaging with suppliers is critical to understanding the product's life cycle and for gathering data. Typically, companies know their own production processes thoroughly; however, beyond the boundaries of the company, knowledge of the processes, materials, energy requirements and waste tends to vary considerably.

As part of the initial internal discussions, it is useful to think through the following:

- Who are the key suppliers, retailers, waste management companies, etc.?
- What information can they provide?
- How willing and/or able are they to support the project, e.g. are there any commercial sensitivities with the information they are being asked to provide?
- Who will take responsibility for the relationships?

Consider drawing up a supplier engagement plan that includes the following:

- How to get suppliers interested in carbon footprinting, including goals of the analysis and potential benefits to suppliers, e.g. the opportunity to:
  – Identify carbon/cost savings opportunities
  – Declare that they are collaborating to manage carbon
  – Create joint emissions targets
  – Improve relationships/credentials with business customers, etc.
- Information they will need to provide, including potential site visits and key contacts
- Estimated meetings/workshops required
- How to address confidentiality concerns – legal/confidentiality issues must be overcome early in order to get access to necessary data

Supplier engagement should be built into the overall project work plan, with roles, responsibilities and milestones clearly defined and understood.

In summary, getting off to the right start will help to ensure the product footprinting process is cost-effective and delivers the full range of possible benefits.

Section II

Calculating product carbon footprints

PAS 2050 takes a process life cycle assessment (LCA) approach to evaluating the GHG emissions associated with goods or services, enabling companies to identify ways to minimise emissions across the entire product system.

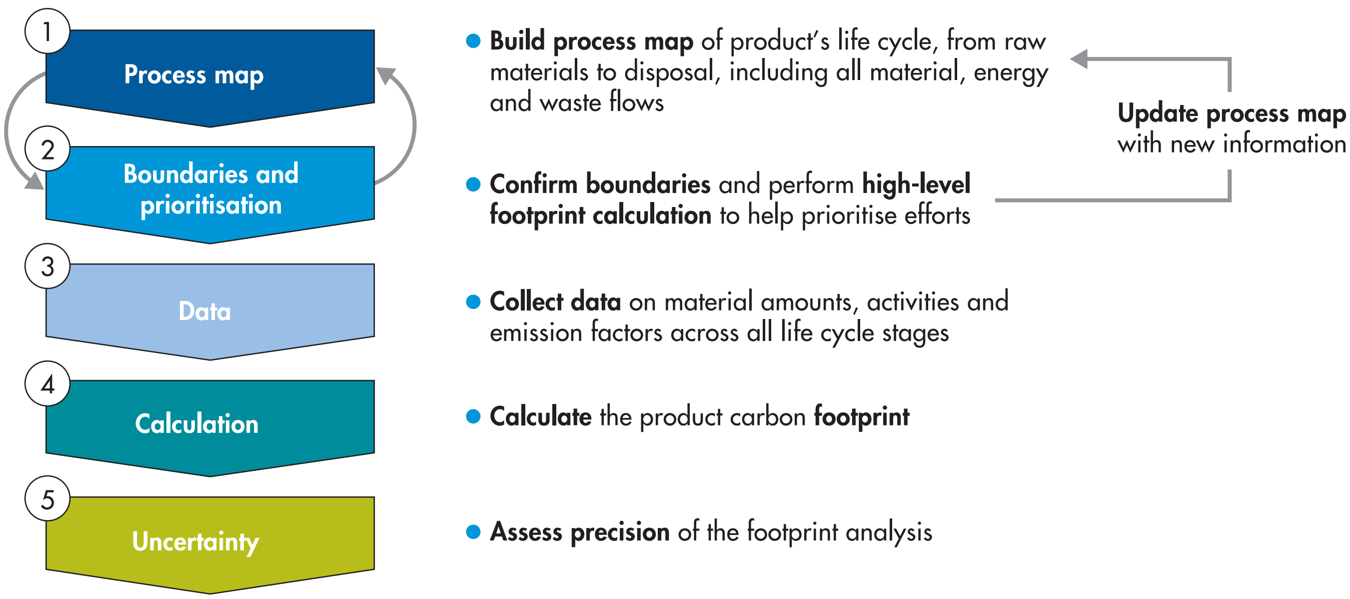
PAS 2050 is anchored in the guiding principles listed in the box below (see PAS 2050 Section 4.2).

There are five basic steps to calculating the carbon footprint of any good or service:

- Building a process map (flow chart)
- Checking boundaries and prioritisation
- Collecting data
- Calculating the footprint
- Checking uncertainty (optional)

Relevance	Select sources, data and methods appropriate to assessing the chosen product's life cycle GHG emissions
Completeness	Include all GHG emissions and storage that provide a 'material' contribution to a product's life cycle emissions
Consistency	Enable meaningful comparisons in GHG-related information
Accuracy	Reduce bias and uncertainty as much as is practical
Transparency	When communicating, disclose enough information to allow third parties to make decisions

'Uncertainty' is a statistical term used to define the accuracy and precision of an input or calculation. For more information, see *Step 5: Checking uncertainty*, in this guide.



Five steps to calculating the carbon footprint

Step 1: Building a process map

The goal of this step is to identify all materials, activities and processes that contribute to the chosen product's life cycle. Initial brainstorming helps to build a high-level process map that can then be refined through desktop research and supply chain interviews. The process map serves as a valuable tool throughout the footprinting exercise, providing a starting point for interviews and a graphical reference to guide both data collection and the footprint calculation.

To develop a product process map, start by breaking down the selected product's functional unit into its constituent parts (e.g. raw materials, packaging) by mass using internal expertise and available data or desktop research. A product specification or bill-of-materials is a good starting point. Focus on the most significant inputs first, and identify their respective inputs, manufacturing processes, storage conditions and transport requirements.

In practice there are considerable benefits to repeating the process map step (Step 1 above) as understanding of the life cycle improves, allowing greater prioritisation and focus. For example, in Step 2 a high-level footprint can be calculated with estimates and readily available data before fully investing in data collection. This approach enables prioritisation based on highest impact emission sources rather than spending time on small or 'immaterial' (less than 1% of overall life cycle emissions) contributors.

Process map steps

Business-to-consumer (B2C)

When calculating the carbon footprint of B2C goods, typical process map steps include those illustrated opposite. From raw materials, through manufacture, distribution and retail, to consumer use and finally disposal and/or recycling.

Business-to-business (B2B)

Business-to-business carbon footprints stop at the point at which the product is delivered to another manufacturer, consistent with the 'cradle-to-gate' approach described in BS EN ISO 14040[3]. The B2B

3) BS EN ISO 14040, *Environmental mamagement — Life cycle assessment — Principles and framework.*

Process map steps for business-to-consumer goods

Process map steps for business-to-business goods

life cycle therefore captures raw materials through production up to the point where the product arrives at a new organisation, including distribution and transport to the customer's site. It excludes additional manufacturing steps, final product distribution, retail, consumer use and disposal/recycling.

This is because B2B goods can be used as inputs to multiple final products with widely divergent use and disposal characteristics (e.g. aluminium can be used in drinks cans or aeroplanes). See PAS 2050 Section 6.2 for more information.

Services

Process maps for services will vary depending on the service chosen. An 'activity-based assessment' is used when considering the life cycle of services, and is derived from the combined activities required to provide the service which may or may not result in a physical output.

A service 'life cycle' therefore involves more than just inputs, outputs and processes: the process map will include all stages and potential emission sources from any activity that contributes to the delivery or use of the service. When mapping the service life cycle, try to define it in a way that would be most useful both for internal use and for others using the footprint, i.e. make it:

- Easily comparable to other services internally or from competitors;
- Likely to generate actionable opportunities to reduce emissions; and
- Relatively easy to describe the supply chain

See Appendix II for examples of how to develop the process map for two different services.

Product carbon footprinting in action – croissants example

Croissants are used as a rolling example throughout this guide to demonstrate how to use PAS 2050 to calculate a product carbon footprint. This simplified example is designed to be a representation not a complete or exhaustive description of the croissants' life cycle. All figures are purely illustrative.

Building a process map for croissants involves the following brainstorming stages.

1. Define the functional unit – the appropriate functional unit is driven by how the product is typically consumed (e.g. one 100 g croissant); however, it may be easier to collect data and calculate the footprint using a larger unit, such as one tonne of croissants
2. List the ingredients and proportions
   - Flour (wheat) – 60%
   - Water – 20%
   - Butter – 15%
   - Other (e.g. yeast) – 5%
   - Packaging material (film and secondary packaging)
3. List the activities involved in producing and consuming croissants
   - Produce and transport raw materials
     - Grow and transport wheat; mill into flour
     - Supply water
     - Produce milk; manufacture butter
     - Produce other ingredients
     - Produce film packaging
   - Manufacture and package croissants
   - Distribute finished product
   - Retail
   - Use (eat)
   - Dispose of waste
4. Reflect on what might have been missed
   - Have all raw materials been traced back to their origin, including intermediate processes?
     - Include the GHG impact of grazing and cows to the butter process; add wheat drying as an intermediate process
   - Were any by-products created during manufacturing?
     - Milling produces wheat germ and animal feed as well as flour
   - Have all waste streams and emissions been accounted for?
     - In flour milling, baking, retailing and consumer use; in transport, waste treatment and decomposition
   - Has the transport of waste been accounted for?
     - Need to include transport at every stage where waste is created
   - Have multiple distribution stages been accounted for, including all transport links and storage conditions?
     - Add in regional distribution centre
   - Was energy consumed during the consumer use phase?
     - Consumers may freeze and heat before eating

Continue to update the process map until all inputs have been traced back to their original sources, and all outputs have been tracked until they stop emitting GHGs attributable to the product. This process typically takes multiple attempts with management, suppliers, distributors and customers. The process map should be exhaustive and include all possible drivers of emissions; however, the footprint calculation focuses on the more significant contributors.

Once a full picture of the steps in the product's life cycle has been built, the next step is to confirm boundaries and prioritise.

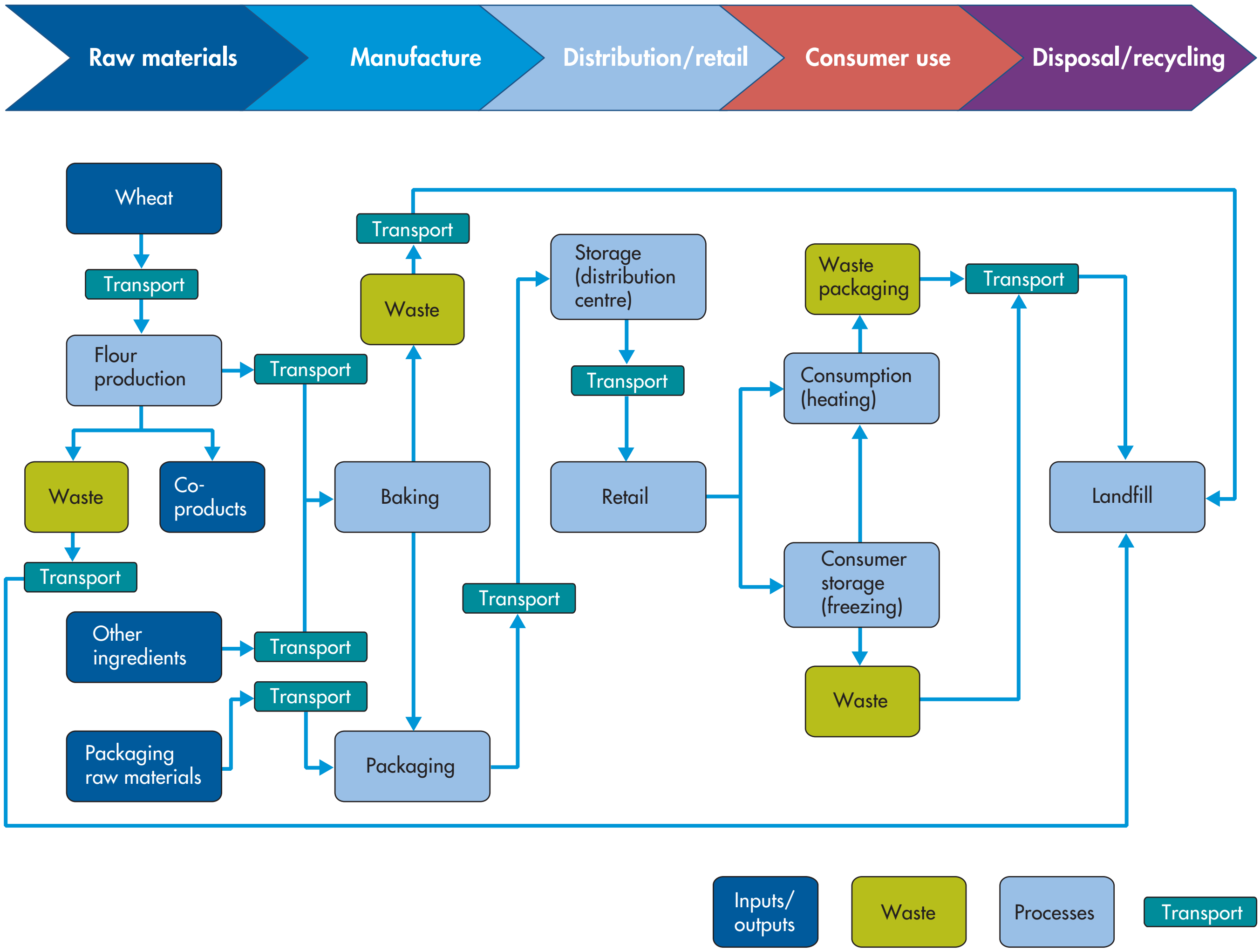
Step 2: Checking boundaries and prioritisation

Boundaries

The system boundary defines the scope for the product carbon footprint, i.e. which life cycle stages, inputs and outputs should be included in the assessment.

Once a high-level process map has been developed (see example opposite), the relevant boundaries for the carbon footprint analysis must be determined. For conformity to PAS 2050 the product life cycle system boundaries should be consistent with a Product Category Rule (PCR), where available, as outlined in BS ISO 14025[4].

[4] BS ISO 14025, *Environmental labels and declarations — Type III environmental declarations — Principles and procedures.*



In this simplified example, a reliable and representative emission factor for wheat is assumed to exist, and therefore wheat production is not decomposed into its upstream activities (e.g. fertiliser production, transport and use; impact of land use change). Similarly, other ingredients and packaging are assumed to have reliable and representative emission data available. Although butter would be an important contributor to the product's overall footprint, for simplicity it is not included in detail in the calculations.

Process map: croissants example

If a PCR is not available for the product, the system boundary should be clearly defined. System boundaries apply primarily to goods and need to be adapted to consider a service. See PAS 2050 Sections 6.1, 6.4 and 6.5 for more information and specific guidelines.

See PAS 2050 Section 5.3 for more detail on potential sources of GHG emissions to include in the process map.

Product category rules (PCRs) are a set of specific rules, requirements and guidelines for developing environmental declarations for one or more groups of products that can fulfil equivalent functions. PCRs offer a consistent, internationally-accepted approach to defining a product's life cycle. They are emerging but still cover a limited number of products. To check whether the product being footprinted is covered by a PCR, refer to the PCR section of *www.environdec.com*.

Raw materials

- All inputs used at any stage in the life cycle
- Include processes related to raw: materials
  - – Mining/ extraction (minerals)
  - – Farming
  - – Forestry
  - – Pre-processing
  - – Packaging
  - – Storage
  - – Transport
- Account for impact of raw materials:
  - – Fertilisers (production, transport, application)
  - – Land use change

Manufacture

- All activities from collection of raw materials to distribution:
  - – All production processes
  - – Transport/ storage related to production
  - – Packaging
  - – Site-related emissions (e.g. lighting, ventilation, temperature)
- All materials produced:
  - – Product
  - – Waste
  - – Co-products (useful by-products)
  - – Direct emission

Distribution/retail

- All steps in transport and related storage
- Retail storage and display

Consumer use

- Energy required during use phase:
  - – Storage
  - – Preparation
  - – Application
  - – Maintenance/ repair (e.g. for long use phases)

Disposal/recycling

- All steps indisposal:
  - – Transport
  - – Storage
  - – Processing
- Energy required in disposal/recycling process
- Direct emissions due to disposal/ recycling:
  - – Carbon decay
  - – Methane release
  - – Incineration

Common materials/activities to include within a product's life cycle boundary

The key principle for system boundaries is to include all 'material' emissions generated as a direct or indirect result of the chosen good or service being produced, used and disposed of or recycled.

A material contribution is a contribution from any one source resulting in more than 1% of the total anticipated life cycle emissions of the product.

PAS 2050 allows immaterial emissions to be excluded – any single source resulting in less than 1% of total emissions. However, the total proportion of immaterial emission sources cannot exceed 5% of the full product carbon footprint. Detailed specifications of the boundaries are described in PAS 2050 Section 6.

For further detail on inclusions and exclusions, see *Step 4: Calculating the footprint*.

Boundaries: what not to include

- Immaterial emissions sources (less than 1% of total footprint)
- Human inputs to processes
- Transport of consumers to retail outlets
- Animals providing transport (e.g. farm animals used in agriculture or mining in developing countries)

Materiality and prioritisation

To decide whether an emission source is likely to be material, it helps at this point to do a high-level footprint analysis using estimates and readily accessible data (see *Step 3: Collecting data* for guidance on potential sources). This analysis includes the full life cycle of the product but relies on estimates and generic data to build a high-level footprint. Significant sources of emissions can then be replaced by more specific and better quality data.

For example, the high-level analysis of the life cycle carbon footprint of croissants shown in the table below could be built from a desktop internet search of published academic work, other LCA studies of similar products, industry association published data and selected use of standard LCA databases. A list of datasets can also be found at *http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm*.

The results shown in Table 1 suggest that data collection efforts should begin with raw material production and transport, particularly wheat. The initial assessment also suggests that three steps in the process flow may be immaterial: water supply, storage and retail. These steps are unlikely to produce substantial GHG emissions, so collecting data for these areas should be given a lower priority.

A range of data may be available for each material, but the data should be sufficient to allow for prioritisation of further data collection.

Armed with a better sense of where – and where not – to focus, the next step is to collect more detailed data specific to the product being footprinted. For a high-level analysis it may be sufficient to stop here and use this carbon footprint figure to identify emissions 'hot spots'; however, this would not be rigorous enough to achieve full compliance with and certification against PAS 2050, for external claims or for most product or process comparisons.

Step 3: Collecting data

Guided by the initial calculations in Step 2, begin collecting more specific data following the requirements and recommendations of PAS 2050, which will enable assessment of the carbon footprint in more detail.

All data used in a PAS 2050-compliant carbon footprint assessment must meet the Data Quality Rules (see PAS 2050 Section 7.2). This assures accurate, reproducible and more readily comparable carbon footprints. Good quality data helps to build a footprint that represents a 'typical' product's life cycle, over a defined time period, recognising variations in geography, distance and materials.

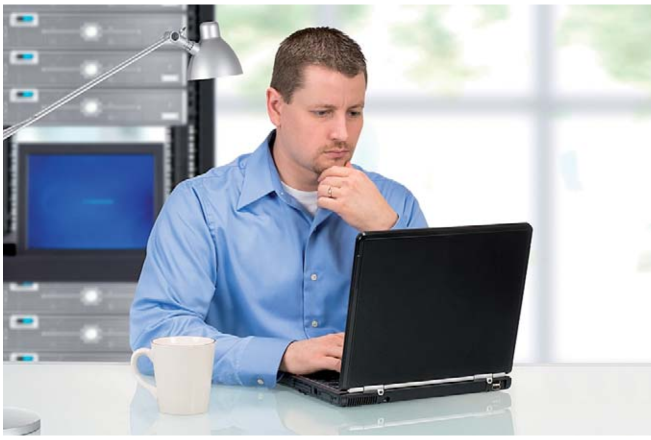


Table 1: High-level footprint analysis (croissants example)

Raw materials (including transport)		Manufacturing		Distribution/ retail		Consumer use		Disposal/ recycling		Total
Wheat agriculture	500	Plant A	200	Transport	30	Freezing	50	Transport	50	
Flour milling	50			Storage	0	Toasting	40	Decay	100	
Water supply	0			Retail	0					
Other ingredients	100									
Film packaging	20									
Total	**670**		**200**		**30**		**90**		**150**	**1140**

All figures are in grams CO_2e per tonne croissants, and are for illustration purposes only.

In order to comply with the requirements of PAS 2050, data quality should be judged according to the rules described in PAS 2050 Section 7.2.

- How specific is it to the declared reporting period? (Ideally the data would cover the exact time period)
- How specific is it to the product's relevant geography?
- How specific is it to the product's relevant technologies and processes?
- How accurate is the information used (e.g. data, models and assumptions)?
- How precise is the information? i.e. measure the variability of the data values (see *Step 5: Checking uncertainty*)
- How complete is it? i.e. is the sample size sufficiently large and representative of all potential sub-categories of the product? What percent of the data used was actually measured vs. taken from a general database?
- How consistent is it?
- How reproducible is it? i.e. what is the extent to which an independent practitioner could reproduce the results?
- What sources are used?

These rules are subjective; however, their application will allow companies to identify the most appropriate data for their circumstances.

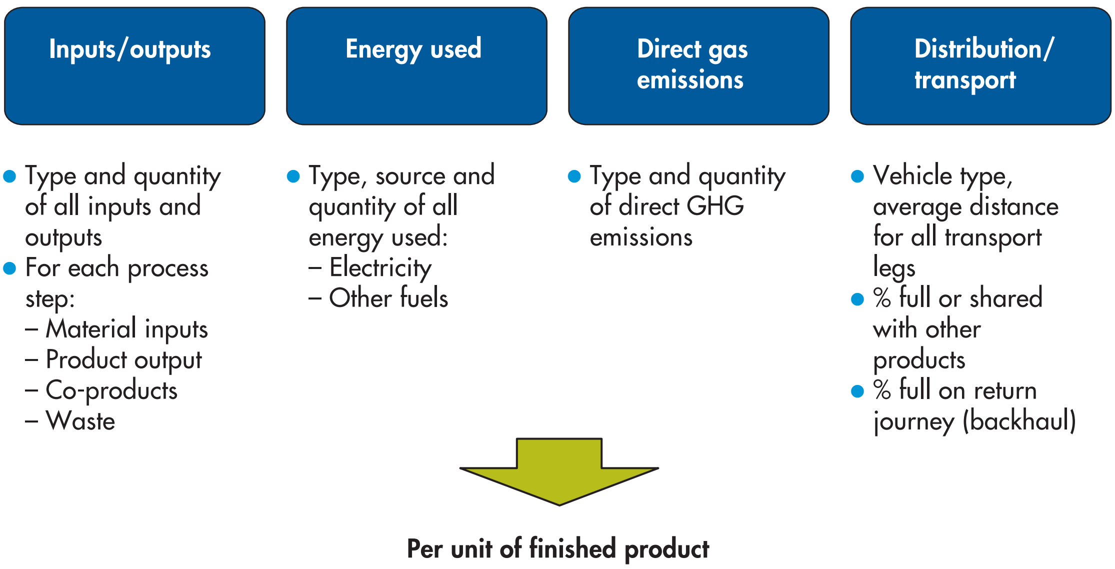
Data types

Two types of data are necessary to calculate a carbon footprint: **activity data** and **emission factors**. Activity data refers to all the material and energy amounts involved in the product's life cycle (material inputs and outputs, energy used, transport, etc.) – see below.

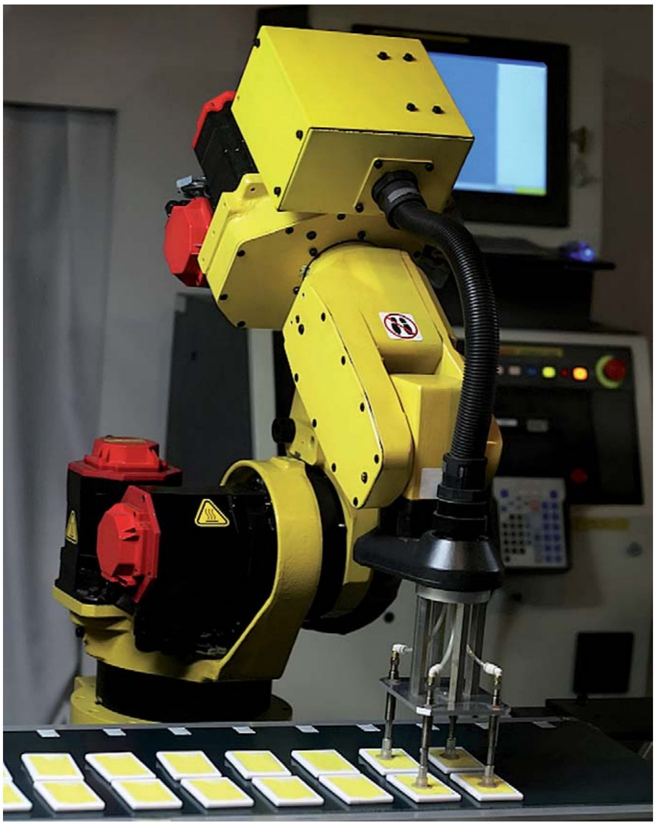
Emission factors provide the link that converts these quantities into the resulting GHG emissions: the amount of greenhouse gases emitted per 'unit' of activity data (e.g. kg GHGs per kg input or per kWh energy used).

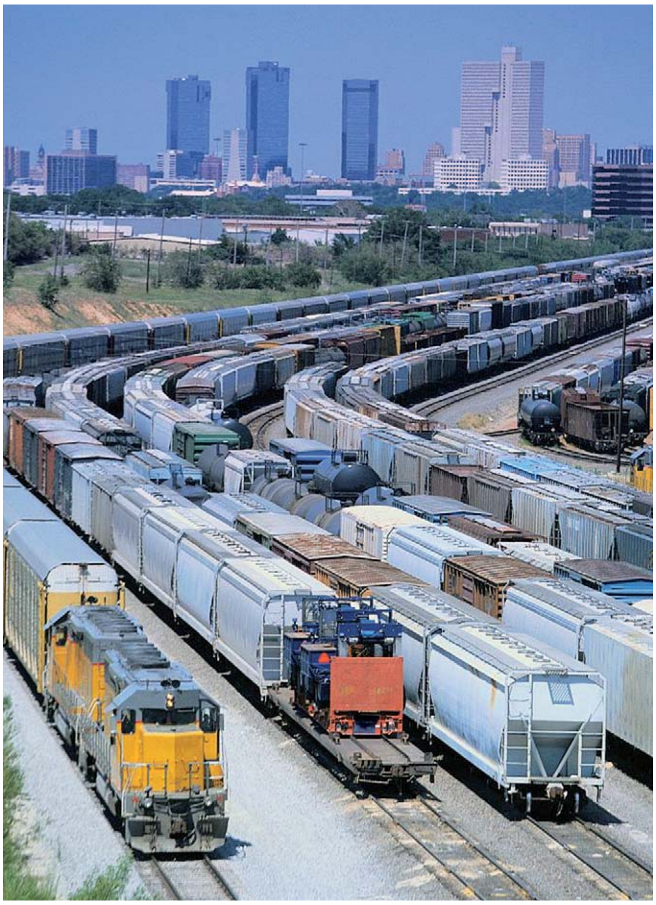
Activity data and emissions factors can come from either primary or secondary sources:

- Primary data refers to direct measurements made internally or by someone else in the supply chain about the specific product's life cycle
- Secondary data refers to external measurements that are not specific to the product, but rather represent an average or general measurement of similar processes or materials (e.g. industry reports or aggregated data from a trade association)



Common activity data





Primary activity data

PAS 2050 requires that primary activity data be used for all processes and materials owned, operated or controlled by the footprinting organisation (see PAS 2050 Section 7.3). For retailers or other organisations that do not contribute a significant amount to the product's emissions, primary activity data is required for the processes and materials controlled by the first (closest) upstream supplier. These data should be relatively easy to measure, and are necessary to ensure the carbon footprint result is specific to the chosen product. Primary activity data is not required for downstream sources of GHG emissions (e.g. consumer use, disposal).

In general, use as much primary activity data as possible, since it allows for better understanding of the actual emissions and helps identify real opportunities to improve efficiency.

Primary activity data should be representative, reflecting the conditions normally encountered by the product being assessed. For more guidance on gathering primary activity data in variable supply chains, see PAS 2050 Section 7.6

Primary activity data can be collected across the supply chain either by an internal team or by a third party (e.g. consultants). In practice, it helps to speak to at least one person in each part of the supply chain to ensure the process map is correct and that sufficient data is collected. The data may already exist within the organisation, or it may require new analysis. In some cases, gathering primary activity data may require installing new ways to collect data, such as measurement meters and sub-meters.

Data collection templates may be a useful method of formalising the data collection process, helping to:

- Structure an interview with a supplier
- Ensure completeness, thereby minimising the number of interviews required
- Prioritise the likeliest/largest carbon reduction opportunities

For example, when collecting data on flour milling, a spreadsheet such as that shown in Table 2 may be useful to capture key pieces of primary activity data. For more complex processes, more information on the technology and sub-process steps would be required (such as source of wheat, fertiliser used, etc.).

Secondary data

Where primary activity data is not available, or is of questionable quality (e.g. when appropriate measurement meters are not available), it is necessary to use secondary data derived from sources other than direct measurement.

In some cases, secondary data may be preferable to enable consistency and, where possible, comparability:

- Global warming potential of greenhouse gases
- Electricity emissions (in kg CO_2e per kWh) from various energy sources
- Fertiliser/pesticide emissions per kg
- Fuel emissions per litre
- Transport emissions per km per vehicle type
- Waste emissions per kg
- Agriculture emissions from livestock and/or soils

Global warming potential (GWP) is a term used to describe the impact over 100 years of one unit of a greenhouse gas relative to an equivalent unit of carbon dioxide.

Table 2: Example of a data collection template

Data collection example: flour supplier interview	Notes
T flour / T croissants	0.6
Wheat production breakdown (1 T wheat yields):	
% flour	80%
% wheat germ	10%
% animal feed	5%
% waste	5%
kWh to produce 1 T wheat milled	100
Electricity source	UK grid average
On-site storage?	Ambient
On-site transport?	None
Transport to croissant factory:	
Vehicle type	Articulated truck
Distance between supplier and factory	200 km
Fuel consumed per trip	80 L
# of trips per tonne flour	0.3
% of vehicle dedicated to flour	100%
% of return journey filled with other goods	0%

CO_2e stands for 'carbon dioxide equivalent', a unit used to measure the global warming potential for all greenhouse gases.

Data sources

Relevant databases are continually being developed and updated, so it is not possible to provide a definitive list in this document. However, guidance is included below to help in finding potential sources and assessing their quality.

For secondary data, PAS 2050 recommends the use of verified PAS data from other sources where available (e.g. a supplier who has completed a PAS 2050-compliant product carbon footprint). Otherwise, use data from peer-reviewed publications, together with data from other competent sources (e.g. national government, official UN publications and publications by UN-supported organisations).

Types of databases that have been used to calculate product carbon footprints are:

- Multi-sector life cycle databases, either commercial or publicly available (note some of these datasets can also be accessed through commercial LCA software programmes)
- Industry-specific databases
- Country-specific data sources, e.g. government agencies such as Defra in the UK

A list of LCA databases provided by the EU can be found at *http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm*. Some databases are free, whereas some charge a licence fee. Over time, more databases may become available, such as the International Reference Life Cycle Data System (ILCD), which will contain life cycle inventory datasets for selected materials and processes. It is important to confirm that sources are as representative as possible of the time period being analysed. In any case, data chosen from any database should be assessed against the quality criteria defined in PAS 2050 Section 7.2, which are consistent with existing BS EN ISO 14044[5] data quality criteria.

Understanding exactly what is included in – or missing from – any secondary data is important. For example, when using secondary sources for agricultural product emissions, have land use change and emissions from nitrous oxide been included, or will these need to be calculated separately? (See PAS 2050 Sections 5.5 and 7.5.) Also watch out for other situations that can be more complicated (see *Treatment of specific emission drivers*).

Consumer use emissions

Data describing how consumers use products (the 'use profile') can be particularly difficult to find. PAS 2050 offers a hierarchy of sources for use profile data (see PAS 2050 Section 6.4.8.2):

1. Product Category Rules (PCRs)
2. Published international standards (e.g. Energy Star database *www.eu-energystar.org/en/en_database.htm*)
3. Published national guidelines (e.g. Market Transformation Programme energy in use data *http://whatif.mtprog.com*)
4. Published industry guidelines

Each source should be considered only if it specifies a use phase for the product being footprinted. If no public information is available, check with all relevant industry associations or other potential sources of expertise.

Use phase and Use profile

'Use phase' describes the activities and energy consumed when the product is used by the end consumer. This could include energy associated with storage, e.g. refrigeration, or application, e.g. electricity for a light bulb.

'Use profile' describes the average behaviours of the end consumer, e.g. the average percentage of food products that go to waste.

[5] BS EN ISO 14044, *Environmental management — Life cycle assessment — Requirements and guidelines.*

For full compliance with PAS 2050, it is necessary to disclose the basis of any use phase calculation (data sources, assumptions, etc.) – see PAS 2050 Section 6.4.8.

Records

PAS 2050 requires that detailed records be kept of all data sources and any assumptions that are used to carry out the emissions assessment. To communicate the footprint externally, details of boundaries, use profile and all data sources should be disclosed to ease transparency.

Armed with sufficient data, now it is time to put it all together and calculate the carbon footprint of the product (see *Communicating the footprint and claiming reductions*).

Step 4: Calculating the footprint

The equation for product carbon footprinting is the sum of all materials, energy and waste across all activities in a product's life cycle multiplied by their emission factors. The calculation itself simply involves multiplying the activity data by the appropriate emission factors.

Carbon footprint of a given activity =
Activity data (mass/volume/kWh/km) ×
Emission factor (CO_2e per unit)

Once GHG emissions are calculated for each activity, convert to CO_2e using the relevant global warming potential (GWP) factors described in PAS 2050 Table A.1

Calculating the carbon footprint normally requires a 'mass balance' to ensure all input, output and waste streams are accounted for.

Mass balance

The quantification of the total amount of all materials into and out of a process is referred to as 'mass balance'. The mass balance step provides confirmation that all materials have been fully accounted for and no streams are missing.

The fundamental concept is that total mass flowing into a process should equal total mass flowing out. In practice, it is a useful way to identify previously hidden waste streams: if the mass coming out of a process is less than the combined mass of the inputs, then some other stream – most likely waste – must be leaving the process too. Note that for some complex natural systems, like agriculture, mass balance may not be practical or relevant.

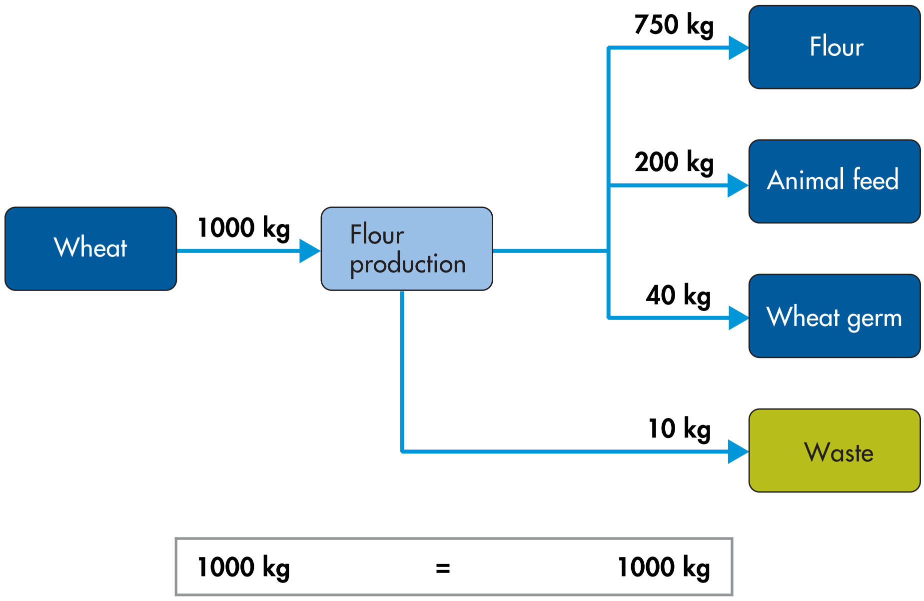
Services note: The services equivalent of a mass balance calculation is called an activity-based assessment. For a given activity, all processes and materials flowing into and out of that activity stage must be analysed for their GHG emissions.

For example, a mass balance check on the flour production stage for croissants would be as shown opposite.

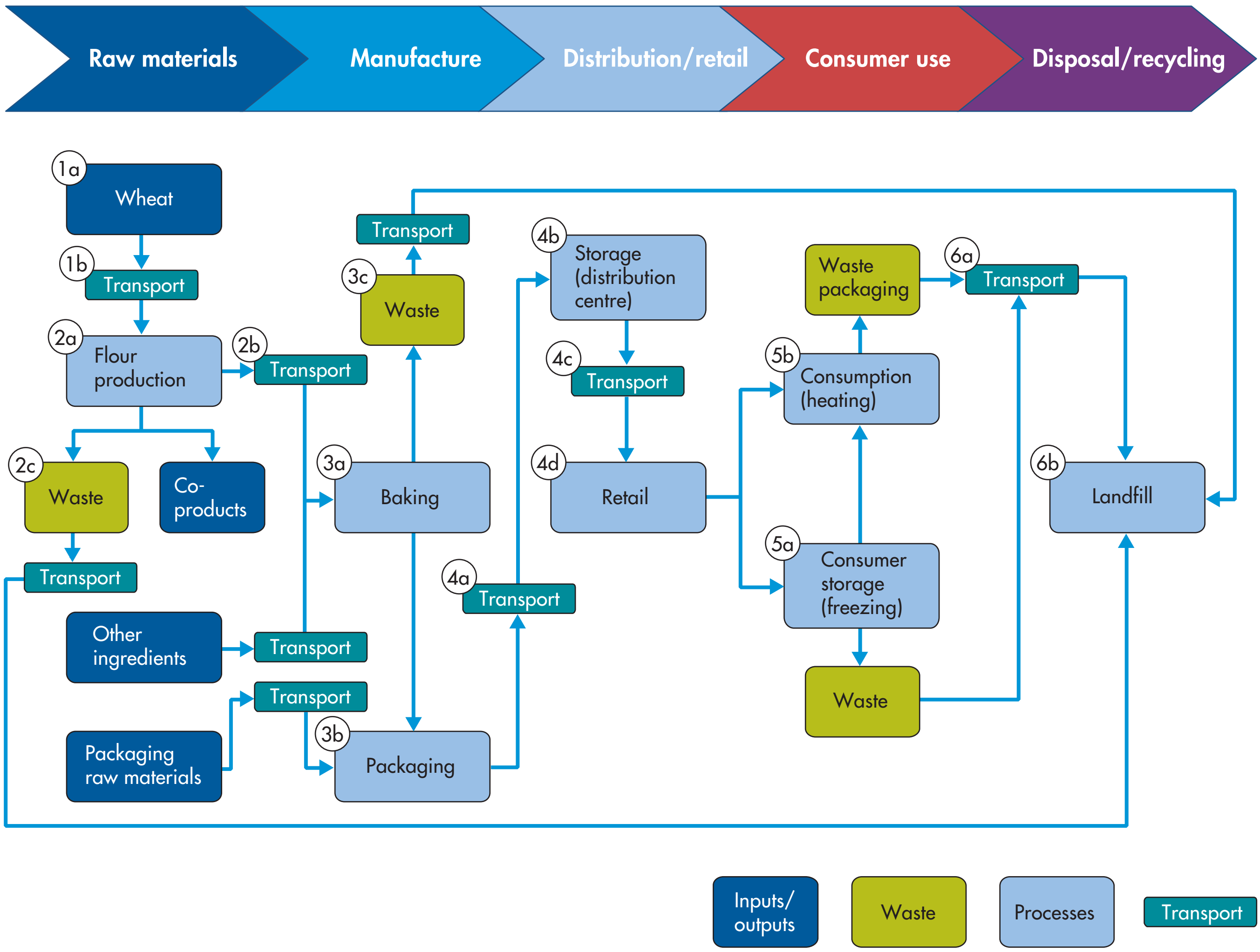
It is easiest to calculate mass balances while the data is being collected. First work backwards from the point of purchase: all materials, energy and direct emissions to produce a unit should be included, and all the mass accounted for. Then use a similar process to ensure the full mass of the product is captured in the use and disposal phases.

Footprint calculation

The actual calculation involves multiple steps, which are shown in the croissants example. For reference, each step is numbered in the process map opposite and corresponds to a discrete part of the detailed calculation diagram (pages 22–26) and the worked example in Appendix III.



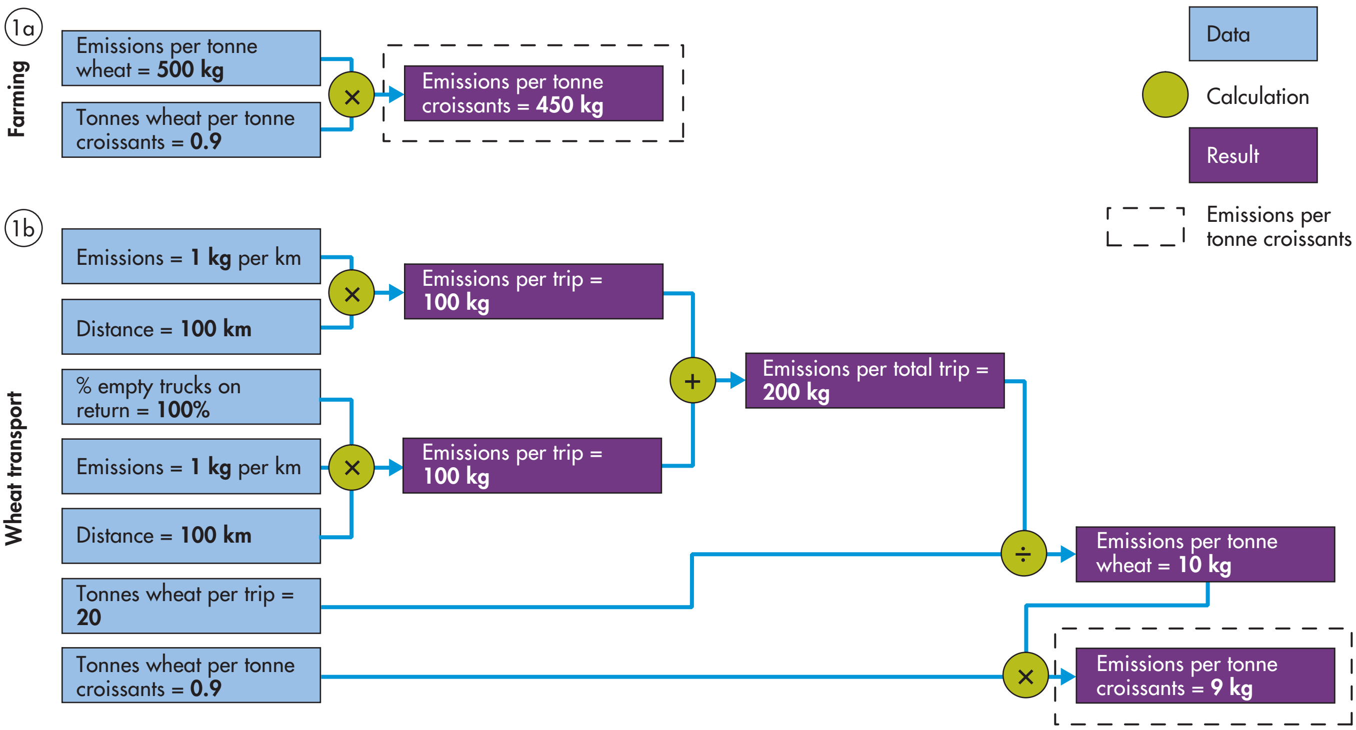
Mass balance example: flour production



Process map: croissants example

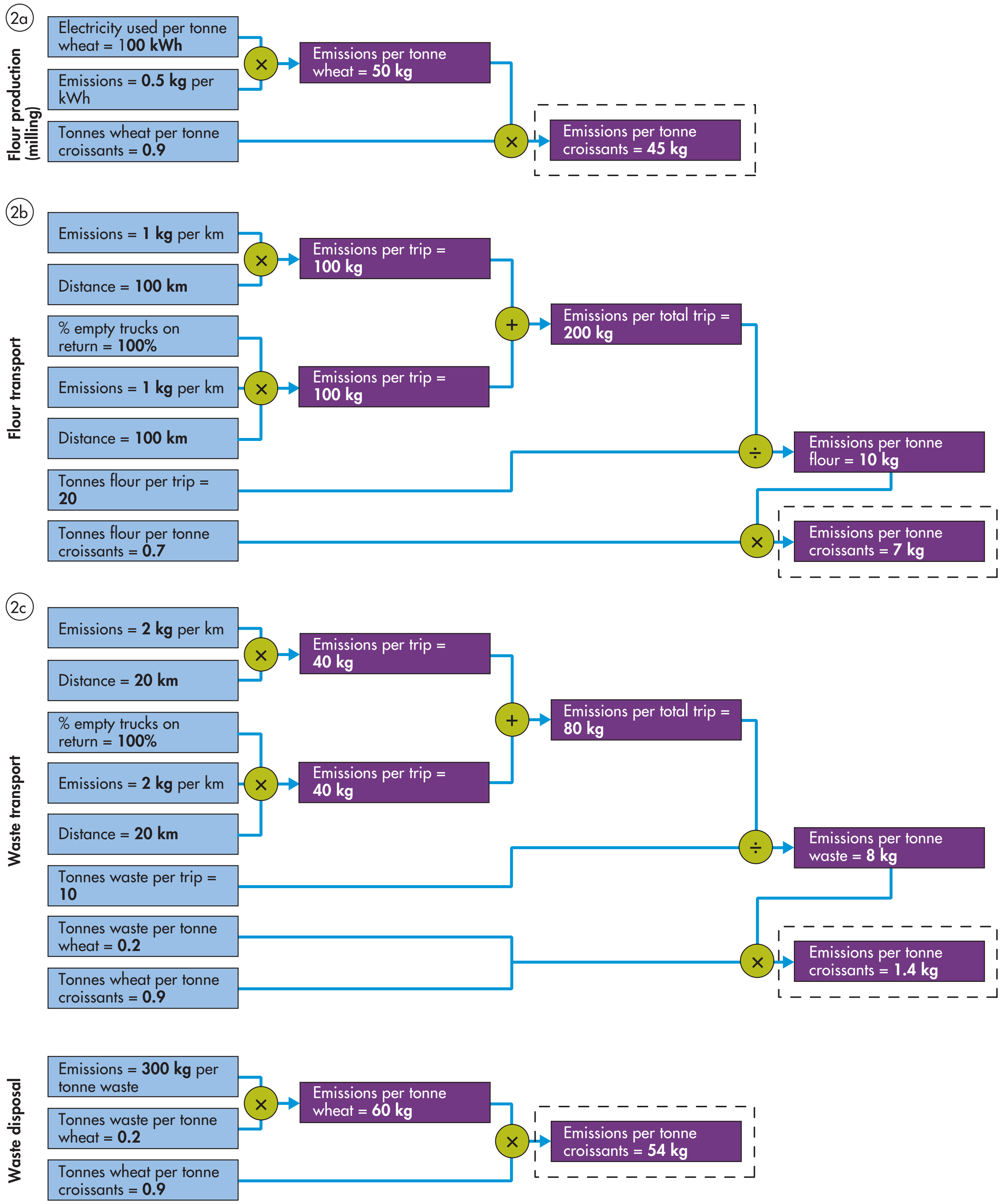
This simplified example aims to build basic understanding of the product footprinting calculation using illustrative values. It does not reflect a complete or fully representative calculation. In practice, software programmes are available – some with data sets attached – that can help with the calculations.

The footprint calculation table can be found in Appendix III. Below is a series of diagrams describing the calculations for each activity step-by-step.



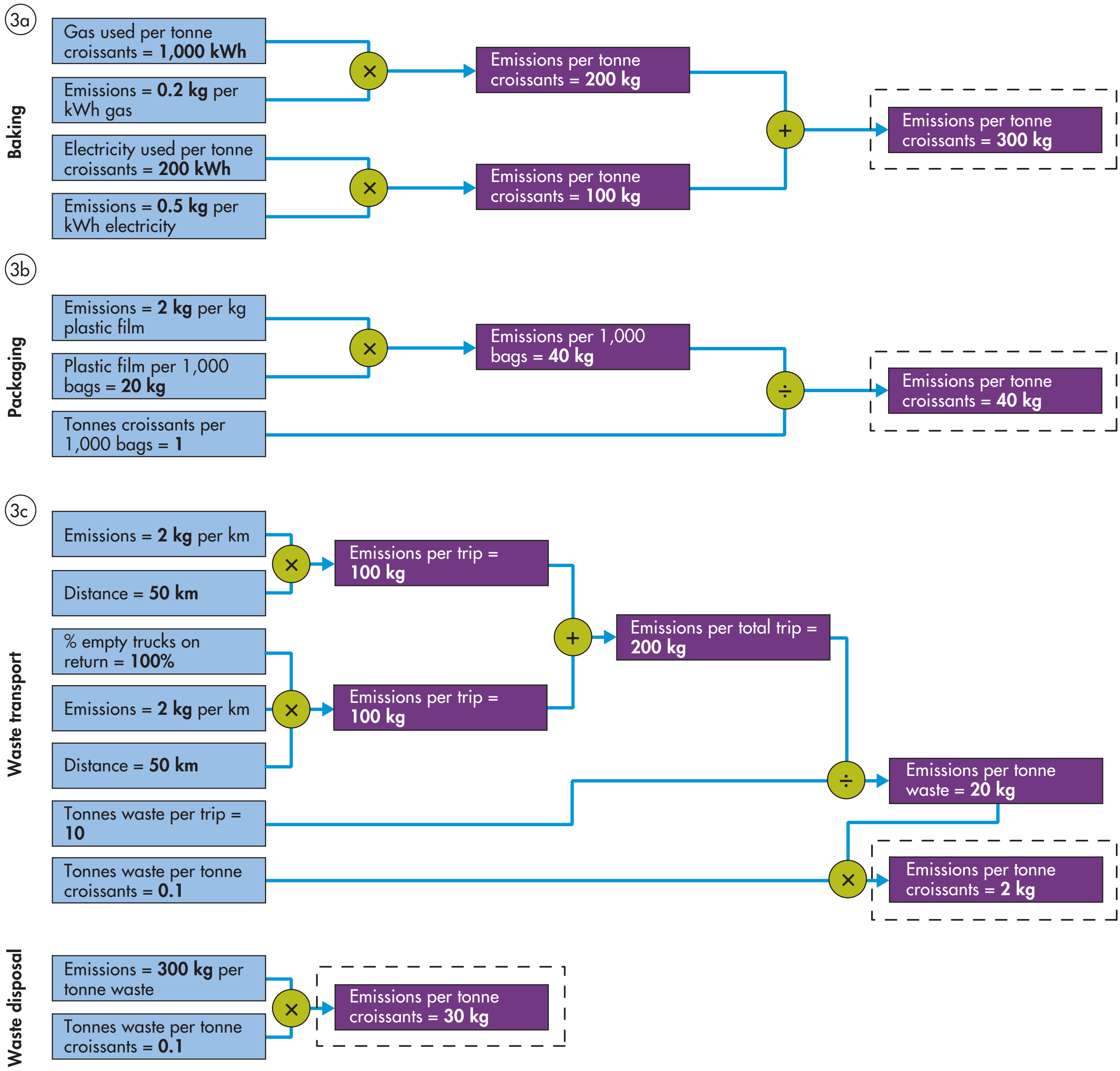
Note: all emissions described in kg CO_2e

Raw material cultivation and transport (wheat example)



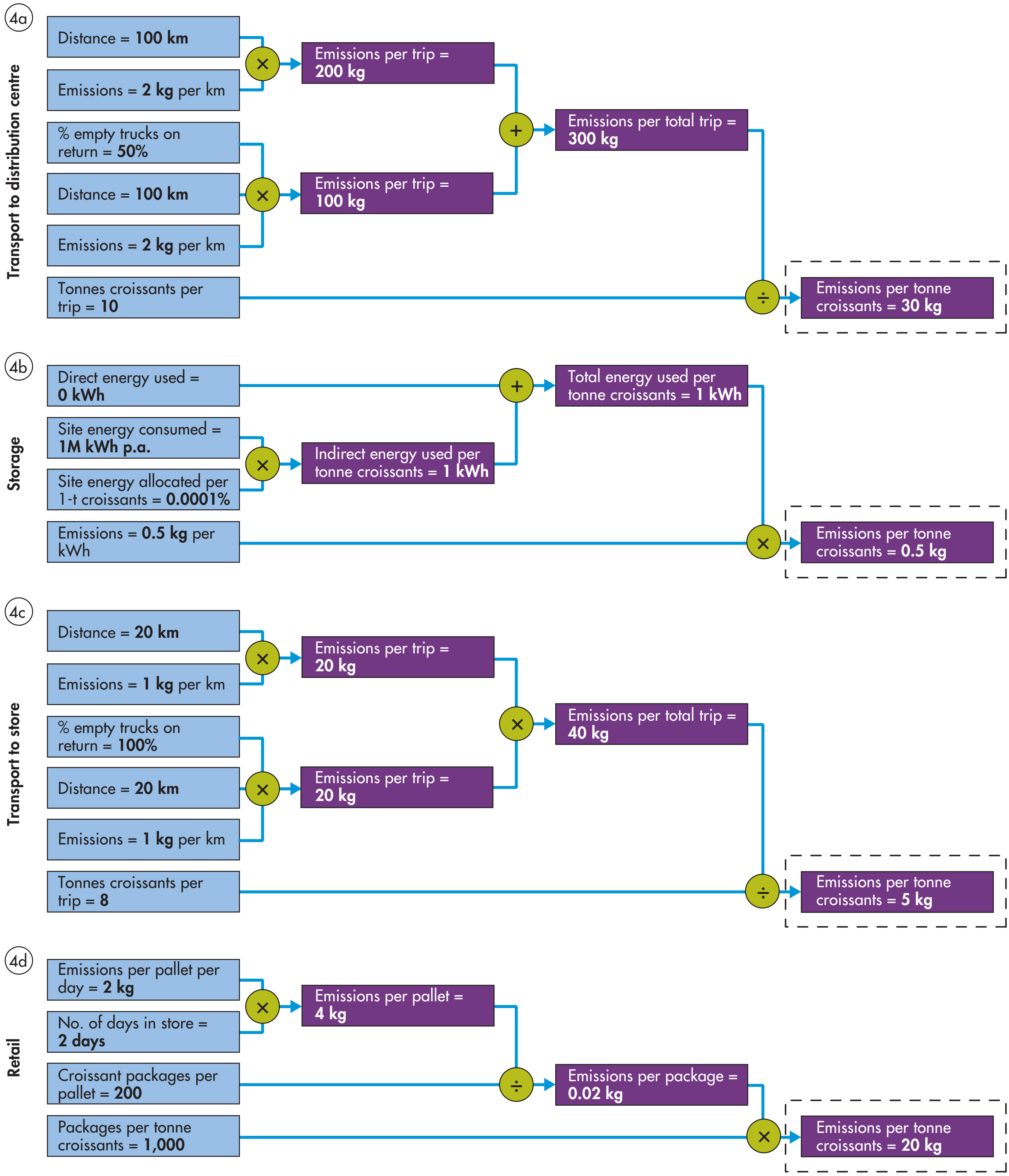
Note: all emissions described in kg CO_2e

Raw material production (flour example)



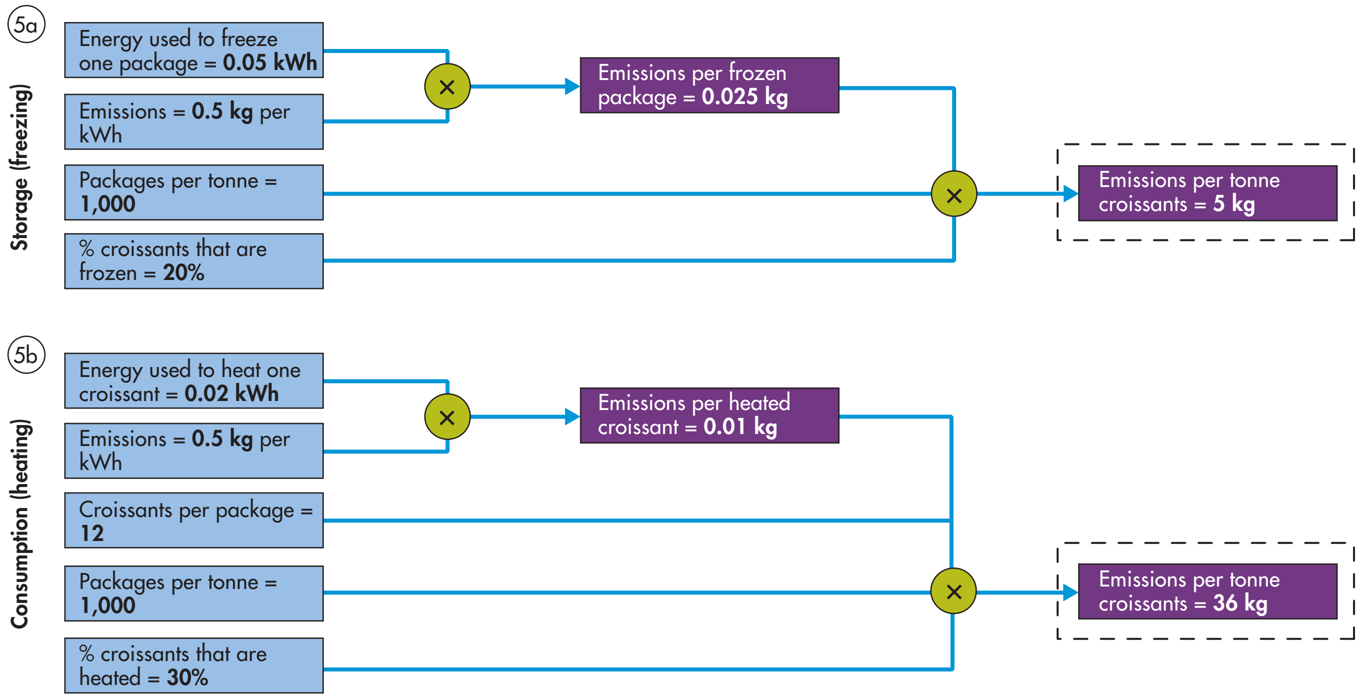
Note: all emissions described in kg CO_2e

Croissant production



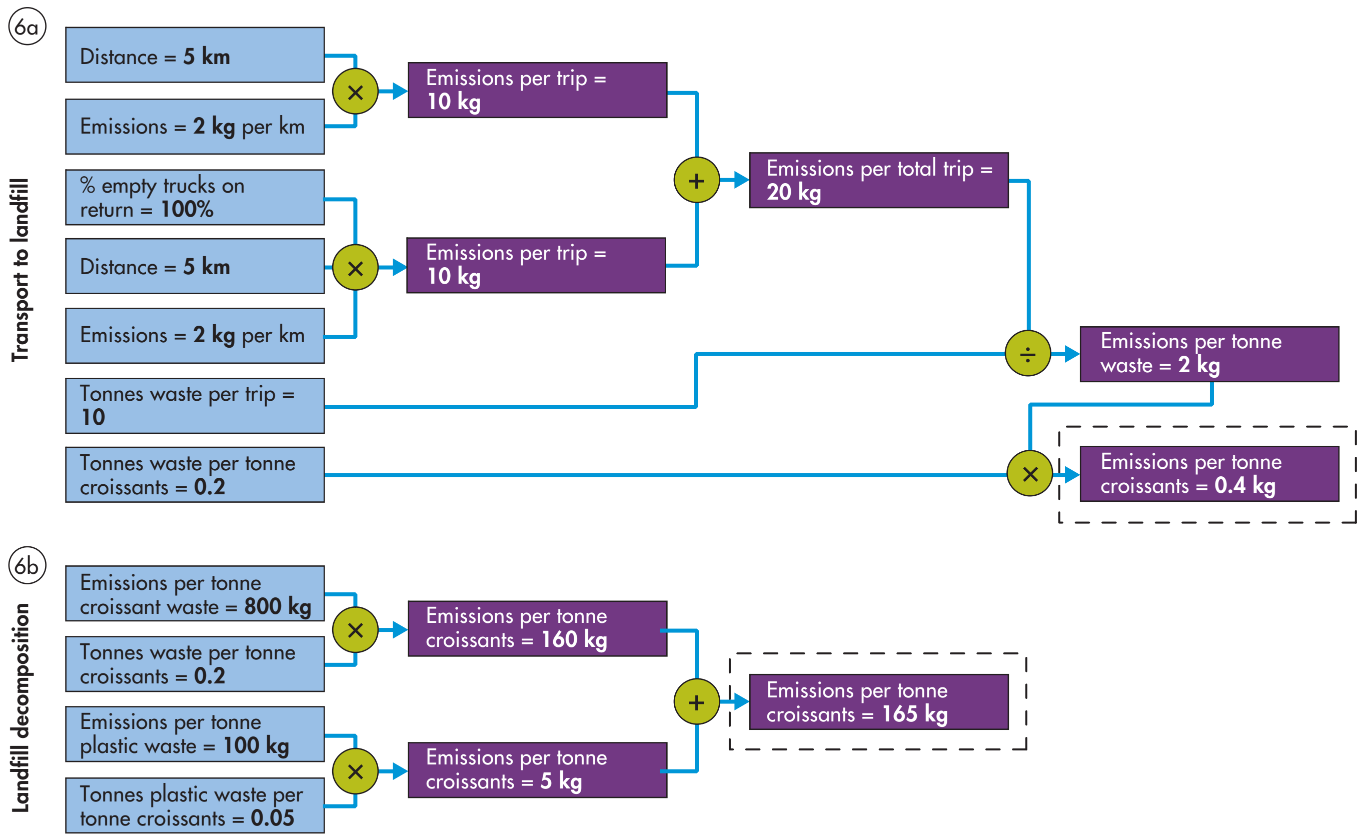
Note: all emissions described in kg CO_2e

Distribution and retail



Note: all emissions described in kg CO_2e

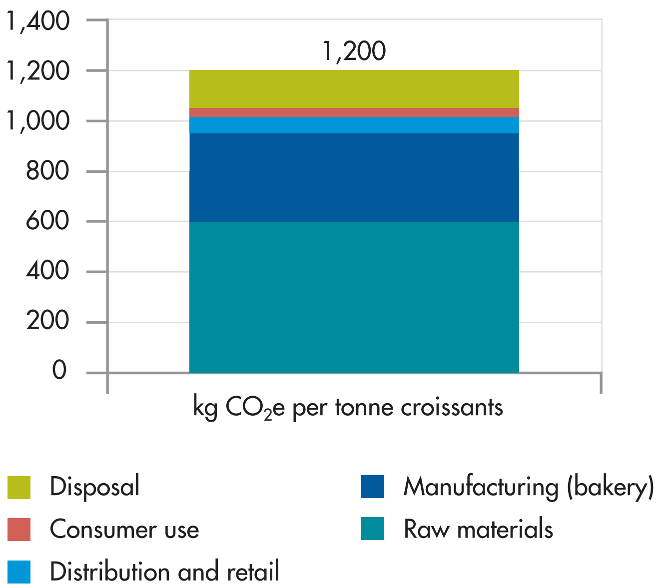
Consumer use



Note: all emissions described in kg CO_2e

Disposal

Having calculated the emissions for each step, deduct any carbon stored during the life cycle (see detail in *Carbon storage in products*). The net amount represents the total GHG emissions caused by each material and process across the product's life cycle, and therefore the final product carbon footprint – in this case, 1,200 kg CO_2e per tonne croissant, or 1.2 kg CO_2e per 12-pack.



Product carbon footprint: croissants example

Treatment of specific emission drivers

Some GHG emission sources have unique aspects that affect their assessment and are specified to more detail in PAS 2050 (see specific references in the text below). These situations, which concern measurement and allocation, are described here, with accompanying guidance.

Measurement

Delayed emissions

Emissions that are released over time through long use (e.g. light bulbs) or final disposal phases cannot be treated as a single release of emissions at the start of the 100-year assessment period. Therefore, these emissions must be calculated to represent the weighted average time in the atmosphere during the assessment period. PAS 2050 provides the calculation method and an example in Annex B.

> **100-year assessment period**
> **The PAS 2050 method assesses the impact of GHG emissions arising from the life cycle of products over a 100-year period following the formation of the product.**

Carbon storage in products

Some products that are formed from plant-based carbon (not fossilised) actually store carbon and therefore create 'negative' emissions by taking GHGs out of the atmosphere. PAS 2050 (Section 5.4) contains details on the circumstances when stored carbon can be counted and how to calculate the storage benefit. A summary is also given below.

Eligibility
Products can claim a storage benefit in the following situations.

1. The product is not a food (for humans) or feed (for animals)
   - To simplify the application of PAS 2050, there is no requirement to calculate the carbon storage in food products
2. Greater than 50% of the plant-based component's mass remains removed from the atmosphere for one year or more following production (e.g. wooden furniture such as a table)
   - This rule again simplifies the application of PAS 2050, so that products containing minor amounts of carbon do not have to undergo the carbon storage analysis
3. Material containing the plant-based carbon was especially created or recycled/re-used to input to this product and thus the storage benefit is *additional* to what would have occurred without the product being created
   - For example, products made from timber from a managed plantation forest would receive a carbon storage benefit; however, products using timber from a native, unmanaged forest (e.g. primary rainforest) would not receive a carbon storage benefit

- This is a key requirement: PAS 2050 allows for a carbon storage benefit *only* where the material storing the carbon is additional to the storage that would have occurred anyway

Calculation

PAS 2050 uses the same approach for carbon storage (release) as for delayed emissions (see PAS 2050 Annex C).

Calculation of the carbon storage of products requires an understanding of the fate of the products over a 100-year period. Over this time, some of the product may be burnt (releasing CO_2), some may end up as waste (with or without CO_2 release), some will be recycled and some will remain as the original product.

In these different situations, it is important to understand how much of the carbon in the product is released as CO_2 over the 100 years, and when it is released. Carbon released as CO_2 early in the 100-year period has much less impact on the carbon storage assessment than carbon that has been retained by the product for the full 100 years.

Where a product is recycled, the carbon storage benefit ends for that product; however, a product using recycled material receives a carbon storage benefit (as long as you can demonstrate that the recycled material was created for the purpose of being used in the product).

Example: If a table built from wood satisfied the eligibility conditions and lasted for 10 years, it would have a storage benefit for 10 years, but the magnitude of that benefit would decrease each year. The equation is in PAS 2050 Annex C.

Agriculture

Non-CO_2 emissions from livestock, their manure or soils should be included and estimated based on the approach described by the most recent IPCC Guidelines for National Greenhouse Gas Inventories or the highest Tier approach – latest peer-reviewed science – used by the relevant country (see PAS 2050 Section 7.8 and Clause 2 in IPCC Guidelines).

Land use change

If the product's supply chain directly caused non-agricultural land to be converted to agricultural use on or after 1 January 1990, then GHG emissions associated with the land use change must be included in the carbon footprint calculation (see PAS 2050 Section 5.5). If the timing of land use change is unknown, assume it occurred on 1 January of either (1) the earliest year when it can be confirmed that the land was used for agriculture, or (2) the current year.

Where land use change has occurred on or after 1 January 1990, the total GHG emissions from the change in land use are assumed to be released in equal annual amounts for 20 years.

Calculation

- Identify the country where the land use change took place
- Refer to PAS 2050 Table E.1 to find the appropriate emission factor (in tonnes CO_2e per hectare per year)
  - If unknown, use the highest potential emission factor

Note that GHG emissions from land use change are calculated separately from emissions arising from agriculture.

Also note that while PAS 2050 includes emissions arising from the conversion of (for example) forest to annual cropland, it does not include changes in soil carbon in existing agricultural systems.

Examples (agriculture emissions plus land use change):

- **Wheat imported from Argentina; farm converted from forest in 1980**
  - **Wheat emission factor: use IPCC average unless reputable Argentina-specific data can be found**
  - **Land use change emissions = 0**
- **Wheat imported from Argentina; farm converted from forest in 1995**
  - **Wheat emission factor: same as above**
  - **Land use change emissions = 17 tonnes CO_2e per hectare per year (from PAS 2050 Table E.1) for each year up to and including 2014**

Variable supply chain

Changes may happen frequently in supply chains, due to diverse causes such as unexpected supply disruptions, planned process improvements or different seasons causing changes to sources of raw materials and transportation routes.

To account for these changes, PAS 2050 specifies the following.

1. Temporary, unplanned change in the supply chain (see PAS 2050 Section 7.5.1)
   - Impact: if the disruption causes a greater than 10% increase in the product's carbon footprint and lasts for longer than three months, then reassess the product's GHG emissions
   - Example: if a company usually sources from two different plants, but one plant goes off-line for six months and the remaining plant has higher emissions, this would constitute a temporary, unplanned change. However, if after a quick screening analysis the total impact on the product's carbon footprint is only to increase it by 5%, then there is no need to reassess fully using primary activity data
2. Planned change in the supply chain (see PAS 2050 Section 7.5.2)
   - Impact: if the planned change causes a 5% increase or greater in the overall product footprint for three months or more, then the footprint must be reassessed and verified again
   - Example: a company decides to change its plastic packaging supplier to a new supplier with 20% higher emissions; if after a quick screening analysis the impact of this switch on the company's product footprint is 5% or more, then reassess and, if appropriate, repeat verification
3. Inherently variable and unpredictable supply chains (see PAS 2050 Section 7.6). In some cases, the supply chain may not change, but the amount of emissions coming from the supply chain varies. For example, when an organisation buys grid electricity, there may be no change in the supply chain – the organisation still buys grid electricity – but the GHG emissions from the electricity vary all the time.

   In these cases, data should be averaged over time to ensure that the result is representative of the variations in GHG emissions over the period of assessment.

Sampling

When an input comes from multiple sources (e.g. many small farms produce wheat for a particular flour mill), data can be collected from a representative sample. The use of sampling data must be justified against the requirements of PAS 2050 (see PAS 2050 Sections 7.7 and 7.2).

Example: If there are 100 small mills producing flour, measure the activity data and emissions at 10 mills chosen at random, then take the weighted average.

One method for determining the sample size is to use a square root approach: randomly select the square root, i.e. √(the total number of sources).

This technique should be used in accordance with data quality rules. For example, a wide range of answers from the sampling would suggest the need for further sampling to draw a clearer picture of the weighted average.

Recycling

The approach to calculating emissions from recycled inputs depends on the material (e.g. aluminium, glass, plastic) and whether the material's recycling system is part of a product system or not. A closed loop system implies that when recycled, the material does not change and is used again for the same purpose. For example, PET (polyethylene terephthalate) bottles can only be manufactured using recycled PET bottles (not other PET material). The material system is therefore considered closed.

To calculate the emissions of an input material containing recyclable matter:

1. Assess whether the recycled material is derived from a 'closed-loop' process (if not, see below)
2. Determine the proportion of input from recycled content vs. virgin material
   - Use the industry average unless the product's inputs are known to be different, e.g. if the specific product only uses 100% recycled PET bottles
3. Collect data on emissions caused by creating input material through recycling and virgin
4. Calculate the weighted average emissions per unit input according to the proportion of recycled vs. virgin material

For inputs with recycled material that is not part of a closed-loop recycling system, PAS 2050 requires that

the emissions arising from that material is assessed using an approach consistent with BS EN ISO 14044 which factors in the recycling rate across the entire material system. This allows some flexibility for those sectors that have little control over the recycled content of the input because it is purchased as a commodity, and also acknowledges sectors where there are high recycling rates, e.g. the aluminium industry.

Note that recycling is also considered at the disposal stage of the life cycle, where the recycled portion of a product is excluded from its life cycle emissions (and included in the product that uses it as a raw material input).

Energy

Energy-related emissions can be derived from fuel combustion, electricity or heat generation.

Emission factors for energy should include all emissions associated with the entire life cycle of the energy input, including:

- Mining, refining and transport of raw materials (e.g. coal, oil, gas)
- Generation of electricity
- Distribution
- Consumption
- Disposal of waste

For more details see PAS 2050 Section 6.4.2.

Different sources of energy can be treated differently depending on how they are generated.

1. On site generation and use: the emission factor is calculated from primary activity data and must include emissions from the fuel input's life cycle
2. Off site generation: use the emission factor provided by the supplier or other reliable secondary source
3. Renewable electricity

   Renewable electricity-specific emission factors (vs. national grid averages) can only be used when both:

   a) The specific process uses the renewable energy generated on site or an equivalent amount of the same type of renewable energy; and

   b) This renewable energy has not already been counted in any other emission factor (i.e. incorporated into the national grid average)

   The main purpose of this rule is to ensure no double counting of renewable energy. Often renewable energy is automatically incorporated into national averages as a source of zero-emissions electricity
4. Biomass/biofuels: include emissions arising from production but exclude CO_2 emissions arising from any plant-based carbon component
   - When fuel is produced from waste, the relevant emissions are those caused by the conversion of waste to fuel
   - When fuel is produced from plant matter, include the full life cycle emissions created by producing and using the fuel

Transport

Any GHG emissions arising from any transport required during the product's – and its raw materials' – life cycle are included in the carbon footprint assessment. Emission factors for transport should include emissions associated with creating and transporting the fuels required.

When products are distributed to different locations and transport distances vary, calculate the average GHG emissions based on the average distribution distance of the product within each country over the chosen time period, *unless more specific data is available*. For more information, see PAS 2050 Section 6.4.6.

Exclusions

The following emission sources are excluded from the PAS 2050 life cycle GHG emission assessment.

1. Capital goods

   These emissions are excluded based on:

   - lack of carbon footprint data currently available to identify sectors where capital goods emissions are material and
   - cost/complexity of analysis

'Capital goods' are the goods used in the life cycle of a product, such as machinery, equipment and buildings.

2. Aircraft emissions uplift factor

   This is excluded due to considerable uncertainty on the relative size of the impact of non-CO_2 emissions from aviation through radiative forcing

3. Offsets

   These are excluded because PAS 2050 is an assessment of a specific product's life cycle GHG emissions; any reductions to the footprint should be directly attributable to changes made to the product's life cycle, not through unrelated activities such as purchase of emissions credits.

Allocation

Allocation of emissions is required where a process contributing to a given product's life cycle results in more than one useful product, i.e. a co-product, or by-product other than waste. Unlike waste, co-products have economic value and can be sold – as such they represent other discrete products.

'Allocation' involves the partitioning of GHG emissions from a single process to the different outputs of that process.

PAS 2050 specifies the following approach to allocation.

First, break down the process into sub-processes that each have only one output.

If this cannot be done, then expand the system to include impact of displaced products (e.g. avoided electricity due to a process relating to the product also generated electricity)

When neither of these avoidance measures is possible or practical, allocate GHG emissions in proportion to the economic value of the co-products (economic allocation), unless otherwise stated in PAS 2050.

In our croissants example, flour milling produces two co-products in addition to flour (the relevant product input): animal feed and wheat germ. For the purposes of this example, assume the milling process cannot be broken down into sub-processes resulting in discrete outputs, nor can system expansion be applied because no single displaced/avoided product can be identified for either of the two co-products.

In this case, economic allocation would be used: the GHG emissions arising from flour production – and the associated inputs – would be shared across these products according to revenue (as shown in Table 3).

Thus, in this example, the GHG emissions arising from flour production would be allocated to the three products according to revenue:

- 78% to flour
- 20% to wheat germ
- 2% to animal feed

Table 3: Allocating emissions across co-products

	Tonnes output per 1 tonne wheat input	£ per tonne output	Total £ per tonne wheat	% of total revenue
Flour	0.80 tonne	£200/tonne flour	£160	**78%**
Wheat germ	0.10 tonne	£400/tonne wheatgerm	£40	**20%**
Animal feed	0.10 tonne	£50/tonne animal feed	£5	**2%**
Total	*1.00 tonne*	*n/a*	*£205*	*100%*

Waste

Waste generates emissions when it breaks down in landfills or is incinerated. The PAS 2050 method treats these emissions differently depending on the material and process of disposal as follows.

Landfill

- CO_2 emissions from plant-based carbon in the waste are excluded, i.e. given a GWP of 0

- CO_2 emissions from fossil carbon are included in the product footprint with a GWP of 1
- All non-CO_2 emissions from any part of the waste are included and assigned the relevant GWP (see PAS 2050 Annex A), net of any CO_2 absorbed during plant growth

Incineration and methane combustion

- Generating useful energy – when methane is captured and used to generate electricity, any emissions are excluded from the product footprint and allocated to the energy being created (as input to another product's life cycle)
- No energy recovery – when methane is created but not used to generate electricity, emissions caused by fossil carbon (not plant-based carbon) are included in the product footprint (as with landfill)

Combined Heat and Power (CHP)

The total emissions from the CHP source are allocated to electricity and heat according to the amount of useful energy delivered in each. This varies depending on type of CHP input (see PAS 2050 Section 8.3):

- Boiler-based (e.g. coal, wood, solid fuel) – the ratio of emissions per MJ electricity to MJ heat is 2.5 to 1, based on the process-specific heat to electricity ratio: therefore, if 350 kg CO_2e were emitted by a CHP plant to generate 100 MJ electricity and 100 MJ heat, 250 kg CO_2e should be allocated to electricity and 100 kg CO_2e to heat
- Turbine-based (e.g. gas) – the ratio of emissions per MJ electricity to MJ heat is 2.0 to 1, again based on the process-specific heat to electricity ratio

Transport

When the product is transported along with other products, transport emissions are allocated on the basis of mass or volume, whichever is the limiting factor.

For example, if 1 tonne of croissants is shipped in a 2-tonne container along with 1 tonne of bread, the croissants would be allocated 50% of the emissions associated with that transport leg.

Reuse and remanufacture

Total product life cycle GHG emissions, excluding the use phase, are divided by the expected number of times the product is reused, including emissions associated with any remanufacturing required to make it usable again. Then this figure is added to a single use phase's emissions, resulting in a product footprint includes only a portion of the life cycle emissions, plus those from one full use phase.

For example, if a tyre can be re-treaded up to four times over the course of its life, this creates five distinct use phases, four of which require a re-manufacturing step. To calculate total product GHG emissions over one life cycle:

- Calculate all life cycle emissions excluding the use phase – for simplicity say this comes to 100 g CO_2e
- Add emissions from four re-manufacturing steps: assuming 25 g CO_2e per re-tread, for a total of $4 \times 25 = 100$ g CO_2e; thus the total emissions over the full life of a tyre are 200 g CO_2e
- Divide this by the anticipated number of uses: $200/5 = 40$ g CO_2e
- Now add the use phase emissions from a tyre to 40 g CO_2e for the total emissions over one life cycle

Now that the carbon footprint figure has been calculated, it is time to understand how precise and reproducible the measurement is. The next section explains this concept of uncertainty.

Step 5: Checking uncertainty (optional)

Uncertainty analysis in product carbon footprinting is a measure of precision. While not prescribed in PAS 2050, companies can benefit from assessing the uncertainty of their carbon footprint as described below – more detail on how to calculate uncertainty can be found in Appendix IV.

The objective of this step is to measure and minimise uncertainty in the footprint result and to improve confidence in footprint comparisons and any decisions that are made based on the footprint. Uncertainty analysis provides several benefits:

- Enables greater confidence in comparisons between products and in decision making
- Identifies where to focus data collection efforts, and where not to focus
- Contributes to better understanding of the footprinting model itself – how it works, how to improve it and when it is robust enough
- If communicated it indicates robustness of the footprint to internal and external audiences

Best practice in product carbon footprinting, as encouraged by PAS 2050, aims to minimise the uncertainty in the footprint calculation to help provide the most robust, reliable and replicable result. PAS 2050 does not explicitly require uncertainty analysis, although it may be necessary to meet data quality specifications. In practice, it is useful to delegate this task to someone experienced in uncertainty analysis and familiar with the product's carbon footprint model.

Reducing uncertainty

Once sources of uncertainty have been identified through the process described in Appendix IV, they can usually be reduced in the following ways:

- Replace secondary data with good quality primary activity data, e.g. replace an estimated electricity consumption factor with actual measurements from a line sub-meter

- Use better quality secondary data i.e. more specific, more recent, more reliable and/or more complete
- Improve the model used to calculate the carbon footprint by making it more representative of reality e.g. estimate each distribution leg individually, rather than a single estimate for total distribution
- Additional peer review and/or certification of the carbon footprint

It is not always the case that primary data will have lower uncertainty than secondary data, but an uncertainty estimate is a good way to decide whether to use primary or secondary activity data for a particular process/emission source.

Section III
Next steps

Depending on the objectives for the assessment, several different actions may be taken once a product carbon footprint has been calculated. Organisations that are only using PAS 2050 to guide a high-level analysis may want to move straight into identifying emission reduction opportunities. Others may want to verify the footprint method and number, either to provide more confidence in their own internal decision making or as a step towards making external claims.

Validating results

In general, it is useful to verify the product carbon footprint in order to ensure any actions or decisions are made on the basis of a correct and consistent analysis. However, the level of verification necessary depends on the project goals – for communication to customers, a higher level of verification is needed than if the data is only be used internally.

PAS 2050 specifies three levels of verification depending on how the product carbon footprint will be used (see PAS 2050 Section 10.3 for more information):

1. Certification – independent third party certification body accredited by an internationally recognised accreditation body (e.g. United Kingdom Accreditation Service, UKAS). Here, an auditor will review the process used to estimate the carbon footprint, check the data sources and calculations and certify whether PAS 2050 has been used correctly and whether the assessment has achieved conformity. This is advisable for external communication of the footprint results and may be desirable in any case, to ensure decisions are made on the basis of correct information.
2. Other-party verification – non-accredited third parties should demonstrate compliance with recognised standards for certification bodies and provide for external validation on request. This approach may not offer the level of confidence that fully accredited certification bodies can provide.
3. Self-verification – if choosing to self-verify, follow the method outlined in BS EN ISO 14021[6)]. Note that users of the footprint may have lower confidence in this option.

Independent certification is highly encouraged when companies want to communicate the carbon footprint publicly. Third party certification by accredited experts also provides peace of mind that any subsequent decisions made (e.g. to reduce emissions and costs, choose suppliers, change receipts and discontinue products) are supported by robust analysis.

Different product footprints are not truly comparable unless the same data sources, boundary conditions and other assumptions are used.

Reducing emissions

Product carbon footprints can provide valuable insights to help reduce GHG emissions. The footprinting exercise both provides a baseline against which to measure future reductions and helps identify opportunities to reduce emissions across all phases of the product's life cycle. The analysis offers a way to

[6)] BS EN ISO 14021, *Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)*.

Common emission reduction opportunities

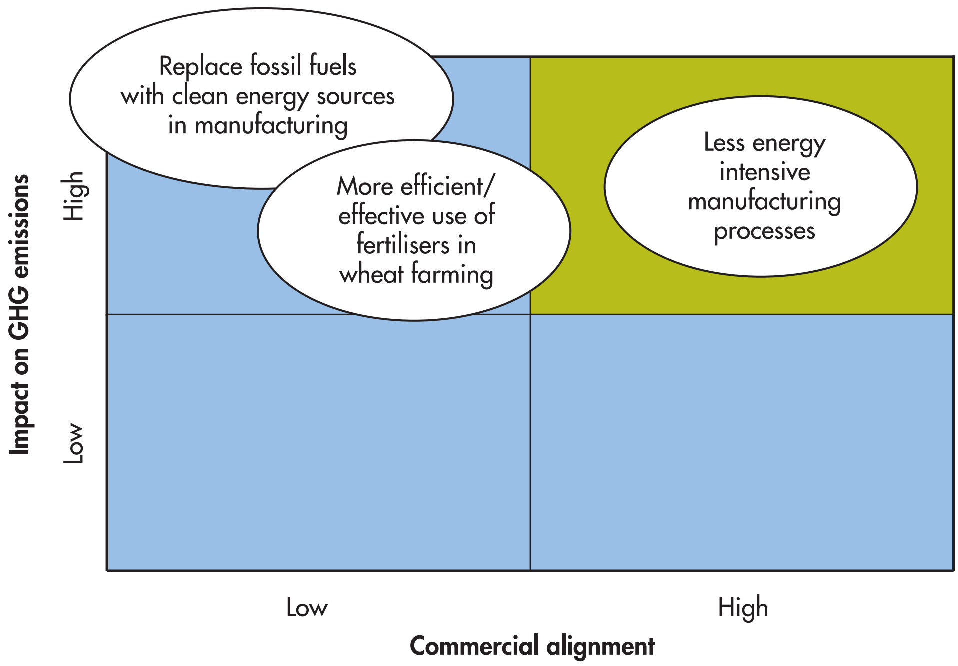
- Energy use
  - Change from electricity to gas
  - Increase proportion of energy from renewables
- Production
  - Decrease waste volumes
  - Increase scale
  - Decrease amount of processing
  - Change manufacturing practices and improve efficiency
- Distribution
  - Decrease heating/cooling in storage and transport
  - Decrease distances travelled
- General
  - Include energy/carbon criteria in purchasing/supplier choices
  - Include energy/carbon criteria in design decisions
  - Change product design/configuration/materials, e.g. 100% recycled bottles
  - Change technology choice (e.g. upgrading equipment to be more energy efficient)
  - Improve inventory management

engage with suppliers, distributors, retailers and consumers on how to reduce emissions (see box, left).

The product footprint analysis itself helps to identify the main drivers of GHG emissions. It may be useful to classify these according to who has control over each driver (e.g. industry-wide, market/customers, supply chain, internal). For all main drivers, explore ways to reduce emissions and consider actions that can be taken across the value chain to achieve these reductions. Then assess the GHG impact, cost, feasibility and potential market reaction of each action, across all product life cycle steps. One helpful approach is to use sensitivity analysis in the carbon footprint model in order to help quantify impacts and make these decisions.

Considerable cost savings can be achieved by decreasing energy use and waste. These should be compared to the investment required and any potential increases to operating costs as a result of emission/cost reduction strategies (see the prioritisation framework, below).

Prioritise potential emissions reduction strategies according to likely impact on both GHG emissions and commercial goals



Prioritisation framework

The potential impact of any carbon reduction activity on customers should also be considered, including: perceptions of value, quality and service; choice and range; availability and convenience; and differentiation.

Prioritisation criteria are specific to each company's situation, but most companies choose a combination of emissions impact and commercial opportunities (cost reduction and/or revenue potential), followed by other strategic considerations, when deciding on actions.

Communicating the footprint and claiming reductions

PAS 2050 does not specify any requirements for communicating a footprint or making reduction claims. One source of detailed guidance can be found in the *Code of Good Practice for product GHG emissions and reduction claims*[7)], sponsored by the Carbon Trust and the Energy Saving Trust and developed through a consultative process in conjunction with PAS 2050. This document provides guidelines for consistent, transparent communication of product emissions and reduction claims.

Another source for guidance on making environmental product claims is Defra's *Green Claims* guide.[8)] This guide, supported by the Confederation of British Industry, the British Retail Consortium, the Local Authorities Coordinating Body on Food and Trading Standards and the British Standards Institution, helps businesses present environmental information and claims to customers about their products.

The decision to communicate a product carbon footprint – and how – depends on the original objectives and can include many different messages, formats and audiences, including:

- Customers, via carbon footprint information provided on-pack, at point-of-sale, in product instructions, advertisements, sales materials, websites, press releases, etc.
- Internal management
- Employees
- Supply chain partners
- Industry associations
- Media
- Investors

[7)] *Code of Good Practice for product GHG emissions and reduction claims* (2008) is available at *www.carbontrust.co.uk*.
[8)] *Green Claims – Practical Guidance, How to Make a Good Environmental Claim* (2003) is available at *www.defra.gov.uk/environment/consumerprod/pdf/genericguide.pdf*.

Appendix I

PAS 2050 application across different product types

	B2C goods	B2B goods	Services
Product functional unit definition	• Typical size/quantity sold to consumer (e.g. one 12-pack croissants)	• Typical size/quantity sold to business consumer (e.g. one tonne flour)	• Typical, comparable offering (e.g. one night's hotel stay)
Process map/ boundaries	• Include all life cycle stages: – Raw materials – Manufacturing – Distribution/retail – Use – Disposal/recycling	• Include life cycle stages until point of delivery to customer: – Raw materials – Manufacturing – Delivery to customer gate	• Varies with type of service • Could include: – Opening/start-up – Ongoing use – Close-down • Include all activities, materials, energy and waste associated with providing a unit of service
Data collection	←	***Same for any product type***	→
Calculation	←	***Same for any product type***	→
Uncertainty	←	***Same for any product type***	→
Verification/ communication	←	***Same for any product type***	→

Impact of different product types on PAS 2050 implementation

Appendix II
Services examples

Calculating the carbon footprint of services follows exactly the same steps as for goods: PAS 2050 specifies a method that can be applied equally to services and goods. However, correctly identifying and understanding the service 'product' definition and the life cycle stages in the process map may be more challenging and may require extra effort to define.

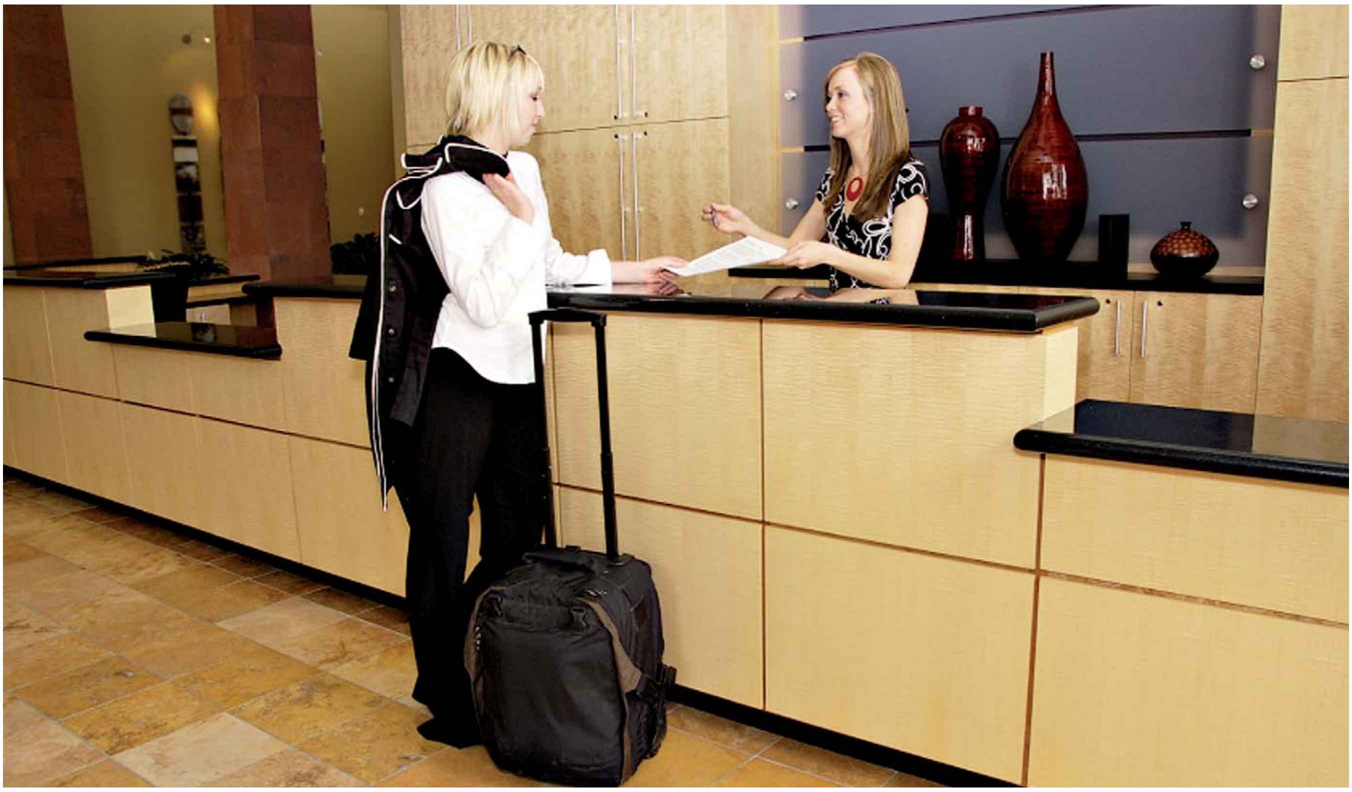
When choosing a service to footprint, try to define it in a way that would be most useful to the company and others using the footprint, i.e. make it:

- easily comparable to other services within your or your competitors' offering
- likely to generate actionable opportunities to reduce emissions
- relatively easy to understand and describe supply chain/process map

Example 1: one night's hotel stay

Consider a hotel chain that wants to calculate the carbon footprint of one night's stay.

First, define the functional unit. Assuming the hotel has different types of rooms, e.g. standard, deluxe, suite, it is likely that each class or size of room has a different footprint. To make a meaningful product definition, the hotel company chooses to assess its typical standard



rooms first, potentially rolling out the methodology to other classes of room later on. However, the functional unit must be defined in more detail to make data collection and comparisons easier. One possible definition could be the following: one night's hotel stay = 24 hours' worth of room/hotel usage.

Next, develop a process map for a night's hotel stay. Some possible components in the life cycle:

- Check-in
- Stay/use of the room
- Check-out
- Clean-up/preparation for next guest

Using these components, we can then dissect the activities, materials, energy and waste associated with each phase:

- Check-in
  - Computer used by Reception
  - Key
- Stay/use of the room
  - Electricity used by guest for lighting, TV, mini-bar
  - Energy for heat/air conditioning determined by guest
  - Water used by guest
  - Waste generated by guest
  - Proportion of overall hotel facilities used by guest (e.g. lifts, common areas, recreation/gym)
  - Toiletries
- Check-out
  - Computer used by Reception
  - Payment system
  - Paper for receipt
- Clean-up/preparation for next guest
  - Washing/drying linens
  - Use of cleaning products, vacuum, etc.

For the remainder of the footprinting analysis – data collection, the footprint calculation itself and uncertainty/quality-check of the result – follow Steps 3, 4 and 5 as described in the main text of this guide.

Example 2: IT services

For this example, a consumer-facing company wants to assess the carbon footprint of a particular package of customer support delivered through IT, such as an on-line payments system.

The first step is to define the functional unit. In this case, one hour of use of the online IT service by the customer was chosen as the functional unit. Next the process map was drawn, with help from suppliers and internal management, to include all supply chains that contribute to the provision of the IT service, customer use and any end-of-service impacts.

The following components in the life cycle were identified:

- Provision of hardware, software and updates to the service provider
- Office accommodation of service and support staff

- Updates to the service, providing call centre and on-line support
- Use of the service by customers
- Decommissioning of IT equipment

The activities within these life cycle stages include:

- Using current applications and services, and the activities and equipment needed to maintain this level of functionality
- Technology updates to software and hardware
- Paper use (e.g. print volumes)
- Call centres, and buildings housing the services (allocated as appropriate when these also provide services to other functions)
- Service provider and end users' equipment
- Staff associated with service development and delivery
- Operational emissions to include business travel and staff commuting
- Embedded emissions to be included from building and services
- Decommissioning to include the IT equipment and electronic archive of data
- Treatment of waste and capital allocation.

Once the process map was drawn in detail, the company proceeded with *Step 3: Collecting data* and *Step 4: Calculating the footprint* as described in this guide.

Appendix III

Product carbon footprinting calculation – worked example

This case study is purely illustrative and does not represent a real example of croissant production; the values have been chosen for their simplicity, to make this case study as easy to follow as possible. The results are not intended to reflect a fully representative carbon footprint of croissants.

Input	Amount	Source
Raw materials		
Wheat		
(1a) **Farming**		
kg CO_2e per tonne wheat	500	*Emission factor database*
tonnes wheat per tonne croissants	0.9	*Supplier interview*
kg CO_2e per tonne croissants	**450**	*Calculation: emissions per tonne wheat × tonnes wheat per tonne croissants*
(1b) **Transport**		
average distance (km)	100	*Supplier interview*
kg CO_2e per km	1	*Emission factor database; based on vehicle type*
kg CO_2e per outbound journey	100	*Calculation: emissions per km × km per journey*
% empty on inbound journey	100%	*Supplier interview*
kg CO_2e per inbound journey	100	*Calculation: % empty on return × emissions per km × km per journey*
kg CO_2e per total trip	200	*Calculation: emissions outbound + emissions inbound*
tonnes wheat per trip	20	*Supplier interview*
kg CO_2e per tonne wheat	10	*Calculation: emissions per total trip/tonnes wheat per trip*
tonnes wheat per tonne croissants	0.9	*Supplier interview*
kg CO_2e per tonne croissants	**9**	*Calculation: emissions per tonne wheat × tonnes wheat per tonne croissants*
Flour		
(2a) **Production (milling)**		
kWh per tonne wheat milled	100	*Supplier interview*
kg CO_2e per kWh	0.5	*Emission factor database; based on national grid*
tonnes wheat per tonne croissants	0.9	*Supplier interview*
kg CO_2e per tonne croissants	**45**	*Calculation: emissions per kWh × energy used per tonne wheat × tonnes wheat per tonne croissants*
(2b) **Flour transport**		
average distance (km)	100	*Supplier interview*
kg CO_2e per km	1	*Emission factor database; based on vehicle type*

Input		Amount	Source
	kg CO_2e per outbound journey	100	*Calculation: emissions per km × km per journey*
	% empty on inbound journey	100%	*Supplier interview*
	kg CO_2e per inbound journey	100	*Calculation: % empty on return × emissions per km × km per journey*
	kg CO_2e per total trip	200	*Calculation: emissions outbound + emissions inbound*
	tonnes flour per trip	20	*Supplier interview*
	kg CO_2e per tonne flour	10	*Calculation: emissions per total trip/tonnes flour per trip*
	tonnes flour per tonne croissants	0.7	*Supplier interview*
	kg CO_2e per tonne croissants	**7**	*Calculation: emissions per tonne flour × tonnes flour per tonne croissants*
(2c)	**Waste**		
	Transport		
	average distance (km)	20	*Supplier interview*
	kg CO_2e per km	2	*Emission factor database; based on vehicle type*
	kg CO_2e per outbound journey	40	*Calculation: emissions per km × km per journey*
	% empty on inbound journey	100%	*Supplier interview*
	kg CO_2e per inbound journey	40	*Calculation: % empty on return × emissions per km × km per journey*
	kg CO_2e per total trip	80	*Calculation: emissions outbound + emissions return*
	tonnes waste per trip	10	*Supplier interview*
	kg CO_2e per tonne waste	8	*Calculation: emissions per total trip/tonnes waste per trip*
	tonnes waste per tonne wheat	0.2	*Supplier interview*
	tonnes wheat per tonne croissants	0.9	*Supplier interview*
	kg CO_2e per tonne croissants	**1.4**	*Calculation: emissions per tonne waste × tonnes waste per tonne wheat × tonnes wheat per tonne croissants*
	Disposal		
	kg CO_2e per tonne waste	300	*Emission factor database; based on carbon content, likely decay rate and % escaped gas*
	tonnes waste per tonne wheat	0.2	*Supplier interview*

Input	Amount	Source
kg CO_2e per tonne wheat	60	*Calculation: emissions per tonne waste × tonnes waste per tonne wheat*
tonnes wheat per tonne croissants	0.9	*Supplier interview*
kg CO_2e per tonne croissants	**54**	*Calculation: emissions per tonne wheat × tonnes wheat per tonne croissants*

Other raw materials calculated as above

Other raw materials include butter, which due to its high emissions factor represents a higher proportion of the total footprint than that suggested by its mass (and thus a higher proportion of the overall product footprint than is suggested by these results).

Manufacturing

(3a) **Baking**

Input	Amount	Source
kWh gas used per tonne croissants	1000	*Supplier interview*
kg CO_2e per kWh gas	0.2	*Emission factor database; based on gas source*
kg CO_2e per tonne croissants	200	*Calculation: kWh gas used per tonne croissants × emissions per kWh gas*
kWh electricity used per tonne croissants	200	*Supplier interview*
kg CO_2e per kWh electricity	0.5	*Emission factor database; based on national grid*
kg CO_2e per tonne croissants	100	*Calculation: kWh electricity used per tonne croissants × emissions per kWh electricity*
total baking kg CO_2e per tonne croissants	**300**	*Calculation: kWh gas emissions per tonne croissants + kWh electricity emissions per tonne croissants*

(3b) **Packaging**

Input	Amount	Source
kg CO_2e per kg plastic film	2	*Emission factor database*
kg plastic film per 1,000 bags	20	*Supplier interview*
kg CO_2e per 1,000 bags	40	*Calculation: emissions per kg plastic film × kg plastic film per 1,000 bags*
tonnes croissants per 1,000 bags	1	*Internal data*
kg CO_2e per tonne croissants	**40**	*Calculation: emissions per 1,000 bags/tonnes croissants per 1,000 bags*

(3c) **Waste**

Transport

Input	Amount	Source
average distance (km)	50	*Supplier interview*

Input	Amount	Source
kg CO_2e per km	2	*Emission factor database; based on vehicle type*
kg CO_2e per outbound journey	100	*Calculation: emissions per km × km per journey*
% empty on inbound journey	100%	*Supplier interview*
kg CO_2e per inbound journey	100	*Calculation: % empty on return × emissions per km × km per journey*
kg CO_2e per total trip	200	*Calculation: emissions outbound + emissions inbound*
tonnes waste per trip	10	*Supplier interview*
kg CO_2e per tonne waste	20	*Calculation: emissions per total trip/tonnes waste per trip*
tonnes waste per tonne croissants	0.1	*Supplier interview*
kg CO_2e per tonne croissants	**2**	*Calculation: emissions per tonne waste × tonnes waste per tonne croissants*
Disposal		
kg CO_2e per tonne waste	300	*Emission factor database; based on carbon content, likely decay rate and % escaped gas*
tonnes waste per tonne croissants	0.1	*Supplier interview*
kg CO_2e per tonne croissants	**30**	*Calculation: emissions per tonne waste × tonnes waste per tonne croissants*
Distribution		
(4a) **Transport to distribution centre**		
average distance (km)	100	*Distributor interview*
kg CO_2e per km	2	*Emission factor database; based on vehicle type*
kg CO_2e per outbound journey	200	*Calculation: emissions per km × km per journey*
% empty on inbound journey	50%	*Distributor interview*
average distance (km)	100	*Distributor interview*
kg CO_2e per km	2	*Emission factor database; based on vehicle type*
kg CO_2e per inbound journey	100	*Calculation: % empty on inbound × emissions per km × km per journey*
kg CO_2e per total trip	300	*Calculation: emissions outbound + emissions inbound*
tonnes croissants per trip	10	*Distributor interview*

Input		Amount	Source
	kg CO_2e per tonne croissants	**30**	*Calculation: emissions per total trip/tonnes croissants per trip*
(4b)	**Storage**		
	direct energy used (kWh)	0	*Distributor interview*
	annual kWh used by storage site	1,000,000	*Distributor interview*
	portion attributed to 1 T croissants	0.0001%	*Distributor interview*
	indirect energy used per tonne croissants (kWh)	1	*Calculation: site energy × allocation per tonne croissants*
	kg CO_2e per kWh	0.5	*Distributor interview*
	kg CO_2e per tonne croissants	**0.5**	*Calculation: emissions per kWh × kWh per tonne croissants*
(4c)	**Transport to stores**		
	average distance (km)	20	*Distributor interview*
	kg CO_2e per km	1	*Emission factor; based on type of vehicle*
	kg CO_2e per outbound journey	20	*Calculation: emissions per km × km per journey*
	% empty on inbound journey	100%	*Distributor interview*
	average distance (km)	20	*Distributor interview*
	kg CO_2e per km	1	*Emission factor; based on type of vehicle*
	kg CO_2e per return journey	20	*Calculation: % empty on inbound × emissions per km × km per journey*
	kg CO_2e per total trip	40	*Calculation: emissions outbound + emissions return*
	tonnes croissants per trip	8	*Distributor interview*
	kg CO_2e per tonne croissants	**5**	*Calculation: emissions per total trip/tonnes croissants per trip*
(4d)	**Retail**		
	kg CO_2e per pallet per day	2	*Emission factor database; based on storage conditions (ambient)*
	average # of days in store	2	*Retailer interview*
	total kg CO_2e per pallet	4	*Calculation: emissions per pallet per day × # of days in store*
	No. of croissant packages per pallet	200	*Customer interview*
	kg CO_2e per package	0.02	*Calculation: emissions per pallet/croissant packages per pallet*

Input	Amount	Source
No. of packages per tonne croissants	1,000	*Retailer interview*
kg CO_2e per tonne croissants	**20**	*Calculation: emissions per package × packages per tonne croissants*
Consumer use		
(5a) **Storage (freezing)**		
kWh for freezing 1 package	0.05	*Industry association*
kg CO_2e per kWh	0.5	*Emission factor database; based on electricity grid*
kg CO_2e per frozen package	0.025	*Calculation: emissions per kWh × kWh per package frozen*
No. of packages per tonne croissants	1,000	*Internal data*
% of croissants that are frozen	20%	*Internal survey data*
kg CO_2e per tonne croissants	**5**	*Calculation: emissions per frozen package × packages per tonne croissants × % of croissants that are frozen*
(5b) **Consumption (heating)**		
kWh for heating 1 croissant	0.02	*Government data*
kg CO_2e per kWh	0.5	*Emission factor database; based on electricity grid*
kg CO_2e per heated croissant	0.01	*Calculation: emissions per kWh × kWh per croissant heated*
No. of croissants per package	12	*Internal data*
No. of packages per tonne croissants	1,000	*Internal data*
% of croissants that are heated	30%	*Internal survey data*
kg CO_2e per tonne croissants	**36**	*Calculation: emissions per heated croissant × croissants per package × packages per tonne croissants × % of croissants that are heated*
Disposal		
(6a) **Transport to landfill**		
average distance (km)	5	*Municipal waste interview*
kg CO_2e per km	2	*Emission factor database; based on vehicle type*
kg CO_2e per outbound journey	10	*Calculation: emissions per km × km per journey*

	Input	Amount	Source
	% empty on return journey	100%	*Municipal waste interview*
	average distance (km)	5	*Municipal waste interview*
	kg CO_2e per km	2	*Emission factor database; based on vehicle type*
	kg CO_2e per return journey	10	*Calculation: % empty on return × emissions per km × km per journey*
	kg CO_2e per total trip	20	*Calculation: emissions outbound + emissions return*
	tonnes waste per trip	10	*Municipal waste interview*
	kg CO_2e per tonne waste	2	*Calculation: emissions per total trip/tonnes waste per trip*
	tonnes waste per tonne croissants	0.2	*Internal survey data: 20% of croissants thrown away*
	kg CO_2e per tonne croissants	**0.4**	*Calculation: emissions per tonne waste × tonnes waste per tonne croissants*
(6b)	**Landfill decomposition**		
	Croissants		
	kg CO_2e per tonne croissant waste	800	*Emission factor database*
	tonnes waste per tonne croissants	0.2	*Internal survey data: 20% of croissants thrown away*
	kg CO_2e per tonne croissants	160	*Calculation: emissions per tonne croissant waste × tonnes waste per tonne croissants*
	Plastic bags		
	tonnes plastic waste per tonne croissants	0.05	*Internal data (assume 100% of bags thrown away)*
	kg CO_2e per tonne plastic waste	100	*Emission factor database*
	kg CO_2e per tonne croissants	5	*Calculation: emissions per tonne plastic waste × tonnes plastic waste per tonne croissants*
	kg CO_2e per tonne croissants	**165**	*Calculation: croissant waste emissions + plastic waste emissions*
	Total per tonne	**1,200**	
	Total per 12-croissant package	**1.2**	

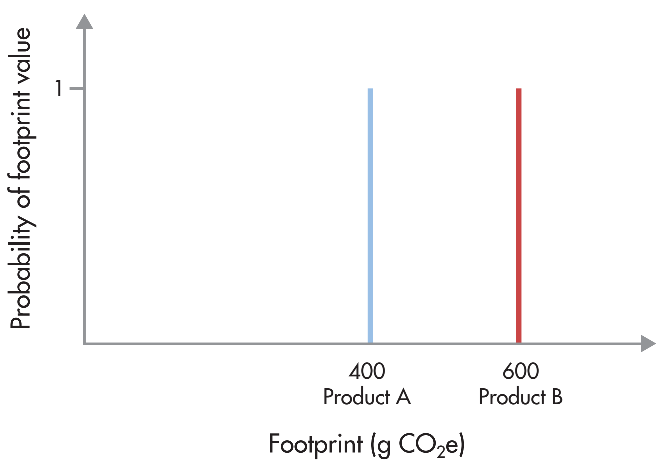
Appendix IV
Uncertainty analysis

With zero uncertainty, there is no variation in the carbon footprint assessments (illustrated below, left). In this ideal scenario, the two product footprints can be compared, and users of the footprint information can be confident their decisions are based on accurate data.

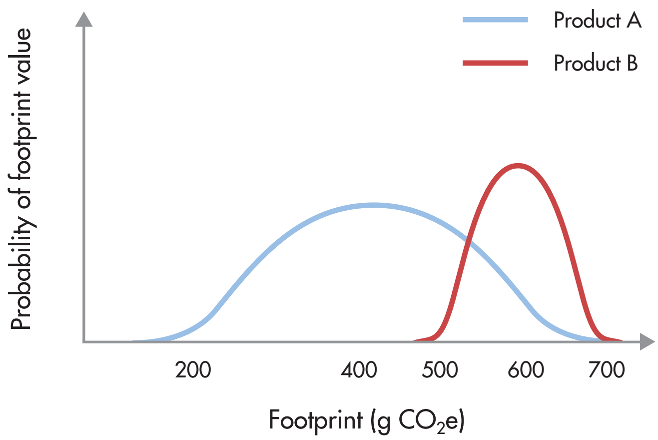
However, uncertainty creates challenges for comparisons and decision making as illustrated below, right.

Uncertainty in carbon footprinting comes from two sources: technical uncertainty and natural variability. Technical uncertainty is created by limited data quality, ineffective sampling, wrong assumptions, incomplete modelling and other flaws in the footprint calculation itself. These factors are analysed in the uncertainty calculation described overleaf. Natural variability is accounted for in the definition of a product carbon footprint as an average, or representative figure, so it does not need to be quantified.

Because the nature of a footprint calculation involves estimates and judgement, every model input has some degree of uncertainty associated with it. Each input has a probability distribution around the mean value, or the number used in the model. The distribution curves can take any shape, e.g. normal (as in the example below).



Zero uncertainty



Uncertainty in this example is the value along the x-axis greater or less than the products' footprint estimates of 400 and 600.

Product A has greater uncertainty than Product B.

Higher uncertainty in footprint result = lower confidence in comparisons

Uncertainty calculation

The recommended approach for calculating uncertainty is to perform a Monte Carlo analysis of the carbon footprint model created in Step 4. There are many software packages available for conducting a Monte Carlo analysis; alternatively some LCA packages have integrated Monte Carlo functionality. A Monte Carlo analysis involves three stages:

1. Define the probability density for each input by identifying: the distribution type (e.g. normal or lognormal); upper/lower bounds of the input value to reach 95% confidence; and correlation factors
2. Next, through a process of many repetitions, randomly vary each input value according to its distribution, and record the resulting new value of the output (carbon footprint)
3. Repeat the process for each input, thereby building up a probability density of the footprint result. This uncertainty resultt can then be reported as a '±%' or a range of values.

Defining the probability density of each model input is best performed during the data collection in Step 3. In some cases the model input probability density will already be established, such as the precision of an electricity meter or the uncertainty of an emission factor from a published study; in other cases the input's probability density must be determined by an expert, most likely the person who measured the input in the first place. Some secondary databases also include uncertainty information.

Using uncertainty

Uncertainty analysis produces data that can help in the following ways:

- To quantify the overall uncertainty of a carbon footprint (range and distribution of the carbon footprint itself), as described above
- By providing a sensitivity/contributory analysis: analysing uncertainty by life cycle stage or model input to identify relative 'hot spots', which have higher uncertainty than others

Glossary

Allocation
Partitioning the input or output flows of a process between the product system under study and one or more other product systems

Biogenic
Derived from biomass, but not fossilised or from fossil sources

Biomass
Material of biological origin excluding material embedded in geological formations or transformed to fossil

Boundary
Set of criteria specifying which unit processes are part of a product system (life cycle)

Business-to-business (B2B)
Provision of inputs, including products, to a third party that is not the end user

Business-to-consumer (B2C)
Provision of inputs, including products, to the end user

Capital goods
Goods, such as machinery, equipment and buildings, used in the life cycle of products

Carbon dioxide equivalent (CO_2e)
Unit for comparing the radiative forcing (global warming impact) of a greenhouse gas expressed in terms of the amount of carbon dioxide that would have an equivalent impact

Carbon footprint
The level of greenhouse gas emissions produced by a particular activity or entity

Carbon storage
Retaining carbon of biogenic or atmospheric origin in a form other than as an atmospheric gas

Combined heat and power (CHP)
Simultaneous generation in one process of useable thermal energy and electrical and/or mechanical energy

Co-products
Any of two or more products from the same unit process or product system [BS EN ISO 14044:2006, 3.10]

Data quality
Characteristics of data that relate to their ability to satisfy stated requirements

Downstream emissions
GHG emissions associated with processes that occur in the life cycle of a product subsequent to the processes owned or operated by the organization in question

Emission factor
Amount of greenhouse gases emitted, expressed as carbon dioxide equivalent and relative to a unit of activity (e.g. kg CO_2e per unit input).

NOTE Emission factor data is obtained from secondary data sources.

Emissions
Release to air and discharges to water and land that result in greenhouse gases entering the atmosphere

Functional unit
Quantified performance of a product for use as a reference unit

Greenhouse gases (GHGs)
Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds

NOTE GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluoro-carbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6)

Input
Product, material or energy flow that enters a unit process

Life cycle
Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to end of life, inclusive of any recycling or recovery activity

Life cycle assessment (LCA)
Compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle

Life cycle GHG emissions
Sum of GHG emissions resulting from all stages of the life cycle of a product and within the specified system boundaries of the product

Mass balance
Quantification of total materials flowing into and out of a process

Material contribution
Contribution of any one source of GHG emissions to a product of more than 1% of the anticipated life cycle GHG emissions associated with the product

NOTE A materiality threshold of 1% has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources.

Offsetting
Mechanism for claiming a reduction in GHG emissions associated with a process or product through the removal of, or preventing the release of, GHG emissions in a process unrelated to the life cycle of the product being assessed

Output
Product, material or energy that leaves a unit process

Primary activity data
Quantitative measurement of activity from a product's life cycle that, when multiplied by an emission factor, determines the GHG emissions arising from a process

NOTE Examples include the amount of energy used, material produced, service provided or area of land affected.

Product(s)
Any good(s) or service(s)

NOTE Services have tangible and intangible elements. Provision of a service can involve, for example, the following:

- *an activity performed on a consumer-supplied tangible product (e.g. automobile to be repaired);*
- *an activity performed on a consumer-supplied intangible product (e.g. the income statement needed to prepare a tax return);*
- *the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission);*
- *the creation of ambience for the consumer (e.g. in hotels and restaurants)*
- *software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.*

Product category
Group of products that can fulfil equivalent functions

Product category rules (PCRs)
Set of specific rules, requirements and guidelines for developing environmental declarations for one or more product categories according to BS EN ISO 14040:2006

Raw material
Primary or secondary material used to produce a product

Renewable energy
Energy from non-fossil energy sources: wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases

Secondary data
Data obtained from sources other than direct measurement of the processes included in the life cycle of the product

NOTE Secondary data is used when primary activity data is not available or it is impractical to obtain primary activity data. In some case, such as emission factors, secondary data may be preferred.

System boundary
Set of criteria specifying which unit processes are part of a product system (life cycle)

Upstream emissions
GHG emissions associated with processes that occur in the life cycle of a product prior to the processes owned or operated by the organization in question

Use phase
That part of the life cycle of a product that occurs between the transfer of the product to the consumer and the end of life of the product

Use profile
Criteria against which the GHG emissions arising from the use phase are determined

Useful energy
Energy that meets a demand by displacing an alternative source of energy

Waste
Materials, co-products, products or emissions which the holder discards or intends, or is required to, discard

PUBLICLY AVAILABLE SPECIFICATION

PAS 2050:2008

Specification for the assessment of the life cycle greenhouse gas emissions of goods and services

CARBON TRUST

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Contents

Foreword

This Publicly Available Specification (PAS) has been prepared by BSI to specify requirements for assessing the life cycle greenhouse gas emissions (GHG) of goods and services. The development of this PAS was co-sponsored by the Carbon Trust and the Department for Environment, Food and Rural Affairs (Defra).

It has been assumed in the preparation of this PAS that the execution of its provisions will be entrusted to a competent person or persons for whose use it has been produced.

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Technical author

Dr Graham Sinden

Organizations

- Carbon Trust
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PAS Steering Group

Professor Jim Skea (Chair)
UK Energy Research Centre

Dr Paul Jefferiss
Independent expert (and Carbon Trust Director)

Professor Roland Clift
University of Surrey

Professor Tim Jackson
University of Surrey

Terence Ilott
UK Department for Environment, Food and Rural Affairs

Mark Kenber
The Climate Group

Michael Roberts/Rhian Kelly
Confederation of British Industry

Stephen Reeson
UK Food and Drink Federation

Nick Monger-Godfrey
John Lewis plc.; Park Royal plc.

Nigel Dickie
Heinz UK & Ireland

Ken Double/Dan Staniaszek
Energy Saving Trust

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This PAS is not to be regarded as a British Standard, European Standard or International Standard. In the event that this PAS is put forward to form the basis of a full British Standard, European Standard or International Standard, it will be withdrawn.

Presentational conventions

The provisions of this PAS are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall". Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material, e.g. Notes, is presented in italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with this PAS does not in itself confer immunity from legal obligations.

0 Introduction

0.1 General information

Climate change has been identified as one of the greatest challenges facing nations, governments, business and citizens over future decades (IPCC 2007 [1]). Past and current actions, including the release of carbon dioxide (CO_2) and other greenhouse gases through human activities such as the burning of fossil fuels, emissions from chemical processes, and other sources of anthropogenic greenhouse gases, will have an effect on future global climate.

While greenhouse gas (GHG) emissions are often viewed at global, national, corporate or organizational levels, emissions within these groupings can arise from supply chains within business, between businesses, and between nations. The GHG emissions associated with goods and services reflect the impact of processes, materials and decisions occurring throughout the life cycle of the goods and services.

PAS 2050 has been developed in response to broad community and industry desire for a consistent method for assessing the life cycle GHG emissions of goods and services. Life cycle GHG emissions are the emissions that are released as part of the processes of creating, modifying, transporting, storing, using, providing, recycling or disposing of goods and services. PAS 2050 recognizes the potential for organizations to use this method to deliver improved understanding of the GHG emissions arising from their supply chains, and to provide a common basis for the comparison and communication of results arising from the use of PAS 2050. Although there is no requirement for communication or standardization of communication techniques in this specification, this PAS supports the assessment of life cycle GHG emissions of goods and services that can be later reported and communicated to stakeholders, including consumers. Where an organization implementing this PAS chooses to communicate specific result of the assessment of GHG emissions, it is required to make other information available as specified in this PAS.

0.2 Background and benefits

PAS 2050 builds on existing life cycle assessment methods established through BS EN ISO 14040 and BS EN ISO 14044 by specifying requirements for the assessment of the life cycle GHG emissions of goods and services. These requirements further clarify the implementation of the above standards in relation to the assessment of GHG emissions of goods and services, and establish additional principles and techniques that address essential aspects of GHG assessment, including:

a) business-to-business and business-to-consumer use of partial GHG assessment data in full GHG assessments of goods and services;
b) scope of greenhouse gases to be included;
c) criteria for global warming potential data;
d) treatment of emissions from land use change, and biogenic and fossil carbon sources;
e) treatment of the impact of carbon storage in products, and offsetting;
f) requirements for the treatment of GHG emissions arising from specific processes;
g) data requirements and accounting for emissions from renewable energy generation; and
h) claims of conformity.

This PAS is intended to benefit organizations, businesses and other stakeholders by providing a clear and consistent method for the assessment of the life cycle GHG emissions associated with goods and services. Specifically, this PAS provides the following benefits:

a) For organizations that supply goods and services, this PAS:
   - allows internal assessment of the existing life cycle GHG emissions of goods and services;
   - facilitates the evaluation of alternative product configurations, sourcing and manufacturing methods, raw material choices and supplier selection on the basis of the life cycle GHG emissions associated with goods and services;
   - provides a benchmark for ongoing programmes aimed at reducing GHG emissions;
   - allows for a comparison of goods or services using a common, recognized and standardized approach to life cycle GHG emissions assessment; and
   - supports reporting on corporate responsibility.

b) For consumers of goods and services, this PAS:
   - provides a common basis for reporting and communicating the results of life cycle GHG emissions assessments that supports comparison and uniformity of understanding; and
   - provides an opportunity for greater consumer understanding of life cycle GHG emissions when making purchasing decisions and using goods and services.

1 Scope

This PAS specifies requirements for the assessment of the life cycle GHG emissions of goods and services (collectively referred to as "products") based on key life cycle assessment techniques and principles. This PAS is applicable to organizations assessing the GHG emissions of products across their life cycle, and to organizations assessing the cradle-to-gate GHG emissions of products.

Requirements are specified for identifying the system boundary, the sources of GHG emissions associated with products that fall inside the system boundary, the data requirements for carrying out the analysis, and the calculation of the results.

This PAS addresses the single impact category of global warming, and does not assess other potential social, economic and environmental impacts arising from the provision of products, such as non-greenhouse gas emissions, acidification, eutrophication, toxicity, biodiversity, labour standards or other social, economic and environmental impacts that may be associated with the life cycle of products. The life cycle GHG emissions of products, calculated using this PAS, do not provide an indicator of the overall environmental impact of these products, such as may result from other types of life cycle assessment.

This PAS does not include product category-specific rules for goods and services; however, it is intended that selected product category-specific rules for goods and services, developed in accordance with BS ISO 14025, will be adopted where available, as specified in this PAS.

It is one of the intentions of this PAS to allow for the comparison of GHG emissions between products, and to enable the communication of this information. However, this PAS does not specify requirements for communication.

2 Normative references

The following referenced documents are indispensable for the application of this PAS. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 14021, *Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)*

BS EN ISO 14044:2006*, Environmental management – Life cycle assessment – Requirements and guidelines,* **Clause 4.3.4.3**

BS EN ISO/IEC 17050-1, *Conformity assessment – Supplier's declaration of conformity – Part 1: General requirements*

ISO/TS 14048:2002, *Environmental management – Life cycle assessment – Data documentation format,* **Clause 5.2.2**

IPCC 2006, *Guidelines for National Greenhouse Gas Inventories.* National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change

Note *Subsequent amendments to IPCC 2006 also apply.*

IPCC 2007, *Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp., **Chapter 2, Table 2.14**

Note *Subsequent amendments to IPCC 2007 also apply.*

3 Terms and definitions

For the purposes of this PAS the following terms and definitions apply.

3.1 allocation

partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems

[BS EN ISO 14044:2006, **3.17**]

3.2 anticipated life cycle greenhouse gas emissions

initial estimate of greenhouse gas (see **3.26** for a definition of greenhouse gases) emissions for a product (see **3.37** for a definition of product) that is calculated using secondary data (see **3.43** for a definition of secondary data) or a combination of primary (see **3.36** for a definition of primary activity data) and secondary data, for all processes used in the life cycle of the product

3.3 biogenic

derived from biomass, but not fossilized or from fossil sources (see **3.22** for a definition of fossil)

3.4 biomass

material of biological origin, excluding material embedded in geological formations or transformed to fossil

[Adapted from CEN/TR 14980:2004, **4.3**]

3.5 business-to-business

provision of inputs, including products, to another party that is not the end user

3.6 business-to-consumer

provision of inputs, including products, to the end user

3.7 capital goods

goods, such as machinery, equipment and buildings, used in the life cycle of products

3.8 carbon dioxide equivalent (CO_2e)

unit for comparing the radiative forcing of a GHG to carbon dioxide

[BS ISO 14064-1:2006, **2.19**]

Note 1 *The carbon dioxide equivalent value is calculated by multiplying the mass of a given GHG by its global warming potential (see **3.25** for a definition of global warming potential).*

Note 2 *Greenhouse gases, other than CO_2, are converted to their carbon dioxide equivalent value on the basis of their per unit radiative forcing using 100-year global warming potentials defined by the Intergovernmental Panel on Climate Change (IPCC).*

3.9 carbon sequestration

removal of carbon from the atmosphere

3.10 carbon storage

retaining carbon of biogenic or atmospheric origin in a form other than as an atmospheric gas

3.11 combined heat and power (CHP)

simultaneous generation in one process of useable thermal, electrical and/or mechanical energy

3.12 competent person

person with training, experience or knowledge and other qualities, and with access to the required tools, equipment and information, sufficient to enable them to carry out a defined task

3.13 consumable

ancillary input that is necessary for a process to occur but that does not form a tangible part of the product or co-products arising from the process

Note 1 *Consumables include lubricating oil, tools and other rapidly wearing inputs to a process. Consumables differ from capital goods in that they have an expected life of one year or less, or a need to replenish on a one year or less basis.*

Note 2 *Fuel and energy inputs to the life cycle of a product are not considered consumables.*

3.14 consumer

user of goods or services

3.15 co-product

any of two or more products from the same unit process or product system

[BS EN ISO14044:2006, **3.10**]

Note *Where two or more products can be produced from a unit process, they are considered co-products only where one cannot be produced without the other being produced.*

3.16 data quality

characteristics of data that relate to their ability to satisfy stated requirements

[BS EN ISO14044:2006, **3.19**]

3.17 downstream emissions

GHG emissions associated with processes that occur in the life cycle of a product subsequent to the processes owned or operated by the organization implementing this PAS

3.18 economic value

market value of a product, co-product or waste (see **3.50** for a definition of waste) at the point of production

3.19 emission factor

amount of greenhouse gases emitted, expressed as carbon dioxide equivalent and relative to a unit of activity

Note *For example, kgCO_2e per unit input. Emission factor data would be obtained from secondary data sources.*

3.20 emissions

release to air and discharges to water and land that result in GHGs entering the atmosphere

3.21 environmentally extended input–output (EEIO) analysis

method of estimating the GHG emissions (and other environmental impacts) arising from sectors within an economy through the analysis of economic flows

Note *Alternative terms, such as economic input-output life cycle assessment (EIO-LCA), input output based life cycle assessment (IOLCA) and hybrid life cycle assessment (HLCA) refer to different approaches to implementing EEIO analysis.*

3.22 fossil

derived from fossil fuel or another fossil source, including peat

[Adapted from IPCC 2006 Guidelines for National Greenhouse Gas Inventories, **Glossary**, see **Clause 2**]

3.23 functional unit

quantified performance of a product system for use as a reference unit

[BS EN ISO 14044:2006, **3.20**]

3.24 GHG emissions

release of GHGs to the atmosphere

3.25 global warming potential (GWP)

factor describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to an equivalent unit of carbon dioxide over a given period of time

[BS ISO 14064-1:2006, **2.18**]

Note *Carbon dioxide is assigned a GWP of 1, while the GWP of other gases is expressed relative to the GWP of carbon dioxide from fossil carbon sources.* ***Annex A*** *contains global warming potentials for a 100-year time period produced by the Intergovernmental Panel on Climate Change. Carbon dioxide arising from biogenic sources of carbon is assigned a GWP of zero in specific circumstances specified in this PAS.*

3.26 greenhouse gases (GHGs)

gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds

Note The GHGs included in this PAS are specified in Annex A.

3.27 input

product, material or energy flow that enters a unit process

[BS EN ISO 14040:2006, **3.21**]

3.28 intermediate product

output from a unit process that is an input to other unit processes involving further transformation within the system

3.29 International Reference Life Cycle Data System (ILCD)

series of technical guidance documents with quality, method, nomenclature, documentation and review requirements for quality ensured life cycle data and studies, coordinated for Europe by the European Commission's Joint Research Centre [2]

3.30 life cycle

consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to end of life, inclusive of any recycling or recovery activity

[Adapted from BS EN ISO 14040:2006, **3.1**]

3.31 life cycle assessment (LCA)

compilation and evaluation of inputs, outputs and potential environmental impacts of a product system throughout its life cycle

[BS EN ISO 14040:2006, **3.2**]

3.32 life cycle GHG emissions

sum of greenhouse gas emissions resulting from all stages of the life cycle of a product and within the specified system boundaries of the product

Note This includes all emissions that are released as part of the processes within the boundary of the life cycle of the product, including obtaining, creating, modifying, transporting, storing, operating, using and end of life disposal of the product.

3.33 material contribution

contribution from any one source of GHG emissions of more than 1% of the anticipated life cycle GHG emissions associated with a product

Note A materiality threshold of 1% has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources.

3.34 offsetting

mechanism for claiming a reduction in GHG emissions associated with a process or product through the removal of, or preventing the release of, GHG emissions in a process unrelated to the life cycle of the product being assessed

Note An example is the purchase of Certified Emission Reductions generated by Clean Development Mechanism projects under the Kyoto Protocol [3].

3.35 output

product, material or energy that leaves a unit process

[Adapted from BS EN ISO 14044:2006, **3.25**]

Note Materials may include raw materials, intermediate products, co-products, products and emissions.

3.36 primary activity data

quantitative measurement of activity from a product's life cycle that, when multiplied by an emission factor, determines the GHG emissions arising from a process

Note 1 Examples of primary activity data include the amount of energy used, material produced, service provided or area of land affected.

Note 2 Primary activity data sources are typically preferable to secondary data sources as the data will reflect the specific nature/efficiency of the process, and the GHG emissions associated with the process.

Note 3 Primary activity data does not include emission factors.

3.37 product

any good or service

Note Services have tangible and intangible elements. The provision of a service can involve, for example, the following:

a) an activity performed on a consumer-supplied tangible product (e.g. automobile to be repaired);

b) an activity performed on a consumer-supplied intangible product (e.g. the income statement needed to prepare a tax return);

c) the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission);

d) the creation of ambience for the consumer (e.g. in hotels and restaurants);

e) software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.

[Adapted from BS ISO 14040:2006, **3.9**]

3.38 product category

group of products that can fulfil equivalent functions

[BS ISO 14025:2006, **3.12**]

3.39 product category rules (PCRs)

set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories

[BS ISO 14025:2006, **3.5**]

3.40 product system

collection of unit processes with elementary and product flows, performing one or more defined functions, that models the life cycle of a product

[BS EN ISO 14040:2006, **3.28**]

3.41 raw material

primary or secondary material that is used to produce a product

Note Secondary material includes recycled material.

[BS EN ISO 14040:2006, **3.15**]

3.42 renewable energy

energy from non-fossil energy sources: wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases

[Adapted from Directive 2001/77/EC, **Article 2** [4]]

3.43 secondary data

data obtained from sources other than direct measurement of the processes included in the life cycle of the product

Note Secondary data is used when primary activity data is not available or it is impractical to obtain primary activity data.

3.44 system boundary

set of criteria specifying which unit processes are part of a product system

[BS EN ISO 14040:2006, **3.32**]

3.45 unit process

smallest portion of a life cycle for which data are analysed when performing a life cycle assessment

3.46 upstream emissions

GHG emissions associated with processes that occur in the life cycle of a product prior to the processes owned, operated or controlled by the organization implementing this PAS

3.47 use phase

that part of the life cycle of a product that occurs between the transfer of the product to the consumer and the end of life of the product

Note For services, the use phase includes the provision of the service.

3.48 use profile

criteria against which the GHG emissions arising from the use phase are determined

3.49 useful energy

energy that meets a demand by displacing another source of energy

Note For example, where heat production from a CHP unit is utilized to meet a demand for heat that was previously met by another form of energy, or meets a new demand for heat that would have required additional energy input, then the heat from the CHP is providing useful energy. Had the heat from the CHP not met a demand, but instead been dissipated (e.g. vented to the atmosphere), the heat would not be considered useful energy (in which case no emissions from the CHP would be assigned to the heat production).

3.50 waste

materials, co-products, products or emissions which the holder discards or intends, or is required to, discard

4 Principles and implementation

4.1 General requirements

Assessment of the GHG emissions of products shall be carried out using LCA techniques. Unless otherwise indicated, the assessment of the life cycle GHG emissions of products shall be made using the attributional approach, i.e. by describing the inputs and their associated emissions attributed to the delivery of a specified amount of the product functional unit.

Note *LCA techniques are specified in BS EN ISO 14040 and BS EN ISO 14044. Where the approach described in these standards is incompatible with the requirements of this PAS, the requirements of this PAS take precedence.*

4.2 Principles

Organizations claiming conformity with this PAS shall ensure that the assessment of the life cycle GHG emissions of a product is complete, and shall be able to demonstrate that the following principles have been taken into consideration when carrying out the assessment:

a) **Relevance:** select GHG sources, carbon storage, data and methods appropriate to the assessment of the GHG emissions arising from products;

b) **Completeness:** include all specified GHG emissions and storage that provide a material contribution to the assessment of GHG emissions arising from products;

c) **Consistency:** enable meaningful comparisons in GHG-related information;

d) **Accuracy:** reduce bias and uncertainties as far as is practical;

e) **Transparency:** where the results of life cycle GHG emissions assessment carried out in accordance with this PAS are communicated to a third party, the organization communicating these results shall disclose GHG emissions-related information sufficient to allow such third parties to make associated decisions with confidence.

Note *The above principles are adapted from BS ISO14064-1:2006,* ***Clause 3****.*

4.3 Product differentiation

The GHG emissions assessment specified in this PAS shall apply to the product for which the assessment is conducted. Where similar products are being assessed, a separate assessment shall be carried out for each product that is provided to a third party, unless the similar products are provided in such a manner as to make them indistinguishable from each other by the third party.

4.4 Supporting data

Data supporting the assessment of life cycle GHG emissions, including but not limited to, product and process boundaries, materials, emission factors and emissions, and other data as required in this PAS, shall be documented and a record maintained in a format suitable for analysis and verification for the greater of either five years or the life expectancy of the product.

Note *Data records should be made available to support claims of conformity no matter what form of verification is chosen. The basis of support for self verification of conformity is no different from that required for other party verification or independent third party certification (see* ***Clause 10****).*

4.5 Implementation of this PAS

The assessment of life cycle GHG emissions for products shall be carried out as either:

a) a business-to-consumer assessment, which includes the emissions arising from the full life cycle of the product; or

b) a business-to-business assessment, which includes the GHG emissions released up to and including the point where the input arrives at a new organization (including all upstream emissions).

Note 1 *The above two approaches are respectively referred to as "cradle-to-grave" approach (see BS EN ISO 14044) and "cradle-to-gate" approach (see BS EN ISO 14040).*

Note 2 *See* ***6.2*** *for the assessment of the emissions arising from part of the life cycle of the product for business-to-business assessment purposes.*

5 Emission sources, offsetting and unit of analysis

5.1 Scope of GHG emissions

The assessment of life cycle GHG emissions shall include the gasses listed in **Annex A**.

5.1.1 Global warming potential (GWP)

GHG emissions shall be measured by mass and shall be converted into CO_2e emissions using the latest IPCC 100-year global warming potential (GWP) coefficients (**Annex A**), except where otherwise specified in this PAS.

Note For example, methane has a GWP coefficient of 25, and 1 kg of methane is equivalent to 25 kg CO_2e in terms of its GWP.

5.1.2 Aircraft emissions

No multiplier or other correction shall be applied to the GWP of emissions arising from aircraft transport.

Note The application of a multiplier for aircraft emissions will be given further consideration in future revisions of this PAS, once there is scientific consensus regarding the approach to be taken.

5.2 Time period for assessment of GHG emissions

The assessment of the impact of GHG emissions arising from the life cycle of products shall be the CO_2e impact of the GHG emissions over the 100-year period following the formation of the product (i.e. the 100-year assessment period).

Emissions arising from all life cycle phases of the product, except the use phase (see **6.4.8**) and the final disposal phase (see **6.4.9**), shall be treated as a single release of emissions at the beginning of the 100-year assessment period.

Where all GHG emissions arising from the use phase or from final disposal occur within one year following the formation of the product, those emissions shall be treated as a single release of emissions at the beginning of the 100-year assessment period. Where emissions arising from the use phase or from final disposal occur over more than one year, a factor shall be applied to represent the weighted average time the emissions are present in the atmosphere during the 100-year assessment period (for use phase emissions see **6.4.8.1** and **Annex B**; for emissions from final disposal see **6.4.9.1** and **Annex B**).

Note Examples of use phase and final disposal emissions occurring over more than one year include emissions from the use phase of a long-life light bulb, or emissions arising from final disposal of the product at a later stage (e.g. from landfill or from incineration after the first year).

The impact of carbon storage in products shall be as described in **5.4**.

5.3 Sources of GHG emissions

The assessment shall include GHG emissions arising from processes, inputs and outputs in the life cycle of a product, including but not limited to:

a) energy use (including energy sources, such as electricity, that were themselves created using processes that have GHG emissions associated with them);
b) combustion processes;
c) chemical reactions;
d) refrigerant loss and other fugitive gases;
e) operations;
f) service provision and delivery;
g) land use change;
h) livestock and other agricultural processes;
i) waste.

*Note See **6.2** for the assessment of the emissions arising from part of the life cycle of the product for business-to-business assessment purposes, and **Clause 7** for data sources.*

5.3.1 CO_2 emissions originating from fossil and biogenic carbon sources

CO_2 emissions arising from fossil carbon sources shall be included in the calculation of GHG emissions from the life cycle of products.

CO_2 emissions arising from biogenic carbon sources shall be excluded from the calculation of GHG emissions from the life cycle of products, except where the CO_2 arises from land use change (see **5.5**).

5.3.2 Non-CO_2 emissions originating from fossil and biogenic carbon sources

Non-CO_2 emissions arising from both fossil and biogenic carbon sources shall be included in the calculation of GHG emissions from the life cycle of products. The GWP factor for non-CO_2 emissions originating from biogenic carbon sources shall be corrected to take into account the sequestration of the CO_2 that gave rise to the biogenic carbon source.

5.4 Carbon storage in products

Where atmospheric CO_2 is taken up by a product, and that product is not a living organism, the impact of this carbon storage over the 100-year assessment period shall be included in the assessment of the life cycle GHG emissions of the product, subject to the conditions described in **5.4.3** and **5.4.4**.

Where carbon of biogenic origin forms part of a product, the impact of this carbon storage over the 100-year assessment period shall be included in the assessment of the life cycle GHG emissions of the product, subject to the conditions described in **5.4.1** to **5.4.4**.

Note *Carbon storage may arise where biogenic carbon forms part or all of a product (e.g. wood fibre in a table), or where atmospheric carbon is taken up by a product over its life cycle (e.g. cement).*

5.4.1 Eligible products for the assessment of stored biogenic carbon

For products containing carbon of biogenic origin, the impact of carbon storage shall be included in the assessment of the life cycle GHG emissions of the product where:

a) the product is not for human or animal ingestion (i.e. not a food or feed);

b) more than 50% of the mass of carbon of biogenic origin in the product remains removed from the atmosphere for one year or more following production of the product; and

c) the material containing the biogenic carbon is obtained from either:

  i) an input that is the result of human actions that cause its formation for the purpose of using it as an input to a process (e.g. managed forestry); or

  ii) a recycled or re-use input that contains material that is demonstrated to comply with point (i) above.

Note 1 *The purpose of a) is to limit the need to carry out a carbon storage assessment to non-food items; the purpose of b) is to ensure that this provision is not required to be implemented for products of biogenic origin that have a short life span; the purpose of c) is to ensure that the storage of biogenic carbon in products is additional to that*

which would have occurred without human intervention.

Note 2 Storage of biogenic carbon in products will vary depending on the type of product, the mean life span of the product, its rate of recycling and its disposal route (e.g. landfill, incineration).

Note 3 While forest management activities may result in additional carbon storage in managed forests through the retention of forest biomass, this potential source of storage is not included in the scope of this PAS.

5.4.2 Treatment of stored biogenic carbon

5.4.2.1 Treatment of biogenic carbon at disposal

Where products are disposed of in a manner that prevents some or all of the biogenic carbon being re-emitted to the atmosphere within the 100-year assessment period, the portion of biogenic carbon not re-emitted to the atmosphere shall be treated as stored carbon for the purpose of this PAS (see **5.4.3** for the assessment method).

5.4.2.2 Treatment of biogenic carbon in recycled material

Where a product is recycled within the 100-year assessment period, the impact of carbon storage shall be determined for the product giving rise to the recycled material up to the point at which recycling occurred.

Note A product using recycled biogenic material receives a storage benefit from the carbon stored in the recycled material in accordance with this section.

5.4.2.3 Treatment of CO_2 emissions arising from products containing biogenic carbon

Where a product containing carbon of biogenic origin degrades and releases CO_2 to the atmosphere, the CO_2 emissions arising from the biogenic carbon shall not be included in the assessment of emissions associated with the product.

*Note CO_2 emissions from products containing biogenic carbon are included in the assessment of the life cycle GHG emissions via the calculation of the weighted average carbon stored over the 100-year assessment period (see **5.4.3**), and do not need to be included here.*

5.4.2.4 Treatment of non-CO_2 GHG emissions from products containing biogenic carbon

Non-CO_2 GHG emissions arising from products containing carbon of biogenic origin over the 100-year assessment period shall form part of the life cycle emissions of the product being assessed. Where non-CO_2 GHG emissions are captured and used for energy recovery, the treatment of such emissions shall be in accordance with **8.2.3**.

Note Non-CO_2 emissions, such as CH_4, may arise through the decomposition of the product in any form or location, such as in landfill.

5.4.3 Calculation of the CO_2 impact of stored carbon

5.4.3.1 Weighted average of stored biogenic carbon and atmospheric CO_2 taken up by products

The impact of carbon storage shall be determined from the weighted average of the biogenic carbon (measured as CO_2) in a product, or atmospheric CO_2 taken up by a product, and not re-emitted to the atmosphere over the 100-year assessment period. The method for calculating the weighted average carbon storage impact shall be that given in **Annex C**.

5.4.3.2 Inclusion of the GHG impact of stored carbon

The weighted average carbon storage impact calculated in accordance with **5.4.3.1** shall be included as a negative CO_2e value in the assessment of GHG emissions arising from the life cycle of the product.

5.4.4 Recording the basis of the carbon storage assessment

Where the assessment of the life cycle GHG emissions of a product includes the impact of stored carbon, the data sources from which the impact of stored carbon was calculated, together with the carbon storage profile of the product over the 100-year assessment period, shall be recorded and retained (see **4.4**).

5.5 Inclusion and treatment of land use change

The GHG emissions arising from direct land use change shall be assessed for any input to the life cycle of a product originating from agricultural activities, and the GHG emissions arising from the direct land use change shall be included in the assessment of GHG emissions of the product.

The GHG emissions occurring as a result of direct land use change shall be assessed in accordance with the relevant sections of the IPCC Guidelines for National Greenhouse Gas Inventories (see **Clause 2**). The assessment of the impact of land use change shall include all direct land use change occurring on or after 1 January 1990. The total GHG emissions arising from direct land use change shall be included in the GHG emissions of products arising from this land. One-twentieth (5%) of the total emissions arising from the land use change shall be included in the GHG emissions of these products in each year over the 20 years following the change in land use.

Note 1 Where it can be demonstrated that the land use change occurred more than 20 years prior to the assessment being carried out in accordance with this PAS, no emissions from land use change should be included in the assessment as all emissions resulting from the land use change would be assumed to have occurred prior to the application of the PAS.

Note 2 Direct land use change refers to the conversion of non-agricultural land to agricultural land as a consequence of producing an agricultural product or input to a product on that land. Indirect land use change refers to the conversion of non-agricultural land to agricultural land as a consequence of changes in agricultural practice elsewhere.

Note 3 While GHG emissions also arise from indirect land use change, the methods and data requirements for calculating these emissions are not fully developed. Therefore, the assessment of emissions arising from indirect land use change is not included in this PAS. The inclusion of indirect land use change will be considered in future revisions of this PAS.

Note 4 It is assumed that prior to the land use change taking place the net GHG emissions arising from the land were zero.

5.5.1 Limited traceability of agricultural products

The GHG emissions from land use change for selected countries, by previous and current land use, shall be as shown in **Annex E**. The following hierarchy shall apply when determining the GHG emissions arising from land use change occurring after 1 January 1990:

1. Where the country of production of the agricultural crop is known and the previous land use is known, the GHG emissions arising from land use change shall be those emissions resulting from the change in land use from the previous land use to the current land use in that country;
2. Where the country of production of the agricultural crop is known, but the former land use is not known, the GHG emissions arising from land use change shall be the highest potential emissions arising from land use change in that country;
3. Where the country of production of the agricultural crop is not known, the GHG emissions arising from land use change shall be the highest potential emissions arising from land use change for all countries (i.e. it shall be assumed that GHG emissions associated with land use change are equivalent to those emissions arising from the conversion of forest land to annual cropland in Malaysia).

Note By requiring worst-in-class data where the land use change impact of an input cannot be determined, an incentive is provided to report the origin of agricultural products. This approach is adopted in preference to an approach of using average data in cases of limited *traceability of agricultural products, as an average approach would encourage poor reporting in areas of high land use change impact.*

5.5.2 Limited knowledge of the timing of land use change

Where the timing of land use change cannot be demonstrated to be prior to 1 January 1990, it shall be assumed that the land use change occurred on 1 January of either:

a) the earliest year in which it can be demonstrated that the land use change had occurred; or

b) on 1 January of the year in which the assessment of GHG emissions is being carried out.

5.5.3 Recording the type and timing of land use change

Data sources, location and timing of land use change associated with inputs to products shall be recorded and retained (see **4.4**) by the organization implementing this PAS.

Note Knowledge of the prior land use can be demonstrated using a number of sources of information, such as satellite imagery and land survey data. Where records are not available, local knowledge of prior land use can be used.

5.6 Treatment of soil carbon change in existing agricultural systems

Changes in the carbon content of soils, either emissions or sequestration, other than those arising from direct land use change (see **5.5**) shall be excluded from the assessment of GHG emissions under this PAS.

Note 1 The above requirement refers to changes such as tilling techniques, crop types and other management actions taken in relation to agricultural land. It does not refer to the impact of land use change on carbon emissions which is included in ***5.5****.*

Note 2 While it is recognized that soils play an important part in the carbon cycle, both as a source and sink for carbon, there is considerable uncertainty regarding the impact of different techniques in agricultural systems. For this reason, emissions and sequestration arising from changes in soil carbon are outside the scope of this PAS. Inclusion of carbon storage in soils will be considered further in future revisions of this PAS.

5.7 Offsetting

GHG emissions offset mechanisms, including but not limited to, voluntary offset schemes or nationally or internationally recognized offset mechanisms, shall not be used at any point in the life cycle of the product in order to claim reduction in the emissions associated with the product.

Note It is the intention that this PAS reflects the GHG intensity of the production process prior to the implementation of external measures to offset GHG emissions. The use of an energy source that results in lower GHG emissions to the atmosphere and therefore achieves a lower emission factor, such as renewable electricity (see ***7.9.3****) or conventional thermal generation with carbon capture and storage, is not a form of offsetting.*

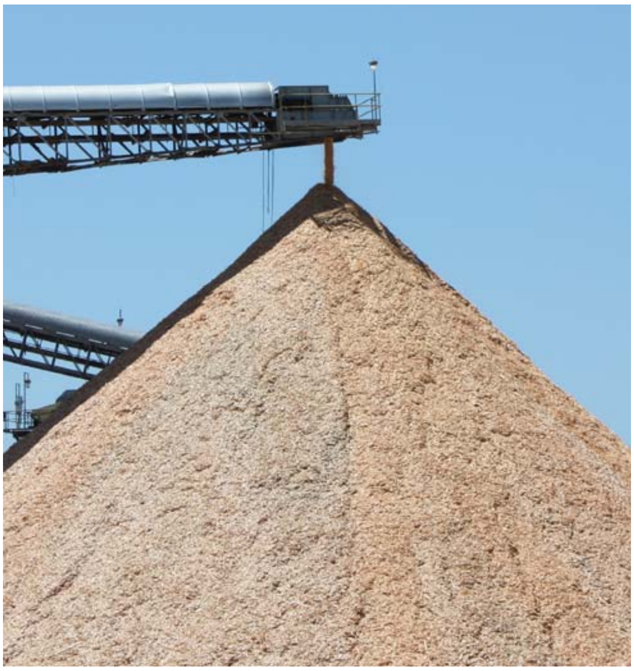
5.8 Unit of analysis

Assessment of the GHG emissions arising from the life cycle of products shall be carried out in a manner that allows the mass of CO_2e to be reported per functional unit for the product. The functional unit shall be reported to two significant figures.

Where a product is commonly available on a variable unit size basis, the calculation of GHG emissions shall be proportional to the unit size (e.g. per kilogram or per litre of goods sold, or per month or year of a service provided).

Note 1 For services the appropriate reporting unit may be established on a time (e.g. annual emissions associated with an internet service) or event basis (e.g. per night emissions associated with a hotel stay).

Note 2 The functional unit may differ according to the purpose of the assessment activity. For example, the functional unit for internal organizational reporting may differ from the functional unit communicated to consumers.



6 System boundary

6.1 Establishing the system boundary

Where a relevant Product Category Rule (PCR) developed in accordance with BS ISO 14025 exists for the product being considered, and the system boundary in the PCR does not conflict with the system boundary established in this clause, the boundary conditions specified in the PCR shall form the system boundary for the product.

Where a PCR developed in accordance with BS ISO14025 does not exist for the product being considered, the system boundary shall be clearly defined for each product and its underlying processes in accordance with **6.4**.

*Note 1 Consideration should be given to the material contribution that different processes within the system boundary will make to the total GHG emissions of a product (see **6.3**).*

Note 2 A list of existing PCRs can be found at www.environdec.com.

6.2 Partial GHG emission information for business-to-business assessment

The system boundary for the assessment of GHG emissions for an input that is made available or used in a business-to-business manner shall include all emissions that have occurred up to, and including, the point where the input arrives at a new organization (including all upstream emissions). Downstream emissions shall be excluded from the system boundary GHG emissions assessments carried out for business-to-business assessments.

Note The purpose of partial GHG emission assessment is to facilitate the provision of consistent GHG emission information within the supply chain for products, and to simplify the implementation of this PAS. This cradle-to-gate perspective of the supply chain allows incremental addition of GHG emissions at different stages of the supply until the product is provided to the consumer (where the assessment of GHG emissions includes the emissions arising from the entire life cycle).

6.2.1 Use of partial GHG emissions assessment information

Partial GHG emissions assessment information shall not be disclosed to consumers as representing a full assessment of the life cycle GHG emissions of a product.

Note 1 Partial GHG emission assessment information should be disclosed to other organizations that may use the product for which the partial GHG emission assessment has been carried out as an input to a process, where this process is not the use phase of the product or downstream of the use phase of the product.

Note 2 For example, the assessment of the GHG emissions associated with the production of flour that is subsequently supplied to a bakery would not include emissions arising from subsequent processes where the flour was provided to a subsequent business. However, a bakery supplying bread to consumers would assess the complete life cycle GHG emissions of the product.

6.2.2 Communication of partial GHG emissions assessment information

Where data arising from a partial GHG emissions assessment are communicated to a third party, the data shall conform to **5.2.2** of ISO/TS 14048 and the scope of emissions sources included within the partial GHG emissions assessment shall also be communicated to the third party.

6.3 Material contribution and threshold

Calculations carried out in accordance with this PAS shall include all emissions within the system boundary that have the potential to make a material contribution to the life cycle GHG emissions of the product.

Note A preliminary assessment of the sources of GHG emissions in the life cycle of a product may be undertaken using secondary data or through an EEIO approach. This preliminary assessment could provide an overview of the key sources of GHG emissions within the life cycle of the product and identify major contributors to the GHG emissions assessment.

For GHG emissions arising from the life cycle of a product, except those from the use phase, the assessment of GHG emissions shall include:

a) all sources of emissions anticipated to make a material contribution to the life cycle GHG emissions of the functional unit;
b) at least 95% of the anticipated life cycle GHG emissions of the functional unit; and
c) Where a single source of GHG emissions accounts for more than 50% of the potential life cycle GHG emissions of a product, the 95% threshold rule shall apply to the remaining GHG emissions associated with the anticipated life cycle GHG emissions of the product.

For GHG emissions arising from the use phase of a product, the assessment of GHG emissions shall include:

a) all sources of emissions having the potential to make a material contribution to the emissions of the use phase;
b) at least 95% of the potential life cycle emissions of the use phase.

Where less than 100% of the anticipated life cycle GHG emissions have been determined, the assessed emissions shall be scaled up to represent 100% of the GHG emissions associated with the functional unit in accordance with **Clause 9**.

6.4 System boundary

The following rules shall define the system boundary for the assessment of the life cycle GHG emissions of products.

Note While the system boundary is defined by the following rules, not all products will have processes or emissions arising from each of the categories.

6.4.1 Raw materials

The GHG emissions resulting from all processes used in the transformation of raw material shall be included in the assessment, including all sources of energy consumption or direct GHG emissions.

*Note 1 GHG emissions from raw materials include, but are not limited to: GHG emissions from mining or extracting raw materials (solids, liquids and gases such as iron, oil and natural gas), including emissions from machinery, consumables as well as exploration and development; waste generated at each stage of the extraction and pre-processing of raw materials (see also **6.4.3**).*

Note 2 Agricultural emissions include, for example, the GHG emissions from farming, fishing and forestry, including emissions from fertilizers (e.g. N_2O emissions arising from the application of nitrogen fertilizer and emissions arising from the production of the fertilizer); emissions from direct land use change and energy intensive atmospheric growing conditions (e.g. heated greenhouse); emissions from crops (e.g. methane from rice cultivation) and livestock (e.g. methane from cattle).

Note 3 Raw materials have zero GHG emissions associated with them when they have not been through any external process transformation, e.g. iron ore before it has been extracted.

6.4.2 Energy

The GHG emissions associated with the provision and use of energy in the life cycle of the product shall be included in the emissions arising from the energy supply system.

Note Emissions from energy include the emissions arising from the life cycle of the energy. This includes emissions at the point of consumption of the energy (e.g. emissions from the burning of coal and gas) and emissions arising from the provision of the energy, including the generation of electricity and heat, and emissions from transport fuels; upstream emissions (e.g. the mining and transport of fuel to the electricity generator or other combustion plant); downstream emissions (e.g. the treatment of waste arising from the operation of nuclear electricity generators); and the growing and processing of biomass for use as a fuel.

6.4.3 Capital goods

The GHG emissions arising from the production of capital goods used in the life cycle of the product shall be excluded from the assessment of the GHG emissions of the life cycle of the product.

Note The treatment of emissions arising from capital goods will be considered further in future revisions of this PAS.

6.4.4 Manufacturing and service provision

The GHG emissions arising from manufacturing and service provision that occur as part of the life cycle of the product, including emissions associated with the use of consumables, shall be included in the assessment of the GHG emissions of the life cycle of the product.

Where a process is used for prototyping a new product, the emissions associated with the prototyping activities shall be allocated to the resulting product(s) and co-product(s) of the process.

6.4.5 Operation of premises

The GHG emissions arising from the operation of premises, including emissions from factories, warehouses, central supply centres, offices, retail outlets, etc., shall be included in the assessment of the GHG emissions of the life cycle of the product.

Note Operation includes the lighting, heating, cooling, ventilation, humidity control and other environmental controls over the premises. An appropriate approach for the division of emissions arising from the operation of, for example, warehouses, would be to use the residence time and volume of space occupied by the product as a basis for the division.

6.4.6 Transport

The GHG emissions arising from road, air, water, rail or other transport methods that form part of the life cycle of the product shall be included in the assessment of the GHG emissions of the life cycle of the product.

*Note 1 Emissions associated with environmental control requirements during transport (e.g. refrigerated transport) are included in **6.4.7**.*

Note 2 GHG emissions from transport include the emissions associated with transporting fuels (e.g. emissions arising from the operation of pipelines, transmission networks and other fuel transport activities).

Note 3 GHG emissions from transport include the emissions arising from transport associated with individual processes, such as the movement of inputs, products and co-products within a factory (e.g. by conveyor belt or other localized transport methods).

Note 4 Where products are distributed to different points of sale (i.e. different locations within a country), emissions associated with transport will vary from store to store due to different transport requirements. Where this occurs, organizations should calculate the average release of GHGs associated with transporting the product based on the average distribution of the product within each country, unless more specific data is available. Where the same product is sold in identical form in multiple countries, country-specific data could be used, or the average could be weighted by the amount of product sold in each country.

6.4.7 Storage

The GHG emissions arising from storage shall be included in the assessment of the life cycle GHG emissions of the product, including:

a) storage of inputs, including raw materials, at any point in the product life cycle;

b) environmental controls (e.g. cooling, heating, humidity control and other controls) related to a product at any point in the product life cycle (see **6.4.5** for the operation, including environmental control, of factories in which products may be stored);

c) storage of products in the use phase (see **6.4.8**);

d) storage prior to re-use or recycling activities (see **8.5**).

*Note GHG emissions identified under **6.4.7** relate to storage activities not already covered by **6.4.5**.*

6.4.8 Use phase

The GHG emissions arising from the use of goods or the provision of services shall be included in the assessment of the life cycle GHG emissions of products, subject to the provisions of **6.2** for business-to-business assessments. The emission factor associated with energy used in the use phase of products shall be determined in accordance with **6.4.2**.

Note The calculation of GHG emissions from energy use is based on country specific annual average emission factor for energy, unless it can be demonstrated that a different emission factor is more representative of the energy use characteristics of the product. For example, where the use phase includes the consumption of electricity by the consumer in relation to the product being assessed, the country specific annual average emission factor of the electricity would be used; where an identical product is supplied to multiple international markets, the emission factor for the energy used by the product in the use phase would be the average emission factor of the countries where the product is supplied, weighted by the proportion of the product supplied in the different countries.

6.4.8.1 Time period for use phase GHG emissions

All emissions arising from the use phase of the product over the 100-year assessment period shall be included. Where the use phase of a product results in the release of GHG emissions over time, the total emissions projected to occur over the 100-year assessment period shall be included in the assessment of GHG emissions of that product. A factor shall be applied to these emissions to reflect the weighted average time these emissions are present in the atmosphere during the 100-year assessment period (see **Annex B**).

6.4.8.2 Basis of the use profile

Determination of the use profile for the use phase of products shall be based on a hierarchy of boundary definitions. The order of preference for the basis of the use profile shall be:

1. Product Category Rules (PCRs) that specify a use phase for the product being assessed;
2. published international standards that specify a use phase for the product being assessed;
3. published national guidelines that specify a use phase for the product being assessed;
4. published industry guidelines that specify a use phase for the product being assessed.

Where no method for determining the use phase of products has been established in accordance with points 1-4 above, the approach taken in determining the use phase of products shall be established by the organization carrying out the assessment of GHG emissions for the product.

Where emissions arise from energy use in the use phase, the use profile shall record the emission factor of each energy type used by the product and the source of the emission factor. Where the emission factor is not an annual average emission factor for a single country, the determination of the emission factor shall be recorded and retained (see **4.4**).

Note 1 The manufacturer's recommended method for achieving the functional unit (e.g. cooking by oven at a specified temperature for a specified time) may provide a basis for determining the use phase of a product. However, actual usage patterns may differ from those recommended, and the use profile should seek to represent the actual usage pattern.

Note 2 It is anticipated that, over time, PCRs and other published material will increasingly form the basis of use phase emissions assessments.

6.4.8.3 Recording the basis of use phase calculations for products

The basis on which the use phase for products is assessed shall be recorded and retained (see **4.4**).

6.4.8.4 Impact of the product on the use phase of other products

Where the operation or application of a product causes a change (either increase or decrease) in the GHG emissions arising from the use phase of another product, this change shall be excluded from the assessment of the life cycle GHG emissions of the product being assessed.

6.4.9 GHG emissions from final disposal

The GHG emissions arising from final disposal (e.g. waste disposed of through landfill, incineration, burial, wastewater) shall be included in the assessment of the life cycle GHG emissions of the product, subject to the provisions of **6.2** for business-to-business assessments.

*Note GHG emissions identified under **6.4.9** relate to emissions from waste not already covered in **Annex D**.*

6.4.9.1 Time period for GHG emissions from final disposal

All GHG emissions arising from final disposal over the 100-year assessment period shall be included. Where the final disposal of materials or products results in the release of GHG emissions over time (e.g. decomposition of food waste sent to landfill), the total emissions projected to occur over the 100-year assessment period shall be included in the assessment of GHG emissions of the product giving rise to the disposal. A factor shall be applied to these emissions to reflect the weighted average time the emissions are present in the atmosphere during the 100-year assessment period (see **Annex B**).

6.4.9.2 Activities following final disposal

Where the emissions from final disposal are diverted to another system (e.g. combustion of methane arising from landfill, combustion of waste timber fibre), the assessment of GHG emissions from the products giving rise to the emissions shall reflect the emissions arising from this diversion, as described in **8.2**.

6.5 System boundary exclusions

The system boundary of the product life cycle shall exclude the GHG emissions associated with:

a) human energy inputs to processes and/or pre-processing (e.g. if fruit is picked by hand rather than by machinery);

b) transport of consumers to and from the point of retail purchase;

c) transport of employees to and from their normal place of work; and

d) animals providing transport services.

7 Data

7.1 General

The data recorded in relation to a product shall include all GHG emissions occurring within the system boundary of that product.

7.2 Data quality rules

When identifying primary activity data and secondary data for use in GHG emissions assessment, preference shall be given as follows:

a) For time-related coverage: age of data and the minimum length of time over which data are collected, data that are time-specific to the product being assessed shall be preferred;

b) For geographical specificity: geographical area from which data is collected (e.g. district, country, region), data that are geographically-specific to the product being assessed shall be preferred;

c) For technology coverage: whether the data relates to a specific technology or a mix of technologies, data that are technology-specific to the product being assessed shall be preferred;

d) For accuracy of the information (e.g. data, models and assumptions), data that are most accurate shall be preferred;

e) For precision: measure of the variability of the data values for each data expressed (e.g. variance), data that are more precise (i.e. has the lowest statistical variance) shall be preferred.

In addition, consideration shall be given to the following:

f) completeness: the percentage of data that are measured, and the degree to which the data represents the population of interest (is the sample size large enough, is the periodicity of measurement sufficient, etc.);

g) consistency: qualitative assessment of whether the selection of data is carried out uniformly in the various components of the analysis;

h) reproducibility: qualitative assessment of the extent to which information about the method and data values would allow an independent practitioner to reproduce the results reported in the study;

i) data sources, with reference to the primary or secondary nature of the data.

*Note 1 Adapted from BS EN ISO 14044:2006, **4.2.3.6.2**.*

Note 2 Assessment of GHG emissions should use data that will reduce bias and uncertainty as far as practicable by using the best quality data achievable. Determination of the best quality data could be supported by a data scoring framework that allows the different attributes of data quality to be combined.

7.3 Primary activity data

Primary activity data shall be collected from those processes owned, operated or controlled by the organization implementing this PAS. The primary activity data requirement shall not apply to downstream emission sources.

Where the organization implementing this PAS does not contribute 10% or more to the upstream GHG emissions of the product or input prior to its provision to another organization or the end-user, the primary activity data requirement shall apply to the emissions arising from those processes owned, operated or controlled by the first upstream supplier that does contribute 10% or more to the upstream GHG emissions of the product or input.

Primary activity data shall be collected for individual processes or for premises where processes are occurring and shall be representative of the process for which it is collected. Allocation between co-products, where required, shall be carried out in accordance with **8.1**.

The requirement to obtain primary activity data shall not apply where implementing the requirement would necessitate the physical measurement of the GHG emissions (e.g. measuring CH_4 emissions from livestock or N_2O emissions from fertilizer application).

Note 1 Where an organization imposes conditions on the supply of products to it, such as a retailer specifying the quality of the product supplied to it or the manner of its packaging, this is evidence of control over the processes upstream of the organization implementing the PAS. In this situation, the requirement for primary activity data applies to the processes upstream of the organization implementing this PAS.

Note 2 Obtaining primary data for operations that are not under the control of the organization implementing the PAS (i.e. upstream emissions) will enhance the ability of the organization to differentiate the GHG assessment of its products from other products.

Note 3 Examples of primary activity data would be the measurement of energy use or material use in a process, or fuel use in transport.

Note 4 To be representative, primary activity data should reflect the conditions normally encountered in the process that are specific to the product being assessed. For example, *if refrigerated storage of a product is required, the primary activity data associated with this refrigeration (e.g. quantity of energy used, and quantity of refrigerant escaped) should reflect the long-term operation of the refrigeration and not those associated with a period of typically higher (e.g. August) or lower (e.g. January) energy consumption or refrigerant release.*

*Note 5 Emissions from livestock, their manure and soils are treated as secondary data (see **7.4**).*

7.4 Secondary data

Secondary data shall be used for inputs where primary activity data is not required.

7.4.1 Use of partial GHG assessment information as secondary data

Where data verified as being compliant with this PAS is available for inputs to the life cycle of the product being assessed (i.e. partial GHG emission information, see **6.2**), preference shall be given to the use of this data over other secondary data.

7.4.2 Other secondary data

Where secondary data in accordance with **7.4.1** is not available, the data quality rules (see **7.2**) shall be used to select the most relevant source of secondary data. Determination of the source of the secondary data (see **7.2 (i)**) shall recognize that secondary data arising from peer review publications, together with data from other competent sources (e.g. national government, official United Nations publications, and publications by United Nations-supported organizations), are preferred over secondary data from other sources.

Note It is intended that a reference to the ILCD as a source of secondary data will be considered in a future revision of this PAS following final agreement of the structure and scope of the ILCD.

7.5 Changes in the life cycle of a product

7.5.1 Temporary unplanned change

Where an unplanned change to the life cycle of a product results in an increase in the assessment of GHG emissions of more than 10% and is experienced for more than three months, a reassessment of the life cycle GHG emissions associated with the product shall be carried out.

7.5.2 Planned change

Where a planned change to the life cycle GHG emissions of a product leads to an increase in the assessment result of 5% or greater for a period exceeding three months, a reassessment of the life cycle GHG emissions associated with the product shall be carried out.

7.6 Variability in emissions arising from the product life cycle

Where the GHG emissions associated with the life cycle of a product vary over time, data shall be collected over a period of time sufficient to establish the average GHG emissions associated with the life cycle of the product.

Where a product is made available on a continuing basis, the assessment of GHG emissions shall cover at least one year. Where a product is differentiated by time (e.g. seasonal products), the assessment of GHG emissions shall cover the particular period associated with the production of the product (see **4.3**, **7.2** and **7.5**).

Note 1 The average result should be informed by historic data where available.

Note 2 The life cycle GHG emissions of sources of energy, particularly electricity, may vary over time. Where this occurs, data representing the most recent estimate of GHG emissions associated with the energy source should be used.

7.7 Data sampling

Where an input to a process arises from multiple sources and emissions data are collected from a representative sample of the sources used in the assessment of GHG emissions for a product, the use of sampling shall comply with the requirements for data quality under **7.2**.

Note Examples of where data sampling may be appropriate include:

a) a bank may include data from a representative sample of its branches, rather than from all branches;

b) a flour mill may include data from a representative sample of grain sources, rather than from all farms that provide it with grain;

c) where a factory has a number of production lines which produce the same product, it may include data from a representative sample of the production lines.

7.8 Non-CO_2 emissions data for livestock and soils

The estimation of the non-CO_2 GHG emissions arising from livestock, their manure or soils shall use one of the following two approaches with reference to the data quality rules specified in **7.2**:

a) the highest tier approach set out in the IPCC Guidelines for National Greenhouse Gas Inventories (see **Clause 2**); or

b) the highest tier approach employed by the country in which the emissions were produced.

Note Where organizations implementing this PAS rely on secondary data sources when assessing the GHG emissions arising from agricultural products, they should confirm whether the secondary data source includes emissions arising from direct land use change or whether this needs to be calculated separately.

7.9 Emissions data for fuel, electricity and heat

Fuel and energy data shall include:

a) the amount of energy used; and

b) the average emission factor of the energy input (e.g. $kgCO_2e$/kg fuel, $kgCO_2e$/MJ electricity or heat) based on the source of energy used.

The emissions associated with fuel and energy used in the life cycle of a product shall be determined in accordance with **6.4.2**.

7.9.1 Onsite generation of electricity and heat

Where electricity and/or heat are generated and used onsite, the emission factor for the electricity and/or heat shall be calculated using the method described in this PAS, including emissions from fuel input and upstream emissions.

7.9.2 Offsite generation of electricity and heat

Where electricity and/or heat are generated offsite, the emission factor used shall be either:

a) for electricity and heat delivered by a stand-alone source (i.e. not part of larger energy transmission system), the emission factor relevant to that source (e.g. for purchases of heat from CHP, the emission factor calculated in accordance with **8.1** and **8.3**); or

b) for electricity and heat delivered via a larger energy transmission system, secondary data that is as specific to the product system as possible (e.g. average electricity supply emission factor for the country in which the electricity is used).

7.9.3 GHG emissions associated with renewable electricity generation

7.9.3.1 Eligibility of renewable energy-specific emission factors

A renewable energy-specific emission factor shall be applied to a process using renewable energy only where both of the following can be demonstrated:

a) the process used the energy (i.e. use of renewable energy generated on-site) or used an equivalent amount of energy of the same type to that generated (i.e. use of renewable energy delivered via an energy transmission network that combines different types of energy generation), and another process did not use the energy generated whilst claiming it as renewable;

and

b) the generation of this renewable energy does not influence the emission factor of any other process or organization using the same type of energy (e.g. renewable electricity).

Where conditions a) or b) are not met, national average energy emission factors for the renewable energy shall be used.

Note 1 Demonstration that the energy is from a renewable source should be carried out independent of other verification or trading schemes.

Note 2 In many situations, the emission factor for renewable energy generation is automatically incorporated into the national average energy emission factor. For example, renewable electricity is typically assumed to be a source of zero-emissions electricity in national reporting of electricity emission factors; were a company to claim a low emission factor for the purchase of renewable electricity (e.g. through the purchase of a "green tariff") that was also included in national reporting, double-counting of the low emissions benefit of the electricity would occur. In some countries (e.g. the UK), methods for reporting the impact of renewable electricity generation on the national emissions factor for electricity are not sufficiently developed to separately account for grid-average and tariff-specific electricity supplies.

*Note 3 In countries where the flow of renewable electricity is accurately accounted for, the requirement of **7.9.3.2** will allow companies that are using renewable electricity, or purchasing renewable electricity through a dedicated tariff, to use the GHG emission of the renewable electricity (rather than grid average carbon intensity) when calculating the emissions arising from their processes.*

7.9.3.2 Emissions from renewable electricity

The assessment of emissions from renewable electricity generation shall include those emissions arising within the system boundary specified in **6.4.2** (e.g. where renewable electricity is generated from biomass, the emissions associated with the electricity generation shall include emissions associated with the direct land use change, growing, harvesting, processing, transporting, etc. of the biomass as applicable).

7.9.4 Emissions from biomass and biofuels

Emissions arising from the use of biomass (e.g. co-firing of biomass, biodiesel, bioethanol) shall include the GHG emissions arising from the production of the fuel, and shall exclude the CO_2 emissions arising from the biogenic carbon component of the fuel.

Note 1 Where biofuel is produced from waste (e.g. cooking oil after it has been used in a cooking process), the GHG emissions arising from the production of the fuel are those arising from the conversion of the waste to fuel.

Note 2 Where the biofuel is not produced from waste (e.g. biodiesel produced from oilseed rape or palm oil, ethanol produced from wheat, sugar beet, sugarcane or corn), the GHG emissions associated with the use of the biofuel include the emission sources occurring within the boundaries of the life cycle of the biofuel.

7.10 Validity of analysis

Results obtained from the implementation of this PAS shall be valid for a maximum period of two years, unless there is a change in the life cycle of the product whose GHG emissions are being assessed (see **7.5**), in which situation, the validity ceases.

Note The length of time that an analysis is valid will vary depending on the characteristics of the life cycle of the product.

7.11 Disclosure

7.11.1 System boundary

Where use phase emissions form part of an assessment carried out under this PAS that is communicated to a third party (e.g. consumers), a description of the system boundary that has been used for the assessment of the GHG emissions of a product shall also be made available. This description shall include decisions taken regarding the system boundary and the use of a PCR as the basis of the system boundary (if applicable).

The description of the system boundary shall be made available at, or prior to, the communication of the assessment of the life cycle GHG emissions of such a product.

7.11.2 Use phase analysis

Where use phase emissions form part of an assessment carried out under this PAS that is communicated to a third party (e.g. consumers), a description of the use profile shall also be made available. The use profile shall be made available at, or prior to, the communication of the use phase emissions to a third party.

Note The use profile does not have to be made available in the same place as the communication of the results of the assessment. However, it should be made available in a readily accessible location (e.g. website).

7.11.3 Carbon storage assessment

Where an assessment of the life cycle GHG emissions of a product that includes an assessment of the impact of carbon storage is communicated to a third party (e.g. consumers), a full description of the basis on which the impact of the carbon storage was calculated, including the emissions profile of the product, shall be made available.

The basis for the calculation of the impact of carbon storage shall be made available at, or prior to, the communication of the assessment of the life cycle GHG emissions of such a product.

Note Disclosure of the basis of the use phase calculation or carbon storage assessment does not have to occur at the same location, or in the same form, as communication of the use phase emissions to a third party occurs. For example, the basis of the use phase calculation or carbon storage assessment may be made available via a web site.

7.11.4 Secondary data sources

Where secondary data are used in the application of this PAS, a description of the source of the secondary data shall also be made available. The description of the secondary data source shall be made available at, or prior to, the communication of the assessment of the life cycle GHG emissions of the product.

Note The description of the secondary data source does not have to be made available in the same place as the communication of the results of the assessment. For example, the basis of the use phase calculation or carbon storage assessment can be made available via a web site.

8 Allocation of emissions

8.1 General requirement

Unless otherwise stated in this PAS, the approach to allocation shall be as described in **8.1.1**.

8.1.1 Allocation to co-products

The preferred approach to allocation of emissions to co-products shall be, in order of preference:

a) dividing the unit processes to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes; or

b) expanding the product system to include additional functions related to the co-products where:

   i) a product which is displaced by one or more of the co-products of the process being considered can be identified; and

   ii) the avoided GHG emissions associated with the displaced product represent the average emissions arising from the provision of the avoided product.

Note 1 *For example, where a process results in the co-production of electricity that is exported to a larger electricity transmission system, the avoided emissions resulting from this co-production of electricity would be based on the average GHG emissions intensity of grid electricity.*

Note 2 *See BS EN ISO 14044:2006, **4.3.4.2(a)**.*

Where it can be demonstrated that neither of these approaches is practicable, the GHG emissions arising from the process shall be allocated between the co-products in proportion to the economic value of the co-products (i.e. economic allocation).

8.1.2 Recording allocation assumptions

The approach to the allocation of emissions to co-product shall be recorded by the organization implementing this PAS. Where the allocation to co-products is carried out by expanding the product system (see **8.1.1** (**b**)), the organization implementing this PAS shall record the assumptions made regarding the scope and emissions of the expanded product system.

8.2 Emissions from waste

Where waste results in GHG emissions (e.g. organic matter disposed of in a landfill), emissions from the waste shall be treated as follows:

8.2.1 CO_2 emissions from waste

Where CO_2 emissions arise from the biogenic carbon fraction of the waste, these emissions shall be assigned a GWP of zero.

Where CO_2 emissions arise from the fossil carbon fraction of the waste, these emissions shall be assigned a GWP of 1 and shall be included in the life cycle GHG emissions of the product that gave rise to the waste.

8.2.2 Non-CO_2 emissions from waste

Where non-CO_2 emissions arise from the biogenic and fossil carbon fraction of the waste, these emissions shall be assigned the appropriate GWP given in Annex A and shall be included in the life cycle GHG emissions of the product that gave rise to the waste.

8.2.3 Combustion of methane emissions from waste

8.2.3.1 Methane combustion with energy recovery

Where methane from waste is combusted to generate useful energy:

a) No GHG emissions shall be incurred where the methane being combusted is derived from the biogenic component of the waste;

b) GHG emissions shall be assigned to the useful energy produced where the methane being combusted is derived from the fossil component of the waste.

Note *See **8.3** for the treatment of emissions from CHP.*

8.2.3.2 Methane combustion without energy recovery

Where methane is combusted without the generation of useful energy (i.e. flaring):

a) No GHG emissions shall be incurred where the methane being combusted is derived from the biogenic component of the waste;

b) GHG emissions shall be assigned to the life cycle of the product that gave rise to the waste when the methane being combusted is derived from the fossil component of the waste.

8.3 Emissions from energy (CHP emissions)

Where energy production from CHP is exported to a larger system (e.g. export of electricity to a national electricity network), the avoided GHG emissions arising from the exported energy shall be assessed in accordance with **8.1.1**.

Where some or all of the heat and electricity production from CHP is used by more than one process, the emissions arising from CHP, less any avoided burden calculated in **8.1.1**, shall be allocated between the heat and electricity used. The allocation shall be carried out in proportion to the amount of useful energy delivered in each form, multiplied by the intensity of GHG emissions associated with each unit of useful energy delivered as heat and electricity. The intensity of GHG emissions shall be:

a) for boiler-based CHP systems (e.g. coal, wood, solid fuel) – emissions per MJ electricity:emissions per MJ heat in the ratio of 2.5:1;

b) for turbine-based CHP systems (e.g. natural gas, landfill gas) – emissions per MJ electricity:emissions per MJ heat in the ratio of 2.0:1.

Note The allocation of emissions to heat and electricity arising from CHP relies on the process-specific ratio of heat to electricity arising from each CHP system. For example, where a boiler-based CHP system delivers useful energy in the electricity:heat ratio of 1:6, 2.5 units of emissions would be allocated to each unit of electricity, and 1 unit of emissions would be allocated to each unit of heat delivered by the CHP system. In this example, while the CHP system had a useful electricity:heat ratio of 1:6, the corresponding GHG emissions ratio was 2.5:6. These results will change with different heat:electricity characteristics of the CHP system.

8.4 Emissions from transport

Where more than one product is being transported by a transport system (e.g. a truck, ship, aircraft, train), the emissions arising from the transport system shall be divided amongst the products on the basis of:

a) where mass is the limiting factor for the transport system: the relative mass of the different products being transported; or

b) where volume is the limiting factor for the transport system: the relative volume of the different products being transported.

Transport emissions shall include the emissions associated with the return journey of a vehicle where the vehicle does not transport products on its return, or for that proportion of the return journey where the vehicle does not transport products.

8.5 Use of recycled material and recycling

The method for assessing emissions arising from recycled material shall be as specified in **Annex D**.

8.6 Treatment of emissions associated with reuse and remanufacture

Where a product is reused, the GHG emissions of the product shall be determined as follows:

a) The life cycle GHG emissions, excluding use phase emissions, shall be determined;

b) The emissions calculated in a) shall be divided by the anticipated number of times the product is re-used;

c) Any emissions associated with remanufacturing the product to make it suitable for reuse shall be included in the assessment.

The emissions per use or reuse shall be the sum of emissions calculated in b), plus any emissions arising from the use phase and remanufacturing for each use or reuse.

9 Calculation of the GHG emissions of products

The following method shall be used to calculate the GHG emissions for a functional unit:

1. Primary activity data and secondary data shall be converted to GHG emissions by multiplying the activity data by the emission factor for the activity. This shall be recorded as GHG emissions per functional unit of product.
2. GHG emissions data shall be converted into CO_2e emissions by multiplying the individual GHG emissions figures by the relevant GWP. The impact of any delay in the release of emissions, calculated in accordance with **5.2**, shall be included in this step.
3. The impact of carbon storage associated with the product and calculated in accordance with **5.4** shall be expressed as CO_2e and deducted from the total calculated at step 2 above.
4. The results shall be added together to obtain GHG emissions in terms of CO_2e emissions per functional unit. When the result is calculated, the result shall be:
   a) business-to-consumer: the complete product life cycle GHG emissions arising from the product (including the use phase), and separately the use phase GHG emissions arising from the product; or
   b) business-to-business: the GHG emissions that have occurred up to, and including, the point where the input arrives at a new organization, including all upstream emissions.
5. The GHG emissions shall then be scaled to account for any minor raw materials or activities that were excluded from the analysis by dividing the estimated emissions by the proportion of emissions calculated for the anticipated life cycle GHG emissions.

10 Claims of conformity

10.1 General

Claims of conformance with this PAS shall be made in the principal documentation or on the packaging provided for the product for which the claim is being made, in accordance with BS EN ISO/IEC 17050-1 and in the form relevant to that particular claim as provided for in **10.4**. This statement shall include unambiguous identification of the organization claiming conformance.

Note In accordance with the relevant definitions given in BS EN ISO/IEC 17000, the term "certified" is used in this PAS to describe the issuing of an attestation document by an accredited independent third party certification body. The term "declared", appropriately qualified, is used to identify the other options accepted in this PAS.

10.2 Scope of claim

In making a claim of conformance with this PAS, the organization shall address all of the provisions of the PAS.

10.3 Basis of claim

10.3.1 General

The claim shall identify the type of conformity assessment undertaken as one of:

a) independent third party certification in accordance with **10.3.2**;

b) other party verification in accordance with **10.3.3**; or

c) self verification in accordance with **10.3.4**.

*Note Attention is drawn to the fact that claims of conformity used to support communication of results calculated under this PAS to third parties, made in accordance with **10.3.2**, are most likely to gain consumers' confidence.*

10.3.2 Independent third party certification

Organizations seeking to demonstrate that their calculations of GHG emissions have been independently verified as being in accordance with this PAS, shall undergo assessment by an independent third party certification body accredited to provide assessment and certification to this PAS.

10.3.3 Other party verification

Organizations using an alternative method of verification involving parties other than those qualifying as accredited independent third parties, shall satisfy themselves that any such party is able to demonstrate compliance with recognized standards setting out requirements for certification bodies.

Note Examples of such recognized standards include BS EN ISO/IEC 17021 and BS EN 45011.

10.3.4 Self verification

In undertaking self verification, organizations shall be able to demonstrate that the calculations have been made in accordance with this PAS, and make supporting documentation available to any interested party. The appropriate method for self verification and for presentation of the results shall be through the application of BS EN ISO 14021.

Note Organizations for whom neither independent third party certification nor other party verification is a realistic option, may rely on self verification. In so doing, organizations should be aware that external verification could be required in the event of challenge and that consumers could have less confidence in this option.

10.4 Identification of the basis of a claim

All claims of conformity with this PAS shall include identification of the basis of the claim, using the appropriate form of disclosure, as follows:

1. For claims of conformity based on certification in accordance with **10.3.2**:

   "Greenhouse gas emission calculated by *[insert unambiguous identification of the claimant]* in accordance with PAS 2050, *[insert unambiguous identification of the certifying body]* certified."

2. For claims of conformity based on other party assessment in accordance with **10.3.3**:

   "Greenhouse gas emission calculated by *[insert unambiguous identification of the claimant]* in accordance with PAS 2050, *[insert unambiguous identification of the validating body]* declared."

3. For claims of conformity based on self verification in accordance with **10.3.4**:

   "Greenhouse gas emission calculated by *[insert unambiguous identification of the claimant]* in accordance with PAS 2050, self declared."

Annex A
Global warming potential (normative)

The values of global warming potentials for GHGs to be used in calculations shall be in accordance with **Table A.1** (IPCC 2007, Table 2.14, see **Clause 2**).

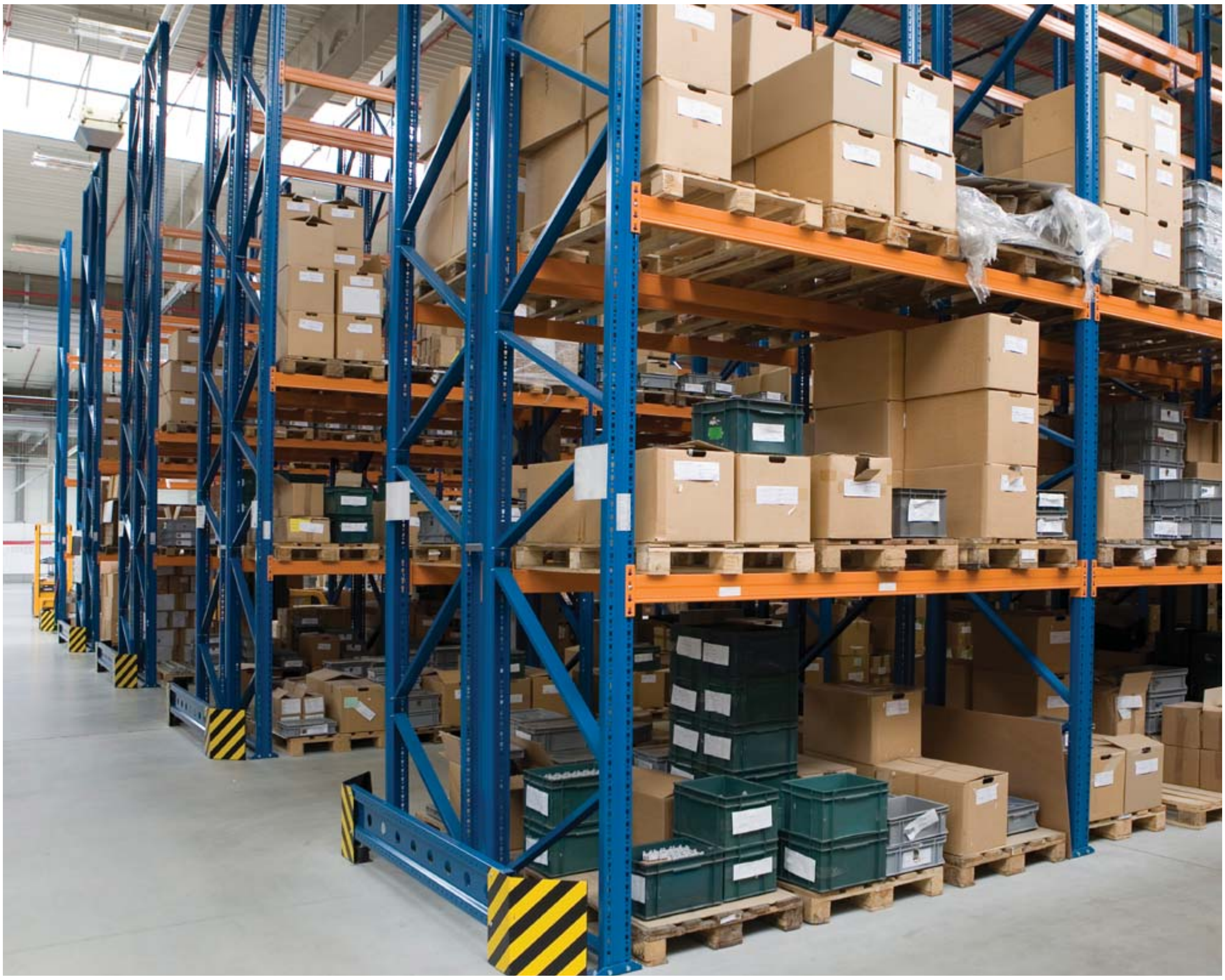
Note *Attention is drawn to the requirement that the GWP actually used in calculations is the latest available from the IPCC (see **5.1.1**). It is the responsibility of the organization undertaking GHG emissions assessment to confirm the currency of GWP values given in **Table A.1** before using them.*

Table A.1 Direct (except for CH_4) global warming potentials (GWP) relative to CO_2

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
Carbon dioxide	CO_2	1
Methane[c]	CH_4	25
Nitrous oxide	N_2O	298
Substances controlled by the Montreal Protocol		
CFC-11	CCl_3F	4,750
CFC-12	CCl_2F2	10,900
CFC-13	$CClF_3$	14,400
CFC-113	CCl_2FCClF_2	6,130
CFC-114	$CClF_2CClF_2$	10,000
CFC-115	$CClF_2CF_3$	7,370
Halon-1301	$CBrF_3$	7,140
Halon-1211	$CBrClF_2$	1,890
Halon-2402	$CBrF_2CBrF_2$	1,640
Carbon tetrachloride	CCl_4	1,400
Methyl bromide	CH_3Br	5
Methyl chloroform	CH_3CCl_3	146
HCFC-22	$CHClF_2$	1,810
HCFC-123	$CHCl_2CF_3$	77
HCFC-124	$CHClFCF_3$	609
HCFC-141b	CH_3CCl_2F	725
HCFC-142b	CH_3CClF_2	2,310
HCFC-225ca	$CHCl_2CF_2CF_3$	122
HCFC-225cb	$CHClFCF_2CClF_2$	595

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
Hydrofluorocarbons		
HFC-23	CHF_3	14,800
HFC-32	CH_2F_2	675
HFC-125	CHF_2CF_3	3,500
HFC-134a	CH_2FCF_3	1,430
HFC-143a	CH_3CF_3	4,470
HFC-152a	CH_3CHF_2	124
HFC-227ea	CF_3CHFCF_3	3,220
HFC-236fa	$CF_3CH_2CF_3$	9,810
HFC-245fa	$CHF_2CH_2CF_3$	1,030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	1,640
Perfluorinated compounds		
Sulfur hexafluoride	SF_6	22,800
Nitrogen trifluoride	NF_3	17,200
PFC-14	CF_4	7,390
PFC-116	C_2F_6	12,200
PFC-218	C_3F_8	8,830
PFC-318	$c\text{-}C_4F_8$	10,300
PFC-3-1-10	C_4F_{10}	8,860
PFC-4-1-12	C_5F_{12}	9,160
PFC-5-1-14	C_6F_{14}	9,300
PFC-9-1-18	$C_{10}F_{18}$	>7,500
Trifluoromethyl sulfur pentafluoride	SF_5CF_3	17,700
Fluorinated ethers		
HFE-125	CHF_2OCF_3	14,900
HFE-134	CHF_2OCHF_2	6,320
HFE-143a	CH_3OCF_3	756
HCFE-235da2	$CHF_2OCHClCF_3$	350
HFE-245cb2	$CH_3OCF_2CHF_2$	708
HFE-245fa2	$CHF_2OCH_2CF_3$	659
HFE-254cb2	$CH_3OCF_2CHF_2$	359
HFE-347mcc3	$CH_3OCF_2CF_2CF_3$	575
HFE-347pcf2	$CHF_2CF_2OCH_2CF_3$	580
HFE-356pcc3	$CH_3OCF_2CF_2CHF_2$	110

Industrial designation or common name	Chemical formula	GWP for 100-year time horizon (at date of publication)
HFE-449sl (HFE-7100)	$C_4F_9OCH_3$	297
HFE-569sf2 (HFE-7200)	$C_4F_9OC_2H_5$	59
HFE-43-10-pccc124 (H-Galden 1040x)	$CHF_2OCF_2OC_2F_4OCHF_2$	1,870
HFE-236ca12 (HG-10)	$CH_2OCF_2OCHF_2$	2,800
HFE-338pcc13 (HG-01)	$CHF_2OCF_2CF_2OCHF_2$	1,500
Perfluoropolyethers		
PFPMIE	$CF_3OCF(CF_3)CF_2OCF_2OCF_3$	10,300
Hydrocarbons and other compounds – direct effects		
Dimethylether	CH_3OCH_3	1
Methylene chloride	CH_2Cl_2	8.7
Methyl chloride	CH_3Cl	13



Annex B
Calculation of the weighted average impact of emissions arising from the use phase and final disposal phase of products (normative)

B.1 General

Where emissions arising from the use phase of a product, or from its final disposal, occur after the first year following the formation of the product but within the 100-year assessment period, the impact of these emissions shall reflect the weighted average time the emissions are present in the atmosphere during the 100-year assessment period.

*Note 1 The formulae presented in this Annex represent a simplification of the approach outlined in Table 2.14 (footnote (a)), Chapter 2 of IPCC 2007 (see **Clause 2**). Full implementation of the IPCC approach will result in a more precise result.*

*Note 2 The approach presented in Table 2.14 (footnote (a)), Chapter 2 of IPCC 2007 (see **Clause 2**) is applicable to CO_2 emissions only, while the approximation presented here is applied to GWP data assessed under this PAS. As a result, the approximation will be less accurate where the overall CO_2e emissions of the product include a significant non-CO_2 component.*

B.1.1 Specific case: delayed single release

Where emissions from the use phase or the final disposal phase of a product occur as a single release within 25 years of the formation of the product, the weighting factor to be applied to the GHG emissions released at that time shall reflect the number of years of delay in the emissions being released (i.e. the number of years between formation of the product and the single release of the emissions) according to:

$$\text{Weighting factor} = \frac{100-(0.76 \times t_o)}{100}$$

where

t_o = the number of years between formation of the product and the single release of the emissions.

B.1.2 General case: delayed release

In cases not covered in **B.1.1**, the weighting factor to be applied to the GHG emissions released in the atmosphere shall be calculated according to:

$$\text{Weighting factor} = \frac{\sum_{i=1}^{100} x_i.(100-i)}{100}$$

where

i = each year in which emissions occur,

x = the proportion of total emissions occurring in any year i.

Note For example, if use phase emissions were to be delayed for 10 years following formation of the product, with total emissions being released evenly over the following five years, then the weighting factor that represents the weighted average time these emissions are present in the atmosphere would be:

$$\frac{(0.2 \times (100-11)) + (0.2 \times (100-12)) + (0.2 \times (100-13)) + (0.2 \times (100-14)) + (0.2 \times (100-15))}{100}$$

$$= 0.87$$

In this example, the total amount of use phase emissions, expressed as CO_2e, released during the 100-year assessment period, would be multiplied by a factor of 0.87 to reflect the weighted average time these emissions are present in the atmosphere during the 100-year assessment period.

Annex C
Calculation of the weighted average impact of carbon storage in products (normative)

C.1 General

Where carbon storage, or the uptake of atmospheric carbon, over the life cycle of the product occur within the 100-year assessment period, the impact of this storage or uptake emissions shall reflect the weighted average time of storage during the 100-year assessment period.

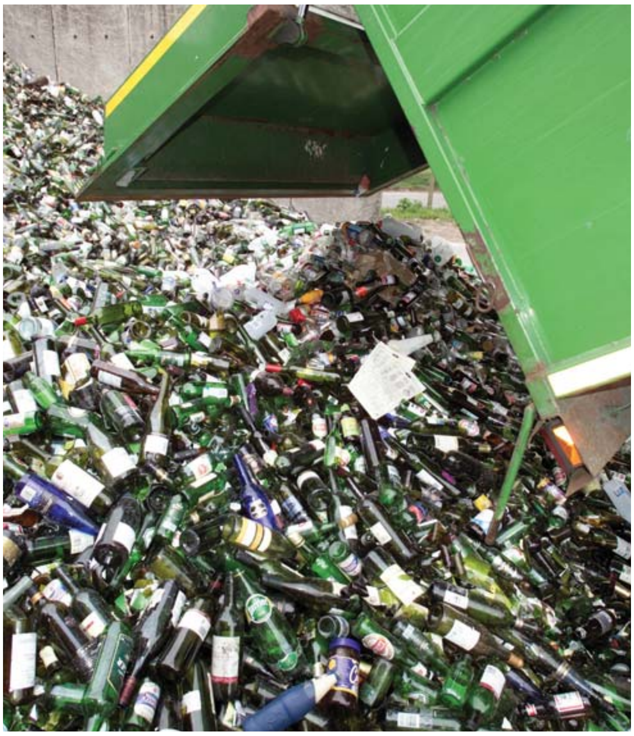
C.1.1 Specific case: biogenic carbon storage following product formation

Where the full carbon storage benefit of a product exists for between 2 and 25 years after the formation of the product (and no carbon storage benefit exists after that time), the weighting factor to be applied to the CO_2 storage benefit over the 100-year assessment period shall be calculated according to:

$$\text{Weighting factor} = \frac{(0.76 \times t_o)}{100}$$

where

t_o = the number of years the full carbon storage benefit of a product exists following the formation of the product.



C.1.2 General case: biogenic carbon storage or atmospheric carbon take-up

In cases not covered in **C.1.1**, the weighting factor to be applied to the CO_2 storage benefit over the 100-year assessment period shall be calculated according to:

$$\text{Weighting factor} = \frac{\sum_{i=1}^{100} x_i}{100}$$

where

i = each year in which storage occurs,

x = the proportion of total storage remaining in any year i.

__Note__ For example, if a product were to store biogenic carbon over a period of five years following formation of the product, and the amount of carbon stored were to then decrease evenly across the following five years, the weighting factor that represents the weighted average time of carbon storage in the product would be:

$$\frac{(1 + 1 + 1 + 1 + 1 + 0.8 + 0.6 + 0.4 + 0.2 + 0)}{100}$$
$$= 0.07$$

In this example, 100% of the carbon storage benefit occurs over the first five years; this then decreases 20% (0.2) per year over the next five years. Therefore, the total amount of biogenic carbon, expressed as CO_2e, stored in the product would be multiplied by a factor of 0.07 to reflect the weighted average impact of biogenic carbon stored in this product over the 100-year assessment period.

Annex D
Calculation of emissions arising from recyclable material inputs
(normative)

D.1 Recycled content originating from the same product system

Where the life cycle of a product includes a material input with recycled content originating from the same product system, the emissions arising from that material shall reflect the product specific recycle content and/or recycling rate based on the calculation given below.

$$\text{Emissions / unit} = (1 - R_1) \times E_V + (R_1 \times E_R) + (1 - R_2) \times E_D$$

where

R_1 = proportion of recycled material input,

R_2 = proportion of material in the product that is recycled at end-of-life,

E_R = emissions arising from recycled material input, per unit of material,

E_V = emissions arising from virgin material input, per unit of material,

E_D = emissions arising from disposal of waste material, per unit of material

D.1.1 Material input with system average recycle content and recycling rate

Where the life cycle of a product includes a material input that contains the system average proportion of recycled content and is recycled at the system average recycling rate for that product category, the calculation in **D.1** shall reflect the system average recycle content and recycle rate.

Note It is assumed that materials are recycled in a steady-state system. This may not be the case for some materials where the total stock of material in use is increasing or decreasing over time.

D.1.2 Material input with a product specific recycle content and/or recycling rate

Where the life cycle of a product includes a material input with a specified proportion of recycled content and/or the material in the product has a recycle rate that is different from the average recycle rate for that product category, the emissions arising from that material shall reflect the product specific recycle content and/or recycling rate.

D.1.3 Demonstration of product specific recycle content and/or recycling rate

Where emissions associated with product specific recycled content and/or recycling rate are determined in accordance with **D.1**, the organization implementing this PAS shall record the product specific recycle content and/or recycling rate.

D.2 Other types of recycling

Where the life cycle of a product includes a material input with recycled content other than that described in **D.1**, the emissions arising from this material shall be assessed using an approach consistent with BS EN ISO 14044:2006, **4.3.4.3**.

Note The treatment of recycling will be given further consideration in future revisions of this PAS.

D.3 Recording the basis of the treatment of recycling

Where the assessment of the life cycle GHG emissions of a product includes emissions arising from the recycling of material, the approach adopted in assessing the GHG emissions associated with recycling shall be recorded and retained (see **4.4**).

Annex E
Default land use change values for selected countries (normative)

GHG emissions arising from specified changes in land use for a selection of countries shall be as given in **Table E.1**.

*Note 1 The information in **Table E.1** is derived from the Office of the Renewable Fuels Agency's technical guidance [5].*

*Note 2 See **5.5.1** for determining the GHG emissions associated with land use change where there is limited knowledge regarding the location or type of land use change.*

*Note 3 For emissions from land use change in countries not listed in this Annex, refer to IPCC Guidelines for National Greenhouse Gas Inventories (see **Clause 2**), with particular reference to Chapter 5, Section 3 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories which provides details on how to apply the standard methodology to calculate the carbon lost when land is converted to cropland.*

Table E.1 Default land use change values for selected countries

Country	Current land use	Previous land use	GHG emissions (t CO_2e / ha/yr)
Argentina	Annual cropland	Forest land	17
		Grassland	2.2
	Perennial cropland	Forest land	15
		Grassland	1.9
Australia	Annual cropland	Forest land	23
		Grassland	2.2
	Perennial cropland	Forest land	21
		Grassland	1.9
Brazil	Annual cropland	Forest land	37
		Grassland	10.3
	Perennial cropland	Forest land	26
		Grassland	8.5
Canada	Annual cropland	Forest land	17
		Grassland	2.2
	Perennial cropland	Forest land	16
		Grassland	1.9
Finland	Annual cropland	Forest land	15
		Grassland	7.3
	Perennial cropland	Forest land	14
		Grassland	6.9
France	Annual cropland	Forest land	18
		Grassland	4.5
	Perennial cropland	Forest land	14
		Grassland	4.2

Country	Current land use	Previous land use	GHG emissions ($t\ CO_2e$ / ha/yr)
Germany	Annual cropland	Forest land	21
		Grassland	7.0
	Perennial cropland	Forest land	14
		Grassland	6.7
Indonesia	Annual cropland	Forest land	33
		Grassland	19.5
	Perennial cropland	Forest land	31
		Grassland	17.7
Malaysia	Annual cropland	Forest land	37
		Grassland	10.3
	Perennial cropland	Forest land	26
		Grassland	8.5
Mozambique	Annual cropland	Forest land	24
		Grassland	3.6
	Perennial cropland	Forest land	22
		Grassland	3.2
Pakistan	Annual cropland	Forest land	16
		Grassland	3.6
	Perennial cropland	Forest land	15
		Grassland	3.2
Poland	Annual cropland	Forest land	21
		Grassland	7.0
	Perennial cropland	Forest land	14
		Grassland	6.7
South Africa	Annual cropland	Forest land	26
		Grassland	1.6
	Perennial cropland	Forest land	25
		Grassland	1.2
Ukraine	Annual cropland	Forest land	18
		Grassland	6.2
	Perennial cropland	Forest land	18
		Grassland	5.8
United Kingdom	Annual cropland	Forest land	27
		Grassland	7.0
	Perennial cropland	Forest land	20
		Grassland	6.7
United States	Annual cropland	Forest land	17
		Grassland	1.9
	Perennial cropland	Forest land	16
		Grassland	1.5

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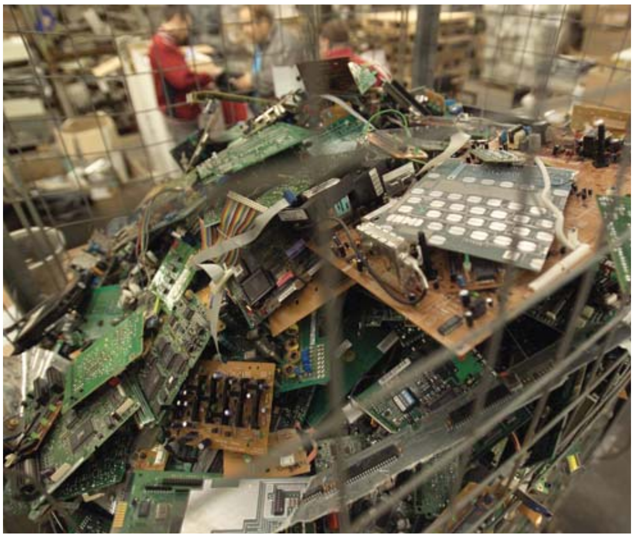

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