Environmental footprint of tomatoes: Summary of the representative product study

Tommie Ponsioen, Roel Helmes

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, 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 variety of applied technologies and origins of productions. These are:

- 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);
- phalaenopsis (ornamental plant cultivated in two stages, in substrate and in greenhouse);
- roses (perennial plant yielding flower stems, grown in soil in a greenhouse, with and without air transport);
- tulip bulbs (annual crop in soil, grown without greenhouse protection, with ornamental function).

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

Goal & scope

The representative product under study is Dutch greenhouse tomatoes. 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 factsheet summarises the screening study for tomatoes, of a regular size of approximately 100 g each, packed, produced in a Dutch greenhouse with a combined heat and power (CHP) system or a geothermal heat system, sold in a Dutch supermarket and consumed in the Netherlands. The reference flow is 1 kg of tomatoes as weighed just after packaging (excluding the packaging weight).

The system includes a greenhouse structure (built from glass, steel, aluminium, concrete, etc.) with a CHP unit with flue gas treatment to provide heat, electricity and purified carbon dioxide, or a geothermal heat system. The tomatoes are grown by planting propagation material on substrate and the crop is then managed with fertilisers, water and pesticides. Surplus electricity produced in the CHP is supplied to the grid. After harvest the tomatoes are packed and transported to retail, then consumed and the packaging and excess organic material is treated at disposal.

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 He 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.
- Distribution was modelled by assuming average distances for the Dutch situation.
- It was assumed that 10% of the harvested tomatoes are not consumed due to losses during post-harvest handling, packaging, distribution, and retail and 19% during the use stage (according to the Organisation Environmental Footprint Sector Rules (OEFSR) Retail, see Quantis (2018)).
- It was assumed that 62% of the tomatoes are transported by the consumer by passenger car and 5% are delivered by the retailer to the consumer (according to the OEFSR Retail, see Quantis (2018)).
- It was also assumed that 5% of the harvest weight is moisture loss during post-harvest handling and packaging.
- It was assumed that tomatoes are mainly consumed raw.

Foreground data was collected as averaged primary data from tomato growing operations in the Netherlands, and augmented with data from literature (see the assumptions above; Montero et al. (2011) for the greenhouse construction, GroentenFruit Huis (2018) and Davis et al. (2011) for packaging and Vlaar (2013) for geothermal heat). For storage, retail and the use stage, datasets were created using default data for these processes in accordance with the PEFCR guidance documentation (EC, 2018).

For the background data, ecoinvent version 3.4 cut-off was used (Wernet et al., 2016), among others for end-of-life modelling. 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;
- Respiratory inorganics;
- 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** are cultivation (which includes capital goods, energy production and carbon dioxide), packaging and use stage (but only in the freshwater ecotoxicity impact category).

Figure 1 and Figure 2 show the contribution of the tomato life cycle stages to the relevant impact categories. From this we observe that the most relevant life cycle stage of the studied tomatoes is cultivation (which includes capital goods, energy production and carbon dioxide). Besides cultivation, packaging and use stage are also relevant stages, but only in the freshwater ecotoxicity impact category.

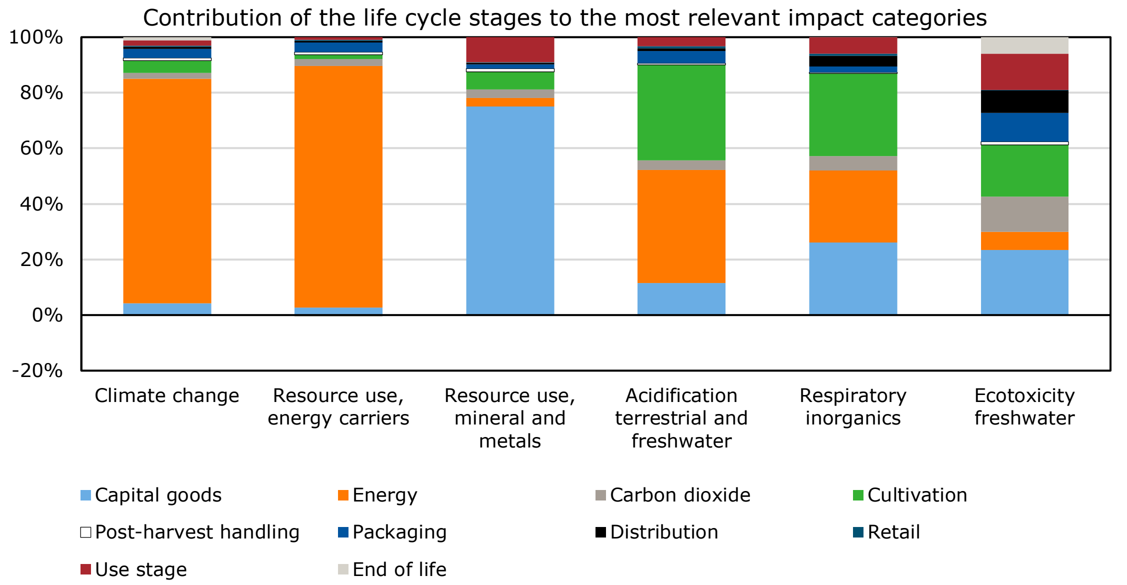

Figure 1 *Contribution of the tomato life cycle stages to the relevant impact categories (energy from CHP system)*

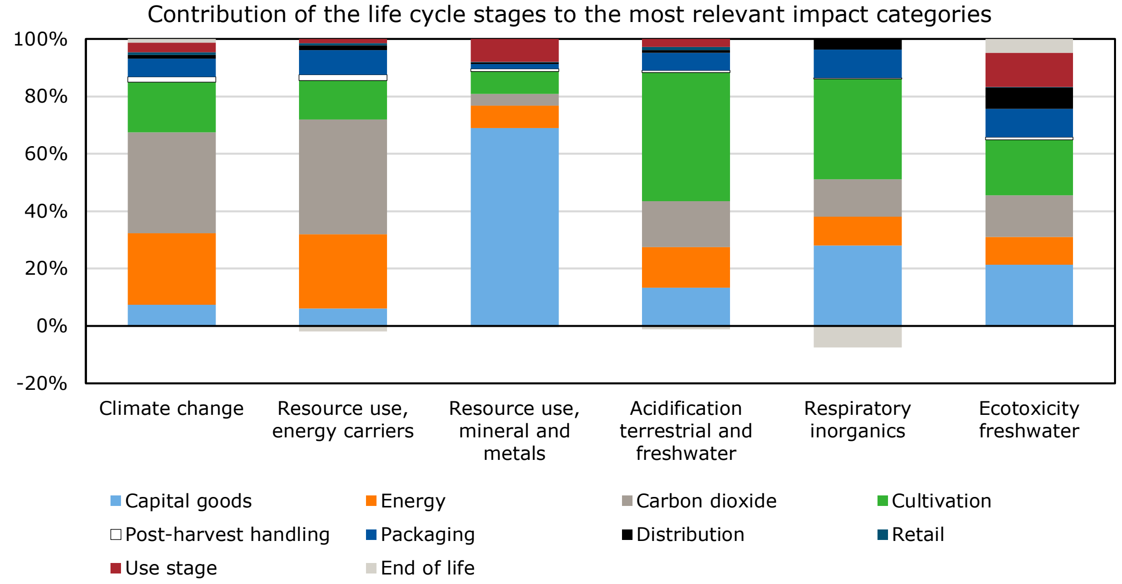

Figure 2 *Contribution of the tomato life cycle stages to the relevant impact categories (geothermal heat and electricity from grid)*

The most relevant processes and most relevant elementary flows are shown in Table 1 and Table 2, respectively.

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

Process	Life cycle stage	Tomato with CHP	Tomato with geothermal heat
Aluminium alloy, AlMg3 {GLO}|	Capital goods	x	
Electronics, for contr. unit {GLO}|	Capital goods		
Flat glass, uncoated {GLO}|	Capital goods	x	
Steel, low-alloyed {GLO}|	Capital goods	x	x
Zinc coat, coils {GLO}|	Capital goods	x	x
Electronics, for control units {GLO}|	Capital goods	x	
Waste polyethylene {Europe}| treatment	Energy		x
Electricity, low voltage {NL}|	Energy		x
Heat from CHP, NL	Energy	x	
Natural gas, high pressure {NL}|	Energy	x	
Electricity from CHP, NL	Energy	x	
Carbon dioxide from external NL	Carbon dioxide		x
Electricity, medium voltage {NL}|	Carbon dioxide		x
Heat, dist./indus., nat. gas {Europe}|	Carbon dioxide		x
Monoethanolamine {GLO}|	Carbon dioxide	x	x
Carbon dioxide from CHP NL	Carbon dioxide	x	
Biowaste {NL}| treatment	Cultivation	x	x
Nitrogen fertiliser, as N {GLO}|	Cultivation	x	x
Tomatoes, at grower, NL	Cultivation	x	x
Corrugated board box {GLO}|	Packaging	x	x
HDPE, granulate {GLO}|	Packaging		x
Transport, lorry >32mt, E6 {GLO}|	Distribution	x	x
Transport, passenger car {RER}|	Use stage	x	x

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

Elementary flow	Emission compartment	Tomato with CHP	Tomato with geothermal heat
Carbon dioxide, fossil	Air	x	x
Gas, natural/m3	Raw material	x	x
Coal, hard	Raw material		x
Oil, crude	Raw material		x
Gold	Raw material	x	x
Cadmium	Raw material	x	x
Lead	Raw material	x	x
Copper	Raw material	x	x
Nitrogen oxides	Air	x	
Ammonia	Air	x	x
Sulfur dioxide	Air	x	x
Particulates, < 2.5 um	Air	x	x
Chromium VI	Water	x	x
Monoethanolamine	Air	x	x
Antimony	Air	x	x
Teflubenzuron	Water	x	x
Chromium	Air	x	x
Zinc	Water	x	x
Zinc	Air	x	x
Teflubenzuron	Air	x	x
Antimony	Water	x	x
Chlorothalonil	Soil	x	x
Vanadium	Air	x	x

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 basis of this study are displayed in Table 3.

Table 3 *Data Quality Requirements (DQR) for the different life cycle stages for tomatoes (Note: DQRs range from very good (1) to very poor (5) quality)*

Life cycle stage	Data collection needs	Data quality requirement (DQR)
Cultivation	Energy: amounts of capital goods, materials and elementary flows	≤1.6; Very good to excellent quality
	Capital goods: amounts of main materials of the greenhouse structure	≤1.6; Very good to excellent quality
	Amounts of all other inputs and elementary flows	≤1.6; Very good to excellent quality
Post-harvest handling	Generic data allowed	≤3.0; Good quality
Packaging	Amounts of components of primary packaging	≤1.6; Very good to excellent quality
	Amounts of all other inputs and elementary flows	≤3.0; Good quality
Distribution	Distance and transport mode	≤1.6; Very good to excellent quality
Retail	Generic data allowed	≤3.0; Good quality
Consumption	Generic data allowed	≤3.0; Good quality
End of life	Percentages and types of waste treatment, generic data allowed	≤3.0; Good quality
Inputs of the processes above and waste treatment processes	Generic data	≤3.0; Good quality

Disclaimer

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

Acknowledgement

This study was carried out in the framework of the public-private partnership project HortiFootprint 'Methodology for environmental footprint TU17005' for the Topsector Agri & Food, as part of the Programme 'Consumer, Market and Society'. The authors would like to thank Hans Blonk from Blonk Consultants for his review of the draft representative product study and also a group of greenhouse vegetable growers for insightful discussion of the results in the workshop organised by Daan van Empel (Dutch Produce Centre) in December 2018.

References

Davis J, Wallman M, Sund V, Emanuelsson A, Cederberg C, Sonesson U (2011) Emissions of orchard gases from production of horticultural products. Analysis of 17 products cultivated in Sweden. SIK. http://www.diva-portal.org/smash/get/diva2:943913/FULLTEXT01.pdf

European Commission (2018) Product environmental footprint category rules guidance – version 6.3, May 2018. http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf.

European Environment Agency (2016) EMEP/EEA air pollutant emission inventory guidebook 2016. Technical guidance to prepare national emission inventories. https://www.eea.europa.eu/publications/emep-eea-guidebook-2016/download

Frischknecht R (1999) Umweltrelevanz natürlicher Kältemittel. Ökobilanzen von Wärmepumpen und Kälteanlagen. Bundesamt für Energie (BfE), Bern as pdf-File under: http://www.waermepumpe.ch/fe/Fr_LCA_SB_Anh.pdf

Gomez DR, Watterson JD, Americano BB, Ha, C, Marland G, Matsika E, Nenge Namayanga L, Osman-Elasha B, Kalenga Saka JD, Treanton K, Quadrelli R (2006) Chapter 2: Stationary combustion. Volume 2, IPCC guidelines for national greenhouse gas inventories. IPCC International Panel on Climate Change, Geneva, Switzerland, p. 47

GroentenFruit Huis (2018) Bijlage II van de Vaststellingsovereenkomst GroentenFruit Huis en Afvalfondsverpakkingen.

He X, Hägg MB (2014) Energy efficient process for CO2 capture from flue gas with novel fixed-site-carrier membranes. Energy Procedia 63:174–185.

Helmes R, Ponsioen T, Blonk H, Vieira M, Goglio P, van der Linden R, Gual Rojas P, Kan D, Verweij-Novikova I (2020) Hortifootprint category rules: towards a PEFCR for horticultural products Wageningen, Wageningen Economic Research. Report 2020-041.

Montero JI, Antón A, Torrellas M, Ruijs M, Vermeulen P (2011) Environmental and economic profile of present greenhouse production systems in Europe. European Commission (Euphoros reports deliverable 5 – annex)

OCAP: www.ocap.nl; access date November 1, 2018

Plomp AJ, Kroon P (2013) De mogelijke aanscherping van vijf eisen in het Besluit emissie-eisen middelgrote stookinstallaties. CEN Report. https://zoek.officielebekendmakingen.nl/blg-231229.pdf

Quantis (2018) Organisation environmental footprint sector rules (OEFSR). Retail. https://ec.europa.eu/environment/eussd/smgp/pdf/OEFSR-Retail_15052018.pdf

Velden van der N, Smit P (2017) Effect intensivering, extensivering en energiebesparing op CO_2-emissie Nederlandse glastuinbouw. Wageningen, Wageningen Economic Research, Rapport 2017-060.

Veneman R, Kamphuis H, Brilman DWF (2013) Post-combustion CO_2 capture using supported amine sorbents: a process integration study. Energy Procedia 37:2100-2108

Vlaar LNC (2013) Aardwarmte, basis voor duurzame productie van warmte in de glastuinbouw Inzicht in duurzaamheid van aardwarmte in het glastuinbouwcluster Koekoekspolder en perceptie daarvan in de markt. CLM Onderzoek en Advies BV. Culemborg, mei 2013. CLM 828 - 2013

Wernet G, Bauer C, Steubing B, Reinhard J, Moreno-Ruiz E, Weidema B (2016) The Ecoinvent Database Version 3 (Part I): overview and methodology', Int J of Life Cycle Assess 21:1218–30, https://doi.org/10.1007/s11367-016-1087-8.

More information
Roel Helmes
T +31 (0)6 10 05 27 78
E roel.helmes@wur.nl
www.wur.eu/economic-research

2020-041b