Carbon Footprint Measurement Methodology

Version 1.3
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CARBON TRUST

Making business sense of climate change

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1 Introduction and Background

1.1 The Carbon Trust, through its work on supply chain analysis, has developed a methodology to estimate the total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding in-use emissions).

1.2 The methodology will enable businesses to quantify the emissions across the product supply chain. Through the development of a carbon footprint label to be displayed on products, it will also provide consumers with information on the carbon footprint of a product, which could be used by them to inform their purchasing decision. In the long run, Carbon Trust expects that the development of a carbon footprint label will lead to changes in market behaviour by:

- enabling consumers to differentiate between specific products on the basis of their carbon content and potentially influence switching to other brands;
- enabling consumers to understand which types of products are carbon intensive, and potentially influence changes in their lifestyles;
- enabling companies to compete on green credentials;
- enabling/encouraging companies to improve their efficiency and influence up the supply chain; and
- enabling/encouraging companies to begin to switch away from carbon intensive products.

1.3 Ultimately, this will form part of the Carbon Trust's long term strategy to help business and consumers make the transition to a low carbon economy.

1.4 The methodology outlines a technique for identifying and measuring the individual greenhouse gas emissions from each activity within a supply chain process step and the framework for attributing these to each output product (we will refer to this as the product's 'carbon footprint'). This first draft of the methodology is based on a number of carbon supply chain measuring pilots completed by the Carbon Trust. The methodology tries to strike a balance of being analytically rigorous and at the same time being simple and practical to apply by businesses. It has been developed in conjunction with businesses participating in our pilots and captures the latest thinking on our approach on supply chain analysis. It is therefore currently written in the style of a guide to how the Carbon Trust has applied the methodology in these pilots, not in the form of a publishable standard.

1.5 This is the first step in a long journey. Our vision is to develop this methodology to become the agreed UK standard on how to calculate the carbon footprint of products. It is our intention to develop this methodology into an open standard through a consultation process which will be managed by a panel of experts in this field. This panel will form a Technical Advisory Group (TAG) which will help to develop this methodology further through consultation with other stakeholders and by piloting this methodology further with a number of companies over the next 12 to 18 months.

2 Purpose of the Document

2.1 The main purpose of this document is to provide details of the methodology and its implementation approach for carbon supply chain measurement meeting the Carbon Trust requirements. This document is intended to inform stakeholders about the approach that has been used in the pilots to date, and on areas that will be developed further in the future.

2.2 The document provides details on each of the steps, guidelines for defining a supply chain process map, collecting data and calculating the mass balance and the GHG emissions from each activity within a supply chain process step.

3 Methodology Overview

3.1 Key Steps

3.1.1 The methodology comprises five major steps to enable calculation of the greenhouse gas emissions from the supply chain. The steps should be completed in order although some overlap is possible. Each step comprises several activities and builds on the previous step(s).

Figure 1. Methodology Overview

Step 1	Analyse Internal Product Data
Step 2	Build Supply Chain Process Map
Step 3	Define Boundary Conditions and Identify Data Requirements
Step 4	Collect Primary and Secondary Data
Step 5	Calculate Carbon Emissions by Supply Chain Process Steps

3.2 Units of Analysis

3.2.1 All GHG emissions are measured by mass and are converted into CO2 equivalent emissions using 100-year global warming potential (GWP) coefficients (from the Intergovernmental Panel on Climate Change (IPCC)). For example methane has a GWP coefficient of 23, because 1kg of methane has the global warming potential of 23kg of CO2.

3.2.2 Calculation of greenhouse gas emissions is done at a ‘Product Unit’ level with a product unit defined as the item that can be purchased by the consumer. The ‘Product Unit’ is inclusive of the individual packaging in which the product is sold. To enable comparison across products, the carbon emission can also be calculated in kg of CO2 per kg of product.

3.3 Boundaries

3.3.1 The methodology can cover all supply chain steps from raw material to disposal, and in the pilots to date the analysis has been done for all steps. However, the product carbon footprints used in the product label include steps up to the arrival of the product at the retail store, plus disposal. Emissions in-store e.g. from heating, lighting and refrigeration were not included, although this will be reviewed in future methodology development. The emissions in the use of the product are not included, as the supply chain companies have limited influence in changing use behaviour, and are highly variable depending on the user of the product. Examples of emissions in use include those from the energy used to cook food, to refrigerate a product in the home, or to power an electrical appliance. The emissions from the other steps can be influenced by companies in the supply chain: directly, for steps up to the point of sale, and indirectly for disposal, for example through choice of packaging material. It is proposed that this approach is used in future methodology development. Note however, that the methodology could also be used without the disposal step, for products that are raw materials for other products. In those cases, GHG emission analysis ends at the transfer point of the finished product.

3.3.2 Offsetting of emissions from any part of the supply chain will not be included in the carbon footprint of the product. This is because the aim of the methodology is to provide information on the actual emissions associated with the product supply chain, to enable comparison between products, and to identify potential emissions reductions.

3.3.3 The methodology aims to include all emissions that make a significant contribution to the carbon footprint of the product. In the pilot completed to date, the level of significance was defined by mass, with at least 90% of the mass of the final product being analysed. In future, this criterion may be adapted to be based on likely percentage contribution to the carbon footprint of the final product. This is discussed further in section 4.3.2.1.

3.3.4 Clear accounting rules have been developed for the purpose of carbon attribution and are as follows:

- An input is attributed with zero GHG emissions when it is in elementary form and has not been through any external process transformation e.g. iron ore before it has been extracted.
- All inputs which have been through any process transformation that require an external energy source may have some GHG emissions attributed to them e.g. a field of crops which has been treated with pesticides and fertiliser should be attributed with GHG emissions based on the GHG intensity of the pesticides and fertilisers used.
- An output does not have GHG emissions attributed to it when either:
  - The product becomes the raw material for a new product e.g. when the product is sent to recycling
  - The product reaches a state where it stops emitting carbon e.g. a non-biodegradable plastic sent to landfill does not decay, and therefore does not emit any GHG
  - All other outputs should have GHG emissions attributed to them unless/until they fulfil one of the two above criteria
- Where a process has more than one useful output (co-product) then this should be valued, either through allocation (splitting of upstream emissions) or through substitution (giving a credit to the primary product).
- A unit process GHG emission is not attributed when it is indirectly impacting the supply chain e.g. emissions during commuting to a factory by workers is not attributed to the product. However all direct processes should be included in the analysis.

- Embodied energy, i.e. that used in the manufacture of process equipment, or in building construction, will not be included, as this is likely to make a small contribution to overall emissions.

- No reference systems have been included in the pilots, and it is proposed that, in general, these should not be used. For example, in agriculture, change in land use or alternative current uses of the land will not be considered. Similarly for waste, avoided alternative disposal methods will not be included. However, it may be necessary to use these for particular products, for example where there is a significant likelihood of impacts from land use change.

3.3.5 Beyond these general principles for all products, there may be specific requirements for boundaries to be set for particular products. Further information on this is given in section 4.3.2.

3.4 Limitations of Analysis

3.4.1 Given that this methodology is intended to be applied widely by industry, rather than as part of an academic study, it focuses on the most important steps across the supply chain and allows for use of secondary data (i.e. from secondary sources) where collection of primary data (i.e. actual data collected from supply chain) is not feasible.

3.4.2 As the primary purpose of the methodology is to measure the primary sources of GHG emissions, it does not enable the following:

- In depth understanding of GHG emissions from each raw material or individual process

- Identification of GHG emissions from activities that are not normally part of the supply chain process map (i.e. activities which are required only in exceptions)

- Calculation of the differences in GHG emissions from using all alternate supply chain options (i.e. the analysis focuses on the process map for the most common supply chain used by a company for the product in question). This options analysis may be completed as a secondary step

3.4.3 Exclusion of the emissions associated with a product's use is a limitation of the methodology, but impacts upon some products more than others. For all products, the emissions depend on the way the consumer chooses to use them, and therefore can be difficult to reflect in a carbon footprint figure. However, for products that do not use energy, and do not produce emissions directly, the uncertainty in in-use emissions may outweigh the value of including them. For appliances using energy, emissions in use could be large, and can be an important industry driver and purchase criterion. However, consumer information on energy use by appliances is available through other labelling schemes[1]. For fuels, the emissions in use are very important, and as a result we do not plan to apply the methodology to fuels at this stage. For transport fuels, this is being addressed at an EU level[2].

[1] For example, the EU Energy Label, and the Energy Saving Trust's Energy Saving Recommended label

[2] The European Commission has recently published a proposal for amending the Fuel Quality Directive, which would require transport fuel suppliers, among other things, to achieve annual reductions in the lifecycle greenhouse gas emissions associated with their fuels. Details of the proposal are available at: http://ec.europa.eu/environment/air/pdf/fuel/com_2007_18_en.pdf

3.4.4 The methodology can calculate the emissions for all steps of a product's lifecycle. However, in practice, any emissions arising after the carbon footprint value has been printed on a product label will necessarily be average figures: one product type will be transported to retailers in different locations, stored and displayed in retail stores with different heating/cooling and lighting requirements, and disposed of in different ways. This means that the methodology and label will not capture differences in practice between retail stores, or differences in how consumers choose to dispose of the product and so will not drive emissions reductions in these areas. Note that the methodology used for the pilots to date does not include emissions at the retail store, and this will be addressed in future methodology development.

4 Methodology Details

4.1 Step 1: Analyse Internal Product Data

4.1.1 **Objective for the step:** Develop deeper understanding of the product including raw materials required, production activities needed for converting the raw materials into the finished product, waste and co-products produced, and the storage and transportation required between each process step.

4.1.2 This will require input from internal sources to gain a preliminary overview of the product lifecycle. Suitable internal sources for this may include the product technologist, production manager and head of logistics and distribution.

4.1.3 Internal data collection should start by obtaining a breakdown of the product by mass (often available in recipe format). Recipe details, along with individual packaging format, material and mass will allow an initial prioritisation of effort so that the most significant raw materials are analysed first. Other key data points which are required to construct the process map and are often available internally include:

- Details of manufacturing processes carried out internally
- Storage conditions at each supply chain step
- Transport of the final product

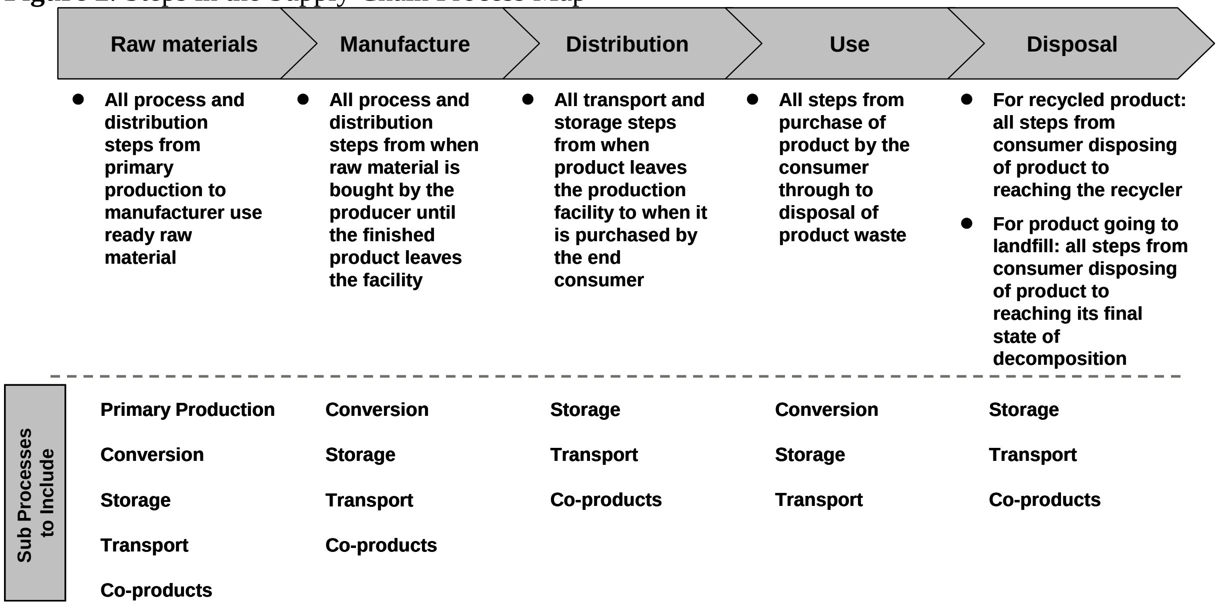
4.1.4 For the raw material stage in the supply chain there is often less internal data available. There is limited information on the manufacturing process steps needed to produce the raw materials and the distribution of raw materials to the manufacturing sites. However, raw material buyers may be able to provide enough detail for the purposes of drawing the process map and they should also be able to provide contacts at the raw material suppliers who should be consulted for further process information. It may also be necessary to consult these suppliers when data is being gathered to calculate the GHG emissions footprint.

4.2 Step 2: Build Supply Chain Process Map

4.2.1 **Objective for the step:** Define the Product Supply Chain Process Map which will identify all inputs, outputs and unit processes that will be analysed as well as forming the basis for data collection and for mass balance calculation.

4.2.2 The simplified supply chain process map might cover the following steps:

Figure 2. Steps in the Supply Chain Process Map



4.2.3 The process map should include every significant process step and raw material. Each raw material might be a finished product from another supply chain; e.g. sugar is an input for making chocolate, but sugar is a finished product which has been manufactured from sugar cane. Therefore, in order to ensure that every relevant process step is included, each raw material process needs to be detailed back until it is possible to identify primary raw materials which have zero associated GHG emissions.

4.2.4 When constructing the process map it is important to use a structured approach which helps to avoid missing important process steps and working both forwards and backwards from the final product unit is a good way to avoid missing any steps.

4.2.5 As an additional method of including all relevant steps, it is helpful to work through each possible sub-process within each supply chain area:

1. **Primary production** – the initial production of raw materials e.g. farming or mining (primary production can only take place at the raw materials step)
2. **Conversion** – the conversion of materials from one product to another (can be applicable in the pre-processing of raw materials, in manufacturing, or in use)
3. **Storage** – the storage of raw materials, semi-processed materials, finished product or waste at any stage in the supply chain
4. **Transport** – the transportation of raw materials, semi-processed materials, finished product or waste at any stage in the supply chain
5. **Disposal** – the disposal of waste products from primary production, conversion or after use (such as decomposition in a landfill site)

4.2.6 Each sub-step may be repeated several times within a supply chain step, in any order, and it is important to take multi-step processes into account. This repetition of steps is particularly likely in the distribution stage, e.g.: Transport to retail distribution centre → storage at retail distribution centre → transport to wholesaler → storage at wholesaler → transport to retailer

4.2.7 This stepwise approach to mapping the supply chain is repeated until all inputs have been traced back to their ultimate source and all outputs have been tracked until they have stopped attributing GHG emissions to the final product unit.

4.3 Step 3: Define Boundary Conditions and Identify Data Requirements

4.3.1 **Objective for the step**: Identify and define the boundary conditions which should be followed for the product. Identify the data required for building the product mass balance and carbon footprint as well as identifying the potential sources for each of the required data points.

4.3.2 **Boundaries:** It is critical that appropriate boundary conditions are defined. It will also be essential that the value of other products produced in the supply chain (co-products) is taken into account.

4.3.2.1 **Input Boundaries** - For the pilots completed to date, a sufficient number of input raw materials was analysed to ensure that at least 90% of the mass of the final product was being analysed. This approach was used as the pilots focused on the principal supply chain steps for the product being analysed, and had a limited timeframe.

4.3.2.2 However, for the methodology to be applicable to, and robust for a wider range of different product types, it will be important that all inputs having a significant contribution to the GHG emissions of the finished product should be included. A defined level for this could be developed, for example, 95% of the likely emissions must be accounted for, with the remaining 5% consisting only of inputs with contributions of less than 1%. In order to assess which inputs might have significant emissions, without having to undertake detailed analysis for each, it is envisaged that the Carbon Trust could gather data associated with inputs, to build up lists of inputs that can be excluded, and those that must be included. For example, embodied energy can be excluded, but inputs from processes using high GWP gases should be included. In the case of the pilots completed to date, inputs that have been included are given below:

- Raw material analysis should include all processes used in transformation of the raw material into an input which is ready for manufacture, up to a level where there is confidence that at least all major sources of energy consumption or direct GHG emissions have been included. This analysis would require inclusion of:
    - GHG emissions from farming, mining or extracting the raw materials, including the use of fertilisers, pesticides and irrigation as well as direct emissions from machinery and energy intensive atmospheric growing conditions.
    - GHG emissions from the recycling process of recycled materials, starting at the point of disposal of an output from another supply chain. The recycling GHG emissions would thus include transport from the disposal site to the recycling plant and GHG emissions from recycling.
    - Any pre-processing stage requiring direct energy that the raw materials undergo to transform them into inputs ready for manufacture.
    - The transport and storage of raw materials up until they are used in manufacture.
    - Waste generated at each stage of the production and pre-processing of raw materials.
- Raw material GHG emissions that have **not** been included are:

- GHG emissions from very minor raw materials which make up small fractions of the total weight of the product. Emissions for these raw materials may still however be calculated, based on the average of other similar raw materials. Note that in future methodology versions, the criteria for exclusion may be based on the raw materials' emissions, rather than on mass, as above.

- Human energy consumption in production of raw materials (e.g. if fruit is picked by hand rather than by machinery) and pre-processing or energy from natural sources (e.g. sunlight).

- GHG emissions from the initial manufacture of a recycled material used as a raw material input, before it is transported for processing.

• Other inputs may be required later on in the supply chain during the distribution and disposal stages. Only inputs that are directly required for the distribution or disposal of the product should be included: e.g. the liquid nitrogen used for storing a product at a low temperature should be included.

4.3.2.3 **Output Boundaries** - GHG emissions from outputs should be included up to the point where:

- The product or co-product becomes the raw material for a new product e.g. when the product is sent to recycling or when a co-product is used in another supply chain. Instead GHG emissions should be attributed to the new product in which the useful by-product is being used as a raw material.

- The product or waste reaches a state when it stops emitting carbon. However, the GHG emissions of any waste (non-useful co-product) produced in the manufacture of the product should be attributed to it, e.g. GHG emissions from transporting waste to landfill and GHG emissions from the waste whilst in the landfill site should be attributed to the product.

4.3.2.4 **Co-products** - Many processes involving conversion of materials have more than one useful output, or co-product. In the pilots completed to date, many of the processes are optimised for the primary product. As a result, to reduce complexity, no 'value' in emissions terms was given to the co-products. However, in future methodology development it will be essential to value co-product production assessing GHG emissions associated with a product, both to avoid over-estimation of emissions for the product, and to enable the carbon footprint value for the co-product to be used as an input to separate co-product supply chain analyses.

4.3.2.5 This can been done in two principal ways: through allocation (dividing up all upstream emissions between the products produced based on their energy content, price or mass) or by substitution (also called system expansion – considering what emissions the use of the co-product is displacing, and giving a credit for this to the primary product). System expansion is currently favoured by some Life Cycle Assessment (LCA) experts, and is recommended where possible by ISO 14040, as it gives more information about the consequences of particular activities. However, allocation has been found to be more appropriate where raw materials and products need to have a GHG intensity attributed to them, so that this information can be used in trading, or as input to other supply chains' GHG analyses. It may therefore be the most appropriate approach here, with the requirement for allocation based on price, mass or energy content being made as appropriate to the product considered. This is an area that will need further analysis in the course of Carbon Trust's methodology development.

4.3.2.6 **Process Boundaries** - Only processes that are directly attributable to the product should be included. These include:

- Growing and pre-processing of relevant raw materials, (relevant raw materials are identified using the input boundary conditions above);
- Production and manufacturing of packaging materials, (relevant packaging materials are identified using the input boundary conditions above);
- All manufacturing processes which are used to produce the final product. This includes processes which must occur due to the manufacture of the product, e.g. cleaning of the manufacturing vessel after use;
- Transport of all raw materials and packaging materials, and intermediate products;
- Storage of the product at the manufacturing plant, in a warehouse and transport of a product between these points; and
- Processes used in the disposal of the product, e.g. transport to landfill and processing at landfill.

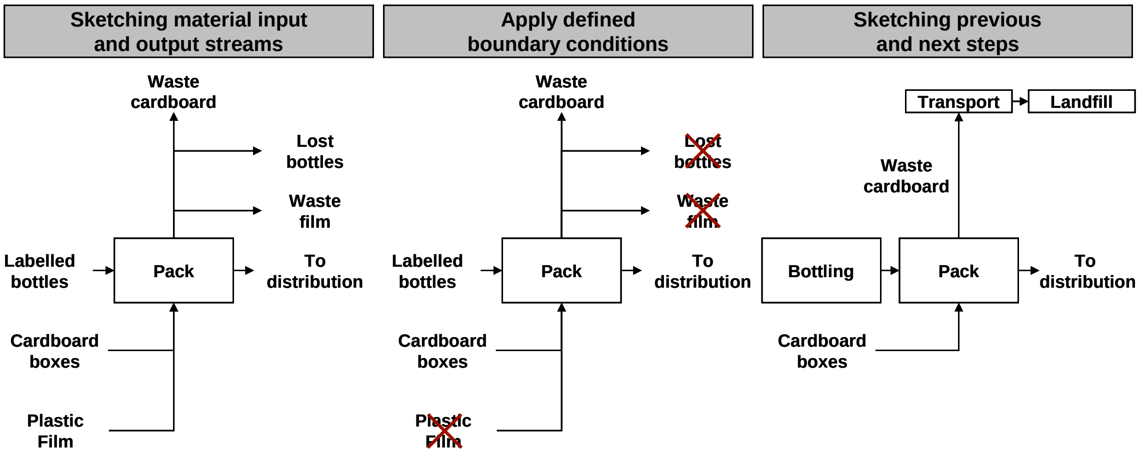
4.3.2.7 Processes that can only be indirectly associated with the product have not been included. These include, for example:

- Transport of workers to the factory;
- Transport of consumers to the shop to buy the product and transport of the product to the consumer's home: it is unclear how GHG emissions should be attributed if the consumer is buying more than one product, and/or making the transport step for reasons other than purchasing products; and
- Lighting and heating of factories where many other products are also being made has been excluded in pilots completed to date, but may be included in future methodology versions. Heating and lighting have, however, been included if a product is being stored in a warehouse.

4.3.2.8 Additionally, all GHG emissions from the manufacture and ongoing maintenance of capital goods, such as plant machinery, transport equipment etc, used in the manufacturer of the product are excluded from the calculation.

4.3.2.9 In order to apply boundaries to inputs, outputs and processes, all material input and output streams for the process first need to be sketched. At this point, some input and output streams can be eliminated because they are a very small proportion of the final product mass (in future those may be excluded that have very low contribution to the GHG intensity of the finished product). When working backwards from the final product unit in the supply chain, the next previous process step is mapped for all inputs. Process steps for co-products and waste may also need to be mapped.

Figure 3. Constructing Stepwise Process Map



4.3.2.10 A similar methodology is applied when working forwards from the final product unit with the next process step being mapped for all outputs during the disposal stage.

4.3.2.11 For each input, output and process identified once boundary conditions have been met, data is required to calculate the mass of inputs and their corresponding outputs, as well as the energy used in each process and the associated GHG emissions.

4.3.3 Data Requirements

4.3.3.1 Sufficient data at each process step must be collected to construct the mass balance and the carbon footprint.

4.3.3.2 To construct the mass balance, the mass flow of all major input and output streams per accounting unit (e.g. kg sand / kg glass produced) is essential to enable emissions at each step to be assessed on a comparable basis.

4.3.3.3 GHG emissions may be directly released into the atmosphere at the site of the process e.g. chemical reactions emitting GHGs, livestock methane emissions, refrigerant loss etc. Alternatively GHGs may be emitted to the atmosphere due to consumption of energy (e.g. fuel being burnt for transport, grid electricity, natural gas etc). In this case, a conversion factor into GHG emissions based on the life cycle of the specific energy source should be calculated (e.g. grid electricity GHG emissions will be dependent upon the energy source used for electricity generation and the losses occurring when distributing the electricity through the grid). Secondary data sources exist which provide emissions coefficients for kg CO2 emissions per kWh for a number of energy sources.

4.3.3.4 To enable measurement of GHG emissions, data on energy consumption and/or direct emissions needs to be collected at each process step. The first data to collect is the type of energy that is being consumed, or gas that is being emitted. This can be separated into three main categories:

1. Energy from electricity
2. Energy from fuel (e.g. gas, diesel, gasoline, biomass etc)
3. Direct gas emissions

4.3.3.5 The data required and the emissions coefficients vary depending on what type of energy is being used and the type of direct gas that is being emitted.

4.3.3.6 **Data requirements if energy source is electricity**

1. Process level energy consumption from each energy source (in kWh / kg of product produced)
2. If grid electricity is being used, the emissions coefficient in kg CO_2 per kWh in the specific country which is supplying the electricity (the carbon intensity of grid electricity varies greatly across countries). If an electricity tariff with a different emissions coefficient is being used, for example a renewable tariff, this figure could be used. Note that the current proposal is only to allow this in the UK if the Renewables Obligation Certificates (ROCs) and Climate Change Levy Exemption Certificates (LECs) associated with the renewable electricity generation are retired, or if equivalent additionality criteria are met if outside the UK
3. If a plant/organisation is generating its own electricity, (e.g. from an onsite CHP plant or other energy source), or buying in steam, the emissions coefficient in kg CO_2 per kWh should be determined in consultation with the plant/organisation

4.3.3.7 **Data requirements if energy source is fuel**

1. Type of fuel being used (e.g. natural gas, diesel etc)
2. kg/litres/energy content of fuel consumed per kg of product produced
3. The emissions coefficient in kg CO_2 per kg/litre/energy unit based on the type of fuel being used

4.3.3.8 **Data requirements if direct gas emissions are being produced**

1. Type of emissions (CO_2, CH_4, N_2O, also potentially SF6, HFCs, perfluorocarbons)
2. kg of gas emitted per kg of product produced
3. The GWP of the gas to allow conversion from kg gas to kg CO_2

4.4 Step 4: Collect Primary and Secondary Data

4.4.1 **Objective for the step:** Collect the data required to develop the Mass Balance and calculate the GHG emissions from each process step

4.4.2 Approach for initial data collection

4.4.2.1 Primary data sources are preferable to secondary data sources, if energy requirements/GHG emissions can be measured accurately, because primary data will reflect the specific nature/efficiency of the process. This will also more accurately reflect the relevant GHG emissions at the manufacturer of the product in question. Increased use of primary data will also lead to an increased identification of potential for GHG emissions reductions.

4.4.3 Collecting Primary Data

4.4.3.1 Primary data could be collected internally by the company or by a third party advisor. In both instances it is useful to introduce the project to supply chain contacts in the organisation itself and to any raw material suppliers before contacting them to request data. Once an introduction has taken place, a clear data request outlining the exact information that is required, and the format in which it is needed, will ensure that the contact is well informed about the type of data that they should be providing. In the longer term, raw material suppliers could use this methodology to determine the GHG emissions of their products, and therefore provide the company with all upstream information. This would allow the raw material suppliers to compete in terms of GHG intensity.

4.4.3.2 When collecting primary data, top down energy and production data at a plant level can be used if the specific process being analysed can be isolated (e.g. the plant manufactures only one type of product and therefore all products have the same energy requirements).

4.4.3.3 Otherwise, it may be possible to obtain bottom up estimates for energy requirements/GHG emissions in cases where individual pieces of equipment can be monitored/metered for a set period of time. This method may be appropriate, but care must be taken that the result will be representative of an "average product unit" (e.g. the energy requirements of a refrigeration unit in August will not be representative of an annual average energy requirement). If individual processes are being metered, it is important that every relevant process in the factory is taken into account in the bottom up calculations (e.g. sanitisation of manufacturing vessels).

4.4.4 Collecting secondary data

4.4.4.1 Where accurate primary data is not available secondary data sources may be considered.

4.4.4.2 The Carbon Trust's aim could be to build up a set of recommended data, which can be used where primary data is not available. If companies wanted to use other secondary data, this would be possible, as long as they provided justification of why this was appropriate. In addition to this, one option would be only to allow companies to use secondary data for smaller contributions to their product GHG intensity, and require primary data for the steps with the largest emissions. For example, a drinks manufacturer being required to use primary data for the drink's ingredients, transport etc, but being allowed to use secondary data for the paper for the label.

4.4.4.3 Often this data will be in the form of generic coefficients for a given process. Therefore in order to retain accuracy, it is important that where secondary data is used, it is as specific as possible to the relevant process step.

4.4.4.4 It is equally important to research the exclusions and limitations that secondary data may have, by contacting the research body, or referring back to the original source of the data when it is quoted elsewhere. This is particularly important when life cycle analysis for a given raw material is being used as part of the calculation. Triangulation of the data point should be done where possible to ensure accuracy and to give a feel for the uncertainty regarding a given calculation. For a figure to become part of a Carbon Trust recommended data set, it is likely that consultation with the Technical Advisory Group and industry stakeholders would be needed. The Carbon Trust also plans to build upon other existing

LCA databases for imputing the material and energy inputs associated with various commodities.

4.4.4.5 Note also that there are some key pieces of secondary data, such as emissions coefficients for fossil fuels, GWPs of GHGs, and the carbon intensity of the UK grid mix that are a) very important to consistency across different products and companies and b) very difficult for an individual company or consultant to establish. The future methodology may include a list of sources for these key pieces of data, and a process to update them as required.

4.5 Step 5: Calculate GHG Emissions by Supply Chain Process Steps

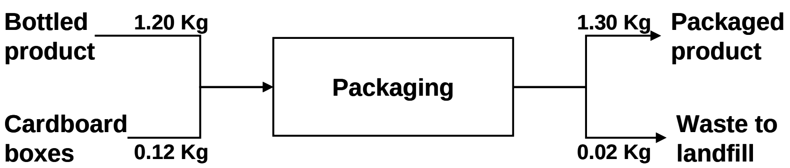
4.5.1 **Objective for the step:** Develop model to calculate the mass balance and the GHG emission from each process activity step.

4.5.2 Calculating the Mass Balance

4.5.2.1 Once the process map is complete and data has been captured for every process step included in the process map, a mass balance should be constructed which will track the flows of materials through the process map required to produce one final product unit. In a similar manner to constructing the process map, the mass balance is best completed in a structured stepwise manner working outwards from the final product unit. All process steps which have more than one input or output should have a mass balance step constructed. It is important to include small waste streams as many small losses across the supply chain may have a significant cumulative effect once aggregated.

4.5.2.2 Each mass balance step should be considered as having its own system boundary. Once inside the system boundary, mass cannot be created or destroyed. In terms of mass: Input = Accumulation + Output.

Figure 4. Illustrative Mass Balance Step



Input	=	Accumulation	+	Output
1.32	=	0	+	1.32

4.5.2.3 Once the mass balance stepwise methodology is repeated for the entire process map, the mass of each ultimate raw material is known per product unit, and the mass of waste and/or by-product produced at each process step per product unit is known.

4.5.3 Calculating GHG Emissions

4.5.3.1 The methodology for calculating CO2 equivalent emissions for a product unit is as follows:

1. Energy data obtained through primary or secondary research is often collected in the form of (or can be manipulated into) kWh per kg of product produced. Data on direct GHG emissions should be collected in the form of kg gas per kg product produced.

2. Using emissions coefficients for the energy source used, or the type of direct gas being emitted, the data can be converted into CO_2 equivalent emissions per kg of product produced.

3. The mass balance results at the relevant process step can then be used to calculate CO_2 emissions per product unit for each process step. This will include allocation or substitution to account for co-products.

4. The CO_2 emissions can then be scaled to account for the minor raw materials that were excluded from the analysis. To estimate the emission for the minor raw materials use the average emission from the other raw materials and adjust it for mass. Note that this step will not be required if minor raw materials are excluded on the basis of emissions, rather than mass.

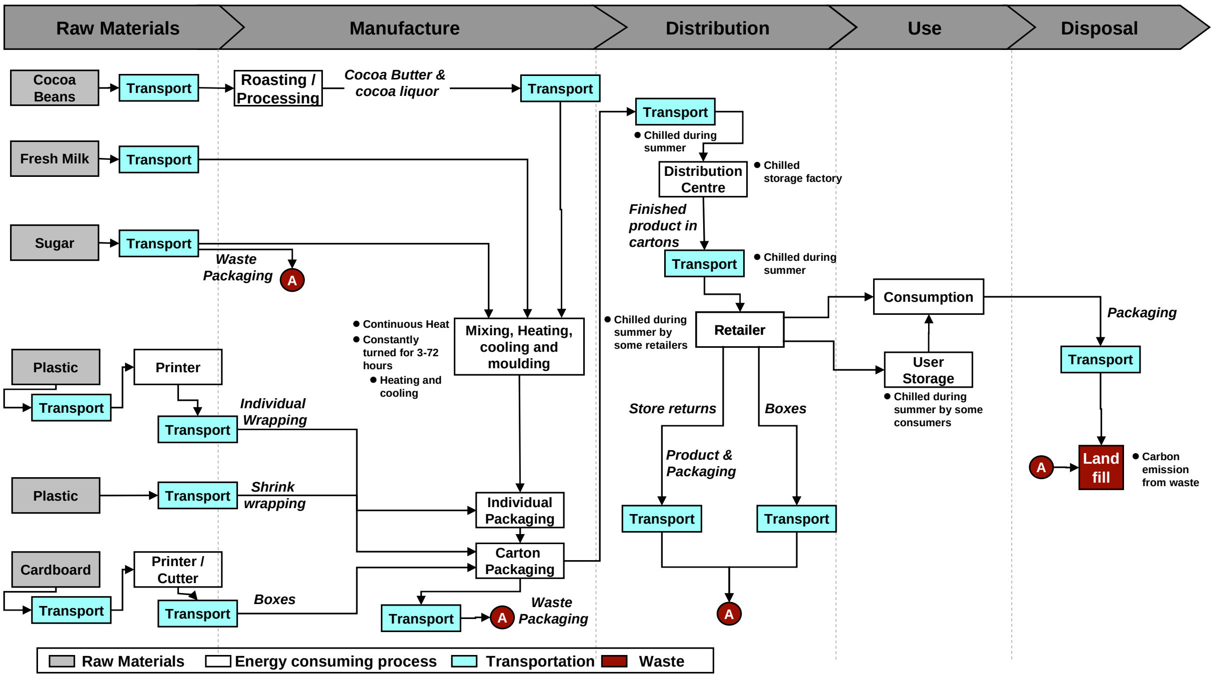
5. After the CO_2 equivalent emissions have been calculated for each individual process step, the results can be added together to obtain an overall carbon footprint in terms of CO_2 equivalent emissions per product unit for the entire product supply chain.

5 Best Practices and Learning

5.1 Process Mapping

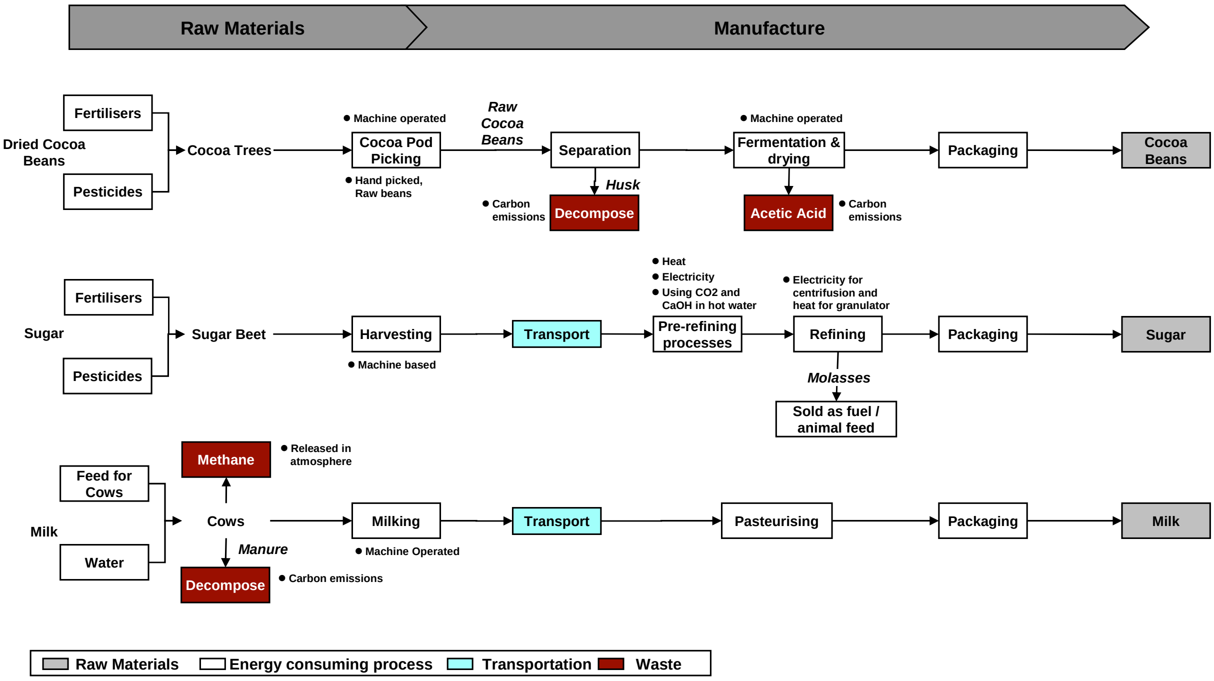
5.1.1 Process mapping is an iterative process which should be done with the input of all key stakeholders. The process map is a very useful document for explaining the background behind the project to buyers, technologists, marketing departments etc as it allows people to understand where their department fits within the supply chain and how their input will contribute to an overall carbon footprint rather than be used in isolation.

Figure 5. Illustrative example of part of a process map



5.1.2 To provide a full and complete process map, each raw material depicted requires its own process map characterising the required steps from "ultimate raw materials" to the raw materials depicted here.

Figure 6. Illustrative example of a raw material process map



5.2 Data Collection and Validation

5.2.1 On some occasions there are no relevant external sources for the calculation of energy consumption, and sub-metering is not possible. In these instances bottom-up calculations based on first principles may be necessary to estimate the energy requirements of a process. Factors such as the efficiency of the equipment being used must also be taken into consideration to align the answer more closely with what is likely to be the case in reality.

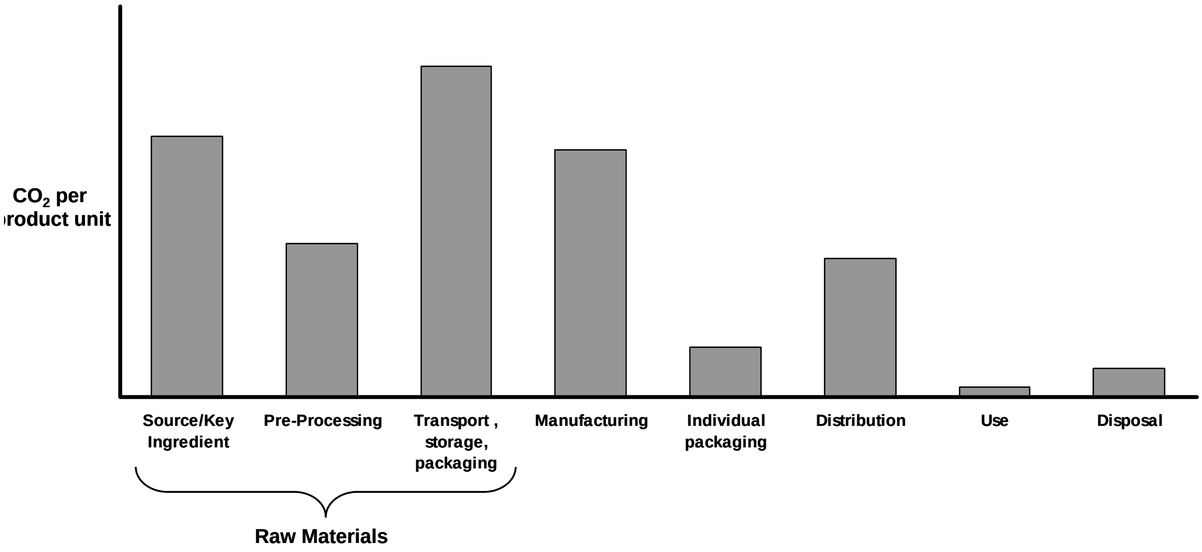
5.2.2 However they are obtained, data points should be triangulated in order to build confidence in their accuracy. Where secondary sources and bottom-up calculations are used, it is worthwhile communicating the methodology and findings with the relevant knowledgeable people within the supply chain as another route of triangulation.

6 Using the Carbon Footprint Calculation Output

6.1 Approach for Analysing Output

6.1.1 Output can be analysed on a process step basis as the data permits. It may also be useful to gain an overall perspective on how different sections of the supply chain contribute to the total carbon footprint and therefore help focus efforts for GHG emission reduction initiatives. Groups of process steps need not be constrained to raw materials, manufacturing, distribution, use and disposal but may take the form of groupings which may be easier to identify with.

Figure 7. Illustrative Carbon Footprint for a Food Product



7 Areas for Methodology Development

7.0 The following areas have been identified which will require further development, including consultation with the Technical Advisory Group and wider stakeholders, and in some cases through piloting. Note also that methodology development will be an ongoing process, to ensure that the methodology is up to date, and continues to be appropriate to business needs.

7.1 Alignment with other standards

7.1.1 To be able to become a more generic standard, the methodology will need to include further comparison with the framework defined in ISO standards 14040 and 14041 for Life Cycle Assessment (LCA) and by the Life Cycle Inventory Analysis (LCI) toolkit. It will also seek to align with ISO 14064 on company greenhouse corporate accounting, ISO 14025 on type III ecological product labelling and the Greenhouse Gas Protocol for corporate GHG reporting developed jointly by WBCSD and WRI[3].

7.2 Applicability for all products

7.2.1 This methodology has so far been tested on food products and consumer perishables. It may require modifications if other types of product (e.g. consumer durables) are to be analysed. The balance between the methodology giving guidelines for application to specific product types and allowing for judgement will need to be decided upon.

7.3 Boundary conditions

7.3.1 Further consideration of the boundary conditions and their applicability to different product types is needed. For example, classification of processes as direct or indirect, the use of reference systems for land use change and waste, and the inclusion of emissions from storage and display of products at the retail store. Also, certain input and output cut-offs also need to be decided upon, e.g. if transport of recycled packaging to the recycling plant should be included in the upstream or downstream supply chains.

7.4 Co-products

7.4.1 The most appropriate method for valuing co-products needs to be established and agreed upon. This includes deciding whether allocation or system expansion should be used, and if allocation is used, whether this should be based on the price, mass, energy content, or another attribute of the co-products. It will also need to be established whether the approach used will vary between co-product types.

7.5 Data validity

7.5.1 This covers the period over which the carbon footprint for the product is considered to be valid, as well as the requirements for an individual piece of data. It is likely that recalculation of GHG emissions for a particular supply chain should be required on a regular basis (at least every 2 years). Recalculation would also be required whenever there are changes in the equipment being used in any of the processes, changes to the processes themselves or changes

[3] Greenhouse Gas Protocol http://www.ghgprotocol.org/

in composition or mass of the inputs, although this requirement needs to be set so as to achieve a balance between robustness of the analysis and complexity for the companies involved. Requirements for individual pieces of data will include rules on how current, representative, and accurate they should be, and also the level of evidence needed.

7.6 Secondary sources

7.6.1 During the development of the methodology, suitable sources of secondary data will be identified and the Technical Advisory Group and representative stakeholders consulted before a list of proposed sources of secondary data is produced. As a minimum, secondary data sources will need to be identified for global constants and emissions coefficients for common energy inputs. Guidance will also need to be developed to establish when use of secondary data (as opposed to primary data) is acceptable, and also if and when secondary data from alternative sources can be used.

7.7 Interaction with code of practice and application rules

7.7.1 It will be important that the methodology is developed in conjunction with the development of the code of practice and application rules. For example, this will ensure that the detail required by the methodology fits with the frequency of recalculation, and the needs and capabilities of companies involved. Decisions made in methodology development in the short term will affect delivery models possible in the longer term, for example through influencing how data is collected and passed down the supply chain, and the approach used to the chain of custody for raw materials.

8 Glossary of common terms

Boundaries	The limits of emissions included in the carbon footprint calculation
Carbon equivalents	A measure of the combined impact of all GHGs. GHGs other than CO_2 are converted to their carbon equivalent value on the basis of their contribution to radiative forcing using 100-year global warming potentials defined by the Intergovernmental Panel on Climate Change (IPCC).
Carbon footprint	The total emission of greenhouse gases (GHG) in carbon equivalents from a product across its life cycle from the production of raw material used in its manufacture, to disposal of the finished product (excluding emissions during use of the product)
Co-product	Any of two or more products from the same process
Emissions coefficient	The GHG emissions associated with use of a unit of energy e.g. kg CO2 equivalent per kWh, kg, or MJ
GHG	Greenhouse gas - CO_2, CH_4, N_2O, SF_6, HFCs, perfluorocarbons
Input	Inputs to the supply chain e.g. raw materials, energy
Life Cycle Analysis (LCA)	A methodology for analysing and evaluating quantitatively the environmental impact of a product in the stages of its life
Mass balance	The quantification of total materials into and out of a process
Output	Outputs from the supply chain e.g. co-products, wastes
Primary data	Actual data collected from the supply chain
Product unit	The item that can be purchased by the consumer
Raw material	A material used as an input to the supply chain under consideration. Can be an unprocessed natural resource, or the output of another supply chain
Secondary data	Data from secondary sources used when primary data is not available
Unit process	The smallest portion of a supply chain for which data are analysed when performing a life cycle assessment

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