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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Acknowledgements

Acknowledgement is given to the following organizations who assisted in the development of this guide.

Carbon Trust
Defra
BSI British Standards
PE International
Food and Drink Federation
Manchester Business School
EuGeos Ltd
ADAS UK Ltd

First published in the UK in 2008
by
BSI
389 Chiswick High Road
London W4 4AL

Typeset by Helius, Brighton and Rochester, UK.
Printed in Great Britain by The Charlesworth Group, Wakefield, West Yorkshire, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-0-580-64636-2

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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.

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

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

- – 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.

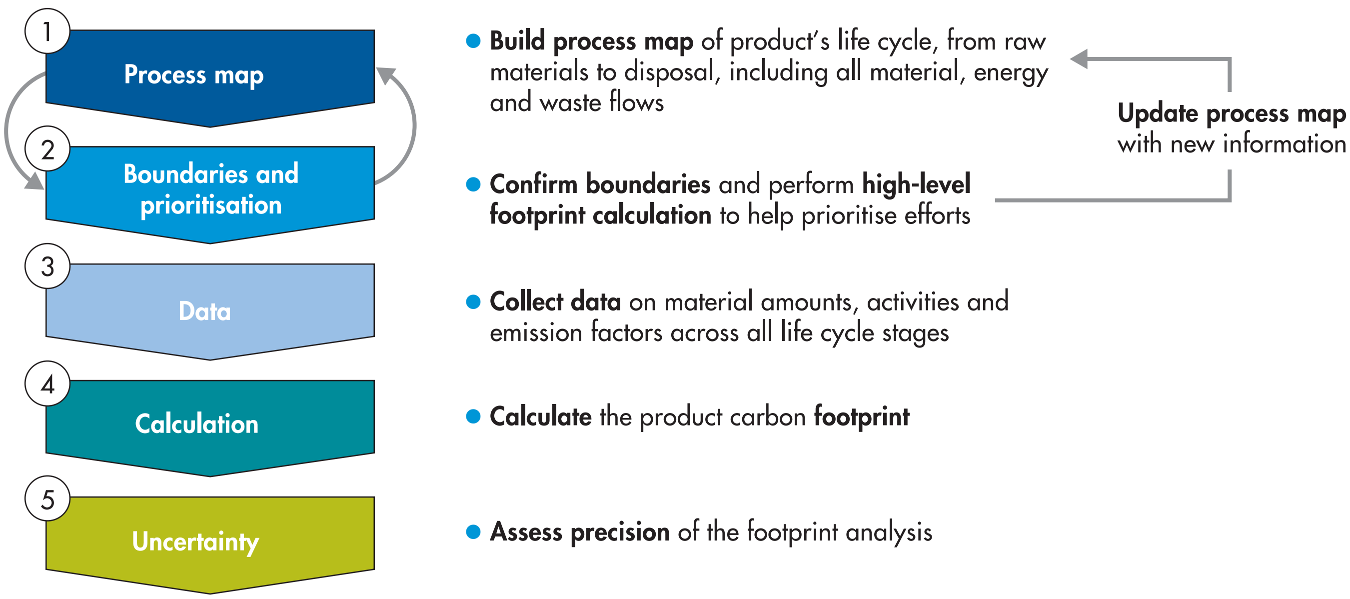
PAS 2050 is anchored in the guiding principles listed in the box below (see PAS 2050 Section 4.2).

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.

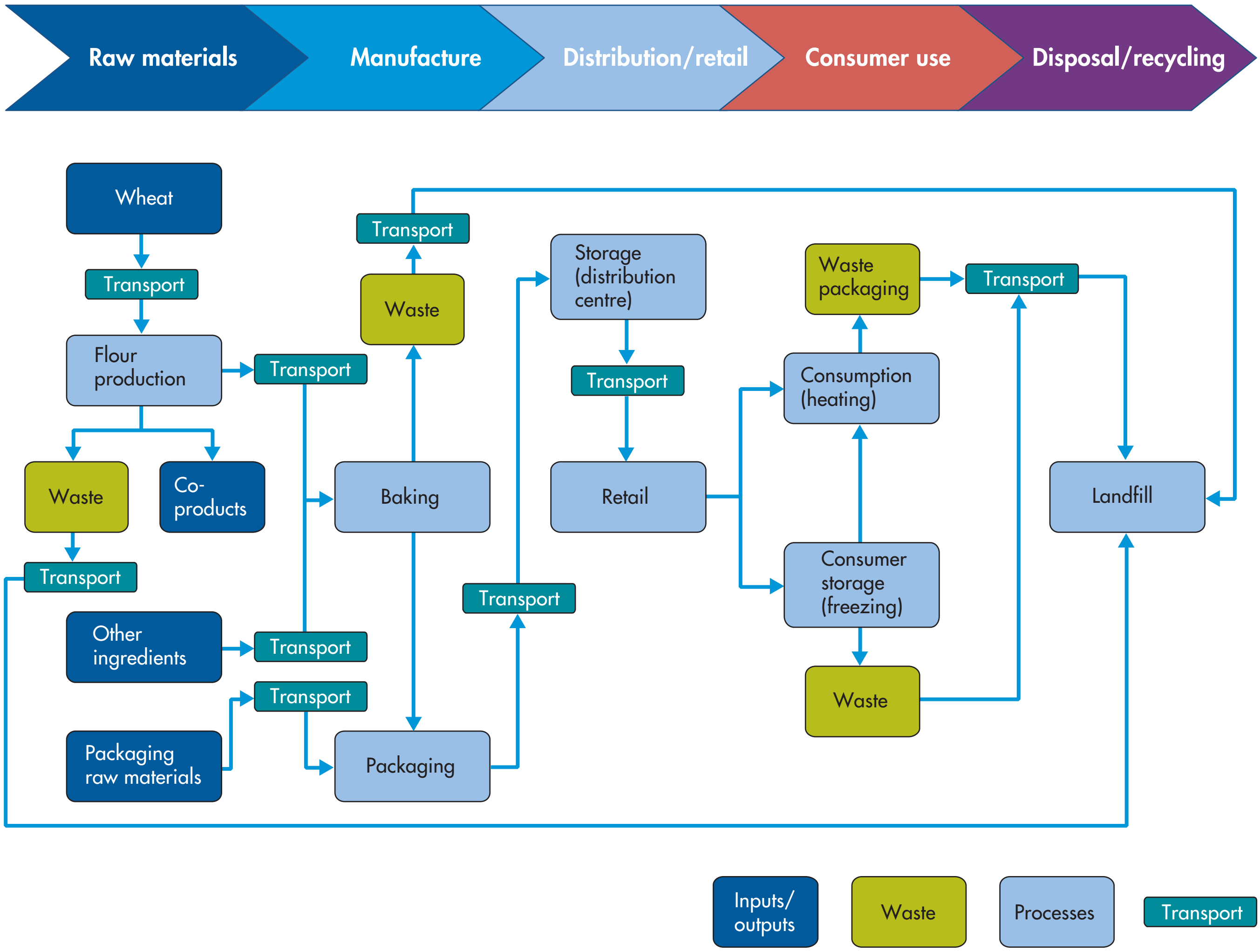
Step 2: Checking boundaries and prioritisation

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,

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

Raw materials (including transport)			Manufacturing			Distribution/retail			Consumer use			Disposal/recycling			Total
Wheat agriculture	500	44%	Plant A	200	17%	Transport	30	3%	Freezing	50	4%	Transport	50	4%	
Flour milling	50	4%				Storage	0	0%	Toasting	40	4%	Decay	100	9%	
Water supply	0	0%				Retail	0	0%							
Other ingredients	100	9%													
Film packaging	20	2%													
Total	**670**	**59%**		**200**	**17%**		**30**	**3%**		**90**	**8%**	**150**		**13%**	**1140**

Figures are in grams CO_2e per tonne croissants, and are for illustration purposes only.
Percentages are per cent of total.

over a defined time period, recognising variations in geography, distance and materials.

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.

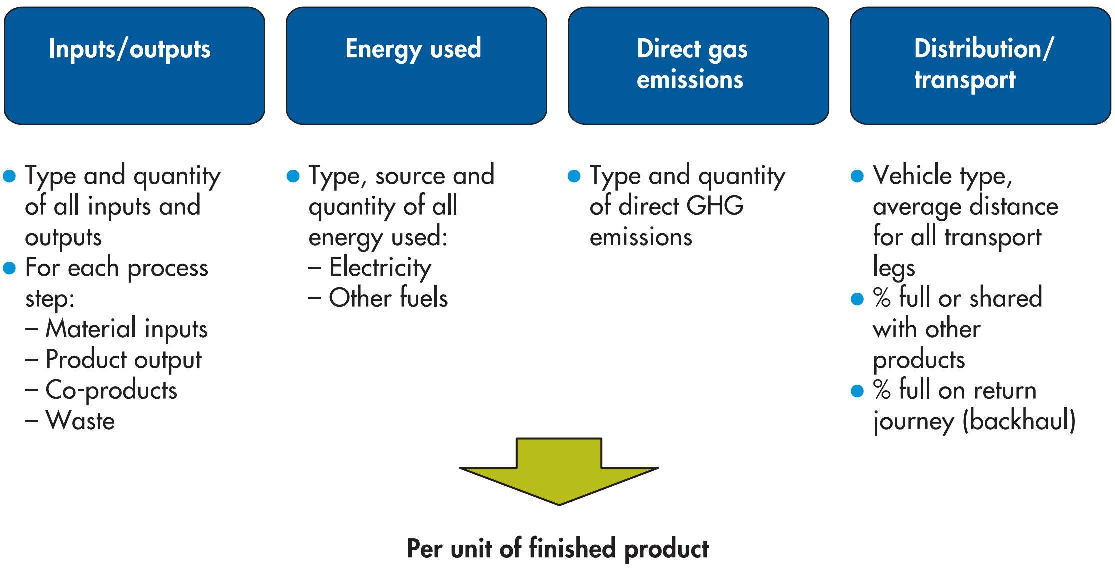
Data types

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.

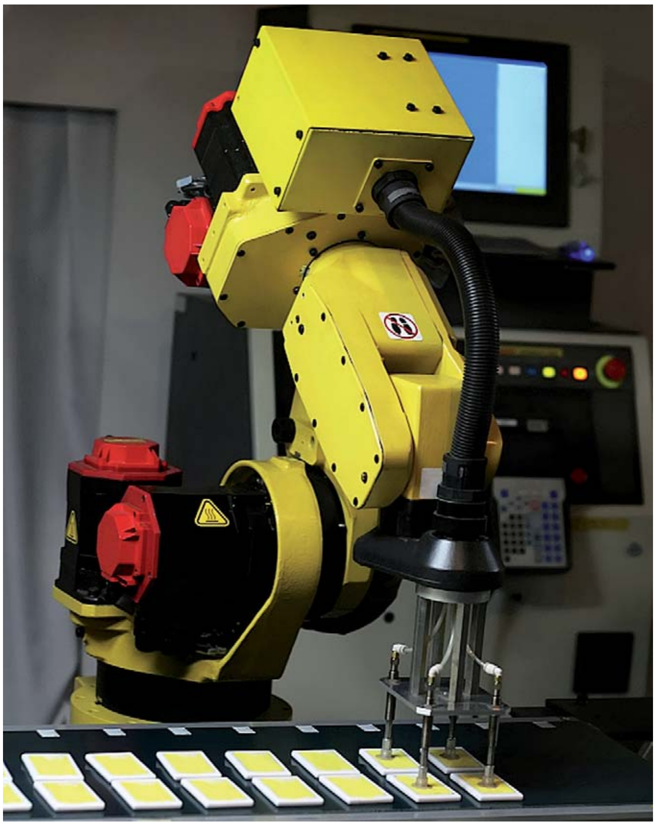
Emission factors provide the link that converts these quantities into the resulting GHG emissions: the amount of greenhouse gases emitted per 'unit' of activity data (e.g. kg GHGs per kg input or per kWh energy used).

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)



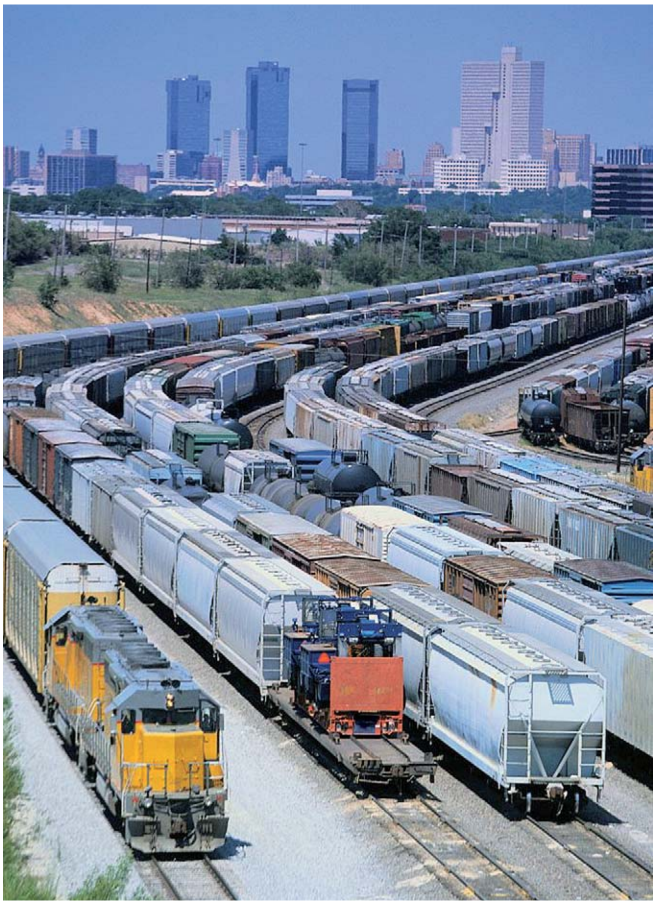
Common activity data



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.

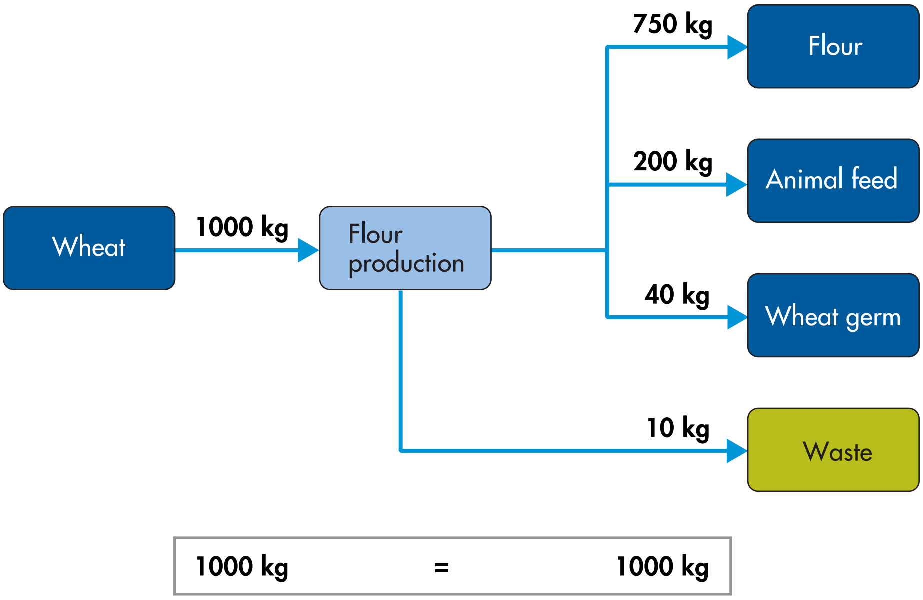
Services note: The services equivalent of a mass balance calculation is called an activity-based assessment. For a given activity, all processes and materials flowing into and out of that activity stage must be analysed for their GHG emissions.

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

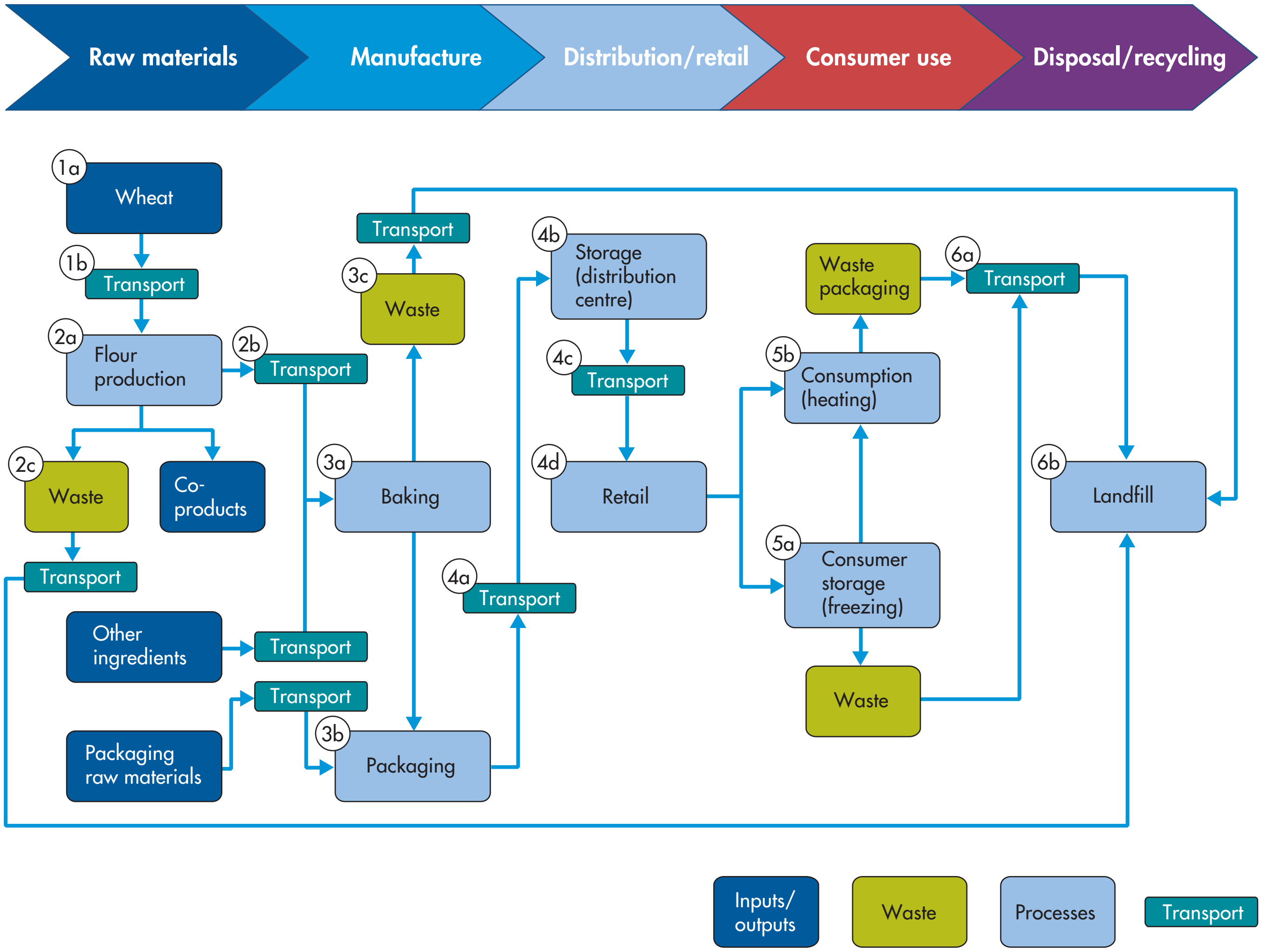
It is easiest to calculate mass balances while the data is being collected. First work backwards from the point of purchase: all materials, energy and direct emissions to produce a unit should be included, and all the mass accounted for. Then use a similar process to ensure the full mass of the product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



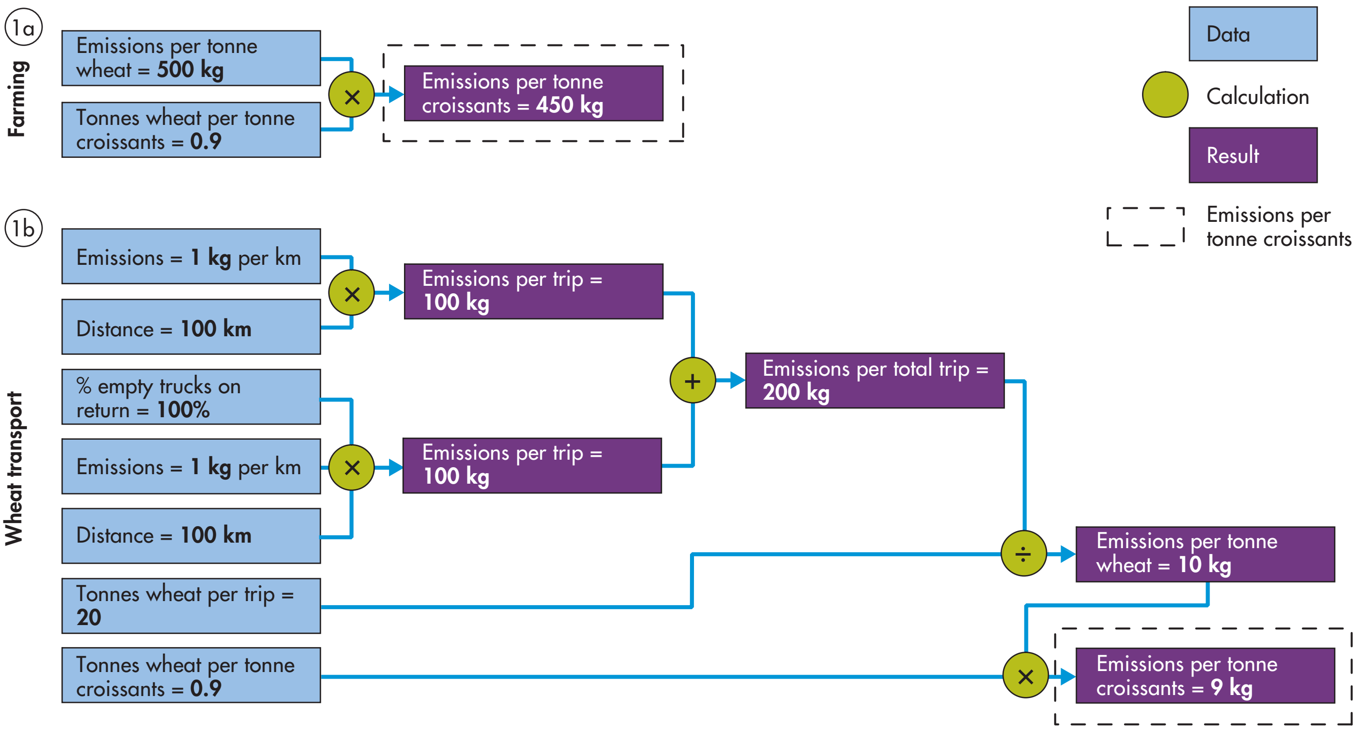
Mass balance example: flour production



Process map: croissants example

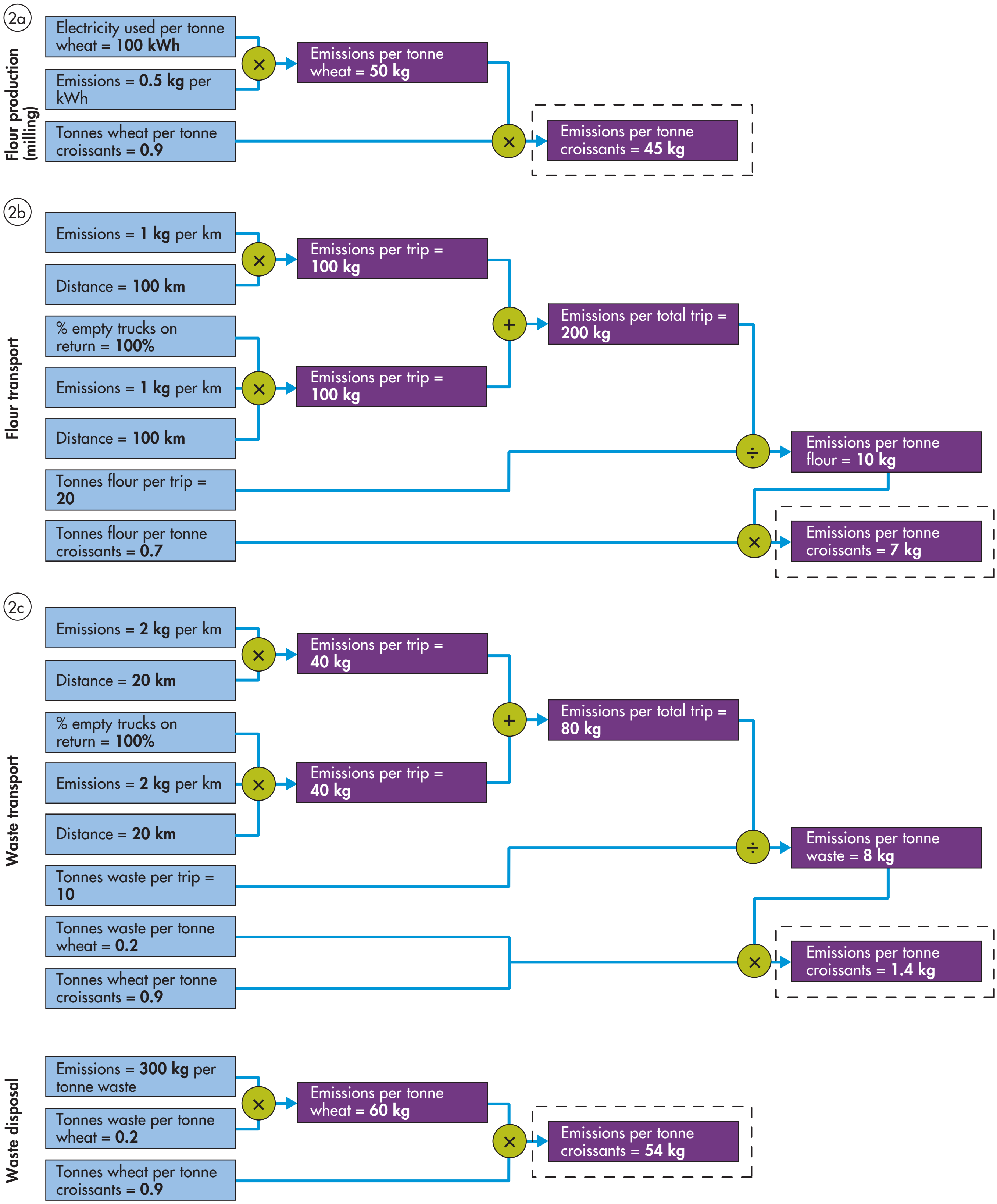
This simplified example aims to build basic understanding of the product footprinting calculation using illustrative values. It does not reflect a complete or fully representative calculation. In practice, software programmes are available – some with data sets attached – that can help with the calculations.

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.



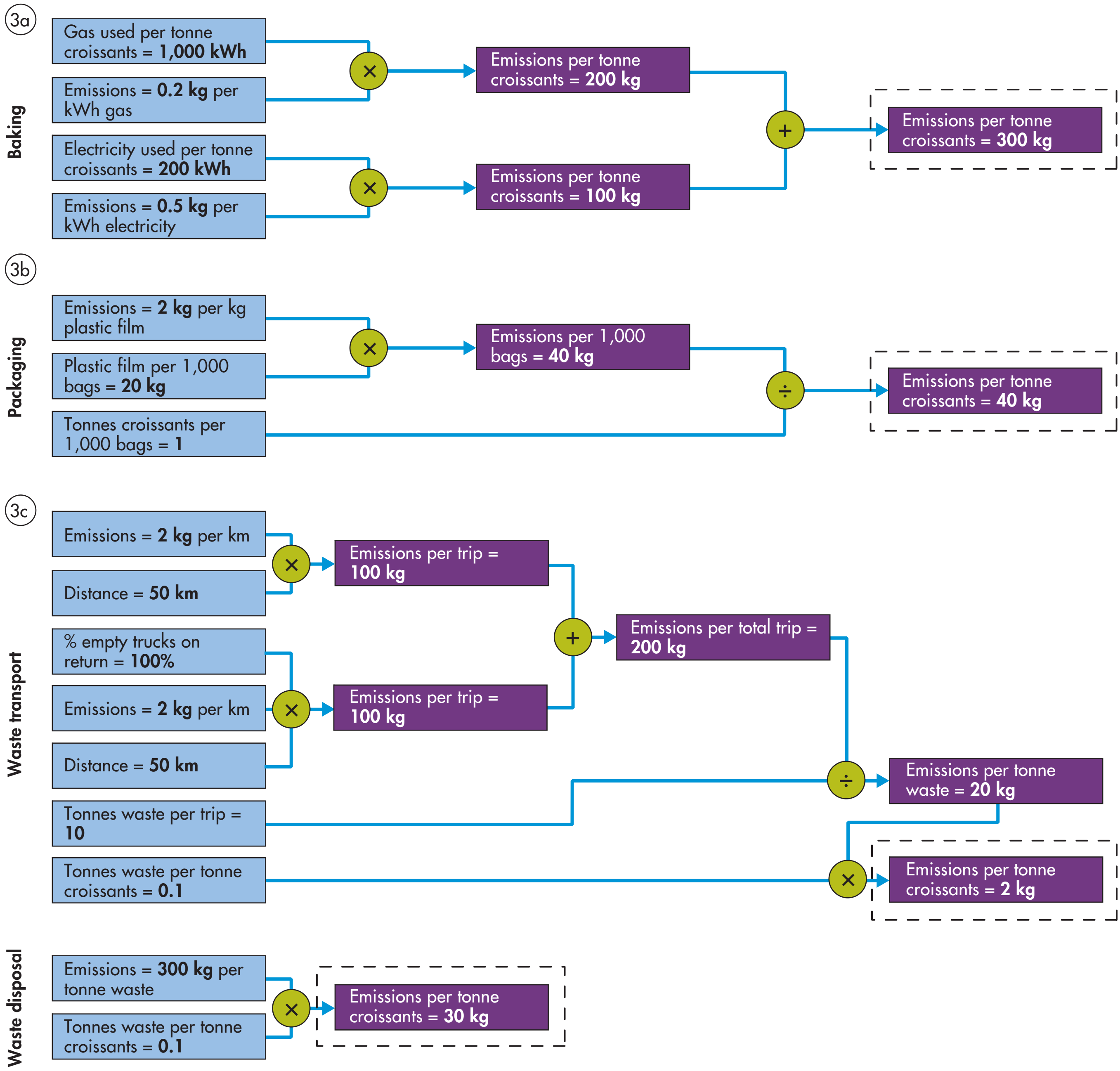
Note: all emissions described in kg CO_2e

Raw material cultivation and transport (wheat example)



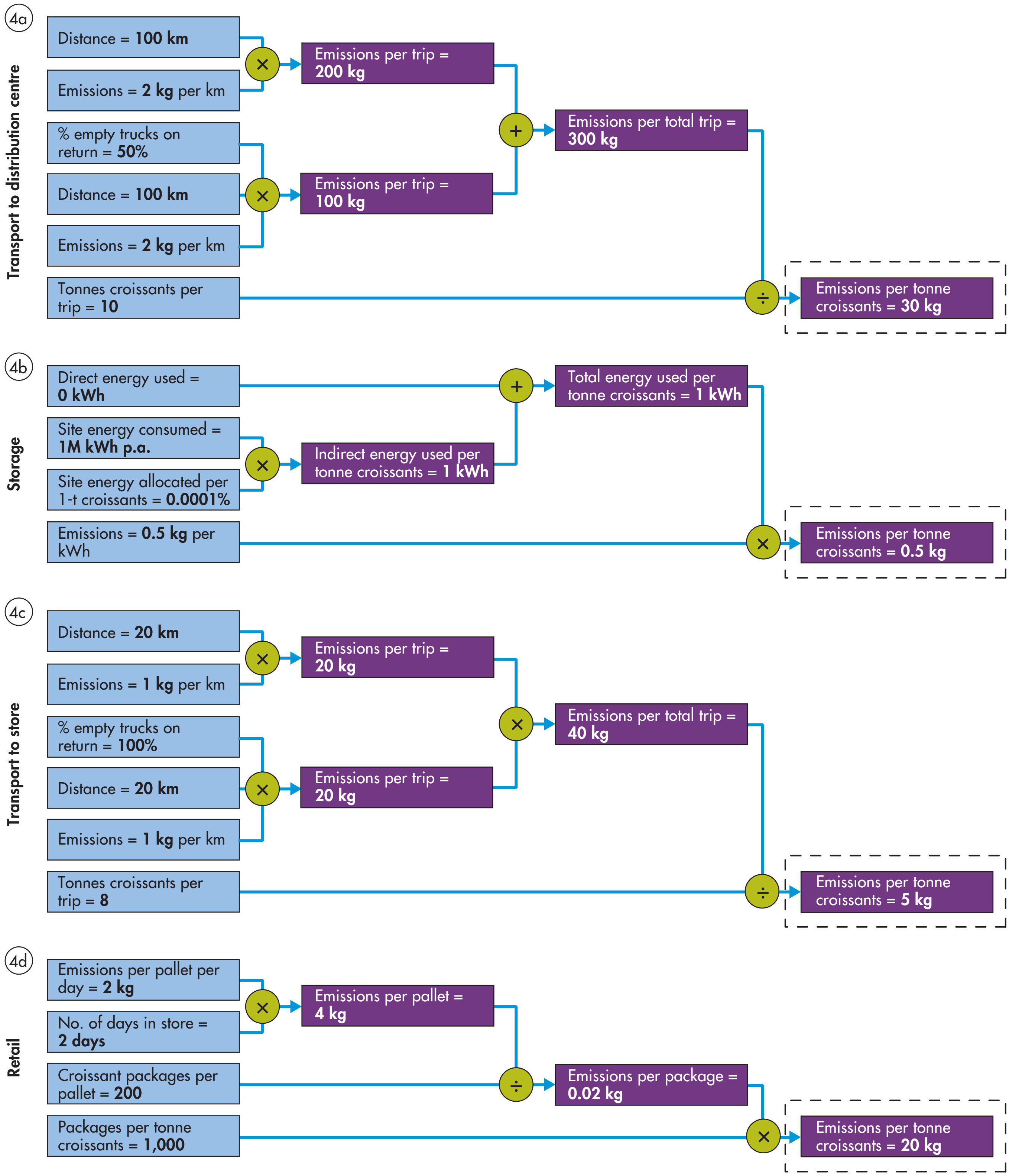
Note: all emissions described in kg CO_2e

Raw material production (flour example)



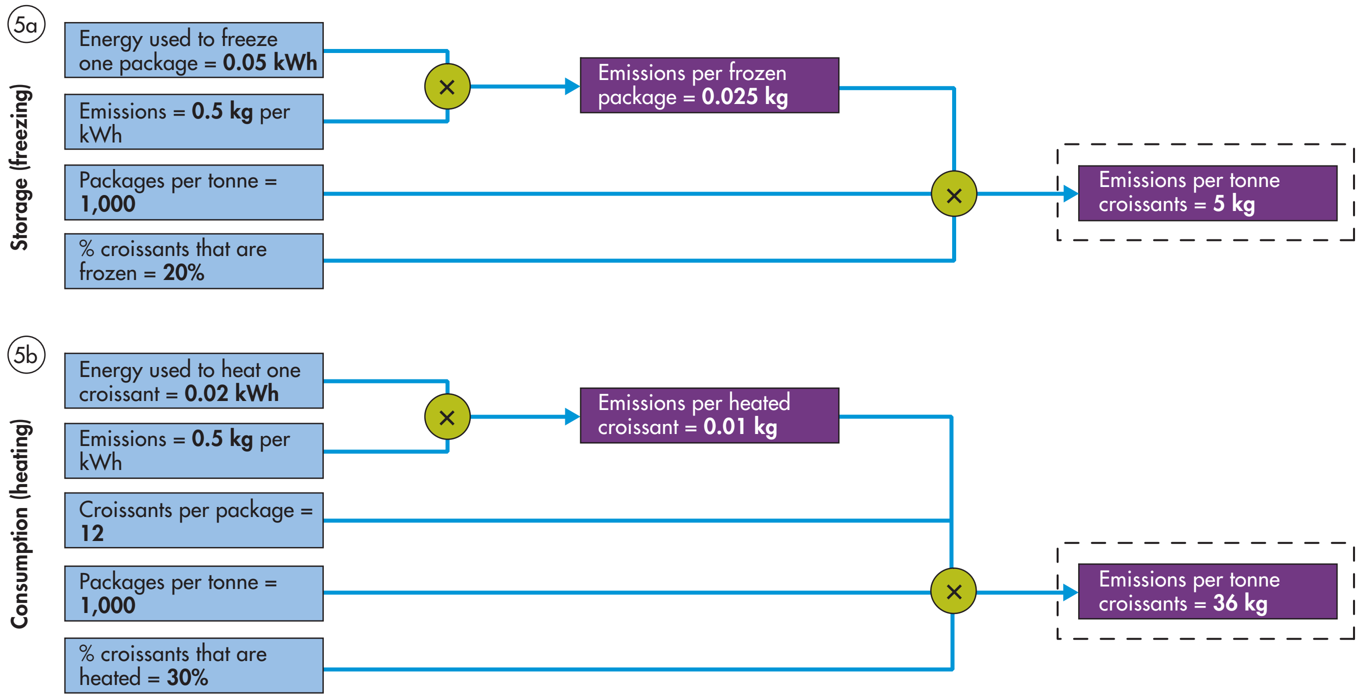
Note: all emissions described in kg CO_2e

Croissant production



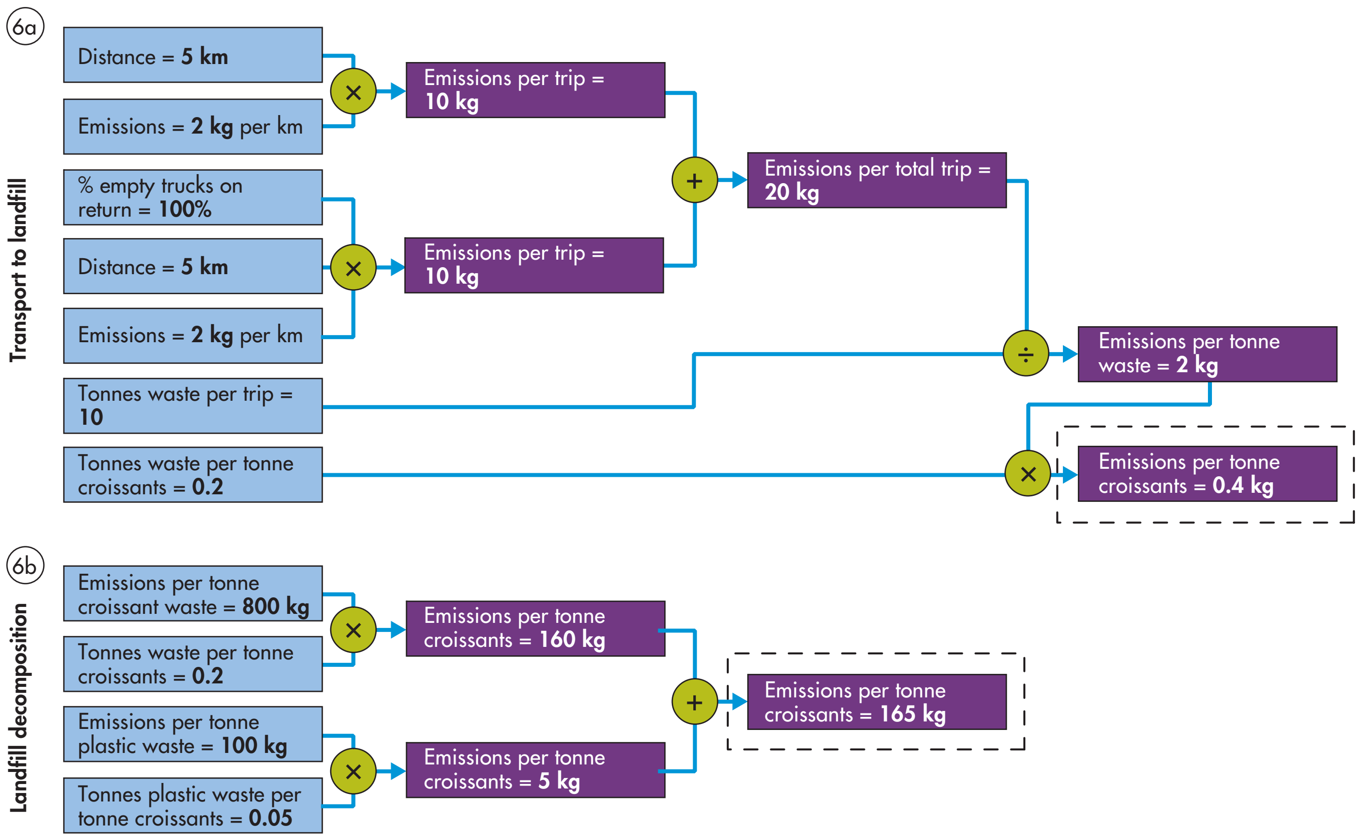
Note: all emissions described in kg CO_2e

Distribution and retail



Note: all emissions described in kg CO_2e

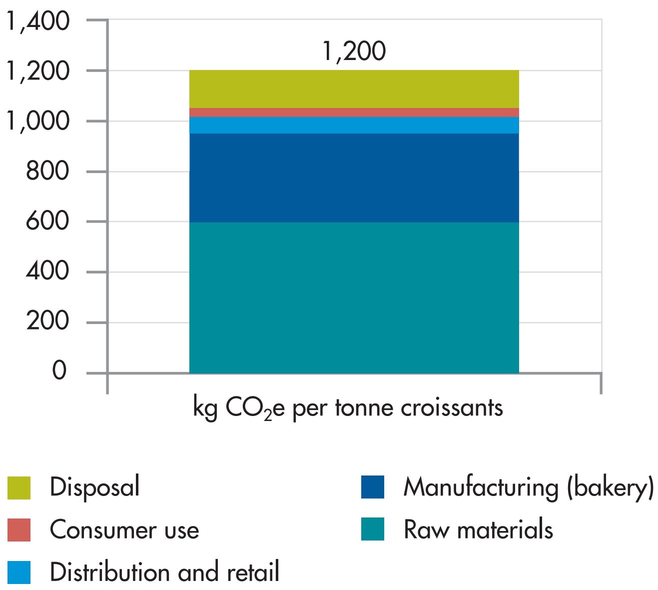
Consumer use



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 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).*

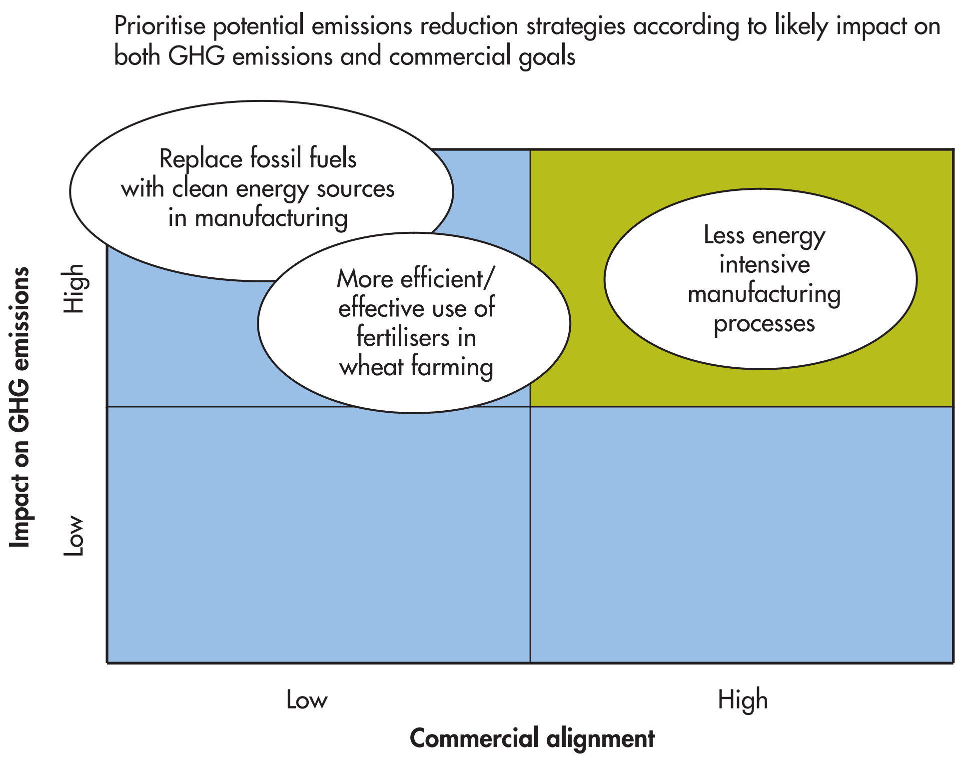
Common emission reduction opportunities

- 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).



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.

[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*.

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

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.

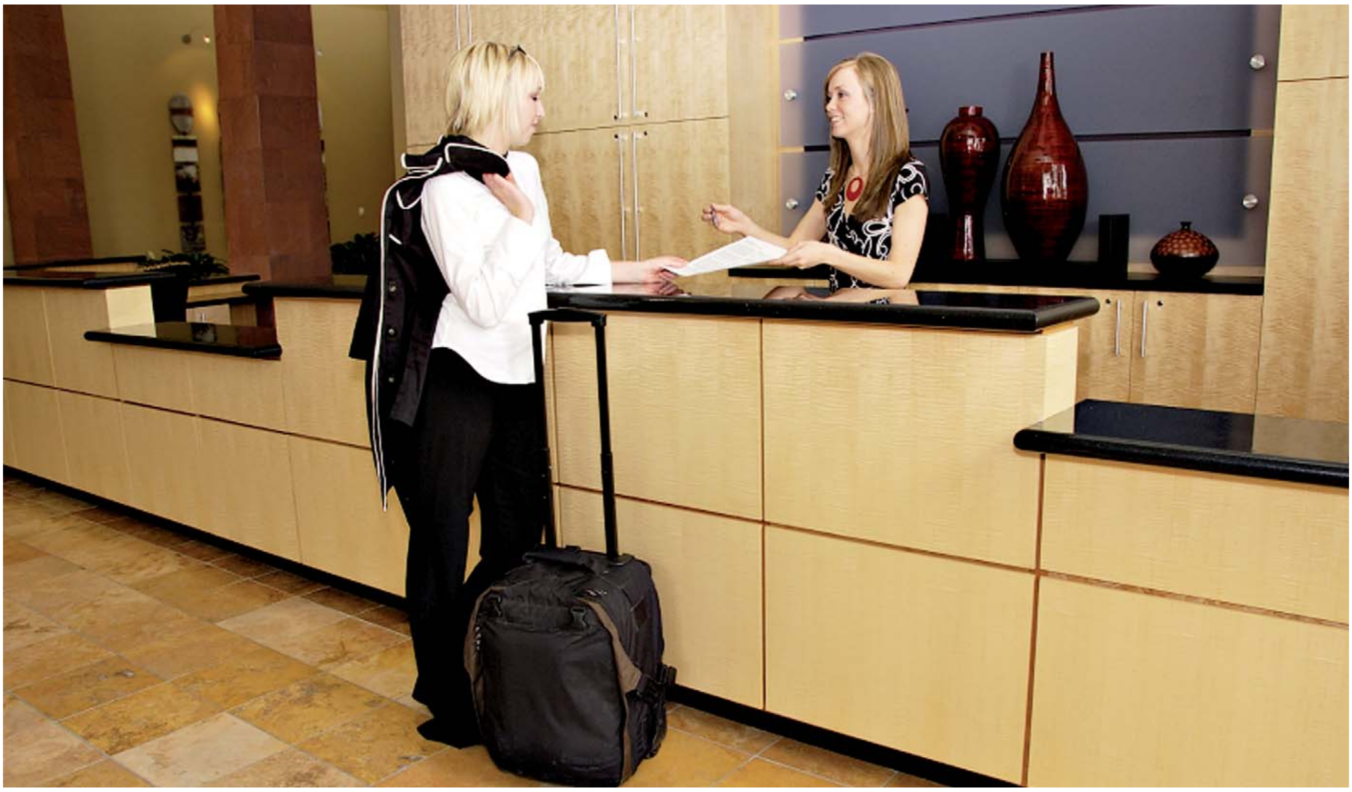
When choosing a service to footprint, try to define it in a way that would be most useful to the company and others using the footprint, i.e. make it:

- 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
- Decommissioning to include the IT equipment and electronic archive of data
- Treatment of waste and capital allocation.

Business travel and embedded emissions in the building and services were considered, but rejected because they are outside the scope of PAS 2050 (see PAS 2050 Sections 6.4.3 and 6.5).

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**

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**

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

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**	

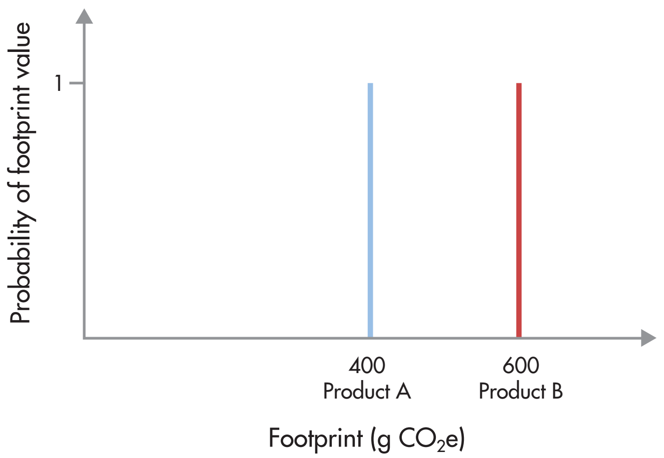
Appendix IV
Uncertainty analysis

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.

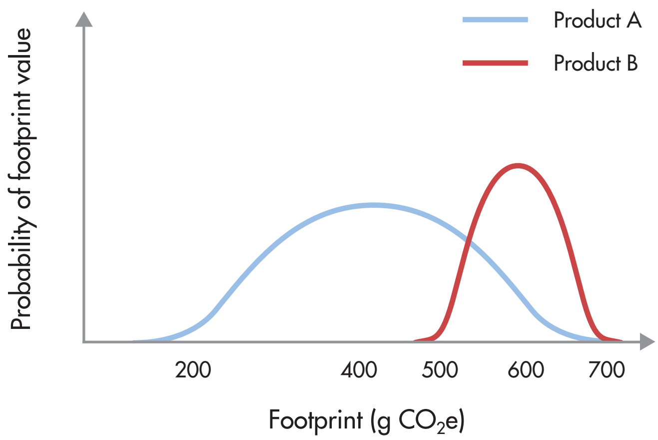
However, uncertainty creates challenges for comparisons and decision making as illustrated below, right.

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