Partners for Innovation

LCA QUICK-SCAN FLOWER AND PLANT SLEEVES

Life cycle assessment comparing the environmental impact of different flower and plant sleeve materials

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TABLE OF CONTENT

SUMMARY

Chapter 1: Introduction

Royal FloraHolland wants to guide growers in making sustainable packaging choices, by providing their members with more insight into the environmental considerations of different flower and plant sleeve materials. The purpose of the LCA quick-scan is to determine the environmental impact of different types of flower and plant sleeves from cradle to grave. Please note that the results should only be used to this end, and should under no circumstance be used for marketing purposes or commercial claims on environmental performance.

Six sleeves of different materials are compared:

- Two PP sleeves: a virgin BOPP sleeve and a CPP sleeve made of 40% recycled content
- Two LDPE sleeves: a virgin LDPE sleeve and a LDPE sleeve made with 40% recycled content
- Two paper sleeves: a virgin kraft paper sleeve and a paper sleeve made of 100% recycled content.

For the analysis, two different End-of-Life scenarios are considered; an European average scenario and a sorted recycling stream scenario.

Chapter 2: Methodology

An LCA quick-scan (also called streamlined or screening LCA) seeks to identify the most important factors that determine the environmental impact of a product in a limited time frame. Results are expressed in global warming (in kilograms of CO_2 equivalent emissions) and an aggregated ReCiPe 2016 single score indicator (in points, Pt)

The choice for sleeves are determined using input from a number of producers of flower and plant sleeves. Data on End-of-Life scenarios of packaging waste is collected from public sources. Data on the weights, production and transport of the sleeves is collected from producers of plant and flower sleeves.

Chapter 3: Results

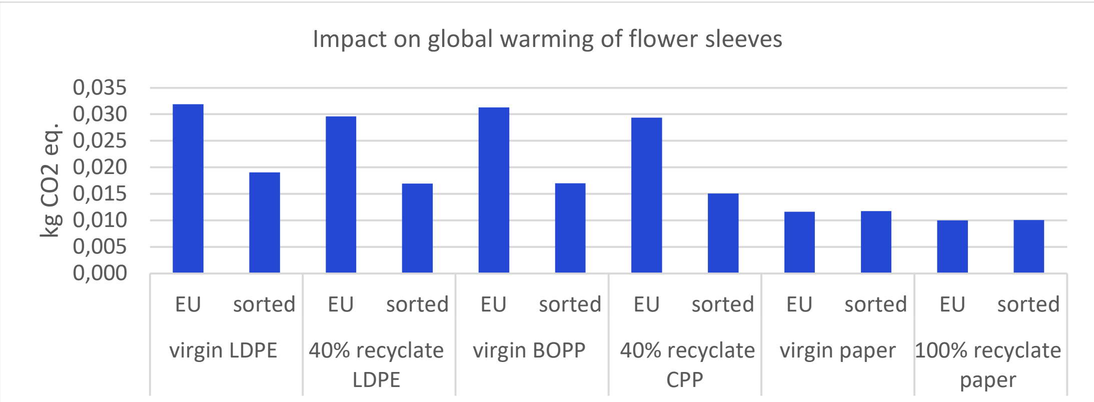

Figure 1. Global warming impact of flower sleeves from different materials with a European average End of Life scenario (EU) and a separated waste stream End-of-Life scenario (sorted)

In terms of impact on global warming, the paper sleeves have the least impact in all studied End-of-Life scenarios. The paper sleeve made out of 100% recycled content shows a slight advantage over the virgin sleeve in terms of impact on global warming.

All four studied plastic sleeves have a higher impact on global warming compared to the paper sleeves. PP has a marginally lower impact on global warming. Sorted recycling has a large effect of the End-of-Life scenario global warming impacts of global warming sleeves.

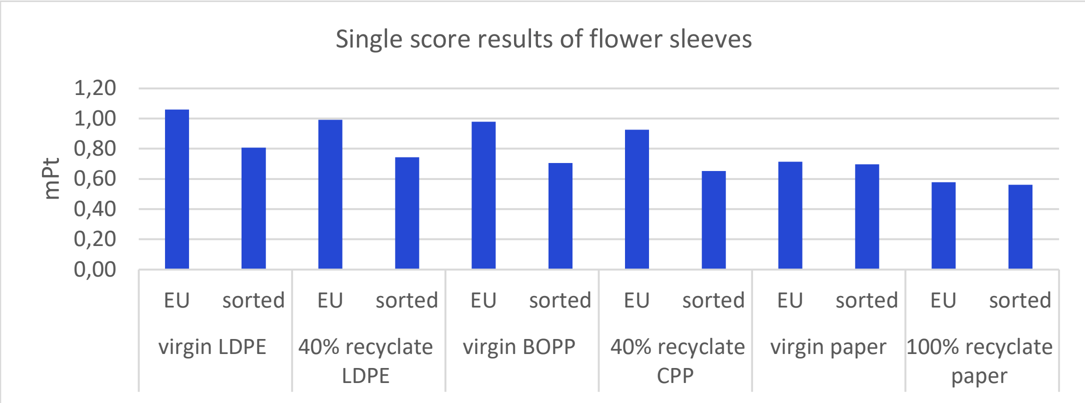

Figure 2. Single score results of flower sleeves from different materials with a European average End of Life scenario (EU) and a separated waste stream End-of-Life scenario (sorted)

The aggregated ReCiPe 2016 single score indicator shows similar results; the paper sleeve consisting of 100% recycled fibre is the most environmental favourable option for both scenarios.

Chapter 4: Sensitivity analysis

The sensitivity analysis provides a reflection on the effect of the assumptions and choices made in the setup of this study.

The sensitivity analysis shows that, in addition to the material choice of the sleeve, the choice for printing on the sleeve has a large effect on the single score results of the sleeves and is therefore another important aspect to consider when choosing a sleeve.

An important assumption made in the study is the percentage of the sleeve material assumed to end in recycling and in incineration in the different End-of-Life scenarios. In the sensitivity analysis a comparison is made to compare other possible End-of-Life recycling scenarios than those included in the study. The analysis show again a difference in benefits accounted to End-of-Life recycling of paper compared to that of plastic. Because of this, at a certain % of recycling End-of-Life, both the virgin BOPP and the 40% recyclate CPP have a lower impact than the virgin paper sleeve.

Chapter 5: Conclusion

The paper sleeves have the lowest global warming impact as well as single score results. The sorted recycling at End-of-Life has a slight positive effect on the results of the paper sleeves. After the paper sleeves, the plastic sleeves with a high percentage of recycling in the End-of-Life have the lowest global warming impact and single score results. Lastly, the plastic sleeves that are not separately sorted for recycling have the highest global warming impact and single score results.

For global warming scores the plastics sleeves from lowest to highest are: 40% recyclate CPP, 40% recyclate LDPE, virgin BOPP, virgin LDPE. For the single score results, the order is: 40% recyclate CPP, virgin BOPP, 40% recyclate LDPE, virgin LDPE.

Though the use of recycled content shows some impact reduction potential, sorted recycling should be prioritized, as it has a more significant impact reduction.

Chapter 6: Discussion

The discussion provides a reflection on the limitations of the study. One important limitation of the study is that biobased sleeves could not be included because the analysis of the benefits that bio-based polymers present using LCA is as of yet inconclusive.

Another important point is that, even though the sleeves perform the same function, their performance in doing differs slightly. There are differences in stiffness, transparency, stretchability and water resistance. This report gives insight in the best option in terms of environmental impact, but does not make statements on the most favourable sleeve in terms of functionality.

1. INTRODUCTION

1.1 BACKGROUND

Royal FloraHolland is a cooperative of growers of plants and cut flowers that manages the largest flower auction in the world. They provide their members with information to make the growers' business more sustainable, including information about sustainable packaging.

The floriculture sector is looking for sustainable packaging for flowers and potted plants. The sleeves that protect the plant are an important part of the packaging. It is not yet clear which material choice is the best option for the sleeve (paper or plastic?). Additionally, it is unclear how using recycled material in the sleeve impacts the environmental impact of the sleeve. Royal FloraHolland wants to guide growers in making sustainable packaging choices, by providing their members with more insight into the environmental impact of different flower and plant sleeve materials.

Partners for Innovation has been asked to provide this quantification by performing a Life Cycle Assessment (LCA) quick-scan of the various commonly used flower and plant sleeves. This report describes the approach, results, and conclusions of the LCA quick-scan.

1.2 OUTLINE OF THIS REPORT

This chapter gives a reason and rationale for this study and describes the approach and methodology used in the LCA quick-scan. The used data for the study are described in chapter 2. Chapter 3 describes the results and interpretation of these results. Chapter 4 describes the sensitivity analysis. In chapter 5 conclusions are drawn. Chapter 6 provides a discussion of the results. In the appendixes a full overview of the used data and assumptions is given, an additional explanation of the used LCA methodology and the Circular Footprint Formula (CFF) method, as well as tables with all the results.

1.3 OBJECTIVE OF THE STUDY

The purpose of the LCA quick-scan is to determine the environmental impact of different types of flower and plant sleeves from cradle to grave. To determine this the entire life cycle of products is involved; from the raw materials, production processes, and transport to the disposal and possible recycling at the end of its life. Various End-of-Life (EoL) scenarios are compared, since the type of collection and processing of the waste can vary widely, even for one sleeve material. Flowers and plants are exported to different countries and the sleeves can be disposed of in both consumer and industrial waste. How the sleeve is sorted into a waste stream determines how much of it will be recycled.

To make a representative selection of sleeve materials, several major Dutch suppliers of sleeves are contacted. An inventory is made of which sleeves are sold the most and what alternatives with recycled content are available. For this LCA a commonly used flower sleeve size is taken as an example. It is predicted that if a different sleeve sizes is chosen (like with plants), the comparative results would remain the same (assuming that other aspects such as thickness, production location, or End-of-Life would remain the same).

The desired result of the LCA quick-scan is that the members of Royal FloraHolland gain insight into the environmental impact of various flower and plant sleeves. The sleeves fulfil a function in which several properties are important, such as the transparency, stiffness, stretchability and water resistance of the materials. The report contains a table in which these properties are compared per material.

1.4 SCOPE OF STUDY

Functional unit

The functional unit is a 'measure of the performance of the functional outputs of the product system' (ISO 14040). The purpose is to provide a common reference on which the different scenarios that are studied can fairly be compared.

To determine a suitable functional unit information is gathered from several flower and plant sleeve suppliers. They have provided data on a commonly used size for flower sleeves, the weights of the sleeves, feasible recycled content percentages, production methods, transport distances and transport modes. The functional unit for this study is defined as: *"To once-only package (protect during transport) one plant or bunch flowers with the dimensions 40x30x12 mm from grower to retailer."*

Subjects of study

6 different sleeves are compared. Figure 3 shows the selection of sleeves included in the study:

BOPP virgin	rCPP	PE virgin	rPE	Paper virgin	rPaper
100% virgin PP	60% virgin PP	100% virgin LDPE	60% virgin LDPE	100% virgin kraft paper	100% recycled paper
	40% recycled PP		40% recycled LDPE		

Figure 3: Flower sleeves included in the study

The chosen materials are based on input from producers of flower and plant sleeves. The materials included are PP, LDPE and paper. For every material, one sleeve made of virgin material and one sleeve made with recycled content are compared. The percentage of recycled content for the sleeves is based on available sleeves on the market and input from the suppliers on realistic percentages of recycled content. A recycled content of 40 percent is chosen for the plastic sleeves. A recycled content of 100 percent is chosen for the paper sleeves.

System boundaries

System boundaries refer to what is included and excluded in the study. The selected system boundaries of this study are cradle-to-grave. This means that the extraction of raw materials, the production of parts, assembly, transport, distribution activities, use and disposal at the end of a product's lifetime are intended to be included in the study. However, there are some slight variations from this overall system boundary, which are described in the following paragraph.

Cut-off criteria

Ideally, an LCA includes every single process in the life cycle of a product in its LCA model. However, there is a practical limit to doing so, especially given the limited time-frame of an LCA quick-scan. Some inputs or processes will have to be excluded from the study for practical reasons. A rule of thumb is to 'cut-off' processes that are assumed to have less than 5% impact on the total environmental impact. For this reason, not all steps of the life cycle are included in the calculations. For instance, the use of the sleeves by the growers is likely to have no impact. The actual act of disposal will also have little to no impact. The packaging that is used for raw material and during transportation of the sleeves is also considered to have a very low impact when considered per unit.

In this LCA quick-scan the printing of the sleeves is not included. This choice is made because the environmental impact of the printing does not contribute to the comparison of the sleeve materials. However, the impact of the printing can be above 5%. The effects of printing inks on the impact of the sleeves is discussed in the sensitivity analysis.

Figure 4 visualizes the system boundaries with the processes included and excluded in the study.

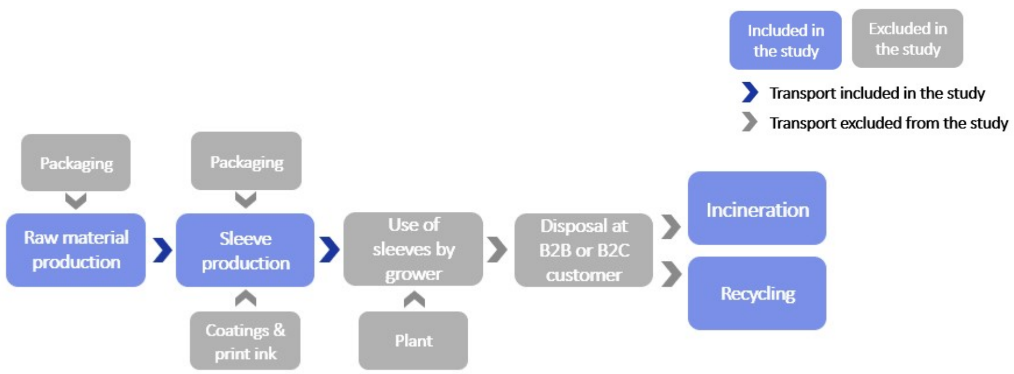

Figure 4: System boundaries for this study

1.5 END-OF-LIFE SCENARIOS

The End-of-Life scenario of a sleeve has a considerable effect on its environmental impact. If a sleeve is recycled at the End-of-Life, part of the environmental impact of the sleeve can be accounted to the following product life cycle. In addition, emissions from waste incineration can be temporarily prevented.

For this analysis two different End-of-Life scenarios are estimated. In the first scenario, the location and type of disposal of the flower sleeve is unknown. In this scenario, European average recycling rates are used This End-of-Life scenario can for example occur when the product is auctioned through the auction clock. The second scenario is when it is known that the sleeve will be collected as a separate waste stream and taken for recycling. This is the case when a closed loop system is in place, where the material is collected in a separated waste stream and taken for recycling.

For the European average scenario, the recycling rates of PE, PP and Paper are determined based on public sources. It is assumed that the recycling rate for paper is 71% (European paper recycling council, 2022, Monitoring report 2021). For PE flexible films, it is found that the average recycling rate is 23% and PP flexible films generally are not recycled (Plastics Recyclers Europe, 2020, Flexible films market in Europe).

Even when the product is collected separately and taken for recycling, not 100% of the product can be assumed to be recycled due to contamination or inefficiencies in the recycling system. For the sorted waste stream scenario, all materials are assumed to be 90% recycled and 10% incinerated.

The resulting twelve scenarios are built up out of three variables as can be seen in table 1. The first variable is the material (column 1). The second variable is the percentage of recyclate in the sleeve material (column 2). The final variable is the assumed % recycling at the End-of-Life of the product.

Table 1. Subjects of study with their End-of-Life scenarios used for the calculation

Material	Recycled content	EoL recycling
PP	0%	0%
		90%
	40%	0%
		90%
PE	0%	23%
		90%
	40%	23%
		90%
Paper	0%	71%
		90%
	100%	71%
		90%

1.6 SENSITIVITY ANALYSES

The previous paragraphs describe a number of the assumptions made to perform the analysis. In reality, many aspects of the life cycle, such as the products or the End-of-Life scenarios, could differ. To understand the effect on the results when different assumptions are made, a number of sensitivity analyses are performed. The analyses describe the effect of a different choice of paper weight, the addition of printing to production, different End-of-Life scenarios and different percentages recycled content in the sleeves. This sensitivity analysis can be found in chapter 4.

2. METHODOLOGY

2.1 METHODOLOGY OF THE LCA QUICK-SCAN

A Life Cycle Assessment (LCA) is a method for analysing the environmental impact associated with every stage of the life cycle of a product, service, technology or process.

LCA quick-scan

An LCA quick-scan (also called streamlined or screening LCA) is our approach to life cycle assessment. This approach seeks to identify the most important factors that determine the environmental impact of a product in a limited time frame.

Time is saved through limiting the scope of a full LCA. In this context, the scope refers to the system to be studied, the resolution of the data collected, and the range of environmental impacts to be addressed. Life cycle stages may be omitted if determined insignificant, generic data may be used more readily instead of system-specific data, and the study can be tailored to focus on impacts that are deemed more relevant to the audience or the product system that is being assessed. With limited effort, we gain a relatively accurate representation of the environmental impacts of the product's life cycle. Deviation from the actual impact is approximated to be around 10%.

An LCA quick-scan is intended for strategic decision making and optimisation of the studied subject through the identification of impact hotspots, exploration of the environmental impacts of different options or scenarios, and the comparison with alternative products, services or technologies that fulfil the same function. For further reading on LCA quick-scan methodology, please see appendix B.

Software and life cycle impact assessment (LCIA) method

The LCA calculations were performed using the specialised LCA-software SimaPro 9.3. This software is developed by Pré in Amersfoort and is used by researchers and companies worldwide. This study uses the ReCiPe 2016 v1.1 Hierarchist version LCIA method. A LCIA method is required to transform the numerous emission results from the LCI database into a set of comprehensible indicators. The ReCiPe method has indicators on two levels: 17 midpoint indicators and 3 endpoint indicators. Midpoint indicators describe impact on separate environmental issues, such as global warming, eutrophication and acidification. Endpoints are aggregations of these midpoints to the eventual consequences these problems will have. These endpoints can be expressed one single score. Appendix C gives a visual representation of the ReCiPe method that provides further understanding.

ReCiPe indicators used for the study

Global warming is used as key impact indicator of this study. Global warming is expressed in kilograms of CO2 equivalent emissions (kg CO2 eq.). This means that all emissions that contribute to climate change are considered and that their effect on climate change is expressed in the reference substance of a kilogram CO2.

However, the impact on the environment is more than just impact on global warming. There are other environmental problems to consider. For instance, the depletion of non-renewable resources, acidification, ecotoxicity and water scarcity are all relevant environmental problems. These problems should also be taken into account when determining which sleeve has the lowest environmental impact.

To provide a more holistic view of environmental impact, we rely on the ReCiPe 2016 aggregated single score indicator. This single score indicator takes into account the impact on all midpoint indicators (i.e. environmental problems), weighs the relevance of these indicators amongst each other (using factors generated by an expert and non-expert panel) and then adds them into a single score. A single score aggregates different environmental impact indicators and thus has no reference substance. The used unit is expressed in points (pt).

Circular Footprint Formula

For the used recycled materials in production and the recycling of the materials after disposal, the impact of the recycling process and the benefits of recycling are allocated according to the Circular Footprint Formula. This is an allocation approach formulated by a joint research committee of the European Commission[1]. This allocation approach is discussed in further detail in appendix D, but can be summarized here as: parts of the impact of the virgin material production and the recycling process are allocated to the recycled content used. By recycling the products at End-of-Life, materials are recovered that avoid production of virgin materials for other products. The benefit of the use of recycled materials in other products is partially allocated to the recycling process of these sleeves.

2.2 DATA COLLECTION

For the LCA quick-scan, different data sources are used. To determine the scope of the study, the product specifications and the production methods and locations, data is gathered from several suppliers of flower and plant sleeves. For more detailed information on the processes and materials, the ecoinvent life cycle inventory database is used.

Life cycle inventory (LCI) databases

The ecoinvent life cycle inventory database (LCI) was used to assess the emissions of the identified materials and processes. Ecoinvent is the most widely used LCI database worldwide, developed and managed by the Technical University ETH in Zürich. When possible, country specific data is selected. If not available, continental data or global data is used. Occasionally, materials or processes are not included in the database. In this case information found through desk research is used to model the material or process when available. If not, similar materials or processes are used as a proxy.

2.3 KEY ASSUMPTIONS

The following paragraphs elaborate on the choices made to form the scenarios and complete the data inventory, which are summarized in Table 2. As explained in the first chapter, the assumptions are based on input from suppliers of flower and plant sleeves.

[1] European Commission, DG ENV, 2020. *The Circular Footprint Formula (CFF) and its practical application*.

Table 2. Life cycle assumptions

	PP virgin	rPP	PE virgin	rPE	Paper virgin	rPaper
Material	BOPP	CPP	LDPE	LDPE	Kraft paper	Paper
% recycled	0%	40%	0%	40%	0%	100%
Thickness	35 micron	35 micron	35 micron	35 micron	45 grams/m^2	45 grams/m^2
Weight	5,4 grams	5,5 grams	5,6 grams	5,7 grams	7,6 grams	7,6 grams
Production method	Plastic film extrusion	Plastic film extrusion	Plastic film extrusion	Plastic film extrusion		
Transport	200 km outside Europe by truck 22.125 km from China to the Netherlands by ship 100 km within the Netherlands by truck					

Sleeve weight calculations

Based on calculation methods of the sleeve suppliers, the surface area of the flower sleeve is the sum of the width at the top and the width at the bottom times the height of the sleeve.

Surface area = height (width bottom + width top) = 40 x (12+ 30)

To calculate the weights of the plastic sleeves, the thickness and the mass per unit volumes are used. For paper the surface area times the weight/square meter is used to calculate the sleeve weights.

The following material weights are used for the calculations:

	PP virgin	rPP	PE virgin	rPE
g/cm3	0,91	0,93	0,96	0,99

Production methods

The production methods are determined together with the producers. Simplifications had to be made. Whereas the production method for BOPP and CPP differ, the ecoinvent database does not include the suitable processes to describe these differences. Therefore, the same production process is used for all plastic sleeves.

For the paper sleeves, the production processes to make paper from paper pulp are included in the raw material production. Therefore, no production processes are included for the paper sleeves.

Processes such as gluing or die-cutting are not included in the database. For the LCA quick-scan method, these processes are likely to have a very minimal effect (<5% of the total) and are thus not included.

Transport

Generally, the sleeves are reported to be imported from outside of Europe, mostly from Asia. From the provided data from the suppliers, no common difference can be seen in transport distances. Therefore, the same distances are taken for all sleeves, which are: 200 km outside Europe by truck, 22.125 km from China to the Netherlands by ship and 100 km within the Netherlands by truck.

3. RESULTS

In this chapter, the results of the LCA quick-scan are presented. First, the impact on global warming results are presented and discussed. Second, the single score results are presented and discussed.

3.1 IMPACT ON GLOBAL WARMING RESULTS

The results of global warming, expressed in kilograms of CO_2 equivalent emissions, are shown in figure 5. The results are presented for all six sleeves, both in the average European recycling scenario (EU) as the scenario of a separate sorting stream for recycling (sorted). The colours represent the different life cycle phases. The total emission for each scenario is indicated by the black horizontal bar. The numeric values of these results can be found in the table in appendix E.

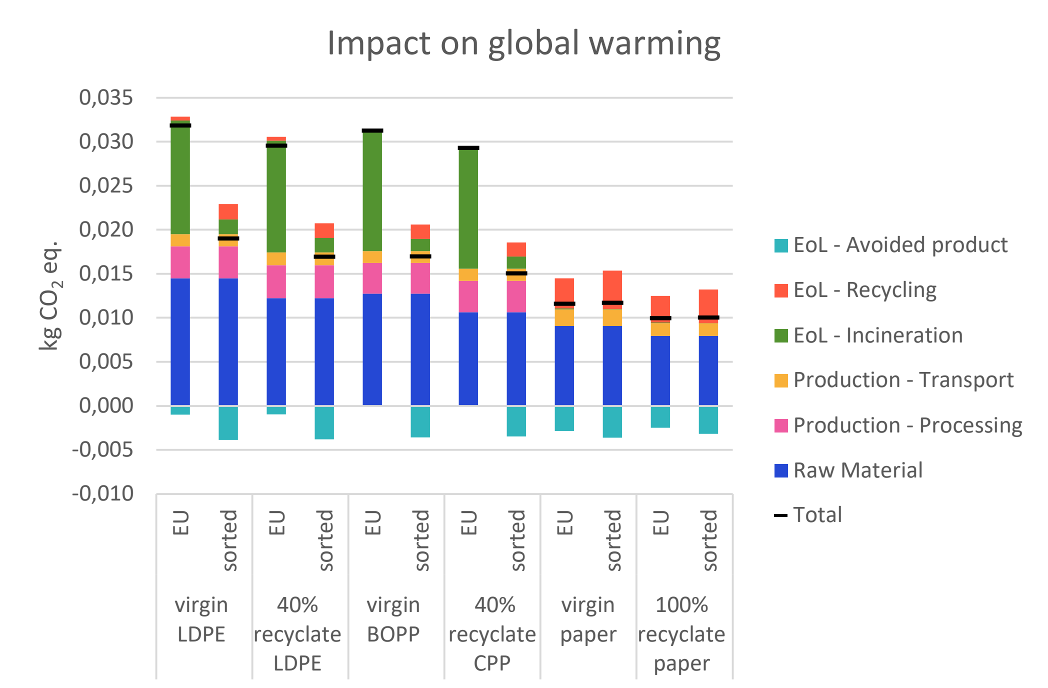

Figure 5: Impact on global warming

3.2 IMPACT ON GLOBAL WARMING DISCUSSION

The virgin LDPE sleeves in the European average End-of-Life scenario have the highest impact on global warming per functional unit, whereas the recyclate paper sleeve has the least impact on global warming. The life cycle phases of raw material and End-of-Life - incineration contribute the most to the total impact. In the following paragraphs, a number of observations are further discussed.

Raw material

The raw material of LDPE has the highest impact. The raw material of the paper sleeves have a much lower impact. The kg CO_2 equivalent of paper material is much lower than that of plastic. Because of a difference in weight between the paper sleeves (7.6 grams) and the plastic sleeves (around 5.5 grams) the difference in the total impact of the raw material is still relatively close together.

Production - Transport

The sleeves are produced in Asia and then transported to Europe. Because of the long distance, the transport impact on global warming shows. However, the transport impact still a relatively small part of the total impact on global warming. Like mentioned before, the transport is assumed to be the same for all sleeves based on the provided data from the suppliers. Because of this, the transport life cycle phase does not differ much between the sleeve materials.

Production - Processes

Next to long transport distances, the production in Asia also has consequences for the impact on global warming of production processes. Most of the impact in the production process are a result of energy consumption during the processing steps. When studying the impact of energy production in the ecoinvent database, energy production in Europe generally has less impact on global warming than energy production in Asia. Therefore, sleeve production in Asia generally has a higher impact on global warming than equivalent sleeves produced in Europe.

End-of-Life - Incineration

Within the analysis the incineration of paper sleeves has almost no impact on global warming. In reality, CO_2 is released in the atmosphere because of the paper incineration. However, these emissions are not included in the analysis because they are released from a biobased material The reason for this is that the carbon released during the incineration was initially taken up from the atmosphere during the growth of the tree (following ISO 14040 guidelines).

End-of-Life - Recycling

Recycling at End-of-Life has considerable effect for the plastic sleeves. This large effect can be explained by the double benefits of End-of-Life recycling for plastics: the material is prevented from being incinerated (which is a large part of the impact for plastic) and recycling avoids the need for virgin material in a subsequent lifecycle, so the net result is a negative impact.
For paper, the End-of-Life scenarios show a much lower effect on the total impact scores for most impact categories (more recycling even adds to the impact on global warming). This is due to two factors. Firstly, the impact of incineration of paper is very low, as is explained in the previous paragraph. Therefore, the large decrease in this life cycle stage seen for the plastic sleeves is not seen for the paper sleeves. Additionally, the production steps of paper that cost most energy are necessary both for the production of virgin paper as well as for the recycling of paper to new paper. So, in terms of impact on global warming, the End-of-Life scenario of recycling paper only has a slightly higher impact than incineration. However, as we will see in section 3.3 and 3.4, there are still considerable benefits for recycling paper for other environmental indicators.

3.3 SINGLE SCORE RESULTS

Sections 3.1 and 3.2 describe the impact on global warming for all studied scenarios. However, as mentioned before, the impact on environment is more than just impact on global warming. There are other environmental problems to take into account. For instance, the depletion of non-renewable resources, acidification, ecotoxicity and water scarcity are all relevant environmental problems. These problems should also be taken into account when determining which sleeve has the lowest environmental impact.

To provide a more holistic view of environmental impact, we rely on a single score indicator. This single score indicator takes into account the impact on all midpoint indicators (i.e. environmental problems) and weighs the relevance of these indicators amongst each other using factors generated by an expert and non-expert panel. Figure 6 shows the single score results.

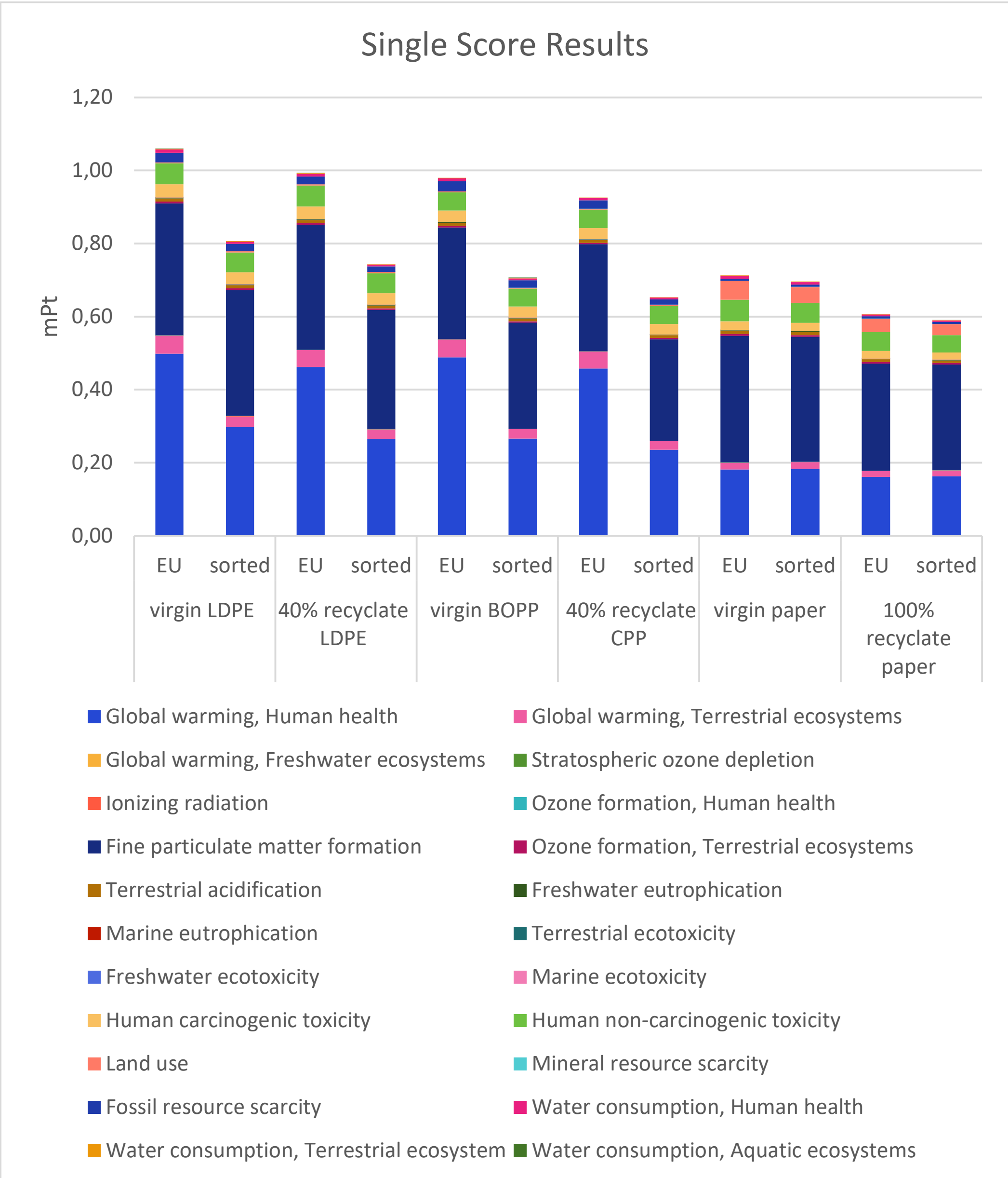

Figure 6: Single scores results

3.4 SINGLE SCORE DISCUSSION

Figure 6 shows the environmental impact expressed as an aggregated single score result based on the ReCiPe 2016 method. The two most influential contributors to the total environmental impact are the effects of global warming and fine particulate matter formation.

Upon further analysis, this can mainly be traced back to extensive use of grey energy in the life cycle in all the sleeve types. This has a double negative effect; next to the global warming it causes, it also results in fine particulate matter formation, which causes a wide range of respiratory diseases. For plastic sleeves, the global warming effect is higher as the incineration emits additional fossil CO_2 into the carbon cycle. As also explained in section 3.1, the incineration of paper does not add additional CO_2 to the carbon cycle.

The ReCiPe 2016 single score result reveals that the recycled paper based sleeve are the most environmentally favourable choice when considering average European recycling rates. Though it scores higher on some midpoint indicators (i.e. land use), the total single score is the lowest of all sleeves. The virgin paper sleeve takes a second place, followed by the plastic based sleeves. Both the recycled PP and virgin PP sleeve seem to perform slightly better in terms of environmental impact than the recycled LDPE and LDPE sleeves, although the differences are small.

In the situation where all sleeves are gathered separately and offered to a recycler in a homogeneous stream (the so called 'sorted scenario'), the recycled paper sleeve remain the most environmentally favourable choice. In this End-of-Life scenario, the PP sleeve with 40% recycled material takes the second place in terms of environmental impact. The virgin paper sleeve is in shared third place with virgin PP foil sleeve. However, as PP foil recycling facilities are still very scarce in Europe, this scenario is rarely realistic. As paper recycling facilities are widespread and the paper collection rate is high throughout Europe, the recycled and virgin paper sleeve remains the best option, environmentally speaking. The recycled LDPE and virgin LDPE sleeves come last in environmental impact for the separate collection scenario. That being said, their impact is relatively close to the other alternatives in the separate collection scenario, and LDPE foil recyclers are more common in Europe than PP recyclers.

4. SENSITIVITY ANALYSIS

To conduct an LCA on plant and flower sleeves, decisions have to be made on what accurately reflects the life cycle of the sleeves in the market. Assumptions must be made to do so. In this sensitivity analysis, we analyse and reflect on the effect of the assumptions and choices made in the setup of this study. The following parameters are selected for further analysis: paper weights, the inclusion of printing inks, the percentage of recycled content in the sleeves and the percentage recycling at the End-of-Life of the sleeves.

Paper weights comparison

Based on feedback from the suppliers, 45 grams paper is chosen for the weight of the sleeves for this LCA quick-scan. This is considered a realistic but low paper weight for the sleeves. Often more heavy papers are used for the flower and plant sleeves as well. To understand the impact on the thickness of the paper, the environmental impact of paper sleeves have been compared with the paper weights of 45 grams (7.6 gram sleeve), 50 grams (8.4 gram sleeve) and 55 grams (9.2 gram sleeve). The single score results for the European average recycling scenario for paper can be seen in figure 7.

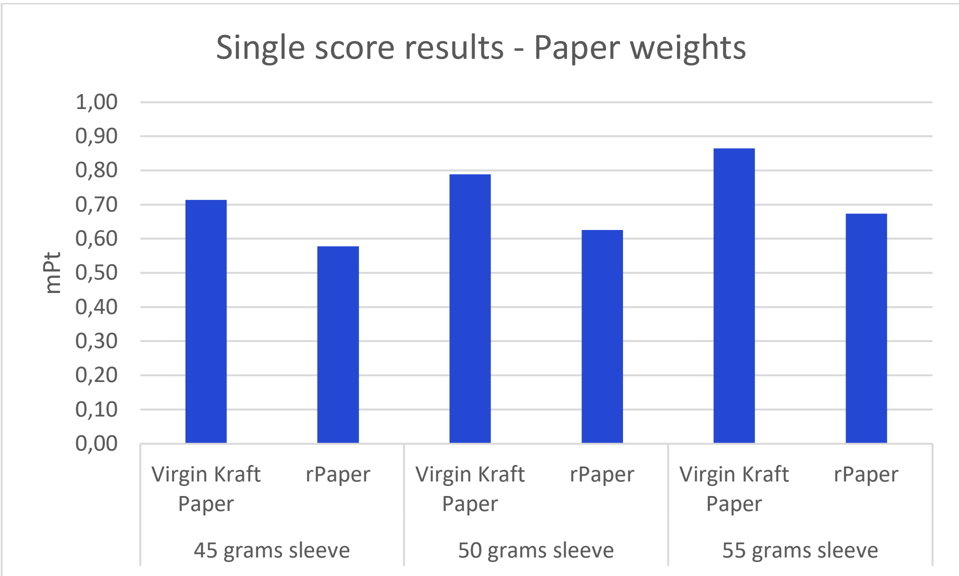

Figure 7: Comparison of single score results for sleeves of three different paper weights

The results show a linear increase in the environmental impact of the paper sleeve with the addition of the paper weight. A virgin paper sleeve with a weight of 55 grams/m2 has a higher single score impact than that of some plastic sleeve alternatives.

Effect of printing inks

The printing inks are not included as they can be assumed to be the same for all sleeve materials and therefore don't contribute to the comparison. To understand the contribution of printing on the environmental impact of the sleeves, two types of printing are analysed. A rotogravure printing method is chosen as this is most often used for the printing of the sleeves, based on data from the suppliers. We compare the printing of a simple logo (1 colour logo of 5 x 5 cm) to the printing of a more extensive design (2 colours covering the half sleeve surface area).

Figure 8 shows the single score results for the printing ink of a 1-colour logo, a 2-colour half sleeve compared to the average single score results for a sleeve (based on the single score results from chapter 3.3). We see that for a small logo in a single colour, the environmental impact is negligible. For a half sleeve with multiple colours however, the printing becomes a large part of the total environmental impact of the sleeves. Compared to an average environmental impact of the studied sleeves, it is almost 1/3rd of the total lifecycle impact. In the market there are also sleeves available that are printed with more colours and on a larger surface, the impact of this printing will be even higher than stated here. When improving the flower sleeve design to reduce environmental impact it is therefore important to choose minimal printing, both in surface and number of colours. In addition to its environmental impact, the ink used for printing is a contamination in the recycling process.

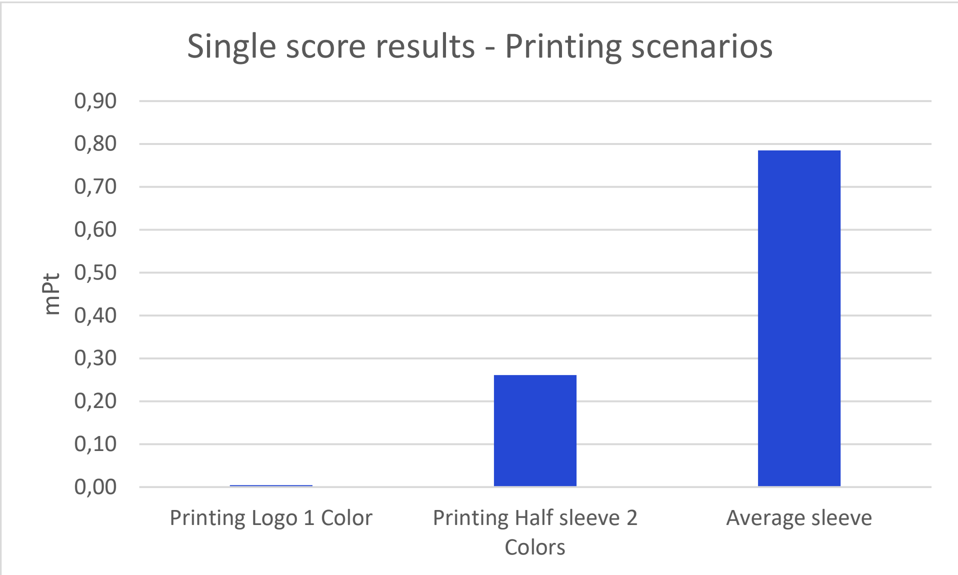

Figure 8: Single score results for different printing scenarios

Effects of End-of-Life scenario

The percentage of material that is recycled at the End-of-Life of the sleeve has a considerable influence on the environmental impact of the sleeves. For the European average scenario, 0% (PP), 23% (PE) and 71% (Paper) recycling are assumed based on average recycling percentages from public sources. However, in reality many different End-of-Life recycling scenarios are possible. Figure 9 shows the midpoint results (in mPt) from a 0% recycling in the End-of-Life scenario to a 100% recycling in the End-of-Life scenario.

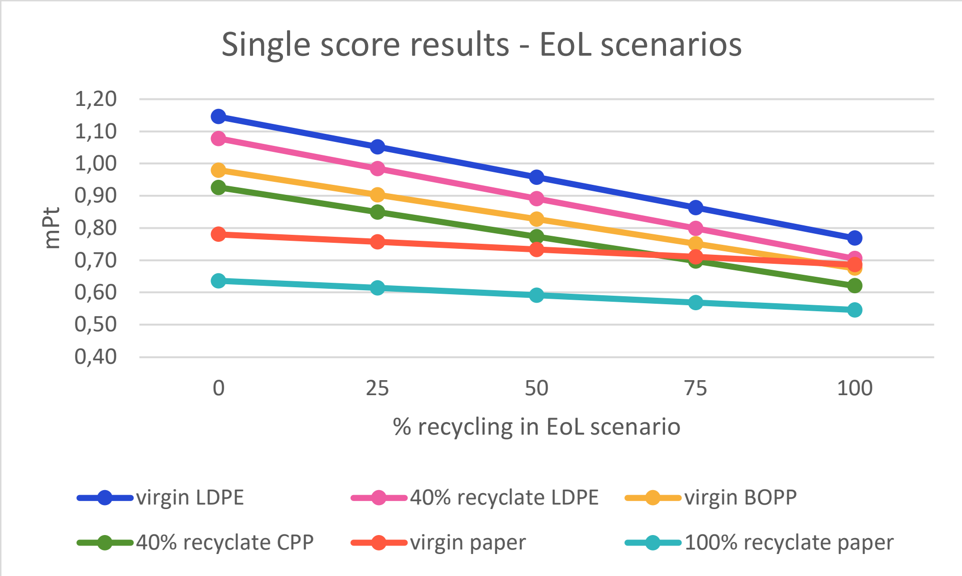

Figure 9: Single score results for different End-of-Life scenarios

The results show that the EoL recycling has a much higher impact on the results of the plastic sleeves than on that of the paper sleeves. It is clear that the percentage of recycling EoL has considerable less effect on the results of the paper sleeves than on that of the plastic sleeves. As explained in the results, the change to a recycling EoL for plastic has a large effect partly because it eliminates the incineration of the plastic material, which is a large part of the total impact. For paper, the incineration has almost no impact, as is further explained in the results.

Because of this difference in effect of the EoL recycling, around the point where 75% of the material is recycled at the End-of-Life, the 40% recyclate CPP sleeve has a lower overall score than the virgin paper. At 100% recycling at EoL, both the virgin BOPP and the 40% recyclate CPP have a lower impact than the virgin paper sleeve.

Percentage recycled content

For this report a 40% recycled content plastic is chosen for plastic and a 100% recycled content is chosen for paper. An analysis is performed to understand the effect of recycled content on the total impact results. For the comparisons the European average recycling scenarios are used.

Figure 10 show the single score results (mPt) of a sleeve from PP with varying percentages of recycled content added.

We see that the effect of the addition of extra recycled content is relatively low. 10 percent of added recycled content has about 1 to 2 percent impact on the single score results.

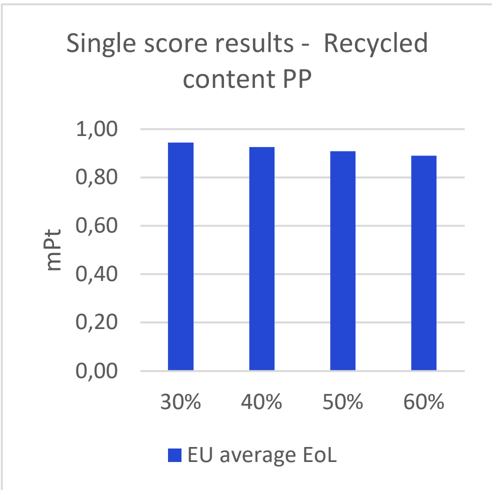

Figure 10: Single score results for varying percentages of recycled content in PP sleeves

Figure 11 shows the single score results (mPt) of a sleeve from LDPE with varying percentages of recycled content added. The observed effects are visible but quite low, similar to those of the PP sleeves. 10 percent of added recycled content has about 2 to 3 percent impact on the single score results.

As described in the results, the Circular Footprint Formula accounts more impact reduction to the recycling of plastics EoL than to the application of recycled content.

Figure 12 shows the single score results (mPt) of a sleeve from paper with varying percentages of recycled content. Again, the effects on the results is quite low. 10 percent of added recycled content has about 1 to 2 percent impact on the single score results. For recycled paper, the accounted impact reduction for recycling is overall low because the recycled paper market is very common and it is relatively easy to use recycled content. In addition, the environmental impact of the recycled content is not very different from that of the virgin paper. The reason for this is that the drying step in the production of the paper, which has significant impact, is the same for both virgin and recycled paper.

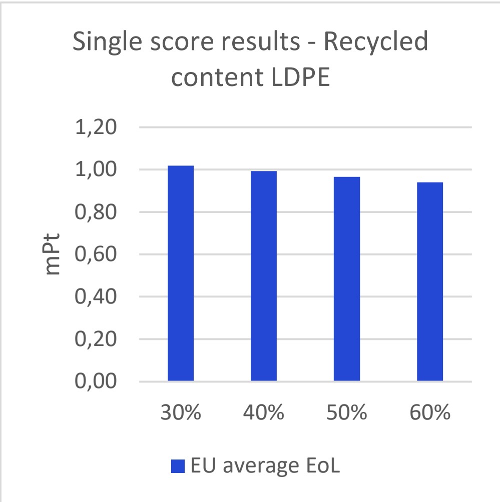

Figure 11: Single score results for varying percentages of recycled content in LDPE sleeves

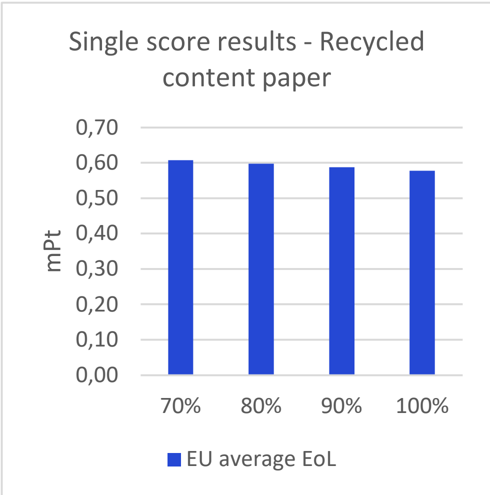

Figure 12: Single score results for varying percentages of recycled content in paper sleeves

5. CONCLUSION

This LCA quick-scan compares different materials for flower and plant sleeves in order to help growers choose the option with least environmental impact.

In terms of impact on global warming, the kraft virgin paper sleeve and the sleeve consisting of 100% recycled fibre have the least impact on global warming in all studied End-of-Life scenarios. All four studied plastic sleeves have a higher impact on global warming and show similar results, though sleeves made of PP appears to have a marginally lower impact on global warming.

The aggregated ReCiPe 2016 single score indicator is used to show a more holistic view of environmental impact. When considering an average European recycling rate, the paper sleeve consisting of 100% recycled fibre is the most environmental favourable option followed by the virgin paper sleeve.

When considering an End-of-Life scenario where the sleeves are collected separately to be recycled, this conclusion shifts slightly. The recycled paper sleeve still remains the most environmental favourable, but the PP sleeve with 40% recycled content is second best. However, as PP foil is scarcely recycled as PP foil recycling facilities are still rare Europe, this scenario does not occur often. The virgin paper sleeve is thus still recommended as the second best choice in terms of environmental impact.

Though the use of recycled content shows some impact reduction potential, sorted recycling should be prioritized, as it has a more significant impact reduction potential.

The sensitivity analysis shows that print has significant environmental impact when making large prints. Printing should thus be kept to a minimum. Furthermore, increasing the thickness paper rapidly diminishes the favourable position of the paper sleeves environmental impact, so this should be avoided when possible.

As mentioned above, the recycling rate has significant influence on the total environmental impact. When growers know that the recycling rates differ significantly from the studied scenarios, figure 9 in the sensitivity analysis can be used to determine the most environmental favourable option in that case.

6. DISCUSSION

Use of the results

The goal of this LCA quick-scan is to provide guidance to the members of Royal FloraHolland insight in selecting the a plant/flower sleeve with the lowest environmental impact. To this end, the report is published on their website to be accessible for members of FloraHolland. The results shown in this report should be used as such and are not to be used for marketing purposes or commercial claims on environmental performance.

Average data

The results of this study are generated using average data of raw materials. Exact sources of electricity and energy, sourcing of raw material as well as the inputs of production processes varies per specific manufacturer and can yield a different conclusion per case. The results should be viewed in light of this fact.

System boundaries

Some processes are cut-off from the study as the impact was deemed neglectable or similar for all products. As system boundaries and functional units differ between LCA studies, results are not to be compared with results of other LCA studies.

Bio-based polymers

In recent years, bio-based polymers have been proposed as an alternative to fossil-based polymers have with less environmental impact. However, the analysis of the actual benefits that bio-based polymers present using LCA is as of yet inconclusive. For instance, Walker & Rothman (2020) analysed “studies of 50 bio-based polymers and 39 fossil-based polymers.” “Results showed significant variation in impact between polymers, both between fossil-based and bio-based categories, between individual polymers within each category, and between different studies of the same polymer. Variation in results of the order of 200% to 400% was observed between studies of the same polymer with the same scope.” “It is therefore not possible to highlight ‘best performing’ polymers, or to suggest whether fossil-based or bio-based polymers perform best in any impact category.” Due to this uncertainty, we have refrained from including bio-based polymers in this LCA. Furthermore, the lack of a biobased PP or LDPE in the ecoinvent and Plastics Europe LCA databases further strengthened this decision. Including a bio-based LDPE or PP in this study would require using data from another database or scientific paper, which are often incompatible due to the differences in scope and allocation rules.

In light of this, we would advise to refrain from using bio-based polymers until a conclusive comparative LCA is published by an authoritative organization such as the Joint Research Centre of the European Union. The recommendation of bio-polymers without proper information is likely to lead to “unintended and potentially undesirable consequences”, says Walker & Rothman.

Functionality different sleeves

For this LCA, it is assumed the different sleeves have the same functionality. In reality however functionalities such as transparency and stiffness differ for the different material types and the recycled content amounts. Based on interviews with the suppliers and indication of the stiffness, transparency, stretchability and water resistance (in a score from 0 to 10) for the sleeve materials are provided as can be seen in table 3. Additional functionalities such as processing possibilities differ between the sleeves.

Table 3: Functionality of sleeves from different materials

Sleeve	Stiffness	Transparency	Stretchability	Water resistance
LDPE virgin	7,5	9	10	10
40% rLDPE	7,5	7	10	10
BOPP virgin	10	10	0	10
40% rCPP	7,5	7	1	10
Kraft paper virgin	9	-	0	0
100% rPaper	9	-	0	0

Use of tray sleeves

Tray sleeves are sleeves that are connected to a tray containing multiple potted plants, rather than to individual plants. Tray sleeves are not included in this analysis. However, the use of these sleeves is assumed to enable the decrease the sleeve material by up to 50 percent. If indeed the material weight is halved by the use of tray sleeves, the environmental impacts of these sleeves could be assumed to be approximately half of the individual sleeves made from the same material. When choosing a sleeve with a lower environmental impact, it is helpful to assess if it is possible to use a tray sleeve instead of individual sleeves without compromising on functionality.

APPENDICES

APPENDIX A: DATA AND ASSUMPTIONS

Table 4 provides an overview of the SimaPro materials and processes used for the analysis.

Table 4: Ecoinvent data used in the study.

	Description	EcoInvent process
Material	BOPP / CPP	Polypropylene, granulate {RoW}| production | Cut-off, S
	rCPP	Polyethylene, high density, granulate, recycled {RoW}| polyethylene production, high density, granulate, recycled | Cut-off, S
	LDPE	Polyethylene, low density, granulate {RoW}| production | Cut-off, S
	rLDPE	Polyethylene, high density, granulate, recycled {RoW}| polyethylene production, high density, granulate, recycled | Cut-off, S
	Kraft paper	Kraft paper, unbleached {RoW}| production | Cut-off, S
	rpaper	Graphic paper, 100% recycled {RoW}| production | Cut-off, S
Production method	Plastic film extrusion	Extrusion, plastic film {RoW}| extrusion, plastic film | Cut-off, S
	Printing	Printing ink, rotogravure, without solvent, in 55% toluene solution state {RoW}| market for printing ink, rotogravure, without solvent, in 55% toluene solution state | Cut-off, S
Transport	Transport outside Europe by truck	Transport, freight, lorry, unspecified {RoW}| market for transport, freight, lorry, unspecified | Cut-off, S
	Transport from China to the Netherlands by ship	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, S
	Transport within the Netherlands by truck	Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S
End-of-Life	Waste incineration	Municipal solid waste (waste scenario) {DE}| treatment of municipal solid waste, incineration | Cut-off, S
	Recycling PP	Polyethylene, high density, granulate, recycled {Europe without Switzerland}| polyethylene production, high density, granulate, recycled | Cut-off, S
	Recycling LDPE	Polyethylene, high density, granulate, recycled {Europe without Switzerland}| polyethylene production, high density, granulate, recycled | Cut-off, S
	Recycling Paper	Graphic paper, 100% recycled {RER}| production | Cut-off, S

Circular Footprint Formula Parameters

Table 5 provides an overview of the parameters used for the Circular Footprint Formula Parameters.

Table 5: Circular Footprint Formula Parameters

Parameter	Value	Comment	Explanation parameter
A paper	0,2		A = Allocation factor of burdens and benefits (jointly: "credits") between supplier and user of recycled materials
A plastic	0,5		
Qp	1		Qp = Quality of the primary material, i.e. quality of the virgin material
Qsin LDPE film	0,75		Qsin = Quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution
Qsin paper	0,85		
Qsin PP	0,75	Use of Qsin LDPE film	
Qsout LDPE film	0,75		Qsout = Quality of the outgoing secondary material, i.e. the quality of the recycled material at the point of substitution.
Qsout paper	0,85		
Qsout PP	0,75	Use of Qsout LDPE film	
R1 recyclate paper	1		R1 = Proportion of material in the input to the production that has been recycled from a previous system.
R1 recyclate plastic	0,4		
R1 virgin paper	0		
R1 virgin plastic	0		
R2 scenario 0% recycling	0		R2 = Proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.
R2 scenario 100% recycling	1		
R3	0		R3 = Proportion of the material in the product that is used for energy recovery within the production facility

APPENDIX B: INTRODUCTION TO THE LCA QUICK-SCAN METHODOLOGY

LCA quick-scan

An LCA quick-scan (also called streamlined or screening LCA) is our approach to life cycle assessment. This approach seeks to identify the most important factors that determine the environmental impact of a product in a limited time frame.

Time is saved through limiting the scope of a full LCA. In this context, the scope refers to the system to be studied, the resolution of the data collected, and the range of environmental impacts to be addressed. Life cycle stages may be omitted if determined insignificant, generic data may be used more readily instead of system-specific data, and the study can be tailored to focus on impacts that are deemed more relevant to the audience or the product system that is being assessed. With limited effort, we gain a relatively accurate representation of the environmental impacts of the product's life cycle. Deviation from the actual impact is approximated to be around 10%.

An LCA quick-scan is intended for strategic decision making and optimisation of the studied subject through the identification of impact hotspots, exploration of the environmental impacts of different options or scenarios, and the comparison with alternative products, services or technologies that fulfil the same function.

An LCA quick-scan follows the procedures of ISO 14040 and 14044. However, it is not fully ISO certified. A fully ISO certified study requires a peer review by three external parties and extensive reporting on data gathering and the calculation method. With a full ISO certified LCA, external (marketing) claims may be made on the environmental performance versus competitors and may be used for sales purposes. Given that this is not such a fully ISO certified study, caution is advised when making marketing claims for specific products. However, the results can be used to inform partners about the differences in environmental impact between various flower and plant sleeves with a non-commercial aim. Therefore, the results may be published on the Royal FloraHolland website.

LCA quick-scan method

In accordance with the standard ISO 14040, the life cycle assessment consists of four interrelated phases as are described in figure 13:

- Goal and scope definition: the product-service system, the system's boundaries and functional unit are identified in consultation with Royal FloraHolland and producers
- Inventory analysis: identification of input and output data of the processes in the system (i.e., production, use and disposal phases)
- Impact assessment: the potential environmental impacts are assessed on the basis of the inventory analysis
- Interpretation: interpretation of the results and drawing of conclusions

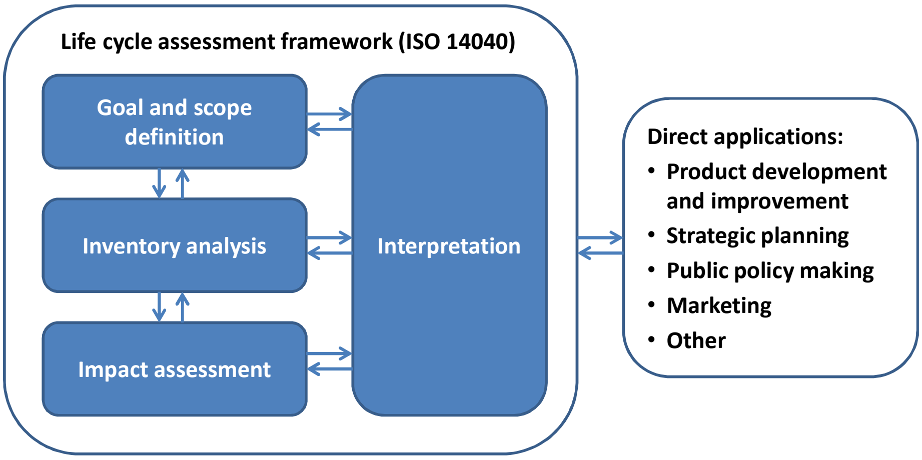

Figure 13: LCA framework (ISO 14040) and direct applications

APPENDIX C: INTRODUCTION TO THE RECIPE METHODOLOGY

This report uses the ReCiPe 2016 method. This impact assessment method is commonly used throughout industry and in research.

An impact assessment method is required to translate the identified emissions and resource extractions into a comprehensible set of indicators. This can be done at two different levels: at midpoint and endpoint level. "Midpoint indicators focus on single environmental problems, for example climate change or acidification. Endpoint indicators show the environmental impact on three higher aggregation levels, being the 1) effect on human health, 2) biodiversity and 3) resource scarcity" (RIVM, 2011). In other words, midpoints are intermediate observable environmental effect. Endpoints are the eventual type of effect that results from the midpoints. Figure 14 illustrates the connection between midpoints and endpoints in the ReCiPe method.

Each midpoint and endpoint has their own unit. Midpoint impacts are expressed in a single reference emission that causes the effect. For instance, all emissions that impact global warming are expressed in kg CO_2 equivalent. An emission such as 1kg CH_4 has the same global warming potential as 25 kg CO_2, and can thus be expressed as 25 kg CO_2 eq.

Endpoint units focus on expressing the caused damage. The damage to human health is expressed in Disability Adjusted Life Years (DALY). DALY indicates the number of premature deaths through illness and the number of years that people will live with the effects of an illness due to the environmental effects. The influence on biodiversity is measured in the number of species that disappears per year as result of the environmental effects. The consumption of resources is expressed in the extra costs that have to be made in the future to mine the mineral and fossil resources that are consumed.

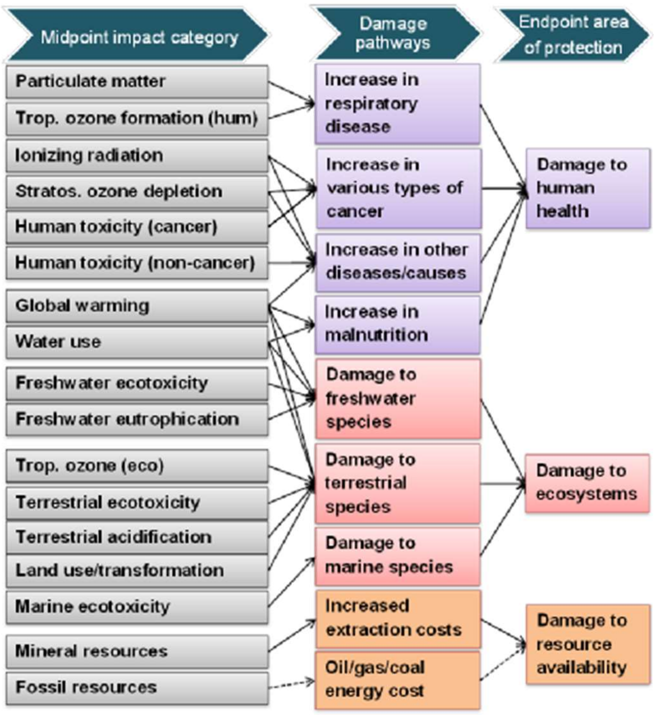

Figure 14: Visualization of the ReCiPe model, (RIVM, 2011, LCIA: het ReCiPe model.)

APPENDIX D: CIRCULAR FOOTPRINT FORMULA

Benefits and burdens arise from the use of recyclate at production and recycling at End-of-Life. In other words, recycling and the use of recyclate often result in a lower overall environmental impact. The question of who receives credit for recycling and the use of recyclate has always been a point of discussion within LCA. One could argue that the user of recycled material receives all credits (100-0 approach) whilst the recycler receives none. On the other hand, one could also argue for giving full credits for recycling the material (0-100 approach). Both allocation methods are technically correct, but incentivize either recycling or the use of recyclate, depending on the method used.

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^* \times \frac{Q_{Sout}}{Q_P}\right) +$$

VIRGin
LCI needed for virgin material acquisition and pre-processing

RECin
LCI needed for the recycled material input

RECout
LCI needed for recycling (or re-using). This includes the credits for the avoided virgin material input (due to recycling)

$$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec}) + (1-R_2-R_3) \times E_D$$

ERout
LCI for energy recovery process, including credits for avoided energy generation (due to this energy recovery)

DISPout
LCI for the disposal of non-recycled and non-recovered materials

Figure 15: Circular Footprint Formula calculation

In order to fairly allocate benefits and burdens over different lifecycles in LCA, the joint research committee of the European Commission formulated the ‘Circular Footprint Formula’ (CFF) as part of PEF LCA methodology. The CFF “allocates burdens and credits from recycling and virgin material production between two life cycles (i.e. the one supplying and the one using recycled material) and it aims to reflect market realities'' (JRC, 2019). In short, part of the impact of the virgin material production and the recycling process are allocated to recycled content. Part of the impact of the recycling process and virgin materials that are avoided are allocated to the recycling process at End-of-Life. In this allocation, exact percentages of recycling and quality factors are taken into account.

APPENDIX E: RESULT TABLES

In this appendix the results of the calculations are presented in tables.

Table 6 presents the global warming impact results in kilograms of CO_2 equivalent emissions. The rows separate the different scenarios. The columns represent the different life cycle stages.

Table 6: Summary results for Global warming impact

Global warming impact in kg CO_2 eq.									
Material	Recycled content	EoL scenario	Raw Material	Production - Processing	Production - Transport	EoL - Incineration	EoL - Recycling	EoL - Avoided product	Total
LDPE	virgin	EU average	0,014	0,004	0,001	0,013	0,000	-0,001	0,032
LDPE	virgin	Sorted	0,014	0,004	0,001	0,002	0,002	-0,004	0,019
LDPE	40% r content	EU average	0,012	0,004	0,001	0,013	0,000	-0,001	0,030
LDPE	40% r content	Sorted	0,012	0,004	0,001	0,002	0,002	-0,004	0,017
PP	virgin	EU average	0,013	0,003	0,001	0,014	0,000	0,000	0,031
PP	virgin	Sorted	0,013	0,003	0,001	0,001	0,002	-0,004	0,017
PP	40% r content	EU average	0,011	0,004	0,001	0,014	0,000	0,000	0,029
PP	40% r content	Sorted	0,011	0,004	0,001	0,001	0,002	-0,003	0,015
Paper	virgin	EU average	0,009	0,000	0,002	0,000	0,003	-0,003	0,012
Paper	virgin	Sorted	0,009	0,000	0,002	0,000	0,004	-0,004	0,012
Paper	100% r content	EU average	0,008	0,000	0,001	0,000	0,003	-0,003	0,010
Paper	100% r content	Sorted	0,008	0,000	0,001	0,000	0,004	-0,003	0,010

Table 7 presents the single score results in midpoint. The rows represent the midpoint indicators. The columns represent the different sleeves and the End-of-Life scenarios.

Table 7: Summary results for Single Score indicator

Single Score indicator in midpoint												
Material	LDPE				PP				Paper			
% recycled content	0		40		0		40		0		40	
EoL recycling (%)	23	90	23	90	0	90	0	90	71	90	71	90
Total	1,0592	0,8064	0,9923	0,7436	0,9795	0,7059	0,9261	0,6531	0,7140	0,6961	0,5778	0,5620
Global warming, Human health	0,4980	0,2974	0,4622	0,2648	0,4885	0,2657	0,4581	0,2354	0,1817	0,1832	0,1556	0,1570
Global warming, Terrestrial ecosystems	0,0498	0,0298	0,0462	0,0265	0,0489	0,0266	0,0458	0,0236	0,0182	0,0183	0,0156	0,0157
Global warming, Freshwater ecosystems	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Stratospheric ozone depletion	0,0001	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0001	0,0001	0,0001	0,0001
Ionizing radiation	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
Ozone formation, Human health	0,0010	0,0009	0,0010	0,0009	0,0009	0,0008	0,0009	0,0008	0,0010	0,0010	0,0008	0,0008
Fine particulate matter formation	0,3604	0,3443	0,3417	0,3258	0,3055	0,2900	0,2929	0,2780	0,3465	0,3418	0,2819	0,2777
Ozone formation, Terrestrial ecosystems	0,0050	0,0046	0,0047	0,0043	0,0044	0,0040	0,0041	0,0038	0,0049	0,0048	0,0039	0,0038
Terrestrial acidification	0,0091	0,0085	0,0085	0,0079	0,0084	0,0077	0,0078	0,0072	0,0089	0,0089	0,0072	0,0072
Freshwater eutrophication	0,0018	0,0017	0,0017	0,0016	0,0015	0,0015	0,0013	0,0014	0,0016	0,0016	0,0014	0,0013
Marine eutrophication	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Terrestrial ecotoxicity	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002	0,0003	0,0002	0,0002	0,0002
Freshwater ecotoxicity	0,0004	0,0003	0,0004	0,0003	0,0003	0,0002	0,0003	0,0002	0,0002	0,0002	0,0001	0,0001
Marine ecotoxicity	0,0001	0,0001	0,0001	0,0001	0,0001	0,0000	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000
Human carcinogenic toxicity	0,0363	0,0336	0,0343	0,0317	0,0320	0,0304	0,0304	0,0288	0,0239	0,0227	0,0201	0,0191
Human non-carcinogenic toxicity	0,0572	0,0541	0,0578	0,0548	0,0493	0,0489	0,0506	0,0499	0,0585	0,0545	0,0482	0,0447
Land use	0,0027	0,0028	0,0028	0,0029	0,0024	0,0026	0,0025	0,0027	0,0516	0,0436	0,0316	0,0246
Mineral resource scarcity	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001
Fossil resource scarcity	0,0265	0,0207	0,0213	0,0156	0,0282	0,0203	0,0226	0,0150	0,0064	0,0065	0,0053	0,0053
Water consumption, Human health	0,0087	0,0060	0,0077	0,0050	0,0074	0,0054	0,0067	0,0048	0,0083	0,0069	0,0045	0,0034
Water consumption, Terrestrial ecosystem	0,0018	0,0013	0,0016	0,0011	0,0015	0,0012	0,0014	0,0010	0,0018	0,0015	0,0010	0,0008
Water consumption, Aquatic ecosystems	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Land use	0,0027	0,0028	0,0028	0,0029	0,0024	0,0026	0,0025	0,0027	0,0516	0,0436	0,0316	0,0246