PUBLICLY AVAILABLE SPECIFICATION

PAS 2050-1:2012

Assessment of life cycle greenhouse gas emissions from horticultural products

Supplementary requirements for the cradle to gate stages of GHG assessments of horticultural products undertaken in accordance with PAS 2050

Productschap Tuinbouw

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Foreword

The development of this Publicly Available Specification (PAS) has been facilitated by BSI Standards Limited and published under licence from The British Standards Institution. It came into effect on 21st March 2012.

This PAS has been prepared by a group of experts from several countries, with experience in the assessment of the greenhouse gas (GHG) emissions from horticultural products, with the objective of providing supplementary requirements that when used in conjunction with PAS 2050 *(Specification for the assessment of the lifecycle greenhouse gas emissions from goods and services)* will enhance the effectiveness of the assessment of GHG emissions from any horticultural product.

The development of PAS 2050-1 was co-sponsored by the Dutch Product Board for Horticulture (Productschap Tuinbouw) and the Dutch ministry of Economic Affairs, Agriculture and Innovations (Ministry of EL&I).

Acknowledgement is given to the significant contribution by Hans Blonk as Technical Author for this project and to the following organizations and individuals that assisted with the development of this specification:

Belgium	Durabilis	An Saveyn
	Technology and Food Science Unit - Agricultural Engineering Dept - Institute for Agricultural and Fisheries Research	Veerle van Linden (PhD)
	COLEACP-PIP	Jeremy Knops
Denmark	AgroTech A/S - Institute for Agri Technology and Food Innovation	Oliver Körner
Germany	INRES- University of Bonn,	Dr Michael Blanke & Florian Schaefer
	Institute of Agricultural Climate Research Johann Heinrich von Thünen-Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries)	Dr Katharina Plassmann
Finland	MTT Agrifood Research	Hanna Hartikainen and Hannele Pulkkinen
Spain	IRTA – Recerca i Tecnologies Agroalimentàries - Generalitat de Catalunya	Dr Assumpció Antón Vallejo
The Netherlands	Landbouw Economisch Instituut (LEI) part of Wageningen UR	P.X. Smit
	Productschap Tuinbouw	Anne Gaasbeek
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United Kingdom	ADAS	Dr Jeremy Wiltshire
	NFU	Dr Ceris Jones & Dr. Chris Hartfield

Comments from other parties were also sought by BSI. The expert contributions from all the organizations and individuals consulted in the development of this PAS are gratefully acknowledged.

Use of this document

It has been assumed in the preparation of this horticultural PAS that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

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

Presentational conventions

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

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

Contractual and legal considerations

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

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

Introduction

This Publicly Available Specification (PAS) contains requirements supplementary to PAS 2050 for the assessment of greenhouse gas (GHG) emissions from the life-cycle of horticultural products.

The purpose of these supplementary requirements is to aid consistent application of the PAS 2050 to the horticulture sector by providing:

- a horticultural focus for aspects of the PAS 2050 assessment where options are permitted;
- rules or assessment requirements that are directly relevant to the main sources of emissions from horticulture; and
- clarity on how to apply specific elements of the PAS 2050 assessment within the horticultural sector.

PAS 2050-1 is provided for use in conjunction with PAS 2050 to provide an homologous method for the reliable, repeatable assessment of GHG emissions from the whole life cycle of horticultural products. However, the supplementary requirements provided in PAS 2050-1 relate only to the cradle-to-gate stages of the life cycle and for all subsequent stages (i.e. retail, use and end-of-life) the requirements of PAS 2050 apply. For this reason PAS 2050-1 adopts the same content sequence and structure as PAS 2050 and within that sequence, some clauses do no more than defer to the equivalent clause in PAS 2050.

PAS 2050 sets out generic requirements for undertaking a GHG emissions assessment, such as transport, energy use, data quality rules etc whilst PAS 2050-1 provides supplementary requirements and additional guidance on those elements that have been found to present particular difficulties in an horticultural context such as land use change and allocation. Although, hitherto, it has been possible for those experienced in the use of PAS 2050 to achieve acceptable assessment outcomes using PAS 2050 alone, for new or less experienced users the use of PAS 2050-1 in conjunction with PAS 2050 in an assessment of the GHG emissions from an horticultural product, can be expected to ensure greater accuracy and uniformity of application.

Because of the global nature of trade in horticultural products it is essential that the supplementary requirements provided in PAS 2050-1 are applicable wherever assessment of emissions from horticultural products is to be made. The development of PAS 2050-1 has therefore been undertaken with participation by experts from different countries with the intention of providing a set of supplementary requirements that can be beneficially applied wherever horticultural products are grown.

During the final stages of the development of this PAS, application trials have been conducted for a number of different horticultural products and the experience gained has been used to improve the focus and application of the supplementary requirements presented here. Further information on these trials will be made available following the publication of PAS 2050-1.

1 Scope

PAS 2050-1 specifies supplementary requirements for use in conjunction with PAS 2050 for the cradle-to-gate assessment of the GHG emissions from the cultivation stages of horticultural products.

PAS 2050-1 is appropriate for use by organizations operating in the horticultural sector, intending to undertake a programme of GHG emission reduction of their product lifecycle or those needing to provide information on the GHG emissions from their products to downstream business partners.

PAS 2050-1, which has been developed in accordance with the principles set out in clause 4.3 of PAS 2050, follows the structure and form of that PAS. It clearly identifies where PAS 2050 requirements are to be applied without supplement and provides sector-specific requirements that are supplementary to PAS 2050 requirements, where permitted by that PAS.

As with PAS 2050, PAS 2050-1 addresses the single impact category of global warming potential. It does not assess other potential social, economic and environmental impacts arising from the provision of horticultural products, such as non-greenhouse gas emissions, acidification, eutrophication, toxicity, biodiversity, labour standards or other social, economic and environmental impacts that may be associated with the life cycle of such products.

An assessment of the GHG emissions of horticultural products using PAS 2050-1 in conjunction with PAS 2050, does not provide an indicator of the overall environmental impact of these products, such as may result from other types of life cycle assessment.

In line with the principle adopted for PAS 2050, PAS 2050-1 does not specify requirements for communication of assessment outcomes but both directly and by reference to PAS 2050, does include specific requirements relating to how information on GHG emissions arising during the cradle-to-gate stages of horticultural products, is to be conveyed to downstream business partners.

The GHG emissions related to the inputs (upstream) and the output (the horticultural product) downstream are defined by PAS 2050 2011 which establishes the overall framework for conducting the GHG assessment.

Note *Global warming potential through GHG emissions is only one of many environmental impacts of processes and activities in the lifecycle of horticultural products. In many horticultural products' lifecycles, water depletion and water pollution could have a larger impact on the environment and society. The lifecycle GHG emissions of horticultural products although important, are emphatically not the only indicator for environmental impacts of horticultural products.*

2 Normative references

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

PAS 2050: 2011 *Specification for the assessment of life cycle GHG emissions from goods and services.*

3 Terms and definitions

For the purposes of PAS 2050-1 the terms and definitions provided in PAS 2050 together with the following, apply:

3.1 cultivation

activities related to the propagation, growing and harvesting of plants including activities to create favourable conditions for their growth.

3.2 horticulture

cultivation, storage and marketing of fruit, vegetables (see 3.7) and flowering or ornamental plants (see 3.6).

3.3 (horticulture) cradle-to-gate assessment

assessment of GHG emissions arising from activity associated with an horticultural product from initial preparation for cultivation through to the point at which the product leaves the organization undertaking the assessment.

Note *This mostly involves multiple cultivation production phases, such as the production of planting material and seeds and all their material inputs and outputs being relevant to and included in, the GHG assessment. See also system boundaries.*

3.4 horticultural product

crop or plant together with all associated containers, growing medium, packaging and labelling employed during propagation and growth and to effect a successful transfer of the crop or plant to the intended purchaser

Note *The product 'pot plant' includes the plant, the pot, the growing medium, packaging material and label.*

3.5 methane slip

unburned methane emitted during the combustion of a methane-containing fuel mix in an engine.

Terms relating to plants and crops

3.6 flowering or ornamental plant

plant produced primarily for decorative or landscaping purposes including, bedding plants; bulbs, corms and tubers; hardy nursery stock; grown flowers; grown foliage; pot plants; shrubs and trees

***Note** The above principles are adapted from Global Gap, annex 1.2. version 2.*

3.7 fruit or vegetable plant

plant produced primarily to provide food for human or animal consumption in fresh, cooked or processed form, including fruit", "vegetables", "edible roots", "bulbs", "tubers", "nuts", "spices" or "herbs" (see list provided in **Annex A**)

***Note** The above definition is adapted from Global Gap, annex 1.2. version 2.*

***Note** to 3.6 & 3.7, Plants can constitute a crop in themselves (e.g. cabbages, leeks) or can yield a crop and remain in growth for subsequent cropping (e.g. raspberries, cut flowers)*

3.8 annual [crop] plant

crop yielding plant that is sown or planted and harvested during one production season.

***Note** This period may fall across two calendar years, e.g. sowing of 'Brussel sprouts' in August and harvesting in March the following year. In this situation, all activities of growing the crop are allocated to the year of harvest; see section 8.2.2 on co-production in crop rotation.*

3.9 perennial [crop] plant

plant from which parts can be harvested over several productive seasons (e.g. sugar cane, asparagus, chicory, fruits, nuts), or which can be harvested entirely after growing for more than two seasons (e.g. trees, shrubs, potted plants)

3.10 open field cropping

growing of annual or perennial [crop] plants, in the open field in soil and without protection from the climate

3.11 protected cropping

growing of annual or perennial [crop] plants under some form of protection from the climate, e.g. in greenhouses or under polythene sheeting, or from the soil, e.g. substrates to favor growing conditions

3.12 crop rotation

growing of crops in a pre-determined seasonal sequence

***Note** Crop rotation is usually introduced to prevent diseases, maintain soil conditions and optimize yields.*

3.13 crop rotation plan

the plan of a grower that provides for the planting of [crop] plants in a pre-determined cycle

***Note** A grower that applies a crop rotation plan often has multiple plots supporting different crops at the same time. Such plans are mostly applied to open field annual crop cultivation, where the grower produces multiple crops per production season*

3.14 multiple cropping

planting and harvesting two or more species of [crop] plant in succession from the same growing area in the same year

3.15 inter cropping

mingling two or more species of [crop] plant at the same time in the same growing area in the same year

3.16 multiple crop production system

production system that yields multiple crops in a year that can be the result of crop rotation, multiple cropping or inter cropping in both open field and protected cropping systems

4 Principles and implementation

4.0 Overview

This PAS focuses on how the assessment of GHG emissions from the cradle-to-gate stages of horticultural production is to be undertaken (**Figure 1**).

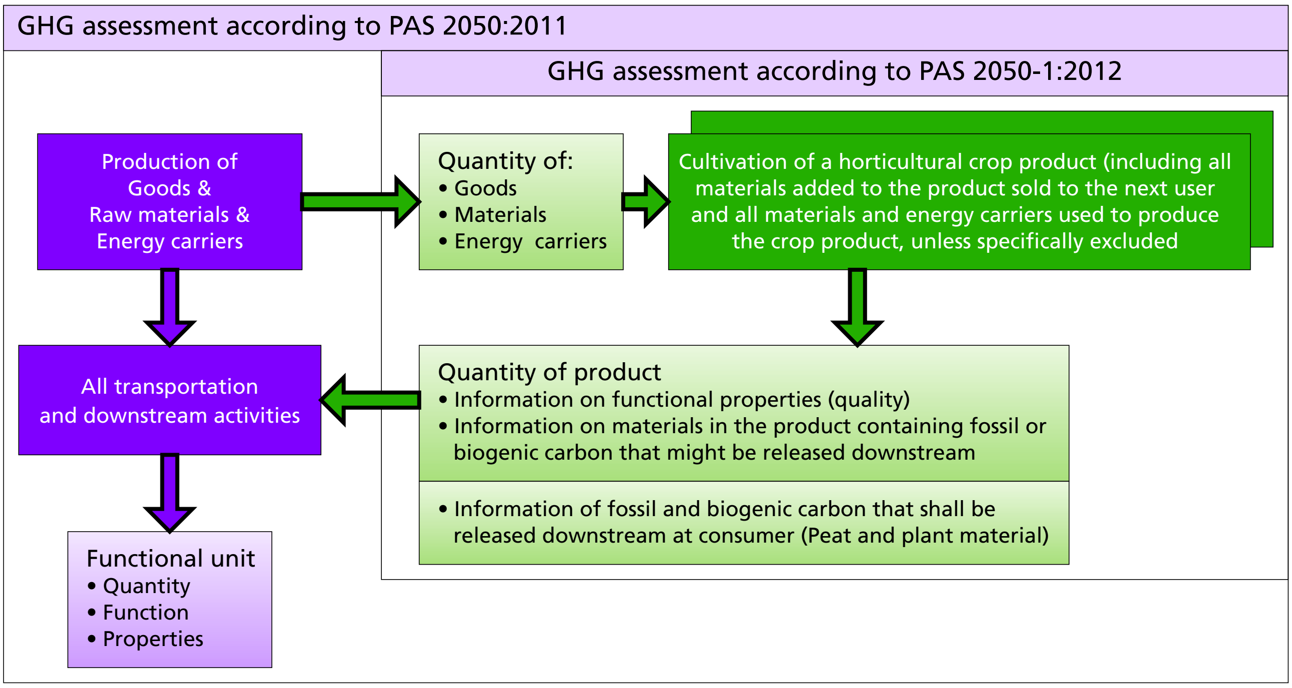
The primary objective of this PAS is to provide greater clarity as to how the inputs of goods, land, materials and energy carriers and related GHG emissions can best be attributed consistently to the quantity and quality of the horticultural product that is being assessed.

The following concepts are important for the proper use and understanding of this PAS.

- it is necessary that the specific quantity and quality of products being assessed be determined as part of the scope of an overall assessment in accordance with PAS 2050:2011. So, the functional unit as such, can only be determined within the scope of such an assessment, in relation to the use and intended purpose of the horticultural product being assessed Therefore this horticultural PAS only addresses the definition of a functional unit and provides some guidance on its determination in relation to specific situations (see **5.2.4**).
- The horticultural crop as a 'product' is assessed including all associated containers, growing medium, packaging and labeling employed during propagation and growth and to effect a successful transfer of the crop or plant to the intended purchaser, in addition to the actual crop or plant.
- The processes to be assessed therefore include all activities related to the propagation, growing, harvesting and marketing of plants including activity to create favorable conditions for growing. There are multiple cultivation steps possible within a GHG assessment of a horticultural product.

To facilitate an assessment of GHG emissions fully in accordance with PAS 2050, this horticultural PAS provides information as to the treatment of fossil and biogenic carbon in horticultural products that are likely to be transferred to users downstream. This is relevant for non-food, non-feed biogenic carbon and for fossil carbon containing materials.

Figure 1 Relationship between PAS 2050-1:2012 & PAS 2050:2011



The potential GHG emissions likely to arise from these materials after the cradle-to-gate stages of production, are to be assessed in accordance with the requirements of PAS 2050:2011. However, in the case of peat that is passed on to the consumer, this horticultural specification sets out specific requirements on how to calculate GHG emissions (**8.2.3.2**). This is particularly relevant for ornamental plants and trees.

Notwithstanding its focus on the cradle-to-gate stages of the horticultural product lifecycle, this PAS can be used in conjunction with PAS 2050 for the proper undertaking of a GHG assessment in accordance with PAS2050: 2011, for both of the situations described in 1 and 2, below:

1) A practitioner intends to undertake an assessment in response to or in anticipation of a request for GHG emission information from the cradle-to-gate stages to support an assessment being performed further on in the production chain, such as by a retailer or processor.
2) A practitioner intends to conduct a whole lifecycle assessment up to and including the disposal stage.

In situation 1 however, where an assessment is being done to provide information to support assessments undertaken at subsequent stages of the supply chain, particular care will be required to ensure that the functional unit used in the cradle-to-gate stages of the assessment is made known as part of the information provided, so as to facilitate the use of a common functional unit throughout (see also **6.2.3**).

4.1 Primary requirements

Assessment of the GHG emissions and GHG removals from horticultural production systems, claimed to be in conformance with PAS 2050-1, shall be carried out using the principles and methods specified in PAS 2050 supplemented by the provisions made in this horticultural PAS in respect of the cradle-to-gate stages of those products.

4.2 Supplementary requirements – implementing PAS 2050-1

In accordance with PAS 2050: 2011:

- the assessment of cradle-to-gate GHG emissions and removals arising from horticultural products shall include the GHG emissions and removals (including all upstream emissions) arising up to the point at which the horticultural product leaves the grower for transfer to another party;
- the assessment shall include the emissions and removals from materials classified as waste from the cradle to gate phases;
- in addition, the potential impact of actions taken during the cradle-to-gate stages that could result in emissions arising during and after transfer of the product to another party shall be assessed and recorded separately (**5.2.2**).

Note 1 *This does not preclude organizations undertaking a cradle-to-grave assessment for horticultural products for which PAS 2050 provides requirements for the other life cycle stages.*

Note 2 *Choices made at the cultivation stage can affect emissions at subsequent stages of the product life cycle. This may result from the choice of a growing medium (peat based or alternatives), pots, containers and packaging. Pots made out of different materials for example, will have different emissions at the disposal phase. Although this PAS only accounts for the cradle-to-gate phases of the product life-cycle, information recorded separately about subsequent emissions at use and disposal is intended to drive choices towards reducing emissions across the product life.*

5 Emission and removals

5.1 Primary requirement

The requirements of PAS 2050 clause 5 shall be applied, supplemented by **5.2.1** to **5.2.3** of this PAS.

5.2 Supplementary requirements implementing PAS 2050-1

5.2.1 Included sources of GHG emissions

In relation to 5.1 of PAS 2050, the cradle-to-gate assessment of horticultural products shall include GHG emissions and removals arising from all processes, inputs and outputs in the cradle-to-gate stages of a horticultural product, including:

- emissions and removals of biogenic carbon (e.g. in burning biomass for fuel) where that biogenic carbon does not become part of the horticultural product;
- CO_2 emissions arising from fossil carbon sources (e.g. fossil fuel, peat and peat based compost, limestone);
- CH_4 (methane) emissions arising from manure used as fertiliser and other agricultural processes;
- N_2O (nitrous oxide) emissions arising from soils and agricultural processes.

CO_2 emissions and removals related to biogenic carbon captured in a horticultural product intended for human or animal consumption (food and feed) may be excluded in accordance with PAS 2050:2011.

The carbon content of dry organic matter of horticulture products is usually between 0.45 and 0.5. IPCC 2006 gives a default of 0.47 for trees. The carbon content of the horticultural product shall be calculated by multiplying the carbon content of dry organic matter by the dry matter mass of the product.

5.2.2 Delayed emissions resulting from actions taken during cradle-to-gate stages

In relation to 5.2 of PAS 2050, where carbon containing materials are added to the horticultural process during the cradle-to-gate stage that are likely to give rise to emissions during the use or end of life stages and within the 100 year assessment period, the potential emissions from those sources shall be assessed as if released at the beginning of the assessment period. A record of that assessment shall be made and retained separately from the overall cradle-to-gate assessment (see also **6.2.3**).

5.2.3 Inclusion and treatment of land use change

5.2.3.1 Limited traceability of products

The following hierarchy shall apply when determining the GHG emissions and removals arising from land use change occurring not more than 20 years or a single harvest period, prior to making the assessment (whichever is the longer):

a) where the country of production is known and the previous land use is known, the GHG emissions and removals arising from land use change shall be those resulting from the change in land use from the previous land use to the current land use in that country; *in this case, the requirements of clause **5.2.3.2** shall be applied;*

b) where the country of production is known, but the former land use is not known, the GHG emissions arising from land use change shall be the estimate of average emissions from the land use change for that crop in that country; *in this case, the requirements of clause **5.2.3.3** shall be applied;*

c) where neither the country of production nor the former land use is known, the GHG emissions arising from land use change shall be the weighted average of the average land use change emissions of that commodity in the countries in which it is grown.

Note *Countries in which a crop is grown can be determined from import statistics, and a cut-off threshold of not less than 90% of the weight of imports may be applied.*

5.2.3.2 Assessment of GHG emissions from land use change when the previous land use is known

The GHG emissions from land use change consist of GHG emissions and removals from vegetation and soil carbon stocks changes. Both vegetation and soil carbon stocks of the previous land use and the current land use shall be assessed in accordance to the relevant sections of the IPCC Guidelines for National GHG Inventories. In accordance with PAS 2050, the carbon stock change shall be linearly amortised during a period of 20 years. All GHG emissions from land use change shall be attributed to crop production.

Note 1 *An Excel tool is available in which the specific situation (when the previous land use is known) can be selected and the GHG emissions are calculated automatically.*

Note 2 The capture of CO_2 in the crop and delayed emissions from harvested and consumed products, burning and decay of biomass, is implicitly included in the land use change calculations and shall not be reported in another part of the GHG assessment, because this will result in double-counting.

5.2.3.3 Assessment of average GHG emissions from land use change when the previous land use is not known

For assessment of the average GHG emissions from land use change when only the crop and country are known, four previous land use categories in the 20 years prior to the assessment shall be considered and the highest GHG emission value shall be taken from two estimates of average land use change:

1) The value calculated by using the average of land use change from either:
   - forest (1/3), grassland (1/3) and perennial (1/3) cropland to annual cropland, or
   - forest (1/3), grassland (1/3) and annual cropland (1/3) to perennial cropland
2) The value calculated by deriving a (weighted) country average of transformation of land use categories in the country to perennial or annual cropland.

***Note** An excel tool is provided to support the calculation of these averages.*

For the assessment of the (weighted) average, the rate of expansion shall be determined on the basis of the share of area expansion during 20 years prior to the assessment and at the time of the assessment, using data from the United Nations Food and Agriculture Organization (FAO) (faostat.fao.org) , starting with the most recent available year in this database. For the evaluation of the trend in land use change of the crop, the average crop area in the most recent three years shall be compared with the three years average of 20 years previously ago.

If there is no expansion, no land use change shall be attributed to the crop. If expansion has taken place, the share of area expansion in relation to total current area of the assessed crop (REC) shall be assessed as follows:

$$REC = \frac{\text{expanded area of assessed crop (ha)}}{\text{current area of assessed crop (ha)}}$$

The remaining (1 – REC) shall be assumed to be not related to any land use change.

The expanded area of the assessed crop consists of (at maximum) four shares:

1) Share of area expansion at the expense of forest land (SEF)
2) Share of area expansion at the expense of grassland (SEG)
3) Share of area expansion at the expense of perennial tree cropland (SEP)
4) Share of area expansion at the expense of annual cropland (SEA)

These shares shall be based on three year rolling averages of area expansion and contraction data of all crops in the country (from FAO statistics) during the 20 years prior to the three most recent years for which data is available.

The share of area expansion for annual or perennial crops at the expense of forest, grassland and annual or perennial crop land, shall be calculated in two steps.

Step 1 First the combined decline in forest and grassland (SEF&G) shall be calculated from area expansion and contraction for all individual crops in the country (annual and perennial crops) as follows:

$$SEF\&G = 1 - \frac{\text{the sum of all crop area contractions (ha)}}{\text{the sum of all crop area expansions (ha)}}$$

When the result is negative, the value of either the decline of forest or grassland shall be set to zero. In this case, only the conversion of perennial to annual or vice versa needs to be calculated.

Step 1.1 (Only to be included if SEF&G > 0)

The share of area expansion at the expense of forest land shall be equal to:

$$SEF = SEF\&G * \frac{\text{contraction forest (ha)}}{\text{contraction forest and grassland (ha)}}$$

If the sum of contractions of forest and grassland area equals zero (due to the lack of specific data), SEF shall equal SEF&G * 1, and SEG shall equal 0.

***Note:** The total forest land or grassland area contraction is not equal to the total land use change in a country. It is not possible to directly determine the share of area expansion at the expense of forest land or grassland from FAO data.*

Step 1.2 *(Only to be calculated if SEF&G > 0)*

The share of area expansion at the expense of grassland shall be equal to:

$$SEG = SEF\&G * \frac{\text{contraction grassland (ha)}}{\text{contraction forest and grassland (ha)}}$$

Step 1.3 If SEF&G < 0, set SEF&G to 0

The share of area expansion at the expense of perennial tree cropland is equal to:

$$SEP = (1 - SEF\&G) * \frac{\text{sum contractions perennial crops (ha)}}{\text{sum contractions all crops (ha)}}$$

Step 1.4 If SEF&G < 0, set SEF&G to 0

The share of area expansion at the expense of annual cropland is equal to:

$$SEA = (1 - SEF\&G) * \frac{\text{sum contractions annual crops (ha)}}{\text{sum contractions all crops (ha)}}$$

Step 2. The shares of different types of land use change shall then be calculated as follows:

Share land use change from forest land:	SF = SEF * REC
Share land use change from grassland:	SG = SEG * REC
Share land use change from perennial cropland:	SP = SEP * REC
Share land use change from annual cropland:	SA = SEA * REC

The GHG emissions from land use change consist of GHG emissions from a change in vegetation and soil carbon stocks. All GHG emissions from land use change shall be attributed to crop production. The soil carbon stock decrease shall be calculated in accordance with the relevant sections of the IPCC Guidelines for National GHG Inventories. For this part (when the previous land use is not known), the following starting points shall be used:

- For each country, the predominant climate and soil type is determined according to IPCC classification to determine the default reference soil organic carbon stocks (IPCC Guidelines, Volume 4, Table 2.3).
- For each crop, full tillage and medium input level is assumed (IPCC Guidelines, Volume 4, Table 5.5).

Note 1 *PAS2050: 2011states that an average of the emission of land use change for that crop in that country shall be estimated where the country of production is known, but the former land use is not known. However, the non weighted average might give an underestimation of the land use change that has taken place. GHG emissions of land use change may have a major contribution in the overall GHG emissions of cultivation. However they are often put out of scope in a GHG assessment due to difficulties in attribution of land use change and availability of data. To promote the collection of primary data on land use change the principle is adopted that these emissions should not be underestimated. Therefore in deviation of PAS 2050:2011 5.6.2.b, the highest calculated value of the average and weighted average is taken.*

Note 2 *Perennial tree crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or as orchards, vineyards and plantations such as cocoa, coffee, tea, oil palm, coconut, rubber trees, and bananas, except where these lands meet the criteria for categorisation as Forest Land (from IPCC Guidelines, Volume 4, Chapter 5.1).*

Note 3 *The PAS 2050-1 LUC Assessment tool contains predominant climate and soil types per country. This information is based on own interpretation of the IPCC climate map (IPCC Guidelines, Volume 4, Figure 3A.5.1 Delineation of major climate zones) and soil type map (IPCC default soil classes derived from the Harmonized World Soil Data Base). For the final version, this will be verified or further specified (shares of several predominant climate and soil types), so that the interpretation of the IPPC climate map is unambiguous.*

Note 4 *Full tillage is a worst case scenario and, in this case, no change in soil carbon stocks occurs related to soil tillage according to IPCC. Other types of tillage (reduced or no tillage) result in less reduction in carbon stocks compared to full tillage.*

Note 5 *Medium input level means that no carbon stock change occurs related to input level. High input level (with or without manure) result in less reduction in carbon stocks compared to medium input level. Low input is worst case, but is not considered realistic for export quality crop production. Therefore, medium input is assumed.*

An average of forest and grassland vegetation carbon stocks of existing forest types shall be calculated by using:

- shares of different types of forest per country as determined by the FAO (Global Forest Resource Assessment 2000);

- default vegetation biomass per forest and grassland type (IPCC Guidelines, Volume 4, Table 4.7 and Table 6.4); and
- default carbon fraction for forest (IPCC Guidelines, Volume 4, Table 4.3) and in general (0.50 tonne C per tonne biomass).

IPCC provides no default values for vegetation carbon stocks of specific crops. As a rough estimate, the carbon stock of annual crops is assumed to be 1 tonnes of dry matter per ha and of perennial crops 20 tonnes of dry matter per ha.

The GHG emission due to Land Use Change (GHG LUC) shall be calculated as follows:

GHG luc = highest value between (1) and (2) as follows:

Average in case of annual crops (1)	
LUC =	1/3* ΔGHGfa+1/3* ΔGHGga+1/3* ΔGHGpa (1a)
ΔGHGfa =	GHG emission due to the transformation of forest to annual crop land
ΔGHGga =	GHG emission due to the transformation of grassland to annual crop land
ΔGHGpa =	GHG emission due to the transformation of perennial to annual crop land

Average in case of perennial crops (1)	
LUC =	1/3* ΔGHGfp+1/3* ΔGHGgp+1/3* ΔGHGap (1b)
ΔGHGfp =	GHG emission due to the transformation of forest to perennial crop land
ΔGHGgp =	GHG emission due to the transformation of grassland to perennial crop land
ΔGHGpp =	GHG emission due to the transformation of annual to perennial crop land

Weighted average in case of annual crops (2)	
LUC =	SF*ΔGHGfa+ SG*ΔGHGga+ SP*ΔGHGpa + SA*ΔGHGaa (=0)

Weighted average in case of perennial crops (2)	
LUC =	SF*ΔGHGfp+ SG*ΔGHGgp+ SP*ΔGHGap + SA*ΔGHGpp(=0)

Note 1 *An Excel tool (PAS 2050-1 LUC assessment tool) is provided in which the crop and country can be selected and the average GHG emissions calculated.*

Note 2 Annex B *provides examples of the calculation of GHG emissions from land use change when the previous land use in not known*

5.2.4 Functional unit In relation to 5.9 of PAS 2050: 2011, the unit of analysis for horticultural products shall be defined in terms of a functional unit that is the quantified performance of the product under analysis.

Note *Horticultural products include a great variety of product types each having their own specific features depending on product characteristics and on the market being supplied. It is therefore not feasible to establish specific requirements for reference flows or reference units, in a document intended to be applicable across all horticultural products. In the scoping phase of a GHG emissions assessment being undertaken in accordance with PAS 2050:2011, the functional unit will be defined. This same process will provide for the precise definition of reference units and reference flows in cradle-to-gate assessment of horticultural products according to PAS 2050-1.*

However, some general guidance with regard to defining reference units and reference flows can be provided, as follows:

- *be precise in the definition of physical properties, such as, size, quality ranking, dry matter content, etc. This is especially important in case of assessments being used for comparison when exploring improvement options;*
- *be aware of the units usually applied in relation to product types, bearing in mind the scope of the assessment. For instance, if the GHG emissions assessment focuses on the impact of cut flowers from different regions, the logical reference unit will be stems (with a certain quality). It is not meaningful and may even hamper interpretation for many stakeholders, to use a weight unit;*
- *be complete in the inclusion of auxiliary products such as pots, labels, substrates packaging, etc... What has to be included follows logically from the functional unit being defined according to PAS 2050 requirements.*

6 System boundary

6.1 Primary requirement

The requirements of PAS 2050 clause 6 shall be applied, supplemented by **6.2.1, 6.2.2 and 6.2.3** of this PAS.

6.2 Inclusion and exclusion of life cycle processes in a cradle-to-gate GHG assessment of horticultural products

6.2.1 Life cycle processes to be Included.

The cradle to gate assessment of an horticultural product shall include the following activities, where they occur:

1) Seed or Young plant production;
2) Storage of young plant material;
3) Crop growing;
4) Storage of crops;
5) Transport;
6) Waste management.

The activities that are actually employed for each specific crop shall be identified and a decision taken as to whether they are separated or integrated in different unit processes. Young plant or seed production are often separate activities taking place at a different location. However, they can also be integrated in a multiple crop production system (as in the cultivation of flower bulbs). It is also possible that even more than two stages in young plant production can be distinguished (as in the cultivation of strawberries with young plant production, cooled storage, and crop production).

In table 1 and table 2, the life cycle processes (e.g. seed, young plant or crop, production) that shall be taken into consideration and those that shall be excluded are identified and explained in more detail. Life cycle processes are included or excluded on the basis of functionality alone.

Note *In the development of these supplementary requirements, consideration was given to the possibility of differentiating between items with the same function on the basis of usable life-span. (e.g. to enable items installed to provide protection from the environment to be subdivided into capital goods and consumables on the basis of the length of their usable life). After due consideration, the Steering Group took the decision that to pursue such a policy could lead to a loss of comparability between systems and potentially impede decisions on changes in product use where lifespan is involved (i.e. crossing the boundary between consumable and capital good would result in the product being excluded or included in the assessment), see* ***Annex C*** *for further information.*

In relation to 6.4 of PAS 2050 and where relevant to the horticultural product being assessed, the GHG emissions from the production and use of the items listed in Table 1 shall be included in the GHG assessment of the horticultural product under assessment. Items listed may however be excluded under the materiality rules (PAS 2050 Clause 6.3) provided the nature and extent of any such exclusion is unambiguously recorded (see also **Annex D**).

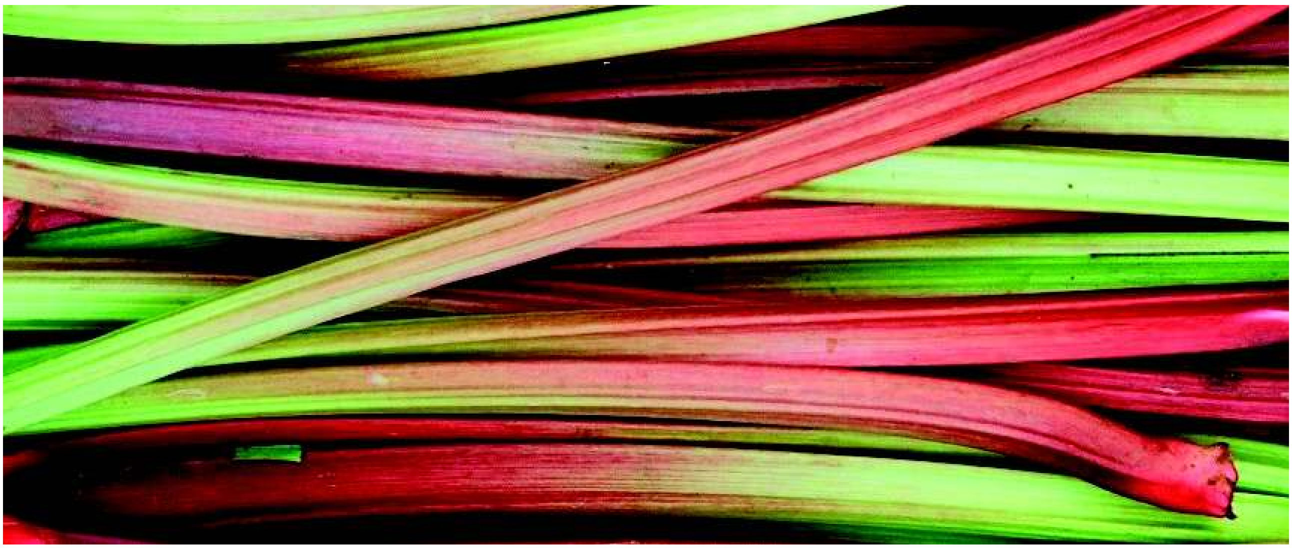


Table 1 List of life cycle processes that shall be taken into consideration (provision 6.2)

Input category (e.g. products/ materials/energy)	Subgroups (not exclusive)	Remarks with regard to contribution (in cradle-to-gate assessment) and data collection	Common unit for data collection
1. Plant input material	• Seeds • Young plants • Root stocks	Can be considerable depending on the relative mass in comparison to the crop; the growing time of the input and the intensity of growing in plant material (cooling , heating, storage)	kg (seeds) per hectare Pieces (young plants, root stocks)
2. Plant protection chemicals and minerals	• Herbicides • Insecticides • Fungicides • Biocides • Soil fumigants • Minerals (Cu, Zn)	Although the emissions resulting from chemical use frequently do not make a material contribution they can be significant in some cases, especially when soil fumigation is applied. GHG emission data of production are available per active ingredient (group)	kg active ingredient per hectare per year
3. Biological pest control	• Insects • Plants	Especially the growing of plants such as Tagetus used in strawberry growing can be important. It is expected that the contribution of the production of insects has a negligible contribution.	Unit depends on specific product
4. Materials used for pest management (no chemicals)	• Netting • Fences • Etc.	Materials used for prevention of damage by birds, mammals, etc., other than pesticides or biogenic pest control. Use refers to, mostly a low contribution to overall GHG emissions.	kg material/ha/year (for products with a longer lifespan per year, the annual consumption must be calculated)
5. Synthetic and mineral fertilizers	• N (nitrate based) • N (urea based) • N (sulphate based) • P2O5 • K2O • Lime	The production and use of N fertilizer can have a high contribution to the GHG emissions (up to 50% in case of open field crops). GHG emission data are both available on substance level or on formula level. A further specification to the type of N fertilizer is important because large of differences in GHG emissions values of production	kg substance per hectare per year

Input category (e.g. products/ materials/energy)	Subgroups (not exclusive)	Remarks with regard to contribution (in cradle-to-gate assessment) and data collection	Common unit for data collection
6. Organic fertilizer	Manure Compost Co-products from industry, such as: • animal meals • fertilizers from processing of crops	Both the volume and the composition of manure is of importance. GHG information of co-products from industry is limited.	Total volume per hectare/year and kg nutrients/ha/year
7. Supplementary CO_2	• CO_2 from fossil origin • CO_2 derived from biogenic fuels	Significant contribution if used. Mostly no information of production is available, see section 8.2.3.	kg CO_2 per ha/year
8. Energy carriers	• Diesel • Gas • Kerosene • Propane • Other fuels from fossil origin • Fuels from biogenic origin • Electricity • Heat • Etc.	Energy inputs have significant contribution and all use of energy carriers for production activities needs to be included. This needs special consideration for smaller farms where energy use is integrally measured with other activities. Also important is to include the energy use of contractors hired for cultivation operations.	Any appropriate energy measure that (per ha-year) can be unambiguously linked to GHG emissions of use and production.
9. Materials used as substrate	• Rock wool • Glass wool • Potting soil • Coco peat • Etc.	Substrates often have a significant contribution. The list of substrate materials is very long. (Be precise in composition of potting soil, with regard to peat composition.)	kg material/ha/year (for substrates with a longer lifespan per year, the annual consumption shall be calculated)
10. Materials used for containing substrates	• Pots, containers • Foils	Most applied are plastics (PP/PE), however also materials from natural origin are also used for pots. (Do not forget the foils used around stone and glass wool)	kg material/ha/year (for substrates with a longer lifespan per year, the annual consumption shall be calculated)
11. Materials used for soil covering	• Plastic foils • Mulch • Etc.	These materials are used for prevention of weeds (plastics, natural materials) or for temperature regulation. Can have a considerable contribution	kg material/ha/year (for products with a longer lifespan per year, the annual consumption shall be calculated)

Input category (e.g. products/ materials/energy)	Subgroups (not exclusive)	Remarks with regard to contribution (in cradle-to-gate assessment) and data collection	Common unit for data collection
12. Materials used for guiding growth of plants and trees	• Wires (steel, nylon) • Tape, Nails • Posts, etc.	This materials use has mostly a low contribution to the GHG emissions.	kg material/ha/year (for products with a longer lifespan per year, the annual consumption must be calculated)
13. Treated water and materials used for water treatment	• Treated water • Chemicals used for water treatment	Water treatment can be undertaken remotely or directly as part of the process.	kg material/ha/year
14. Packaging materials (labels included)	• Consumer packaging (Primary & Secondary packaging) • Industrial packaging for transportation issues	Primary consumer packaging refers to the packaging that has direct contact with the product. This category in particular may have a considerable contribution	kg material/ product unit per year
15. Transport	• Transport of materials and products within or between lifecycle processes included in the cradle-to-gate assessment • Transport of horticultural products to the retailer or other downstream life cycle process where the entity undertaking the assessment owns or is financially responsible for that transport	Transport may have a significant contribution to emissions depending on distance travelled, means of transport and load efficiency employed.	Frequently applied method: km* CO2e/tonkm[TM]/ product unit per year where TM stands for transport means distance to be determined on the basis of measurements/ book keeping CO2e/tonkm[TM] to be determined in relation to specific parameters on load fraction and fuel use See also PAS2050: 2011
16. Consumables used for maintenance of capital goods	• Non fuel oil use in transport equipment and machinery • Cleaning products for glass greenhouses • Cooling agents	Consumption of non fuel oils (for lubrication) or cleaning agent often have a low contribution	kg material/ha/year

6.2.2 Inputs to be excluded.

The input categories identified in table 2 shall be excluded from the GHG assessment of a horticultural product.

Table 2 List of inputs that shall be excluded from the analysis (capital goods and buildings)

Input category (e.g. products/ materials/energy	Subgroups (on data acquisition level)	Remarks with regard to contribution and future development
1. Production and maintenance of goods used for climate control	Greenhouses (from glass or plastic) and all other equipment in the greenhouse not mentioned in table 1. Other climate control systems, such as plastic tunnels and their materials input except for consumables to maintain these goods for as mentioned in table 1	This category may have considerable contribution; up to 50% of the GHG emissions of cultivation. Inclusion of this category is hampered by lack of data. In the next update inclusion will be reconsidered (see for rationale behind this decision).
2. Production and maintenance of tractors, machines and other energy using equipment on the farm	Except for consumables to maintain these goods as mentioned in table 1	
3. Production and maintenance of irrigation equipment	Except for consumables to maintain these goods as mentioned in table 1	These goods mostly have a low contribution to the GHG emissions of cultivation
4. Production and maintenance of buildings, roads and pavements and other floor covering on the farm		These goods mostly have a low contribution to the GHG emissions of cultivation

Note *In particular, climate control products a) may make a considerable contribution of up to 50% of the GHG emissions from cultivation. However, inclusion of this category is currently not considered practicable because of a lack of default data and operational tools to make consistent estimations of materials used in the production of these items. In the next update of this PAS, their inclusion will be reconsidered (see **Annex C**).*

6.2.3 Recording and availability of cradle-to-gate GHG assessment outcomes

6.2.3.1 The entity responsible for the undertaking of a cradle-to-gate GHG assessment for a horticultural product shall record the outcome and supporting information in a manner that cannot be misconstrued as a complete life cycle assessment.

6.2.3.2 Where the results of a cradle-to-gate assessment are to be made known to other parties e.g. to a subsequent stage of the supply chain, the following additional information shall be provided in conjunction with that outcome.

a) Confirmation as to whether the GHG emissions arising from the transport of products was included or excluded in assessing the GHG emissions outcome being communicated (**Table 1-15**).

b) Information as to any delayed emissions likely to occur during subsequent life cycle stages as a result of decisions or actions taken during the cradle-to-gate life cycle processes e.g. arising from the choice of potting media (**see 5.2.2**).

7 Data

7.1 Primary Requirement

The requirements of PAS 2050 clause 7 shall be applied supplemented by **7.2** and **7.3** and of this PAS.

7.2 Period of data sampling and variability in emissions in cultivation of horticultural products

In relation to clause 7.6 of PAS 2050, cultivation data shall be collected over a period of time sufficient to provide an average assessment of the GHG emissions associated with the inputs and outputs of cultivation that will offset fluctuations due to seasonal differences.

This shall be undertaken as set out in a) through c) of this clause:

a) For annual crops, an assessment period of three years shall be used on the basis of a three year, rolling average of emissions (to offset differences in crop yields related to fluctuations in growing conditions over the period (e.g. from weather variation or pests and diseases).

   Where data covering a three year period is not available i.e. due to starting up a new production system (e.g. new greenhouse, newly cleared land, shift to other crop), the assessment may be conducted over a shorter period, but shall be not less than 1 year

   Crops/plants grown in greenhouses shall be considered as annual crops/plants, unless the cultivation cycle is significantly shorter than a year and another crop is cultivated consecutively within that year.

b) For perennial plants (including entire plants and edible portions of perennial plants) a steady state situation (**Annex E**) where all development stages are proportionally represented in the studied time period shall be assumed and a three year rolling average shall be used to estimate the inputs and outputs.

   Where the different stages in the cultivation cycle are known to be disproportionate, a correction shall be made by adjusting the crop areas allocated to different development stages in proportion to the crop areas expected in a theoretical steady state. The application of such correction shall be justified and recorded.

c) For crops that are grown and harvested in less than one year (e.g. lettuce produced in 2 to 4 months), data shall be gathered in relation to the specific time period for production of a single crop from at least three recent consecutive cycles.

Note 1 *The underlying assumption in the cradle-to-gate GHG emissions assessment of horticultural products is that the inputs and outputs of the cultivation are in a 'steady state', which means that all development stages of perennial crops (with different quantities of inputs and outputs) shall be proportionally represented in the time period of cultivation that is studied. This approach gives the advantage that inputs and outputs of a relatively short period can be used for the calculation of the cradle-to-gate GHG emissions from the perennial crop product. Studying all development stages of a horticultural perennial crop can have a lifespan of 30 years and more (e.g. in case of fruit and nut trees).*

Note 2 *The GHG assessment of perennial plants and crops should not be undertaken until the production system actually yields output.*

Note 3 *Averaging over three years can best be done by first gathering annual data and calculating the GHG emissions per year and than determining the three years average.*

Note 4 *Tomatoes, peppers and other crops which are cultivated and harvested over a longer period through the year are considered as annual crops. Energy inputs differ strongly due to seasonal variation, which can be monitored and recorded but in the end only the average GHG value over the year is meaningful information.*

7.3 Data sampling – representative samples

In relation to clause 7.7 of PAS 2050, if horticultural products are sourced from a large number of growers (>10) a representative sample may be used that represents the group, if the purpose is:

a) to calculate the average GHG emissions across all growers;

b) to prove reduction of the average GHG emissions across all growers.

The following examples provide guidance on how to determine a representative sample

Example 7.3.1: how to define the sample size

Choosing the sample size is dependent on the objective, the acceptable uncertainty error, the anticipated distribution in variation and if the group can be divided into subgroups. Division into subgroups can be appropriate when there is a relation in GHG relevant data with, for instance, growing conditions and management practices. Two ways of sampling can be distinguished: sampling without grouping and sampling with grouping. For dairy farming the carbon trust defined a method for taking samples that can also be a used for determining sample sizes where a large group of horticulture farms supply crop products in a pool of products that are traded or further processed, such as tropical fruits.

Example 7.3.2: Sampling without grouping

This option requires collecting data from a random sample of the growers. The minimum sample size can be determined via a statistical approach that is further explained in the "Guidelines for the Carbon Footprinting of Dairy Products in the UK, 2010" (Chapter 4 and Appendix 4). **Table 3** provides quick reference for values for total number of growers needed when a confidence interval of 0.95 is applied.

Table 3 Example data for random sampling of growers – without grouping

Total number of growers	Random sample size	Percentage sampling rate
5	5	100%
10	9	90%
20	17	85%
30	23	77%
40	28	70%
50	33	66%
70	41	59%
100	49	49%
150	59	39%
200	65	33%
300	73	24%
400	78	20%
500	81	16%
1000	88	9%
5000	94	2%

Example 7.3.3: Sampling with grouping

Grouping may be undertaken, when a difference in the assessment outcome can be expected on the basis of environmental or management characteristics. If the total set of growers can be placed in distinct groups, a different approach can be used. This method requires the collection of preliminary data from all the growers in order to conduct grouping based on the most important differences between the growers.

After the grouping random sampling can be applied for each of these groups. The objective of the grouping is to divide the total set of growers into groups of growers that are expected to have similar GHG emissions assessment outcomes. Grouping reduces the standard deviation within each group, and thus reducing the total number of growers that must be sampled to achieve an acceptable margin of error. **Table 4** provides values for a certain total number of growers.

Table 4 Example data for sampling of growers after grouping (for each group)

Total number of growers	Random sample size	Percentage sampling rate
5	5	100%
10	9	90%
20	10	50%
30	10	33%
40	10	25%
50	10	20%
70	10	14%
100	10	10%
150	12	8%
200	14	7%
300	17	6%
400	20	5%
500	22	4%
1000	32	3%
5000	71	1%

8 Allocation of emissions

8.1 Primary requirement

The requirements of PAS 2050 clause 8 shall be applied supplemented by **8.2** of this PAS.

Clause **8.2.1** describes the applied hierarchy of allocation within the GHG assessment of horticultural products. Clauses **8.2.2** and **8.2.3** further define two specific allocation topics.

8.2 Supplementary requirements implementing PAS 2050-1

8.2.1 Allocation to co-products

In relation to clause 8.1.1 of PAS 2050, the approach towards allocation of emissions to co-products shall be, in order of preference.

a) Avoidance: by dividing the unit processes to be allocated or expanding the product system (PAS 2050 8.1.1 a) & b);

b) Where inputs in a multiple crop production system benefit all crops but are not specifically assigned to products, the allocation to those crops shall be based on crop needs when sufficient information is available;

c) Where crop rotation is applied in open field cultivation, allocation of emissions of fertilizer inputs and soil improvers that do not benefit the crop of application but the crop in a next year, shall be on the basis of the area occupied by each crop in the same year when the non "beneficial" application took place (**8.2.2**);

d) If the co-products have similar characteristics and/or functionality, (e.g. as different qualities of fresh apples, with different prices but all sold as fresh apples at retail) allocation shall be based on mass;

e) If the co-products do not have similar characteristics and/or functionality, allocation shall be based on the economic value of the co-products (economic allocation) and shall be calculated over a period of not less than one year.

Whatever the method of allocation, the underlying calculations, assumptions and applied data shall be recorded.

***Note 1** The needs of crops, such as nutrients, CO_2 and heat, can be derived from technical cropping manuals or advice of agricultural consultancies that help growers in defining necessary inputs. Data of nutrient needs can be motivated by expected yields in combination with nutrient content of the entire plant (plant, fruit and roots) and N-fixation in case of pulses and beans. If it is not feasible to come to a well motivated and transparent attribution of inputs to crop need, allocation will be based on revenue dispersion (economic allocation).*

Note 2 *Calculation over longer periods has been shown to provide more accurate assessment with five years being a sensible maximum.*

Note 3 *These allocation rules can be combined with each other, following the prescribed hierarchy. For instance, a CHP in a greenhouse can provide heat, electricity and CO_2 for multiple crops in a greenhouse. The first allocation step concerns the calculation of the net GHG emissions to be attributed to the crops by accounting for the avoided electricity production (8.2.1a). The remaining GHG emissions of the CHP then need to be divided over the multiple crops (8.2.1b), which can either be done on the basis of the needs or the economic value of the crops.*

8.2.2 Allocation of soil emissions of organic fertilizers and soil improvers in crop rotation

8.2.2.1 The application of organic fertilizers (e.g. animal manure, peat products, compost) in horticulture production systems favours not only the crop of application but also subsequent crops. GHG emissions related to application (production and use) that favour crops in subsequent years shall be allocated across the crops in the crop rotation scheme in the year of application in accordance with a) , b) or c) of this clause:

a) GHG emissions that occur in the same year of organic fertilizer application shall be fully allocated to the crop of application;

b) GHG emissions that occur after one year of organic fertilizer application shall be allocated to all crops in the crop rotation plan based on area coverage of the crops in the year of application;

c) N2O emission arising from nitrogen in crop residues of green manure shall be allocated to all crops in the crop rotation plan based on area coverage of the crops in the year of application.

The calculation and allocation of delayed emissions per crop shall be done per year and averaged over three years, unless no three years period is available (see **7.2a**)

When there is no crop rotation scheme (e.g. if there is only one crop) all emissions (within and after one year) shall be allocated in total to the crop of application.

Example allocation in crop rotation

In a production system of annual crops that are grown in a crop rotation plan, a steady state is presumed to simplify the calculation of GHG emissions from nutrient application and nutrient losses. In a crop rotation plan, annual crops are more or less grown in a fixed sequence of crops for several agronomic reasons, such as disease control, maintaining soil fertility and economic profitability. For the calculation of GHG emissions, the nitrogen fluxes in the system are very important (in open field systems, the nitrogen often contributes about 50% of GHG emissions from horticultural products). A crop may profit from the nitrogen management of the previous crop. Also, the previous crop can increase available nitrogen in soil for the next crop by crop residues or biological nitrogen fixation. The GHG emissions from nitrogen application (direct and indirect) can be grouped in emissions occurring during the growing cycle of the crop and emissions that can be attributed to the next crop because nitrogen of the previous growing cycle become available. However, determining the actual nitrogen interactions between the previous crop and the following crop is very difficult in practice because of many uncertainties and the need to define a sequence of crops to attribute nitrogen flows. Therefore, the attribution of GHG emissions from nitrogen flows is simplified by averaging the delayed emissions of manure and green manure to the other crops that are grown in one year on a real basis.

8.2.2.2 Formula for the application of 8.2.2.1

The application of 8.2.2 a) b) and c) requires that the N-application in a crop rotation scheme shall be calculated according to Formula 0.1 (see Figure 5 for example calculation).

Formula 0.1

$$N_{\text{applied to crop }A} = NmmA + NfmA + NfixA + NcrA + aA/aT \times (NmoT + NfoT + NfgT + NcrgT)$$

Where

NmmA = Mineral nitrogen from animal manure applied to crop A (kg N/ area unit)
NfmA = Mineral nitrogen from fertilizer applied to crop A (kg N/ area unit)
NfixA = Mineral nitrogen fixation of crop A (kg N/ area unit)
NcrA = Nitrogen from crop residues of crop A (kg N/ area unit)
aA = Area of crop A (area unit)
aT = Total area of crop rotation system (area unit)
NmoT = Organic nitrogen from animal manure applied on all area (kg N/ area unit)
NfmA = Organic nitrogen from fertilizer applied on all area (kg N/ area unit)
NfixA = Nitrogen applied to green manure on all area (kg N/ area unit)
NcrA = Nitrogen from crop residues of green manure on all area (kg N/ area unit)

8.2.3 Allocation of emissions from fossil carbon containing fertilizers or soil improvers

8.2.3.1 Application of supplementary CO_2

Many industries such as the oil industry produce CO_2 as a co-product often identified as industrially produced CO_2. This is supplied to the horticultural industry and applied within horticultural production systems as a fertilizer and shall be calculated according to the following criteria:

The industrially produced CO_2 needs to purified, compressed and distributed to be used in the horticultural industry. All the specific emissions related to purification, compression and distribution of the CO_2 shall be 100% allocated to the horticultural system using the supplementary CO_2, using the following methods as applicable:

a) where price data of CO_2 production is available, economic allocation shall be applied for the division of GHG emissions of the producer before purification; or

Table 5 Example of calculation of N emissions in crop rotation plan

	area	N-Manure	available in year of application	to be allocated	allocated N-manure	N fertilizer (100% available in year of application)	allocated fertilzer of green manure	N fixation	Crop residues	Allocated Crop residues	Total allocated N
	(ha)	All values are in kg N									
1. sugar beet	1	190	133	57	35	150	7.5	0	174	20	519
2. potato	1	275	220	55	35	255	7.5	0	26	20	563
3. winter wheat	1				35	100	7.5	0	28	20	190
4. spinach spring	0.5	90	63	27	17	58	3.8	0	31	10	183
5. green bean summer	0.5				17	20	3.8	15	31	10	97
sum	4		416		139	583	30	15	290	80	1552
N animal manure all to crop 1-5				139							
green manure	1					30		0	80		
Total based on application		555				613		15	370		1552

***Note** Nitrous oxide emissions from biological nitrogen fixation and nitrogen in crop residues are accounted to the same crop in which these nitrogen flows occur.*

b) If the calculation of specific emissions is not practicable and/or price data of CO_2 production is not available, the worst case emission factor of 0.5 kg CO_2-equivalents per kg of CO_2 shall be applied for all upstream emissions.

CO_2 emissions, due to the use of the supplementary CO_2 in the greenhouse itself, which can occur directly during cultivation or indirectly during consumption of the horticultural product, shall not be accounted for.

Note *The use and release of CO_2 during production or consumption of horticultural products can either be considered as a delayed CO_2 emission of the providing industry or it can be considered as a product as any other that feeds the horticultural production. Industry promotes selling of CO_2 as a mitigation option and this is underpinned by assessments on a national level. The use of CO_2 by horticulture appears to be an effective mitigation option. This would be discouraged if the fossil emissions of release of fossil carbon in the CO_2 were to be fully allocated to horticulture. Therefore the CO_2 emission of this application in horticulture is neglected (clause 4)). Conversely, the proposed default value of 0.5 kg CO_2e is a very conservative one for only the production and transportation of CO_2. However, applying this latter value, which is expected to be done in practice because more accurate industry data on CO_2 production is often not available, is a reasonable conservative estimate that reflects both the embodied CO_2 and the mitigation on macro level.*

8.2.3.2 Application of peat products

a) **Indoor:**

Oxidation of fossil carbon from peat used during cultivation in indoor growing systems (greenhouses and mushroom sheds) shall be calculated by using a default value of 1% oxidation per week and including full oxidation of the fossil carbon present in peat containing substrates included in the product at the point of transfer to a subsequent stage in the supply chain or to the final user.

b) **Open field**

The fossil carbon in peat containing products applied at cultivation in open fields shall be assumed to oxidize completely and shall be allocated either as a non-attributable input in a crop rotation plan when it concerns a soil improver (e.g. spent mushroom compost) or as an attributable input to a crop when appropriate (e.g. potting soil of young plant material).

8.2.3.3 Application of other fossil based products

The CO_2 emissions related to the oxidation of fossil containing co-products (e.g. lime fertilizers from the sugar industry) being used in the horticulture system as a fertilizer, soil improver or growing media shall be fully accounted for as either a non-attributable or attributable input in a crop rotation plan, using full oxidation of the fossil carbon present in lime fertilizers and spent mushroom compost used in open field applications.

8.2.4 Accounting for methane leakage in CHP

In relation to clause 8.5 of PAS 2050, the GHG emissions of CHP in horticulture shall include the emissions resulting from methane slip. If engine and fuel specific information are not available a default value of 2.3% of the fuel input, shall be applied.

Note *The average value for methane slip is derived from studies in the Netherlands on CHP use in horticulture. On average, methane slip in CHP in horticulture is 1230 mg C per m^3 (or a methane slip of 2.3% as a percentage of the fuel input). This value is equivalent to a methane emission of 13.7 g CH4 per m^3 natural gas burned in the CHP. Converted to GHG equivalents (the GWP of methane is 25, IPPC 2007), this gives a GHG emission of 343 g CO_2e per m^3 gas consumption by the CHP unit. This emission from methane slip is therefore in addition to the emissions from the production and consumption of natural gas. However, the carbon dioxide emitted from the combustion of natural gas in the CHP unit should be adjusted to account for the unburned methane (2.3% methane slip), because this 2.3% from the methane is not burned and would therefore otherwise be counted twice. The combustion of 1 m^3 natural gas, with a methane slip of 2.3%, therefore emits 1.73 kg CO_2e (instead of 1.77 at 0% methane slip). Given the above, the combustion of 1 m^3 natural gas in the CHP unit therefore produces a GHG emission of 1.73+0.100+0.34 = 2.17 kg CO_2e per m^3 gas input.*

9 Calculation of the GHG emissions of products

The requirements of PAS 2050 clause 9 shall be applied without supplement.

10 Claims of conformity

The requirements of PAS 2050 clause 10 shall be applied without supplement.

Annex A (normative)
Alphabetical list of Fruit or Vegetables

A

Acacia Pennata Leaves
Acerola
Almond
Aloe vera
Apple
Appleberry
Apricot
Artichoke (Globe Artichoke)
Arugula
Asian pear
Asparagus
Atemoya
Aubergine
Avocado

B

Baby banana
Baby corn
Baby leafy crops
Balsam apple
Bamboo shoot
Banana
Bean
Beetroot
Bilberry
Bitter melon
Black salsify
Blackberry
Blackcurrant
Blueberry
Boysenberry
Brazil nut
Brassica spp
Broccoli
Broccoli romanesco
Brocolini
Brussel sprout
Butternut

C

Cabbage
Calabash
Caper
Capsicums (Pepper)
Carambola (Starfruit)
Cardamom
Carrot
Cashew nut
Cassava root (manioc, yucca)
Cauliflower
Celeriac
Celery
Chard
Chayote
Cherry
Chestnut
Chicory (Witloof)
Chillies
Chinese artichoke
Chinese bayberry
Chinese cabbage
Chinese convolvulus
Chive
Chokeberry
Clementine
Coconut
Coriander
Corn salad (Lamb's Lettuce)
Courgette (Zucchini, Marrow)
Cranberry
Cress
Cucumber
Curly Endive
Curry leaves
Custard apple (Chirimoya)

D

Date
Dolicho
Dragon fruit
(Pitaya)
Drumstick
Durian

E

Edible flower
Edible gourd
Elderberry
Elephant garlic
Endive

F

Feijoa
Fennel
Flat nectarine
Flat peach (Paraguayan)
Fig

G

Galangal
Garlic
Garlic Chives
Gherkin
Ginger
Ginseng root
Glasswort
Goji berry (Wolfberry)
Gooseberry
Grape
Grape leaves
Grapefruit
Guava

H

Hazelnut
Herbs-misc (see note)
Horse radish

J

Jack fruit
Japanese horseradish (wasabi)
Japanese Edible Burdock
Japanese Edible chrysanthemum
Japanese mustard spinach
Jerusalem

Note *Herbs (referred to under H, above) includes: Aniseed, Balm, Basil, Borage, Caraway, Catnip, Chamomile, Chervil, Chicory, Chives, Coriander, Dill, Fennel, Houttuynia (Yabka), Laurel, Lavender, Lemon grass, Lovage, Marjoram, Mizuna, Nettle, Oregano, Parsley, Peppermint, Rocket, Rooibos, Rosemary, Sage, Savory, Sorrel, Spearmint, Stevia, Tarragon, Thyme.*

It does not include medicinal herbs or herbs used solely for their aromatic purposes.

K

Kale
Kiwano
Kiwi
Kohlrabi
Krachai
Kumquat

L

Leek
Lemon
Lemon grass
Lettuce
Lime
Limequat
Lingonberry
Litchi
Longan
Longkong
Loquat
Lotusroot
Lucuma
Luffa

M

Macadamia
Malabar Spinach
Malacca Apple (Milk apple)
Mandarin
Mangetout
Mango
Mangosteen
Medlar
Melon
Mineola
Mulberry
Mungbean
Mushroom
Mustard

N

Nectarine

O

Okra
Olive
Onion
Orange

P

Pakchoi
Pak plang
Palm heart
Papaya
Parsley
Parsnip
Passion fruit (Maracuya)
Pea
Pea Eggplant
Peach
Pear
Pecan nut
Peppercorn
Persimmon / Kakis
Physalis
Pineapple
Pine nut
Pistachio
Plantain
Plum
Plumcot
Pluot (Aprium)
Pomegranate
Pomelo
Poppy seed
Prickly pear
Pumpkin
Purslane

Q

Quince

R

Radish
Radicchio
Ragweed
Rambutan
Raspberry
Red currant
Rhubarb
Rose apple
Rose hip

S

Salak
Salsify
Sanchu
Santol
Sapodilla
Satsuma
Sea aster
Scarole (Broad leaf endive)
Sea buckthorn
Shallot
Soursop
Spinach
Spring Onion
Sprouts
Squash
Star apple
Strawberry
Sugarloaf
Swede
Sweetcorn

T

Tamarillo
Tamarind
Tangelo
Tangor
Taro
Tayberry
Thistle
Tindori
Tomato
Turnip
Turnip top

V

Vanilla bean

W

Walnut
Water convolvulus
Water cress
Watermelon
Wax apple
White currant
White turmeric
Wild Garlic
Witloof

Y

Yacon
Yam
Yard Long Bean

Annex B (informative)
Calculation of GHG emissions from land use change – Examples of the calculation of GHG emissions from land use change when the previous land use is not known

Example B1

Country: **Guatemala** Crop: **Bananas**

The share of area expansion in relation to total area of the assessed crop (REC):

$$\text{REC} = \frac{\text{expended area of assessed crop} = 58133 - 18436 = 39697 \text{ ha}}{\text{current area of assessed crop} = 58133 \text{ ha}} = 0.683$$

The share of area expansion at the expense of grassland and forest:

$$\text{SEF\&G} = 1 - \frac{\text{the sum of all crop area contractions} = 9000 \text{ ha}}{\text{the sum of all crop area expansions} = 199391 \text{ ha}} = 0.996$$

The share of area expansion at the expense of forest land:

$$\text{SEF} = \text{SEF\&G} * \frac{\text{contraction forest} = 979\,000 \text{ ha}}{\text{contraction forest and grassland} = 979\,000 + 550\,000 \text{ ha}} = 0.636$$

The share of area expansion at the expense of grassland:

$$\text{SEG} = \text{SEF\&G} * \frac{\text{contraction grassland} = 550\,000 \text{ ha}}{\text{contraction forest and grassland} = 979\,000 + 550\,000\text{ha}} = 0.358$$

The share of area expansion at the expense of perennial tree cropland:

$$\text{SEP} = (1 - \text{SEF\&G})* \frac{\text{sum contractions perennial crops} = 1260 \text{ ha}}{\text{Sum contractions all crops} = 1260 + 88209 \text{ ha}} = 0.00009$$

The share of area expansion at the expense of annual cropland:

$$\text{SEA} = (1 - \text{SEF\&G}) * \frac{\text{sum contractions annual crops} = 88209 \text{ ha}}{\text{Sum contractions all crops} = 1260 + 88209 \text{ ha}} = 0.00607$$

Share land use change from forest land:	SF = SEF * REC = 0.434
Share land use change from grassland:	SG = SEG * REC = 0.244
Share land use change from perennial tree crops:	SG = SEP * REC = 0.00006
Share land use change from annual crops:	SG = SEA * REC = 0.00415

For forest and grassland:		
Reference soil carbon stock (ton C/ha) =	tropical moist climate and HAC soils	65
Factor for soil carbon stock change =	perennial crop (1) * default tillage (1) * medium input level (1)	1
Resulting carbon stock change (ton C/ha) =	65 – 1 * 65	0
LUC from soil carbon stock change (ton CO_2eq/ha*year) =	0 * (44/12) * (1/20)	0
For forest:		
Reference vegetation carbon stock (ton C/ha) =	240 ton biomass/ha * 0.47 kg C/kg biomass	113
Current vegetation carbon stock (ton C/ha) =	default perennial	9.4
LUC from vegetation carbon stock change (ton CO_2eq/ha*year)	(113 – 10) * 44/12 * (1/20)	18.9
For grassland:		
Reference vegetation carbon stock (ton C/ha) =	4.25 ton biomass/ha * 0.47 kg C/kg biomass	2.0
Current vegetation carbon stock (ton C/ha) =	default perennial	9.4
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(2.12 – 10) * (44/12) * (1/20)	-1.4
For perennial tree crops:		
Reference vegetation carbon stock (ton C/ha) =	20 ton biomass/ha * 0.47 kg C/kg biomass	9.4
Current vegetation carbon stock (ton C/ha) =	default perennial	9.4
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(10 – 10) * (44/12) * (1/20)	0
For annual crops:		
Reference vegetation carbon stock (ton C/ha) =	4 ton biomass/ha * 0.47 kg C/kg biomass	1.9
Current vegetation carbon stock (ton C/ha) =	default perennial	9.4
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(0.5 – 10) * (44/12) * (1/20)	-1.4
Reference soil carbon stock (ton C/ha) =	tropical moist climate and HAC soils	31
Factor for soil carbon stock change =	perennial crop (1) * default tillage (1) * medium input level (1)	1
Resulting carbon stock change (ton C/ha) =	31 – 0.48 * 65	-16.2
LUC from soil carbon stock change (ton CO_2eq/ha*year) =	-16.2 * (44/12) * (1/20)	-3.0
The weighted average (ton CO_2eq/ha*year) =	**0.434 * 18.9 + 0.244 * - 1.4 + 0.00006 * 0 + 0.00415 * - 4.4**	**7.9**

The average ton CO2e/ha* year =0.683 * (1/3 * 18.9 + 1/3 * -1.4 + 1/3 * - 4.4) = 0.683 * 4.4 = 3.0
So in this case the weighted average shall be used.

Example B2

Country: **Cöte d'Ivoire**   Crop: **Green beans**

The share of area expansion in relation to total area of the assessed crop (REC):

$$\text{REC} = \frac{\text{expended area of assessed crop} = 1293 - 1200 = 93 \text{ ha}}{\text{current area of assessed crop} = 1293 \text{ ha}} = 0.07$$

The share of area expansion at the expense of grassland and forest:

$$\text{SEF\&G} = 1 - \frac{\text{the sum of all crop area contractions} = 737369 \text{ ha}}{\text{the sum of all crop area expansions} = 1293993 \text{ ha}} = 0.43$$

The share of area expansion at the expense of forest land:

$$SEF = SEF\&G * \frac{\text{contraction forest 0 ha}}{\text{contraction forest and grassland 0 ha}} = 0.43$$

The share of area expansion at the expense of grassland:

$$SEG = SEF\&G * \frac{\text{contraction grassland 0 ha}}{\text{contraction forest and grassland 0 ha}} = 0.00$$

The share of area expansion at the expense of perennial tree cropland:

$$SEP = (1 - SEF\&G) * \frac{\text{sum contractions perennial crops = 709182 ha}}{\text{sum contractions all crops = 1446551 ha}} = 0.28$$

The share of area expansion at the expense of annual cropland:

$$SEA = (1 - SEF\&G) * \frac{\text{sum contractions annual crops = 737369 ha}}{\text{Sum contractions all crops = 709182 + 737369 ha}} = 0.29$$

Share land use change from forest land:	SF = SEF * REC = 0.031
Share land use change from grassland:	SG = SEG * REC = 0.000
Share land use change from perennial tree crops:	SG = SEP * REC = 0.020
Share land use change from annual crops:	SG = SEA * REC = 0.021

For forest, grassland and perennial tree crops:		
Reference soil carbon stock (ton C/ha) =	tropical wet climate and HAC soils	44
Factor for soil carbon stock change =	annual crop (0.48) * default tillage (1) * medium input level (1)	0.48
Resulting carbon stock change (ton C/ha) =	44 – 0.48 * 44	22.9
LUC from soil carbon stock change (ton CO_2eq/ha*year) =	22.9 * (44/12) * (1/20)	4.2
For forest:		
Reference vegetation carbon stock (ton C/ha) =	292 ton biomass/ha * 0.47 kg C/kg biomass	137
Current vegetation carbon stock (ton C/ha) =	default annual	1.9
LUC from vegetation carbon stock change (ton CO_2eq/ha*year)	(137 – 1.9) * 44/12 * (1/20)	24.8
For grassland:		
Reference vegetation carbon stock (ton C/ha) =	4.25 ton biomass/ha * 0.47 kg C/kg biomass	2.0
Current vegetation carbon stock (ton C/ha) =	default annual	1.9
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(2.0 – 1.9) * (44/12) * (1/20)	0.02
For perennial tree crops:		
Reference vegetation carbon stock (ton C/ha) =	20 ton biomass/ha * 0.47 kg C/kg biomass	9.4
Current vegetation carbon stock (ton C/ha) =	default annual	1.9
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(9.4 – 1.9) * (44/12) * (1/20)	1.4
For annual crops:		
Reference vegetation carbon stock (ton C/ha) =	4 ton biomass/ha * 0.47 kg C/kg biomass	1.9
Current vegetation carbon stock (ton C/ha) =	default annual	1.9
LUC from vegetation carbon stock change (ton CO_2eq/ha*year) =	(1.9 – 1.9) * (44/12) * (1/20)	0
The weighted average (ton CO_2eq/ha*year) =	**0.031 * 29.0 + 0.000 * 4.22 + 0.020 * 5.6 + 0.021 * 0.0**	**1.0**

The average (ton CO2e/ha* year) =0.07* (1/3 * 29.0+ 1/3* 4.22 + 1/3 * 5.6) =0.07* 12.9 = 0.9

So in this case the weighted average shall be used.

Annex C (informative)
Capital Goods – Assessment of the contribution of materials and products used for greenhouses (glass or plastics) in the cradle-to-gate GHG lifecycle of a horticultural product

C.1 Introduction

This annex explores the contribution in the cradle-to-gate GHG emissions of goods used for the exterior and interior of a greenhouse . In the process of coming to this PAS, this information has been used to consider if these goods need to be included. For this purpose, the following issues have been explored:

a) contribution of greenhouses in the carbon footprint of horticultural products (significance);

b) consequences of exclusion or inclusion in the comparison of horticultural production systems;

c) feasibility of inclusion with regard to data requirements;;

d) consistency with PAS 2050:2011 exclusion of capital goods.

C.2 Exploration of issues

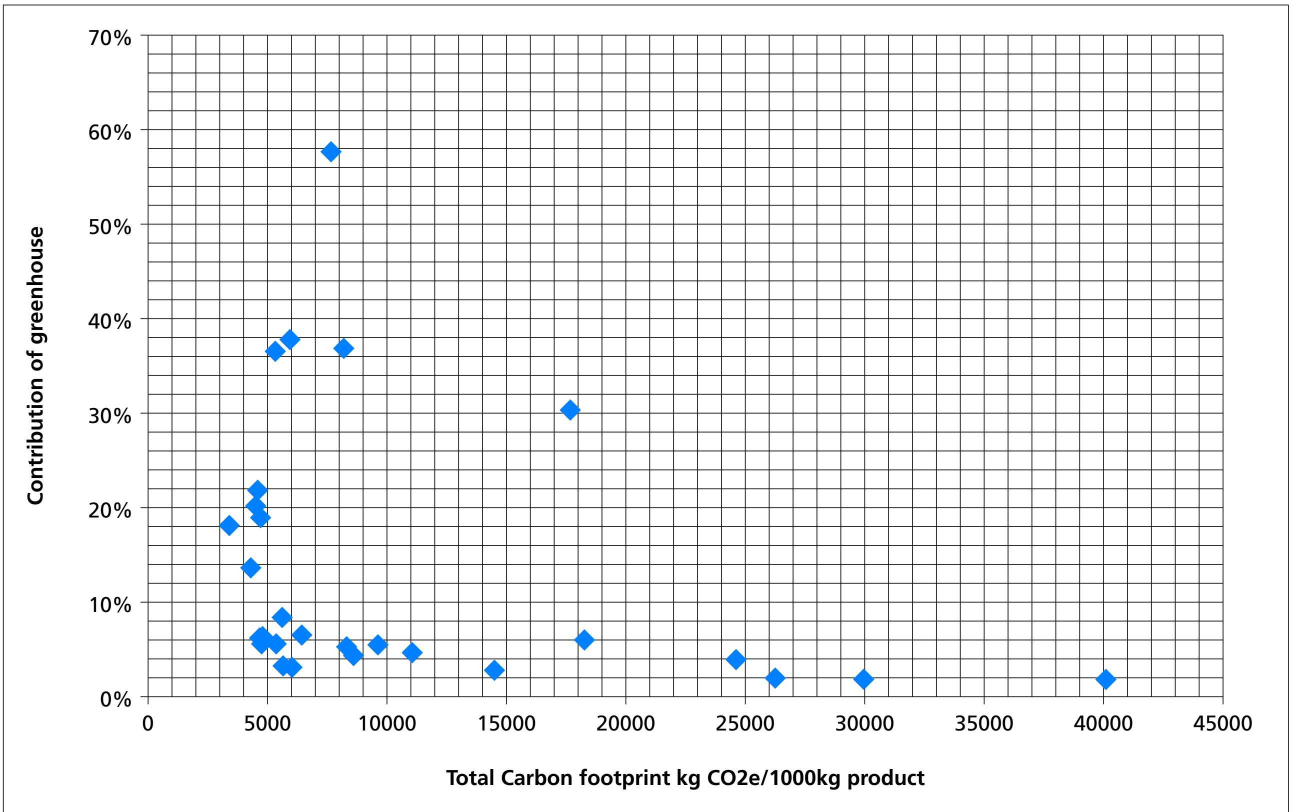
C.2.1 Contribution of greenhouses in GHG results of cradle-to-gate lifecycle of horticultural products

Contribution of the greenhouse in the GHG emissions of Dutch horticultural production systems.

In figure 1 and 2, results are presented of a GHG calculation of Dutch horticulture for the crop cultivation stage. The upstream GHG emissions from growing and providing young plant material and the downstream distribution emissions are excluded.

For most potting plants the depreciation of the greenhouse and its equipment has a contribution ranging from 2.5 to 10%. However, for a considerable number of crops the contribution is much higher, even up to 40%.

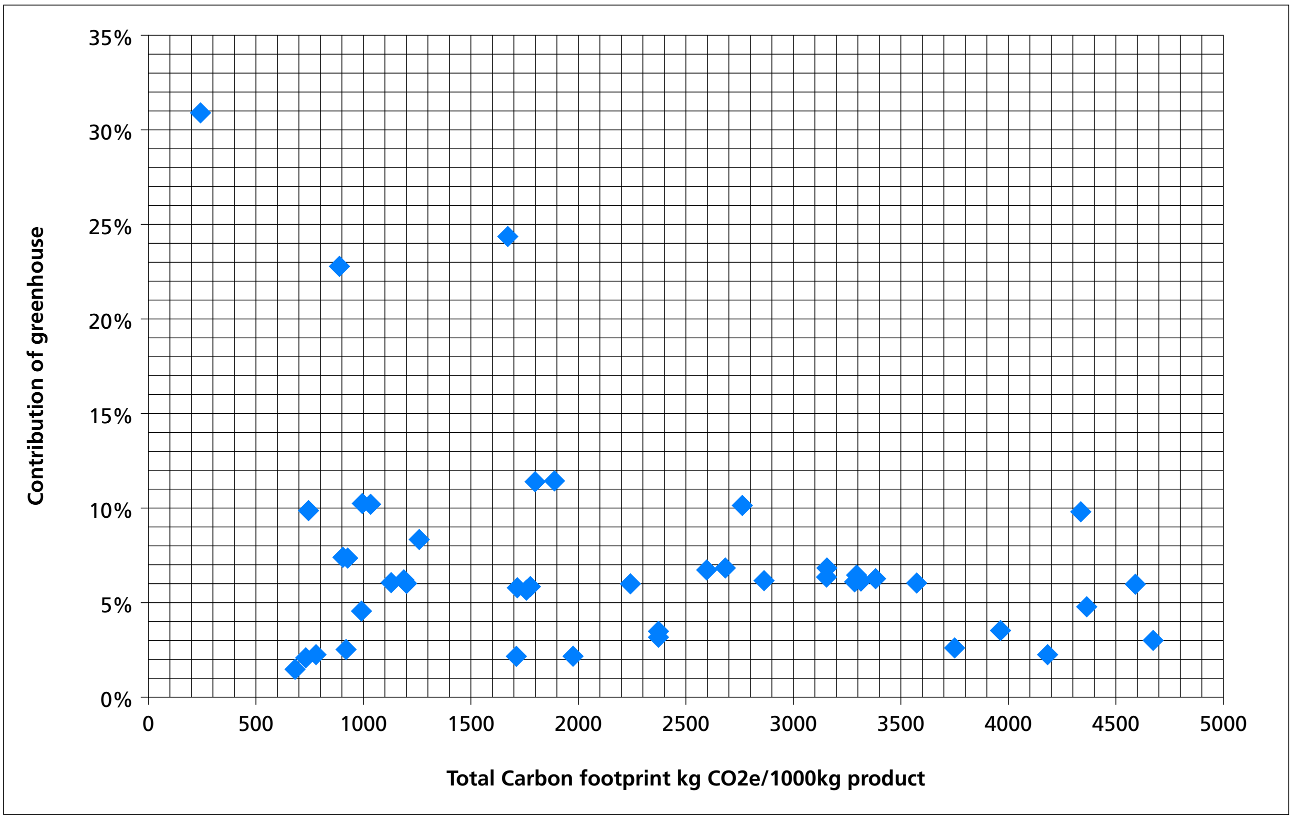
Figure C.1 Contribution of greenhouses to GHG assessments of potted plants



***Note** Undertaken according to default cultivation scenarios as defined in the Dutch technical handbook on horticulture in greenhouses (KWIN glastuinbouw 2010) based on a constant depreciation over 15 years.*

In the case of vegetables, the contribution of greenhouses in the GHG emissions of the cultivation system is (excluding some exceptional cases) in the range of 2.5 to 10%.

Figure C.2 Contribution of greenhouses in overall GHG emissions of vegetables according to default cultivation scenarios



Note *As defined in the Dutch technical handbook on horticulture in greenhouses (KWIN glastuinbouw 2010) based on a constant depreciation over 15 years.*

There appears to be a very weak negative correlation between the (energy) intensity of the cropping system and the contribution of the greenhouses in the GHG emissions in both the cases of potting plants and vegetables. This means that the variety in greenhouse constructions is large and therefore the logical relation between contribution of the GHG emissions of greenhouse and energy intensity does not exist across different cultivation systems. Within a single crop it is likely however that there is a much stronger correlation.

Contribution of greenhouses in Spanish horticulture

There were also some estimates available on the contribution of materials use for greenhouses in Spanish horticulture. (Blonk et al 2010, Vermeulen 2008) comes to a contribution of 29%. (Blanke 2011, Fallstudie 2009) calculates a contribution of ca. 33.5 % in the case of strawberries. So in both cases, the contribution of "greenhouses" (plastic greenhouse and plastic tunnel) is considerable.

C.2.2 Consequences of exclusion or inclusion of greenhouses in GHG assessment

Inclusion of greenhouses in horticulture would be desirable from both the viewpoint of materiality and the great variation in contribution. If they were excluded this may considerably lower the calculated GHG emissions of horticultural products where greenhouses or their plastic equivalents are used. To what extent cannot be predicted beforehand because the contribution is not a fixed percentage over the different cultivation systems (Figure 1 and 2). Excluding them may therefore lead to misinterpretation where cultivation systems are compared, or even when mitigation options are being defined.

Inclusion of capital goods, however, leads to data gathering problems. This might be solved by building data systems on material use of cultivation systems.

C.2.3 Feasibility of inclusion with regard to data requirements

Especially data for greenhouses are not easily available since the building of a greenhouses is a one time activity that mostly happens outside the scope of the grower. Most of the data is also not readily available for GHG calculations. Weights of applied goods and materials need to be determined per surface unit, which requires a considerable time effort and the willingness of suppliers to cooperate in this information finding exercise. At this time, this is judged not to be feasible and to require it would potentially obstruct the use of this horticulture specification. A second option, the use default data for the calculation of the GHG contribution of production and depreciation of greenhouses, has been rejected because data would only be available and representative for some production systems.

C.2.4 Consistency with PAS 2050: 2011 exclusion of capital goods

Consistency with the overall PAS2050: 2011 approach, and especially the exclusion of capital goods, was also an issue in the debate concerning whether or not to include the greenhouses in the GHG assessment. The original motivation for exclusion in PAS 2050 had to do with the relatively low materiality of capital goods and the high data needs. This is absolutely true for most industrial production systems but in farming systems, buildings, sheds, housing systems, etc. often have a contribution of around 10% of the GHG impact (Frischknecht et al 2007). So there is evidence that exclusion of capital goods for farming products in general is not desirable in the GHG assessment. In a further update of PAS 2050 this should be reconsidered.

However, to remain as consistent as possible with the current PAS2050:2011 it was decided that greenhouses should be excluded. Also because of the fact that use of the horticulture specification is strongly recommend within PAS2050 but not mandatory. To prevent a situation where users may choose the easiest way to do their assessment according to PAS 2050, by not taking capital goods into account, it was decided that greenhouses and for reasons of functional consistency their plastic equivalents, should be excluded.

C.3 Conclusion

In horticulture there is wide variety of goods used for sheltering and controlling climate conditions. The goods and materials used for that purpose may have a short lifespan (goods that are used and disposed of in one year, such as growing media, covering materials like foils or straw) or a longer lifespan, such as plastic tunnels or glass greenhouses, shelves, etc.

A part of these goods would qualify as capital goods, such as the greenhouse and its energy installation and other equipment in the greenhouse. The contribution of these goods in the GHG emissions can be quite significant, as well in heated greenhouse systems as in tunnel or other sheltered systems. So from a viewpoint of materiality, inclusion is desirable. However, inclusion would create a huge data collection problem for the operator that also has the option to conduct its assessment under PAS2050: 2011 without using the supplement. Therefore greenhouses, equivalents and other related goods, are excluded in this specification. Inclusion should be reconsidered in the future update of the horticulture specification.

References from Annex C

Blank, M. 2011, Personal communication.

Blonk et al 2010, Methodology for assessing carbon footprints of horticultural products; A study of methodological issues and solutions for the development of the Dutch carbon footprint protocol for horticultural products, Blonk Milieu Advies, Gouda, http://www.blonkmilieuadvies.nl/en/pdf/engels%20rapport%20pt%202010.pdf

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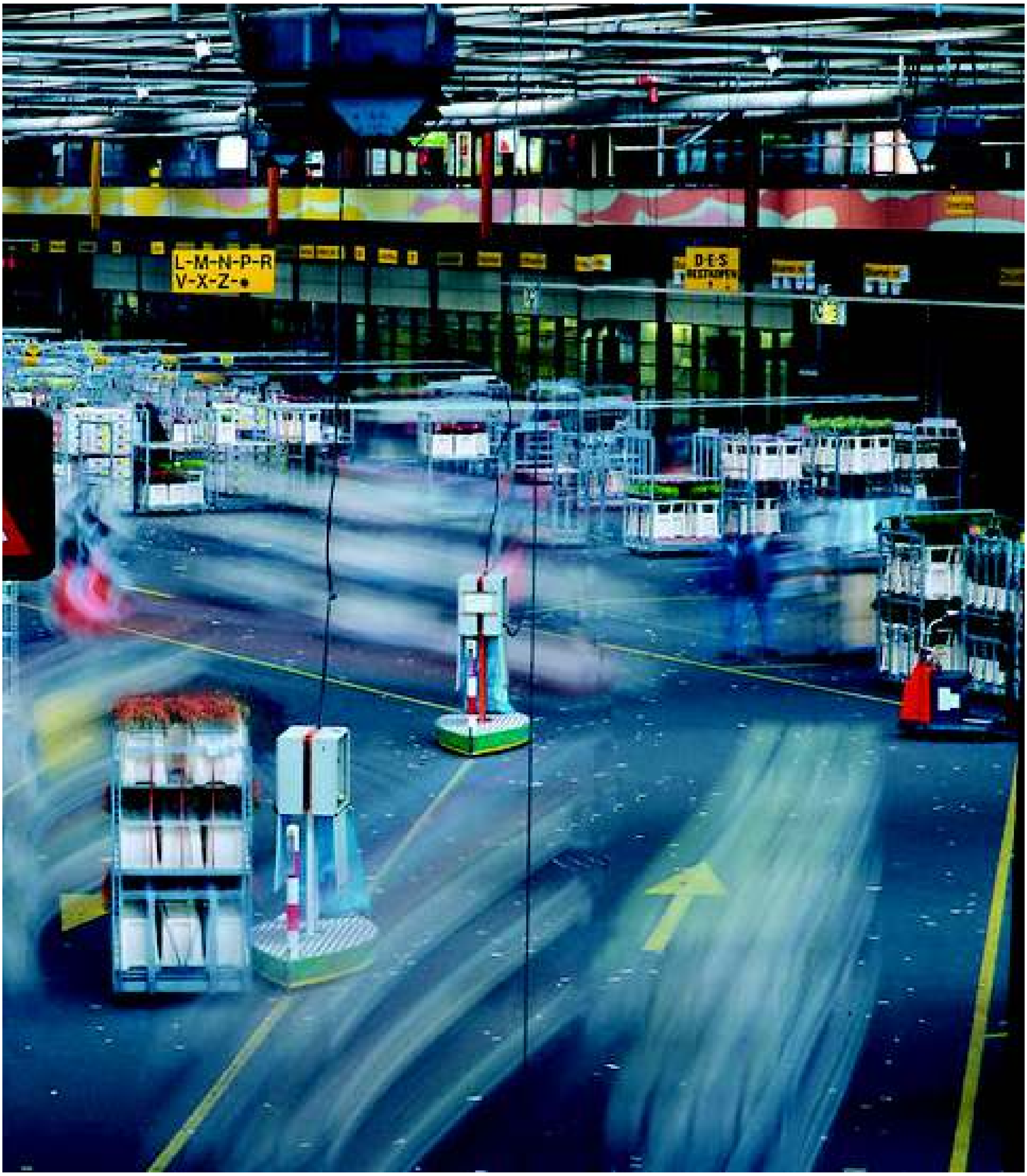


Annex D (informative)
Materiality – Subdivision of types of horticultural products and the contribution of emission sources

D.1 Introduction

Case studies undertaken (see **Figure D1**), provide for a good understanding of which processes make a substantial contribution to the GHG emissions of horticultural products and which processes make smaller contributions. This information can assist in the determination of which processes to include in a GHG emissions assessment for horticultural products, which can considerably speed up the process of data collection and the calculation of emissions in the supply chain. The breakdown of the overall GHG emission's (relative contributions of different emission sources) can be used to divide horticultural products into the categories a) through f), below:

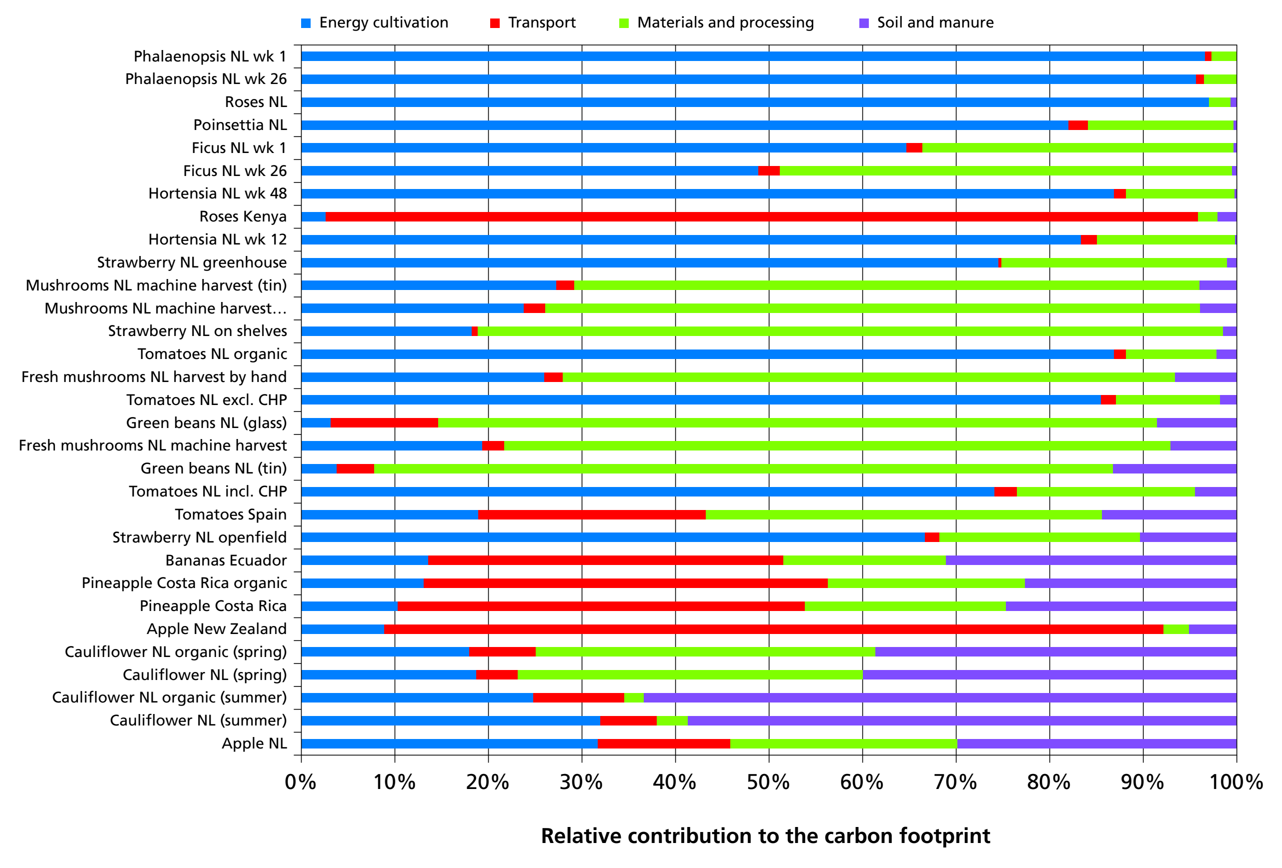
a) Heated cultivation without air transport
b) Heated cultivation with air transport
c) Protected and/or unheated cultivation in soil, with air transport
d) Protected and/or unheated cultivation in soil, without air transport
e) Field cultivation without air transport, processed
f) Field cultivation without air transport, unprocessed

Assessment of the contributions of each category is set out in Table D1.

Table D.1 Indication of contribution of inputs in the GHG emission of horticultural products including transport to retail

	Indication GHG emission (kg CO_2e/ ton)	Contribution >5%	Contribution 1-5%	Contribution <1%
1. Greenhouse production without air transport	500-50000	Energy use; Peat in growing media; Greenhouse, Planting material	Growing media (non peat); N-fertiliser; Greenhouse; Packing material; Transport; Cooling and storage	Pesticides; Phosphate; Potassium
2. Greenhouse production with air transport	3000-60000	Energy use; Peat in growing media; Greenhouse, Planting material; Air transport	Growing media (non peat); N-fertiliser; Greenhouse; Packing material; Transport; Cooling and storage	Pesticides; Phosphate; Potassium
3. Protected and/ or field production, not heated, with air transport	3000-12000	Peat growing media; Planting material; Air transport; N-fertiliser	Packing material; Building material; Protection material; Farm energy use; Transport (non-air); Cooling and storage	Pesticides; Phosphate; Potassium
4. Protected and/or field production, not heated, processed, without air transport	300-2500	Peat growing media; Planting material; N-fertiliser; Material use; Transport (large distance)	Packing material; building material; protection material; farm energy use; transport (short distance); cooling and storage	Pesticides; Potassium Phosphate
5. Field production, without air transport, processed	500-25000	N-fertiliser; transport (large distance); Energy processing; Packaging	packing material; farm energy use; transport (short distance); cooling and storage	Pesticides; Phosphate; Potassium
6. Field production, without air transport, without processing	100-800	N-fertiliser; transport (large distance); N-fertiliser production; Farm energy use	Pesticides; potassium and phosphate; cooling;	

Figure D.1 Relative contributions by various life cycle elements to the total greenhouse effect



***Note** The greenhouse effect increases from the bottom to the top of the chart.*

Annex E (informative)

Steady-state – Defining the inputs and outputs of perennial and annual crops over a specified period

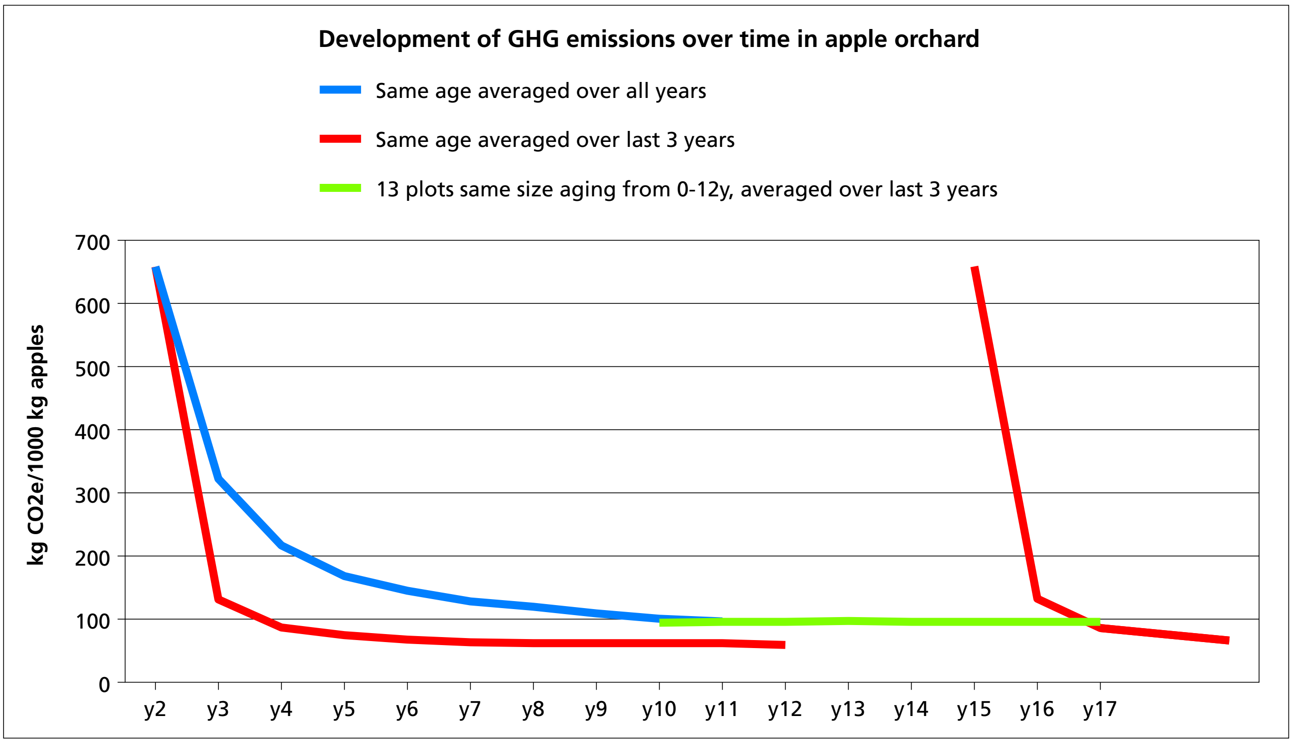
E.1 Assuming a steady state situation for perennial crops as starting point for the calculation of GHG emissions

Example: Using the three year period in the 'steady state' of perennial crops

It may take several years before fruit and nut trees reach their full potential in annual production, while especially the inputs in the first years are much higher than in the following years. shows the development of the GHG emissions of a Dutch apple orchard over time. In the first year, the major contributors are young plant material and the use of potting soil. In the following years, the inputs develop in relation to the amount of crop yield of the trees and the labour needed for the trees. The GHG emissions per hectare vary slightly over the years, but not so much as in the first years.

If the GHG emission of the apples are calculated over all development stages of the tree up to the year of assessment, a high value results in the first years of production that rapidly declines in the following years (see blue line in). After 12 years, the trees are taken out of production. The average carbon footprint over 12 years is, in this example, 91 kg CO2e per 1000 kg apples for cultivation (included are the full lifecycle of young plant material production at the start and the waste treatment, recycling and end of life. Storage is excluded in this example). The calculation method according to provision , where the average value is determined over the last three years, would also result in 91 kg CO2eq per 1000 kg of apples if the orchard exists for at least 13 years and has an evenly representation of plots with trees from 0 to 12 years (see green line in). This means that the farmer replaces old for new trees when they are 12 years old on 7.7% of his area. By doing this, he or she will theoretically retain a constant crop yield. This mathematical precision will not be found in reality for many reasons, such as the switch to other more economically viable apple varieties or that plots have deviating measurements. In general, it can be found that in older orchards the calculated GHG emissions over three years will give a good reflection of the management of the farmer.

Figure E.1 Example of the development of GHG emissions over time in an orchard



Using the three years period for defining inputs and outputs needs further consideration in two particular situations:

a) The orchard consists of apple trees of all the same age. Here it will be found that the calculated GHG emissions will evolve as the red line in , which gives values around 60 kg CO_2e per 1000 kg from the age of seven years.

b) The orchard is young compared to the expected final age of the trees. For example, in the case of an orchard of 8 years, the GHG emissions assessment outcome would be 113 CO_2e pr 1000 kg instead of 91 CO_2e per 1000 kg in the case of a 12 year orchard.

The GHG emission in both situations shall be corrected by bringing the areas of different growing stages in proportion to the expected proportion in steady state. This correction must be motivated and recorded transparently Two types of information is needed for this. First, the different production stages of the trees with their inputs and outputs must be defined, so that per life stage a GHG emission per hectare and tonnes output can be calculated. Second a scenario needs to be defined in which the different areas of production stages are in proportion for steady state situation. See a for a calculation example in case of an apple orchard where all trees are in their high productive stage for some years.

Table E.1 Correction on bringing the different development stages of an orchard in proportion

	Current area	Av. kg CO2e/ last 3 years	Area needed for steady state	GHG emissions/ha	GHG emissions
High productive	100 ha; 50 t/ha		100 ha; 50 t/ha	3000	300000
Semi productive			20 ha; 40 t/ha	3300	66000
Low productive			5 ha; 30 t/ha	4000	120000
Non productive (young trees)			5 ha; 0 t/ha	9000	45000
Kg CO2eq		300000			531000
Yield in tonnes		5000			5900
Kg CO2e/tonnes		60			90

Annex F (informative) Bibliography and data sources

F.1 Bibliography

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