Life Cycle Assessment of Production and Handling of Flowers

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May 2023
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1. Introduction

Danish Technological Institute (DTI), Centre for Food Technology has carried out a life cycle assessment (LCA) from December 2022 till May 2023 for the company, Flowering ApS with the aim of assessing the environmental impact of the flowers used in their products and comparing them to conventional flowers. The task has been assigned by Flowering ApS who sell products which include a mix of flowers grown internationally according to environmental standards, Danish-grown flowers, and surplus flowers from various growers.

The basis of calculation has been established for the flowers by a collaboration between Asger Smidt-Jensen (and others), Danish Technological Institute, and Johan Vang Wildt and Artin Hodanloo, Flowering ApS.

The LCA has been carried out by Asger Smidt-Jensen, Danish Technological Institute, Food and Production, in accordance with the principles for LCA as outlined in DS/EN ISO-standard 14044:2006/A1:2018. The reporting follows the requirements of the ISO-standard for a comparative LCA to be published through critical review by experts within the field of LCA and horticulture/floriculture.

2. Goal

The goal of the LCA-study which is documented within this report was to assess and compare the environmental impacts of two different systems for the production of flowers for use in flower bouquets through the use of LCA-methodology:

1. The production of flowers for a flower bouquet using no plastic packaging, recycled water and a mix of internationally grown environmentally certified flowers purchased through wholesalers, Danish flowers traded directly, and surplus flowers grown conventionally but which would otherwise have been wasted.
2. The production of flowers for a flower bouquet through conventional means using plastic wrapping, and conventionally grown flowers exclusively purchased through wholesalers.

Further description of the two compared systems can be found in Section 4.3.

The main goal of the study was to assess and compare the CO_2-impact, i.e. GWP (Global Warming Potential), between the two systems. However, to ensure that no significant environmental impacts have been excluded from the analysis, additional impact categories are included which can be seen in Table 1.

It was part of the task to ensure that the systems are comparable in terms of function and quality as LCA-methodology cannot be used to assess differences between non-comparable systems. To ensure this comparability, a further discussion of the functional unit is included in Section 3.1, limitations are discussed in Section 6, and review by an external and an expert panel were included.

The material based upon this assessment is to be used by Flowering ApS in communication with customers, investors and other potential stakeholders as part of their marketing, as the potential environmental consequences of a choice of flower bouquets can be seen as a potential decision parameter.

3. Scope

3.1. Functional unit

The functional unit chosen for this study is 1 flower stem ready for distribution in Denmark. This is in accordance with the Hortifootprint Category Rules outlined in (Helmes, et al., 2020). A broader discussion of the significance of this functional unit can be found in the Hortifootprint Category Rules. However, as flowers serve a function which can be difficult to quantify due to their primary ornamental and cultural function, a flower stem is used as it is the smallest divisible unit.

The functional unit is, however, based on average values for production for a yearly period in order to eliminate any seasonal effects. This means that a larger basis of calculation than a single flower stem has been used for most of the calculations and that aggregated amounts have been used which have then been divided out unto single flower stems.

Flowers are seldom sold separately but in bouquets. Other materials than flowers can be present in such a bouquet such as leafy greens and branches. As a result of the choice of functional unit, this study cannot support a direct comparison of bouquets as a different number of flowers and different amounts of other materials might be present in such bouquets (see Section 6 for a more thorough discussion).

The comparison is based upon the same type of flowers used for bouquets for the two different systems – mainly tulips (Tulipa), sunflowers (Helianthus) and waxflowers (Chamelaucium), which were chosen to represent seasonal variations.

3.2. System boundaries

The LCA-study is limited to considering 1 flower-stem delivered to Denmark, cut, wrapped and ready for distribution. Thus, the processing of the flowers at the distribution center is also considered (including collection of flowers, cutting, storing and wrapping). This means that the system boundaries considered are from cradle to factory gate.

The utilized datasets for materials from the EcoInvent/Agribalyze-databases contain data from cradle to gate data for those materials, meaning that the distribution of those materials to the distributor of the flowers and the growers have been modelled on the basis of the average distances described in Section 4.5.

This means that this study considers the following stages of the life cycle (see Figure 1 for more detail):

- Cultivation
- International transport
- Post-harvest handling (storage, cutting etc)
- Packaging

These limited system boundaries mean that the following phases are not included within the boundaries of the analysis:

- Distribution to sales channels (wholesalers or consumers)
- Retail (including storage, repackaging etc)
- Consumer-handling
- Waste-handling/end-of-life of the final products

These have not been included as they are not expected to contribute to the aim and scope of the study or alter the results of the analysis significantly (see Section 6.2 for a more thorough discussion).

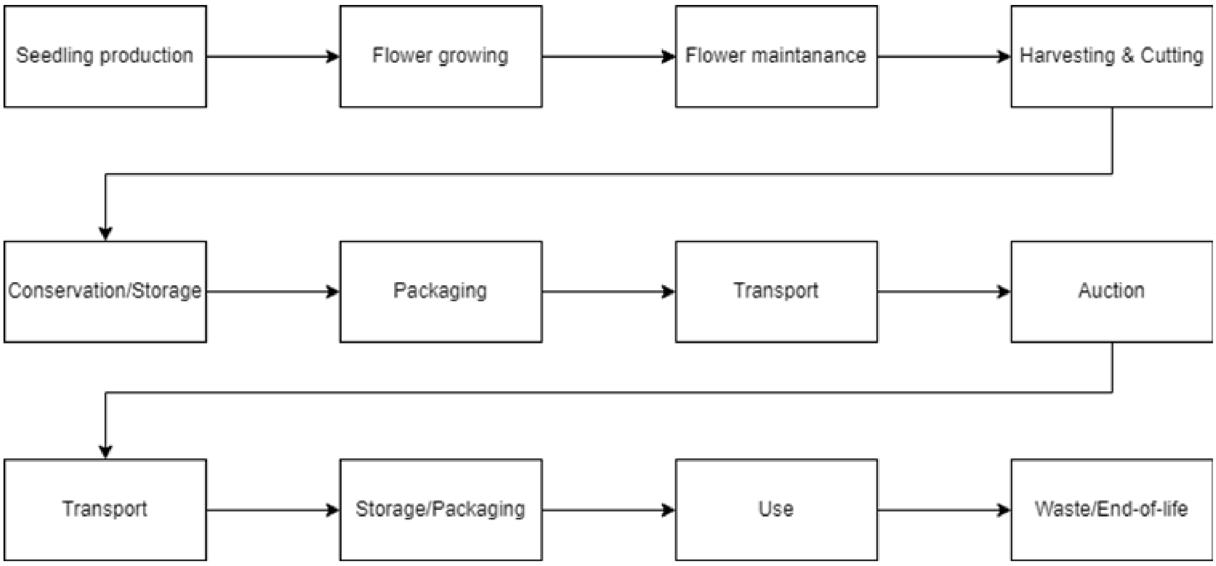

Figure 1 - Conceptual overview of the flower life cycle. Adapted from (La, Tam, Xing, Datt, & Chan, 2022).

Depreciation of buildings as well as other permanent fixtures have not been included in this analysis. However, the depreciation of agricultural machinery has been included (see Section 4.4 for more details)

4. Methods

4.1. LCA-modelling and LCA-method

For calculating the results of this LCA-study, OpenLCA 1.11.0 has been used to classify and characterize input and output flows. The results are presented as characterized results, meaning Life Cycle Impact Assessment (LCIA) results.

The used LCIA-methodology is the EF 3.0 methodology and the calculations have been carried out for the LCIA impact categories given in Table 1, and which are covered by the EF 3.0 LCIA-method:

Table 1 – List of impact categories assessed in this study (from the EF 3.0 LCIA-method). NMVOC's are non-methane volatile organic compounds.

Impact category	*Indicator (incl. abbreviation)*	*Unit*
Acidification	Accumulated Exceedance (AE)	mol H^+ eq.
Climate change	Global Warming Potential (GWP100)	kg CO_2-eq.
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq.
Particulate matter	Impact on human health	Disease incidence
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq.
Land use	Soil quality index Biotic production Erosion resistance Mechanical filtration Groundwater replenishment	Pt
Resource use, fossils	Abiotic ressource depletion – fossil fuels (ADP-fossil)	MJ
Ressource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	Kg Sb eq.

The selection of these eight impact categories is in accordance with the Hortifootprint Category Rules outlined in (Helmes, et al., 2020).

The LCIA-results are relative expressions, meaning that they do not predict impacts of category-endpoints or exceedance of threshold values, safety margins or risk levels.

No allocation has been performed in the present LCA-study. The study has been carried out only for the flower production and handling and data inputs for these operations have been based on datasets from the EcoInvent and Agribalyze databases. If allocation has been necessary for these products, it has been performed in the preparation of those datasets and is expected to have been handled correctly.

4.2. Critical review

In accordance with the ISO-standard, an independent review of the LCA-study was performed. This review was led by environmental engineer Birna Hallsdóttir with input from M.Sc in Environmental Management and sustainability expert Stefán Gíslason of Environice. This review-panel received a final draft of the report for review on which they based their initial draft of the review report which Danish Technological Institute received and adjusted this report accordingly. The adjusted report was then presented to the panel and a final review report was completed which can be found in Appendix 9.2.

Furthermore, an expert panel was part of the critical review ensuring comparability of the functional units and that the surplus flowers were modelled correctly (see Section 4.4.1 and 6.1 for a more thorough discussion). This expert panel consisted of LCA-specialist Beatriz Chambel Soares Vieira of the Centre for Bioresources at the Danish Technological Institute and business leader Hanne Bjørn Nedergaard of the Centre for Food Technology at the Danish Technological Institute.

4.3. Process overview

A conceptual overview which shows the processes within the system boundaries and material flows can be seen in Figure 2 and Figure 3 for the flowers used for Flowering's bouquet and a conventional bouquet. All processes shown are within the system boundaries, and the red lines indicate where primary data has been collected (the foreground system).

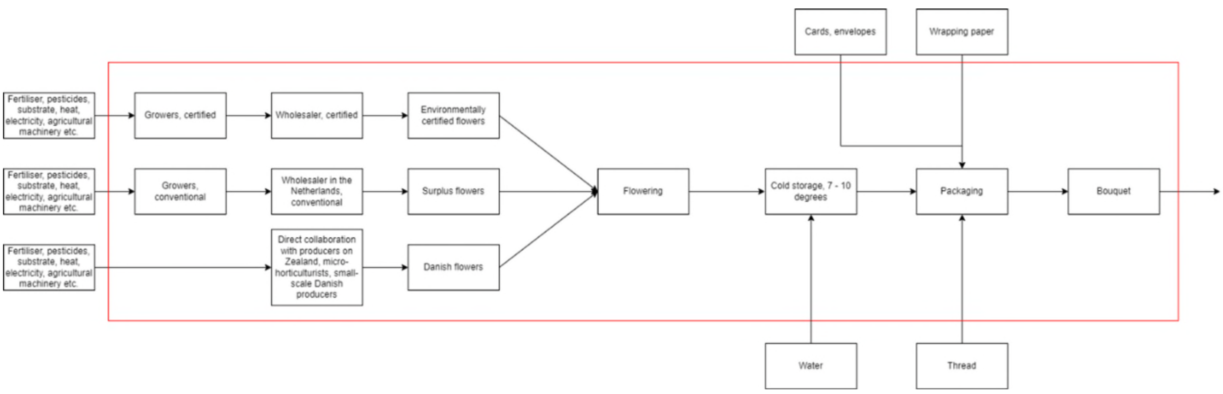

Figure 2 - Conceptual flow chart for Flowering ApS' production of flower bouquets ready for distribution using three sources of flowers assessed in this study. The red line indicates the part of the system which has been considered the foreground system in this study.

The surplus flowers used by Flowering come from wholesalers delivering flowers to distributors in Denmark from the Netherlands. These wholesalers discard any unsold flowers to municipal waste-handling before the trucks make the return-journey. These are then the surplus flowers used which are then transported to Flowering's distribution centers and sorted for incorporation in their bouquets.

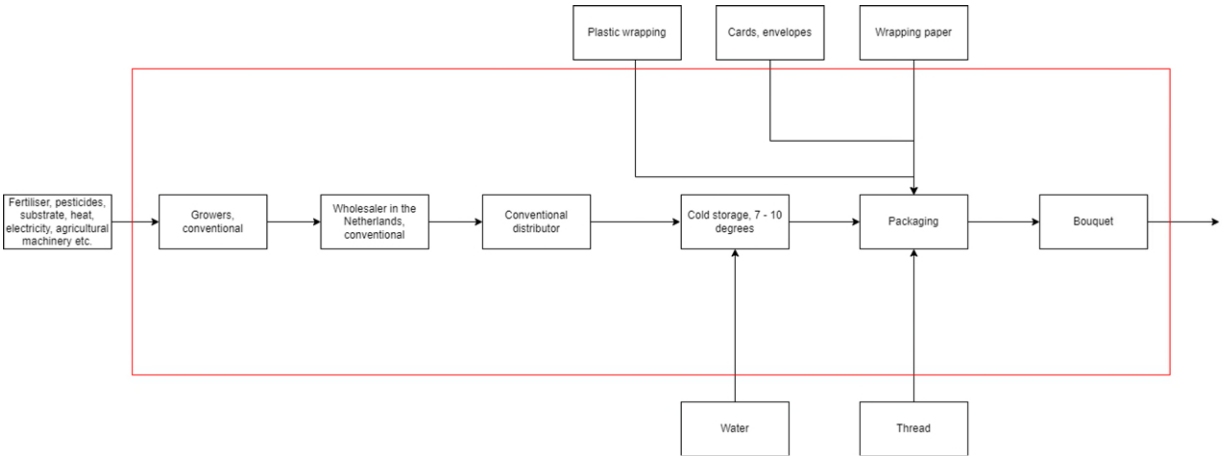

Figure 3 - Conceptual flow chart for the conventional production of flower bouquets ready for distribution assessed in this study. The red line indicates the part of the system which has been considered the foreground system in this study.

4.4. Data collection and modelling

Electricity usage was modelled as a consumption mix for the applicable country (Denmark, Israel, Italy, the Netherlands). The depreciation of agricultural machinery has been considered with a standard operating time of 4000 hours for agricultural machinery (a conservative estimate). Emissions from application of fertiliser was modelled after IPCC Tier 1 (The Intergovernmental Panel on Climate Change (IPCC), 2006). Any carbon sequestration during growth has not been included in this analysis, as the end-of-life phase is not included in the assessment where any such sequestered carbon would be either released or stored.

4.4.1. Flowers from Flowering

Data for the handling of flowers, storage and packaging performed by Flowering was collected through interviews with owners of Flowering ApS, Johan Vang Wildt and Artin Hodanloo. Through these interviews, data has been collected on the following points using recent sales data representative of the year 2022:

- Total production volume
- Electricity use
- Water use
- Heating and cooling use (including source)
- Use of packaging materials
- Other materials used
- Green waste generated
- Other waste generated

Data for the cultivation of flowers was collected from two representative Danish producers and two representative international environmentally certified growers. The Danish growers were Bakkegårds Blomster ApS where data was collected through interview with owner Henning Bakkegård Hansen, and Lille Torpegård where data was collected through interview with owner Rikke Råhauge Petersen. The international growers were Saidi-Ronen farm in Israel, which is certified by FSI and Global G.A.P where data was collected through interview with owner Arnon Ronen and from selected producers who are part of Coop Del Golfo in Italy, which is certified by FSI, GLOBAL G.A.P. and MPS (B certification). The collected data represented the following points:

- Historical area utilization
- Yield
- Rotation of crops
- Planting density
- Substrate
- Depreciation of machinery
- Water use
- Use of protection agents (insecticides, herbicides etc)
- Synthetic and mineral fertilisers
- Organic fertilisers
- Electricity usage
- Heating and cooling use
- Fuel usage
- Other materials used
- Green waste generated
- Other waste generated

The collected data reflects the increased loss of flowers caused by the utilization of surplus flowers in the bouquets, which means that a larger input of stems is needed for the production of a single stem. This loss is due to sorting of the secondhand flowers which means that a portion is discarded. Thus, a larger input of surplus flowers is needed. The discarded flowers are handled as green waste. The surplus flowers have been assumed to have no impact during production. However, their impact has been calculated through system expansion to include the end-of-life composting of them as green waste. Thus, the total impact of the surplus flowers corresponds to the additional impact of producing an identical amount of compost from green waste as their utilization instead of waste-handling results in an increased production of compost. An argument can be made that the flowers could potentially still be utilized for compost production during the end-of-life handling. However, as this depends on consumer and retail handling, this assumption is highly uncertain, and a more conservative estimate is therefore that their utilization in Flowering's bouquets results in an increase in compost production. A more thorough discussion of the inclusion of additional phases in the LCA-study can be found in Section 6.2.

4.4.2. Flowers from conventional distributor

Data on cultivation of tulips, sunflowers and waxflowers, storage, and post-harvest handling as well as any materials used have been taken mainly from the representative studies of the Hortifootprint PEFCR (Helmes, et al., 2020). Data on tulip cultivation was taken from the representative tulip study (Giglio, 2020), meaning that the data represents tulip production in the Netherlands in open field conditions. Data on wax flower cultivation as well as sunflower cultivation were taken from various literature sources (Alfredo, Rieradevall, & Gabarell, 2010) (Michael, 2011). Where necessary, data was fitted to the relevant national context. All data considered was cradle-to-gate, however, the Hortifootprint PEFCR does contain additional information on use and retail phases which were left out of this analysis.

4.5. Choice of specific materials

The material flows used for production of 1 flower stem ready for distribution in Denmark by Flowering can be seen in Table 2 to Table 4 together with their assumed transport distances and data sources. Calculation approaches of the respective amounts are presented in Appendix 9.1.

Table 2 – Input materials and relative amounts for production of 1 flower stem ready for distribution in Denmark by Flowering ApS.

Material	*Properties*	*Amount pr. functional unit*	*Data source*	*Transport distance*
Danish flowers	Supplier 1	0.18846 items	Primary data	55.5 km
Danish flowers	Supplier 2	0.06154 items	Primary data	116.2 km
International flowers	Average of suppliers	0.55 items	Primary data	3418 km
Surplus flowers	Modelled as compost from green waste	0.30 items	Primary data	35.6 km

Electricity		0.016074245 kWh	Electricity, medium voltage {DK}, market for, EcoInvent 3.9	N/A
Heat		0.05247 kWh	Heat, district or industrial, other than natural gas {DK}, EcoInvent 3.9	N/A
Water		0.00017 kg	Tap water {DK}, EcoInvent 3.9	N/A
Thread		0.00040 kg	Yarn, jute {GLO}, market for, EcoInvent 3.9	108 km
Wrapping paper		0.00350 kg	Kraft paper, unbleached {RER}, production, EcoInvent 3.9	108 km
Cards and envelopes		0.0072 kg	Cardboard, GLO, Agribalyze 3.1	108 km
Green waste		0.01799 kg	A. Compost of green waste, Agribalyze 3.1	16.0 km
Plastic waste		0.00415 kg	Disposal, plastics, mixture, to municipal waste treatment, DK, Agribalyze 3.1	16.0 km

Table 3 – Input materials and relative amounts for cultivation of 1 flower stem, produced internationally by certified growers.

Material	*Properties*	*Amount pr. functinal unit*	*Data source*	*Transport distance*
Nitrogen fertilizer	Used as proxy for fertilizer production based on N-amount.	0.00051 kg	Average mineral fertilizer, as N, at regional storehouse, Il, Agribalyze 3.1	108 km
Potassium fertilizer	Used as proxy for fertilizer	0.00056 kg	Average mineral fertilizer, as K2O,	108 km

	production based on K-amount.		at regional storehouse, Il, Agribalyze 3.1	
Phosphate fertilizer	Used as proxy for fertilizer production based on P-amount.	0.00000384 kg	Average mineral fertilizer, as P2O5, at regional storehouse, Il, Agribalyze 3.1	108 km
Diesel		0.00034 kg	Diesel, burned in agricultural machinery {GLO}, EcoInvent 3.9	N/A
Occupation, arable		0.00001733 ha*a	Elementary flow	N/A
Electricity		0.00759 kWh	Electricity, medium voltage {Il}, market for, EcoInvent 3.9	N/A
Water		11.43940 kg	Tap water {Il}, EcoInvent 3.9	N/A
Pesticide production	Used as proxy for all pesticide production	0.00020394 kg	Pesticide, unspecified {RER} production, EcoInvent 3.9	108 km
Fertilizer applicaiton	Used as proxy for all fertiliser application	0.000001733 ha	Application of liquid mineral fertilizer, Agribalyze 3.1	N/A

Table 4 – Input materials and relative amounts for cultivation of 1 flower stem, produced locally in Denmark

Material	*Properties*	*Amount pr. functional unit*	*Data source*	*Transport distance*
Nitrogen fertilizer	Used as proxy for fertilizer production based on N-amount.	0.000030 kg	Average mineral fertilizer, as N, at regional storehouse, DK, Agribalyze 3.1	108 km
Potassium fertilizer	Used as proxy for fertilizer	0.000010 kg	Average mineral fertilizer, as K2O,	108 km

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	production based on K-amount.		at regional storehouse, DK, Agribalyze 3.1	
Phosphate fertilizer	Used as proxy for fertilizer production based on P-amount.	0.000025 kg	Average mineral fertilizer, as P2O5, at regional storehouse, DK, Agribalyze 3.1	108 km
Diesel		0.04250 kg	Diesel, burned in agricultural machinery {GLO}, EcoInvent 3.9	N/A
Occupation, arable		0.0000250 ha*a	Elementary flow	N/A
Electricity		0.01001 kWh	Electricity, medium voltage {DK}, market for, EcoInvent 3.9	N/A
Water		12.5 kg	Tap water {DK}, EcoInvent 3.9	N/A
Fertilizer applicaiton	Used as proxy for all fertiliser application	0.0000250 ha	Application of liquid mineral fertilizer, Agribalyze 3.1	N/A
Substrate		0.0504 kg	Peat {NORDEL} production, EcoInvent 3.9	108 km
Substrate		0.00101 kg	Coconut fibre, at regional storehouse, DK, Agribalyze 3.9	108 km
Sunflower seed		0.00118 kg	Sunflower seed, organic, at farm gate, DK, Agribalyze 3.9	108 km
Compost		0.5101 kg	A. Compost, of green waste, Agribalyze 3.9	N/A

The material flows used for production of 1 flower stem ready for distribution in Denmark by the conventional distributor can be seen in Table 5 to Table 6 together with their assumed transport distances and data sources. Calculation of the respective amounts are presented in Appendix 9.1.

Table 5 – Input materials and relative amounts for production of 1 flower stem ready for distribution in Denmark by a conventional flower distributor.

Material	*Properties*	*Amount pr. functional unit*	*Data source*	*Transport distance*
Conventional sunflowers		0.23 items	(Alfredo, Rieradevall, & Gabarell, 2010)	837 km
Conventional tulips		0.34 items	(Giglio, 2020)	837 km
Conventional wax flowers		0.43 items	(Michael, 2011)	4564 km
Electricity		0.01001 kWh	Electricity, medium voltage {DK}, market for, EcoInvent 3.9	N/A
Heat		0.04820 kWh	Heat, district or industrial, other than natural gas {DK}, EcoInvent 3.9	N/A
Water		0.239 kg	Tap water {DK}, EcoInvent 3.9	N/A
Thread		0.00040 kg	Yarn, jute {GLO}, market for, EcoInvent 3.9	108 km
Plastic wrapping		0.00379 kg	Ethylvinylacetate, foil {RER}, production, EcoInvent 3.9	108 km
Cards and envelopes		0.0072 kg	Cardboard, GLO, Agribalyze 3.1	108 km
Green waste		0.01799 kg	A. Compost of green waste, Agribalyze 3.1	16.0 km
Plastic waste		0.00444 kg	Disposal, plastics, mixture, to	16.0 km

			municipal waste treatment, DK, Agribalyze 3.1	

Table 6 – Input materials and relative amounts for cultivation of 1 flower stem, produced conventionally.

Material	*Properties*	*Amount pr. functional unit*	*Data source*	*Transport distance*
Nitrogen fertilizer	Used as proxy for fertilizer production based on N-amount.	0.00677 kg	Average mineral fertilizer, as N, at regional storehouse, DK, Agribalyze 3.1	108 km
Potassium fertilizer	Used as proxy for fertilizer production based on K-amount.	0.00335 kg	Average mineral fertilizer, as K2O, at regional storehouse, DK, Agribalyze 3.1	108 km
Phosphate fertilizer	Used as proxy for fertilizer production based on P-amount.	0.00383 kg	Average mineral fertilizer, as P2O5, at regional storehouse, DK, Agribalyze 3.1	108 km
Diesel		0.00293 kg	Diesel, burned in agricultural machinery {GLO}, EcoInvent 3.9	N/A
Occupation, arable		0.00834 ha*a	Elementary flow	N/A
Electricity		0.04291 kWh	Electricity, medium voltage {NL}, market for, EcoInvent 3.9	N/A
Electricity		0.00328 kWh	Electricity, medium voltage {IL}, market for, EcoInvent 3.9	N/A
Water		5.442 kg	Tap water {DK}, EcoInvent 3.9	N/A

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Fertilizer application	Used as proxy for all fertiliser application	0.00748 ha	Application of liquid mineral fertilizer, Agribalyze 3.1	N/A
Pesticide production	Used as proxy for all pesticide production	0.00007981 kg	Pesticide, unspecified {RER} production, EcoInvent 3.9	108 km
Lime		0.0114814 kg	Lime {RER}, market for lime, EcoInvent 3.9	108 km
Sunflower seed		0.000227 kg	Sunflower seed, at farm gate, DK, Agribalyze 3.9	108 km
Agricultural machinery		0.000148 kg	Agricultural machinery with electronic motor, production {GLO}, Agribalyze 3.1	N/A
Aluminium sulfate		0.0000030546 kg	Aluminium sulfate, powder {GLO}, market for, EcoInvent 3.9	108 km
Ammonium nitrate		0.00001568 kg	Ammonium nitrate, as N, at plant {RoW}, Agribalyze 3.1	108 km
Calcium nitrate		0.0002471 kg	Calcium nitrate {RER}, production, EcoInvent 3.9	108 km
Magnesium sulfate		0.0001207 kg	Magnesium sulfate {RER}, production, EcoInvent 3.9	108 km
Carbon dioxide		0.01439 kg	Elementary flow	108 km
Plastic film extrusion		0.0002165 kg	Extrusion, plastic film {GLO}, market for, EcoInvent 3.9	N/A

Packaging		0.005216 kg	Packaging for fertilisers or pesticides {GLO}, EcoInvent 3.9	108 km
Polypropylene	Packaging material	0.0002165 kg	Polypropylene, granulate {GLO}, market for, EcoInvent 3.9	108 km
Seedling		0.0006443 items	Fruit tree seedling, for planting {GLO}, EcoInvent 3.9	108 km
Nitric acid		0.0001432 kg	Nitric acid, without water, in 50 % solution state {GLO}, market for, EcoInvent 3.9	108 km
Potassium hydroxide		0.00018 kg	Potassium hydroxide {GLO}, market for, EcoInvent 3.9	108 km
Benzimidazole	Pesticide modelled as active compound	0.000004841 kg	Benzimidazole-compound {RER}, production, EcoInvent 3.9	108 km
Pyridine	Pesticide modelled as active compound	0.000003989 kg	Pyridine compound {GLO}, market for, EcoInvent 3.9	108 km
Triazine	Pesticide modelled as active compound	0.0000008148 kg	Triazine-compound, unspecified {GLO}, market for, EcoInvent 3.9	108 km

5. LCA-model

The production of flowers for a flower bouquet at Flowering's facilities in Birkerød, Denmark has been modelled using OpenLCA version 1.11.0 by Asger Smidt-Jensen (Danish Technological Institute) and can be seen below in Figure 4.

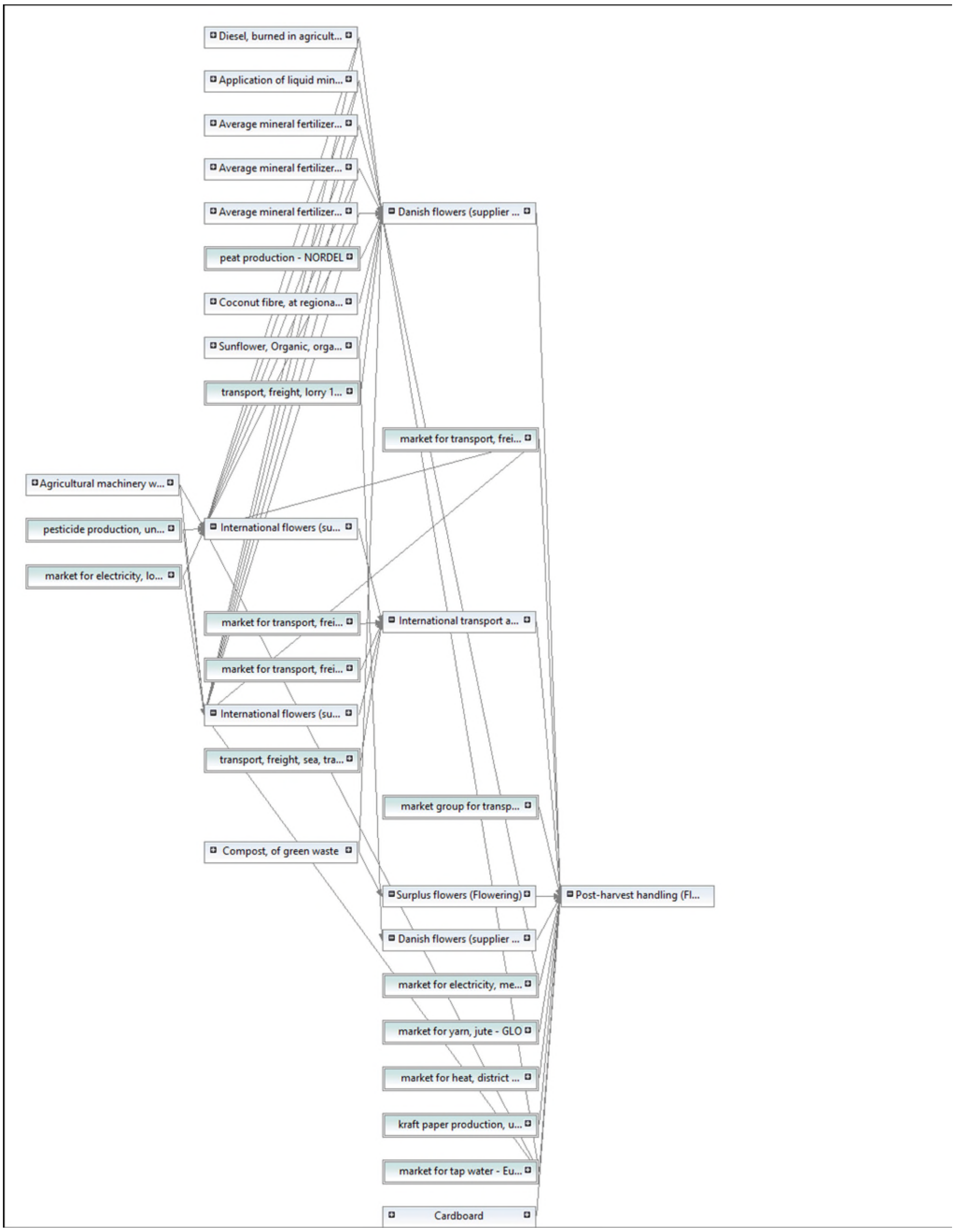

Figure 4 – OpenLCA-model for 1 flower stem ready for distribution in Denmark by Flowering ApS.

Likewise, the production of flowers for a flower bouquet by a conventional distributor of flowers has been modelled using OpenLCA version 1.11.0 by Asger Smidt-Jensen (Danish Technological Institute) and can be seen below in Figure 5.

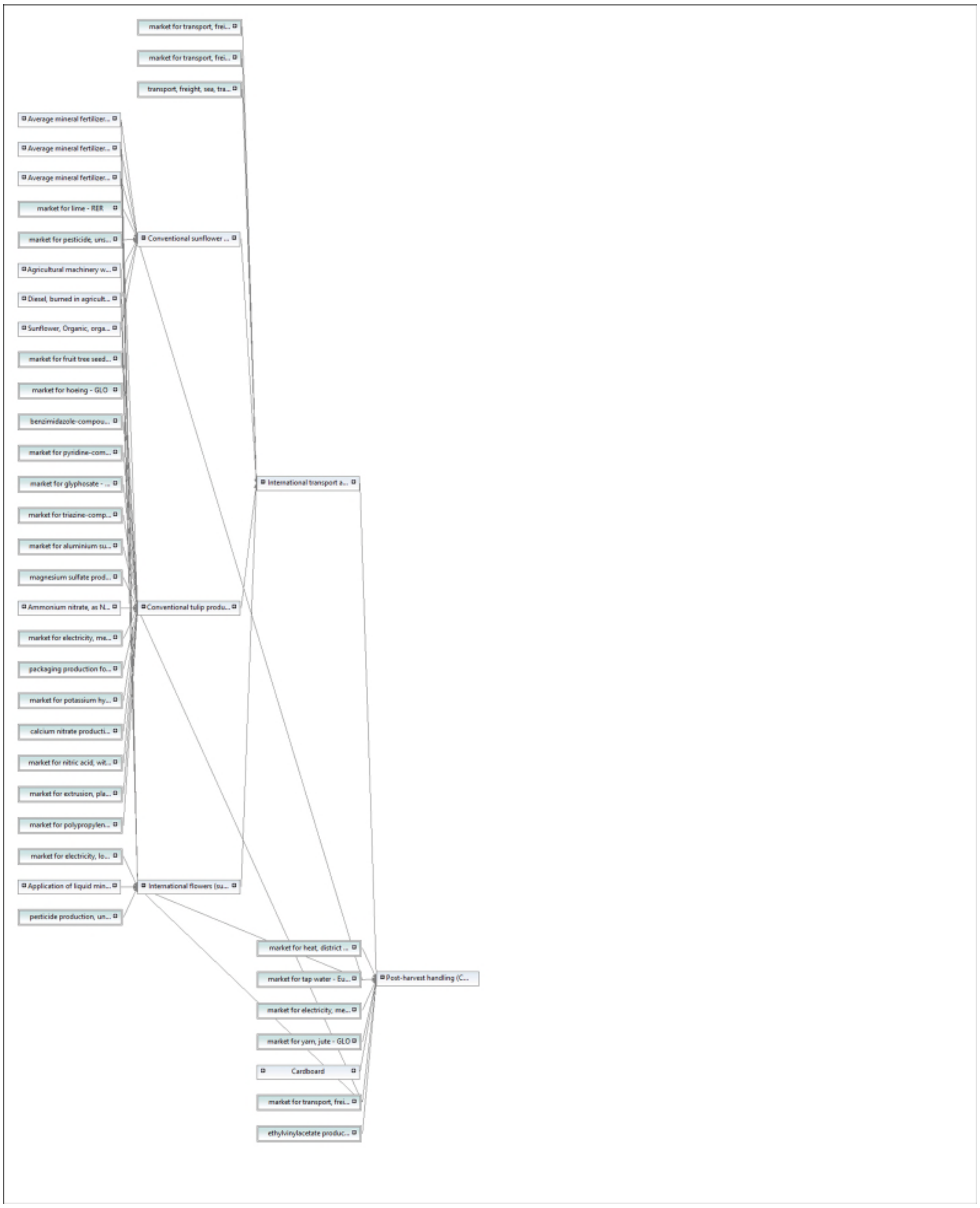

Figure 5 - OpenLCA-model for 1 flower stem ready for distribution in Denmark by a conventional flower distributor.

6. Results and discussion

Results are given in the following section for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

The results of the assessment for both flowers ready for distribution by Flowering and a conventional distributor are shown in Table 7 where positive values indicate an environmental impact and negative values indicate an environmental benefit. A relative comparison of both systems is given in Figure 6. The results are subject to several limitations as described further in detail in Section 6.1 and 6.3.

Table 7 – Results of the impact assessment given for eight chosen impact categories using EF 3.0 midpoint indicators. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers. Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center). The analysis has been performed from cradle to factory gate.

Impact category	*Mix of surplus, Danish and environmentally certified flowers*	*Conventional flowers*	*Unit*
Acidification	8.10E-04	9.60E-04	mol H^+ eq.
Climate change	1.08E-01	1.67E-01	kg CO_2-eq.
Eutrophication, terrestrial	4.24E-03	2.90E-03	mol N eq.
Land Use	1.03E+01	5.16E+00	Pt
Particulate matter	9.37E-09	6.36E-09	Disease incidence
Photochemical ozone formation	5.10E-04	7.00E-04	kg NMVOC eq.
Resource use, fossils	1.27E+00	2.28E+00	MJ
Ressource use, minerals and metals	3.05E-07	4.37E-07	Kg Sb eq.

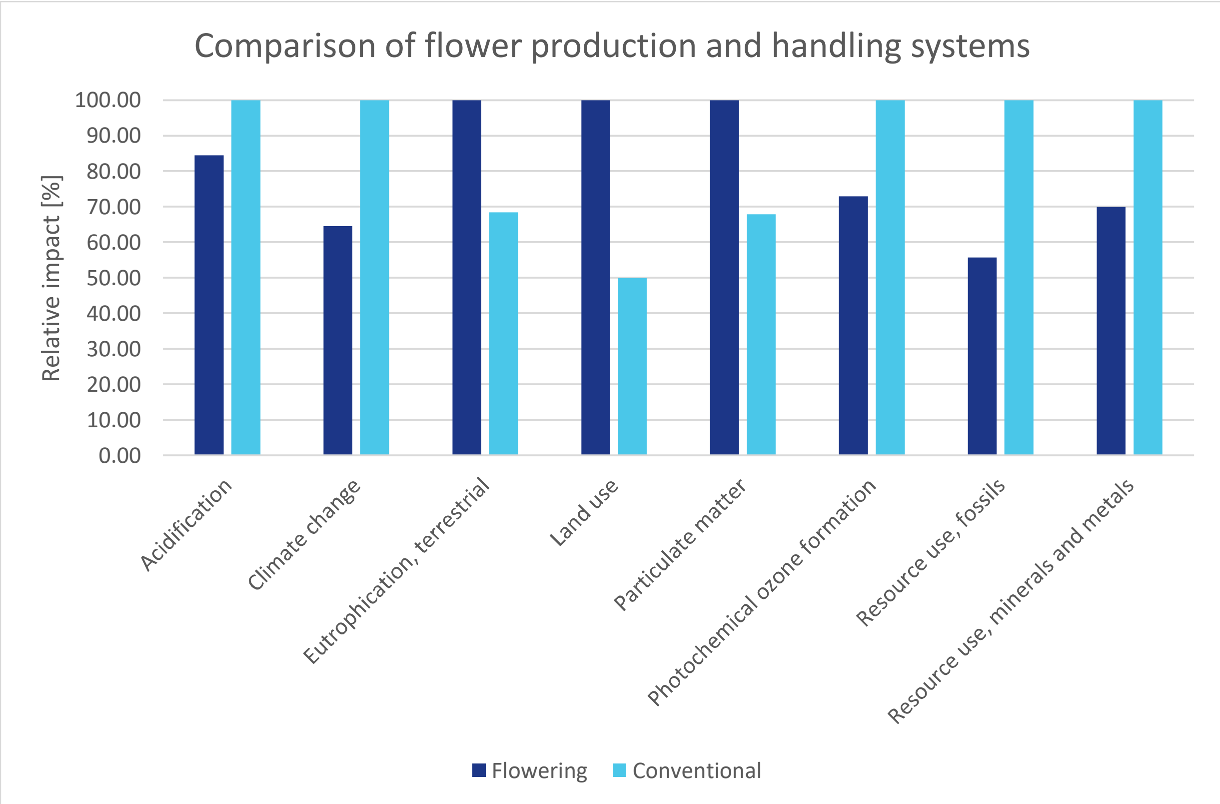

Figure 6 – Comparison of the impact assessment for eight chosen impact categories using EF 3.0 midpoint indicators. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

Results indicate a variation in which flower production and handling system has the largest environmental impact. For the categories Acidification, Climate Change, Photochemical Ozone Formation, Resource Use (Fossils), and Resource Use (Minerals and Metals), the conventional production and handling system has the largest environmental impact. In the categories Eutrophication (Terrestrial), Land Use, and Particulate Matter the system utilized by Flowering ApS has the largest environmental impact.

Specifically, for GWP, the production and handling system utilized by Flowering results in an impact of 0.108 kg CO_2 eq. pr flower stem ready for distribution whereas the conventional production and handling system results in an impact of 0.167 kg CO_2 eq. pr flower stem ready for distribution.

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The relative contributions of the subprocesses can be seen in Figure 7 to Figure 9 for Climate Change, Land Use and Resource Use (Fossils). The relative contributions for the remainder of the impact categories can be seen in Appendix 9.2.

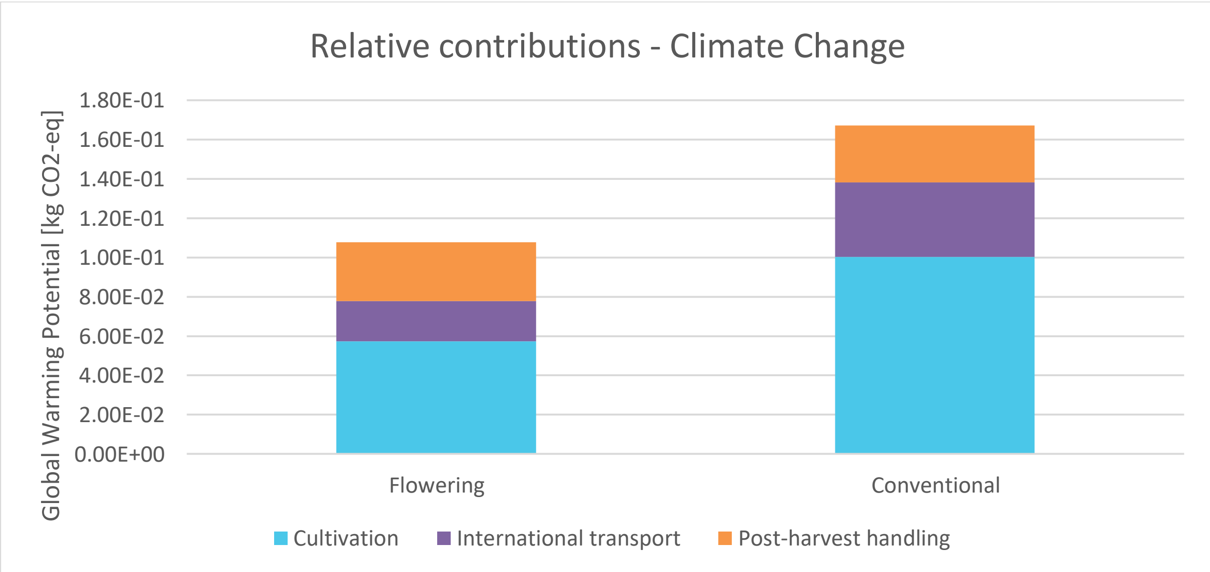

Figure 7 - Relative contributions to the global warming potential of the phases of production for the compared production and handling systems for flowers.

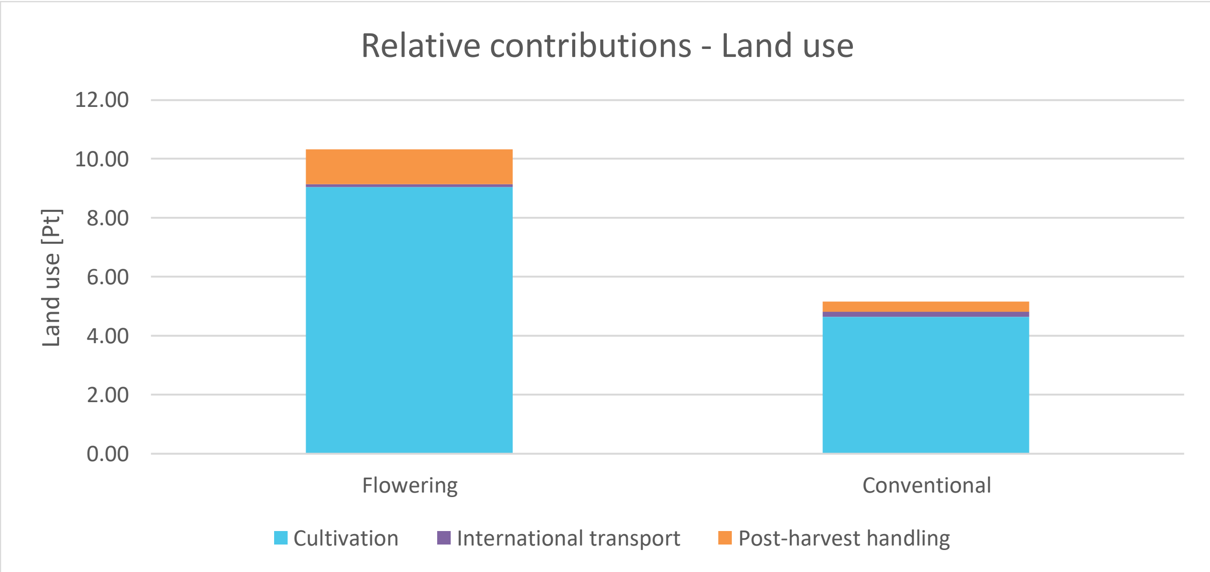

Figure 8 - Relative contributions to the land use of the phases of production for the compared production and handling systems for flowers.

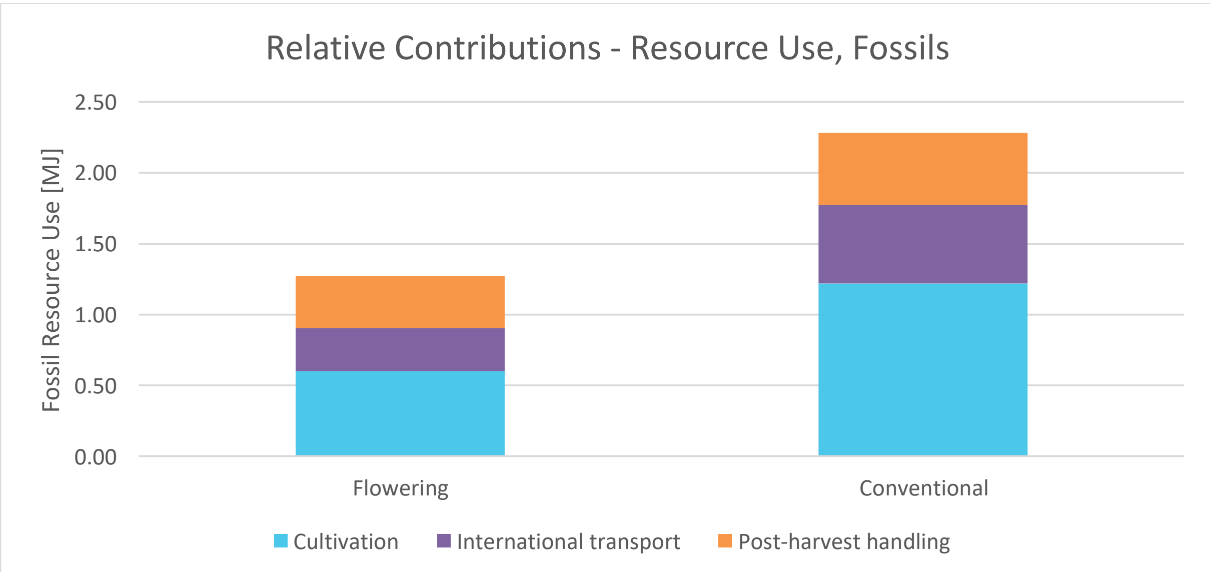

Figure 9 - Relative contributions to the fossil resource use of the phases of production for the compared production and handling systems for flowers.

From the relative contributions it is evident that the main contribution to all assessed impacts for both production and handling systems is the cultivation phase. The higher impacts seen for five of the impact categories for the conventional production and handling system is mostly a result of the more intensive cultivation phase meaning utilizing more fertilizers, pesticides and materials and the surplus flowers having considered as having little material input. However, the larger impact on land use observed for the production and handling system utilized by Flowering is a result of a lower yield of flowers and therefore results in a larger land use.

6.1. Modelling of surplus flowers

The surplus flowers have been assumed to have no impact during production. However, their impact has been calculated through system expansion to include the end-of-life composting of them as green waste. Thus, the total impact of the surplus flowers corresponds to the additional impact of producing an identical amount of compost from green waste as their utilization instead of waste-handling results in an increased production of compost. An argument can be made that the flowers could potentially still be utilized for compost production during the end-of-life handling. However, as this depends on consumer and retail handling, this assumption is highly uncertain, and a more conservative estimate is therefore that their utilization in Flowering's bouquets results in an increase in compost production.

The transport of the surplus flowers to Flowering's facilities has been included within the analysis. However, the transport of the surplus flowers to Denmark has not, as this would have taken place anyway. Additional transport could potentially also be avoided by utilization of the surplus flowers, as they do not need to be handled as waste. This therefore potentially results in a slight overestimation of the environmental impact of the surplus flowers.

As seen in the previous section, the low material use assumed for the surplus flowers can significantly affect the results of the analysis. Similarly, the low intensity cultivation phase for the Danish flowers utilized by Flowering also has a large impact on the results. Thus, it is expected that the overall result of the analysis is very sensitive to the sales distribution between the three different types of flowers used by Flowering. A sensitivity analysis to assess the impact on the results is therefore carried out in Section 6.3.

The scalability of the utilization of surplus and Danish flowers is uncertain, meaning that if the analysis is sensitive to changes in the proportion of these flower types utilized, caution should be exercised in interpreting the results, as these proportions may change significantly in the future.

6.2. Inclusion of other phases

As mentioned in Section 3.2, this LCA-study has been limited to the production of flowers for a bouquet of flowers. The excluded phases have therefore been listed in Table 8 with a short description of their expected influence on the main outcome of the study (GWP) if they were to be included in the study.

Generally, these phases have been excluded as they are not expected to significantly affect the outcome of the analysis and which of the two compared systems have the largest environmental impacts. Use and retail phases can be difficult to predict and model, however, in this section consumer-use and their end-of-life handling has been assumed.

Table 8 – Expected influence on GWP-results by including other phases in the LCA-study

Phase	*Comment*	*Expected influence on Global Warming Potential (GWP)*
Distribution to sales channels	Flowering utilizes less conventional sales channels with the main part of their sales happening online or through their own physical store. However, this is not necessarily inherent to their product and a similar production and handling system could be used by a conventional distributor. The mass of flowers transported is not expected to be different between the two systems either.	Direct distribution to individual consumers can potentially increase GWP due to less efficient delivery compared to delivery to stores. However, this distribution model is not unique to flowering and can be similar for a conventional distributor.
Retail	The retail step will tend to increase GWP, but specific retail channels are not inherent to any of the two systems.	Any retail step will tend to increase GWP for both systems similarly, as flowers have to be stored, heating and electricity is used within the store, and some waste is generated.
Consumer-handling	Differences might arise in consumer handling due to the inclusion of surplus flowers in the bouquets produced by Flowering. These flowers can have a slightly lower life expectancy at the consumer and therefore require more rapid changing. Similarly, the inclusion of local flowers can increase the life expectancy of a bouquet due to a shorter time from cutting to the consumer. Both of these effects	Little influence is expected but a slightly higher GWP might be seen for the flowers produced by Flowering for their boquets due to an increase in waste. A sensitivity analysis of the amount of flowers wasted in the production can be seen in Section 6.3.

	are expected to be minor and are difficult to quantify.	
End-of-life	The end-of-life step can potentially decrease GWP slightly, as the flowers can be utilized for compost. However, no difference in end-of-life handling is expected between the two systems.	No expected difference.

6.3. Sensitivity analysis

In order to test the robustness of the results towards variations or uncertainties in the used datasets, a number of sensitivity analyses have been carried out.

The first series of sensitivity analyses assesses parameters where the environmental data is subject to some degree of uncertainty. These are described in Table 9 (U-scenarios).

Plastic wrapping has been assumed to be composed by EVA-plastic for the conventional production and handling system and the production system for this type of plastic has been assumed for the wrapping utilized within this production and handling system. As these assumptions are categorized as highly uncertain, the relevant interval of variation for these parameters is deemed to be 90 %.

Pesticide production has been assumed as a general unspecified pesticide production for all pesticides. As these assumptions are categorized as moderately uncertain, the relevant interval of variation for these parameters is deemed to be 50 %.

Table 9 – Parameters, which have been assessed in the sensitivity analysis due to uncertainty in their environmental data.

Parameter	*Source of uncertainty*	*Uncertainty level*	*Sensitivity scenario*	*Interval of variation*
Plastic wrapping	Assumption of material type	High	U1	± 90 %
Pesticide production	Generic process used for all pesticides	Moderate	U2	± 50 %

The other series of sensitivity analyses assesses parameters which have a large influence on the results for GWP and thereby potentially the results of the study. These are described in Table 10 (I-scenarios). Here the interval of variation is set at an unchanging level of 10 % for all parameters. This corresponds to potential variations in both amounts and data for the parameters (for example variations in amounts of surplus flowers, Danish flowers used, international transport distances and diesel use)

Table 10 – Parameters, which have been assessed in the sensitivity analysis due to their influence on the results of the analysis

Parameter	*Sensitivity scenario*	*Interval of variation*
Proportion of surplus flowers	I1	± 10 %
Proportion of Danish flowers	I2	± 10 %
International transport distances	I3	± 10 %
Diesel use	I4	± 10 %

The effect of all the sensitivity scenarios on GWP can be found in Table 11. The effect on the remaining impact categories can be seen in Appendix 9.2. None of the scenarios warrant a significant change to the conclusion of the study.

Table 11 – Global Warming Potential (GWP) for all sensitivity scenarios

Sensitivity scenario	*Parameter*	*Interval of variation*	*GWP – Flowering*	*GWP - Conventional*
U1	Plastic wrapping	± 90 %	0.108 kg CO_2-eq	0.176 kg CO_2-eq
U2	Pesticide production	± 50 %	0.108 kg CO_2-eq	0.165 kg CO_2-eq
I1	Proportion of surplus flowers	± 10 %	0.115 kg CO_2-eq	0.167 kg CO_2-eq
I2	Proportion of Danish flowers	± 10 %	0.108 kg CO_2-eq	0.167 kg CO_2-eq
I3	Transport distances	± 10 %	0.110 kg CO_2-eq	0.171 kg CO_2-eq
I4	Diesel use	± 10 %	0.110 kg CO_2-eq	0.167 kg CO_2-eq

The results are therefore considered to be robust against variations or uncertainties of the chosen size for the most important input parameters. However, some sensitivity is seen towards the proportion of surplus flowers used in the inventory for the production and handling system utilized by Flowering. As the amount of surplus flowers is considered to vary depending on availability and the scalability of utilization of this type of flower is uncertain, care should be taken in interpreting the presented results. The results will not accurately reflect the impact of the production and handling system utilized by Flowering if this proportion were to ever change.

7. Conclusion

In this task, commissioned by Flowering ApS, the environmental impact of two different production and handling systems has been assessed using LCA-methodology:

1. The production of flowers for a flower bouquet using no plastic packaging, recycled water and a mix of internationally grown environmentally certified flowers purchased through wholesalers, Danish flowers traded directly, and surplus flowers grown conventionally but which would otherwise have been wasted.
2. The production of flowers for a flower bouquet through conventional means using plastic wrapping, and conventionally grown flowers exclusively purchased through wholesalers.

The two systems serve the same function and the functional unit was chosen as 1 flower-stem delivered to Denmark, cut, wrapped and ready for distribution. Thus, the processing of the flowers at the distribution center is also considered (including collection of flowers, cutting, storing and wrapping). This means that the system boundaries considered are from cradle to factory gate.

Primary data has been collected from the post-harvest handling and for cultivation of Danish as well as environmentally certified flower productions with the remainder of the data coming from literature, representative studies and databases (EcoInvent 3.9 and Agribalyze 3.1).

Modelling was performed by Asger Smidt-Jensen of the Danish Technological Institute, Food and Production, and eight impact categories were considered.

The main goal was to assess global warming potential (GWP) where production and handling system 1 (utilized by Flowering ApS) had an impact of 0.108 kg CO_2 eq. per flower stem ready for distribution, while production and handling system 2 (conventional distribution) had an impact of 0.167 kg CO_2 eq. pr flower stem ready for distribution. Additionally, production and handling system 1 had the highest impact in the categories Eutrophication (Terrestrial), Land Use, and Particulate Matter. For the remaining categories Acidification, Climate Change, Photochemical Ozone Formation, Resource Use (Fossils), and Resource Use (Minerals and Metals), production and handling system 2 had the highest impact.

The main contribution to the impact for all impact categories was the cultivation phase for both systems. The lower impact for production and handling system 1 was mainly caused by less intensive production practices for the surplus and Danish flowers, while the categories with higher impact for system 1 was caused mainly by lower yields and compost production.

These results are, however, subject to several limitations, as this study cannot support a direct comparison of bouquets as a different number of flowers and different amounts of other materials might be present in such bouquets. Similarly, the LCIA-results are relative expressions, meaning that they do not predict impacts of category-endpoints or exceedance of threshold values, safety margins or risk levels.

Finally, a sensitivity analysis has been performed indicating that the results are robust against the considered variations in the most important process parameters. However, some sensitivity is seen towards the proportion of surplus flowers used in the inventory for production and handling system 1. As the amount of surplus flowers is considered to vary depending on availability and the scalability of utilization of this type of flower is uncertain, care should be taken in interpreting the presented results. The results will not accurately reflect the impact of production and handling system 1 if this proportion were to ever change.

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8. References

Journal articles, papers, reports:

Alfredo, I., Rieradevall, J., & Gabarell, X. (2010). Life cycle assessment of sunflower and rapeseed as energy crops. *Journal of Cleaner Production*, 336-345.

Giglio, P. (2020). *Environmental footprint of tulip bulbs: Representative product study (FULL REPORT).* Wageningen: Wageningen Economic Research.

Helmes, R., Ponsioen, T., Blonk, H., Vieira, M., Goglio, P., Linden, R. v., . . . Verweij-Novikova, I. (2020). *Hortifootprint Category Rules - Towards a PEFCR for horticultural products.* Wageningen: Wageningen Economic Research.

La, Y.-C., Tam, V. W., Xing, W., Datt, R., & Chan, Z. (2022). Life Cycle Environmental Impacts of Cut Flowers: A Review. *Journal of Cleaner Production*.

Michael, D. (2011). Life cycle assessment of waxflowers (Chamelaucium Spp.). *Australian Life Cycle Assessment Society (ALCAS) Conference*.

The Intergovernmental Panel on Climate Change (IPCC). (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Institute for Global Environmental Strategies (IGES) for the IPCC.

Producers:

Flowering ApS: https://flowering.dk/
Saidi-Ronen Farm: https://www.sr-farm.com/
Coop del Golfo: http://www.coopdelgolfo.com/index.php

Databases:

Agribalyze 3.1: https://doc.agribalyse.fr/documentation-en/
EcoInvent 3.9: https://ecoinvent.org/

Methods:

Environmental Footprint 3.0: https://eplca.jrc.ec.europa.eu/LCDN/EF_archive.xhtml

9. Appendices

9.1. LCA-modelling calculations

General:	Value:	Unit:	Pr. FU:
Flowers sold:	659.440,00	stems/year	1
Surplus flowers, share [%]:	30,00	%	N/A
Danish flowers, share [%]:	25,00	%	N/A
Internationally certified flowers flowers, share [%]:	55,00	%	N/A
Consumption data:			
Electricity usage, yearly [kWh]	10.600,00	kWh/year	0,016074245
Heating and cooling, yearly [kWh]	34.600,00	kWh/year	0,052468761
Water consumption, yearly [m^3]:	111,00	m^3/year	0,000168325
Material usage:			
Envelope and cards, yearly [kg]	473,00	kg/year	0,000717275
Wrapping paper, yearly [kg]	2.308,00	kg/year	0,003499939
Thread, yearly [kg]	263,00	kg/year	0,000398823
Plastic wrapping [kg]	-	kg/year	0
Waste			
Cut off, green, yearly [kg]	11.863,00	kg/year	0,017989506
Plastic waste, HDPE, yearly [kg]	2.738,00	kg/year	0,004152008
Transport:	**Value:**	**Unit**	**Pr. FU:**
Kilometers driven, yearly [km]	128.736,00	km/year	0,195220187

Figure 10 - Data collected from Flowering's own production.

General:	Value:	Unit:	Pr. FU:
Area [ha]	260.00	ha	1.73333E-05
Plant density [stems/ha]	50,000.00	stems/ha	0.003333333
Consumption data:			
Electricity usage, yearly [kWh]	113,899.00	kWh/year	0.007593267
Water consumption, yearly [m^3]:	171,591.00	m^3/year	0.0114394
Diesel consumption, yearly [L]	6,000.00	L/year	0.0004
Material usage:			
Fertiliser usage, yearly, 5-1-5+3% micro [L]	5,760.00	L/year	0.000384
Fertiliser usage, yearly, 4-0-6 [L]	39,196.00	L/year	0.002613067
Fertiliser usage, yearly, 5-0-5 [L]	115,517.00	L/year	0.007701133
Pesticide usage, yearly, BIFENTHRIN [L]	12.00	L/year	0.0000008
Sulfur, yearly [L]	400.00	L/year	2.66667E-05
Boscalid 26.7% + PYRACLOSTROBIN 6.7% WG, yearly [L]	60.00	L/year	0.000004
Penthiopyrad, yearly [L]	44.00	L/year	2.93333E-06
Iron Sulfide, yearly [kg]	2,500.00	kg/year	0.000166667
Fertiliser emissions:	**Value:**	**Unit**	**Pr. FU:**
Direct emissions	35,737.46	kgCO2eq/år	0.002382498
Leaching/run-off	8,040.93	kgCO2eq/år	0.000536062
Fugitive emissions	3,573.75	kgCO2eq/år	0.00023825

Figure 11 – Data collected from Saidi Ronen Farm and Coop Del Golfo. Aggregated for confidentiality.

General:	Value:	Unit:	Pr. FU:
Area [ha]	0.05	ha	0.000025
Plant density [stems/ha]	450,000.00	stems/ha	225
Consumption data:			
Electricity usage, yearly [kWh]	20.00	kWh/year	0.01
Water consumption, yearly [m^3]:	25.00	m^3/year	0.0125
Diesel consumption, yearly [L]	10.00	L/year	0.005
Material usage:			
Fertiliser usage, yearly, 6-5-2% [kg]	1.00	kg/year	0.0005
Pesticide usage, yearly [kg]	-	kg/year	0
Substrate, yearly [kg]	100.00	kg/year	0.05
Compost, yearly [kg]	1,000.00	kg/year	0.5
Fiber cloth, yearly [kg]	2.00	kg/year	0.001
Waste			
Plastic waste, HDPE, yearly [kg]:	5.00	kg/year	0.0025
Cardboard, yearly [kg]:	5.00	kg/year	0.0025
Fertiliser emissions:	**Value:**	**Unit**	**Pr. FU:**
Direct emissions	0.23414	kgCO2eq/år	0.000117069
Leaching/run-off	0.0527	kgCO2eq/år	2.63406E-05
Fugitive emissions	0.02341	kgCO2eq/år	1.17069E-05

Figure 12 - Data collected from Bakkegårds Blomster

General:	Value:	Unit:	Pr. FU:
Area [ha]	0.67	ha	0.000109388
Plant density [stems/ha]	9,141.79	stems/ha	1.492537313
Consumption data:			
Electricity usage, yearly [kWh]	-	kWh/year	0
Water consumption, yearly [m^3]:	-	m^3/year	0
Diesel consumption, yearly [L]	-	L/year	0
Material usage:			
Fertiliser usage, yearly, 6-5-2% [kg]	-	kg/year	0
Pesticide usage, yearly [kg]	-	kg/year	0
Substrate, yearly [kg]	-	kg/year	0
Compost, yearly [kg]	-	kg/year	0
Fiber cloth, yearly [kg]	-	kg/year	0
Waste			
Plastic waste, HDPE, yearly [kg]:	-	kg/year	0
Cardboard, yearly [kg]:	-	kg/year	0
Fertiliser emissions:	**Value:**	**Unit**	**Pr. FU:**
Direct emissions	-	kgCO2eq/år	0
Leaching/run-off	-	kgCO2eq/år	0
Fugitive emissions	-	kgCO2eq/år	0

Figure 13 - Data collected from Lille Torpegård

9.2. Relative contributions of subprocesses to impact categories

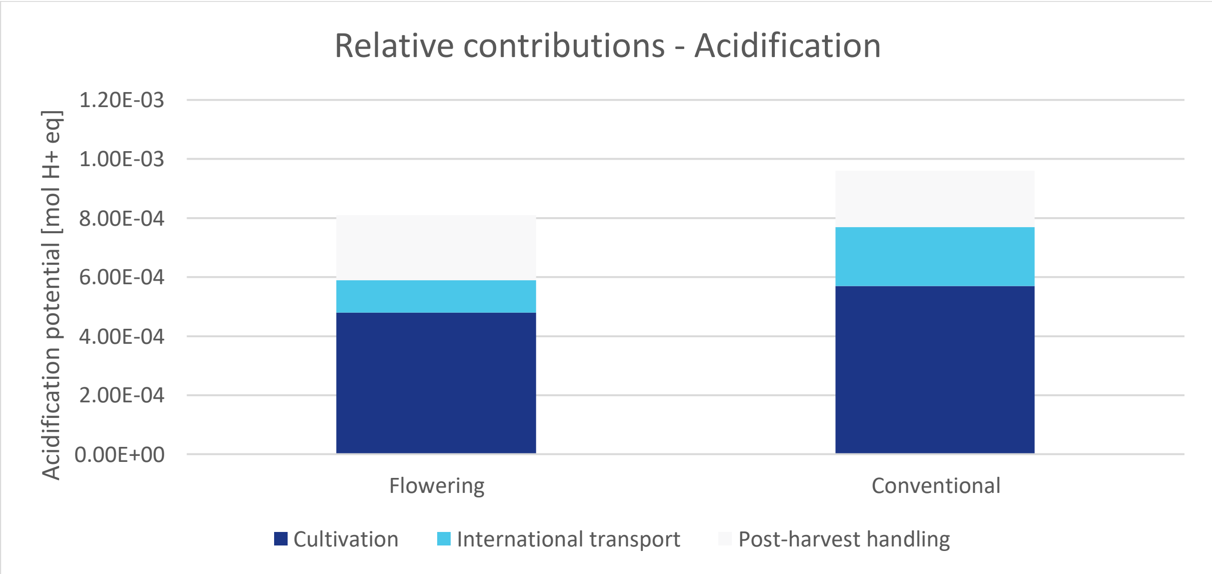

Figure 14 - Relative contributions to the acidification potential of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

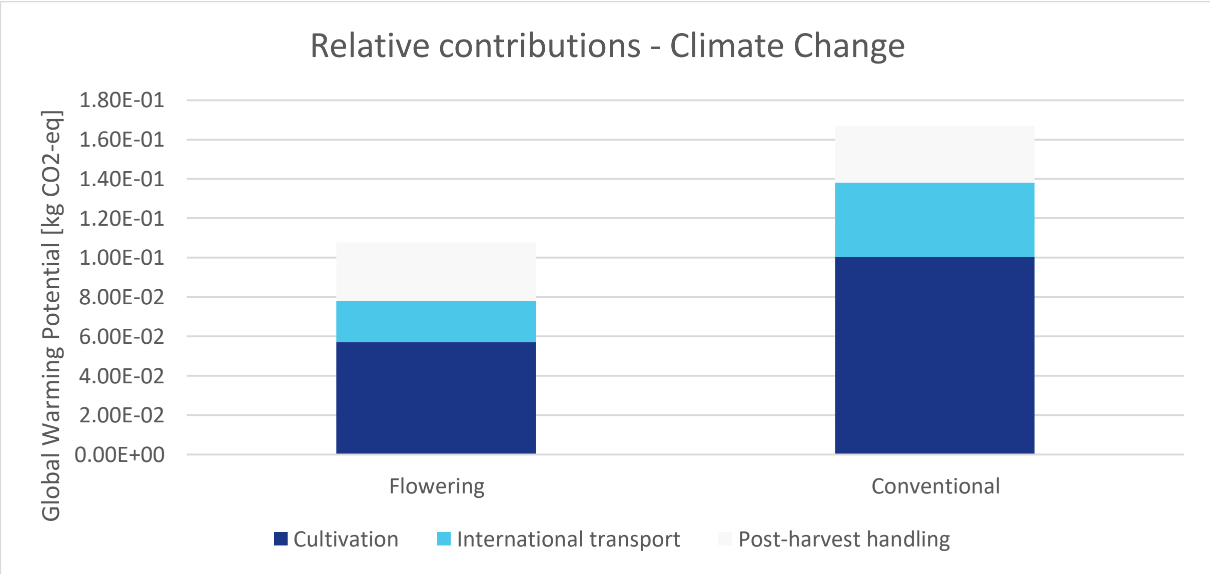

Figure 15 - Relative contributions to the global warming potential of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

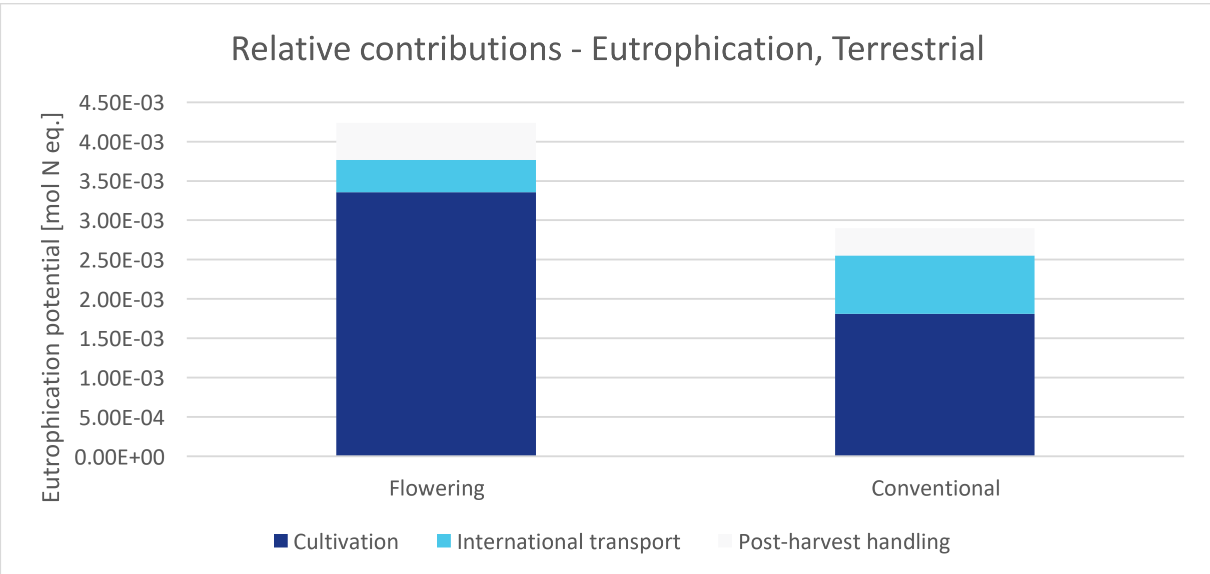

Figure 16 - Relative contributions to the terrestrial eutrophication potential of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using

recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

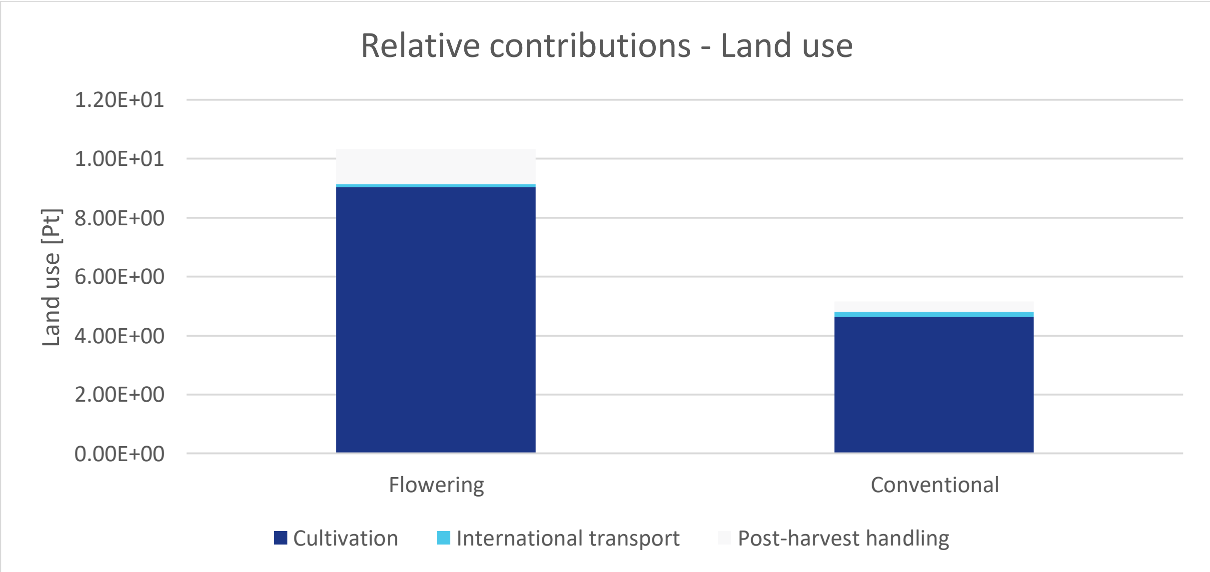

Figure 17 - Relative contributions to the land use of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

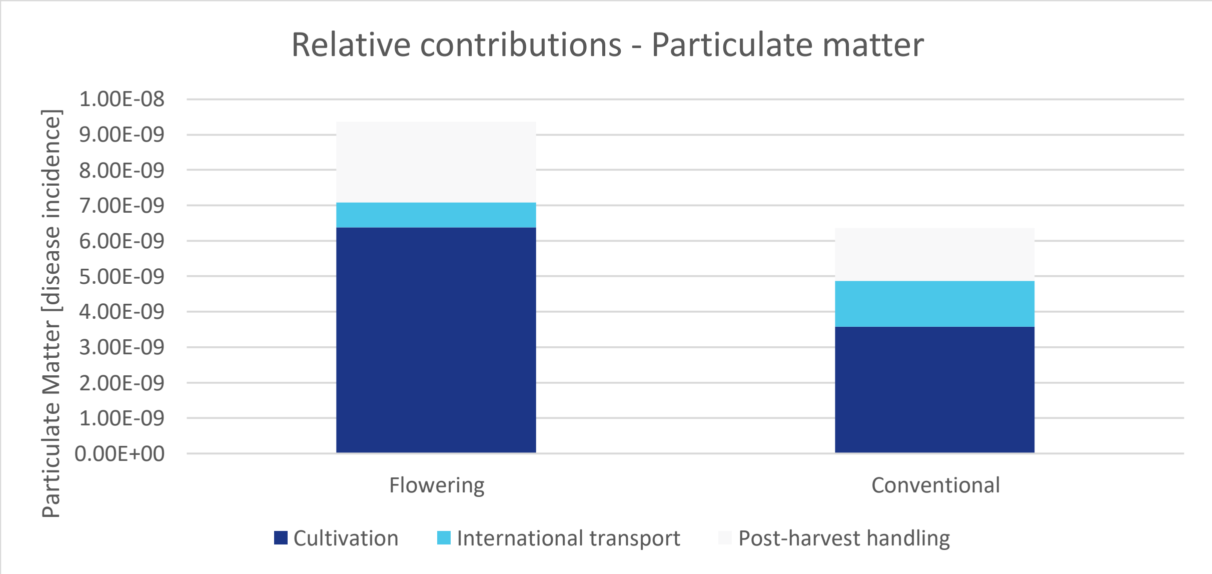

Figure 18 - Relative contributions to the particulate matter of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

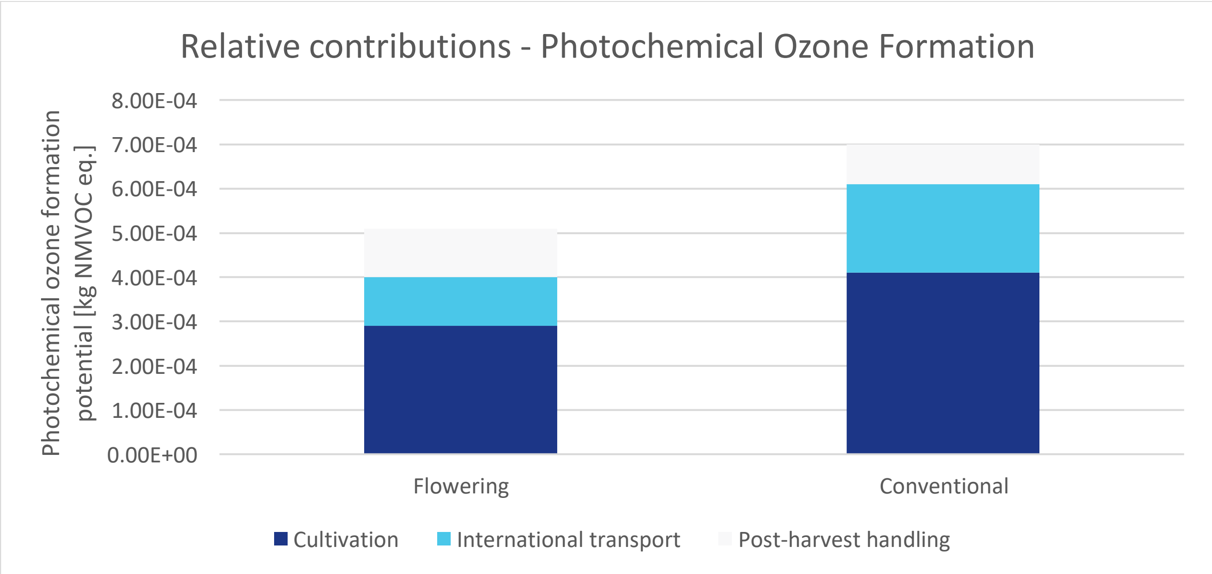

Figure 19 - Relative contributions to the photochemical ozone formation potential of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international

flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

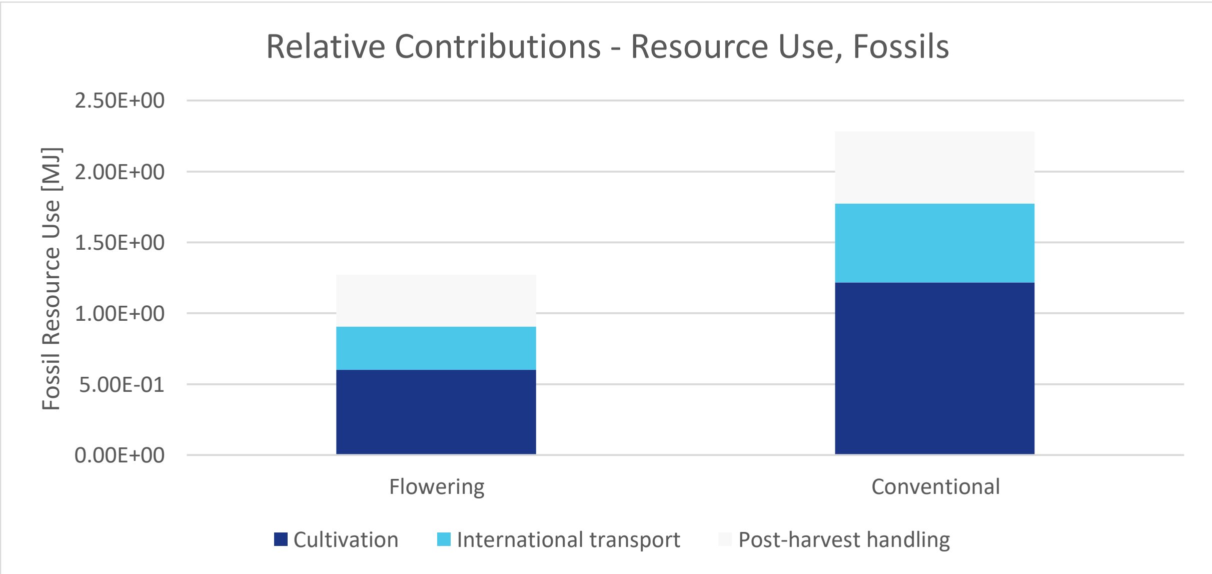

Figure 20 - Relative contributions to the fossil resource use of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as "Flowering"). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as "Conventional"). The analysis has been performed from cradle to factory gate.

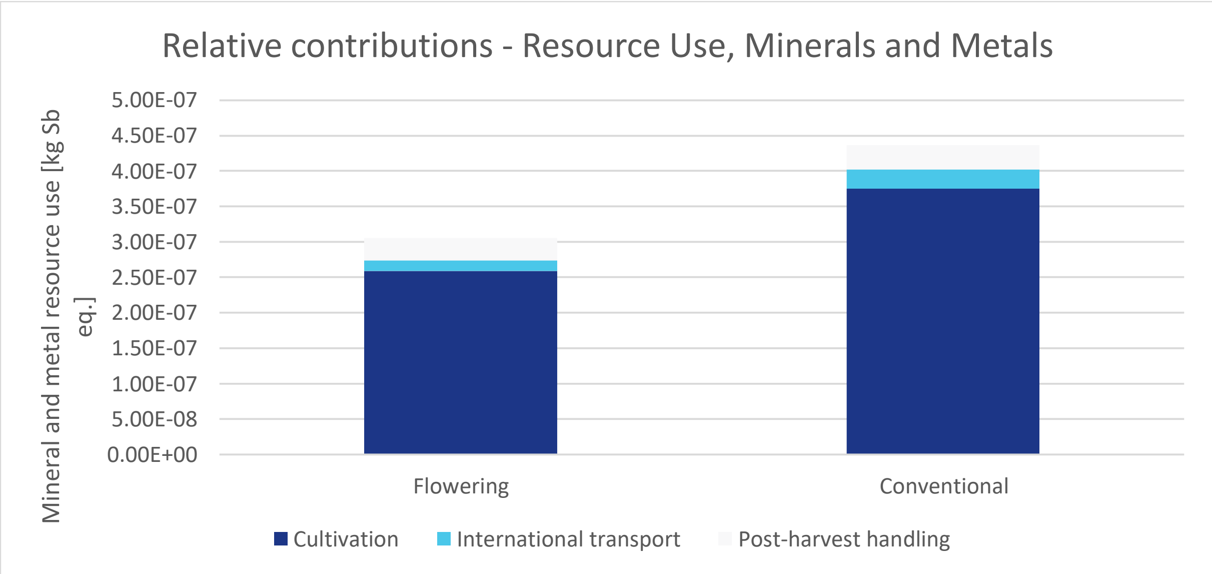

Figure 21 - Relative contributions to the mineral and metal resource use of the phases of production for the compared production and handling systems for flowers. Results are given for flowers produced by Flowering using recycled water, no plastic materials and a mixture of Danish flowers, environmentally certified international flowers and surplus flowers (referred to as “Flowering”). Results are also given for flowers produced using a mix of the same flowers produced conventionally (i.e., without certification, no surplus flowers and use of plastic materials at the distribution center) (referred to as “Conventional”). The analysis has been performed from cradle to factory gate.

9.3. Extended results of sensitivity analyses

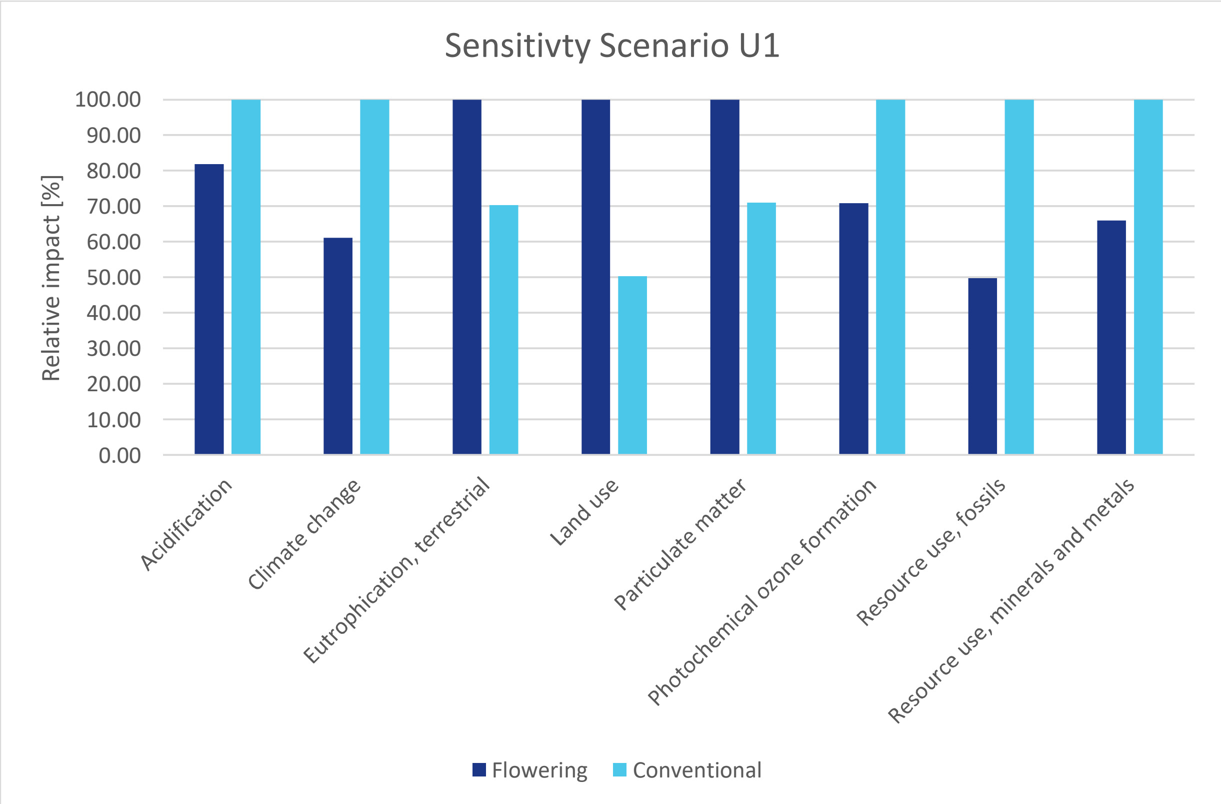

Figure 22 – Result of Sensitivity Scenario U1, amount of plastic wrapping varied with 90 %. Relative comparison of all chosen impact categories for the two production and handling systems.

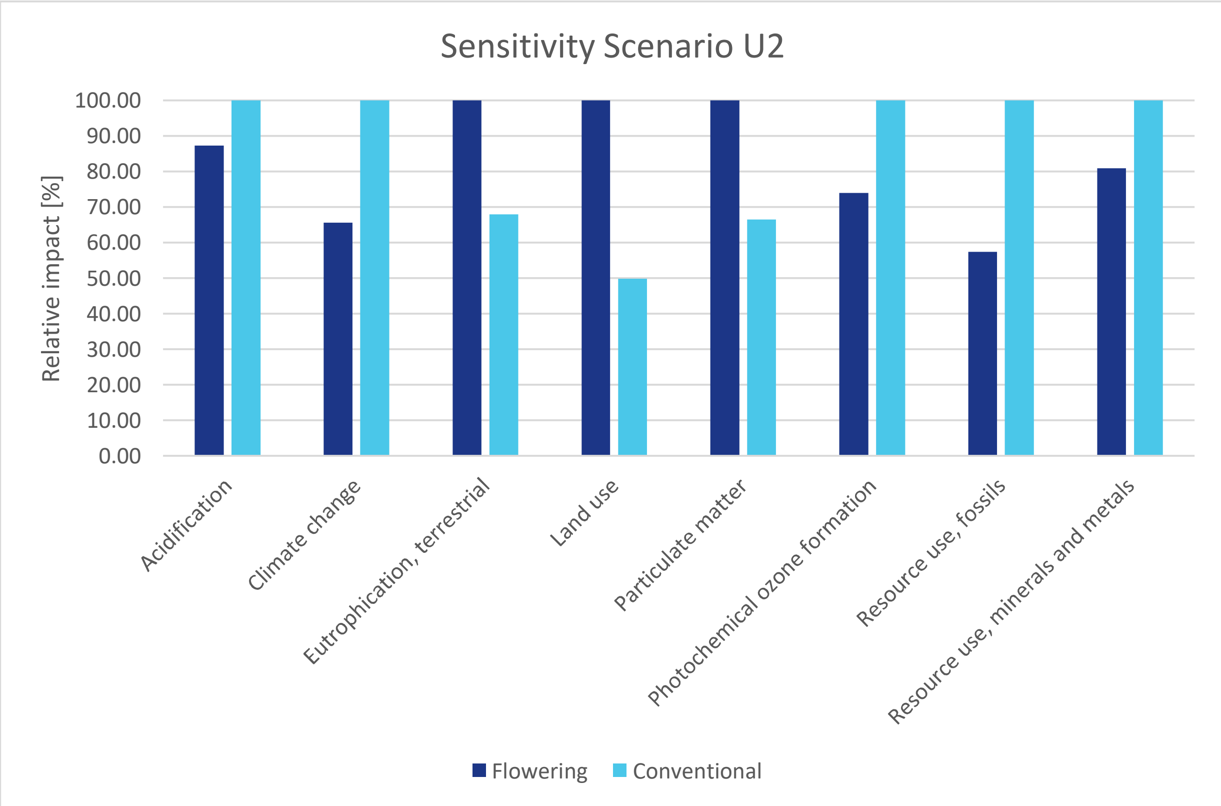

Figure 23 - Result of Sensitivity Scenario U2, amount of pesticide used varied with 50 %. Relative comparison of all chosen impact categories for the two production and handling systems.

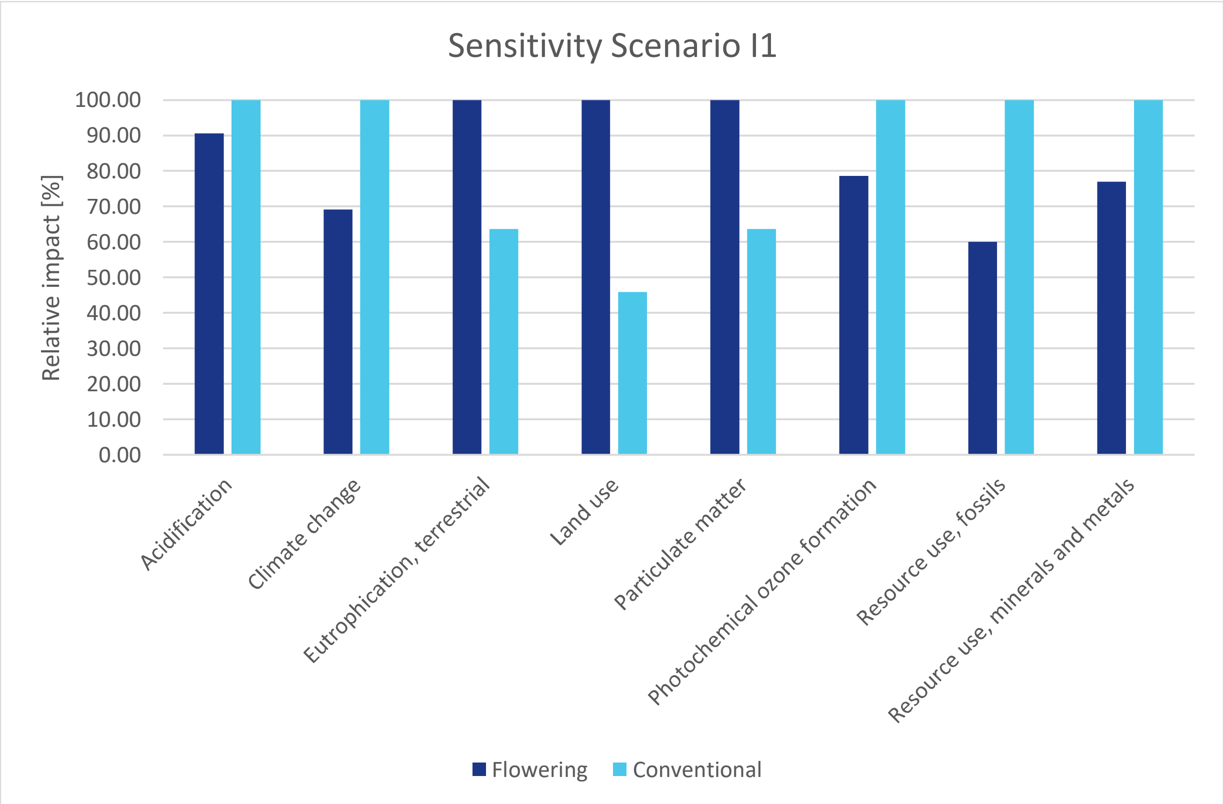

Figure 24 - Result of Sensitivity Scenario I1, amount of surplus flowers used varied with 10 %. Relative comparison of all chosen impact categories for the two production and handling systems.

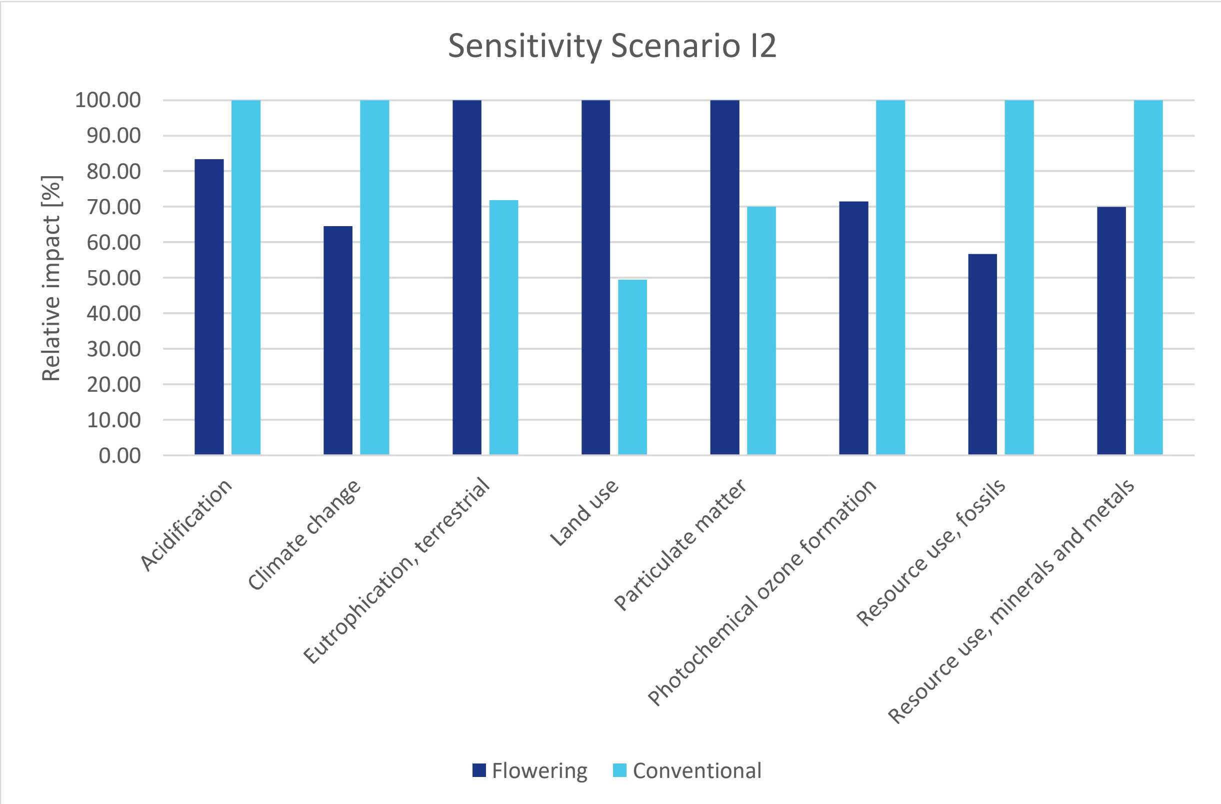

Figure 25 - Result of Sensitivity Scenario I2, amount of Danish flowers used varied with 10 %. Relative comparison of all chosen impact categories for the two production and handling systems.

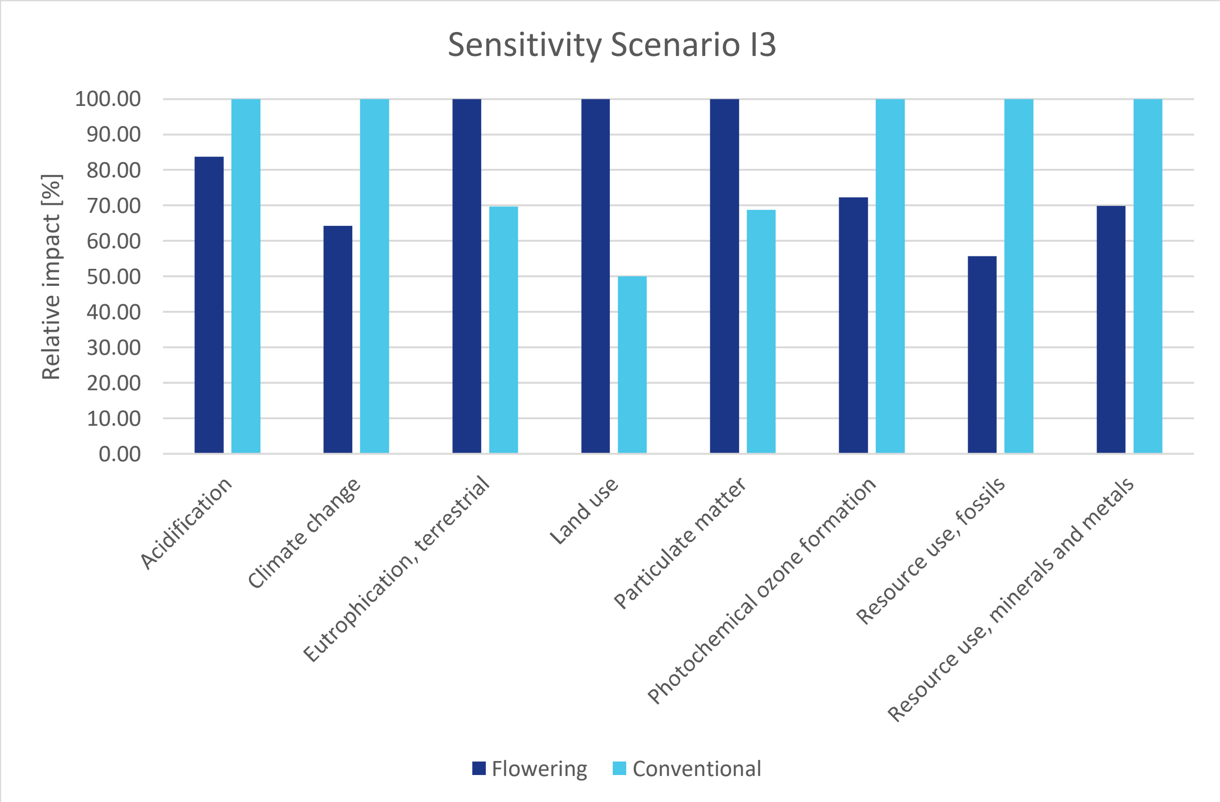

Figure 26 - Result of Sensitivity Scenario I3, length of international transport distance varied with 10 %. Relative comparison of all chosen impact categories for the two production and handling systems.

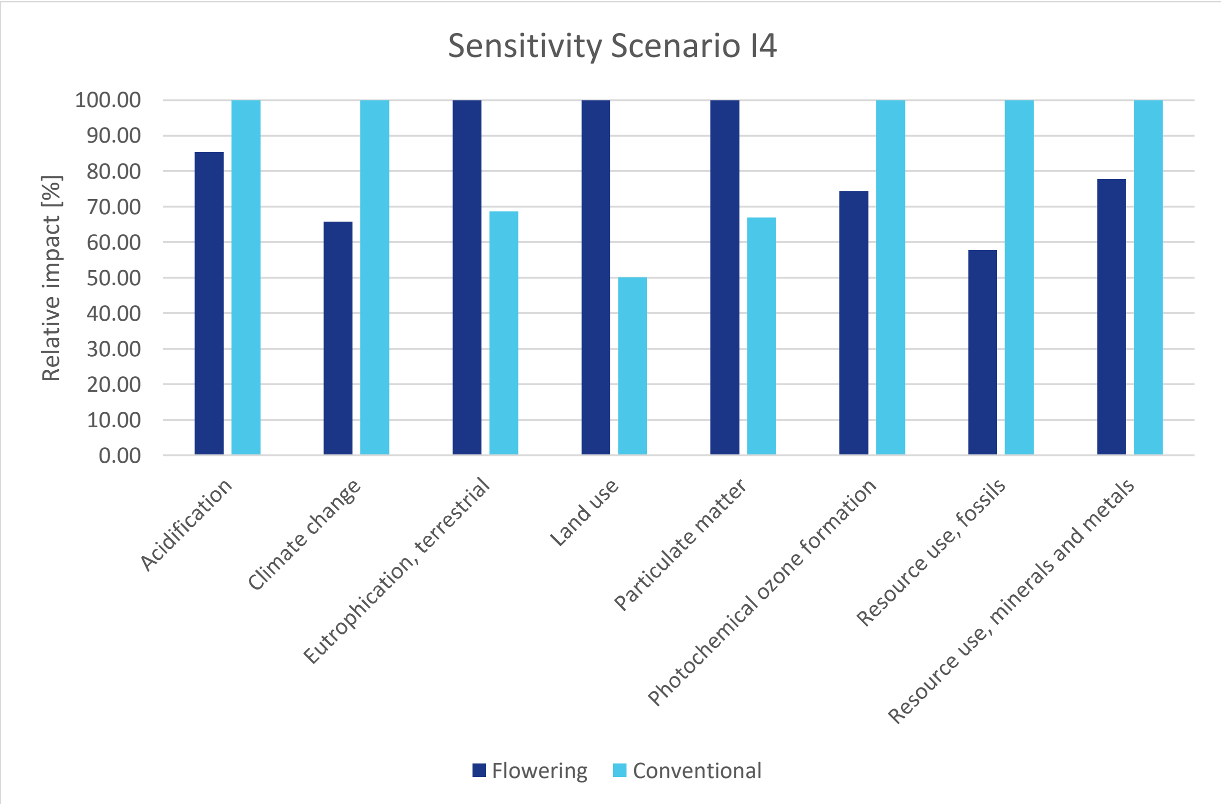

Figure 27 - Result of Sensitivity Scenario I4, diesel use varied with 10 %. Relative comparison of all chosen impact categories for the two production and handling systems.

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9.4. External review report

The report was sent for review on the 17th of April 2023. What follows is the report from the review panel:

Verification of Life Cycle Assessment of Production and Handling of Flowers

According to DS/EN ISO-standard 14044:2006/A1:2018

Prepared for:
Teknologisk Institut
Kongsvang Allé 29
8000 Aarhus C
Food Technology

May 2023

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1 Introduction

The verification of the Life Cycle Assessment of Production and Handling of Flowers, prepared according to the DS/EN ISO-standard 14044:2006/A1:2018, is performed in accordance with the assurance standard ISO 14064-3.

The reviewed report concerns a life cycle assessment (LCA) for the company Flowering ApS, with the aim of assessing the environmental impact of the flowers used in their products and comparing them to conventional flowers. The main goal of the study was to assess and compare the CO_2-impact between the two systems. However, to ensure that no significant environmental impacts have been excluded from the analysis, additional impact categories are included. The LCA-study is limited to considering 1 flower-stem delivered to Denmark, cut, wrapped and ready for distribution. Thus, the processing of the flowers at the distribution center is also considered (including collection of flowers, cutting, storing, and wrapping). This means that the system boundaries considered are from cradle to factory gate. The LCA report was sent to the review panel on 17.4.2023 and an updated version on 12.5.2023. A first version of this review report was sent to Teknologisk Institut on 17.5.2023. An updated LCA-report was sent to the review panel on 18.5.2023.

The aim of the review report is to verify the LCA comparing flowers distributed by Flowering to conventional flowers. The following cases where compared:

1. The production of flowers for a flower bouquet using no plastic packaging, recycled water, and a mix of internationally grown environmentally certified flowers purchased through wholesalers, Danish flowers traded directly, and surplus flowers grown conventionally but which would otherwise have been wasted.
2. The production of flowers for a flower bouquet through conventional means using plastic wrapping, and conventionally grown flowers exclusively purchased through wholesalers.

This review has been performed by third-party specialist Birna Sigrún Hallsdóttir, an environmental engineer and independent consultant on climate issues. Input was also received from Stefán Gíslason M.Sc. in Environmental Management and a sustainability expert.

2 Summary of the work

A summary of the work performed to verify the above-mentioned assertion can be found in Table 1. The LCA compiler was contacted before the review began to clarify a few issues including system boundaries, flower stems and mismatches in Table 7 and Figure 6. These issues were addressed, and the report sent again to the review panel on the 12.5.2023. These improvements added to the transparency of the report.

Some general considerations not included in the below table:

- The methods used are generally in accordance with the ISO standard 14044:2006/A1:2018.
- The methods are scientifically and technically valid.
- The utilized data is appropriate and reasonable.
- The interpretation reflects the identified limitations and the aim of the assessment.
- The report is transparent and consistent. Figures 7 to 9 would be easier to read if the y-axis was not with scientific formatting and the post-harvest handling had some other color than white.

Table 1 – Checklist of considerations.

Considerations	**Comments from reviewer**	**Steps taken to conform:**
General information, study objectives and scope		
Contact information	Name and date appear on frontpage.	
The LCA adequately explains the system under study, the system boundaries, the criteria (criteria) used to determine the system boundaries and the justification of these criteria (criteria)	OK. Described in section 2 and 4.3. A visual overview is provided. In the report, system boundaries are both defined as Cradle to factory gate and cradle to distribution gate.	The study is cradle to factory gate. Any reference to cradle to distribution gate have been removed to clear up any confusion.
The LCA contains explained reasons for conducting the study	OK. Described in section 2.	
The LCA explains in detail the stakeholders or to whom the study is intended	OK. Stated in section 2.	
The LCA defines the function unit accordingly	Stated in section 3.1. On page 10 it is stated that utilization of surplus flowers in the bouquets from Flowering means that a larger input of stems is needed for the production of a single stem. It would add to clarity if this could be further explained.	An additional comment has been in added in section 4.4.1: "This loss is due to sorting of the secondhand flowers which means that a portion is discarded. Thus, a larger input of surplus flowers is needed. The discarded flowers are handled as green waste."
The LCA defines the impact categories accordingly	OK. In section 4.1.	
The LCA explains the chosen methodology accordingly	OK. In section 4.1.	

The LCA adequately explains the data, data quality, assumptions (system level and data assumptions) and limitations	Section 4.4. Better explanation of depreciation would be helpful. It might also be helpful to disclose GHG emission factors as the main focus of the LCA is on GHG emissions. That would make checks easier. Also, though page states that depreciation of buildings is not included, property is included on page 10. In table 5 (input for conventional flowers) the sum of flower stems is 1.1 but on page 10 it is explained that "The collected data reflects the increased loss of flowers caused by the utilization of surplus flowers in the bouquets, which means that a larger input of stems is needed for the production of a single stem." This needs further explanation.	Any reference to depreciation of property has been removed – both data on depreciation of agricultural machinery and property were collected from primary producers, but property has been excluded from the analysis. Assumptions on depreciation of the agricultural machinery have been delineated in section 4.4. Several copying errors have been identified in table 5 – including the flower stems. These errors slightly affect the results, and thus they have been updated as well as the graphs and numbers quoted in the text. This does, however, not alter any conclusions significantly. Individual GHG emission factors have not been disclosed due to data aggregation being performed directly in the software utilized. Output of this data would therefore be impractical. Instead, all input data and direct database references have been given as well as any underlying assumptions.
Data inventory (LCI)		
The LCA explains the period during which the data were collected and data source	In section 4.4.1	
The LCA explains the data collection, how representative they are, the assumptions	Section 4.4.1.	
The LCA explains the validation process – whether appropriate data quality validation has been performed	OK. Section 4.2.	
The LCA contains the relevant calculations based on the data provided	It might be helpful to disclose GHG emission factors as the main focus of the LCA is on GHG emissions.	Individual GHG emission factors have not been disclosed due to data aggregation being performed directly in the software utilized. Output of this data would therefore be

		impractical. Instead, all input data and direct database references have been given as well as any underlying assumptions.
Interpretation		
The interpretation is in line with the objectives and scope of the study	OK.	
The LCA explains (source and emissions) the main impacts and processes accordingly	OK.	
The LCA adequately analyses the significance of relevant and irrelevant assumptions through sensitivity analysis	OK. In section 6.3.	

3 Conclusion

The LCA report describes the results of LCA regarding environmental impact of two different production and handling systems of flowers. The main goal of the LCA was to assess the global warming potential (GWP) of the two different systems. The report is generally transparent and consistent. Thus, this review report verifies with limited assurance that the report can be used to support the results of LCA regarding environmental impact of the two different production and handling systems of flowers, i.e., that production and handling system 1 (utilized by Flowering ApS) had an impact of 0.108 kg CO_2 eq. per flower stem ready for distribution, while production and handling system 2 (conventional distribution) had an impact of 0.167 kg CO_2 eq.

This review report concludes that the methods used in the report entitled “Life Cycle Assessment of Production and Handling of Flowers” are consistent with the DS/EN ISO-standard 14044:2006/A1:2018 and that the data used, and interpretation of results are appropriate and in accordance with the aim of the assessment.

Some key issues were corrected and clarified before the review report was written. Some limitations and areas of improvement were found and are highlighted in Table 1. These were adequately addressed in the version of the LCA-report that was sent to the review panel on 18.5.2023.