Environmental footprint of Phalaenopsis: Summary of the representative product study

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Introduction

This document is a summary of a representative product (RP) study carried out in the context of the development of a methodology for calculating the environmental footprints of horticultural products, according to the HortiFootprint Category Rules (HFCR, see Helmes et al., 2020). The development of the HFCR was initiated by Royal FloraHolland, Dutch Fresh Produce Centre and Wageningen Economic Research, with co-financing from the Dutch Fund for Horticulture & Propagation Materials, ABN AMRO Bank N.V., the Dutch sector organisation for greenhouse horticulture (Glastuinbouw Nederland), MPS, Rabobank, Foundation Benefits of Nature and in co-production with experts from Blonk Consultants and PRé Sustainability.

This is one of the six studies on horticultural representative products that have been selected based on a wide and economically relevant variety of applied technologies and origins of productions. These are:

- Roses (perennial plant yielding flower stems, grown in soil in a greenhouse, with and without air transport);
- Phalaenopsis (ornamental plant cultivated in two stages, in substrate and in greenhouse);
- Tulip bulbs (annual crop in soil, grown without greenhouse protection, with ornamental function);
- Tomatoes (annual vegetable cultivated in greenhouse, on substrate);
- Bananas (tropical perennial fruit with variability in energy-consuming global transport);
- Apples (temperate perennial fruit with variability in energy-consuming storage and global transport).

This summary is prepared on the basis of an RP study for assessing the environmental footprint of the complete life cycle of greenhouse Phalaenopsis plant, which was completed in 2018.

Goal & scope

The representative product under study is Dutch greenhouse Phalaenopsis. The objectives of this study are:

- To identify the most relevant impact categories, life cycle stages, and processes;
- To determine the data (quality) requirements;
- To support the development of the HFCR; an earlier draft of the HFCR was tested to check the draft HFCR for completeness and clarity, and to check the feasibility of completing a study in accordance with the draft HFCR.

This fact sheet summarises the representative product (RP) study for Phalaenopsis plants, packed, produced in a Dutch greenhouse with combined heat and power (CHP) system in the young plant stage, and geothermal heat in the large plant stage, sold in a Dutch supermarket and consumed in the Netherlands. The plant of focus is in a 12 cm pot of a two-stem Phalaenopsis as sold in retail. This is also the reference flow.

The system includes a greenhouse structure (built from glass, steel, aluminium, concrete, etc.) with a combined heat and power unit with a flue gas treatment to provide heat, electricity and purified carbon dioxide, and a greenhouse with a geothermal heat system at another location. The Phalaenopsis are grown by planting propagation material on substrate and the plant is then treated with fertilisers, water and pesticides in two stages. Surplus electricity is supplied to the grid. After harvest the Phalaenopsis are packed and transported to retail. In the use phase, consumers use the plant for decoration during which the substrate decomposes a little. Once the decoration value has diminished, the plant, the packaging, pot and substrate in the pot are treated at disposal in the end-of-life phase.

Data collection and modelling

The following key methodological choices and assumptions were made:

- The cultivation, combined heat and power and carbon dioxide purification processes were divided into different unit processes.
- For the co-production of heat and electricity, energy allocation was applied.
- The heat production efficiency was assumed at 48% and the electricity production efficiency 40% (Van der Velden and Smit, 2017).
- The emissions from burning natural gas in the CHP system were derived from IPCC (Gomez et al., 2007) for CO_2 and N_2O, from Plomp and Kroon (2013) for CH_4, and from the European Environmental Agency (EEA, 2016) for NO_x, CO, non-methane volatile organic compounds, SO_2 and particulate matter.
- Industrial CO_2 production was modelled according to Xuezhong and Hägg (2014), Veneman et al. (2013), Frischknecht (1999) and OCAP (2018).
- The technical lifetime of the capital goods for cultivation (greenhouse structure) is assumed to be 15 years.
- The technical lifetime of the capital goods for geothermal heat production is assumed to be 30 years.
- The approach of PAS2050-1 (BSI, 2012) to calculate CO_2 and N_2O, emissions from peat substrate was followed, with the interpretation that the remaining mineralisation after cultivation occurs during the use stage.
- Distribution was modelled by assuming averaged distances for the Dutch situation.
- Retail was modelled with data and guidance from the OEFSR Retail (Quantis, 2018).
- Mass balances relevant for major emissions were modelled according to the PEFCR guidance (EC, 2018):1); this considered field N_2O, nitrate, ammonia emissions. 2) Biogenic CO_2 uptake and release from plant and substrate were calculated based on Blonk et al. (2009), Paradiso et al. (2012) and PAS2050-1 (BSI, 2012).
- Biowaste treatment processes were modelled as adaptations from the ecoinvent process Biowaste {GLO}| treatment of biowaste, municipal incineration | Cut-off, U (Wernet et al., 2016).

Foreground data was collected as averaged primary data from orchid-growing operations in the Netherlands as compiled by Benefits of Nature, including packaging, and augmented with data from literature (see the assumptions above, Montero et al., 2011 for the greenhouse construction and Vlaar et al., 2013 for geothermal heat). For storage, retail and the use stage, datasets were created using default data for these, processed using the PEFCR guidance documentation (EC, 2018). The end of life was modelled using details from Annex C from the same document.

For the background data, ecoinvent version 3.4 cut-off was used (Wernet et al., 2016) as well as Agri-footprint 4.0 (economic, see Agri-footprint 2018 a, b). The EF Life Cycle Inventory (LCI) database could not be used, because the original study was not part of an official PEF pilot by the European Commission, as it was conducted before the current transition phase. The conclusions in this study and the aims this study can be used for have been drafted in such a way to ensure validity (see disclaimer). The modelling was done in SimaPro version 8.5.2, following the PEF rules at that time (EC, 2018). The impact assessment was done using the EF impact assessment model version 2.0.

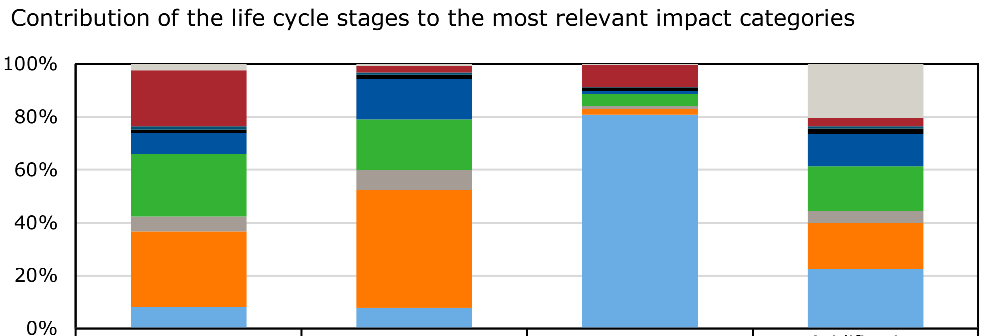
Most relevant impact categories, life cycle stages and processes

The **most relevant impact categories**, which contribute cumulatively to at least 80% of the normalised and weighted life cycle results of this study, are:

- Climate change;
- Resource use, energy carriers;
- Resource use, mineral and metals;
- Terrestrial and freshwater acidification;
- Freshwater ecotoxicity (not included in the weighted results, but considered as relevant due to the perceived importance of the environmental impact of pesticides).

The **most relevant life cycle stages** of the studied Phalaenopsis plant are capital goods, energy production, cultivation, packaging, use and end of life.

Freshwater ecotoxicity was not included in the weighted results, but considered as relevant due to the perceived importance of the environmental impact of pesticides. Figure 1 shows the contribution of the Phalaenopsis life cycle stages to the relevant impact categories. The most relevant processes and most relevant elementary flows are shown in **Table 1** and **Table 2**, respectively.



	Climate change	Resource use, energy carriers	Resource use, mineral and metals	Acidification terrestrial and freshwater
End of Life	2%	1%	0%	20%
Use	21%	2%	8%	3%
Retail	1.2%	1%	0%	1%
Distribution	1%	2%	1%	2%
Packaging	7.9%	15%	1%	12%
Cultivation	24%	19%	5%	17%
Carbon Dioxide	6%	7%	1%	4%
Energy	29%	45%	2%	17%
Capital Goods	8%	8%	81%	23%

Figure 1 *Contribution of the Phalaenopsis life cycle stages to the relevant impact categories*

Table 1 *The most relevant processes contributing in total at least 80% to the impact of one or more relevant impact categories*

	Climate change	Resource - energy	Resource - minerals	Acidification	Ecotoxicity
Emissions during use	19%	-	-	-	-
Heat from CHP	18%	-	-	7%	-
Emissions during cultivation	9%	-	-	-	-
Electricity from grid, low voltage	6%	7%	-	5%	2%
Polypropylene	5%	14%	-	7%	5%
Peat substrate	5%	5%	-	-	-
Polystyrene	4%	8%	-	6%	4%
Natural gas production	3%	37%	-	5%	-
Electricity from grid, medium voltage	3%	4%	-	3%	-
Deep well	2%	2%	-	5%	6%
Transport with car by user	2%	2%	8%	3%	10%
Heat from boiler	2%	2%	-	-	-
Plastic waste processing	2%	-	-	-	5%
Zinc coat in greenhouse	-	-	33%	3%	-
Aluminium in greenhouse	-	-	22%	3%	3%
Electronics in greenhouse	-	-	12%	-	-
Steel in greenhouse	-	-	6%	3%	12%
Biowaste treatment	-	-	-	19%	-
Glass in greenhouse	-	-	-	4%	-
Thermoforming plastic	-	-	-	3%	-
Transport in lorry, EURO5, global	-	-	-	2%	9%
Moulding plastic	-	-	-	2%	-
Municipal waste treatment	-	-	-	-	14%
Coconut fibre	-	-	-	-	5%
Chromium steel in greenhouse	-	-	-	-	2%
Ethanol	-	-	-	-	2%
Carbon dioxide fertilisation	-	-	-	-	2%
Remaining processes	19%	19%	18%	20%	19%

Table 2 *Most relevant elementary flows contributing in total at least 80% to the impact of one or more relevant impact categories*

	Climate change	Resource - energy	Resource - minerals	Acidification	Ecotoxicity
Carbon dioxide, fossil	87%	-	-	-	-
Gas, natural/m^3	-	55%	-	-	-
Oil, crude	-	22%	-	-	-
Coal, hard	-	11%	-	-	-
Cadmium	-	-	34%	-	-
Lead	-	-	23%	-	-
Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In	-	-	6%	-	-
Chromium	-	-	5%	-	-
Zinc	-	-	4%	-	-
Gold, Au 6.7E-4%, in ore	-	-	4%	-	-
Gold	-	-	4%	-	-
Gold, Au 4.9E-5%, in ore	-	-	3%	-	-
Sulfur dioxide	-	-	-	42%	-
Ammonia	-	-	-	29%	-
Nitrogen oxides	-	-	-	29%	-
Antimony, to water	-	-	-	-	31%
Chromium VI, to water	-	-	-	-	17%
Antimony, to air	-	-	-	-	10%
Chromium, to air	-	-	-	-	5%
Zinc, to water	-	-	-	-	5%
Zinc, to air	-	-	-	-	4%
Zinc, to soil	-	-	-	-	3%
Pyrene, to water	-	-	-	-	3%
Copper, to air	-	-	-	-	2%
Arsenic, to water	-	-	-	-	2%
Remaining substances	13%	12%	18%	0%	17%

Overall appreciation of the uncertainties of the results
The uncertainty of the results is due to different factors depending on the impact category. A large part of the uncertainty is caused by the quality of the background databases and on the main assumptions listed above. There are also several important parameters in the foreground data which have been estimated based on various sources, which may not be representative or accurate, specifically considering the mineralisation and waste treatment of peat. For the purpose of the current study, all assumptions and data estimations are considered adequate.

Data quality requirements

This study also aimed at identifying the data collection and data quality requirements to ensure robust and high-quality results for similar horticultural products. The requirements determined on the basis of this study are displayed in Table 3.

Table 3 *Data quality requirements (DQR) for the different life cycle stages for Phalaenopsis*

Life cycle stage	Current DQR	Data quality requirement (DQR score)
Cultivation	Amounts of inputs and elementary flows	≤1.6; Very good to Excellent quality
Post-harvest handling	No post-harvest handling	Not applicable
Packaging	Generic data allowed	≤1.6; Very good to Excellent quality
Distribution	Distance and transport mode	≤3.0; Good quality [1]
Storage	Generic data allowed	≤3.0; Good quality
Retail	Generic data allowed	≤3.0; Good quality
Use	Generic data allowed	≤3.0; Good quality [2]
End of life	Percentages and types of waste treatment, generic data allowed	≤3.0; Good quality [3]
Inputs of the processes above and waste treatment processes	Generic data allowed	≤3.0; Good quality

Disclaimer

The RP study is NOT intended to make statements about the product group impacts as such, nor is it intended to be used in the context of comparison or for comparative assertions to be disclosed to the public. The results can be used to see where potential hotspots are by looking at the most relevant impact categories, life cycle stages, processes and elementary flows.

In practice, there is a clear variety in Dutch greenhouse Phalaenopsis production with respect to how energy is produced, and what sources of energy and purified carbon dioxide are, and in what quantities they are used. In many cases like the current case, a mix of different sources is used and the quantities will vary year by year due to weather conditions and economic developments. The absolute results of the current case cannot be regarded as representative of the large variety in practice, but the general conclusions on the hotspots and the resulting data quality requirements will apply to Dutch heated and protected Phalaenopsis production in general.

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[1] The variation in distance and transport mode need to be reviewed.

[2] Because peat is a fossil material causing fossil CO_2 emissions, the share of mineralisation of peat should be set as a default generic value of high data quality.

[3] For the same reason as footnote 2, the carbon emissions from biowaste treatment should be set as a default generic value of high data quality.

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