Multi-value comparison for (raw) materials and innovations in the growing media sector

A Multi-Criteria Decision Analysis comparing alternatives to contribute towards the use of more sustainable materials in the growing media sector considering all the business constraints, applied to a selection of materials from growing media company Kekkilä-BVB

TU Delft Delft University of Technology

Kekkilä BVB

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A Multi-Criteria Decision Analysis comparing alternatives to contribute towards the use of more sustainable materials in the growing media sector considering all the business constraints, applied to a selection of materials from growing media company Kekkilä-BVB

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Preface

Hereby I present the result of my graduate research in fulfilment of the Master program Engineering & Policy Analysis at Delft University of Technology. When I started the first steps of this research, the COVID-19 pandemic overwhelmed the Netherlands. The lockdown made it no longer possible to meet the supervisors in person. As a result, the Kick-Off of the project took place online in May 2020. Working from home was quite challenging, not seeing fellow students, colleagues and supervisors made it difficult to discuss the research from time to time. Despite these limitations, I have worked with great pleasure and dedication on my research and would like to thank all my colleagues at Kekkilä-BVB and my supervisors for their guidance, feedback and support during this research. As always, I said to myself, "Everything is going to be all right!".

And everything turned out well, because I am proud to present my master thesis here. I would like to thank a number of people for this. Firstly, I would like to thank Pieter Bots for supervising the research. I was very pleased to see that during the research you shared the enthusiasm with me, which motivated me even more to get the most out of the research. Your critical view and structured working method have helped to carry out this research in a thorough scientific manner. Secondly, I would like to thank Jaco Quist. Participating in the thesis circle "Circular Economy" allowed me to gain more knowledge about this relatively small but very interesting part of my research and also to talk to fellow graduates from whom I could draw inspiration and discuss difficulties with. Furthermore, the open-mindedness you had towards this research and your knowledge of innovation systems were very useful during the thesis.

I would also like to thank all colleagues within Kekkilä-BVB for sharing information, providing detailed feedback and going through the study from time to time. Especially, I would like to thank Marck Hagen for his role as external supervisor during the graduation. Where you always made sure that I ended up with the right people with my questions, you were always there to talk through the research. But first of all, you always asked me if I still enjoyed the research. Although sometimes it was a challenging research, I really enjoyed working on it. Finally, I would like to thank my family and friends for their continuous support, advice and distraction when needed.

Investigating raw materials for substrates remains a complex matter due to their natural properties and changes in society. The issues facing the growing media sector are challenging, but not impossible. I hope that this thesis helps to clarify the many good and bad properties of incoming materials and how they relate to each other, so that the growing media sector can focus on the right aspects to contribute towards a sustainable society.

When submitting my thesis, my time as a student has come to an end. Thanks to the Bachelors and Masters programmes, I have grown as a person and a human being and I am grateful for all the opportunities that have been offered to me during this period. Now it is time to apply the obtained knowledge in practice, and I hope that in the future I will be able to contribute to improving our world towards a sustainable society.

Enjoy reading!

Martijn van Vliet
Maasland, December 2020

Executive summary

The world population is expected to grow to 8.5 billion by 2030 and to 9.7 billion by 2050, while the current population is 7.7 billion. The increase in the global population and the shift towards a healthier diet is leading to several global challenges such as the growing demand for safe and healthy food and therefore also for growing media. A study by Wageningen University & Research shows that a 400% growth is expected for growing media globally between 2017 and 2050. Currently, peat is the most common raw material (76%) and it is complex to find similar raw materials. The sector is looking for sustainable alternative raw materials, but at the same time the global population needs to be provided of food. The aim of this research is to contribute to the use of more sustainable materials in the European growing media sector, considering all the business constraints. The following research question has been formulated for this goal:

What developments and analytical tools can contribute to decision-making in the growing media sector in its transition to a sustainable sector?

To answer the research question, a system analysis was carried out. Hereafter, the current materials and innovations and the long-term developments in the sector are described. The current raw materials and innovations have been compared with each other by means of a MCDA for the current and future situation on business, social and environmental level. An expert panel was asked to indicate their preferences for the selection criteria in order to determine the impact of the criteria.

The results of the system analysis show that the following developments are important in the transition to a sustainable growing media sector. A (1) circular economy provides opportunities for the introduction of residual flows and local materials. Next, trends such as (2) data-driven and (3) microbial horticulture contribute to better control and utilization of the raw materials, which offers opportunities for alternative materials. (4) Increasing legislation may put peat use at risk, which on the one hand leads to fewer greenhouse gas emissions, but on the other hand food security may be compromised. In the MCDA, four groups of alternatives have been defined on the results of all respondents and the different actors. The most preferred alternatives are white peat, perlite and woodfibre, followed by Accretio, mineral wool, foam and black peat. The third group includes bark, followed by (standardized) compost and the coir materials. The scenarios show that in the future the results will be very robust. However, the importance of peat will decrease and materials such as wood fibre, perlite and inorganic materials will score better.

The system analysis shows developments in the European area, but due to the geographical conditions of the market and Kekkilä-BVB these developments are focused on Northern and Central Europe. In addition, the respondents determine the results of the study, a different composition may lead to different results. The MCDA is not comprehensive, since only measurable criteria can be taken into account. A different MCDA method may also result in differences in the outcomes. Despite the above discussion points, interesting conclusions emerge from the research.

The growing demand for growing media does not require a choice between the different alternatives, but requires to focus on the low scores of the MCDA and the utilisation of current and future developments in order to make all raw materials attractive for use in the substrate sector. In addition, the sector will have to cooperate with all those involved in order to operate more sustainably. This will minimise the importance of peat and ensure that the sector can continue to provide the global food demand in a sustainable manner.

Samenvatting

Naar verwachting zal de wereldpopulatie in 2030 zijn gegroeid tot 8,5 miljard mensen en naar 9,7 miljard mensen in 2050, dit terwijl de huidige populatie 7,7 miljard mensen bedraagt. De toename van de wereldbevolking en het streven naar een gezonder dieet leidt tot verschillende wereldwijde uitdagingen zoals de groeiende vraag naar voedsel en daardoor ook naar substraten. Een studie van Wageningen University & Research laat zien dat er tussen 2017 en 2050 een 400% groei wordt verwacht voor substraten wereldwijd. Momenteel is veen de meest voorkomende grondstof (76%) en is het complex om voor veen gelijkwaardige grondstoffen te vinden. De sector is opzoek naar duurzame alternatieve grondstoffen, echter dient tegelijkertijd te worden voorzien in de voedselvoorziening van de wereld. Het doel van dit onderzoek is om bij te dragen aan het gebruik van duurzamere grondstoffen in de Europese substraat sector, rekening houdend met alle zakelijke aspecten. De volgende onderzoeksvraag is hiervoor geformuleerd:

Welke ontwikkelingen en analytische hulpmiddelen kunnen bijdragen aan de besluitvorming in de substraatsector in haar transitie naar een duurzame sector?

Om de onderzoeksvraag te beantwoorden is in dit onderzoek een systeem analyse uitgevoerd om te kijken naar de ontwikkelingen in de sector. Hierna zijn de huidige materialen en innovaties en de lange termijn ontwikkelingen in de sector beschreven. De huidige materialen en innovaties zijn door middel van een MCDA voor de huidige en toekomstige situatie met elkaar vergeleken op zakelijk, sociaal en milieu gebied. Een expert panel is daarbij gevraagd om hun preferenties voor de selectie criteria op te geven om de impact van de criteria te kunnen bepalen.

Uit de resultaten van de systeem analyse blijkt dat de volgende ontwikkelingen belangrijk zijn in de transitie naar een duurzame substraatsector. Een (1) circulaire economie geeft mogelijkheden voor het introduceren van reststromen en lokale materialen. Vervolgens dragen trends als (2) data-driven en (3) microbische tuinbouw bij aan het beter controleren en benutten van de grondstoffen, wat kansen biedt voor alternatieve materialen. Door (4) toenemende wetgeving kan het veengebruik in geding komen wat aan de ene kant leidt tot minder uitstoot van broeikasgassen, maar aan de andere kan de voedselveiligheid in het gedrang komen. In de MCDA zijn vier groepen van alternatieven gedefinieerd over de resultaten van alle respondenten en de verschillende actoren. De meeste geprefereerde alternatieven zijn witveen, perliet en houtvezel, gevolgd door Accretio, steenwol, schuim en zwartveen. In de derde groep zit bark, gevolgd door (gestandaardiseerde) compost en de kokos materialen. De scenario's laten zien dat naar de toekomst toe de resultaten zeer robuust zijn. Wel zal het belang van veen afnemen en zullen materialen als houtvezel, perliet en anorganische materialen beter scoren.

De systeemanalyse geeft ontwikkelingen op Europees gebied, echter door de geografische bepalingen van de markt en Kekkilä-BVB zijn deze ontwikkelingen gericht op Noord en Centraal Europa. Hiernaast bepalen de respondenten de uitkomsten van het onderzoek, een andere samenstellingen kan leiden tot andere uitkomsten. De MCDA is niet alles omvattend, alleen meetbare criteria kunnen worden meegenomen. Ook een andere MCDA methode kan leiden tot verschillen in de uitkomsten. Ondanks bovenstaande discussie punten komen er interessante conclusies uit het onderzoek naar voren.

Zo vraagt de groeiende vraag naar substraten niet om een keuze tussen de alternatieve grondstoffen, maar vraagt om te focussen op de lage scores van de MCDA en het benutten van de huidige en toekomstige ontwikkelingen om zo alle grondstoffen aantrekkelijk te maken voor gebruik in de substraatsector. Daarnaast zal de sector samenwerkingen aan moeten gaan met alle betrokkenen om duurzamer te kunnen opereren. Hierdoor kan het belang van veen worden geminimaliseerd en kan de sector op een duurzame manier blijven voorzien in de wereldwijde voedselbehoefte.

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List of abbreviations

AHP	Analytical Hierarchy Process
CAP	Common Agriculture Policy
CE	Circular Economy
EC	Electrical Conductivity
EC	European Commission
GHG	Greenhouse Gasses
GME	Growing Media Europe
IPS	International Peat Society
LCA	Life Cycle Assessment
MCDA	Multi-Criteria Decision Analysis
MLP	Multi-Level Perspective
OEF	Organisation Environmental Footprint
PDF	Potentially Disappeared Fraction
PEF	Product Environmental Footprint
PESTEL	Political, Economical, Social, Technological, Environmental and Legal
pH	Potentia hydrogenill
R&D	Research & Development
RHP	Regulering Handels Potgronden
RPP	Responsibly Produced Peat
S&OP	Sales & Operations Planning
SDG	Sustainable Development Goal
SMART	Simple Multi-Attribute Rating Technique
UN	United Nations
VPN	Vereniging Potgrond en Substraatfabrikanten Nederland
WOK	Water Uptake Characteristic

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1 – Introduction

1.1 Research background

The world population is expected to reach 8.5 billion people in 2030 and 9.7 billion in 2050, while the current population is around 7.7 billion people (United Nations, 2019). This rising population leads to several challenges such as a rising demand for food. The United Nations incorporated this challenge as Sustainable Development Goal (SDG) 2: Zero hunger (United Nations, 2015). This goal not only acknowledges the rising global demand, but also tackles the current undernourishment and trends. The products at the basis of food production make a crucial contribution to the goal of ensuring global food security.

> "In Europe peat is used in ± 90% of all substrates."
>
> - Kern et al. (2017)

One of the bases for food production in horticulture are substrates. A substrate can be seen as a product where food and flowers can be grown on. Substrates are often referred to as 'Growing media' or 'Potting soil'. At the moment peat is the main constituent for substrates and originates out of bogs (Growing Media Europe, 2016). In Europe peat is used in around 90% of all substrates (Kern, et al., 2017). Peat is seen as a fossil resource because it takes more than 1000 years for a peat field to recover, so the volume to be used decreases as more is harvested than is recovered. In addition to the fossil character, harvesting peat also releases stored greenhouse gases (GHG) (IUCN, 2017). After the oceans, peat represents the largest single carbon store. Here, 3% of the land area holds 30% of the carbon storage (Taft, Cross, Hastings, Yeluripati, & Jones, 2019). Not only harvesting contributes to GHG emissions, but damaged peat fields also contribute an average of 10% to GHG emissions in the land use sector (IUCN, 2017).

As a result of GHG emissions, peat is seen as unsustainable and governments in several European countries have implemented policies on the use of peat, such as Germany and Ireland (The Guardian, 2018). Some countries are investing in the preservation and expansion of bogs since they have the capability to store CO_2. At the same time, the growing global population and the shift from cultivation out of the ground to substrates is causing an enormous increase in the demand for substrates. A research from Wageningen University & Research (Blok, 2020) predicts that between 2017 and 2050 global demand will rise with more than 400%. This challenge requests for innovations within the market of substrates to (1) use less resources within substrates and (2) limit the use of peat within substrates by introduction of more (raw) materials in the sector. Due to these innovations the estimated growth of 400% will probably not result in a 400% growth in volume.

> "The global demand for substrates is estimated to grow with more than **400%** between 2017 - 2050."
>
> - Blok e.a. (2020). Acta horticulturae, in press

Within the market of growing media all stakeholders are involved in the search for a more sustainable substrate. The use of peat as growing media is estimated at 2000 km^2, which represents only 0.05% of the worldwide peatlands (Kern, et al., 2017). The share in used peatlands seems small, but represents a market with 11,000 jobs across Europe and a €1.3 billion turnover. Furthermore this market is essential to the horticultural sector representing 750,000 jobs with a €60 billion turnover (Growing Media Europe, 2016).

1.2 Research relevance

Peat has been considered a non-sustainable raw material for a considerable time, which is why new raw materials have been introduced into the substrates market in recent years, such as coir and wood products (Barrett, Alexander, Robinson, & Bragg, 2016). It is generally assumed that these products are more durable than peat products, mainly because they are (partly) made from residual materials. However, the demand for these materials has grown to such an extent that land is planted for them instead of being sold as residual material. When considering the entire life cycle of raw materials, different methods lead to different results on the sustainability of alternative raw materials for peat (Litterick, Bell, Sellars, & Carfrae, 2019).

"Comparing different raw materials is very complex"

- Barret, et al. (2016) & Litterick, et al. (2019)

According to Barrett, Alexander, Robinson, & Bragg (2016), significant progress has been made in the last decade to the understanding of the environmental effects of growing media, but there still are many knowledge gaps. These are mainly due to the fact that natural raw materials are always different and that the conditions under which the raw material is obtained are very important for the comparison of raw materials. In several scientific articles (Barrett, et al., 2016; Litterick, et al, 2019) there is concluded that comparing different raw materials among each other is complex, because of the many different characteristics and origins of the raw material. This research contributes towards the comparison of raw materials within the growing media sector by introducing a comparison tool for incoming (raw) materials and describing the driving factors and trends that influence the transition towards a more sustainable growing media sector.

1.3 Research scope

This research focusses on the different incoming (raw) material and upcoming innovations in the growing media sector on European level with international influences, due to the fact that various raw materials come from outside Europe. Commissioner and problem owner is Growing Media Europe (GME) which represents the producers of growing media within Europe. This research is initiated by Kekkilä-BVB, member of GME and a global leader in the production of growing media. With (production) locations in Finland, Sweden, Estonia, Germany, Spain and the Netherlands Kekkilä-BVB deliverers their substrates worldwide to 100+ countries. The company's position in the market makes it possible to perceive the European prospects and to carry out the research effectively.

1.4 Research objective and research questions

The scientific relevance shows that it is currently difficult to compare different incoming materials for substrates. On the other hand, the social relevance shows that the sector needs to become more sustainable. Therefore, the goal of this research is to contribute towards the use of more sustainable (raw) materials in the Growing Media sector considering all the business constraints. Kekkilä-BVB, as a growing media company, wants to make the right decisions in the transition towards a sustainable growing media sector. Based on these needs, the following main research question has been formulated:

What developments and analytical tools can contribute to decision-making in the growing media sector in its transition to a sustainable sector?

First, to come to a recommendation for the sector and Kekkilä-BVB, it is necessary to understand how the sector works and how it relates to the system. By means of a market description (Chapter 2) and system analysis (Chapter 4), insight has been provided into the growing media sector and the developments that foresee in the transition to a sustainable sector have been identified. This answers the following research sub-question:

1. *What are the main developments, in the field of market trends and innovations, to make the growing media sector more sustainable?*

Subsequently, the focus of the research was placed on the incoming materials for substrates, because the social and scientific relevance shows that it is difficult to determine which of the incoming raw materials contributes the most to sustainability. For this purpose, it is important to know which different alternatives are currently on the market or are expected to be available in the short term, and which long-term alternatives (chapter 5) are expected. To this end, the following research sub-question has been formulated:

2. *What are the alternatives for peat substrates in the short and long term and what are the advantages and disadvantages for market expansion?*

Once the developments from the system analysis and the alternatives have been described, it is then important to look at how these different alternatives can be compared with each other, including sustainability, in order to be able to give advice to the sector. In this study it was decided to carry out a Multi-Criteria Decision Analysis (MCDA) (chapter 6), which is further explained in the methodology (chapter 3). First, the criteria that apply to raw materials and the importance of these criteria needs to be determined. This results in the following research sub-question:

3. *What are the criteria for growing media selection and where are the priorities between these criteria for the sector and different actors?*

The next step in the MCDA is to score the various alternatives on the basis of these criteria and the prioritisation. As soon as the criteria and priorities are clear, an order of the alternatives can be presented with the required data. In this way, it can be seen what the ranking order of the alternatives is and whether they differ between the different actors. To this end, the following research sub-question has been formulated:

4. *With this prioritisation, how do the alternatives score and can differences be seen between the actors?*

The decision the sector wants to make in order to act more sustainably needs to be effective in the short term as well as being robust for the future. Scenario analysis (chapter 7) will be used to carry out various future projections. The sensitivity of the outcomes of these scenarios shows how robust a choice for a particular material is or is not. To this end, the following research sub-question has been formulated:

5. *What kind of scenarios infer from the driving forces and how robust are the outcomes under these scenarios?*

The results of the scenario analysis will be followed by the discussion, conclusion and recommendations. In paragraph 1.5 the structure will be outlined briefly.

1.5 Report structure

This research is structured as follows: Chapter 2 provides a general market analysis of the European growing media sector. Followed by the methodology in chapter 3. Chapter 4 contains the system analysis, after which the short and long term alternatives for the raw materials in the growing media sector will be discussed in chapter 5. The short term alternatives will then be included in chapter 6 in the Multi-Criteria Decision Analysis. Various scenarios will be elaborated in chapter 7. Chapters 8 and 9 deal with the discussion, conclusion and recommendations.


VOLVO
TOYOTA

2 – Growing Media sector description

2.1 Market description

In the growing media sector, the product consists of a mixture of different raw materials and additives that are supplied to customers in different market segments. Within the sector there are companies that serve all segments and companies that focus specifically on one of the segments. The competitiveness of the sector depends on the areas in which the companies are active. The various segments within the growing media sector, which will be discussed in more detail in section 2.3, are:

- Professional Horticulture
- Retail & Consumer
- Landscaping

Companies within the growing media sector differ from each other in the focus and expertise in the different fields of this sector. This expertise on certain domains results in the exchange of raw materials between competitors. Among the companies this means that besides competitors the companies are also suppliers / customers from each other. This relationship between competitors is also shaped by the structure of the market where several companies have insourced the supply of peat-based materials, where others are dependent of these peat-based material suppliers. In the sector, the trend is observed that companies want to insource the production of incoming raw materials. In this way, the quantity and quality of the raw material can be better controlled and there is greater certainty that a high-quality product can be delivered to customers. Quality assurance and control is of great importance in the sector, because the raw materials must not contain any harmful properties and customers are looking to receive a consistent product, despite the composition of the substrate changing from time to time.

"In the growing media sector companies are not only each other's competitors, but also their customers."

A substrate rarely consist of only one material, mainly substrates consist of a blend from different raw materials and additives that would results in the best possible mixture for the customer. Even for the cultivation of the same plants different mixtures are used among customers, since the mixture is dependent on the cultivation method. Important factors in the cultivation strategies are the water management, the heat / moisture regulations and the use of pesticides. The water management strategy is determined by the times a day water is given, what quantity is it given with and the method used. Different methods are water giving from the bottom, water giving via the top-side of the crop or via a dripping device. Heat / moisture regulations influences the growth rate of the crop. Pesticides are used to overcome diseases within the crops. These are becoming more biological / sustainable, which also has an effect on the substrate.

Within Europe growing media companies are located near harvesting locations, ports and horticultural hubs. This depends on the company's strategy and destination of the produced substrate. The production locations near a harvesting location are more cost beneficial for the products that have to be exported to international locations. At port locations can be seen that the incoming bulk products are mainly transported to inland production facilities. Because these port locations mainly function as hubs cooperation's between different growing media companies can be seen there. Examples are the cooperation's between BOL PEAT B.V. and Kekkilä-BVB in the port of Schiedam and a cooperation between three companies in the port of Amsterdam. The inland production facilities are located near consumer hubs, so raw materials can be transported in bulk towards these locations. Examples can be found in 'Het Westland', the largest horticultural hub of the world (World Horti Center, 2020) and the mushroom hub in the southern part of the Netherlands and Germany.

The shipments of large quantities results in a more efficient way of transportation and the ability to produce large batches of substrate mixtures leading to less transportation and production costs. Next to cooperation's in port areas, there can also be seen cooperation's within the sector on Research and Development (R&D) projects and project initiated from GME. For R&D projects growing media companies are working together with research institutes, universities and other companies that align with the project. Initiated project from GME acquire an active participations of all members and include projects in the standardisation of LCA throughout the sector and the representing the values and opinions of the sector within the European Union.

2.2 Incoming (raw) materials

In this section, the raw materials used to compose the substrates will be discussed on the basis of the categories defined by Schmilewski (2017). At first the peat based products are discussed followed by the organic constituents; bark, coir and woodfibre, excluding composts which is the third category. Mineral materials are the fourth category, which consist of products as perlite, clay, sand & grid materials and mineral wool. The fifth category explains the additives that are added to the substrates to get good characteristics. Within these categories the products are explained with their origin, annual volume, transportation method and the trends that can be seen in the market regarding this product.

2.2.1 Peat

Peat products are the main constituent within substrates and represent 76% of all incoming products in Europe (Schmilewski, 2017). Within the growing media sector peat is used as soil improvement and ingredient. The material is extremely useful for horticultural and gardening purposes, because of its water and air content and physical characteristics (IPS, 2020). When harvesting peat, stored CO_2 is emitted in the air resulting in the pollution of GHG emissions. Peat has the ability to store CO_2, but when a peat bog has been damaged it is polluting CO_2 as well. For those peatbogs harvesting and restoration can help in lowering the GHG emissions on the long term (RPP, 2017).

Within the market the harvested peat consist of two layers; **white peat** and **black peat**. White peat is the top layer of the bog field, where black peat is the layer of peat below the white peat. Between the white and black peat a mixture can be found which is called brown peat. White peat is loose material and therefore has a high air capacity, where black peat is more compressed which results in a higher water capacity. The average depth to which is harvested is assumed to be around 1.5 meter for each layer (Blok, 2020), but in practice the harvested depth could go up to 10 meters in total.

Figure 1: White Peat

Figure 2: Black Peat

Historically peat was used as energy source in many countries around Europe. Nowadays energy is produced from peat in Finland, Sweden and Ireland (IPS, 2020). Over the last years the energy production from peat declined significantly. In 2018 peat was used in 4% of the total energy consumption of Finland and Ireland is phasing out peat in power generation in 2028. In this countries the companies VAPO (Finland) and Bord na Móna (Ireland) both make the transition to more sustainable energy production and the use of peat for growing media purposes instead of energy.

The origin of peat harvesting for growing media in Europe could be found in Germany, but due to governmental restrictions on peat harvesting the origin shifted towards the Baltic states and Scandinavian countries. From Germany peat is still supplied to growing media companies, but in smaller quantities. This peat is transported by road or via inland waterway barges. Peat coming from the Baltic states and Scandinavian countries is transported to the nearest sea port and then shipped as bulk or container shipment to the port of destination. This process is visualised in figure 3. The estimated volume of peat use within Europe in 2013 was 25,990,000 m^3 (Schmilewski, 2017). From internal data at Kekkilä-BVB (Kekkilä-BVB, 2020)[1] is shown that around 55% of the volume is white peat, 18% brown peat, 27% black peat.

Figure 3: Supply chain of peat

In order to guarantee the long-term use of peat in the growing media sector, the fields must be harvested in a responsible way. Within the sector, the quality mark responsibly produced peat (RPP) ensures that peat fields with a certificate are responsibly harvested and that after use the field is returned to its original state (RPP, 2017). The certificate ensures that the owner of the bog field complies to all national and international laws and agreements. The owner must also actively participate with all stakeholders. For example, local and national government should be consulted and an Environmental Impact Assessment should be carried out, including a rehabilitation plan for the bog field. Priority is given to fields that have been drained or degraded because they also emit GHG when not in use. The rehabilitation after harvesting of damaged peatlands results in less GHG emissions then when peatlands remain in their original conditions. Having an RPP certification for bog fields is becoming an increasingly important theme within the sector in order to act in a sustainable manner.

2.2.2 Organic constituents

Organic constituents are the organic materials other than peat that are used within substrates. Three main product groups can be identified as organic constituents; Bark, Coir and Woodfibre.

Bark is the protective outer layer of a tree its trunk, branches and twigs and finds it origin in Spain and Portugal (Growing Media Europe, 2016). The bark is transported per container to the production locations where it is used within orchid substrates as main constituent and as mulching materials within other substrates. Substrates containing bark have a high air content ratio. Bark is available in different sizes between 2 and 20 mm. Within Europe the estimated volume of 2013 was around 915.000 m^3 (Schmilewski, 2017).

Figure 4: Bark (8-12 mm)

[1] Source originates from Dynamics 365 Business Central (not publicly accessible) from Kekkilä-BVB.

Coir products are a result from the husk of the coconut. The main origin of coir products lies in India and Sri Lanka. Smaller quantities are produced in Vietnam, Nepal and the Dominican Republic. Together these countries represent approximately around 80-90% of the coir industry with a global volume of 11,000,000 m^3 (Blok, 2020). In Europe there was used around 1,300,000 m^3 in 2013 (Schmilewski, 2017). Three different products are produced out of a coconut husk:

Coir Pith

Figure 5: Coir pith

Coir Fibre

Figure 6: Coir fibre

Coir Chips

Figure 7: Coir chips

Coir Pith and Fibre are seen as waste materials from the production of other Cocos related materials. Coir products have good properties for substrates, with a high air and water holding capacity. Difficulties lie within the quality and uniformness of the product. Also does every company have their own production process, which make it difficult to get a uniform product when multiple suppliers are used. For transportation of Coir products the material is mainly compressed in 5kg blocks and then shipped to the growing media production locations by container. At the growing media companies the blocks are decompressed to 10-13 times their volume. After decompressing the treatment process starts, where after the material has to meet the quality demands to be used in substrates. These treatment processes differs between the growing media companies. Examples include the addition of water for rinsing the material and the addition of (biological) additives. The different treatment processes result in different quality ranges for coir products throughout the sector.

Figure 8: Woodfibre

As third organic constituent **Woodfibre** is described. The fibres come from un-treated wood and / or wood waste (Growing Media Europe, 2016), because wood fibres are partly considered as rest material the fibres have a sustainable character. However woodfibre is mainly produced through the use of planted trees within Europe. At this moment Germany, Poland and Belgium are the main woodfibre producers in Europe. Trees have also been planted in the Netherlands to meet the need for woodfibre. Within Europe the demand has been rising over the past years and the estimated European volume in 2013 was 1,396,000 m^3 (Schmilewski, 2017). Woodfibres treated as rest materials are demanded in other sectors and do not guarantee the quality demands, therefore un-treated wood is used as woodfibre in the growing media sector. There is expected that due to demand increases in other sectors the share of wood fibres in the growing media sector stays limited (Barrett, Alexander, Robinson, & Bragg, 2016).

2.2.3 Compost

Compost is seen as a residual material made from pruning wood, such as branches, roots and sand that comes with the pruning of trees (Growing Media Europe, 2016). This is combined into one big pile where the composting starts, after several weeks the product is ready to be used in a substrate. Within the Netherlands RHP-rules for the shares of branches, roots and sand are in place to ensure the quality of the compost. Also European companies are members of RHP, so most compost for substrate production has to comply with these rules. Because of the strict regulations regarding the use of compost, it is often referred to as standardised compost.

Compost has a local origin since it is very heavy material and local resources can be used to create composts. It is however not possible to create a substrate that only consist of compost, because of the characteristics. Therefore compost is seen as a good partial replacement within peat based substrates. Within Europe the estimated volume of compost in 2013 was 2,748,000 m3 . As can be seen in figure 17 not a high growth can be expected in composts, because the local quantities from the pruning wood are not expected to rise.

2.2.4. Mineral materials

The mineral materials as discussed by Schmilewski (2017) are Perlite, Clay, Sand, Lava, Pumice and Mineral Wool. **Perlite** is made from volcanic rock which can be found around many places in the world. Within Europe the volcanic rock originates mainly from the Greek island Milos. From there the material is shipped towards production facilities around Europe. At these facilities the volcanic material is crushed, sieved and heated in an oven. When heated the volcanic rock pops open, like popcorn, and becomes perlite. Within the growing media sector perlite is available in three sizes; 0-6 mm, 0-3 mm and 2-6 mm and is used as an additive in substrates. The material is added because it gives the mixture more air and water content. In Europe the volume used in 2013 was estimated at 414,300 m^3 (Schmilewski, 2017).

Figure 9: Perlite

For **clay** the estimated volume in 2013 was 420,600 m^3 (Schmilewski, 2017). Clay is used in various forms in the market; fresh, dried granules and as dry powder. At this moment the powder clay is the main used clay element in substrates and originates from northern European countries such as Germany, Denmark and Sweden (Bos, Keijzer, Schie, Verhagen, & Zevenhoven, 2003). The most important characteristic from clay is the reduction in easily available water content. This can be compared to the effects of ice cubes when melting, because they 'release' the water bit by bit. Clay is able to store water and release it to its environment over time.

Figure 10: Clay granules

Figure 11: Clay powder

Figure 12: Sand

The mineral materials Sand, Lava and Pumice represent a small volume (662,100 m^3 (Schmilewski, 2017)) within Europe and can be grouped as sand and grid materials. **Sand** has a heavy weight and is therefore gathered locally. When sand is added to a substrate mixture it results in a good drainage within the potting soil and stable pot. Only river sand can be used, because it doesn't contain salt as in sea sand. Lava and pumice are both volcanic products.

Figure 13: Lava

Lava is broken and sieved magma and mainly used in civil engineering. As growing media product it is mainly used because it gives some more air content when used as a layer and the material is not chemically and biologically degradable (Bos, Keijzer, Schie, Verhagen, & Zevenhoven, 2003). Due to the sharp edges it is not preferred in most potting soils when much manual labour is required, also it can damage the machinery.

Figure 14: Pumice stone

Pumice stone is het volcanic materials that is released in the air at an volcanic eruption which than solidifies. It can be found at many places around the world, but for the European growing media sector it mainly originates from the Eiffel district in Germany and areas in Iceland. In contradiction with lava, pumice stone has a high air and water content ability.

The last mineral material is not an additive to substrate mixtures, but is a pure substrate. The **mineral wool** is made out of basaltic rock and can be used as substrate for vegetables and potted plants. The material is used as isolation material within the building sector. The production of growing media is not the core businesses of these companies. The volume used in the growing media sector in 2013 was 530,000 m^3 (Schmilewski, 2017). Grodan ,a supplier of mineral wool substrates, claims that in Europe they have received at least around 90% circulation, by using the substrates in the production of bricks (Grodan, 2017).

Figure 15: Mineral wool

2.2.5 Additives

In the mixture of raw materials, small amounts of additives are often added to give the substrate the right characteristics. These additives can be divided into **fertilisers**, **lime** and **organic additives**. Fertilizers are used for the nutrition of plants and are available in many different forms. Measurements from the laboratory give input for the amount of fertilizers used in substrates. Lime is added to steer the pH-value of the mixture. When using lime, the pH value can only be increased. This is why lime is mainly used for peat-based substrates because peat has a low pH value. Biological additives help to strengthen and improve the rooting of plants. Also, they can help to protect the plants against fungi. Although the additives are a fixed component of substrates, they are not included in the study because they serve as a control for the mixture.

2.3 Outgoing products

The incoming products are processed within the production facilities. The produced substrates are used within different market segments. These segments are professional horticulture, retail & consumer and landscaping. Within the European market around 500 companies are producing growing media, of which most are small and medium-sized companies. Around 70 – 80 European companies are considered medium to large-sized companies within this sector. Per market segment the product range, market size and trends are discussed.

2.3.1 Professional horticulture

The professional horticulture sector for growing media can be divided into five different categories; Ornamental Plants, Vegetables, Soft Fruits, Forest / Tree nursery and Young plants. The biggest horticultural hub in the world is 'Het Westland', located in the Netherlands. The estimated European market share for professional horticulture in the growing media sector is estimated at 55% In Europe (Kekkilä-BVB, 2020)[2]. around 60 – 70 medium to large-sized companies produce growing media for the professional horticulture.

Ornamental Plants
Products: Cut flowers and pot plants, such as orchids and pot roses
Raw materials: Full range
Customer base: Internationally, mainly Europe

Vegetables
Products: Mushrooms, tomatoes, paprika, cucumbers, etc.
Raw materials: Full range
Customer base: Internationally

Soft Fruits
Products: Strawberries, blueberries and raspberries
Raw materials: Full range, excluding sand & grid materials
Customer base: Europe, Africa & South America

Forest / Tree nursery
Products: Perenials, Shrubs & fruit trees, Conifers, Christmas Trees, etc.
Raw materials: Full range, excluding mineral wool
Customer base: Europe

Young plants
Products: Plugs, Press pots, Super seedlings
Raw materials: Full range, excluding sand & grid materials
Customer base: Europe

[2] Source originates from Sharepoint (not publicly accessible) from VAPO Group.

2.3.2 Retail and consumer

The retail market consist of the production of consumer soils. These soils are sold in bags between 20 and 70 litres. Consumers can purchase these products at garden centres and supermarkets. The growing media companies sell the products in palletised batches to these locations. In the retail market there is a wide product range. The most common products are potting soil, garden soil and ornamental barks, but also more specific products as patio plants potting soil or vegetable garden soil are sold to customers. More often, Cocos soil is used within the retail and consumer market as a replacement for the peat-based soils. The estimated European market share for retail & consumer in the growing media sector is estimated at 37% (Kekkilä-BVB, 2020)[3]. Around 30 – 40 medium to large-sized companies are involved in this European segment.

2.3.3 Landscaping

The landscaping segment focusses on the soils needed for green roofs, golf courts and city parcs. Therefore landscaping departments of growing media companies are cooperating with local governments, civilians and other suppliers of the designed landscape. The focus of the landscape project is concentrating on a circular design. In practice landscaping can be done everywhere throughout Europe. The market share is estimated at 8% (Kekkilä-BVB, 2020)[3], but is expected to increase since cities have to become more climate resilient. Within this market segment around 10 – 30 medium to large-sized growing media companies are involved.

2.4 System overview

In figure 16 a bow tie for the growing media sector can be seen, representing the incoming raw materials and outgoing volume per market segment. For the incoming raw material European market data from 2013 is used (Schmilewski, 2017). Last years an upcoming trend can be seen for Coir and Woodfibre, so the actual share is expected to be larger. GME started a project in cooperation with Rabobank to estimate the European volumes of the past year, the data of this project is expected in 2021. The outgoing volume is determined by the market segment shares from Kekkilä-BVB (2020)[3]. Kekkilä-BVB is one of the leading growing media companies in Europe and therefore representative for the growing media sector.

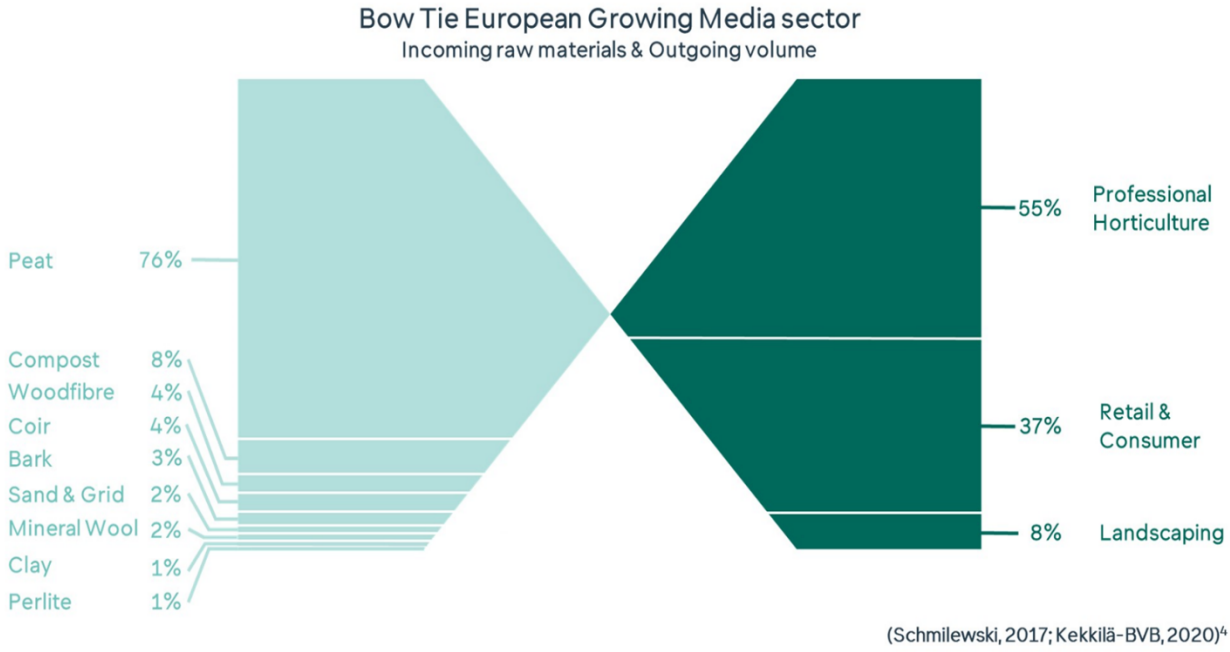

Figure 16: Bow Tie European Growing Media sector

[3] Source originates from Sharepoint (not publicly accessible) from VAPO Group.

The long term market estimation shows an global increase in demand for growing media of 400% (Blok, 2020). The research of Wageningen University & Research shows that within Europe there is expected a rise in volume of 200% in 2050 compared to the market volume of 2017 (Blok, 2020). Other continents are expected to have a higher percental increase in volume, since the market for growing media is at this moment relatively small in these areas. Volume wise only Asia and North America have a higher estimation of volume growth than Europe. In figure 17 the global demand for substrates is shown compared between 2017 and 2050. For the estimations of the demand for 2050 there is assumed that the population and income growth is equal to the forecasts of the United Nations. Per income class there is also an assumed growth in the demand for vegetables and ornamentals. The global trend for Coir, Woodfibre and Bark can be seen in the figure, compared to the European data from 2013. For new product innovations there is a huge market potential. New products are needed to provide plants and food to the global population.

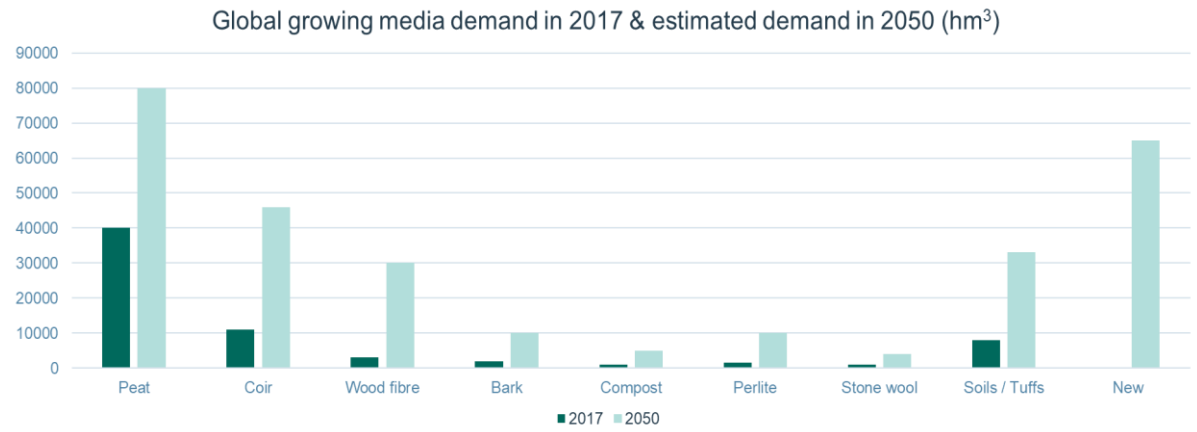

Figure 17: Global demand for Growing Media in 2017 & 2050 (Blok, 2020)

3 – Methodology

Chapter 2 gave an overview of the European growing media sector. For the incoming (raw) materials can be seen that the main material is Peat with a share of 76%. The main constituents for peat consist of the organic constituents and compost, which have a small share in current substrates and therefore are market niches. As shown in section 1.2 there is a scientific and societal relevance to be able to compare these constituents and new innovations among each other, to foresee in the use of more sustainable (raw) materials in the Growing Media sector considering all the business constraints. This research will first look at which trends are relevant to the sustainability of the sector, after which it will look at the comparison of incoming materials in order to select more sustainable materials. The trends within the sector will be determined in a system analysis, which will be elaborated in section 3.1. The materials that can be seen as alternatives for peat are described along the terms for eco-innovations in section 3.2. For the comparison of materials a multi-criteria decision analysis (MCDA) will be applied, which will be described in section 3.3.

3.1 System Analysis

At present, peat and coir products in particular are generally accepted throughout the sector. Of course, several materials are used, only these can be seen as niche markets. To analyse this system, with all (new) products, the multi-level perspective of van Geels (2018) is very suitable. The system for innovations consist of three levels; the socio-technical landscape, socio-technical regime and niche-innovations. In figure 18 can be seen that changes in the landscape can create 'windows of opportunity' in the regime (Geels, Sovacool, Schwanen, & Sorrell, 2017), where innovations can be implemented in the market. This three-level innovation system approach shows which developments per level are contributing towards a more sustainable growing media sector.

Within each level of the multi-level perspective, the key factors will be described using the PESTEL framework. This framework consist of six factors: Political, Economic, Social, Technical, Environmental and Legal (Aquilar, 1967). With the PESTEL categories the market structure is explored and mapped with its driving factors and developments (Song, Sun, & Jin, 2017). Since the transportation of products plays an important role in the supply chain of growing media a logistical factor is added to the PESTEL categories.

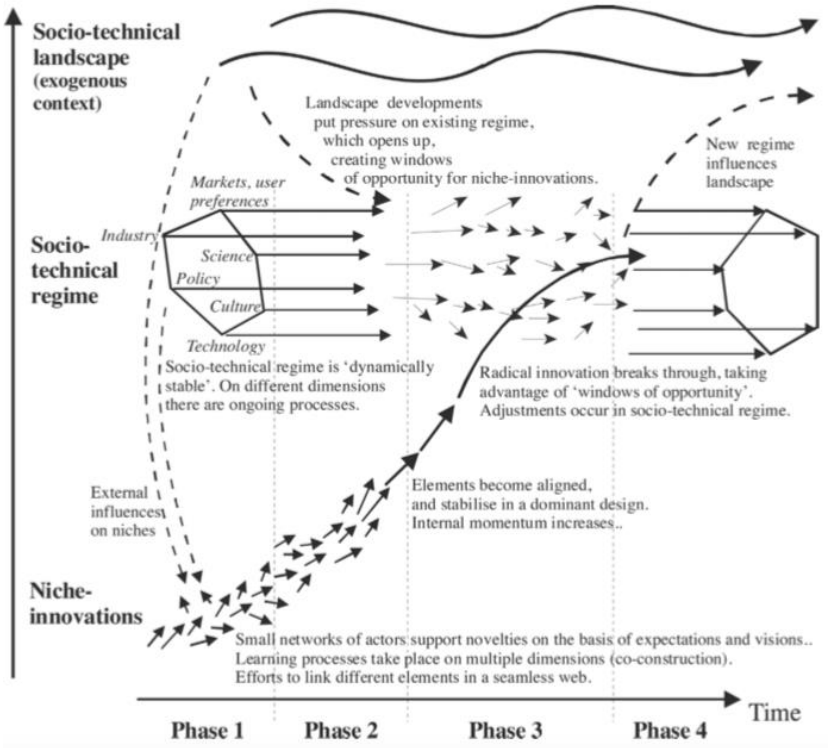

Figure 18: Multi-level perspective (Geels, 2018)

In addition to the multi-level perspective, the system analysis in this study consists of a stakeholder analysis. The different stakeholders and their role within the (innovation) system will be discussed, this information will be compiled in a technological map. In a technological map the formal and informal relationships between the stakeholders will be presented, from which the connections within the system will be clarified.

3.2 Alternatives

In chapter 2.2 the current incoming (raw) materials have been discussed. In order to compare raw materials, a distinction has been made between short-term and long-term alternatives for peat products. Short-term alternatives include peat products and all raw materials for which data is available for the defined criteria. These alternatives are included in the MCDA and consist partly of the raw materials described previously and partly of products recently introduced on the market. The long-term alternatives consist of the expected new materials and developments in the sector. Should there be sufficient data available in the future, the products that are currently named for long-term alternatives can be added to the MCDA.

The short and long term alternatives can be seen as eco-innovations within the growing media sector. In the framework of Carillo-Hermosilla, Rio & Könnöla (2010) incremental or radical change in the sustainability of the system can be seen for the alternatives. In the middle of figure 19 three groups can be seen. Component addition can result in better sustainable results, but will not change the main process. An example within growing media companies is the partial replacement of peat in substrates by coir products and compost. By the replacement of peat the problem is partly resolved, but the overall process is still the same. Sub-system change is the second group and focusses on innovations that lead to the creation of more substrates with less resources. This optimization of the processes can be characterised by the term eco-efficiency (Schmidheiny, 1992). The third group System Change contains the innovations that cause a radical difference in the system. In the growing media sector an innovation with these characteristics is the rock wool substrate for Orchids, that would fully replace the currently used substrate. This innovation would foresee in a complete change of the production process for the growing media companies and growers. Within appendix I a more detailed description of the eco-innovations can be found.

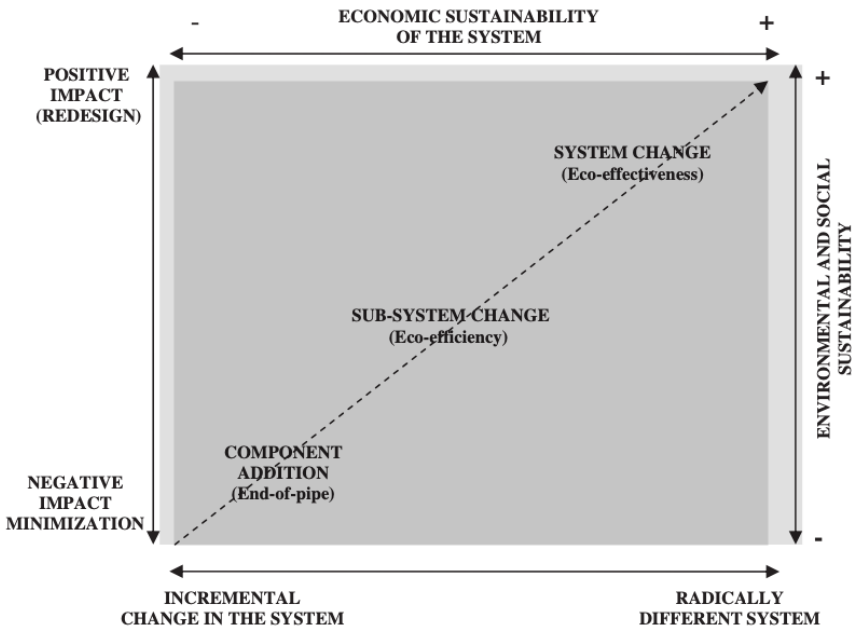

Figure 19: Eco-innovations framework (Carillo-Hermosilla, Rio, & Könnöla, 2010)

The short and long term alternatives will be discussed on the basis of one of the eco-innovation groups. The pros and cons of each alternative will be presented. This concerns certain product characteristics, expected pros and cons in terms of future prospects and market barriers that need to be overcome when implementing and/or scaling up the alternative. Short-term alternatives will be included in the MCDA, where the long-term alternatives will influence the elaboration of the scenarios.

3.3 Multi-Criteria Decision Analysis

From the eco-innovation framework (Carillo-Hermosilla, Rio, & Könnöla, 2010), it can be deduced that sustainability takes place along the lines of economic, social and environmental sustainability. Within the growing media sector, the current comparison of materials is mainly economic, although social and environmental sustainability is increasingly considered. In addition, extensive (laboratory) analyses are being carried out to compare the raw materials over the technological criteria. At the moment, the comparison takes place on economic and technological grounds, two of the six elements of PESTEL.

Next to these aspects there is a need to compare growing media on the social and environmental sustainability level (Barrett, Alexander, Robinson, & Bragg, 2016; Litterick, Bell, Sellars, & Carfrae, 2019). The comparison of these sustainability levels and the technical feasibility is very useful with a Multi-Criteria Decision Analysis (MCDA) (Dias & Domingues, 2014; Motuziene, Rogoza, Lapinskiene, & Vilutiene, 2016; Myllyviita, Leskinen, & Seppälä, 2014). MCDA can be used to rank different alternatives, group acceptable possibilities or identify preferred options (Belton & Stewart, 2002). Within Zanghelini, Cherubini and Soares (2018) there are shown several opportunities to include sustainability and technical values into an MCDA., which is developed by Saaty (1980).

In complex systems where many criteria apply, the criteria are often presented in a hierarchical way to create structure (Zanghelini, Cherubini, & Soares, 2018). The Analytical Hierarchy Process (AHP) is an example of this, only preferences are given on a nine-point scale (Zanghelini, Cherubini, & Soares, 2018). In this study, it was decided to determine the preferences over the criteria by means of a single pairwise comparisons. The hierarchical structure of the criteria using a target tree as developed by Keeney (1988) makes a significant contribution to this. The Simple Multi-Attribute Rating Technique (SMART) as developed by Edwards (1977) is the used MCDA method. Within SMART, each criterion is given a weight that indicates its relative importance. Also, the trade-offs can be made between economic, social, environmental and technical aspects, while using different data inputs and formats. The MCDA can be divided into 5 steps: Hierarchy, Preferences, Effects table, Impact table and Scenarios. The steps can be seen in figure 20 and will be highlighted in more detail in the following sections.

Figure 20: Flow diagram MCDA method

Throughout this research the system elements are described using the PESTEL categories added with a Logistical factor. The elements are interdependent on each other and therefore the decision was made to divide the categories. For the categories Economical, Social, Technological and Environmental (ESTE) measurable criteria are defined which are incorporated in the MCDA. The political, legal and logistical factors partly determine the criteria for the ESTE categories. These factors will be used to define the scenarios, which will be discussed later in this chapter.

In order to determine the hierarchy for the ESTE categories, a goal tree is established. A goal tree starts with the main goal at the top, after which the sub-criteria / sub-goals and criteria follow in the levels below (Keeney, 1988). An example of this is shown in Figure 21. The hierarchy will be determined by developments or factors from the system analysis, desktop research and the available knowledge within Kekkilä-BVB.

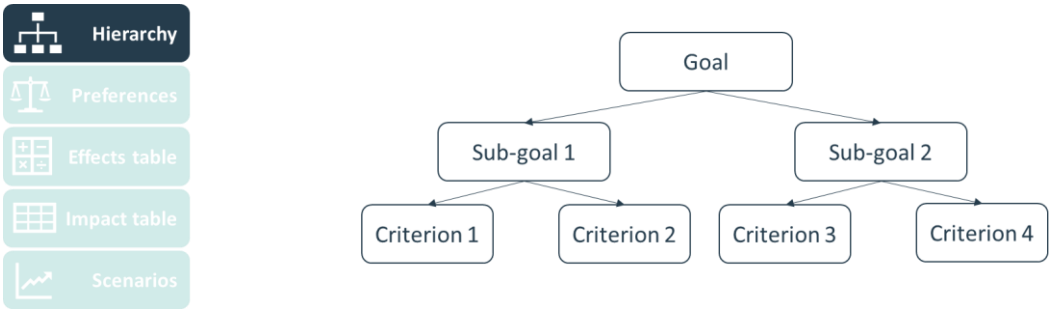

Figure 21: Example goal tree

The next step consist of the determination of the preferences between the selection criteria. A survey among an expert panel will provide insights in the preferences. The expert panel has been composed according to interest and availability. The large interest for the research in the sector allowed the survey to be distributed to many different actors in the sector, such as European growing media companies, research institutes, quality marks and associations and customers. Since the research is carried out at Kekkilä-BVB, many respondents are associated with the company. Through this availability, the differences in preference between the departments and different stakeholders can be made clearly visible. In figure 22 an example of the preferences between the sub-goals and criteria is shown.

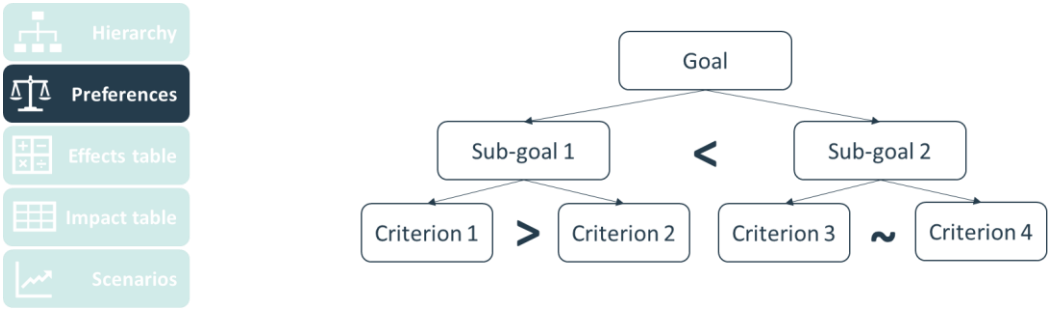

Figure 22: Example goal tree with preferences

In order to determine the relative weighting of the criteria, the preferences must be converted into weights. This can be done in two ways. 1) For the preferences per respondent a group preference is determined and based on this the weights are determined or 2) per respondent the weights are calculated and these are then aggregated. In the second way, the respondent must have given a consistent ranking, otherwise the weights cannot be assigned. In the first way, however, it is possible to include inconsistent answers, because a group preference is determined for each pair of equations.

The determination of the group preferences is done with a majority rule, but if there is no consistent order over the level, the Condorcet method (Condorcet, 1785) has been considered, a further elaboration of this is given in chapter 6.2. It was not possible to arrive at a group preference by means of the Borda count because respondents regularly rated the criteria as equal. The allocation of weights for the selection criteria is carried out using three different methods, which are discussed in Chapter 6.2:

- Normalised
- Rang reciproke
- Rietveld & Ouwersloot (1992)

Once the alternatives and criteria have been determined, the data for the alternatives on the criteria should be entered in an effects table, an example of which is shown in figure 23. The data comes from public sources, such as scientific articles and specialist literature, but also from available internal data such as lab analyses and cost prices. Furthermore, the data has been validated by various departments within Kekkilä-BVB that relate to certain criteria. The data in the effects table will be normalised so that the different types of data can be compared with each other.

Criteria		Alternatives			
		Alternative 1	Alternative 2	Alternative 3	Alternative 4
Sub-goal 1	Criterion 1	0.45	0.05	1.00	0.00
	Criterion 2	0.25	1.00	0.00	0.75
Sub-goal 2	Criterion 3	0.73	0.00	0.06	1.00
	Criterion 4	1.00	0.08	0.12	0.00

Figure 23: Example effects table

Now that there is a standardised effects table, the relative weightings for the criteria can be added to it. The values in the impact table are determined by the relative weighting of the criterion multiplied by the data of the alternative. The sum of these scores per alternative gives the weighted sum score on which the final ranking is based. The higher the weighted sum score, the better the alternative scores on the selection of criteria. This is visualised in figure 24 .

Criteria		Impact factor	Alternatives			
			Alternative 1	Alternative 2	Alternative 3	Alternative 4
Sub-goal 1	Criterion 1	0.24	0.11	0.01	0.24	0.00
	Criterion 2	0.13	0.03	0.13	0.00	0.10
Sub-goal 2	Criterion 3	0.23	0.17	0.00	0.01	0.23
	Criterion 4	0.40	0.40	0.03	0.05	0.00
Weighted sum score			0.71	0.17	0.30	0.33
Ranking			1	4	3	2

Figure 24: Example of impact table

The impact table now reflects the values obtained from the current situation. In order to make policy that is resilient to the future, concerning the choices between certain raw materials for growing media, different scenarios need to be outlined in order to be able to determine different future effects. These scenarios are based on the exogenous trends and market expectations. These exogenous trends are defined within the Political, Legal and Logistical categories. In the survey the respondents are asked to elaborate on their future expectations for the (European) growing media sector in terms of the PLL categories. By combining the responses with desk research, the scenarios will be drawn up.

Criteria		Impact factor	Alternatives			
			Alternative 1	Alternative 2	Alternative 3	Alternative 4
Sub-goal 1	Criterion 1	0.24	0.18	0.00	0.24	0.10
	Criterion 2	0.13	0.03	0.13	0.00	0.09
Sub-goal 2	Criterion 3	0.23	0.17	0.00	0.01	0.23
	Criterion 4	0.40	0.40	0.20	0.00	0.00
Weighted sum score			0.78	0.33	0.25	0.52
Ranking			1	3	4	2

Figure 25: Example for the operationalisation of scenarios

Thereafter, the developments described in the scenarios have to be operationalized to the MCDA model. Different values can be adjusted for several alternatives because the described developments give cause for change, this can be seen in the table of figure 25. The explored scenarios are used to look at the sensitivity of the criteria and if shifts in alternatives take place. The event of a scenario is completely uncertain among the sector.

The outcomes can differ over the scenarios and therefore it could be useful in decision making to see if there is an preferred alternative over all scenarios. With completely uncertain scenarios there are four decision criteria that determine a preferred alternative (Bots & Heijnen, 2020):

- The Maximin Criterium from Wald (1950): Chooses the alternative that has the best worst value over all scenarios
- Lest-regret Criterium from Savage (1950): Chooses the alternative where the difference in scores is the lowest between the scenario and most favourable alternative.
- Optimism-Pessimism Criterium from Hurwicz (1951): Uses a risk parameter to determine a score for all the alternatives. The choses alternative has the highest score.
- Indifference Criterium from Laplace (1825): Chooses the alternative where the sum over all scenarios is the highest. This criterium assumes every scenario is as likely to happen.

On the bases of the outcomes in the current situation and scenarios decision making takes place. The robustness of the outcomes in the model determines the influence the model has in decision making. When the outcomes over the different scenarios do not shift extremely, the outcomes are more trustworthy for decisionmakers. The MCDA will be a tool in decision making since the product specific criteria are not included and for every end-product different aspects are of importance. The tool allows decisionmakers to make well-considered choices between the various alternatives to growing media in which the various trade-offs are transparent. As a result, more sustainable materials can be used without major consequences for the social and business constraints.

3.4 Methodology framework

In figure 26 the methodology framework is shown. After a general system analyses the PESTELL categories are explored with a Multi-level perspective and the short- and long-term alternatives are described. Within the MCDA the ESTE categories are converted into business, social and environmental criteria with an objective tree. The PLL categories together with the long-term alternatives are the input for the scenarios. Next is the operationalisation of the scenarios into the MCDA model. The outcomes of the MCDA model will help in decision making for the selection of (raw) materials in the Growing Media sector.

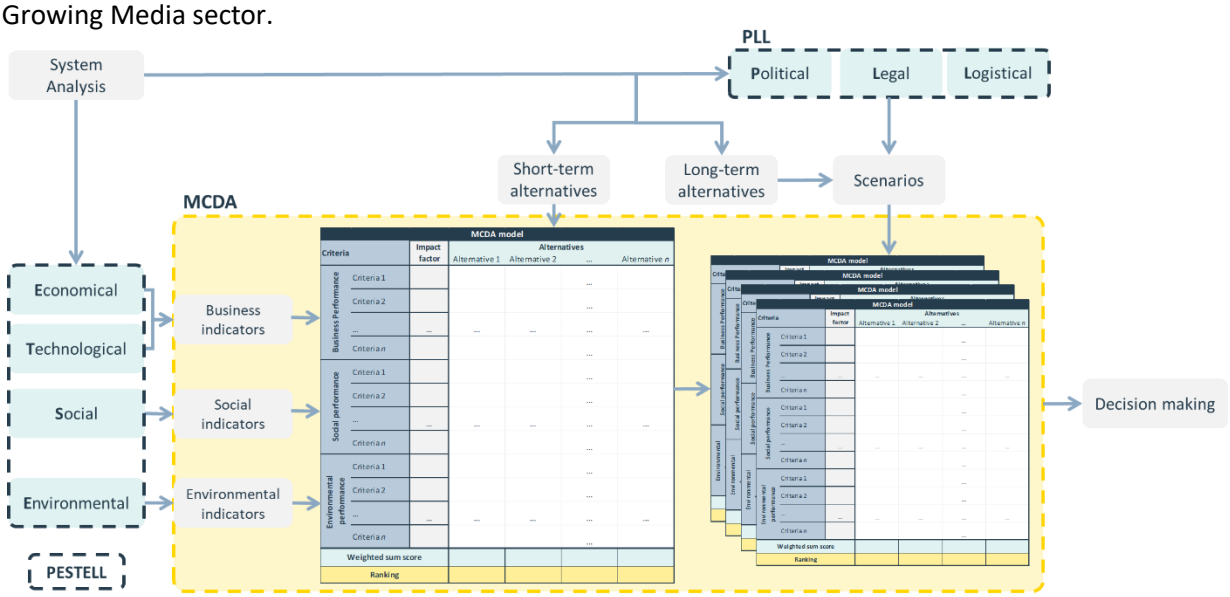

Figure 26: Methodological framework


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4 – System analysis

4.1 Multi-level perspective

4.1.1 Landscape factors

The landscape factors influencing the growing media regime are discussed following the categories of the PESTEL framework. A political factor that influences every category is the Farm to Fork strategy as presented by the European Commission (EC), which is part of the European Green Deal (European Commission, 2020). The farm to fork strategy aims to become the global standard for sustainable food production (FAO, 2020) and is an incentive for the food chain to become a fair, healthy and environmental-friendly food system. Within the food chain several key elements of the Farm to Fork strategy are identified and can be seen in figure 27.

Figure 27: Farm to Fork strategy (European Commission, 2020)

The EC's formulated strategy is the basis for national governments to form policies for the food industry. At this moment the Common Agriculture Policy (CAP) is in place to guide national governments. In 2023 the EC will present a legislative framework for sustainable food systems (European Commission, 2020). The economical factor that is also included in the Farm to Fork strategy is to become a circular economy. Within the food chain there are many potentials to become a circular economy. Great things can be achieved if the food chain becomes circular and works towards closed loop supply chains. In appendix I, a detailed description of what a closed loop supply chain entails can be found.

All social landscape factors relate to people's wellbeing. Within the food chain and growing media the wellbeing of people and environments has a high priority. Produced food must at all times be safe for human and animal health and then there needs to be sufficient food for the population. Formulated by the UN as SDG 2: Zero hunger (United Nations, 2015). Another social factor is included in the Farm to Fork strategy as the shift towards healthy and sustainable diets, resulting in healthier citizens. Unhealthy diets in the EU have resulted in the loss of healthy life years for 16 million citizens and over 950,000 deaths in 2017 (European Commission, 2020).

To meet the goals of the Farm to Fork strategy technological factors mainly focus on the improvement of the current system or the replacement by new innovations. In the food chain new technologies create possibilities for more efficient, result-bases and sustainable food production. Investments in R&D and European collaborations can create the possibilities for innovations to be scaled up and implemented in the food chains. Within every category of the PESTEL framework environmental factors are of importance, since it is all related to becoming a more sustainable society. The Sustainable Development Goals (United Nations, 2015) are the global environmental factors influencing decisions made on landscape, regime and niche level. The importance of sustainability is prioritized throughout the landscape, which resulted in environmental consideration such as an circular economy, but also in the implementation of legislation to protect the environment.

With the Green Deal the European Commission presented legislations for environmental friendly food production. Standards for Environmental footprints are the Product Environmental Footprint (PEF) (European Commission, 2012) and the Organisation Environmental Footprint (OEF) (European Commission, 2012), that show standards to determine Environmental Footprints from product or organisational perspective. National governments also have their own legislations or restrictions in place, Germany and Ireland have for example boundaries and guidelines on peat harvesting (Carrol, 2018). Germany even requires that within the retail sector at least 30% of the materials should be non-peat based. The production of growing media have to conform to several ISO standards. ISO standards apply globally and an example that applies to the growing media sector is ISO 14067, which gives requirements and guidelines for the quantification of greenhouse gases (ISO, 2018).

Landscape factors in the logistical category are linked to a more efficient and sustainable transportation of products throughout Europe. To reduce traffic jams and kilometres made on land, there is an incentive to shift transportation towards a multi-modal transport system (European Commission, 2020). While using multiple modes of transport can result in a positive contribution to traffic flows and the environmental footprints, economically it is not viable to transport products on short distances via waterways, because this requires the handling of products on the modes of transport. Next to the aim to shift towards a multi-modal transport system, environmental considerations are an important logistical factor. These considerations include the reduction of pollutions by the transport sector and the implementation of sustainable solutions to reach the goals as set by the United Nations (2015). These two factors are complemented by the digitalisation of the transport and logistics sector. Digitalisation can result in more efficient and sustainable logistics.

Landscape factors

Political	Farm to Fork strategy
Economical	Circular Economy (CE)
Social	Peoples wellbeing & Sustainable and healthy diets
Technological	Data gathering & R&D investments create opportunities
Environmental	SDG's / Green Deal / Farm to Fork
Legal	PEF / OEF & ISO standards, national boundaries
Logistical	Multi-modal transport & Sustainable logistics

4.1.2 Regime factors

Regime factors are the factors that play within the growing media sector and are bounded by the regime. The landscape factors set the environment in which the sector is operating. On political level within the regime European and national branch organisations, such as GME and 'Vereniging Potgrond – en Substraatfabrikanten Nederland' (VPN), represent the sector at the political landscape level. These organisation translate the formulated political goals, as the Farm to Fork strategy, to specific actions and requirements for the growing media companies. The socio technical regime is bounden by the growing media sector and its components to professional horticulture, retail & consumer and landscaping.

The economic factors in the regime focus on being economically viable and to have sustainable companies delivering the best possible product. Becoming more circular plays an important role within the different divisions of the sector. In the horticulture market there is looked at every product how the left-over material can be used afterwards. The re-use of substrates is complex in this market because of the high quality demands for growing media. The rest material can be used as compost, but at this moment it is not possible to get the same material characteristics as before.

For the retail market circularity is partly achieved by the use of waste streams for the production of retail products and the composting of used materials. Within the landscaping market circularity is most of the times a requirement from the customers. The needed substrates for the development of landscaping do not require a high quality product. Excavated materials from building sites are stored and mixed at a production located, from where it is used as substrate for landscaping purposes.

Social factors in the growing media sector are the wellbeing of employees and surrounding communities of companies. The excavation of materials results in pollution. In the case of peat stored CO_2 comes free during harvesting or when peatlands are damaged. It is important that after harvesting the natural environment is restored and protected to their original function. Next to the social factors at harvesting locations, the factors also apply at the production facilities. When producing growing media several requirements and guidelines have to be followed using specific materials and safety measures to ensure the wellbeing of employees and surrounding communities (Clarke & Rieley, 2019). Growing media companies provides employment opportunities within regions where economic activity is rather low, such as the coir plantations in India (Centre for Market Research & Social Development, 2015).

Technological regime factors can be split in two categories. The first category entails the technological factors for the transition from growing in the ground towards growing with growing media. Within Europe most horticulture companies are cultivating out of the ground and therefore the second category is the efficient use of growing media and becoming more efficient and sustainable. Becoming more efficient includes process optimization and the use of less resources in substrates. Funds for more R&D research is provided to find innovative ways to produce substrates in the Farm to Fork strategy (European Commission, 2020).

The environmental factor is related to the technological factor, since it includes the transition to more sustainable products. Within the regime the environment is top priority, since the sector is using raw materials to produce substrates. The environmental factors focus on (1) more sustainable products and (2) the preservation, restoration and protection of peatlands. Sustainable products can be achieved when the substrate is made with sustainable products, produced using less resources, transported environmentally friendly. Another environmental factor in the regime is that (3) the customers determines the mixture. The use of sustainable materials is therefore dependent on the demands of the customers.

Legal factors in the regime are formed by legislation from the EU and national governments. Within European countries there are legal restrictions on peat use and the restoration of peatlands. Germany requires a fixed quota for the use of peat free substrates in the Retail sector. Next to the legal obligations from governments there are requirements for growing media determined by quality marks as ‘Regulering Handels Potgronden’ RHP (RHP, 2016) and ‘Responsible Peat Production’ RPP (RPP, 2017). Companies have to meet the quality standards set by RHP or RPP. There are quality requirements for every material used in the growing media sector. New products first have to be approved by the organisation before it can be used to produce substrates.

The logistical landscape factors are multi-modal transport and sustainable logistics. In the regime can be seen that the most important logistics factor is the transportation price. Possibilities as multi-modal transport and sustainability are considered when the transportation price is less or equal to current transportation price. At this moment peat is shipped in bulk to the harbours and then transported by inland barges and trucks to inland production facilities. Other materials that need transport sea transportation are containerised. Materials transported over land are loaded as loose material in trucks. For peat and containers inland barges are seen as price efficient and sustainable transportation. While at moments there is a need for small batches or a shortage at a production facility the material is transported by road instead of using the inland barges.

Regime factors

Political	Sector represented by branch organisations
Economical	CE – *Horticulture:* Low, *Retail:* Medium, *Landscaping:* High
Social	Wellbeing employees and surrounding communities
Technological	Cultivation out of the ground / Higher efficiency
Environmental	Customer determines sustainability of mixture
Legal	European and National Laws & Quality marks
Logistical	Transport is determined by price and need

4.1.3 Niche factors

Niches in the growing media sector can be found within R&D departments of companies and sector cooperation's. The high quality demands and inhouse knowledge of companies is important within this sector and therefore the platform Horti Heroes is launched for start-ups to have an impact in the food and flower industry (HortiHeroes, 2020).

The political niche factors focus on the Farm to Fork strategy, which explains that extra EU funds will become available for R&D projects within the food industry (European Commission, 2020). The European Commission and National governments stimulate cooperation's in the sector and connects stakeholders by creating different hubs. An example of a knowledge and innovation hub is the World Horti Center located in the region 'het Westland' in the Netherlands (World Horti Center, 2020). This hub serves as a knowledge and research platform for international greenhouse horticulture where businesses, education, research and governments come together.

Niches do not immediately have to perform on economical level, but important requirement for niche innovations is that the price has to be comparable to other growing media. There can be seen a focus on niches that increase the circularity of a product if it is economically viable. New ideas on a closed loop supply chain are introduced by all stakeholders included in the supply chain. A good example is the re-use of orchids by a Dutch grower. The old orchids are collected and with a few actions the orchid is able to grow again within a shorter time period then a new orchid (Derksen, 2020). It is complex to start with a circular idea like this, because it requires several modifications to the supply chain and production process. The feasibility of innovations as these are rather low, since consumers are probably not willing to perform an extra activity. While many incentives can be seen in the sector the change to a more circular economy is complex to achieve since it requires the alignment of all involved stakeholders.

When a product is within the niche regime, there is less attention for social factors. The focus is on the performance of the innovation. When products increase their share in the sector the social factor is becoming relevant. This can be seen with the current trend of Coir products which are gaining market share and therefore the social factor gained more attention. Are the working conditions on coir plantation on a high level, are there any consequences for the environment while producing coir, woodfibre or another alternative for peat. For peat bogs every social factor have been investigated, while for the other products this is partly known.

Technological niche factors focus on three horizons (Baghai, Coley, & White, 1999). The first horizon is to maintain and defend core-business. Innovation in this horizon focus on quick-wins, such as a shift in the shares of the used materials for a growing media. In horizon two the focus is to nurture emerging business. In this horizon the technological niche factors focus on the efficient use of resources while cultivating.

Examples of innovations in the second horizon are the efficient water usage in a greenhouse, the use of less raw materials in substrates and vertical farming, which requires less space for plants to grow. The third horizon focusses on the creation of genuinely new businesses. The technological factors focus on the creation of several options for an long term strategy. At this moment one of long term visions is that growing media can be produced locally and do need the right micro-life and nutrients to create the characteristics needed for cultivation. In the long term the cultivation is data driven and the decisions on mixtures are made on the available data (Saiz-Rubio & Rovira-Más, From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management, 2020).

In the niche-regime a guideline is that an innovation has a positive impact on the environment. The environmental niche factors focus on a closed loop supply chain and the use of sustainable raw materials. The performance of an innovations is vital to the environmental factors, since a less performance of a growing medium results in the waste of resources (Klasmann-Deilmann, 2019). Therefore the environmental factors focus on a more sustainable and circular product with an even or higher performance than the previous product.

At the different innovations stages there are different legal requirements in the growing media sector. When there is started with an innovation there are no legal barriers for doing research with the material and improving the innovation. Once the innovations can be introduced to the market the product has to apply for an RHP-status. Every product has to comply to the RHP regulations to assure the quality of the products. An external commission will research the characteristics of the innovations. Once the RHP-status is granted the product can be sold to customers. This applies for all growing media companies connected to RHP. If a company is not a member of RHP is does not have to apply for a RHP-status for market introduction, but most customers only buy products from companies connected to RHP.

Logistical factors in the niche regime consist of the needed transportation once the product can be introduced to the market. An innovation first has to be suitable for market introduction, but before upscaling the transportation has to be arranged efficiently and the transportation cost should be in the same range as for other products. First there should be determined if the material can be transported in an efficient manner. Can the material be compressed or stacked efficiently? Second the way of transportation via bulk or containers and via which channels have to be determined. Third, the various transportation options and prices are compared and the viability of upscaling the innovation is calculated.

Niche factors

Political	Stimulation for cooperation & Creating of hubs
Economical	Circular Economy & Closed Loop Supply Chain
Social	Not important till introduced in the market
Technological	*Now:* Quick-wins / *Short term:* Efficiency / *Long term:* Locally & Data-driven
Environmental	Sustainable and Circular with even / higher performance
Legal	No barriers at start, comply to RHP for upscaling
Logistical	Crucial factor for upscaling of innovation

4.2 Stakeholder analysis

The stakeholder analysis consist of a general overview of stakeholders and presenting grouped actors with their formal and informal relations within a stakeholder map. The stakeholders are grouped over; Governmental bodies, Growing Media Companies, Suppliers, Customers, Organisations, Knowledge partners, Logistics and Finance.

4.2.1 Stakeholders

Governmental bodies

The governmental bodies that play a role within this system are the **European Commission** (EC), the **United Nations** (UN) and **National Governments**. The EC is the political and legislator for Europe. The farm to fork strategy is a political goal drafted by the EC in cooperation with the UN, National governments and associations. Where the EC and national governments have a legislative power the UN can only advise to their member states. The SDG's drawn up by the UN are followed by the EC and National governments, which formulate strategies to reach the goals.

Growing Media Companies

As explained in chapter 1.5 there are around 500 companies involved in the growing media sector (Schmilewski, 2017). **Growing media companies** are a central part in the system and therefore influence many PESTEL categories. Some growing media companies have an inhouse logistics department, which includes the logistical category. It is difficult to compare companies on their size, because of all the different market segments and specialisations. Therefore an estimation is made for the top five growing media companies in Europe, which are:

Company	**Origin**
• Kekkilä-BVB	Finland / Netherlands
• Klassmann-Deilmann	Germany
• Agaris	Belgium
• Jiffy	Norway / Canada / Netherlands
• Van der Knaap	Netherlands

Suppliers

The suppliers are grouped over **raw material suppliers, additive suppliers** and **packaging supplier**. Like the growing media companies the suppliers influence many PESTEL categories and some suppliers also have inhouse logistics. Raw material suppliers are located internationally and are discussed in chapter 1.4. Some growing media companies have insourced some of the raw materials. Kekkilä-BVB owns several peatbogs in Finland, Sweden and Estonia and Van der Knaap has its own Coir plantation in India. One of the suppliers for Bark is Alfaroxxo from Portugal. Within the sector there are many suppliers for fertilizers, lime and biological additives. Common companies for these additives are ICL, DCM, Yara and Haifa. The packaging supplier consist of suppliers for pallets, big bales and foil.

Customers

The customers are divided over the groups explained in chapter 2.3. They represent economic value and are important in realising a closes loop supply chain resulting in a circular economy. Social factors are important within every company and therefore for importance for the customers. The used technology differs between these customer groups, because **professional horticulture** expects higher quality then **Retail & consumer** and **Landscaping**. The pressure on the growing media market to become more sustainable mainly comes from the customers. The environment is a crucial part of the customers strategy and story to their customers.

Organisations

Organisations in the growing media sector consist of associations and several quality marks. The associations have different scopes in which they operate; internationally, European and national. Internationally the **International Peat Society** represents their members at global organisation as the UN and FAO, but also at governmental levels where needed. On European level **Growing Media Europe** represents the interests of their members. They conduct researches on European level and lobby for the sector's interest. The national associations follow up on the International and European agreements and represent the companies interest at national governments. For the Netherlands the '**Vereniging Potgrond- en Substraatfabrikanten Nederland'** (VPN) is the national association.

Where the associations have political influence, the quality marks can set regulations for growing media producers. Well known quality marks in the sector are **ISO**, **RHP**, **RAL** and **Responsible Peat Production** (RPP). ISO standards are used internationally for environmental and production standards at growing media companies. Companies with an RHP and / or RAL status have to comply to the quality standards set by RHP and RAL . Next to the companies also products have to meet quality standards set by RHP and RAL. RPP is the quality mark that focusses on peat production in the most responsible way, peat producing companies have to meet the guidelines set by RPP. Where after the quality mark can be used throughout the sector when peat is supplied from a RPP certified bog field.

Knowledge partners

External partners and **knowledge hubs** can both function as knowledge partners within the sector. Per research the right partner or hub is selected on the contribution they can make. Some external partners in the sector are DSM, DCM, ICL, Koppert Biological and Wageningen University & Research. Knowledge hubs combine external partners, education, organisations and governments. Examples are Let's Grow, HortiHeroes and the World Horti Centre.

Logistics

The logistical stakeholders are grouped between **shipping companies** and **road transportation**. The shipping companies consist of container shipping companies as MSC, Maersk and Evergreen which are used for the import of Coir, Bark and Peat products and global export of growing media. Also, shipping companies are involved in the bulk transportation overseas and the inland waterway transportation of containers and bulk. For road transportation the transportation is arranged by the supplier of by the growing media company. For both there can be used inhouse logistics or an external logistics provider.

Finance

For research on innovations and market studies financial resources are needed. The financial resources can come from the growing media companies, associations or governments, but if more resources are needed **banks** and **investors** can financially contribute to the researches or knowledge hubs. The Rabobank is well known for its investments in agricultural businesses and the market studies it performs. Investors in research for the growing media sector are organisations as NWO, SIA and Topsector Agri & Food.

4.2.2 Stakeholder map

In figure 28 the stakeholder map for the European Growing Media sector is shown. In the stakeholder map a distinction is made between formal and informal relations. Formal relations are laws, quality standards and requirements, agreements and contracts. Informal relations are cooperation's, alignments and other relationships between stakeholders. The map shows the hub function of the growing media companies, which already could be seen in the bow tie (figure 16) in chapter 2.4. Also the central role for knowledge partners which connect all stakeholder to each other becomes clear in the map.

The stakeholder map consist of stakeholders active within the landscape, regime and niche and how these different levels are connected to each other. Stakeholder identified as landscaping actors are the governmental bodies and associations. The regime stakeholders include the quality marks, Suppliers, Growing Media companies and Customers. The knowledge partners together with the R&D departments from Growing Media companies can be seen as stakeholders in the niche level. Logistics and Finance are an important link in the stakeholder map, but do not significantly interfere with one of the system levels.

The EC has a formal relation with NGOs, because laws made by the EC do apply for National governments. This formal relation continuous from national governments to Growing media companies where several national laws are in place to secure sustainable practices. For raw material suppliers there are national and European laws on the quantity of peat that can be harvested in for example Ireland and Germany. In most European countries the peat bogs have to comply to the RPP and RHP requirements. Also ISO and RAL terms are in place to secure a qualitative and save practice. Quality requirements from all marks are in place for raw materials, additive materials and growing media companies. Other formal relations between suppliers, growing media companies and customers are based upon contracts and agreements between these companies.

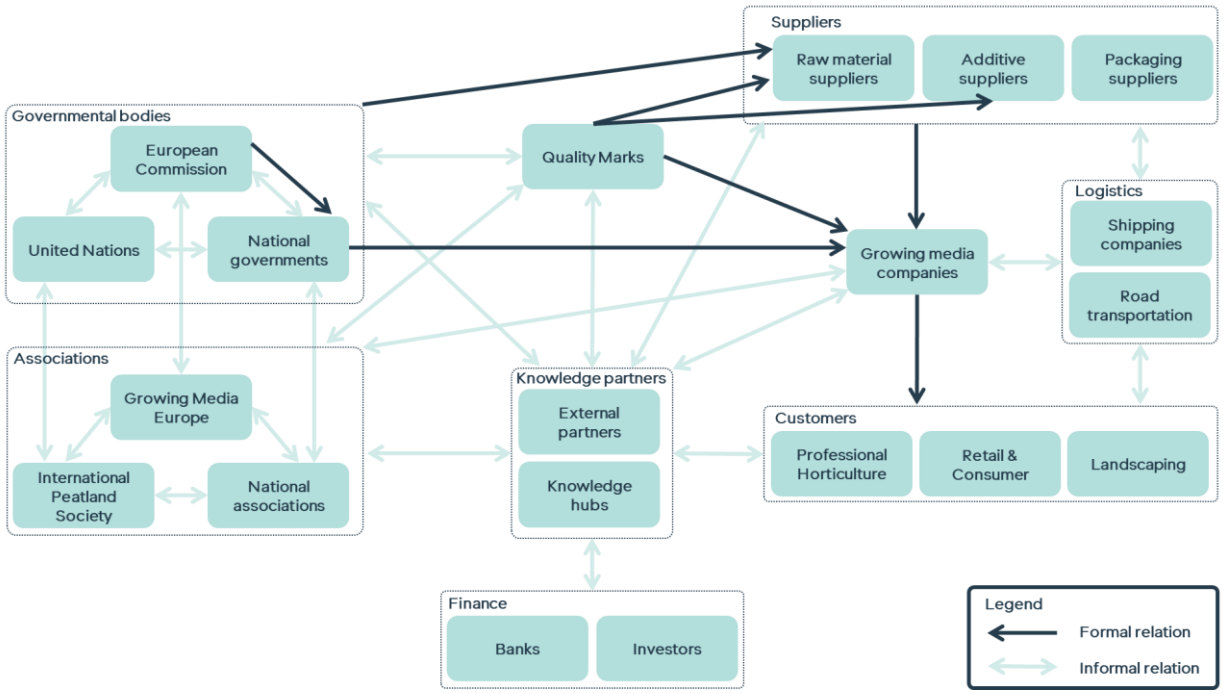

Figure 28: Stakeholder map European Growing Media sector

5 – Alternatives

The alternatives are divided in short and long term alternatives. Both are described with their barriers and opportunities that are contributing to their current market. The short term alternatives are scored in the MCDA to compare them on the criteria. in 5.3 an overview is given of the short- and long-term alternatives and the group of eco-innovations to which they belong. General barriers and opportunities will also be discussed.

5.1 Short-term alternatives

The short-term alternatives consist of peat-based materials, Accretio, coir-based materials, wood-based materials, Perlite, Compost and Inorganic materials. Most of these products are known within the market and have already been described in chapter 1.4 Incoming products.

Peat-based materials

The peat based materials taken into account are **white peat**, **black peat**. Even though there are many different forms of peat materials, there is chosen for the bulk materials in this research. The environmental concerns for peat-based materials are resulting in (local) authorities implementing more regulations and becoming more protective about peatlands, which is a barrier to ensure the peat supply of the future. Within the sector there is a necessity of peat because of the excellent physical characteristics. Peat products are very clean materials, where it is possible to control the characteristics of the material using additives. The European retail branch and national governments are putting more pressure on the use of peat, while especially in the professional market segment peat will remain the main constituent of substrates.

White & Black peat

- \+ Perfect characteristics
- \+ Locally sourced within Europe
- \- GHG emissions
- \- Harvesting regulations

Accretio

Within the market a new alternative called Accretio is recently introduced, better known as bio sphagnum moss. Accretio is the layer above the white peat, which normally is removed before harvesting. This material contains a lot of similarities with the physical characteristics of white peat and has the ability to grow back in around 30 years (Silvan, Jokinen, Näkkilä, & Tahvonen, 2015). Accretio is therefore not categorised as fossil fuel and has a high potential when the quality can be assured and controlled. It is an interesting opportunity because it has a more sustainable character than white and black peat. The use of Accretio is bounded by the harvested volume, since only 30cm of the peat bog is harvested. Furthermore, it is not known whether harvesting regulations will also apply to Accretio, due to the fact that it concerns the top layer of a peat field that will then recover relatively quickly.

Accretio

- \+ Close to White Peat characteristics
- \+ 30 years grow back time
- \+ Lower emission of GHG
- \- Available future volume
- ? Harvesting regulations

Coir-based materials

Coir pith, **coir chips** & **coir fibre** are all coir alternatives that can be used within substrates and differentiate from each other. Apart from their physical and chemical differences the opportunities and barriers can be grouped for the products. Where coir-based growing media products started with a rest material stream of coconuts the increased demand results in coconut plantations especially for growing media. The opportunity as waste stream has now also become a barrier since the high demand for coir-based materials is creating a new waste stream resulting in a higher environmental footprint. Coir materials have a rather low CO_2 emission, even though the product is exported from India and Sri Lanka.Because the material is compressed on a scale of approximately 1:13, the emissions are relatively low for the distribution of the coir products.

To get the right circumstances for growing media coir materials are 'cleaned' with water in the harvesting and production locations, therefore the water usage is very high. Other barriers are the dependency on a few (far) countries for the supply, different production processes per suppliers and manufacturers and the different characteristics from peat. Due to palm diseases and climate conditions the available future volume is threathened. During production, a lot of particulate matter is released that is harmful to workers who often come into contact with it. Added chemicals for cleaning the material also often flow away in the environment of the production site. Compared to other materials, coir products have a higher risk of heavy metals.

Coir-based materials

+	Low GHG emissions	-	Not a locally sourced product
+	Efficient logistics	-	Dependent on a few countries
+	Fast water uptake	-	Material differences per manufacturer
?	Waste stream material	-	Risk for heavy metals
-	Very high water use	-	Concern about social conditions

Wood-based materials

Two types of wood-based materials, **Woodfibre** and **Bark** are seen as current constituents in substrates. Both are partly supplied of a waste stream from trees, but with a rising demand tree plantations are used especially for the supply of wood-based materials. Next to the growing media sector the energy sector and pulp industry are interested in the waste stream of these wood products.

Overall woodfibres have good characteristics to be used within substrates, nevertheless the fibres cannot fully replace peat within substrates. Within the United States there are developments to have higher shares of woodfibre within substrates (Onder Glas, 2020). The fibres from different tree types differ in quality and useable ways, this can be seen as a barrier and opportunity. A barrier because the differences in quality, while the different types create new opportunities for the use of woodfibre in other product groups.

Opportunities for Bark are the availability of the material in different sizes and the local sources for supply. At the same time bushfires in southern Europe have put pressure on the local supply of Bark and the quality assurance of the product. The future supply is expected to be limited due to the destroyed tree plantations by the bushfires. For wood materials there is a risk of mold and fungi within substrates, which are harmful for the roots of the plants.

Woodfibre

+ Good characteristics
+ Local resources
? Waste stream material
- Cannot fully replace peat in substrates

Bark

+ Different sizes
+ Local resources
? Future material supply
- Difficulties in quality assurance

Perlite

The advantages of **perlite** are the quality assurance and the good water and air characteristics of the material. Because the material is heated in an oven the quality of the material is consistent. For certain professional market segments, perlite is increasingly used as a pure substrate (RHP, 2020). Although the properties are generally quite good, perlite also has a number of disadvantages. The use of perlite can lead to potential damage in sensitive parts of the potting system (Kekkilä Professional, 2020). Another disadvantage is that the small granules of perlite can block the growth of roots when plants grow aggressively (Storey, 2016). With perlite substrates frequent watering is necessary, this can create an extra risk fro the plant when a problem in watering occurs.

Perlite

+ Good quality assurance
+ Good water and air characteristic
+ Can be used as pure substrate
? Frequent watering
- Difficulties in production process
- Root system blockage

(Standardised) Compost

In the current market situation **compost** consists of a standardised form in which the proportions of different components are determined. As demand for compost increases over the next few years, either more different standards will be needed or a wider range of proportions. Under the long-term alternatives, the future perspective of compost in the sector will be further explained.

The advantages of compost are that the material is affordable, local and produced out of waste streams. However, compost must be produced locally because it is a heavy material, which allows small quantities to be transported and contributes significant to GHG emissions during distribution. The composting technique can lead to harmful emissions and the quality is difficult to control. At this moment compost cannot be used as a pure substrate because of the high risk of plant damage and disease (RHP, 2020). Due to the high pH value of compost, raw materials with a low pH, such as German and Swedish black peat, have to be added before use to achieve the optimum pH characteristic. According to research from EPAGMA (2012) shows that compost affects the human health most of all constituents.

(Standardised) Compost

+ Local resource
+ Waste product
+ Non-standardised compost
+ Affordable material
? Emissions while composting
- Quality assurance
- Not applicable as pure substrate
- Affects human health the most of all constituents

Inorganic materials

The following inorganic materials are currently used in the sector: **mineral wool** and **foam**. The great advantage when using inorganic materials is the consistency of the material. Inorganic material can also commonly be recycled, as long as the material is well separated. Separation of the inorganic material can be a barrier for the end consumer, who are not used to separating the substrate from plants. Mineral wool and foam also consist of natural raw materials from the source, such as cobalt for the mineral wool. The issue here is whether enough of these raw materials are available for the long term. The use of inorganic materials is not applicable within every market segment, for instance blocks of mineral wool or foam will not easily be found in the retail and landscaping segment. For the professional grower, inorganic materials can be very interesting, but this requires a complete transformation of the production process. Inorganic materials require a frequent watering, when problems in watering occur this could result in problems for the plant. The plant resilience on inorganic material is believed to be lower than when the plant is grown on organic material (Toju, et al., 2018).

Inorganic materials

- \+ Always the same quality
- \+ Recyclable
- ? Enough resources
- ? Frequent watering
- \- Not applicable for every product range
- \- Change in production process
- \- Lower plant resilience

5.2 Long-term alternatives

This chapter discusses long-term alternatives. It discusses certain products expected on the market and expected long-term market trends with their possibilities and barriers for further implementation. The products expected are: grass substrates, coco crush and residual materials in which a circular product can be created through composting. These residual materials include coffee, peanut shells, pine cones, corn, grain and biofuels. Two specific long-term trends will be described in this chapter. These are hydroponics and microbial horticulture.

Grasses

Within the growing media sector, trials are being carried out with different types of grass, such as canary and elephant grass. This shows that, compared to other materials, grass has a relatively low water capacity and fast vegetation (Kuisma, Palonen, & Yli-Halla, 2014). In addition to these grass types, opportunities are seen with the use of roadside grasses / weeds for substrates. The grasses can be harvested locally and are sufficiently available when there is an efficient production process. The energy sector also has a demand for grass to be used as renewable energy source (Wageningen University & Research, 2014). Being able to control and maintain quality is the biggest challenge to be able to use grass as a growing media. When harvesting / mowing, different weeds can come along and the type of grass can vary locally. This increases the risk of fungi and contamination of the material. In addition to these difficulties, it is also necessary to create a network to introduce grass trials in the market. Together with partners, authorities and research institutes, a supply chain needs to be set up for the use of grass as a substrate.

- \+ Local product
- \+ Widely available
- ? Production process
- ? Supply chain creation
- \- Quality assurance and control
- \- Fast vegetation

Coco crush

Coco crush can be seen as a combination of the three different Cocos materials. The complete husk is shredded which increases the usable volume of the coconut. It also simplifies the production process because only one product is made from the coconut. This product can, however, reduce the efficient compression of the material, making transport per m3 of material more expensive. This future product will not eliminate the negative impact of the coconut products as discussed in paragraph 4.1.2, because it is simply an aggregation of the already existing products.

+ Simplifies production process
+ Increases quantity
? Efficient transportation
- No elimination of negative impacts

Residual materials

Residual materials can be described for the future perspective on internal and external residual materials. Internally, this means being able to compost residual flows from market segments. Currently, this is not possible due to regulations regarding the use of compost in the substrate, but within certain segments it is being investigated whether a more circular product flow is possible through composting. An example of this is the creation of a circular flow at bedding peat, which is used in cattle stables, to create a fertilizer that can be added to certain substrates. These 'compost' streams are thoroughly different from the current 'standardised' compost. The knowledge gained from the use of current compost is important for the creation of a circular economy in the growing media sector through composting.

External residual materials can provide completely new raw materials for growing media. Every natural residual product could be reused as a substrate wherever possible. Within the sector, the following residual streams are currently seen as possible raw materials: Coffee, Peanut shells, Pine cones, Corn, Grain and Biofuels. Several start-ups concerning coffee as a substrate can be found in the Netherlands, Rotterzwam (2020), and Zwolsche Zwammen (Muller, 2020), where oyster mushrooms are grown on coffee grounds to be sold to the local horeca and consumers. For all these residual materials, the growing media sector is not the only one that sees opportunities in the residual flow, especially the energy sector that can make good use of these residual flows for renewable energy.

The creation of a circular economy and the reduction of (local) waste streams are the reasons to focus more on the residual materials. The search for the right partners in the development of a supply chain and production process is of crucial importance to allow the raw material to enter the market. The availability of the material on a local or global scale plays a major role in this, because the product must have the possibility to grow into a permanent component in substrates. The most difficult challenge with residual materials is to control and monitor the quality, because every residual stream will have just different properties and it is relatively easy to have harmful substances in the waste stream. Circular raw materials can give unpredictable reactions of the material and cannot always be combined due to nitrogen fixation and EC / pH values. This makes it necessary, as for compost, to counterbalance these values by using black peat.

+ Create circular product
+ Reduce (local) waste materials
? Supply chain creation
? Availability of the material
- Quality assurance and control

Hydroponics

Hydroponics implies that the plant grows on water. In the first stage of the plant it will be propagated in a plug, after which this plug will be placed in a holder for further cultivation on water. For the propagation of the plant there is still a need for raw materials, although this share is very limited. The reduced consumption of raw materials is a good way to prevent the shortage of raw materials. With hydroponic cultivation the plants grow up in a controlled environment (Treftz & Stanley, 2016), which allows dosed nutrients and fertilizers to be added to the water. The continuous recirculation of water provides little wastewater in the growing process (Benoit & Ceustermans, 2004), but when a problem in watering occurs it will immediately manifest itself in problems with the plant. When a plant grows on a substrate, it will be able to retain water, so that in case of problems in watering, there will not be an immediate problem with the plant.

The absence of the substrate can lead to differences in quantity and quality of the product, this will give different results between the various products. The absence also means that the added nutrients and fertilisers cannot adhere to the rooting of the plant, because they have to be added continuously by the recirculation of the water. Furthermore, despite the controlled environment, diseases can still develop. Microbiological contamination, such as salmonella, is possible due to contamination of the irrigation system (Orozco, Rico-Romero, & Escartín, 2008). Nevertheless, hydroponics has an enormous potential to contribute to the sustainable cultivation of food, especially when space and resources are limited. That is why it is very suitable for use in vertical farming, in which space for a product is very limited and must therefore be very efficient.

- \+ Resource efficient
- \+ Controlled environment
- \+ High potential for vertical farming
- ? Continuous watering
- ? Same quality and quantity as with substrate
- \- No adhesion of nutrients / fertilizers to the roots
- \- Microbiological contamination possible

Microbial horticulture

Microbial activity play an important role in the growth and development of the plant (Gerrewey, et al., 2020). More research is being carried out to understand the role of microbiological activity, which aspects have a positive influence on the growth and rooting of the plant and which aspects have a negative influence. When it is clear which microbes are important, it is possible to deliver tailor-made solutions to the customer. In addition, it is then possible to add the right set of microbiological activity to locally obtained material, making it unnecessary to use materials from all over the world. This hypothesis must first be proven before it can be applied.

However, it is certain that microbiological activity improves the plant's resilience (Gerrewey, et al., 2020). In order to make microbial horticulture a success, data must be collected from each individual product in order to determine the microbiological activity to be added. This data-driven decision making will become much more important in the future, because natural materials continuously differ in quality. The sector is therefore examining how certain data-driven technologies can be applied to determine the state of the substrate / plant (Saiz-Rubio & Rovira-Más, From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management, 2020). These technologies include sensors, monitoring and the use of drones.

- \+ Increased use local materials
- \+ Increase plant resilience
- \+ Tailored solution
- ? Valid hypothesis
- ? Supply chain creation
- \- Micro life could be harmful to the plant
- \- Natural raw materials differ continuously

5.3 Overview

Table 1 shows the short and long term alternatives and subdivides them into the eco-innovation groups (Carillo-Hermosilla, Rio, & Könnöla, 2010). For the short term alternatives the focus is mainly on the component addition. For Accretio some modifications to the current system are necessary and for Mineral wool and Foam a completely different production process is used. In the long term you see that focus shifts more to (sub) system changes. This is also because changes to the current system take time to implement. Companies often come up against market barriers if they want to adapt the system. An explanation of these barriers can be found in appendix I. Common market barriers in professional horticulture are (Dennis, et al., 2010; McCarthy & Schurmann, 2014; McCarthy & Schurmann, 2015):

- Financial
- Market demand and consumer behaviour
- Industry / Structural Barriers (Production process)
- Lack of assurance of sustainable farming systems

Alternatives	Component addition (End-of-pipe)	Sub-system change (Eco-efficiency)	System change (Eco-effectiveness)
Short-term alternative	Peat-based Coir-based Wood-based Perlite (Standardised) compost	Accretio	Mineral wool Foam
Long-term alternative	Coco crush	Grasses Residual materials	Hydroponics Microbrial Horticulture

Table 1: Alternatives per eco-innovation group (Carillo-Hermosilla, Rio, & Könnöla, 2010)

6 – MCDA

In this chapter the Multi Criteria Decision Analysis will be discussed. First, the criteria will be drawn up on the basis of a hierarchical tree. Next, the preferences between the criteria will be given, leading to the weights used in the impact table. But first the data of the alternatives on the criteria in the impact table will be discussed. The weights and effects together form the impact table, after which the results are presented.

6.1 Criteria

The criteria that apply to growing media have been collected through the system analysis, desk research and discussions with stakeholders from various departments within Kekkilä-BVB. From the system analysis, certain market developments and trends are significant to select reliable criteria for the future. Furthermore, the desk research and discussions provide a considerable amount of information about the available criteria. In determining the criteria, the following PESTELL categories have been used: Economical, Social, Technological and Environmental, as described in chapter 3.3. It is important that the selected criteria should be measurable so that scores can be given on the alternatives.

The desk research has identified many possible criteria for the ESTE categories, all of which can be found in appendix II. From the available criteria, selections have been made which apply to all alternatives. For this purpose, the criteria have been set out per category, as can be seen in the conceptual model in figure 29. The main goal of (raw) materials in growing media is a good performance, this is therefore formulated as: High performance of raw material. This objective was then divided into Economical, Social, Environmental and Technological performance, with measurable criteria for each of the categories.

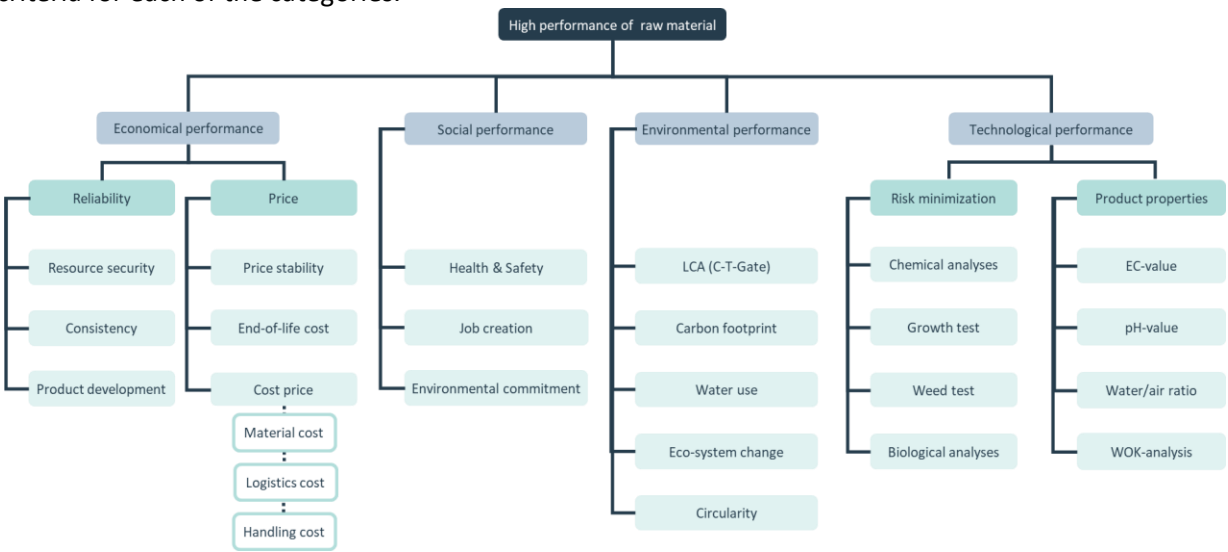

Figure 29: Conceptual model criteria

The conceptual model is the basis for the hierarchical tree that will be used to determine the preferences per level. Because of the comparison per level, it is especially interesting to merge the economic and technological performance into the business performance, so that reliability, price, risk minimization and product properties are compared to each other. This provides more knowledge about the preferences between the economic and technical level in the growing media sector. The hierarchical tree used within the MCDA can be seen in figure 30. In the following sections the selection criteria for each performance group will be discussed with their units. The units and elaborations will be further discussed in chapter 6.3.

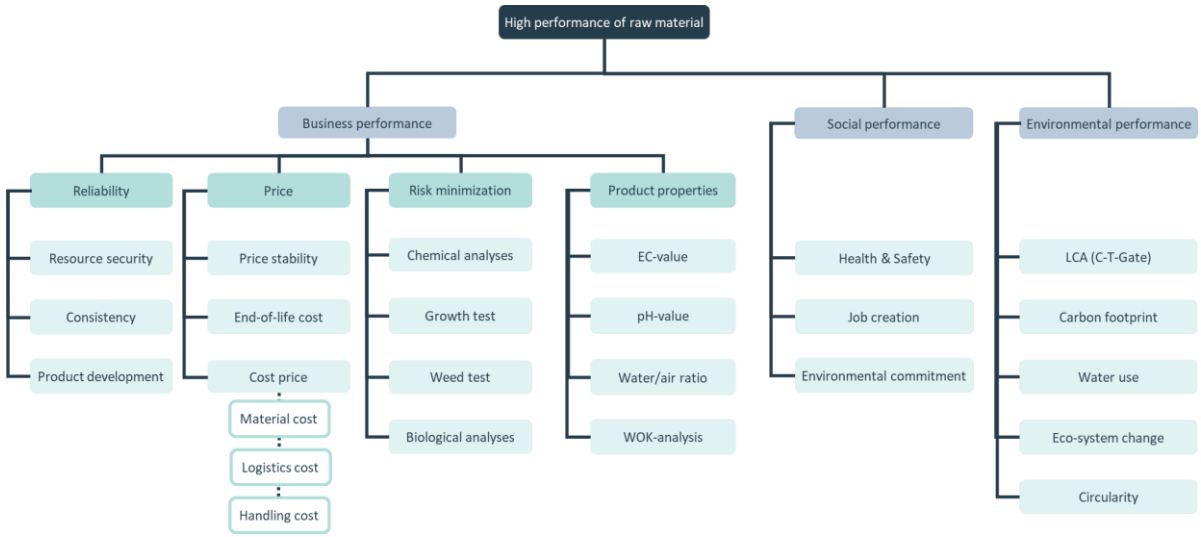

Figure 30: Hierarchical tree selection criteria

6.1.1 Business performance

The business performance includes the reliability, price, risk and product properties criteria. These entail the availability of (natural) resources, cost prices, price fluctuations, product consistency & development, risk minimization and several product properties that are typically measured by laboratory tests. Below the description of the business performance criteria are given. The next subdivision of the business performance criteria is shown per level with their units in table 2.

Reliability

The reliability comprises the business performance of a (raw) material in terms of quality and availability. These terms are resource security, product consistency and product development.

Price

Price is related to all costs associated with the (raw) materials. Price comprises the cost price, price stability and end-of-life costs.

Risk minimization

A substrate can largely contribute to the growth of a plant, but harmful substances in the (raw) material can cause a lot of damage to the plant. By carrying out several laboratory analyses the risk of harmful substances is minimized. These specific risk reduction strategies are: chemical analysis, growth test, weed test and biological analysis.

Product properties

Product properties represent the important general characteristics for (raw) materials that influence the growth of a plant. The properties taken into account are the EC-value, pH-value, Water to air ratio and the WOK-analysis. The product properties are generic. Product-specific criteria are not taken into account, because different plants will grow differently on different Growing Media materials.

Reliability	Description	[Unit]
Resource security	The security is determined by the expected market volume and availability of the (raw) material over a longer period of time.	[1-5]
Consistency	The consistency of (raw) materials refers to the homogeneity of a product and can be determined by the standard deviations of the materials at the laboratory analyses.	[High, Medium, Low]
Product development	The opportunities that exist for the development of a product over time. Examples are the efficient use of materials and an increased consistency.	[High, Medium, Low]
Price	**Description**	**[Unit]**
Price stability	The stability is affected by fluctuations in the cost price and exchange rates. Fluctuations in cost price can be in material cost, logistical cost (oil price etc.) and handling cost.	[High, Medium, Low]
End-of-life cost	These include all the costs at the end of a product life cycle, such as the restoration of landscapes or the cost for removal and / or re-use of the material.	[High, Medium, Low]
Cost price	The cost price of (raw) materials is the sum of the material cost, logistical cost and handling cost per m^3.	[€ / m^3]
Risk minimization	**Description**	**[Unit]**
Chemical analysis	The analysis gives insights in the nutritional conditions, trace elements, pH, heavy metals and nitrogen fixation of a (raw) material. Chemical properties indicate whether a (raw) material is suitable for use in substrates (Bos, et al., 2003).	[1-5]
Growth test	The growth of cress, lettuce and kohl rabi is measured on a substrate with (a share of) the selected (raw) materials and a reference substrate. Growth is an important indicator to see whether the material contains harmful substances (Bos, et al., 2003).	[%]
Weed test	Weeds can cause loss of product, quality reduction and a higher risk of diseases and pests. A germination test shows if weeds are present in the (raw) material (Bos, et al., 2003).	[Weed / m^2]
Biological analysis	The analysis gives insights in the micro-life of a substrate that consists bacteria, fungi and micro-organisms that can stimulate or damage the plant resilience (Toju, et al., 2018). The risk of harmful micro-life is estimated per (raw) material using the results of the biological analysis.	[1-4]

Product properties	Description	[Unit]
EC-value	Electrical conductivity (EC) reflecs the quantity of nutrients in the (raw) material. In general, a low EC-value is preferred because then the necessary nutrients can be added to obtain optimal concentrations (Kekkilä Professional, 2020).	[mS / cm]
pH-value	pH measures the acidity of a (raw) material on a scale from 0 to 14, with 7 as neutral level. When the pH is on the right level, it stimulates plant growth and rooting (Kekkilä Professional, 2020).	[High, Medium, Low]
Water/air ratio	The water to air ratio is measured at different pressure heights (-3.2, -10, -32, -50 and -100 cm) and depends on the sizes of the pores in the (raw) material. These ratios indicate how a (raw) material responds when water is given and how long it retains water (Bos, et al., 2003).	[High, Medium, Low]
WOK-analysis	In the WOK-analysis, the water uptake is measured at the 50% uptake point and after 24 hours. These measures determine the water-uptake characteristic (WOK) that provides insight in the response of a (raw) material to water supply (RHP, 2016).	[1-4]

Table 2: Business performance criteria

6.1.2 Social performance

The criteria of social performance consist of growing media production and / or use that may affect the health or safety of people, employment and social equality. The commitment of the producers and / or users to the well-being of their employees and affected communities, and to preserving their environment. In table 3 the social criteria are presented with their description and measurable unit. These criteria are based upon the pillars of the ISO 26000 – Guidance on social responsibility (ISO, 2018) and SAI 8000 – Social accountability (SAI, 2016) standards.

Social performance	Description	[Unit]
Health & Safety	This is about the Health & Safety of employees and surrounding communities of the producers and / or users of (raw) materials.	[High, Medium, Low]
Job creation	How dependent are the communities on the production and / or use of (raw) materials. Does the presence of growing media producers in the region foresee in essential employment opportunities for the (local) community?	[High, Medium, Low]
Environmental commitment	The commitment of the suppliers of a certain product group to act sustainably throughout their business process. This includes the extent to which the (raw) material is produced ecologically.	[High, Medium, Low]

Table 3: Social performance criteria

6.1.3 Environmental performance

The environmental performance of growing media can be measured in terms of greenhouse gas emissions, and the impact of their production and/or use on eco-system and landscape. Within table 4 the environmental performance criteria are shown with their description and unit.

Environmental performance	Description	[Unit]
LCA (C-T-Gate)	The Life Cycle Analysis gives the total environmental impact of a material per m3. The LCA is calculated from cradle to gate, which shows the impact on the environment from harvesting until the product leaves the gate of the Growing Media company.	[€ / m^3]
Carbon footprint	The Carbon footprint is the total of emitted greenhouse gasses in the life cycle of a (raw) material, represented as its CO2-equivalent.	[CO_2eq / m^3]
Water use	The total amount of water used during the life cycle of a (raw) material. An average will be taken, since there are many growing techniques and different compositions, but water use also varies per (raw) material.	[Litre / m^3]
Eco-system change	The effect of harvesting, production and / or use of a (raw) material on the eco-system of the environment. This can be observed as the land use change.	[(PDF*m^2*y) / m^3]
Circularity	The percentage of a (raw) materials that currently can be reused or recycled to create a circular system with the product.	[%]

Table 4: Environmental performance criteria

6.2 Preferences

Preferences should be established between the criteria at all levels so that the weights can then be determined. They have been determined through a survey conducted by an expert panel. The survey will be discussed in more detail in 6.2.1. In 6.2.2 the group preference will be presented, this group preference leads to different impact scores through different methods which are discussed in 6.2.3.

6.2.1 Survey

The survey submitted to the expert panel consisted of 40 pairs of comparisons. In total, the survey was completed 30 times out of 37 invitations sent out, representing a participation rate of 81%. 23 of the 30 are respondents from a growing media company. 2 are from a growing media association / quality mark. Also 2 people came out for the research institutions and 3 customers participated in this survey. The results of the survey can be found in appendix III.

Of the 1200 (30 respondents * 40 pairwise comparisons) data points it was noticeable that 469 times "The criteria are equally important" was answered, which is 39%. The fact that many respondents found the criteria equally important made it more difficult for them to give a consistent order of importance for the level in question. In total, 53 out of 240 rankings were inconsistent (22%), how they are distributed along the respondents and levels and how they are treated within this research can be found in appendix III. To determine the rankings per respondent and whether they are consistent a Python script was used, which can be found in appendix V.

6.2.2 Group preferences

To determine the group preference, the Condorcet (1785) method was used, which looks at the results of all pairwise comparisons within a certain level. When one criterion is chosen more often than the other, the most frequently chosen criterion is ranked higher. Because only the criteria are taken into account and not the equal answers, a different method is used which looks at the three answer possibilities instead of the two criteria in Condorcet. If this does not result in a logical order, Condorcet with two variables is considered. The adaptation to the method shows the impossibility theorem of Arrow (Arrow, 1951). There would be no pareto-optimality when using two variables. The use of three variables does not solve Arrow's theorem, but it does give a more representative picture of the group preferences. In table 5 the group preference for all respondents is shown, within appendix IV the group preferences per group are presented.

Category	Group preference	Method	
		Majority rule	Condorcet
High performance of raw material	Business performance > Social performance > Environmental performance		
Business performance	Risk minimization > Reliability > Product properties > Price		
Business performance: Reliability	(Resource security ~ Consistency) > Product development		
Business performance: Price	Price stability > Cost price > End-of-life cost		
Business performance: Risk minimization	(Chemical analysis ~ Growth test ~ Biological analysis) > Weed test		
Business performance: Product properties	EC ~ pH ~ Water / air ratio ~ WOK-analysis		
Social performance	(Health & Safety ~ Environmental Commitment) > Job creation		
Environmental performance	LCA (C-T-Gate) > (Carbon footprint ~ Water use ~ Eco-system change ~ Circularity)		

Table 5: Group preferences for all respondents

6.2.3 Impacts scores

Now that the group preference has been determined, the preferences can be converted into weights. The choice was made to determine the weights using four methods: normalised, rang reciproke, Rietveld & Ouwersloot and aggregate per respondent using the rang-reciproke method. For all methods, the divisor should be determined first. For the normalised method, the divisor for 3 criteria is equal to 1 + 2 + 3 = 6. The weights are then: 3/6 (0.50), 2/6 (0.33) and 1/6 (0.17). For rang reciproke the divisor is equal to 1 + 1/2 + 1/3 = 11/6, the numerator becomes the denominator for the weights, which results in 6/11 (0,55), 3/11 (0,27), 2/11 (0,18). For Rietveld & Ouwersloot, the divisor is equal to the sum of: 1 + 1/2 + 1/3 + 1/2 + 1/3 +1/3 = 11/6 + 5/6 + 2/6 = 18/6. Here too, the numerator for the weights is the denominator. The weights in these methods are 11/18 (0.61), 5/18 (0.28) and 2/18 (0.11) as follows.

The fourth method is based on the rang reciproke, but is then determined per respondent and then aggregated. For this method, however, only consistent rankings can be taken into account, whereas the methods based on group preference also include inconsistent rankings. The scores are determined per level of the criteria tree. The score of the upper level times the score of the lower level gives the impact scores as can be seen in Table 6. To show how this process works the division of the rang reciproke method is presented within the criteria tree in the figure below. There can be seen that the sum of a certain level is the score of the upper level.

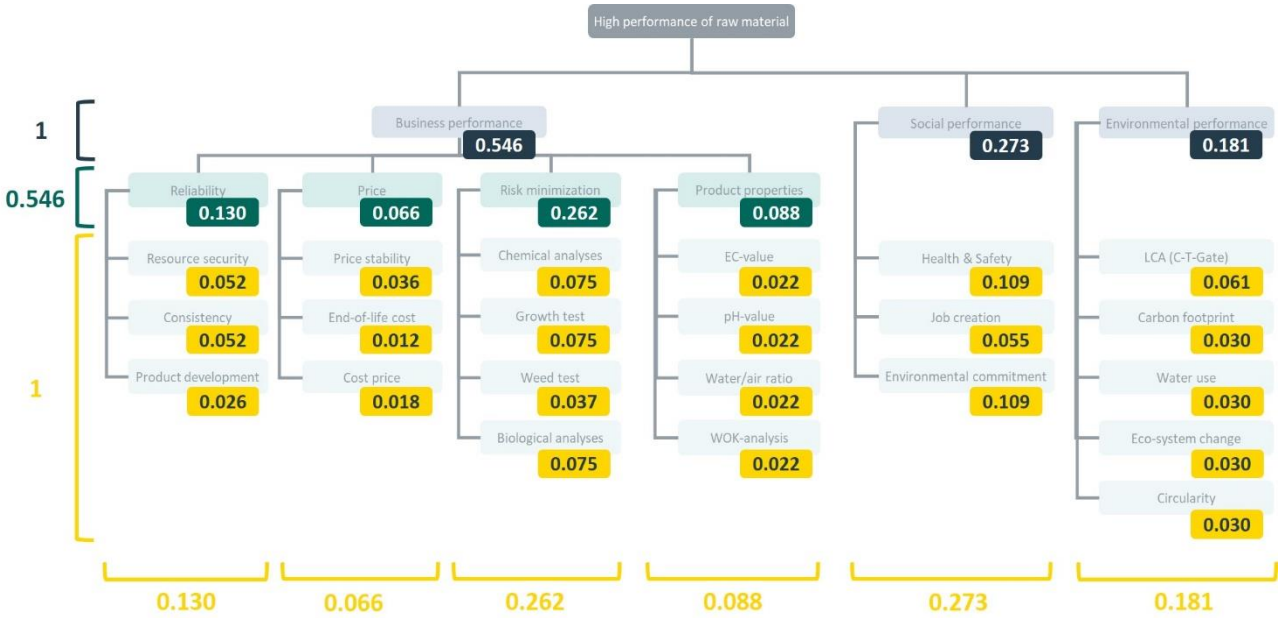

Figure 31: Division of impact scores according to rang reciproke

What can be deduced from the heatmap is that despite the fact that business performance has a greater preference than social performance, the social criteria have the greatest impact. This can be explained by the fact that there are fourteen business criteria and three social criteria. It is also noteworthy that the price criteria have the lowest impact scores. Despite the fact that the price in the sector is often a deal maker or breaker, the other business criteria must first be in order. The method based on the group preference (Agg. per respondent) shows the same distribution of the impact, where the aggregation over the respondents shows the same highest and lowest impacts, the impacts are closer together.

Criteria	Normalised	Rang reciproke	Rietveld & Ouwersloot	Agg. per respondent
Resource Security	0.060	0.052	0.071	0.046
Consistency	0.060	0.052	0.071	0.044
Product development	0.030	0.026	0.024	0.035
Price stability	0.025	0.036	0.023	0.023
End-of-life cost	0.008	0.012	0.004	0.014
Cost price	0.017	0.018	0.011	0.023
Chemical Analyses	0.057	0.075	0.095	0.042
Growth Test	0.057	0.075	0.095	0.039
Weed Test	0.029	0.037	0.032	0.031
Biological analyses	0.057	0.075	0.095	0.036
EC-value	0.025	0.022	0.022	0.035
pH-value	0.025	0.022	0.022	0.032
Water/air ratio	0.025	0.022	0.022	0.029
WOK-analysis	0.025	0.022	0.022	0.027
Health & Safety	0.133	0.109	0.119	0.118
Job creation	0.067	0.055	0.040	0.063
Environmental commitment	0.133	0.109	0.119	0.101
LCA (C-T-Gate)	0.056	0.061	0.048	0.077
Carbon footprint	0.028	0.030	0.016	0.052
Water use	0.028	0.030	0.016	0.045
Eco-system change	0.028	0.030	0.016	0.049
Circularity	0.028	0.030	0.016	0.040
	1.000	**1.000**	**1.000**	**1.000**

Table 6: Impact scores for the selection criteria presented as heatmap

6.3 Effects table

The effects table shows the data of the alternatives on all criteria. Therefore, all data input is first discussed, after which the effects table is examined in more detail. The data has been collected from internal and external sources for the various alternatives according to criteria. These internal sources concern the laboratory test and specific product properties that are measured. For external sources, the available scientific and professional literature on the characteristics of the materials was examined. In table 7 the criteria will be treated with their scale or unit of scoring followed by the source from which the data came. Further elaboration of the data including assumptions made can be found in appendix VI. Assumptions mainly occur with the alternatives Accretio and Foam because they are relatively new products / innovations on the market and therefore relatively unknown. All data points have been validated with the involved departments of Kekkilä-BVB: R&D, Procurement and Sustainability.

Criteria	Scale or unit	Sources
Resource Security	1 = Very limited 2 = Limited 3 = Sufficient 4 = Plenty 5 = No limitation	Based on the expected volumes over a longer period of time (Internal data projections) and the (expected) market barriers for expansion as explained in chapter 5.
Consistency	1 = High consistency 2 = Medium consistency 3 = Low consistency	Based on the standard deviations of the different laboratory tests and field experiences with the alternatives.
Product development	1 = High development 2 = Medium development 3 = Low development	Based on the potential of the material, discussed with the Procurement and R&D department
Price stability	1 = High price stability 2 = Medium price stability 3 = Low price stability	Cost price fluctuations over the years 2018-2020.
End-of-life cost	1 = Low end-of-life cost 2 = Medium end-of-life cost 3 = High end-of-life cost	Based on the end-of-life data found in the EPAGMA report (EPAGMA, 2012).
Cost price	€ / m^3	Cost prices per cubic meter in 2020.
Chemical Analyses	1 = Very high risk 2 = High risk 3 = Low risk 4 = Very low risk 5 = No risk	The results of the performed chemical analyses in the past year. There is looked at the number of outliers and if these are important for use of the alternative.
Growth Test	1 = Always bad growth 2 = Regularly bad growth 3 = Sometimes bad growth 4 = Sometimes moderate growth 5 = Always good growth	The results of the performed growth test in the years 2019-2020. Based on the number of outliers.
Weed Test	Weeds / m^3	The results of the performed weed test in the past years.
Biological analyses	1 = High risk 2 = Medium risk 3 = Low risk 4 = Very low risk	The results of the performed biological analyses on (human) pathogens, fungi, etc.
EC-value	mS / cm	Average of the EC-value over the performed laboratory test the past years.

pH-value	1 = Bad pH 2 = Medium pH 3 = Good pH	Average pH-value of the material over the past years, compensated to the acceptable range (RHP, 2018).
Water/air ratio	1 = Bad water / air ratio 2 = Medium water / air ratio 3 = Good water / air ratio	The ratio is determined with the water and air content at -10 cm (%-v) found from laboratory test.
WOK-analysis	1 = Water uptake fast 2 = Water uptake sufficient 3 = Water uptake moderate 4 = Water uptake slow	The WOK results are based on the scale of RHP (RHP, 2018). Depends on the 50% and 24 hour point. For some materials assumptions have been made.
Health & Safety	1 = Low Health & Safety 2 = Medium Health & Safety 3 = High Health & Safety	The score is based on the Code of Conduct, supplier ratings, procurement opinions, location and health score as mentioned in the EPAGMA report (EPAGMA, 2012).
Job creation	1 = Low job creation 2 = Medium job creation 3 = High job creation	Job creation is based on market information on job dependency of region / country on the alternative.
Environmental commitment	1 = Low commitment 2 = Medium commitment 3 = High commitment	Based on the use of alternatives with eco-labels and quality marks, such as RPP, FSC, EU eco-label, PEFC and OMRI-listed.
LCA (C-T-Gate)	€ / m^3	The LCA (Kekkilä-BVB, 2020)[4] is calculated with databases from Ecochain (Ecochain, 2020).
Carbon footprint	CO_2eq / m^3	Data as presented in the EPAGMA report (EPAGMA, 2012). For data not included assumptions have been made. For foam the Idemat (2020) database is used.
Water use	Litre / m^3	Data on the harvesting process is requested at the suppliers and combined with data from internal processes.
Eco-system change	(PDF*m^2*y) / m^3	Data as presented in the EPAGMA report (EPAGMA, 2012). For data not included assumptions have been made. For foam the Idemat (2020) database is used.
Circularity	%	For most alternatives an assumptions is used to look at the reuse after the substrate is used. Mineral wool is based on number from Grodan (2017). Foam is based on a report from Covestro (2018).

Table 7: Data input for effects table

In figure 31 the effects table can be seen. Per criteria and alternative the data is filled in. Subsequently, this data has been normalised. The best score for a substrate gets the score 1, where the worst score scores 0. Depending on the scale, the other data get their standardised value. For a number of criteria the full scale is not used for the data, for those criteria the choice has been made to do so. These concern the criteria resource security, growth test and water / air ratio. In the case of circularity, each percentage contributes to the reuse of materials, which is why 0% is used as the lowest possible value in scale. The standardized effects table is shown in figure 32, in which the values are represented as heatmap (red is a good score, blue a bad score). In the effects table it can be seen that there is one dominated alternative. The coconut chips always score equal to or less than the coconut fibre. Where normally dominated alternatives are taken out of the comparison, the choice has been made to leave the coconut chips in the comparison, because in the future probably all materials have to be used to answer the demand for substrates.

[4] Source originates from Dynamics 365 Business Central (not publicly accessible) from Kekkilä-BVB.

Data sheet													
Criteria		Alternatives											
		White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Business Performance	Reliability: Resource Security	3	3	3	2	3	3	4	2	4	3	3	4
	Reliability: Consistency	1	1	2	2	2	2	2	3	1	3	1	1
	Reliability: Product development	3	3	1	2	2	2	1	2	3	1	1	1
	Price: Price stability												
	Price: End-of-life cost	3	3	2	1	1	1	1	1	1	2	2	2
	Price: Cost price												
	Risk minimization: Chemical Analyses	4	4	4	2	2	3	3	3	4	1	5	5
	Risk minimization: Growth Test	4	4	4	3	3	3	4	3	5	4	5	5
	Risk minimization: Weed Test												
	Risk minimization: Biological analyses	3	3	2	2	2	2	1	2	4	1	4	4
	Product properties: EC-value												
	Product properties: pH-value	3	3	3	2	2	2	3	3	2	1	3	3
	Product properties: Water/air ratio	3	2	2	3	2	2	2	2	2	2	2	2
	Product properties: WOK-analysis	3	4	4	1	3	1	3	4	1	2	2	1
Social performance	Health & Safety	3	3	3	1	1	1	3	3	3	2	2	3
	Job creation	2	2	1	3	3	3	1	1	1	1	1	1
	Environmental commitment	3	3	3	1	1	1	3	3	2	3	3	2
Environmental performance	LCA (C-T-Gate)												
	Carbon footprint	170	310	125	70	70	70	65	105	100	280	100	110
	Water use												
	Eco-system change	25	35	15	95	95	95	20	40	20	50	20	11
	Circularity	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%	30%

Figure 32: Effects table

Data sheet													
Criteria		Alternatives											
		White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Business Performance	Reliability: Resource Security	0,50	0,50	0,50	0,25	0,50	0,50	0,75	0,25	0,75	0,50	0,50	0,75
	Reliability: Consistency	1,00	1,00	0,50	0,50	0,50	0,50	0,50	0,00	1,00	0,00	1,00	1,00
	Reliability: Product development	0,00	0,00	1,00	0,50	0,50	0,50	1,00	0,50	0,00	1,00	1,00	1,00
	Price: Price stability	0,50	0,50	0,50	0,00	0,50	0,50	1,00	0,00	1,00	0,50	0,50	0,50
	Price: End-of-life cost	0,00	0,00	0,50	1,00	1,00	1,00	1,00	1,00	1,00	0,50	0,50	0,50
	Price: Cost price	0,97	0,97	0,93	0,90	0,86	0,90	0,96	0,82	0,93	1,00	0,00	0,36
	Risk minimization: Chemical Analyses	0,75	0,75	0,75	0,25	0,25	0,50	0,50	0,50	0,75	0,00	1,00	1,00
	Risk minimization: Growth Test	0,75	0,75	0,75	0,50	0,50	0,50	0,75	0,50	1,00	0,75	1,00	1,00
	Risk minimization: Weed Test	0,35	0,20	0,67	0,00	0,34	1,00	1,00	0,90	1,00	1,00	1,00	1,00
	Risk minimization: Biological analyses	0,67	0,67	0,33	0,33	0,33	0,33	0,00	0,33	1,00	0,00	1,00	1,00
	Product properties: EC-value	0,98	0,93	0,98	0,56	0,78	0,94	0,91	0,89	1,00	0,00	0,97	0,97
	Product properties: pH-value	1,00	1,00	1,00	0,50	0,50	0,50	1,00	1,00	0,50	0,00	1,00	1,00
	Product properties: Water/air ratio	1,00	0,50	0,50	1,00	0,50	0,50	0,50	0,50	0,50	0,50	0,50	0,50
	Product properties: WOK-analysis	0,33	0,00	0,00	1,00	0,33	1,00	0,33	0,00	1,00	0,67	0,67	1,00
Social performance	Health & Safety	1,00	1,00	1,00	0,00	0,00	0,00	1,00	1,00	1,00	0,50	0,50	1,00
	Job creation	0,50	0,50	0,00	1,00	1,00	1,00	0,00	0,00	0,00	0,00	0,00	0,00
	Environmental commitment	1,00	1,00	1,00	0,00	0,00	0,00	1,00	1,00	0,50	1,00	1,00	0,50
Environmental performance	LCA (C-T-Gate)	0,83	0,74	0,84	0,83	0,84	0,84	0,86	0,93	0,80	1,00	0,54	0,00
	Carbon footprint	0,57	0,00	0,76	0,98	0,98	0,98	1,00	0,84	0,86	0,12	0,86	0,82
	Water use	0,99	1,00	1,00	0,14	0,00	0,14	0,99	0,99	0,99	1,00	1,00	1,00
	Eco-system change	0,83	0,71	0,95	0,00	0,00	0,00	0,89	0,65	0,89	0,54	0,89	1,00
	Circularity	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,90	0,30

Figure 33: Standardised effects table presented as heatmap

6.4 Results

The impact scores combined with the standardised effects table gives the weighted sum of the scores of the alternatives on the criteria. On the basis of these weighted sum scores the ranking of the alternatives can then be determined. In figure 34 the impact table shows where the impact scores, according to the rang reciproke method, are combined with the effects table. In this section the results of all respondents and about the four main groups will be discussed. The results of all groups and about all weighing methods can be found in appendix VII.

MCDA model													
Criteria		Impact factor	Alternatives: White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Business Performance	Reliability: Resource Security	0,052	0,03	0,03	0,03	0,01	0,03	0,03	0,04	0,01	0,04	0,03	0,03	0,04
	Reliability: Consistency	0,052	0,05	0,05	0,03	0,03	0,03	0,03	0,03	0,00	0,05	0,00	0,05	0,05
	Reliability: Product development	0,026	0,00	0,00	0,03	0,01	0,01	0,01	0,03	0,01	0,00	0,03	0,03	0,03
	Price: Price stability	0,036	0,02	0,02	0,02	0,00	0,02	0,02	0,04	0,00	0,04	0,02	0,02	0,02
	Price: End-of-life cost	0,012	0,00	0,00	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Price: Cost price	0,018	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,02	0,02	0,00	0,01
	Risk minimization: Chemical Analyses	0,075	0,06	0,06	0,06	0,02	0,02	0,04	0,04	0,04	0,06	0,00	0,07	0,07
	Risk minimization: Growth Test	0,075	0,06	0,06	0,06	0,04	0,04	0,04	0,06	0,04	0,07	0,06	0,07	0,07
	Risk minimization: Weed Test	0,037	0,01	0,01	0,03	0,00	0,01	0,04	0,04	0,03	0,04	0,04	0,04	0,04
	Risk minimization: Biological analyses	0,075	0,05	0,05	0,02	0,02	0,02	0,02	0,00	0,02	0,07	0,00	0,07	0,07
	Product properties: EC-value	0,022	0,02	0,02	0,02	0,01	0,02	0,02	0,02	0,02	0,02	0,00	0,02	0,02
	Product properties: pH-value	0,022	0,02	0,02	0,02	0,01	0,01	0,01	0,02	0,02	0,01	0,00	0,02	0,02
	Product properties: Water/air ratio	0,022	0,02	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
	Product properties: WOK-analysis	0,022	0,01	0,00	0,00	0,02	0,01	0,02	0,01	0,00	0,02	0,01	0,01	0,02
Social performance	Health & Safety	0,109	0,11	0,11	0,11	0,00	0,00	0,00	0,11	0,11	0,11	0,05	0,05	0,11
	Job creation	0,055	0,03	0,03	0,00	0,05	0,05	0,05	0,00	0,00	0,00	0,00	0,00	0,00
	Environmental commitment	0,109	0,11	0,11	0,11	0,00	0,00	0,00	0,11	0,11	0,05	0,11	0,11	0,05
Environmental performance	LCA (C-T-Gate)	0,061	0,05	0,04	0,05	0,05	0,05	0,05	0,05	0,06	0,05	0,06	0,03	0,00
	Carbon footprint	0,030	0,02	0,00	0,02	0,03	0,03	0,03	0,03	0,03	0,03	0,00	0,03	0,02
	Water use	0,030	0,03	0,03	0,03	0,00	0,00	0,00	0,03	0,03	0,03	0,03	0,03	0,03
	Eco-system change	0,030	0,03	0,02	0,03	0,00	0,00	0,00	0,03	0,02	0,03	0,02	0,03	0,03
	Circularity	0,030	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,01
Weighted sum score			0,760	0,709	0,716	0,398	0,416	0,482	0,735	0,618	0,790	0,518	0,766	0,744
Ranking			3	7	6	12	11	10	5	8	1	9	2	4

Figure 34: Impact table for all respondents presented as heatmap

The results on all respondents for all four weighing methods are shown in table 8. It can be seen that the different weighting methods do not give the same ranking. The first seven alternatives are different over the four methods, for ranking 8 to 12 there are no differences between the methods. There are no major shifts between the alternatives. The inorganic materials: Perlite, Mineral Wool and Foam all score very well. This can be explained by their high scores for many of the business performance criteria, because they are 'clean' materials. Of the natural materials, white peat and wood fibre also score highest, followed by black peat and Accretio. They score higher than the other natural materials because they do well on the social criteria and then the cleanliness of the material determines the ranking. This is followed by bark, (standardised) compost and coir products. Bark is less stable than the other natural materials, but it is more stable than the (standardised) compost and coir materials. While compost has more deviations than the coir materials, compost scores better because of the good performance on social and environmental level. The low scores of the coir products are due to the relatively lower scores on the business performance criteria, the products have more deviations than the other alternatives, except compost, and they also score relatively low on the social performance criteria.

Ranking per method		Normalised	Rang Reciproke	Rietveld & Ouwersloot	Agg. per respondent
Alternatives	White Peat	1	3	4	3
	Perlite	2	1	1	2
	Mineral Wool	3	2	2	5
	Woodfibre	4	5	7	1
	Foam	5	4	3	6
	Black Peat	6	7	5	7
	Accretio	7	6	6	4
	Bark	8	8	8	8
	(Standardised) Compost	9	9	9	9
	Coir fibre	10	10	10	10
	Coir chips	11	11	11	11
	Coir pith	12	12	12	12

Table 8: Results per ranking method

In order to make the differences between the scores more transparent, figure 35 shows the weighted sum of the scores of the alternatives over the weighing methods. It can be seen that the top 4 are close together, the same goes for places 5 to 7. The coir materials are also close together. The fact that the result over the various weighing methods is so uniform is due to the relatively large differences between the groups of alternatives, which explains the small shifts that can be seen within the top, middle or bottom.

In figure 36 a subdivision is made between the business, social and environmental performance of the alternatives for the weighted sum scores of the rang reciproke method. From a business point of view, the inorganic materials score well above the other alternatives. What is remarkable is that the coir materials score equally well on the business criteria as woodfibre, Accretio and black peat. From a social point of view, everything is reasonably close to each other, except for the coir materials that score the least there. The environmental performance of the alternatives is fairly close together, the products that score well here are woodfibre, Accretio and perlite. These alternatives have a low LCA value combined with a low carbon footprint and water usage which makes them more environmentally preferred then others. The ranking over the performance levels per weighing method can be found in appendix VII.

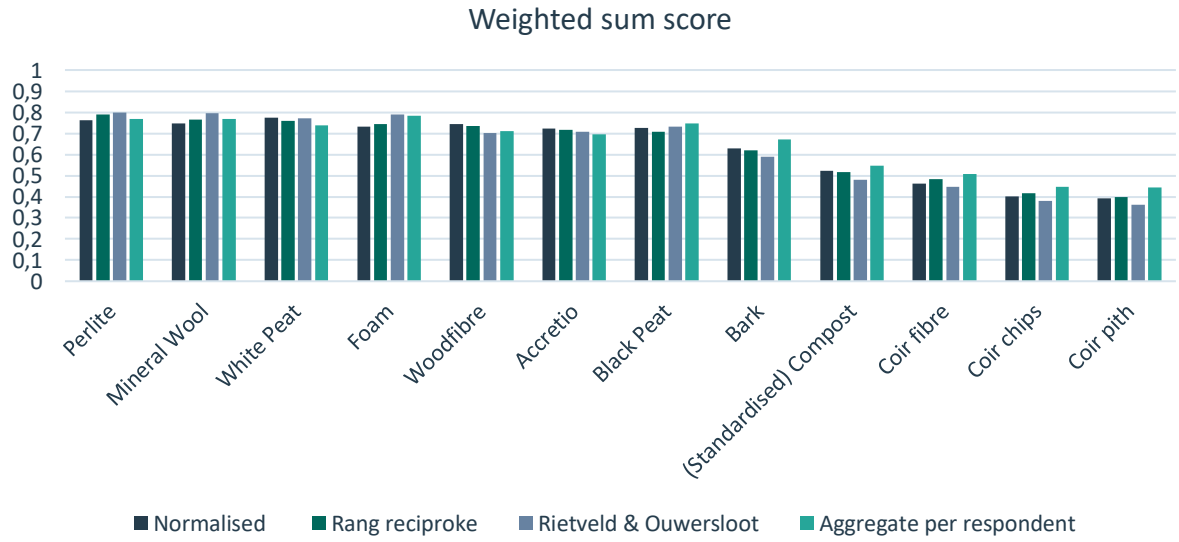

Figure 35: Weighted sum score per weighing method

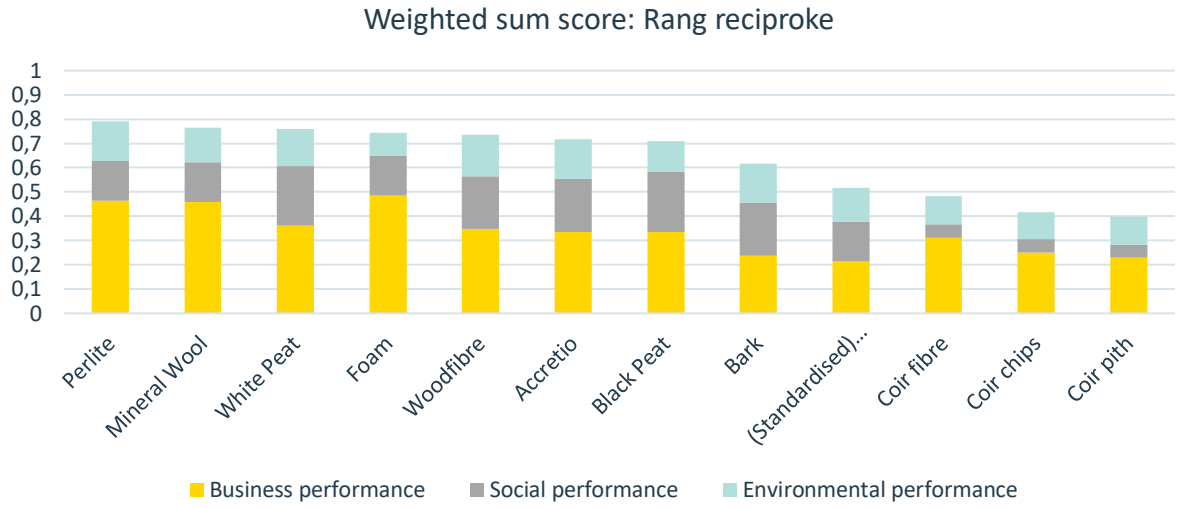

Figure 36: Weighted sum score divided over business, social and environmental performance

6.4.1 Groups

Four different groups of actors were drawn up among all respondents: The growing media companies, growing media association / quality mark, research institution and customers. It was examined whether the different group preferences (appendix IV) they defined gave different rankings with regard to the alternatives. In table 9 the results of the ranking with the grade reciprocal method are shown, in appendix VII the rankings can be found under the other weighting methods. The results show that the alternatives are shifting between the actors within a certain range.

Over all respondents woodfibre scores higher then looked at the specific groups. This is not determined by one factor, but in every group different factors contribute to this. For the growing media association / quality mark and customers the LCA and Carbon footprint have more impact, which results in a higher score since woodfibre performs well on the environmental criteria. Within the group of growing media company respondents the social criteria have a higher preference, which results in this shift. The research institutions give more value to resource security and the EC value, which is why woodfibre scores higher there. Overall, the groups have given less impact to risk minimization and product property criteria. As a result, the clean inorganic materials are much lower in the rankings compared to all respondents.

Rang reciproke		All respondents	Growing Media company	Growing media association/ quality mark	Research institution	Customers
Alternatives	White Peat	3	1	3	3	2
	Woodfibre	5	2	2	1	3
	Perlite	1	3	1	2	1
	Accretio	6	4	5	4	5
	Black Peat	7	5	7	7	7
	Mineral Wool	2	6	4	5	4
	Bark	8	7	8	8	8
	Foam	4	8	6	6	6
	(Standardised) Compost	9	9	12	9	10
	Coir fibre	10	10	9	10	9
	Coir chips	11	11	10	11	12
	Coir chips	12	12	10	11	12

Table 9: Results per actor group

The distribution of alternatives can be seen in the weighted sum scores of the alternatives, as shown in figure 37. In general, the scores over the different groups do not differ that much, but in the case of black peat, bark, compost and the coir materials differences can be observed between the groups. Black peat, bark and compost score higher for the growing media companies than for the other groups. The opposite is true for the coir related materials. This can be explained by the fact that the growing media companies consider the business performance and social performance to be the equal, whereas the other groups consider the business performance to be more important than the social performance. Another thing that is remarkable is the large differences between the groups at the coir materials. The research institutions assign a higher impact to the environmental criteria, as a result of which the overall score of the coir materials improves significantly but does not cause a shift in ranking.

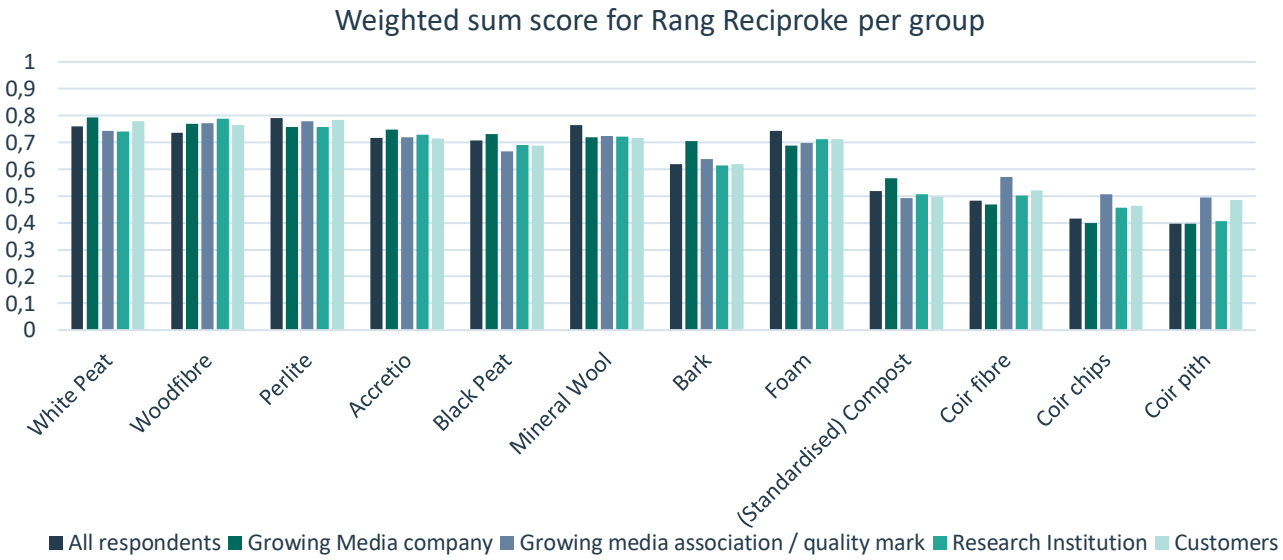

Figure 37: Weighted sum score per actor group

6.4.2 Conclusion

It can be concluded from the results that, despite the differences in preferences between the groups, the results are very stable. This is due to the relatively large differences between the products. There are small shifts between the groups, however, because the scores are so close together. There were also differences in preferences, but these too were relatively small and there were no completely different preferences between the groups. From the results, four groups of alternatives can be distinguished, which are shown below.

White peat Perlite Woodfibre	Accretio Mineral wool Foam Black peat	Bark	(Standardised) Compost Coir pith Coir fibre Coir chips

These results are based on the preferences and data of the current situation. For the future situation it can be assumed that certain products and scores on criteria will change positively or negatively. In order to take these shifts and expectations into account, various scenarios have been drawn up, which will be discussed in the next chapter.

7 – Scenarios

The scenarios are based on the respondents' future expectations of the political, legal and logistical trends. The future expectations of respondents can be found in Annex I. The views of the respondents show that they have a clear and generally agreed picture of the future. These PLL context factors are described in section 7.1. In the next section the different scenarios are drawn up with their shifts for the MCDA. Within 7.3 the results of the scenarios and current situation are discussed.

7.1 Context factors

In the political field, the growing media sector has a lot to gain. At the moment, policymakers do not have the right perception and knowledge of the sector and how important it is for the food supply and the contribution to the environment and people's health by gardening and buying plants. As a result, governments are not in a position to make a well-considered choice in policy making. Social pressure is now dominating the political debate instead of the available knowledge about the various raw materials.

> "In general, the important role of growing media is poorly recognised by actors in the chain - and outside it. As a result, 'public opinion' thinks it is fairly easy to form an opinion on what the substrate sector should or should not do (peat-free, organic, no human pathogens, use of residual flows, etc.). In other words, it is important that the sector positions the importance of substrate in a structured and consistent way."
>
> - Respondent Growing Media association / quality mark

In Europe, legal trends are mainly expected on peat and fertilizer use in substrates. For peat these are limiting legislation, where more possibilities are expected for the additives as fertilizers. Regulations on peat can mean that only certified fields may be harvested or that harvesting is even phased out over time. Products that possess peat can also be banned in various countries. Over the next few years the regulations will increasingly differ per region, country or continent. More regulation on peat can have a major impact on the growing media sector, as it is the largest component of substrates. Even though the proportion of peat in the substrate is decreasing, increasing global growth will mean that more peat will still be needed to meet demand. Not only food production can be affected, but also food safety, because peat is a relatively safe product to grow vegetables and plants.

> "More environmental pressure on fossil materials, more legal possibilities for bio stimulants and circular materials as stated in the new EU fertiliser regulations."
>
> - Respondent Kekkilä-BVB R&D

The respondents are also fairly unanimous with regard to the logistics trends, with the following trends emerging: the use of local materials and the circular economy. The use of local materials shortens supply chains, lead times and reduces costs and labour. However, the question remains as to what can be seen as a local product, in which case the sector should establish a good definition of a local material. For some, what is considered local is already a non-local material for others. Despite the fact that there is no precise definition of what is local, the materials are likely to be extracted much closer to home in the future. An example of this could be that in Asia Cocos is mainly used, and in Europe we see a mix of peat and wood products. Innovations are also crucial in this respect. By developing new local products, products purchased from further away can be phased out, and the ability of certain bio-stimulants and fertilisers to control product properties also contributes to the use of more local products.

The creation of a circular economy fits in well with the use of local materials. A substrate of natural material lends itself well to composting. Compost can then be added to the substrate. At present, a substrate cannot yet consist entirely of compost, due to the requirements for product properties and food safety hazards. In the future, the percentage will probably increase because the right scientific knowledge will then be present to be able to control the product properties of the substrate.

"There has been a lot of attention in the most recent decade about the sourcing of local or regional materials for horticulture and food production as a whole. I do not see this changing but only increasing especially with the effects of COVID on communities, states, and nations."

- Respondent Research Institutions

In addition to the PLL factors, it is also noticeable in the MCDA that the social factors play an important role in the outcomes of the alternatives. Worldwide, there is currently a great deal of emphasis on improving the social standards of all continents, especially in Asia, Africa and South America. Improving these standards over time is therefore an important context factor. Improving social standards such as working conditions as working hours and salary can have a negative effect on the price of the alternatives. This can cause a certain demand for the product to decrease as social standards improve, which in turn can lead to more unemployment for these alternatives. However, it should be noted that improving social standards is much more important than the price, which also emerges from the preferences given in the survey.

Of these context factors, two driving forces have been chosen to build around the scenarios. The choice was made to regulate the growing media, especially peat use and harvesting, and to pay increasing attention to social standards. The political and legal factors are covered within the regulation parameter, while the logistical factor returns in the scenarios where the continuous development is included. Figure 38 shows these driving forces and scenarios that have been written at various locations along these driving forces which will be elaborated in the next section.

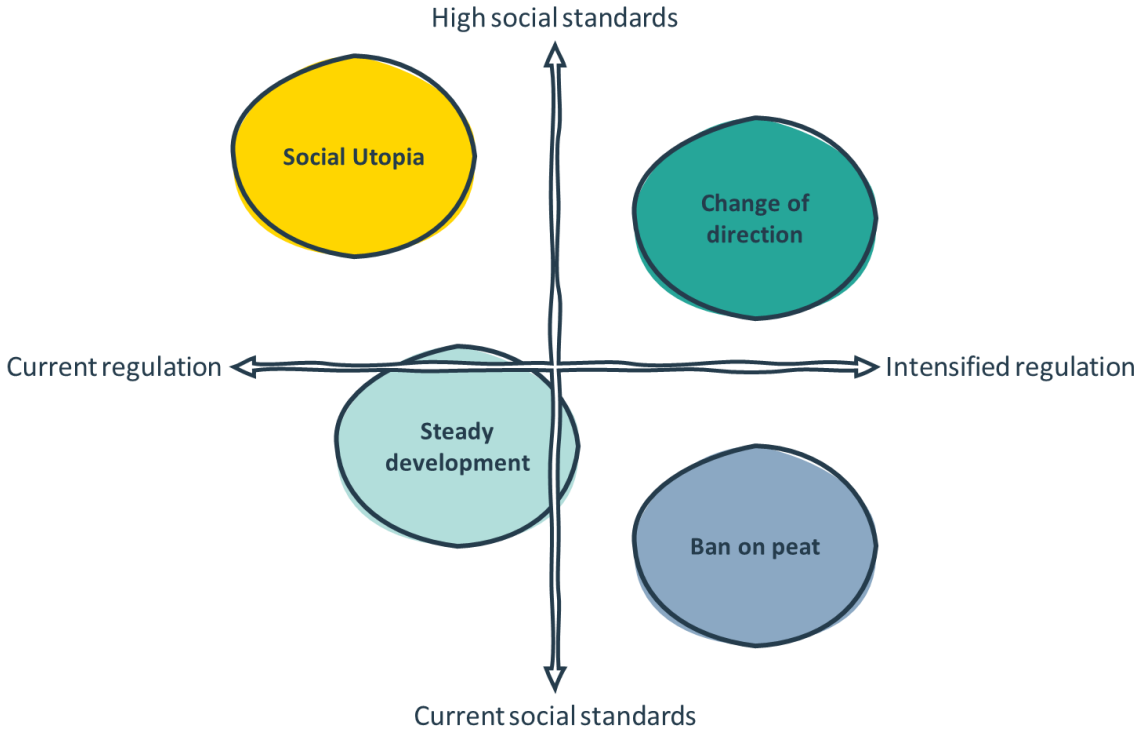

Figure 38: Driving forces with the explored scenarios

7.2 Scenario descriptions

The scenarios as shown in Figure 38 are described in this section. In doing so, the scenarios fall within the European context. First, the steady development will be discussed, followed by Ban on Peat, Social Utopia and Change of direction. The effects described in the scenarios will then be reflected in the MCDA table. For each scenario this may lead to a new ranking of the alternatives. The robustness of the MCDA model can also be assessed with the results of the scenarios (7.3).

7.2.1 Scenario 1: Steady development

Steady development is based on continuous improvement of the alternatives on the basis of the current situation. The products will be further developed, which will lead to a more efficient use of raw materials in the sector and a more efficient supply of substrates, which will lead to lower prices. Attention to social standards will also increase with regard to the seasonal workers deployed in Europe and the working conditions and environmental commitment in India and Sri Lanka. The increase in social standards will lead to a gradual increase in the cost price of the materials. Furthermore, within Europe there will be more regulation of the use of peat, with more and more attention being paid to the certification of peatbogs. This will not apply to professional horticulture because of the quality requirements, but it will apply to the retail & consumer and landscaping segments.

The steady development also has its advantages for the environmental performance of the alternatives. Higher efficiency and improvement of the processes leads to a lower footprint and (re)use of water. Logistics movements will also be increasingly CO_2 neutral, which also contributes to a better environment. Furthermore, the raw materials will comply more with the applicable requirements, they will become more controllable as there are fewer outliers.

Changes in MCDA

- Cost price changes due to higher efficiency rates and increasing social standards
- Improved chemical and biological analyses results and product development of Accretio
- Health & Safety to go up by one step. For example, an Medium health & safety score will become a High health & safety score.
- Environmental commitment to go up by one step.
- LCA values will decrease because of improvements made in the production process. The CO_2 neutral logistics will result in a decrease of 50% of the distribution CO_2 equivalent.

7.2.2 Scenario 2: Ban on peat

If the societal pressure on the carbon footprint continues to increase and becomes more prominent in the public debate, the use of peat will be put under increasing pressure. This will then result in the phasing out of peat within Europe. The choice for this will partly be due to the fact that the public and politicians have not got a good idea of the value of the substrate sector. The use of peat will then only be permitted from RPP certified fields. Depending on the time path to phase out peat to only certified fields, there will be scarcity on the market. The increasing use of other materials, of which less scientific knowledge is available, may lead to an increased risk for food safety.

The replacement of peat, the largest component, will require a lot of resources from other materials, which may also affect other ecosystems. An example of this could be that more Cocos plantations are needed to meet the demand for substrates, resulting in more polluted water and more workers coming into contact with particulate matter released during the production process. The banning of peat is also a great opportunity for innovations and new product developments for which there is then a lot of room due to scarcity. Some raw materials that now have a small share could then quickly gain ground, because there is simply less material available.

Changes in MCDA

- Resource security becomes very limited for peat products and also for the demand on coir products and woodfibres resources become more limited.
- The price stability of peat materials will become very high due to the scarcity of the material.
- The cost prices of all material will increase, because of the overall resource scarcity. Prices for peat material will increase more than prices for the other materials.
- The peat industry is losing its important position in the economy of certain regions, which will lead to the dismissal of workers. Job creation through peat production will lose its value.

7.2.3 Scenario 3: Social Utopia

This scenario is based on the extreme improvement of social standards throughout the world. Good working conditions, environments and ecosystems are not or hardly influenced by the companies activities. Health and safety equals the highest standards everywhere. However, this improvement in social standards also has negative consequences, such as an increase in cost prices and price stability. As a result, users of substrates could make different choices for the content of the substrates, as a result of which the demand for the more expensive products decreases.

Changes in MCDA

- All health & safety and environmental commitment scores go up to the highest scores. Now there is no differentiation between the products on the social performance.
- Cost prices and price stability for the alternatives that are improved at the social performance are less attractive.

7.2.4 Scenario 4: Change of direction

In this scenario, societal pressure will also increase, but not only on peat production, but also on the creation of a circular economy and the use of local materials. This will result in minimising peat production and raw materials from locations that are not considered local, such as Cocos, as much as possible. Peat is a local product for northern and central Europe, which is why its use will not be completely banned, but it will be restricted as far as possible under strict regulation. Through local materials, Cocos will be phased out as much as possible by materials present in Europe. This does not mean that Cocos is no longer suitable as a substrate, but that it will have to be used mainly in the regions where it is produced.

Within Europe this scenario will put a lot of pressure on the suppliers of the wood-based, inorganic and compost materials. Composting techniques will become increasingly important in order to meet the demand for local raw materials. Compost also creates a circular economy in which materials can be reused through composting. Developments from the other scenarios are used within this scenario, for example the development of certain products in terms of efficiency and the greater controllability of raw materials. Here again, social standards will improve and lead to better working conditions.

Changes in MCDA

- Resource security for Peat and coir based materials will become limited. Where compost becomes more widely available and thus resource security increases.
- Due to less available volumes of some of the most important constituents the cost prices of all products will increase due to scarcity.
- Because compost becomes more important, there will be more knowledge how to control all product characteristics which results in better test analyses.
- The circularity of inorganic materials increases within the sector.

7.2.5 Operationalisation

The changes in the MCDA have already been described for each scenario. These changes have been operationalised to the effects table as shown in figure 39. Here, the dark yellow areas show a large change and the light yellow areas a small change compared to the effects table in the current situation. The assumptions made to change the data with regard to the scenarios can be found in appendix VIII.

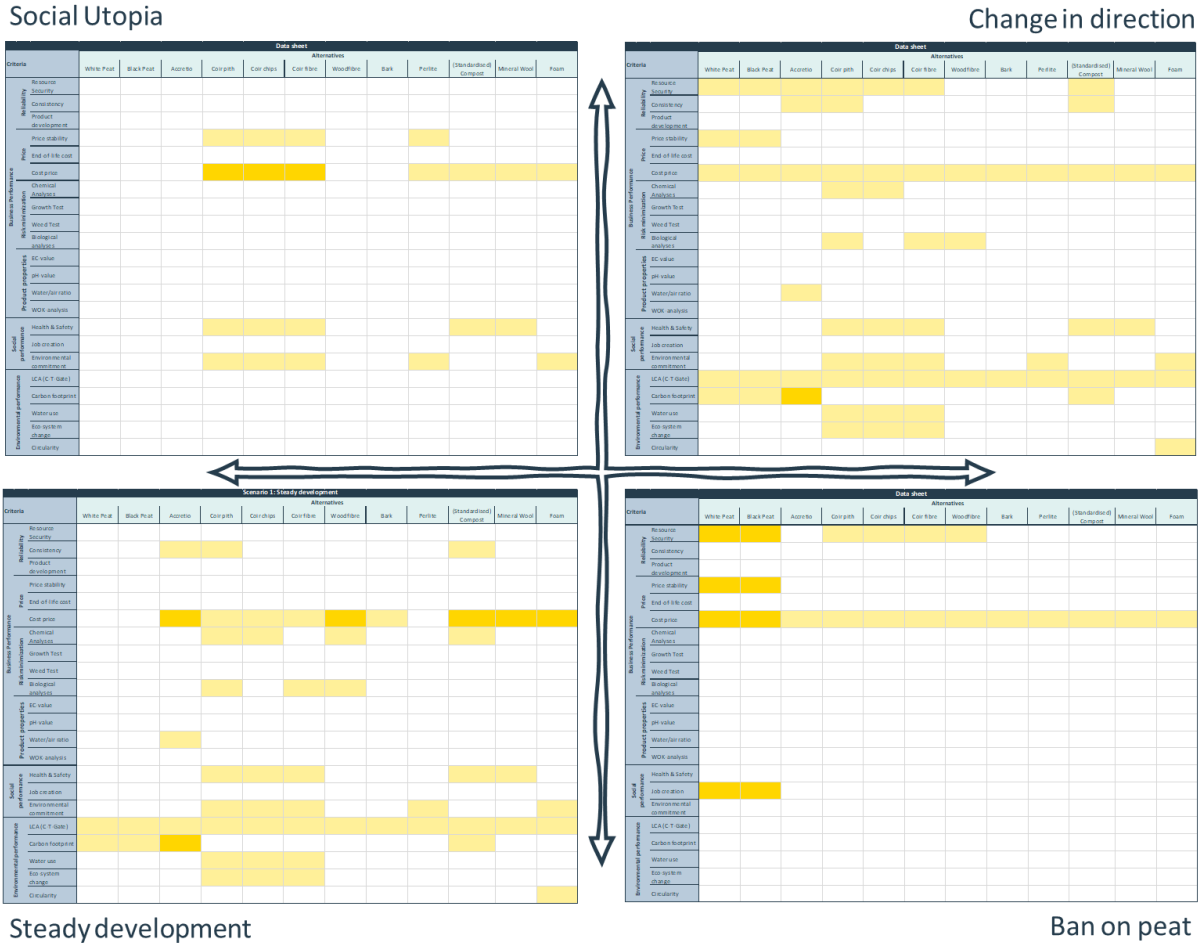

Figure 39: Operationalisation of the scenarios

7.3 Results

The results of the scenarios will be discussed over all the scenarios, but also on the basis of different decision criteria. As in the MCDA chapter, the results will be presented by means of the rang reciproke measurement method, because here too these results are the most representative with the current assumptions of the materials. The results per weighing method can be found in appendix IX.

Table 10 shows the ranking of the alternatives over the current situation and the four scenarios. The results under the scenarios remain relatively similar, with the exception of scenario 3 "Social Utopia". However, white peat scores lower than in the current situation. This can be explained by the increasing legislation for peat and the continuous improvement of the newer alternatives for growing media. The inorganic materials are therefore even more prominent in the scenarios. In the scenarios "steady development" and "change of direction" the continuous improvement and the shift to a more circular economy result in a higher position for compost. In "Social Utopia" the coir materials score better than in all other scenarios because the social criteria are "equal", because here no development has been taken into account compost scores the lowest. The robustness of the results is due to the fact that the differences between the alternatives are relatively large. When changes are made to a number of criteria, this does not lead to major changes in scores and therefore rankings.

Rang reciproke		Current situation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Alternatives	Perlite	1	1	1	1	1
	Mineral Wool	2	2	2	2	2
	White Peat	3	5	4	4	6
	Foam	4	3	3	3	3
	Woodfibre	5	4	5	5	4
	Accretio	6	6	6	6	5
	Black Peat	7	7	7	7	7
	Bark	8	10	8	10	9
	(Standardised) Compost	9	8	9	12	8
	Coir fibre	10	9	10	8	10
	Coir chips	11	12	11	9	12
	Coir pith	12	11	12	11	11

Table 10: Results of the scenarios

The rankings over the scenarios remain relatively the same, this does not apply to the weighted sum scores. In figure 40 it can be seen that the difference between the weighted sum scores has become much smaller. All materials, except the peat materials, generally show better scores, which makes it more attractive to use all alternatives. There can be seen that the weighted sum score of white peat remains relatively the same while the inorganic materials, perlite and woodfibre are all being developed further and will therefore be more attractive in the future than before, as a result of which white peat drops a few places from position 3. At the other side of the figure it can be seen that the (standardised) compost and coir materials all increase their score significantly, due to the improvement on business and social levels. The scenarios show that even though the rankings are very stable the alternatives have come closer together and therefore it becomes more attractive to use all different alternatives within the growing media sector.

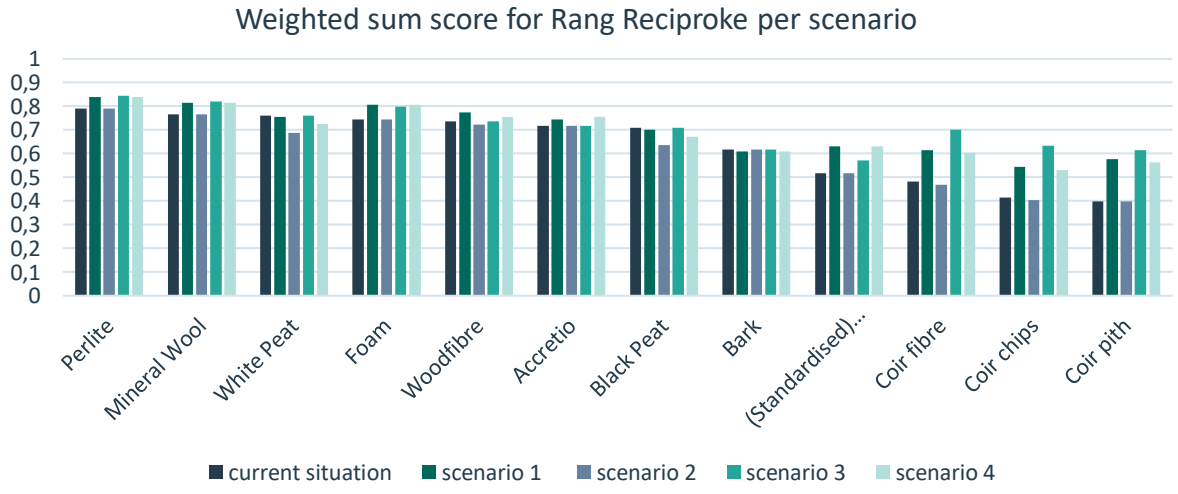

Figure 40: Weighted sum score per scenario for the rang reciproke method

Across the various scenarios, rankings can also be determined for the alternatives. Different decision criteria have been used for this, which look at how decisions can be made under uncertainty. This assumes that there is no certainty about the chance that a scenario will become reality. The first decision criterion is the MaxiMin criterion (Wald, 1950), where the minimum value of the scenarios is selected for each alternative. The alternatives are ranged along the hight of these values. The least regret criterion of Savage (1950) is the second decision criterion. Here the so-called 'regret' is determined for each alternative on the scenarios. The maximum score minus the score of the alternative indicates the regret. The maximum regret value is selected per alternative, after which the materials are ranked according to the least regret.

Thirdly the optimism - pessimism decision criterion of Hurwicz (1951) is used. Hurwicz uses the risk factor α, if the decision-maker does not want to run any risk then the α = 0. If the decision-maker wants to strive for the maximum benefit then it does not avoid any risk, resulting in α = 1. An α of 0.4 has been chosen because the sector is quite risk aversive, the raw materials must provide food safety and there must be no harmful substances in it. Now that the α has been determined, the score is calculated by adding the maximum value over the scenarios times α plus the minimum value over the scenarios times (1-α).

Whereas the first three decision criteria assume a completely uncertain chance that a scenario becomes reality, the fourth decision criterion, the indifference criterion of Laplace (1825), assumes an equal chance that the scenarios become reality. The scores on the scenarios are added together and divided by the number of scenarios to arrive at the weighted sum score. The higher the weighted sum score, the better the alternative scores. As fifth a decision criterion has been used in which is indicated what the chance is that a scenario becomes reality. The "Steady development" is estimated to have a chance of 40%. For the scenarios "Ban on Peat" and "Change of direction" a chance of 25% has been assumed. For "Social Utopia" this leaves a chance of 10%. This says more about the short than long term expectation. It is not possible to determine what the probability is of one scenario taking place earlier than the other. The results of the decision criteria together with the current situation are shown in table 11. The elaboration of the decision criteria can be found in appendix X.

Rang reciproke		Current situation	MaxiMin	Least regret	Optimism Pessimism	Weighted sum	Weighted sum 2
Alternatives	Perlite	1	1	1	1	1	1
	Mineral Wool	2	2	2	2	2	2
	White Peat	3	5	5	5	5	5
	Foam	4	3	3	3	3	3
	Woodfibre	5	4	4	4	4	4
	Accretio	6	6	6	6	6	6
	Black Peat	7	7	7	7	7	7
	Bark	8	8	8	8	8	8
	(Standardised) Compost	9	9	9	9	10	9
	Coir fibre	10	10	10	10	9	10
	Coir chips	11	11	11	11	12	11
	Coir pith	12	12	12	12	11	12

Table 11: Results of the decision criteria

The table shows that the MaxiMin, least regret, optimism - pessimism and weighted sum with certainty about the scenarios show the same results. Also the current situation and the weighted sum score under uncertainty show no major shifts. From this it can be concluded that under the various scenarios the scores of the alternatives are very robust. This can be traced back to the fact that often the values from the laboratory test remain somewhat the same, whereas the (natural) properties do not change or hardly change at all. Also, the price criteria often change in the scenarios, but these have the least impact on the scores, which is why this is hardly noticeable. These small changes will therefore not lead to position changes because the differences between the alternatives are relatively large. Overall, it can therefore be seen that the materials score the same way now and in the future, but that the gap between the scores of the materials is decreasing.

8 – Discussion

In this chapter, the research will be discussed through a reflection on the research method (8.1), a reflection on the used data and the implications in relation to the results and how the results of the research can be generalised to the growing media sector and its stakeholders.

8.1 Reflection on research method

The reflection on the research method is divided into four categories; system analysis, survey, MCDA and the scenarios. Within the categories limitations are addressed and there is discussed how these limitations are influencing the results of the research.

System analysis

In the system analysis the choice was made to describe the innovation system according to the Multi-Level perspective of Geels (2018) on the PESTEL categories (Aquilar, 1967). The multi-level perspective is ideal for the analysis of (innovation) systems, but also other more extensive system analyses could be used for this purpose. As a result, other developments and trends might be seen in some areas. The system analysis also focuses on Europe, given the horticultural hub in the Netherlands and the location of the company in Northern and Central Europe, the multi-level perspective mainly shows the trends and developments that occur there. In addition to the geographical conditions, the sector also serves the horticultural and consumer markets at the same time. These two points show that it matters at which level factors are placed, and that this can vary according to geographical provision and sales market. Certain developments from for instance southern Europe may therefore have been ignored or placed at a different level as when the research would be carried out within southern Europe.

In the system analysis the PESTEL categories (Aquilar, 1967) are used, extended with a logistical factor. This already shows that the categories are not independent. There is also overlap between certain categories, but the choice of the categories determines in which directions the system analysis is looked at. The categories show a very clear overview of the sector, but other choices could be made with regard to the categories which could lead to a different interpretation of the system.

Survey

When questioning the respondents, the choice of survey, the choice of questions and the selection of respondents all have their influence on the final results of the survey. (1) The selection of respondents plays an important role in the results of the survey. The survey tried to combine as much expertise as possible of the materials in the survey. Think of questioning different actors and departments in the sector, this way as many perceptions as possible are taken into account. Given the fact that of the 30 respondents 18 are involved in Kekkilä-BVB, the preference will largely be determined by this. However, Kekkilä-BVB is one of Europe's leading growing media companies, so the results will certainly provide useful insights. However, it cannot be excluded that other growing media companies will have different preferences in certain areas, as can already be seen, for example, in the difference between respondents from Kekkilä-BVB and other companies.

Geographical location also plays a role here, from the Growing Media Associations / Quality Marks and Research Institutions 3 of the 4 respondents are Dutch. As a result, the results may overrepresent north/central European or Dutch preferences, rather than a more divided geographical approach. In order to fill in the survey correctly, the respondents are experts in the sector. Because of this choice the respondents will be positive towards the sector. The conflicting opinions could not be taken into account due to the detailed criteria, as they lack technical knowledge. Think, for example, of certain environmental organisations and lobby movements against the emission of greenhouse gas emissions.

In addition to the selection of respondents, (2) the method of questioning also plays an important role in the final results. In the survey, respondents were presented with pairwise comparisons, making a choice between criterion A, B or indicating that these two criteria were equal. They could also choose to question it in another way, such as using the AHP method (Saaty, 1980). whereby the respondents indicate their preference between the criteria on a nine-point scale. Scaling on a nine-point scale does make it more complex for respondents, so they could quit to complete the survey. In addition to the AHP, there could also be chosen to exclude the choice "the criteria are equal", which obliges the respondents to make a choice. As a result, in addition to the Condorcet (1785) method, Borda can also be used to determine the group preference. Using a different scale can lead to different results of the preference and its use further in the research.

When it comes to the method of questioning you can also question what is being compared (3). In the research it was decided to compare the criteria with each other, but there can also be chosen to compare the different alternatives and to determine the preferences of the criteria on the basis of these preferences. Due to the fact that the materials have so many criteria, it was decided to do the comparison on criteria and not on the alternatives. The fourth point is the survey itself. (4) Preferences can also be determined by other means. For example, you could interview the particular actor groups (expert meetings) and determine the rankings for each group and then aggregate them. This would allow the various actor groups to discuss with each other and share their knowledge, observations and opinions, which might eventually lead to a different picture of preferences.

MCDA

It was decided to perform this research with an MCDA method, in this method the impact table (Edwards, 1977) used. However, as already indicated in the discussion of the survey, other MCDA methods can also be used to compare the raw materials. In the described steps of the MCDA, other choices can also lead to other outcomes, which will be discussed in this section. The first to be discussed are the (1) criteria, which have been drawn up on the basis of a goal tree. As a result, the criteria are clustered and compared per sub-category. Other researchers could make different choices between categories in the distributions of the criteria, leading to different pairwise comparisons. The hierarchy also limits the number of comparisons, which makes it easy for the respondents, but no hierarchy can be made either, which means that all the criteria have to be compared between each other. This way, criteria that have nothing to do with each other are also compared. The distribution of the criteria is based on different scientific articles in which a similar distribution has been made and then validated by the different departments within Kekkilä-BVB.

Only measurable criteria can be included in the MCDA, (2) therefore the method is not comprehensive and (non-measurable) criteria will not be included in the MCDA. For decision making it is important to map out these non-measurable criteria and specific properties of the raw materials in order to be able to make a well-considered choice. An example of these are the certain technical characteristics that are particularly important for one crop while they are not important for another. In determining the group preferences, the choice of the researcher plays an important role. (3) When determining the group preferences, the choice of the researcher always has to deal with the impossibility theorem of Arrow (1951) which indicates that it is never possible to make a group preference that meets all the requirements. Where now the choice has been made to take the group preference with the three answer possibilities where possible and otherwise with two variables. If the answers are not the same, you could also use the method of Borda. The researcher could also take the liberty and determine the group preference with all parties involved on his own interpretation.

Subsequently, the group preferences should be converted into impact scores. (4) Determining these impact scores is complex because of the pairwise comparison, as a result of which the exact trade-off between the criteria is unclear. On a wider scale, the trade-off could be better determined, which leads to a more precise impact score. In order to still provide a complete picture, the impact scores have been calculated in four different ways and the results have been examined. In this way, the flaw of pairwise comparison is compensated for, but it still remains a matter of guessing where the exact trade-off between the criteria lies. The particular preference can therefore lead to the impact scores in many different ways, as a consequence of which the results can differ.

Scenarios
The creation of the scenarios was based on two described context factors around which the scenarios were built. The choice of context factors determines the direction in which the future is explored, another choices leads to different scenarios and perhaps also to outcomes of the scenarios. The choice was made for the two factors, social improvement and increasing legislation, where the most interesting futures could be explored with the MCDA. These two axes do not take into account all the driving factors of the system analysis. Legislation represents the driving forces of political and legal. Where the logistical trend does not show up in the axes, it does show up in the particular scenarios. The same applies to external factors such as a circular economy and the possibilities for data driven growing. Due to the major impact of the social factors, it was decided to take them into account as a context factor, also because of the fact that the sector can exert relatively little influence on the social conditions at suppliers if there is already scarcity of raw materials and can therefore be seen as an external factor. For example, it could also have been decided to include increasing legislation and the transition to data-driven horticulture in the scenarios. A different choice leads to different explorations. The future remains uncertain and another researcher would probably have arrived at different scenarios in consultation with other companies and institutions.

8.2 Reflection on used data

In this section, a reflection will be given on the data used, what influence the particular data assumptions had on the research and how the data was validated. First of all, a reflection on the massive growth expectations for the growing media sector would be appropriate. This growth is a global projection, given the growth in world population and the efficiency that can be achieved by growing on substrates instead of from the ground. This transition will lead to enormous growth, especially in the continents, Asia, South America and Africa. While for the European market, which is already for a large part growing on substrates, a growth of 200% is expected in the year 2050. The growth will probably not lead to the same growth in required volume, while this is mentioned in the report. Due to more efficient cultivation and therefore less consumption of natural materials and a more circular flow, the 200% growth in Europe will not lead to a 200% growth in volume.

Next, a lot of internal data from Kekkilä-BVB was used in this study. For each criterion, we looked at where the most reliable data could be found. This could be via scientific sources and professional journals, which is applicable everywhere. But for many criteria internal data from Kekkilä-BVB was used, which is specifically measured on location level. As a result, the results of the research can be applied on location level and perhaps on a Dutch level for Kekkilä-BVB. For any other company or location the internal data will differ and this can lead to different outcomes in the MCDA. At the same time, the differences between the alternatives are relatively large and the differences in the data of other companies in the Netherlands will probably not differ much. However, the logistical component plays a significant role in a number of criteria, such as price, availability and environmental considerations, which is why the results are not one-to-one transferable to other growing media companies within Europe. The framework does offer a possibility for companies to implement decision making per location. Where the data may not be reproducible, the MCDA model, with its criteria and preferences, can be very valuable to other companies in Europe. Growing media companies can add their own data sources and alternatives to the model in order to compare raw materials themselves.

For the determination of data, certain measurement methods have been used that are most relevant at the moment, however, a number of remarks can be made about certain measurement methods. For example, research is being conducted into creating uniformity of LCA values within the sector. The results of this research may lead to a different interpretation of the LCA value. Furthermore, at the moment there is no single unambiguous analysis to arrive at a biological score. In the coming years a lot of research will be done to gain more insight into the biological activity of the raw materials. The measurement methods used may change over time, which may lead to different results for certain alternatives. Different measurement methods may also be used between countries and continents. An example of this is the different methods used to determine the pH-value, which differs in the Netherlands from other countries in Europe. Different methods may not lead to different outcomes for the alternatives, but it may lead to a different scale having to be applied in the MCDA.

In the research it was necessary to make assumptions about the data for various criteria and alternatives. Assumptions can be filled in in different ways, such as the carbon footprint at Accretio, which is estimated much lower with the use other sources. It was investigated whether major changes to the assumptions led to differences in the results, this was not the case. However, it is important to collect more data in order to arrive at a reliable data point instead of using an assumption. In addition to Accretio, foam also required a number of assumptions due to the lack of data. By looking at other databases and finding relationships with the data from the growing media sources, it was possible to arrive at assumptions, which were then validated by experts within Kekkilä-BVB. Validation of the data took place via experts at relevant departments of Kekkilä-BVB and information and guidelines found in RHP manuals. As a result, validation is mainly based on the knowledge and experience people have with the material. Perhaps other geographical conditions would have resulted in other choices to be made with expert validation. Overall, it can be said that the data used in the MCDA is very reliable for use at local/national level, but that the use of the data for other companies and locations in Europe is not reproducible one to one.

8.3 Implications

The implications will be described by outlining consequences based on the results of the research, after which the general applicability of the research will be examined. Overall, the results are relatively stable, because the differences between the alternatives are significant. For example, the inorganic materials have no technical deviations at all, while compost and coconut materials have a high risk here. In addition to the technical risks, the most socially unfavourable conditions have also been observed with these materials. Many of these technical risks also affect human health and safety. For instance, when methane is released during composting, it is harmful not only for plant growth but also for people coming into contact with it.

In order to improve the score of the low-scoring alternatives in such a way that they are equivalent to the natural products, such as white peat and wood fibre, social conditions need to be improved, as these have the most impact on this. Collaboration between growing media companies and their suppliers is crucial here. Due to the scarcity of raw materials, the growing media companies may have little influence on the social conditions at suppliers, while as a company you want to be sure that the product has been made in compliance with the highest social standards. In addition to good cooperation at regime level, at landscape level the national governments could come up with legislation and the associations and quality marks could carry out more checks to ensure that the social conditions are improved.

Subsequently, the alternative will have to be more stable in order to perform better on the business level. A more stable material can be achieved by improving the production process at the supplier or at the growing media company. In this way, the supplier can try to harvest in a more responsible way or there can be better cleaning upon arrival of the material. In addition to improvements in production, new scientific insights from researchers can also lead to better results for certain alternatives. Naturally, a raw material must not be harmful to public health or to the plant, but there are major differences between the various customer groups in terms of quality. For professional horticulture, the safety and efficiency of the substrate is crucial for the cultivation of vegetables, fruits and plants. But for the retail & consumer and landscaping market, the functionality of the substrate is less essential, here the customer may not mind if growth is slower due to a less optimal composition of raw materials and additives.

In terms of environmental compatibility, the raw materials may not differ very much in terms of scores, but there are differences on the underlying criteria. Notable are the emissions of greenhouse gasses from peat products and the water consumption of coir materials. The underlying distributions between the effects of the production and logistics of the product are also significant. Geographical location and the density of the raw material are of crucial importance here. For the harvesting of peat, there are new developments to reduce greenhouse gas emissions, but these will reduce the volume to be harvested while there is scarcity on the market. The trade-off between food security and limiting environmental damage is a very important one, both of which contribute to the SDGs. This is a trade-off that is important at both landscape and regime level and requires coordination between governments, growing media companies and other interest organisations on the one hand, and cooperation between growing media companies, suppliers, customers and logistics parties on the other, in order to look at the possibilities of both providing food security and improving the environment.

At the niche level, a number of developments can also be seen on the basis of the results. It can be expected from the R&D departments of growing media companies that the alternatives will be developed further and that they will carry out research into possible new (circular) raw materials. The latter can also be seen in a number of start-ups that try to grow certain products on residual flows, this development leads to the use of more local products in the growing media sector. In the coming years, researchers and scientists at universities and companies will pay a lot of attention to biological activity in substrates. Questions that will be addressed here are how this biological activity can contribute to cultivation and be kept at a manageable level. How can (organic) fertilizers contribute to these properties of substrates in order to achieve an optimal cultivation. This will provide more reliable data for the criteria of biological analysis in the MCDA.

Next is the focus on data driven growth, which is gaining ground in professional horticulture. More and more growers want to grow more data driven and the Internet of Things makes it possible to make real-time decisions. This makes it possible to collect information about the state of the substrate during cultivation, which can lead to a higher efficiency and improvement of the substrate. This leads to a more sustainable cultivation strategy. Furthermore, research into the environmental effects of the materials contributes to limiting the damage caused to the environment. For all products, the production process needs to be reviewed by suppliers, logistics parties, growing media companies and customers in which areas in the supply chain more sustainable choices can be made without compromising on price, quality and quantity.

The consequences described with regard to the results can be generalised for the system up to certain dimensions. At landscape level, regulations may vary from country to country, giving other factors greater priority than elsewhere in Europe. Within the various customer segments, differences may also occur at European, national or even local level in terms of legislation and lobbying movements. In this study, western / northern European insights and regulations are taken into account in particular. For the governmental bodies and associations, the results of this research are therefore useful for the western and northern European countries, specifically the Netherlands and Finland.

A similar consideration is possible at regime level. Within Kekkilä-BVB and the Netherlands the results can be generalised, but the data can differ per location. However, this is expected to result in minimal differences. Product specifications will not so much differ, but some are location specific. Results are therefore not transferable one on one, but the framework offered by the MCDA is transferable, because the perspectives on the sector do not differ and give stable results. However, it is possible that on small points the perspectives differ between companies. In principle, it can be said that the framework with its relationships is applicable and representative for the entire European sector, on condition that the data is filled in per company and location.

The results of this research show that innovations can be compared with the current set of raw materials, on condition that data is available. In order to take these innovations into account, a number of assumptions had to be made for recently introduced products, Accretio and Foam. These assumptions were then validated, but are believed to be different from the actual number. The results are therefore generalizable for Kekkilä-BVB, because of their knowledge of the current production process of these innovations and these can differ across other companies in the market, which can make a big difference in the score of the alternative. For the other alternatives there is relatively little difference in the production processes. In addition to the innovations for which data was available, there are also long-term innovations for which data is not yet available. These can be included in the MCDA when data is available. The results from the long-term evaluations with their advantages and disadvantages can be used within Europe, there are no obstacles in terms of generalizability in terms of legislation or geographical locations.

Overall, the results of the study are therefore generalizable, on condition that they are used at the appropriate level and geographical position. The results as well as the data used can be generalised at company and Dutch level, for other companies and countries there can be (large) differences with the use of own data. The framework outlined with the MCDA of the criteria and preferences in place is applicable within the entire European growing media sector and can also apply to continents outside Europe, on condition that the same preferences are assumed there and the necessary technical knowledge about the raw materials is available.

9 – Conclusion & recommendations

This chapter will first give an answer to the main research question (9.1), followed by the answers on the research sub-questions (9.2). After which the recommendations for the growing media sector are presented (9.3). The societal and scientifical contribution are discussed in paragraph 9.4 and 9.5. In 9.6 the future research recommendations are presented.

9.1 Answer main research question

In order to give a clear and precise answer to the main question, it has been phrased below:

What developments and analytical tools can contribute to decision-making in the growing media sector in its transition to a sustainable sector?

The developments that have emerged from this research all contribute to the transition to a sustainable substrate sector. As a first development, the circular economy is relevant. Due to research and embedding of a circular economy, there are many opportunities for circular products such as (standardised) compost and other residual materials to be used more in the growing media sector. In addition, the growing global population and healthier diets show that the demand for substrates will increase worldwide. This will lead to scarcity of raw materials, requiring more sustainable, circular products to meet the demand for food.

On the other hand, customers expect a reliable, stable and save product. The use of materials with more deviations in quality does not contribute to this. Developments such as data driven growing and microbial horticulture make it easier to manage the substrate to the right conditions. Both trends then allow certain characteristics of the materials to be better controlled, making more materials usable to be used in a substrate and on the other hand more stable substrates with less deviations. It makes it more accessible to use local materials. The use of local materials is one of the expected developments, which will minimise the logistical impact on the environment. European legislation on the use of certain materials is a development that is being closely monitored by the sector, given the major impact that stricter regulation may have on peat. On the one hand, this will lead to a reduction in greenhouse gases, but, on the other hand, food security may be compromised. The sector associations should therefore make this important position well known to the policy makers.

Besides the developments the growing media sector can derive insights from the analytical tools, enabling decisions to be made between the various incoming raw materials. In this research a Multi-Criteria Decision Analysis has been developed, as an analytical tool, to compare different incoming materials in the European growing media sector. Each growing media company can include its alternatives and data in the MCDA to compare raw materials on a business, social and environmental level. Based on the MCDA for incoming raw materials of Kekkilä-BVB in the Netherlands, interesting conclusions can be drawn for the European growing media sector to be able to operate in a more sustainable way.

Four groups of alternatives can be identified with regard to the results of all respondents and the different actors. The most preferred alternatives are white peat, perlite and wood fibre, followed by Accretio, mineral wool, foam and black peat. In the third group we find bark, followed by (standardised) compost and the coir materials. For the future, scenarios demonstrated that the order of the alternatives is very robust, which is because of the large differences between the alternatives. However, it can be seen that the importance of white peat will decline in the future and that materials such as wood fibre, perlite and inorganic materials will perform better as white peat as a result of continuous development. It can be concluded that the differences between the materials will decrease in the future, making it attractive to use all the different alternatives in the growing media sector.

Despite the fact that the MCDA is not comprehensive, comparing certain materials against each other is helpful in decision making. In order to meet the future demand, all materials will be important, so this MCDA is not about making a choice between the materials, but rather about looking at where the materials can be improved, so that each material delivers the same benefit to the companies. Current and future developments will contribute to the more efficient use of materials and will ensure that multiple materials can be applied easily through better control of the properties. The future of the sector therefore includes peat, whereby it is necessary to look where its use can be limited and more sustainable materials and improvements can be implemented to foresee in a sustainable growing media sector.

9.2 Answer research sub-questions

1. *What are the main developments, in the field of market trends and innovations, to make the growing media sector more sustainable?*

The main developments are described along the levels of the multi-level perspective. The landscape factors Circular Economy (CE) and the Farm to Fork strategy enable opportunities for the growing media companies to operate more sustainably, at the same time these trends put greater pressure on raw materials, such as peat, which releases greenhouse gases. In the CE there are currently opportunities in the retail & consumer and landscaping segments, if the results of more circular products are successful and it can be applied efficiently and safely it is an opportunity for professional horticulture. However, the transition in professional horticulture will take longer, because the sector has to provide food security for consumers, which is why the current non-circular materials are difficult to exclude. In the field of logistics, the landscape encourages more multi-modal transport and the use of more sustainable options. This will also contribute to a sustainable sector, the logistics movements are significant for some alternatives.

Global population growth and a shift towards a healthier diet will lead to an enormous growth in the demand for substrates. The most important thing is that the substrates provide safe and sufficient food. In order to meet the future demand and a sustainable sector the following trends and developments are important on regime and niche level: Data driven horticulture, Microbial horticulture and the use of more sustainable materials. Data driven horticulture will allow the grower to better steer the substrate and the plant growth, thereby optimising the outcome and reducing waste. Microbial horticulture provides the optimal possibilities to create an optimal bio life for the plant. Once it is known what needs to be added to a particular substrate to achieve the desired outcome, this will lead to larger harvests and less waste. Both trends then allow certain characteristics of the materials to be better controlled, making more materials usable to be used in a substrate and on the other hand more stable substrates with less deviations. The raw materials can therefore be applied more locally, for example, Europe can use peat from RPP certified fields and Asia will make more use of the coir products. By better controlling the properties of the raw materials, the sector will be less dependent on the use of peat in the future.

At present, the sector will still depend on the use of peat to meet demand and guarantee safety. It is easy for politicians and outsiders to form an opinion against the use of peat in the growing media sector, but in reality it is very complex to guarantee quantity and safety with the use of other raw materials that do not have the same clean properties as peat. Where a large amount of knowledge has already been gained about peat, this is less true for the other raw materials. Ongoing projects in Europe will increase knowledge about all materials and their characteristics in order to be able to make a better sustainable choice between them.

2. *What are the alternatives for peat substrates in the short and long term and what are the advantages and disadvantages for market expansion?*

The alternatives are divided into different groups; (1) where the alternative is suitable for the current system, (2) where part of the system needs to be adapted and (3) where a completely new system needs to be implemented. For short-term alternatives, most belong to the first group. This first group includes coir materials, wood-based materials, perlite and (standardised) compost. Advantages for market expansion are overall the good properties of the raw materials. The barrier for expansion lies mainly in the many deviations of these raw materials and it is often not possible to completely replace peat within the substrate.

For Accretio, adaptations to the current production process are necessary and therefore belongs to the second group. The product has a lot of potential because its properties are very similar to those of white peat. Challenges are the available quantity, as the quantity to be harvested is only 30cm. Increasing regulation is also a risk for Accretio, as it concerns the moss layer on peatlands. The inorganic materials belong to the third group, because mineral wool and foam require a completely different system. The great advantage of these materials is that they always have the same properties and are therefore very stable. The disadvantages are that there is no natural protection for the plant and that these products cannot be used in every market segment. Of all the short-term alternatives, only compost is cheaper than peat per m^3, the other alternatives are more expensive and therefore less attractive to use more often in substrates.

Whereas in the short term there are many alternatives that can be used right away, in the long term there are more alternatives that require adjustments to the system. Cococrush, a combination of the coir materials, could be used immediately in the system. It makes the production process easier, but at the same time it does not change any of the negative characteristics. The use of grasses and residual materials does require a different system approach. For grasses, the advantage is that it can be harvested locally and there is sufficient of it, only it has fast vegetation and it is difficult to maintain the same quality. Much is expected of the residual materials as it provides circular and local substrates. However, at the moment this is still very difficult because of the properties of these residual materials, they are not clean and have many deviations in quality.

Hydroponics and Microbial horticulture are long-term trends that require a lot of changes to the system, but they are extremely interesting for the growing media sector to operate more sustainably. Hydroponics, for example, requires little substrate, so the scarcity will be less high. However, microbiological contamination is possible and nutrients and fertilisers cannot adhere to the roots. Microbial horticulture provides a higher plant resilience and an increase in the use of local materials. However, micro life can also be harmful to the plant and is difficult to determine as natural materials are constantly changing. All these alternatives mainly describe structural and technical barriers in the sector. Financial barriers only come up if the material is safe and efficient enough for use in substrates. First, the alternative must meet all the applicable requirements in the technical field and must be sufficiently available.

3. *What are the criteria for growing media selection and where are the priorities between these criteria for the sector and different actors?*

The criteria for growing media selection are subdivided into Business performance, Social performance and Environmental performance. The business performance includes the reliability, price, risk and product properties criteria. These entail the availability of (natural) resources, cost prices, price fluctuations, product consistency & development, risk minimization and several product properties that are typically measured by laboratory tests.

The criteria of social performance consist of growing media production and / or use that may affect the health or safety of people, employment and social equality. The commitment of the producers and / or users to the well-being of their employees and affected communities, and to preserving their environment. The environmental performance of growing media can be measured in terms of greenhouse gas emissions, and the impact of their production and/or use on eco-system and landscape.

Next, the survey shows the priorities of all respondents and the different actors on all the criteria. The results show that the impact scores score relatively equal across the various weighing methods. What stands out from the impact scores is that despite business performance having the highest priority, the social criteria have the highest impact. This is due to the number of criteria that still depend on the business and social criteria. In spite of small differences in the group preferences, the impact of the different actors was more or less the same. For all respondents, more emphasis was placed on the technical criteria, where resource security played a greater role among the actors.

4. *With this prioritisation, how do the short-term alternatives score and can differences be seen between the actors?*

As can be seen from the various weighing methods, despite small shifts in the top seven alternatives, the results are very stable. Four clear groups can be distinguished for all respondents. The first alternatives with the highest weighted sum score are perlite, mineral wool, white peat and foam, closely followed by woodfibre, Accretio and black peat. Between this group and the lowest alternatives is Bark followed by (standardized) compost and the coir materials. The fact that the result over the various weighing methods is so uniform is due to the relatively large differences between the groups of alternatives, which explains the small shifts that can be seen within the top and middle.

This stable order is also reflected in the rankings of the various actors, growing media companies, growing media associations / quality marks, research institutions and customers. However, it was concluded that woodfibre scores much better among the actors than among all the respondents. In contrast, the inorganic materials dropped a number of places among the actors. Both these shifts are due to less impact for risk minimization and product property criteria. In terms of weighted sum scores, changes can be seen between the groups for black peat, bark, compost and the coir materials. For example, black peat, bark and compost score higher among the growing media companies than the other groups. The opposite is true for the coir materials. These score higher with research institutions, but this does not lead to changes in the ranking order.

It can be concluded from the results that, despite the differences in preferences between the groups, the results are very stable. This is due to the relatively large differences between the products. There are small shifts between the groups, however, because the scores are so close together. There were also differences in preferences, but these too were relatively small and there were no completely different preferences between the groups. Four groups of alternatives can be identified with regard to the results of all respondents and the different actors. The most preferred alternatives are white peat, perlite and wood fibre, followed by Accretio, mineral wool, foam and black peat. Bark has again been placed in the third group, as have (standardised) compost and the coir material.

5. *What kind of scenarios infer from the driving forces and how robust are the outcomes under these scenarios?*

For the scenarios, driving forces have been described about the political, legal and logistical factors, as well as driving factors at the MCDA. Therefore, the driving factors of increasing legislation and social circumstances were chosen for the scenarios. Increasing legislation represents the political and legal factors, where the logistical and other driving factors are more evident in the scenarios as a whole. Four scenarios where inferred: Steady development, Ban on peat, Social utopia and Change of direction. 'Steady development' represents the further development of the current situation. With 'ban on peat', the use of peat is restricted, which also has consequences for the other alternatives. In the scenario 'social utopia' the consequences are investigated if social conditions would improve worldwide and the scenario 'change of direction' represents influences of all three scenarios and is therefore the most far reaching.

The results under the scenarios remain relatively similar, with the exception of scenario 3 "Social Utopia" where the coir materials have improved their position. Compared to the current situation white peat scores lower in the scenarios. This can be explained by the increasing legislation for peat and the continuous improvement of the newer alternatives for growing media. The robustness of the results is due to the fact that the differences between the alternatives are relatively large. The scenarios show that even though the rankings are very stable the alternatives have come closer together.

From the different decision criteria it can be concluded that under the various scenarios the scores of the alternatives are very robust. This can be traced back to the fact that often the values from the laboratory test remain somewhat the same, whereas the (natural) properties do not change or hardly change at all. Overall, it can therefore be seen that the materials score the same way now and in the future, but that the gap between the scores of the materials is decreasing. Looking to the future, the scenarios show that the further development of the newer materials, as woodfibre, mineral wool, foam and Accretio will give them a higher / equal score than white peat. In general, materials will be closer together in the future. The difference between the highest and lowest scores is decreasing significantly, making it more attractive to use all alternatives within the growing media sector.

9.3 Recommendations for the growing media sector

The recommendations for the growing media sector include advice on how to use the MCDA tool and how to respond to trends and developments in order to create a more sustainable growing media sector. These recommendations contain advice for all stakeholders involved in the growing media sector.

For the involved stakeholders on landscape level several recommendations are made. Associations, for example, should take better care to ensure that the sector is well represented to the European Union and national governments so that its vital function is better expressed. This will also make it more clear to the authorities that legislating on fewer greenhouse gases can lead to food security being compromised. Next, the national governments could come up with legislation and the associations and quality marks could carry out more checks to ensure that the social conditions are improved. The developments described in the conclusion lead to recommendations at regime and niche level.

The conclusion shows that focusing on data-driven and microbial horticulture creates a more circular and sustainable growing media sector. (1) It results in less waste, (2) it allows better control at the substrate (before and during) which leads to more possibilities for alternative materials and (3) it ensures a better yield at the grower which requires less material for the same yield. To achieve this, the sector will have to invest in research by universities and R&D departments into microbial horticulture and will have to focus on the use of measuring equipment at the customer and establish relationships between the data and what happens to the plant, so that plant growth can be optimised. This include trials with sensors, platforms, artificial intelligence and cooperation between the growing media companies, customers and data platforms.

There is then an opportunity by focusing on a circular economy. Companies are currently focusing on residual flows of materials, but in general there is too little activity here to embrace these residual flows as materials in the sector. For one company it may be difficult to investigate such residual flows, but when they work together or run the project through GME in cooperation with other associations and universities, the residual flows can be better investigated and applied more quickly in the sector. More attention will also have to be paid to residual flows from the sector itself. Although the substrates are not wasted, a more useful alternative could be identified. To this end, the sector would have to look outside its own arena, to see for which parties a used substrate could be of added value.

In the outcomes of the MCDA, companies should focus on the bad scores of the raw materials and start projects to improve these bad scores in cooperation with the involved stakeholders for these criteria. This will make it more attractive to use more materials in the sector. In addition, growing media companies should calculate the MCDA for each site or country to determine which materials are suitable for current use and which should be focused on in the future. Where on landscape level governments can create the infrastructure for better social conditions, the growing media companies and suppliers can cooperate together to improve the social conditions at their sites. Furthermore, better data collection on certain points in the MCDA could lead to precise scores of the alternatives rather than the use of assumptions, which would make the scores more reliable. This data will come from performed researches by universities, R&D departments and research institutions on technical and environmental performance of the substrate.

At present, peat remains essential in the sector in order to move towards a sustainable food chain. However, the sector should look where peat really adds value and where an alternative could give the same result. The RPP certification is a good step in this respect, but within the market segments, too, it is necessary to look at where the share of peat can be reduced and where it is essential to use it. Reviewing all processes to see where it can be more efficient and sustainable also applies to the supply chain. Checking these processes requires cooperation from Growing media companies, suppliers, customers, logistics companies and universities. The international and national associations can play a key role here by facilitating the process. In the environmental area, cooperation is currently taking place, in particular, with a view to finding a uniform method for the LCA in Europe. This cooperation of all parties in the sector with GME is a good example of how action can be taken in this area. Cooperation between the growing media companies, associations and universities makes it possible to set up new studies into the environmental impact of alternatives for peat, so that a more detailed picture can be created.

The recommendations cover advice for actors at landscape, regime and niche level and mainly include opportunities to work together between parties in order to achieve a more sustainable sector. After all, the consumption of peat is not only the responsibility of the growing media companies, but also depends on the alternatives available and the demand from the market. Governments and associations have an important role to stimulate and facilitate this type of cooperation.

9.4 Societal contribution

This research is contributing to society on a number of issues, which are linked to the SDGs. For example, the system analysis and comparison has created insight to operate more sustainably. The substrate sector provides the world with the right soil to grow their fruit and vegetables. As a result, we are working towards a world with zero hunger (SDG 2). A healthy diet and lifestyle (SDG 3: Good health and well-being) are also becoming increasingly important and healthy food plays a crucial role in this. Increasing healthy food can be created by improving the efficiency of growing on substrate or by switching to growing on substrate. This research is helping to make this possible in a sustainable way, using safe and reliable materials.

This study describes the growing media sector and the associated infrastructure at landscape, regime and niche level. It describes relevant developments that contribute to SDG 9: Industry, Innovation and Infrastructure. Actions have been formulated for the various actors in the system to work towards a sustainable future (SDG 17: Partnerships for goals). The circular economy plays a major role in this, with increasing attention given to how products can become more circular and where raw materials are wasted in the production process. This report describes various possibilities for circular alternatives in the substrate sector and which advantages and disadvantages currently still apply. Circularity and less waste contribute to SDG 12: Responsible consumption and production. This research helps actors in the substrate sector to make well-founded choices based on developments and a fair comparison of incoming raw materials that will result in a more sustainable sector.

9.5 Scientific contribution

This research has made several scientific contributions. (1) The combination of methods with the PESTEL categories, for example, is a good way of providing insights into the system and advice on the various alternatives available to contribute to the issue. (2) A method has been used in the elaboration of the group preferences in which a preference is created through three variables. (3) The complete overview of the applicable criteria for substrates and how they can be placed in context indicates where scientific research can focus in order to create the most impact. In this section the lessons learned during this research are also discussed.

(1) The combination of the multi-level perspective and MCDA with the PESTEL categories provides a structure to first define an issue in a broader context and then address the issue more specifically with the same framework. In this way, the system analysis described the developments in the PESTEL categories and the MCDA and scenarios further specified these categories as criteria and driving forces. The contribution of this method is that global developments at the 3 levels are taken into account in an MCDA in which it concerns the incoming raw materials for substrates. Working with a method similar to this ensures that during an research the structure is clear the whole time.

(2) When determining the group preferences, it is important that the preferences represent the respondents' answers as accurately as possible. For this research Condorcet's method was examined, but this method looks at the number of times a respondent chooses a criterion. Therefore, if the criteria were chosen the most often to be equal, this was not taken into account and the Condorcet method went for the criterion that was most often preferred. The used method does take the equal answers into account and looks at which of the three answer options, A, B, the criteria are equal, is chosen the most often. However, should this not result in a consistent group preference, the method of Condorcet has been chosen. This method worked very well in this study and also gave a more representative picture of the respondents' answers. In studies where group preferences should be determined and where there is a possibility to indicate that certain answer options are equal, the method used can really be of added value in order to achieve a more representative group preference.

(3) The certain impacts of the criteria are a contribution to science. The impact shows what is considered to be the most important for substrates. This makes it easier to make choices to start or postpone certain scientific studies based on the impact that the study has on the overall result of the substrate or incoming raw material. For example, studies into the health effects of certain raw materials would be given greater priority in view of the social impact, and at the same time scientific studies into end-of-life costs would be given less priority, while these are important for the continuity of the use of the raw material. However, improving end-of-life costs has less impact than improving social conditions.

A number of lessons have also been learnt during this study, which could help other researchers to carry out similar research better and more efficiently:

- The required data needs to be clear first, then towards the end it is not necessary to adjust units for criteria and it is immediately clear which criteria are measurable and can therefore be included in the MCDA.
- Carrying out surveys with pairwise comparisons provides more input if it is done in consultation with the researcher. Respondents' questions can then be answered immediately and wrong assumptions can be discussed. It is also possible to check for inconsistencies directly and adapt them if necessary, which in return leads to a better application of certain weighing methods.
- It is important to keep the group correspondents as wide as possible, but also to pay attention to the proportions between the groups. In this study, the proportions between the groups are not the same, so that certain groups could have more influence on the results. By having a clear idea in advance of how you want the proportions as a researcher, there is a lot in control. Only if not all respondents within a group fill in the survey the proportions are still different.

9.6 Future research recommendations

Recommendations for further research emerged from the shortcomings of this research. During the study, certain choices were made to which further research could be applied. Because certain knowledge was limited and the study had to be completed within 24 weeks, it is recommended to take further research into the following issues:

- Exploring preferences through an expert panel approaching more growing media companies and other groups of actors, which will provide a better picture of the overall European situation. A cooperation of the whole sector, this requires the sharing of data from the different companies.
- A study of preferences in the different market segments. How do the criteria relate in the retail & consumer and landscaping market. The current research mainly looks at professional horticulture.
- An examination of the criteria that currently fall outside the MCDA and the criteria that are important for certain alternatives. Can it be expected that in the future these criteria will be measurable or will apply to all alternatives?
- A study in which trade-offs are not calculated on the basis of paired equations, but that trade-offs are determined on a 5 or 9 point scale. In this way, the trade-offs can perhaps be determined more precisely, as a result of which the weights represent more representative values.
- An extensive investigation into the possible scenarios for the growing media sector. What effects can be expected and how big are these effects. Where the scenarios are now based on assumptions of change, a more substantiated elaboration would be an added value for this research.

- This MCDA model and the measurable criteria were formulated in cooperation with Kekkilä-BVB. A study of the uniformity of this model for other companies in the sector can help to compare raw materials across the sector. It should be examined whether measurable criteria for one company are also measurable for another company.

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Appendix I – Literature review

The literature review is carried out at online libraries for scientific articles, such as Google Scholar and Scopus. Next to the scientific literature several articles where found in trade magazines, such as "Onder Glas" (Staalduinen, 2020), and grey literature available within the sector. An example of grey literature is the Sustainable Agenda of Growing Media Europe (Growing Media Europe, 2019), which presented useful insights within the market. In this section an overview is presented into the search for scientific articles at online libraries. After the first search, the libraries gave suggested readings which resulted in relevant scientific articles. Next to the suggested readings the technique of snowballing was very effective to find relevant scientific articles for the subjects.

Search term	Library	Scope	Hits
"Substrates"	Google Scholar	> 2015	~ 827,000
"Growing Media"	Google Scholar Scopus	> 2015 Environmental science	~ 13,200 2,223
"Horticultural innovations"	Google Scholar Scopus	- -	~ 63 57
"Substrates" + "Innovations"	Google Scholar Scopus	> 2015 Environmental Science Material science & Agricultural science	~ 25,800 33,510
"Growing Media + "Innovations"	Google Scholar Scopus	- -	~ 2,880 326
"Growing Media" + "Barriers"	Google Scholar Scopus	> 2015 -	~ 1,340 370

Table 12: Literature search terms

A - Transition barriers

Innovations in the growing media sector are crucial to foresee in food security around the world. While with implementing horticultural innovations several barriers have to be encountered. At first, the main barriers are identified at the horticultural growers, where innovations have to be implemented. Here the most common barriers are (Dennis, et al., 2010; McCarthy & Schurmann, 2014; McCarthy & Schurmann, 2015):

- Financial
- Market demand and consumer behaviour
- Industry / Structural Barriers
- Lack of assurance of sustainable farming systems

Financial barriers can be on the short or long term. On the short term investment costs in the innovations can be a barrier, while for the long term the innovation needs to be profitable for the grower. The market demand and consumer behaviour is based upon expectations from the consumer in terms of price and performance. Industry/Structural barriers can be seen in the way growers have to organise their business flow in another way. The last main barrier is the lack of assurance of sustainable farming systems, the performances of the current systems are not easy to reach with a sustainable practice.

Second, the horticultural sector forms a barrier on itself, since it is shown that only 3% of horticultural companies are willing to implement innovations, however clusters as 'Het Westland' are more innovative than companies outside of the cluster (Porter, 2000; Pannekoek, van Kooten, Kemp, & Omta, 2005). Therefore it can be concluded that starting a innovation within a cluster of companies can help by the improvement / implementation of the innovation. The World Horti Center also helps in the implementation of innovations within this cluster of companies. It is however difficult to determine how far growers are willing or able to go with including sustainable practices in their businesses (Dennis, et al., 2010). When governments presents long term goals to the horticultural sector it is shown that the sector is reaching this goal by using back casting (Blom-Zandstra & van Keulen, 2008); the goal is separated in a number of steps, whereby each step (short-term goal) is realizing a part of the goal (Quist, 2013). This stimulates the willingness to adapt within the horticultural sector, since the goal is reachable for the horticultural companies.

As third, barriers can be located at the growing media companies and entails the comparison between different innovations. Growing Media companies have their own R&D capacity from where they monitor incoming materials and develop innovations. These developments are also done with cooperatives with external partners, such as DSM. However, within the horticultural sector it is difficult to compare innovations between each other on multiple values (Barrett, et al., 2016; Litterick, et al, 2019).

B - Eco-innovations

Growing media innovations have to contribute to a better performance and sustainable character of the product. When innovations are seen as eco-innovations the contribution to the sustainable character is proven. Within the paper of (Carillo-Hermosilla, Rio, & Könnöla, 2010) many definitions are given for eco-innovations, which combined resulted in an eco-innovation framework (Figure 41). The definition for eco-innovations close to this research comes from Charter & Clark (2007): "Sustainable innovation as a process where sustainability considerations (environmental, social, financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialisation. This applies to products, services and technologies, as well as new business and organisation models".

The framework of Carillo-Hermosilla, Rio & Könnöla (2010) shows the sustainability of a system whit incremental or radical innovations. In the middle of the figure three groups can be seen. Component addition can result in better sustainable results, but will not change the main process. An example within growing media companies is the partial replacement of a peat in substrates by coir products and compost. By the replacement of peat the problem is partly resolved, but the overall process is still the same.

Sub-system change is the second group and focusses on innovations that lead to the creation of more substrates with less resources. An example could be a substrate that allows for a better growth than before or a substrate using less soil but with the same result. This optimization of the processes can be characterised by the term eco-efficiency (Schmidheiny, 1992). The third group System Change contains the innovations that cause a radical difference in the system. In the growing media sector an innovation with these characteristics is the rock wool substrate for Orchids, that would fully replace the currently used substrate. This innovation would foresee in a complete change of the production process for the growing media companies and growers.

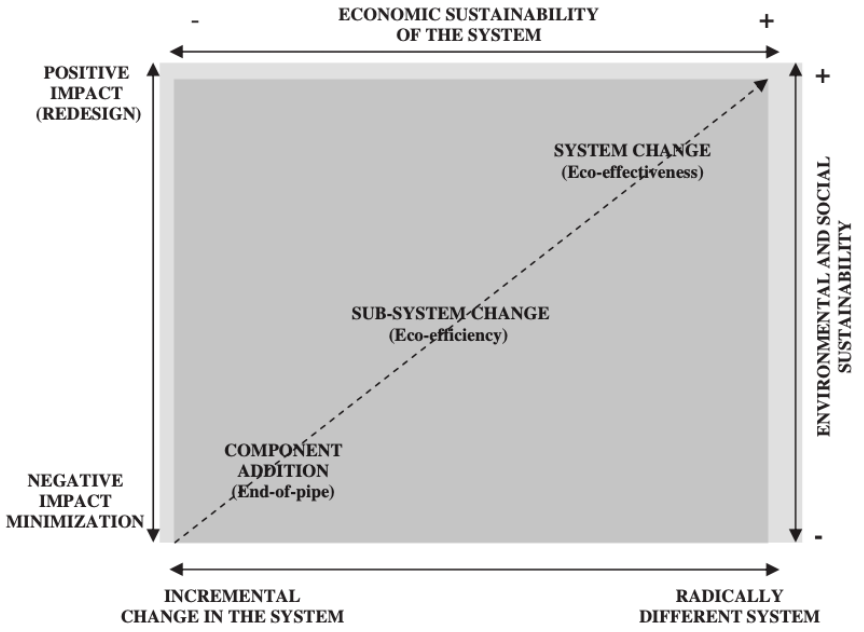


Figure 41: Eco-innovations framework (Carillo-Hermosilla, Rio, & Könnöla, 2010)

Some horticultural innovations are linked to the eco-innovation framework. These horticultural eco-innovations can be described as (1) complex, because of the basic / applied science and performance assessment on different criteria. (2) Innovations are carried out local or independent, because there is not a one-size-fits-all solution. (3) These innovations are often embedded in a long-term perspective that considers the changes in the society (Lauri, et al., 2016). The eco-innovation framework shows similarities with the three innovation horizons framework from Baghai, Coley and White (1999). The defined eco-innovation groups are part of the innovation horizons and can be placed within the same area.

C - Closed-loop supply chains

The sustainable character of the horticultural industry depends not only on minimizing the LCA and implementing eco-innovations, but a circular economy is becoming of more importance in the industry. Circular Economy is looking into Closed-Loop Supply Chains. Guide and van Wassenhove (2009) define a close looped supply chain as “the design, control, and operation of a system to maximize value creation over the entire life cycle of a product. That includes the dynamic recovery of value from different types and volumes of returns over time”.

To realise such a closed-loop supply chain the World Economic Forum (2014) developed a strategy to reach circular economy. (1) Design out waste and pollution, (2) keep products and materials in use, (3) regenerate natural systems. Within horticulture system there are several opportunities to become more circular, for example the re-use / recycling of packaging materials. An second example could be the recycling of the several materials and substrates, however the substrates are custom made and therefore the realisation of recycled substrates is very complex. The recycled material should also foresee in a product that has the same characteristics as a new product.

The transition towards a more sustainable and circular growing media is different across the different segments of the growing media sector, such as professional horticulture, retail & consumer and landscaping. A trend is that innovations are introduced first in the retail & consumer and landscaping segment and then find their way into professional horticulture, because of the higher quality demands. Among all alternatives there cannot be selected one to replace all peat substrates, since every end-product has its own cultivation method and characteristics.

Appendix II – Elaboration of possible criteria

On economic, social, environmental and technological level measurable criteria are defined for incoming raw materials of substrates. In the report from Petrillo, et al. (2016) economic and social indicators are given, see table 13 and 14. These indicators are gathered in within a literature review over multiple studies. From these indicators there is looked into the importance for growing media (raw) materials and what kind of data is available within the sector.

Economic Indicators (Petrillo, et al., 2016):	
Wages costs	Maintenance costs
Material costs (operational costs)	End of life costs
Energy costs (operational costs)	Number of years between present and future time
Equipment costs (investment costs)	Net Present Value
Revenues	Long term commitments
Taxes	Security of supply
Discount analysis	Adequately proven technology
Capital costs	Risk minimization
Interest rate	Strength and diversification of local economy
Repayment period	Reliability of energy
Consumables costs	No blocking of other deliverable developments
Training costs	

Table 13: Economic indicators (Petrillo, et al., 2016)

Social Indicators (Petrillo, et al., 2016):
Total numbers of employees, for type of contract, measured of diversity and type of work
Average salary of workers
Valorisation of the diversity
Health and safety of working conditions
Professional development and employability
Company commitment for improving environmental quality
Child labour
Forced and compulsory work
Marketing policy
Knowledge and management of potential damage of products and services
Practice against corruption and illegal price fixing
Freedom of association and collective bargaining

Table 14: Social indicators (Petrillo, et al., 2016)

The environmental indicators are distracted from the Product Environmental Footprint (PEF) methodology as presented by the European Commission (European Commission, 2012). The PEF methodology describes impact factors to measure environmental performance. From the impact factors is looked at the influence of growing media (raw) materials and what kind of data is available to derive at measurable criteria. The technological indicators are shown in table 16 and are given by the RHP handbook about potting soils and substrates (Bos, et al., 2003). Since different product segments seek different technological performance the criteria focus on risk minimization of harmful substances in the (raw) materials and the most important characteristics for a growing medium.

Environmental indicators (European Commission, 2012)
Climate Change
Ozone Depletion
Ecotoxicity for aquatic fresh water
Human Toxicity – cancer effects
Human Toxicity – non-cancer effects
Particulate Matter / Respiratory Inorganics
Ionising radiation – human health effects
Photochemical Ozone Formation
Acidification
Eutrophication – terrestrial
Eutrophication – aquatic
Resource depletion – water
Resource depletion – mineral, fossil
Land Transformation

Table 15: Environmental indicators (European Commission, 2012)

Technological indicators (Bos, et al., 2003)
Chemical aspects
Chemical Parameters[5]
Trace elements[6]
pH
Heavy metal[7]
Nitrogen fixation
Physical aspects
Moisture content
Organic matter content
Solid phase
Bulk density
Pores
Shrinkage
Water to air ratio
Water capacity after drying out
Fraction distribution
Humidity characteristics and EAW
Phytosanitary aspects
Plant-parasetic fungi
Non-plant-parasetic fungi
Insects
Nematodes
Mosses and algae
Weeds
Peat weeds
Field weeds
Tropical weeds
Ferns

Table 16: Technological indicators (Bos, et al., 2003)

[5] Chemical Parameters: EC, NH_4 + NO_3, K, Na, Ca, Mg, NO_3, Cl, SO_4, P

[6] Trace elements: Fe, Zn, Cu, Mn, B

[7] Heavy metal: Chromium, Nickel, Copper, Zinc, Arsenic, Cadmium, Mercury, Lead

Appendix III – Survey

Within this appendix the survey is shown in more detail. First the expert panel is shown, where the approximate persons per group are listed in alphabetical order. Of the 37 respondents, 30 completed the survey. The results of the survey are shown below. Followed by the number of inconsistent answers per level. After which the answers to the last question of the survey are shown, where the respondents describe their future vision for the growing media sector.

A - Expert panel

Kekkilä-BVB

Andrea Pieri	Sales & Operations Planning; North
Anu Heikilä	Category manager, LT Member
Ari Huunonen	Sales manager ; Project manager complementary raw materials
Arjan Zwinkels	Product development manager
Armand Veenman	Sales & Operations Planning; Central
Berry Mauritz	Category manager Coco peat and other raw materials
Duco Manger	R&D Manager
Folkert Moll	Sustainability manager (successor Julien Boijmans)
Guido Linders	Business Director Professional Growing
Jaco Dijkshoorn	Business director Materials and Procurement
Jannes van der Vaart	Category manager Peat materials
Johan van Geest	Sales director business line Horticulture; Region 2
Julien Boijmans	Sustainability manager
Kirsi Tanski	Director Marketing and Business Development
Marck Hagen	Innovation director
Michael Vandevoorde	Sales director business line Horticulture; Region 3
Milla Ilanen	Customer Engagement Manager
Nina Kinnunen	Business director Sustainability, Brand and Communications
Pekka Järvenpää	Quality assurance & site Quality Control coordinator
Peter Jan Kuiper	CFO, Board member and LT Member
Tiia Kujanpää	BU director Retail and Landscaping, LT Member
Vesa Tempaka	CEO VAPO, Board Member Kekkilä-BVB

Growing Media Europe members

Jan Köbbing	Head of Sustainability at Klasmann-Deilmann
Juha Mäkinen	CEO at Kekkilä-BVB and Chairmain of GME
Nele Ameloot	Business Development Manager at Agaris (Function during questionnaire)
Paul Alexander	Technical support & Product Development Manager at Pindstrup Mosebrug
Roelof Drost	Chief relationship & vision officer at Jiffy

Growing Media associations / quality marks

Han de Groot	Director VPN
Hein Boon	Director RHP

Customers

Beekenkamp	Segment:	Vegetables & Ornamentals
Champignonland	Segment:	Mushrooms
Gipmans	Segment:	Soft fruits
Rijk Zwaan	Segment:	Young Plants
Royal Iemkes	Segment	Ornamentals

Knowledge partners

Brian Jackson	Associate Professor in Horticultural Science at the University of North Carolina
Ir. Chris Blok	Proffesor Rooting media and plant nutrition at Wageningen University and Research
Lambert van Horen	Senior specialist Fresh Produce at Rabo Research Food & Agribusiness

B - Results survey

Forms Survey: Growing Media criteria - Opgeslagen ?

Survey: Growing Media criteria

30	44:28	Gesloten	
Antwoorden	Gemiddelde tijd om te voltooien	Status	ideeën

1. Select the field in which you are active

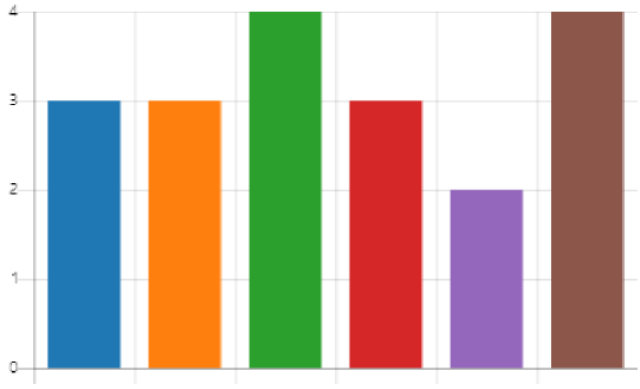
Growing Media Company	23
Growing Media association / ...	2
Research Institution	2
Customer	3

2. Are you active within Kekkilä-BVB?

Yes	19
No	4

3. Select the field in which you are currently active

Procurement	3
Sales	3
Research & Development	4
Sustainability	3
S&OP	2
Other (HR, Finance, etc.)	4



4. Which criterion is more important for the selection of incoming raw materials?

Business performance	17
Social performance	0
The criteria are equally import...	13

5. Which criterion is more important for the selection of incoming raw materials?

Business performance	20
Environmental performance	2
The criteria are equally import...	8

6. Which criterion is more important for the selection of incoming raw materials?

Social performance	12
Environmental performance	8
The criteria are equally import...	10

7. Which business performance criterion is more important for the selection of incoming raw materials?

Reliability	24
Price	0
The criteria are equally import...	6

8. Which business performance criterion is more important for the selection of incoming raw materials?

Reliability	10
Risk minimization	11
The criteria are equally import...	9

9. Which business performance criterion is more important for the selection of incoming raw materials?

Reliability	10
Product properties	9
The criteria are equally import...	11

10. Which business performance criterion is more important for the selection of incoming raw materials?

Price	2
Risk minimization	24
The criteria are equally import...	4

11. Which business performance criterion is more important for the selection of incoming raw materials?

Price	2
Product properties	22
The criteria are equally import...	6

12. Which business performance criterion is more important for the selection of incoming raw materials?

Risk minimization	10
Product properties	9
The criteria are equally import...	11

13. Which reliability criterion is more important for the selection of incoming raw materials?

Resource security	8
Consistency	8
The criteria are equally import...	14

14. Which reliability criterion is more important for the selection of incoming raw materials?

Resource security	21
Product development	5
The criteria are equally import...	4

15. Which reliability criterion is more important for the selection of incoming raw materials?

Consistency	17
Product development	7
The criteria are equally import...	6

16. Which price criterion is more important for the selection of incoming raw materials?

Price stability	21
End-of-life cost	3
The criteria are equally import...	6

17. Which price criterion is more important for the selection of incoming raw materials?

Price stability	12
Cost price	10
The criteria are equally import...	8

18. Which price criterion is more important for the selection of incoming raw materials?

End-of-life cost	4
Costprice	20
The criteria are equally import...	6

19. Which risk minimization criterion is more important for the selection of incoming raw materials?

Chemical analysis	8
Growth test	5
The criteria are equally import...	17

20. Which risk minimization criterion is more important for the selection of incoming raw materials?

Chemical analysis	16
Weed test	2
The criteria are equally import...	12

21. Which risk minimization criterion is more important for the selection of incoming raw materials?

Chemical analysis	7
Biological analysis	1
The criteria are equally import...	22

22. Which risk minimization criterion is more important for the selection of incoming raw materials?

Growth test	15
Weed test	3
The criteria are equally import...	12

23. Which risk minimization criterion is more important for the selection of incoming raw materials?

Growth test	6
Biological analysis	5
The criteria are equally import...	19

24. Which risk minimization criterion is more important for the selection of incoming raw materials?

Weed test	4
Biological analysis	13
The criteria are equally import...	13

25. Which product property criterion is more important for the selection of incoming raw materials?

EC-value	6
pH-value	5
The criteria are equally import...	19

26. Which product property criterion is more important for the selection of incoming raw materials?

EC-value	9
Water / air ratio	6
The criteria are equally import...	15

27. Which product property criterion is more important for the selection of incoming raw materials?

EC-value	12
WOK-analysis	4
The criteria are equally import...	14

28. Which product property criterion is more important for the selection of incoming raw materials?

pH-value	10
Water/air ratio	4
The criteria are equally import...	16

29. Which product property criterion is more important for the selection of incoming raw materials?

pH-value	11
WOK-analysis	3
The criteria are equally import...	16

30. Which product property criterion is more important for the selection of incoming raw materials?

Water/air ratio	8
WOK-analysis	3
The criteria are equally import...	19

31. Which social criterion is more important for the selection of incoming raw materials?

Health & Safety	26
Job creation	1
The criteria are equally import...	3

32. Which social criterion is more important for the selection of incoming raw materials?

Health & Safety	11
Environmental commitment	4
The criteria are equally import...	15

33. Which social criterion is more important for the selection of incoming raw materials?

Job creation	2
Environmental commitment	23
The criteria are equally import...	5

34. Which environmental criterion is more important for the selection of incoming raw materials?

LCA (C-T-Gate)	16
Carbon footprint	5
The criteria are equally import...	9

35. Which environmental criterion is more important for the selection of incoming raw materials?

LCA (C-T-Gate)	19
Water use	7
The criteria are equally import...	4

36. Which environmental criterion is more important for the selection of incoming raw materials?

LCA (C-T-Gate)	12
Eco-system change	8
The criteria are equally import...	10

37. Which environmental criterion is more important for the selection of incoming raw materials?

LCA (C-T-Gate)	14
Circularity	8
The criteria are equally import...	8

38. Which environmental criterion is more important for the selection of incoming raw materials?

Carbon footprint	12
Water use	2
The criteria are equally import...	16

39. Which environmental criterion is more important for the selection of incoming raw materials?

Carbon footprint	9
Eco-system change	4
The criteria are equally import...	17

40. Which environmental criterion is more important for the selection of incoming raw materials?

Carbon footprint	13
Circularity	2
The criteria are equally import...	15

41. Which environmental criterion is more important for the selection of incoming raw materials?

Water use	7
Eco-system change	7
The criteria are equally import...	16

42. Which environmental criterion is more important for the selection of incoming raw materials?

Water use	9
Circularity	6
The criteria are equally import...	15

43. Which environmental criterion is more important for the selection of incoming raw materials?

Eco-system change	8
Circularity	2
The criteria are equally import...	20

44. What are your future expectations for the (European) Growing Media sector?

23
Antwoorden

Meest recente antwoorden

"- *Steeds minder veen gebruik in de markt - Perspotten met minder m...*

"*Everyone is looking for a cheap, local, available, good quality, renewa...*

C - Inconsistent answers

The number of inconsistent answers can be found in table 17. Inconsistencies mean that the respondent's rank in the indicated order of precedence is cyclically dependent on each other. An example of inconsistency is that if the respondent indicates that A is greater than B, B is greater than C and C is greater than A. This is cyclically incorrect because if A is greater than B and B is greater than C, A must also be greater than C.

In this survey, respondents could also choose the option "the criteria are the same". The many inconsistencies can be explained by the frequent use of this option. For example, they indicated that they considered all the criteria equal to each other, but that they considered one criterion more important in a pairwise comparison, which leads to cyclical dependencies and therefore inconsistencies. Since the inconsistencies arose from a single 'wrong' pairwise comparison, it was decided to include all the inconsistent answers when determining the impact scores on the group preferences, as this is based on the preference over the different groups. For the method that determines the weights for each respondent, only the consistent answers can be taken into account, as an inconsistent ranking cannot be directly assigned weights.

Inconsistent answers						
Category	**All respondents**		**GMC**	**GMA / QM**	**Research Institution**	**Customers**
High performance of raw material	7/30	23%	6/23	0/2	1/2	0/3
Business performance	12/30	40%	11/23	0/2	1/2	0/3
Business performance: Reliability	2/30	7%	2/23	0/2	0/2	0/3
Business performance: Price	3/30	10%	3/23	0/2	0/2	0/3
Business performance: Risk minimization	8/30	27%	7/23	0/2	1/2	0/3
Business performance: Product properties	4/30	13%	4/23	0/2	0/2	0/3
Social performance	1/30	3%	1/23	0/2	0/2	0/3
Environmental performance	16/30	53%	15/23	1/2	0/2	0/3
Total	**53/240**	**22%**	**49/184**	**1/16**	**3/16**	**0/24**

Table 17: Inconsistent answers per (sub) category level

D - Future expectations Growing Media sector

Answers of the respondents on the final question of the survey. Answers where is referred to internal or public documents are excluded.

Growing Media companies

Kekkilä-BVB

Procurement

“On the short term (2021) there will be expected a worldwide shortage of growing media in general. On the long term (2022-2030) there will be a serious search for alternatives in order to reduce the use of substrates.”

“The use of energy and water should be limited to the amount which the plant needs to grow. Plant factories will have a more efficient way of growing compared to the traditional way of growing. In these kind of systems the maximum amount of yield will be reached without the use of pesticides, drainage water there will be an efficient use of energy and easier developing robotizing. The harvest would be easier to develop. This solution is also independent on local weather conditions. Growth can be achieved nearby the end consumer everywhere in the world. Less logistics will be needed and food will be more fresh supplied (less residue). Hygienic conditions are better controllable, so food safety regulations will be on high level. This way of growing demands less volume substrate, but more homogeneous and higher quality.”

R&D

"Political trends: politiek reageert op media en ideeën, deze geven geen compleet beeld, daarom worden keuzes gemaakt die niet goed doordacht zijn. Zo zal veenvrij (in Europa) belangrijker worden, maar om verkeerde redenen. Hier zijn we op aan het schakelen, de publieke opinie is belangrijker dan de juiste achtergronden. Legal trends: veenvrij is ook een kans, met Accretio hebben we een goede troef in handen. Als de EU veenproductie aan banden gaat leggen, dan heeft VAPO, maar ook Kekkila een groot probleem. Logistic: transport over de wereld is betaalbaar als er grote (financiële) voordelen te behalen zijn. De teeltkennis en technische mogelijkheden in het buitenland nemen toe, dus neemt het financiële voordeel af. De vraag naar uniformiteit neemt dan weer toe. Als we meer lokaal, en deels met lokale grondstoffen, mengsels kunnen maken; dan moeten we een voorsprong kunnen nemen op onze concurrenten (goedkoper, lokaal, sneller, korter transport dus meer biologie mogelijk of organische meststoffen). In Europa zal veenvrij belangrijker worden, in de rest van de wereld voorlopig nog niet. Welke criteria daar belangrijk worden is afwachten en er kort opzitten. Sturing is helaas (nagenoeg) onmogelijk."

“The need for substrates will grow, because the world population is expected to grow. To serve this expanding market the need for local materials and local production, but also local advise will be higher; with the learnings of COVID-19 that we need to be 'completely in touch without personal contact'. We can't continue in the current way and keep erosing the earth, on the other side we can't permit ourselves to lack our own growth. The balance of business will be in future not reflected to do 'good', but it will be targeted to do 'well'. The challenge of the growing media sector will be related to create: Zero hunger in a liveable world.”

“More environmental pressure on fossil materials, more legal possibilities for bio stimulants and circular materials as stated in the new EU fertiliser regulations. Water use will become more important. Valorisation of waste streams will become more important for the business case. Due to enhance use of circular material risks for contaminants will increase. Local sourcing will become more important. Circularity or complete natural degradability of materials will become more important due to resp. availability of raw materials and pollution. Restoration/cleanup of production sites after usage.”

Sustainability

“I believe that thorough and industry wide shared understanding and transparency of LCA and footprint calculation will be a must and it is important that the growing media industry, growers and retail share the same view on how to calculate these and show them to consumers in a transparent way. Clear actions on minimizing the carbon footprint, water usage and adding circularity in a safe way to the raw materials will be important, as well as innovative products that enable more sustainable growing.”

"- Political trends: Over the years, certain impact factors become trendy (Eutrophication, Ozon, CO2, water in the future) Politicians will always look for quick wins in those areas so whatever raw materials score bad on the trending factor will receive high pressure to either reduce the usage of that material or get rid of it completely. Currently, peat is receiving such pressure and we will not use less peat in absolute numbers but use less peat per mix that we make. - Logistical trends: The future outlook here is to become globally local. Using few global materials such as peat, coir, woodfibre, mineral wool to enable the use of locally sourced raw materials. This leads to shorter lead times and lower costs."

“Increased legislation to reduce environmental impact and promote reuse and recycling. This may mean stricter legislation on the use of certain materials, increased taxing of negative environmental impact and (research) subsidies to create positive impact. The market wants a reliable and effective product for a competitive price. Sustainability is a bonus but not a deal breaker in the coming five years. However, government pressure and pressure from society may change the perspective on sustainability.”

S&OP

“Raising legal obligations and local sourcing”

“Political: pressure to use complementary (circular) raw materials (even though LCA of those might not be better than peat). Legal: could follow political ("ban on peat"). Logistical: covid could impact rigidity of supply chains, especially for coir”

Others

"Fact based evaluation of sustainability, and not focusing only on CO2. Sustainability needs are different depending on use and location, for example some places have lack of water some not."

"GM sector plays an important role in the food supply chain. Industry needs to make sure the political decision makers understand the consequences of their decision when creating for example new laws and regulations. We also need to make sure the general public understands this.
I believe more and more of the raw materials will be sourced from as near the end use as possible for both environmental as well as safety of supply reasons."

"- I expect the growing media sector to formulate more unified all-European sustainability criteria that also take into account the social wellbeing gardening and substrates create. It should be easier for consumers to look at sustainability of products and also the positives aspects of peat-based products.- In Landscaping, there are very strict regulations in Finland concerning responsibilities of growing media producers. Principle of strict responsibility: if producer delivers only one part of the growing media to the site, like for example compost, supplier is responsible of the overall performance of all the growing media in that particular area. This should be changed so that suppliers could more freely deliver just a part of the total solution without carrying the full responsibility. -Overall communication work regarding importance and meaning of soils, also and particularly home gardening and landscaping soils. Substrates enable life."

Growing Media Europe members

"Development and availability of sustainable raw materials, political pressure on the use of peat, without safe and abundant alternatives."

“We will see a push by end consumers for peat free growing media”

"Political - Being UK based we are now moving away from peat and I expect the majority of the UK market to be peat-free within 5 years. This has been a long time in coming with NGO and Government pressure to change. The challenge for those working in this market is making cost effective mixes when the margins are so low. Logistical - This creates all sorts of production headaches. I envisage peat-free mixes to be combinations of 3, 4 or 5 bulky organic materials, whereas previously it was perhaps peat plus one other material. Thus ordering, shipping, handling (eg storage space) etc all become more complicated and therefore costly. Also, the majority of non-peat materials are approx. 4 to 5 times the cost of peat so again a cost implication in an industry with very low margins. Legal - Legislators need to better understand substrates. We are currently engaged with the EU (via the GME) relating to the new fertiliser regulations which are impacting on substrates because it has been grouped with fertilisers by an EU administrator rather than someone who understands the role substrates play. Lobbying for change is energy sapping, time consuming and costly. The sale of plants to the consumer should be valued more (by the regulators) as a more positive contribution to the environment. I accept not all of our practices are environmentally positive but more plants on the planet, i'd argue, is better than less, encouraging gardening is surely a good thing. The industry are trying to make themselves more environmentally friendly and will make change if the associated costs can be accommodated within the business model (but this is not always achievable - low margins). We also ""suffer"" from being a generally small scale industry which isn't attractive to innovators looking to develop new products / processes. By way of an example, we have some horticultural grade fertilisers but the business opportunity isn't there for most fertiliser manufacturers to explore the options that say agriculture receives. Thus horticulture is left with a limited choice but with investment the choice could be improved, as could the environmental suitability."

Growing Media association / quality mark

"opm bij het voorgaande: bij het maken van de afweging in de belangen tussen 2 aspecten was het soms lastig omdat het voor mij niet heel duidelijk is wat het 'referentiekader' is, de actuele situatie, of een doorkijk naar de toekomst. Ik ben uitgegaan van de actualiteit. In mijn keuzes lijken bijv. biologische aspecten (actueel) van minder belang Dit aspect wordt naar verwachting belangrijker in de nabije toekomst (o.a. meer reststromen, hogere eisen door teelt en Retail). Political trends: in zijn algemeenheid wordt de belangrijke rol van growing media, door actoren in de keten -en daar buiten-, slecht onderkend. Dat maakt dat de 'publieke opinie' denkt vrij gemakkelijk een mening te kunnen vormen over wat de substraatsector wel en niet zou mogen of moeten (veenvrij, organisch, geen humaanpathogenen, gebruik van reststromen etc). Het is m.i. van belang dat de sector het belang van substraat positioneert, gestructureerd en een consistent verhaal.

voorbeeld: bij de afweging van 'environmental aspects' is de LCA-beoordeling van groter belang dan bijv, climate change/carbon of watergebruik. Die aspecten vormen een onderdeel van een LCA. De publieke opinie kan echter alle nadruk leggen op bij Carbon-emission en daarmee voorbijgaan aan een genuanceerde afweging van alle aspecten. Als de sector een genuanceerde afweging van belang vindt, dan zal zij zelf het initiatief in communicatie moeten nemen. Legal trends: voor substraat wordt de FPR (meststoffen verordening) leidend voor handelsverkeer van substraten in de EU. FPR regelt aspecten ten aanzien van 'veiligheid voor milieu en gebruiker', het zegt echter niets over kwaliteitsaspecten en geschiktheid voor teelt. Als de sector dit wel van belang vindt, dan zal dat (Europees) georganiseerd moeten worden. Voor handelsstromen in de wereld is geen sprake van een algemene standaard, m.n. fytosanitaire eisen (risk minimization) zijn sterk wisselend. Dit biedt kansen om een standaard te ontwikkelen en daarvoor acceptatie te verkrijgen. "

Research institutions

"Political Trends. These will become more "hot topic" items as more constituencies (voters) begin to become more vocal about climate change, environmental issues, local and sustainable (varying definitions there of course). Political polices that cross states, countries, and continents may be more aligned with trade, supply and demand, and self-preservation than ever before. The struggle between environmental policies, job/economic growth, and social justice is a tug-of-war that is very political between the conservative and liberal viewpoints. The elections of 2020 and 2021 will decide A LOT. Legal Trends. May have a lot to do with point number one above. Legality over product performance, supplies, raw material harvesting, land/resource ownership, product/material consistency or inconsistency, presence of heavy metals (especially in materials used to product Cannabis, food crops, and other consumables), food security, etc. will only increase in civilized countries I think. Logistical Trends. There has been a lot of attention in the most recent decade about the sourcing of local or regional materials for horticulture and food production as a whole. I do not see this changing but only increasing especially with the effects of COVID on communities, states, and nations. The rise in Peri-Urban growing operations to supply large cities with greens and highly perishable consumables is evidence of this movement/trend. Marketing campaigns are really picking up on this and leveraging certain products over others due to these factors, especially to the clientele who can afford to be selective in what they buy and how much they are willing to pay for it. Discussing any of the above ""Trends"" can be defined and re-defined based on demographics for sure."

“Will double the next twenty years (CAGR 3,5%)”

Appendix IV – Preferences and impacts per group

Where in the main text the preferences and impact scores are shown for all respondents, here in the appendix the preferences and impact weights of the different groups are shown.

A - Preferences

Growing Media company

Number of respondents: 23

Category	Group preference	Method	
		Majority rule	Condorcet
High performance of raw material	(Business performance ~ Social performance) > Environmental performance		
Business performance	Risk minimization > Product properties > Reliability > Price		
Business performance: Reliability	(Resource security ~ Consistency) > Product development		
Business performance: Price	Cost price > Price stability > End-of-life cost		
Business performance: Risk minimization	Chemical analysis ~ Growth test ~ Biological analysis ~ Weed test		
Business performance: Product properties	EC ~ pH ~ Water / air ratio ~ WOK-analysis		
Social performance	(Health & Safety ~ Environmental Commitment) > Job creation		
Environmental performance	LCA (C-T-Gate) > Carbon footprint > (Water use ~ Eco-system change) > Circularity		

Table 18: Group preferences of Growing Media company respondents

Growing Media association / quality mark

Number of respondents: 2

Category	Group preference	Method	
		Majority rule	Condorcet
High performance of raw material	Business performance > Environmental performance > Social performance		
Business performance	(Product properties ~ Reliability ~ Risk minimization) > Price		
Business performance: Reliability	Resource security > Consistency > Product development		
Business performance: Price	Price stability > (End-of-life cost ~ Cost price)		
Business performance: Risk minimization	Chemical analysis > Biological analysis > Growth test > Weed test		
Business performance: Product properties	pH > WOK-analysis > (EC ~ Water / air ratio)		
Social performance	Health & Safety > (Environmental Commitment ~ Job creation)		
Environmental performance	LCA (C-T-Gate) > Carbon footprint > Circularity > Water use > Eco-system change		

Table 19: Group preferences of Growing Media association / quality mark respondents

Research Institution

Number of respondents: 2

Category	Group preference	Method	
		Majority rule	Condorcet
High performance of raw material	Business performance > Social performance > Environmental performance		
Business performance	Reliability > (Product properties ~ Risk minimization) > Price		
Business performance: Reliability	Resource security > Consistency > Product development		
Business performance: Price	Price stability > End-of-life cost > Cost price		
Business performance: Risk minimization	Chemical analysis > (Growth test ~ Biological analysis) > Weed test		
Business performance: Product properties	EC > pH > Water / air ratio > WOK-analysis		
Social performance	(Health & Safety ~ Environmental Commitment) > Job creation		
Environmental performance	LCA (C-T-Gate) > Carbon footprint > (Eco-system change ~ Water use) > Circularity		

Table 20: Group preferences of Research Institution respondents

Customers

Number of respondents: 3

Category	Group preference	Method	
		Majority rule	Condorcet
High performance of raw material	Business performance > (Social performance ~ Environmental performance)		
Business performance	(Reliability ~ Product properties) > Risk minimization > Price		
Business performance: Reliability	Consistency > Resource security > Product development		
Business performance: Price	Price stability > Cost price > End-of-life cost		
Business performance: Risk minimization	(Chemical analysis ~ Biological analysis) > Weed test > Growth test		
Business performance: Product properties	(pH ~ Water / air ratio ~ WOK-analysis) > EC		
Social performance	Health & Safety > Environmental Commitment > Job creation		
Environmental performance	LCA (C-T-Gate) > Carbon footprint > Eco-system change > Circularity > Water use		

Table 21: Group preferences of Customers respondents

B - Impact scores

Growing Media company

Criteria	Normalised	Rang reciproke	Rietveld & Ouwersloot	Agg. per respondent
Resource Security	0.032	0.026	0.027	0.039
Consistency	0.032	0.026	0.027	0.039
Product development	0.016	0.013	0.009	0.032
Price stability	0.013	0.013	0.007	0.021
End-of-life cost	0.007	0.009	0.003	0.015
Cost price	0.020	0.026	0.016	0.025
Chemical Analyses	0.040	0.048	0.056	0.042
Growth Test	0.040	0.048	0.056	0.043
Weed Test	0.040	0.048	0.056	0.034
Biological analyses	0.040	0.048	0.056	0.038
EC-value	0.030	0.024	0.029	0.037
pH-value	0.030	0.024	0.029	0.030
Water/air ratio	0.030	0.024	0.029	0.029
WOK-analysis	0.030	0.024	0.029	0.026
Health & Safety	0.160	0.160	0.184	0.121
Job creation	0.080	0.080	0.061	0.062
Environmental commitment	0.160	0.160	0.184	0.102
LCA (C-T-Gate)	0.067	0.083	0.065	0.062
Carbon footprint	0.050	0.041	0.034	0.055
Water use	0.033	0.028	0.018	0.049
Eco-system change	0.033	0.028	0.018	0.053
Circularity	0.017	0.021	0.008	0.046
Total	**1.000**	**1.000**	**1.000**	**1.000**

Table 22: Impact scores of Growing Media company respondents

Growing Media association / quality mark

Criteria	Normalised	Rang reciproke	Rietveld & Ouwersloot	Agg. per respondent
Resource Security	0.071	0.085	0.112	0.068
Consistency	0.048	0.043	0.051	0.048
Product development	0.024	0.028	0.020	0.027
Price stability	0.036	0.039	0.037	0.022
End-of-life cost	0.018	0.019	0.012	0.012
Cost price	0.018	0.019	0.012	0.020
Chemical Analyses	0.057	0.075	0.095	0.055
Growth Test	0.029	0.025	0.027	0.032
Weed Test	0.014	0.019	0.011	0.019
Biological analyses	0.043	0.037	0.050	0.038
EC-value	0.020	0.024	0.018	0.027
pH-value	0.061	0.072	0.101	0.034
Water/air ratio	0.020	0.024	0.018	0.022
WOK-analysis	0.041	0.036	0.046	0.025
Health & Safety	0.083	0.091	0.067	0.092
Job creation	0.042	0.045	0.022	0.051
Environmental commitment	0.042	0.045	0.022	0.082
LCA (C-T-Gate)	0.111	0.119	0.127	0.142
Carbon footprint	0.089	0.060	0.071	0.071
Water use	0.044	0.030	0.025	0.036
Eco-system change	0.022	0.024	0.011	0.028
Circularity	0.067	0.040	0.044	0.047
Total	**1.000**	**1.000**	**1.000**	**1.000**

Table 23:Impact scores of Growing Media association / quality mark respondents

Research Institution

Criteria	Normalised	Rang reciproke	Rietveld & Ouwersloot	Agg. per respondent
Resource Security	0.094	0.128	0.179	0.063
Consistency	0.063	0.064	0.081	0.045
Product development	0.031	0.043	0.032	0.025
Price stability	0.031	0.043	0.032	0.035
End-of-life cost	0.021	0.021	0.015	0.017
Cost price	0.010	0.014	0.006	0.014
Chemical Analyses	0.047	0.050	0.064	0.057
Growth Test	0.031	0.025	0.029	0.029
Weed Test	0.016	0.017	0.012	0.019
Biological analyses	0.031	0.025	0.029	0.029
EC-value	0.050	0.056	0.069	0.026
pH-value	0.038	0.028	0.036	0.018
Water/air ratio	0.025	0.019	0.019	0.015
WOK-analysis	0.013	0.014	0.008	0.009
Health & Safety	0.133	0.109	0.119	0.147
Job creation	0.067	0.055	0.040	0.107
Environmental commitment	0.133	0.109	0.119	0.147
LCA (C-T-Gate)	0.056	0.075	0.051	0.076
Carbon footprint	0.042	0.038	0.026	0.038
Water use	0.028	0.025	0.014	0.025
Eco-system change	0.028	0.025	0.014	0.043
Circularity	0.014	0.019	0.006	0.017
Total	**1.000**	**1.000**	**1.000**	**1.000**

Table 24:Impact scores of Research Institution respondents

Customers

Criteria	Normalised	Rang reciproke	Rietveld & Ouwersloot	Agg. per respondent
Resource Security	0.056	0.048	0.063	0.058
Consistency	0.083	0.096	0.139	0.063
Product development	0.028	0.032	0.025	0.053
Price stability	0.028	0.032	0.025	0.027
End-of-life cost	0.009	0.011	0.005	0.012
Cost price	0.019	0.016	0.011	0.022
Chemical Analyses	0.037	0.031	0.039	0.030
Growth Test	0.012	0.010	0.007	0.028
Weed Test	0.025	0.016	0.018	0.031
Biological analyses	0.037	0.031	0.039	0.030
EC-value	0.024	0.025	0.023	0.021
pH-value	0.048	0.050	0.068	0.051
Water/air ratio	0.048	0.050	0.068	0.048
WOK-analysis	0.048	0.050	0.068	0.043
Health & Safety	0.125	0.136	0.122	0.111
Job creation	0.042	0.045	0.022	0.059
Environmental commitment	0.083	0.068	0.056	0.088
LCA (C-T-Gate)	0.083	0.109	0.091	0.076
Carbon footprint	0.067	0.055	0.051	0.041
Water use	0.017	0.022	0.008	0.043
Eco-system change	0.050	0.036	0.031	0.037
Circularity	0.033	0.027	0.018	0.031
Total	**1.000**	**1.000**	**1.000**	**1.000**

Table 25: Impact scores of Customers respondents

Appendix V – Python script

In the python script the preference of the respondent is checked on consistency and if consistent presented. Next to the preferences the Condorcet group preference method is presented as script.

Input

In [1]:

```
import pandas as pd
import numpy as np
```

In [2]:

```
#number of criteria (elements)
elements= ['A','B','C','D','E'] #length is equal to the number of criteria that
 are compared among eachother
```

In [3]:

```
#Category: High performance of raw material
Level1 = ['Business performance','Social performance','Environmental performanc
e','The criteria are equally important']

#Category: Business performance
Level2Bus =['Reliability','Price','Risk minimization','Product properties','The
 criteria are equally important']

Level3Rel =['Resource security','Consistency','Product development','The criteri
a are equally important']
Level3Pri =['Price stability ','End-of-life cost','Cost price','The criteria are
equally important']
Level3Ris =['Chemical analysis','Growth test','Weed test','Biological analysis',
'The criteria are equally important']
Level3Pro =['EC-value','pH-value','Water/air ratio','WOK-analysis','The criteria
are equally important']

#Category: Social performance
Level3Soc = ['Health & Safety','Job creation','Environmental commitment','The cr
iteria are equally important']

#Category: Environmental performance
Level3Env =['LCA (C-T-Gate)','Carbon footprint','Water use','Eco-system change',
'Circularity','The criteria are equally important']
```

Dataframes

All results

In [18]:

```
#read in the results of the survey
results = pd.read_excel("Survey_ Growing Media criteria(1-30).xlsx")

#create dataframe with the level 1 criteria
results_level1 = results.iloc[:, 8:11]

#create dataframe with the level 2 criteria
results_level2Bus = results.iloc[:, 11:17]
results_level2Bus = results_level2Bus.replace('Risk minimization ','Risk minimiz
ation')

#creates the dataframes with the level 3 criteria
results_level3Rel = results.iloc[:, 17:20]

results_level3Pri = results.iloc[:, 20:23]
results_level3Pri = results_level3Pri.replace('Costprice','Cost price')

results_level3Ris = results.iloc[:, 23:29]

results_level3Pro = results.iloc[:, 29:35]
results_level3Pro = results_level3Pro.replace('Water / air ratio','Water/air rat
io')

results_level3Soc = results.iloc[:, 35:38]

results_level3Env = results.iloc[:, 38:48]
```

Workfield within Growing Media sector

In [19]:

```
#Growing Media Company
GMC = results[results['Select the field in which you are active']=='Growing Medi
a Company']

#create dataframe with the level 1 criteria
GMC_level1 = GMC.iloc[:, 8:11]

#create dataframe with the level 2 criteria
GMC_level2Bus = GMC.iloc[:, 11:17]
GMC_level2Bus = GMC_level2Bus.replace('Risk minimization ','Risk minimization')

#creates the dataframes with the level 3 criteria
GMC_level3Rel = GMC.iloc[:, 17:20]
GMC_level3Pri = GMC.iloc[:, 20:23]
GMC_level3Pri = GMC_level3Pri.replace('Costprice','Cost price')
GMC_level3Ris = GMC.iloc[:, 23:29]
GMC_level3Pro = GMC.iloc[:, 29:35]
GMC_level3Pro = GMC_level3Pro.replace('Water / air ratio','Water/air ratio')
GMC_level3Soc = GMC.iloc[:, 35:38]
GMC_level3Env = GMC.iloc[:, 38:48]
```

In [20]:

```
#Growing Media association / quality mark
GMAQM = results[results['Select the field in which you are active']=='Growing Me
dia association / quality mark']

#create dataframe with the level 1 criteria
GMAQM_level1 = GMAQM.iloc[:, 8:11]

#create dataframe with the level 2 criteria
GMAQM_level2Bus = GMAQM.iloc[:, 11:17]
GMAQM_level2Bus = GMAQM_level2Bus.replace('Risk minimization ','Risk minimizatio
n')

#creates the dataframes with the level 3 criteria
GMAQM_level3Rel = GMAQM.iloc[:, 17:20]
GMAQM_level3Pri = GMAQM.iloc[:, 20:23]
GMAQM_level3Pri = GMAQM_level3Pri.replace('Costprice','Cost price')
GMAQM_level3Ris = GMAQM.iloc[:, 23:29]
GMAQM_level3Pro = GMAQM.iloc[:, 29:35]
GMAQM_level3Pro = GMAQM_level3Pro.replace('Water / air ratio','Water/air ratio')
GMAQM_level3Soc = GMAQM.iloc[:, 35:38]
GMAQM_level3Env = GMAQM.iloc[:, 38:48]
```

In [21]:

```
#Research Institution
RI = results[results['Select the field in which you are active']=='Research Inst
itution']

#create dataframe with the level 1 criteria
RI_level1 = RI.iloc[:, 8:11]

#create dataframe with the level 2 criteria
RI_level2Bus = RI.iloc[:, 11:17]
RI_level2Bus = RI_level2Bus.replace('Risk minimization ','Risk minimization')

#creates the dataframes with the level 3 criteria
RI_level3Rel = RI.iloc[:, 17:20]
RI_level3Pri = RI.iloc[:, 20:23]
RI_level3Pri = RI_level3Pri.replace('Costprice','Cost price')
RI_level3Ris = RI.iloc[:, 23:29]
RI_level3Pro = RI.iloc[:, 29:35]
RI_level3Pro = RI_level3Pro.replace('Water / air ratio','Water/air ratio')
RI_level3Soc = RI.iloc[:, 35:38]
RI_level3Env = RI.iloc[:, 38:48]
```

In [22]:

```
#CUSTOMER
Customer = results[results['Select the field in which you are currently active']
=='Customer']

#create dataframe with the level 1 criteria
Customer_level1 = Customer.iloc[:, 8:11]

#create dataframe with the level 2 criteria
Customer_level2Bus = Customer.iloc[:, 11:17]
Customer_level2Bus = Customer_level2Bus.replace('Risk minimization ','Risk minim
ization')

#creates the dataframes with the level 3 criteria
Customer_level3Rel = Customer.iloc[:, 17:20]
Customer_level3Pri = Customer.iloc[:, 20:23]
Customer_level3Pri = Customer_level3Pri.replace('Costprice','Cost price')
Customer_level3Ris = Customer.iloc[:, 23:29]
Customer_level3Pro = Customer.iloc[:, 29:35]
Customer_level3Pro = Customer_level3Pro.replace('Water / air ratio','Water/air r
atio')
Customer_level3Soc = Customer.iloc[:, 35:38]
Customer_level3Env = Customer.iloc[:, 38:48]
```

Workfield within Kekkila-BVB

In [23]:

```
#PROCUREMENT
procurement = results[results['Select the field in which you are currently activ
e']=='Procurement']

#create dataframe with the level 1 criteria
procurement_level1 = procurement.iloc[:, 8:11]

#create dataframe with the level 2 criteria
procurement_level2Bus = procurement.iloc[:, 11:17]
procurement_level2Bus = procurement_level2Bus.replace('Risk minimization ','Risk
minimization')

#creates the dataframes with the level 3 criteria
procurement_level3Rel = procurement.iloc[:, 17:20]
procurement_level3Pri = procurement.iloc[:, 20:23]
procurement_level3Pri = procurement_level3Pri.replace('Costprice','Cost price')
procurement_level3Ris = procurement.iloc[:, 23:29]
procurement_level3Pro = procurement.iloc[:, 29:35]
procurement_level3Pro = procurement_level3Pro.replace('Water / air ratio','Wate
r/air ratio')
procurement_level3Soc = procurement.iloc[:, 35:38]
procurement_level3Env = procurement.iloc[:, 38:48]
```

In [24]:

```
#SALES
sales = results[results['Select the field in which you are currently active']==
'Sales']

#create dataframe with the level 1 criteria
sales_level1 = sales.iloc[:, 8:11]

#create dataframe with the level 2 criteria
sales_level2Bus = sales.iloc[:, 11:17]
sales_level2Bus = sales_level2Bus.replace('Risk minimization ','Risk minimizatio
n')

#creates the dataframes with the level 3 criteria
sales_level3Rel = sales.iloc[:, 17:20]
sales_level3Pri = sales.iloc[:, 20:23]
sales_level3Pri = sales_level3Pri.replace('Costprice','Cost price')
sales_level3Ris = sales.iloc[:, 23:29]
sales_level3Pro = sales.iloc[:, 29:35]
sales_level3Pro = sales_level3Pro.replace('Water / air ratio','Water/air ratio')
sales_level3Soc = sales.iloc[:, 35:38]
sales_level3Env = sales.iloc[:, 38:48]
```

In [25]:

```
#Research & Development
RandD = results[results['Select the field in which you are currently active']==
'Research & Development']

#create dataframe with the level 1 criteria
RandD_level1 = RandD.iloc[:, 8:11]

#create dataframe with the level 2 criteria
RandD_level2Bus = RandD.iloc[:, 11:17]
RandD_level2Bus = RandD_level2Bus.replace('Risk minimization ','Risk minimizatio
n')

#creates the dataframes with the level 3 criteria
RandD_level3Rel = RandD.iloc[:, 17:20]
RandD_level3Pri = RandD.iloc[:, 20:23]
RandD_level3Pri = RandD_level3Pri.replace('Costprice','Cost price')
RandD_level3Ris = RandD.iloc[:, 23:29]
RandD_level3Pro = RandD.iloc[:, 29:35]
RandD_level3Pro = RandD_level3Pro.replace('Water / air ratio','Water/air ratio')
RandD_level3Soc = RandD.iloc[:, 35:38]
RandD_level3Env = RandD.iloc[:, 38:48]
```

In [26]:

```
#Other (HR, Finance, etc.)
Other = results[results['Select the field in which you are currently active']==
'Other (HR, Finance, etc.)']

#create dataframe with the level 1 criteria
Other_level1 = Other.iloc[:, 8:11]

#create dataframe with the level 2 criteria
Other_level2Bus = Other.iloc[:, 11:17]
Other_level2Bus = Other_level2Bus.replace('Risk minimization ','Risk minimizatio
n')

#creates the dataframes with the level 3 criteria
Other_level3Rel = Other.iloc[:, 17:20]
Other_level3Pri = Other.iloc[:, 20:23]
Other_level3Pri = Other_level3Pri.replace('Costprice','Cost price')
Other_level3Ris = Other.iloc[:, 23:29]
Other_level3Pro = Other.iloc[:, 29:35]
Other_level3Pro = Other_level3Pro.replace('Water / air ratio','Water/air ratio')
Other_level3Soc = Other.iloc[:, 35:38]
Other_level3Env = Other.iloc[:, 38:48]
```

In [27]:

```
#SUSTAINABILITY
sustainability = results[results['Select the field in which you are currently ac
tive']=='Sustainability ']

#create dataframe with the level 1 criteria
sustainability_level1 = sustainability.iloc[:, 8:11]

#create dataframe with the level 2 criteria
sustainability_level2Bus = sustainability.iloc[:, 11:17]
sustainability_level2Bus = sustainability_level2Bus.replace('Risk minimization '
,'Risk minimization')

#creates the dataframes with the level 3 criteria
sustainability_level3Rel = sustainability.iloc[:, 17:20]
sustainability_level3Pri = sustainability.iloc[:, 20:23]
sustainability_level3Pri = sustainability_level3Pri.replace('Costprice','Cost pr
ice')
sustainability_level3Ris = sustainability.iloc[:, 23:29]
sustainability_level3Pro = sustainability.iloc[:, 29:35]
sustainability_level3Pro = sustainability_level3Pro.replace('Water / air ratio',
'Water/air ratio')
sustainability_level3Soc = sustainability.iloc[:, 35:38]
sustainability_level3Env = sustainability.iloc[:, 38:48]
```

In [28]:

```
#Sales & Operations Planning
SandOP = results[results['Select the field in which you are currently active']==
'S&OP']

#create dataframe with the level 1 criteria
SandOP_level1 = SandOP.iloc[:, 8:11]

#create dataframe with the level 2 criteria
SandOP_level2Bus = SandOP.iloc[:, 11:17]
SandOP_level2Bus = SandOP_level2Bus.replace('Risk minimization ','Risk minimizat
ion')

#creates the dataframes with the level 3 criteria
SandOP_level3Rel = SandOP.iloc[:, 17:20]
SandOP_level3Pri = SandOP.iloc[:, 20:23]
SandOP_level3Pri = SandOP_level3Pri.replace('Costprice','Cost price')
SandOP_level3Ris = SandOP.iloc[:, 23:29]
SandOP_level3Pro = SandOP.iloc[:, 29:35]
SandOP_level3Pro = SandOP_level3Pro.replace('Water / air ratio','Water/air rati
o')
SandOP_level3Soc = SandOP.iloc[:, 35:38]
SandOP_level3Env = SandOP.iloc[:, 38:48]
```

Definitions

In [29]:

```
def ranking(df,elements,n_cri,level):
    elements = elements[0:n_cri]
    #number of selected elements = equal to number of criteria
    cri = elements[0:n_cri]
    pairs = []
    comp = []

    #create the pairs from the elements
    for i in elements:
        for j in elements:
            if i != j:
                if (j,i) not in pairs:
                    pairs.append((i,j))
                if j+i not in comp:
                    comp.append(i+j)
    df.columns = comp

    #Add the equal answer to the list of criteria
    cri.append('~')

    for i in list(range(len(cri))):
        df = df.replace(level[i],cri[i])

    n_pairs = list(range(len(pairs)))
    n_elements = list(range(len(elements)))
    col_pair = list(zip(pairs,n_pairs))
    d = dict(col_pair)
    n_resp = list(range(len(df.index)))

    #create an empty string to be able to print the rank
    for k in n_resp:
        s = pd.Series([0]*len(list(elements)),list(elements))
        string_r = ""
        x = 0

        # Here the pairs are selected with their 'neighbours', so with ABC the p
air AB has neighbours AC and BC.
        for (i,j) in pairs:
            ele = list(elements)
            ele.remove(i)
            ele.remove(j)
            for m in ele:
                left = [i,m]
                left.sort()
                left2 = (left[0],left[1])
                right = [m,j]
                right.sort()
                right2 = (right[0],right[1])

                #looks if with an equal answer the total preference is consisten
t
                if '~' == df.iloc[k,d[(i,j)]]:
                    if (df.iloc[k,d[left2]] == m and df.iloc[k,d[right2]] == j)
or (df.iloc[k,d[left2]] == i and df.iloc[k,d[right2]] == m) or (df.iloc[k,d[left
2]] == '~' and df.iloc[k,d[right2]] != '~') or (df.iloc[k,d[left2]]!= '~' and df
.iloc[k,d[right2]] == '~'):
                        if x == 0:
                            print("respondent",k+1,':\t',"Inconsistent preferenc
e")
```

```
                            x = x+1
                    else:
                        s[i] = s[i] + 1
                        s[j] = s[j] + 1
                # looks if with for example A > B the preference is consistent
                else:
                    if df.iloc[k,d[i,j]] == i:
                        if df.iloc[k,d[left2]] == m and df.iloc[k,d[right2]] ==
j:
                            if x == 0:
                                print("respondent",k+1,':\t',"Inconsistent prefe
rence")
                                x = x+1
                        else:
                            s[i] = s[i] + 100
                    # looks if with for example B > A the preference is consiste
nt
                    if df.iloc[k,d[i,j]] == j:
                        if df.iloc[k,d[left2]] == i and df.iloc[k,d[right2]] ==
m:
                            if x == 0:
                                print("respondent",k+1,':\t',"Inconsistent prefe
rence")
                                x = x+1
                        else:
                            s[j] = s[j] + 100

        #If consistent the criteria have scored points. On these points they are
ranked.
        s.index = level[0:len(elements)]
        s1 = s.sort_values(ascending = False)

        #The elements are replaced with the real criteria names again and then p
rinted in the right preference order
        if x == 0:
            for n in n_elements:
                r = s1.index.values[n]
                string_r = string_r + r
                n_1 = len(n_elements)-1
                if n < n_1:
                    if s1[n] > s1[n+1]:
                        string_r = string_r + ' > '
                    if s1[n] == s1[n+1]:
                        string_r = string_r + ' ~ '
            print("respondent",k+1,':\t',string_r)
```

In [30]:

```
def condorcet(df,elements,n_cri,level):
    elements = elements[0:n_cri]
    cri = elements[0:n_cri]
    pairs = []
    comp = []
    df8 = pd.DataFrame(columns= elements, index= elements)

    for i in elements:
        for j in elements:
            if i != j:
                df8.at[i,j] = 0
                if (j,i) not in pairs:
                    pairs.append((i,j))
                if j+i not in comp:
                    comp.append(i+j)
    df.columns = comp
    cri.append('~')

    for i in list(range(len(cri))):
        df = df.replace(level[i],cri[i])

    n_pairs = list(range(len(pairs)))
    n_elements = list(range(len(elements)))
    col_pair = list(zip(pairs,n_pairs))
    d = dict(col_pair)
    n_resp = list(range(len(df.index)))

    for k in n_resp:
        for (i,j) in pairs:
            if i == df.iloc[k,d[(i,j)]]:
                df8.at[i,j] = df8.at[i,j] + 1
            if j == df.iloc[k,d[(i,j)]]:
                df8.at[j,i] = df8.at[j,i] + 1
    print(df8)

    for (i,j) in pairs:
        if df8.at[i,j] > df8.at[j,i]:
            df8.at[j,i] = 0
            df8.at[i,j] = 1

        if df8.at[j,i] > df8.at[i,j]:
            df8.at[i,j] = 0
            df8.at[j,i] = 1

        if df8.at[i,j] == df8.at[j,i]:
            df8.at[i,j] = 0
            df8.at[j,i] = 0

    df8.columns = level[0:n_cri]
    df8.index = level[0:n_cri]
    df8["Score"] = df8.sum(axis=1)
    df8["Rank"] = len(elements) - df8["Score"]

    return df8
```

Level 1

In [31]:

```
ranking(results_level1,elements,3,Level1)
```

```
respondent 1 :   Business performance > Social performance > Environ
mental performance
respondent 2 :   Environmental performance ~ Business performance >
Social performance
respondent 3 :   Social performance ~ Business performance > Environ
mental performance
respondent 4 :   Business performance > Environmental performance ~
Social performance
respondent 5 :   Environmental performance ~ Social performance ~ Bu
siness performance
respondent 6 :   Business performance > Social performance > Environ
mental performance
respondent 7 :   Environmental performance ~ Social performance ~ Bu
siness performance
respondent 8 :   Inconsistent preference
respondent 9 :   Inconsistent preference
respondent 10 :  Social performance ~ Business performance > Environ
mental performance
respondent 11 :  Environmental performance > Business performance >
Social performance
respondent 12 :  Social performance ~ Business performance > Environ
mental performance
respondent 13 :  Inconsistent preference
respondent 14 :  Inconsistent preference
respondent 15 :  Social performance ~ Business performance > Environ
mental performance
respondent 16 :  Business performance > Environmental performance >
Social performance
respondent 17 :  Business performance > Environmental performance >
Social performance
respondent 18 :  Inconsistent preference
respondent 19 :  Business performance > Social performance > Environ
mental performance
respondent 20 :  Social performance ~ Business performance > Environ
mental performance
respondent 21 :  Environmental performance ~ Business performance >
Social performance
respondent 22 :  Social performance ~ Business performance > Environ
mental performance
respondent 23 :  Inconsistent preference
respondent 24 :  Inconsistent preference
respondent 25 :  Business performance > Environmental performance >
Social performance
respondent 26 :  Business performance > Environmental performance ~
Social performance
respondent 27 :  Business performance > Environmental performance ~
Social performance
respondent 28 :  Business performance > Environmental performance >
Social performance
respondent 29 :  Business performance > Environmental performance ~
Social performance
respondent 30 :  Business performance > Social performance > Environ
mental performance
```

In [32]:

```
condorcet(results_level1,elements,3,Level1)
```

```
     A    B    C
A  NaN   17   20
B    0  NaN   12
C    2    8  NaN
```

Out[32]:

	Business performance	Social performance	Environmental performance	Score	Rank
Business performance	NaN	1	1	2.0	1.0
Social performance	0	NaN	1	1.0	2.0
Environmental performance	0	0	NaN	0.0	3.0

Level 2

In [33]:

```
ranking(results_level2Bus,elements,4,Level2Bus)
```

```
respondent 1 :   Product properties ~ Risk minimization ~ Reliabilit
y > Price
respondent 2 :   Inconsistent preference
respondent 3 :   Inconsistent preference
respondent 4 :   Risk minimization > Reliability > Price > Product p
roperties
respondent 5 :   Risk minimization > Product properties ~ Reliabilit
y > Price
respondent 6 :   Reliability > Risk minimization > Product propertie
s > Price
respondent 7 :   Risk minimization > Product properties > Reliabilit
y > Price
respondent 8 :   Inconsistent preference
respondent 9 :   Inconsistent preference
respondent 10 :  Risk minimization > Product properties > Reliabilit
y > Price
respondent 11 :  Inconsistent preference
respondent 12 :  Inconsistent preference
respondent 13 :  Inconsistent preference
respondent 14 :  Inconsistent preference
respondent 15 :  Inconsistent preference
respondent 16 :  Product properties > Risk minimization ~ Price ~ Re
liability
respondent 17 :  Risk minimization > Reliability > Product propertie
s > Price
respondent 18 :  Product properties ~ Risk minimization ~ Reliabilit
y > Price
respondent 19 :  Product properties > Risk minimization > Reliabilit
y > Price
respondent 20 :  Inconsistent preference
respondent 21 :  Risk minimization > Product properties > Reliabilit
y > Price
respondent 22 :  Product properties > Risk minimization > Reliabilit
y > Price
respondent 23 :  Risk minimization ~ Reliability > Product propertie
s ~ Price
respondent 24 :  Inconsistent preference
respondent 25 :  Risk minimization ~ Reliability > Product propertie
s > Price
respondent 26 :  Reliability > Product properties > Risk minimizatio
n > Price
respondent 27 :  Reliability > Product properties > Risk minimizatio
n > Price
respondent 28 :  Inconsistent preference
respondent 29 :  Product properties ~ Risk minimization > Reliabilit
y > Price
respondent 30 :  Product properties ~ Reliability > Risk minimizatio
n > Price
```

In [34]:

```
condorcet(results_level2Bus,elements,4,Level2Bus)
```

```
     A    B    C    D
A  NaN   24   10   10
B    0  NaN    2    2
C   11   24  NaN   10
D    9   22    9  NaN
```

Out[34]:

	Reliability	Price	Risk minimization	Product properties	Score	Rank
Reliability	NaN	1	0	1	2.0	2.0
Price	0	NaN	0	0	0.0	4.0
Risk minimization	1	1	NaN	1	3.0	1.0
Product properties	0	1	0	NaN	1.0	3.0

Level 3: Reliability

In [35]:

```
ranking(results_level3Rel,elements,3,Level3Rel)
```

```
respondent 1 :   Consistency ~ Resource security > Product developme
nt
respondent 2 :   Consistency ~ Resource security > Product developme
nt
respondent 3 :   Inconsistent preference
respondent 4 :   Consistency > Resource security > Product developme
nt
respondent 5 :   Consistency > Resource security > Product developme
nt
respondent 6 :   Consistency > Resource security > Product developme
nt
respondent 7 :   Product development > Consistency > Resource securi
ty
respondent 8 :   Resource security > Product development > Consisten
cy
respondent 9 :   Product development ~ Consistency ~ Resource securi
ty
respondent 10 :  Product development ~ Consistency ~ Resource securi
ty
respondent 11 :  Resource security > Consistency > Product developme
nt
respondent 12 :  Consistency ~ Resource security > Product developme
nt
respondent 13 :  Product development ~ Consistency ~ Resource securi
ty
respondent 14 :  Product development > Consistency > Resource securi
ty
respondent 15 :  Resource security > Consistency > Product developme
nt
respondent 16 :  Consistency ~ Resource security > Product developme
nt
respondent 17 :  Product development > Consistency > Resource securi
ty
respondent 18 :  Inconsistent preference
respondent 19 :  Consistency ~ Resource security > Product developme
nt
respondent 20 :  Consistency ~ Resource security > Product developme
nt
respondent 21 :  Consistency ~ Resource security > Product developme
nt
respondent 22 :  Product development > Resource security > Consisten
cy
respondent 23 :  Consistency ~ Resource security > Product developme
nt
respondent 24 :  Product development ~ Consistency ~ Resource securi
ty
respondent 25 :  Resource security > Consistency > Product developme
nt
respondent 26 :  Resource security > Consistency > Product developme
nt
respondent 27 :  Consistency > Resource security > Product developme
nt
respondent 28 :  Resource security > Product development ~ Consisten
cy
respondent 29 :  Product development > Consistency > Resource securi
ty
respondent 30 :  Resource security > Consistency > Product developme
nt
```

In [36]:

```
condorcet(results_level3Rel,elements,3,Level3Rel)
```

```
     A    B    C
A  NaN    8   21
B    8  NaN   17
C    5    7  NaN
```

Out[36]:

	Resource security	Consistency	Product development	Score	Rank
Resource security	NaN	0	1	1.0	2.0
Consistency	0	NaN	1	1.0	2.0
Product development	0	0	NaN	0.0	3.0

Level 3: Price

In [37]:

```
ranking(results_level3Pri,elements,3,Level3Pri)
```

```
respondent 1 :   Price stability  > Cost price > End-of-life cost
respondent 2 :   Cost price ~ Price stability  > End-of-life cost
respondent 3 :   Cost price ~ End-of-life cost ~ Price stability
respondent 4 :   Cost price > Price stability  > End-of-life cost
respondent 5 :   Price stability  > Cost price > End-of-life cost
respondent 6 :   End-of-life cost > Price stability  > Cost price
respondent 7 :   Cost price > Price stability  > End-of-life cost
respondent 8 :   Cost price ~ Price stability  > End-of-life cost
respondent 9 :   Cost price ~ Price stability  > End-of-life cost
respondent 10 :  End-of-life cost ~ Price stability  > Cost price
respondent 11 :  Price stability  > Cost price > End-of-life cost
respondent 12 :  Cost price > End-of-life cost > Price stability
respondent 13 :  Inconsistent preference
respondent 14 :  Cost price > Price stability  > End-of-life cost
respondent 15 :  Price stability  > End-of-life cost > Cost price
respondent 16 :  Cost price > Price stability  > End-of-life cost
respondent 17 :  Cost price > End-of-life cost > Price stability
respondent 18 :  Inconsistent preference
respondent 19 :  Cost price > Price stability  > End-of-life cost
respondent 20 :  Cost price ~ Price stability  > End-of-life cost
respondent 21 :  Price stability  > End-of-life cost > Cost price
respondent 22 :  Cost price > Price stability  > End-of-life cost
respondent 23 :  Price stability  > Cost price ~ End-of-life cost
respondent 24 :  Cost price ~ End-of-life cost ~ Price stability
respondent 25 :  Cost price ~ Price stability  > End-of-life cost
respondent 26 :  Cost price > Price stability  > End-of-life cost
respondent 27 :  Price stability  > Cost price > End-of-life cost
respondent 28 :  Inconsistent preference
respondent 29 :  Price stability  > Cost price ~ End-of-life cost
respondent 30 :  Cost price > Price stability  > End-of-life cost
```

In [38]:

```
condorcet(results_level3Pri,elements,3,Level3Pri)
```

```
     A    B    C
A  NaN   21   12
B    3  NaN    4
C   10   20  NaN
```

Out[38]:

	Price stability	End-of-life cost	Cost price	Score	Rank
Price stability	NaN	1	1	2.0	1.0
End-of-life cost	0	NaN	0	0.0	3.0
Cost price	0	1	NaN	1.0	2.0

Level 3: Risk minimization

In [39]:

```
ranking(results_level3Ris,elements,4,Level3Ris)
```

```
respondent 1 :   Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 2 :   Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 3 :   Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 4 :   Growth test ~ Chemical analysis > Biological analys
is ~ Weed test
respondent 5 :   Inconsistent preference
respondent 6 :   Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 7 :   Inconsistent preference
respondent 8 :   Inconsistent preference
respondent 9 :   Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 10 :  Inconsistent preference
respondent 11 :  Weed test > Chemical analysis > Biological analysis
> Growth test
respondent 12 :  Biological analysis ~ Growth test ~ Chemical analys
is > Weed test
respondent 13 :  Inconsistent preference
respondent 14 :  Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 15 :  Chemical analysis > Biological analysis ~ Growth te
st > Weed test
respondent 16 :  Inconsistent preference
respondent 17 :  Biological analysis ~ Growth test ~ Chemical analys
is > Weed test
respondent 18 :  Inconsistent preference
respondent 19 :  Biological analysis ~ Chemical analysis > Growth te
st > Weed test
respondent 20 :  Biological analysis ~ Growth test ~ Chemical analys
is > Weed test
respondent 21 :  Biological analysis ~ Growth test ~ Chemical analys
is > Weed test
respondent 22 :  Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 23 :  Inconsistent preference
respondent 24 :  Biological analysis ~ Weed test ~ Growth test ~ Che
mical analysis
respondent 25 :  Growth test > Chemical analysis > Biological analys
is > Weed test
respondent 26 :  Chemical analysis > Biological analysis > Growth te
st > Weed test
respondent 27 :  Weed test > Biological analysis > Chemical analysis
> Growth test
respondent 28 :  Growth test > Biological analysis ~ Chemical analys
is > Weed test
respondent 29 :  Growth test > Chemical analysis > Biological analys
is > Weed test
respondent 30 :  Biological analysis ~ Chemical analysis > Weed test
> Growth test
```

In [40]:

```
condorcet(results_level3Ris,elements,4,Level3Ris)
```

```
     A    B    C    D
A  NaN    8   16    7
B    5  NaN   15    6
C    2    3  NaN    4
D    1    5   13  NaN
```

Out[40]:

	Chemical analysis	Growth test	Weed test	Biological analysis	Score	Rank
Chemical analysis	NaN	1	1	1	3.0	1.0
Growth test	0	NaN	1	1	2.0	2.0
Weed test	0	0	NaN	0	0.0	4.0
Biological analysis	0	0	1	NaN	1.0	3.0

Level 3: Product properties

In [41]:

```
ranking(results_level3Pro,elements,4,Level3Pro)
```

```
respondent 1 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 2 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 3 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 4 :   EC-value > Water/air ratio > pH-value > WOK-analysi
s
respondent 5 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 6 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 7 :   Inconsistent preference
respondent 8 :   WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 9 :   Inconsistent preference
respondent 10 :  WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 11 :  pH-value ~ EC-value > WOK-analysis ~ Water/air rati
o
respondent 12 :  EC-value > WOK-analysis ~ pH-value > Water/air rati
o
respondent 13 :  Inconsistent preference
respondent 14 :  WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 15 :  EC-value > pH-value > Water/air ratio > WOK-analysi
s
respondent 16 :  Water/air ratio > EC-value > WOK-analysis > pH-valu
e
respondent 17 :  pH-value ~ EC-value > Water/air ratio > WOK-analysi
s
respondent 18 :  EC-value > WOK-analysis ~ Water/air ratio ~ pH-valu
e
respondent 19 :  pH-value ~ EC-value > WOK-analysis ~ Water/air rati
o
respondent 20 :  WOK-analysis ~ Water/air ratio ~ EC-value > pH-valu
e
respondent 21 :  WOK-analysis ~ Water/air ratio ~ pH-value > EC-valu
e
respondent 22 :  WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 23 :  Water/air ratio ~ pH-value ~ EC-value > WOK-analysi
s
respondent 24 :  WOK-analysis ~ Water/air ratio ~ pH-value ~ EC-valu
e
respondent 25 :  pH-value ~ EC-value > WOK-analysis > Water/air rati
o
respondent 26 :  pH-value ~ EC-value > WOK-analysis > Water/air rati
o
respondent 27 :  pH-value > Water/air ratio > WOK-analysis > EC-valu
e
respondent 28 :  Inconsistent preference
respondent 29 :  WOK-analysis ~ Water/air ratio > pH-value > EC-valu
e
respondent 30 :  WOK-analysis ~ Water/air ratio ~ pH-value > EC-valu
e
```

In [42]:

```
condorcet(results_level3Pro,elements,4,Level3Pro)
```

```
     A    B    C    D
A  NaN    6    9   12
B    5  NaN   10   11
C    6    4  NaN    8
D    4    3    3  NaN
```

Out[42]:

	EC-value	pH-value	Water/air ratio	WOK-analysis	Score	Rank
EC-value	NaN	1	1	1	3.0	1.0
pH-value	0	NaN	1	1	2.0	2.0
Water/air ratio	0	0	NaN	1	1.0	3.0
WOK-analysis	0	0	0	NaN	0.0	4.0

Level 3: Social performance

In [43]:

```
ranking(results_level3Soc,elements,3,Level3Soc)
```

```
respondent 1 :   Job creation > Health & Safety > Environmental comm
itment
respondent 2 :   Environmental commitment > Health & Safety > Job cr
eation
respondent 3 :   Environmental commitment ~ Health & Safety > Job cr
eation
respondent 4 :   Environmental commitment ~ Health & Safety > Job cr
eation
respondent 5 :   Environmental commitment ~ Job creation ~ Health &
Safety
respondent 6 :   Environmental commitment ~ Health & Safety > Job cr
eation
respondent 7 :   Environmental commitment ~ Health & Safety > Job cr
eation
respondent 8 :   Health & Safety > Environmental commitment > Job cr
eation
respondent 9 :   Inconsistent preference
respondent 10 :  Health & Safety > Environmental commitment > Job cr
eation
respondent 11 :  Health & Safety > Environmental commitment ~ Job cr
eation
respondent 12 :  Health & Safety > Environmental commitment > Job cr
eation
respondent 13 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 14 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 15 :  Environmental commitment ~ Job creation ~ Health &
Safety
respondent 16 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 17 :  Health & Safety > Environmental commitment > Job cr
eation
respondent 18 :  Environmental commitment > Health & Safety > Job cr
eation
respondent 19 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 20 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 21 :  Environmental commitment > Health & Safety > Job cr
eation
respondent 22 :  Health & Safety > Environmental commitment > Job cr
eation
respondent 23 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 24 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 25 :  Environmental commitment ~ Health & Safety > Job cr
eation
respondent 26 :  Health & Safety > Job creation > Environmental comm
itment
respondent 27 :  Health & Safety > Environmental commitment ~ Job cr
eation
respondent 28 :  Health & Safety > Environmental commitment > Job cr
eation
respondent 29 :  Environmental commitment > Job creation ~ Health &
Safety
respondent 30 :  Health & Safety > Environmental commitment > Job cr
eation
```

In [44]:

```
condorcet(results_level3Soc,elements,3,Level3Soc)
```

```
     A    B    C
A  NaN   26   11
B    1  NaN    2
C    4   23  NaN
```

Out[44]:

	Health & Safety	Job creation	Environmental commitment	Score	Rank
Health & Safety	NaN	1	1	2.0	1.0
Job creation	0	NaN	0	0.0	3.0
Environmental commitment	0	1	NaN	1.0	2.0

Level 3: Environmental performance

In [45]:

```
ranking(results_level3Env,elements,5,Level3Env)
```

```
respondent 1 :   Inconsistent preference
respondent 2 :   Inconsistent preference
respondent 3 :   Inconsistent preference
respondent 4 :   Eco-system change ~ LCA (C-T-Gate) > Water use ~ Ca
rbon footprint > Circularity
respondent 5 :   Inconsistent preference
respondent 6 :   Inconsistent preference
respondent 7 :   Inconsistent preference
respondent 8 :   Inconsistent preference
respondent 9 :   Inconsistent preference
respondent 10 :  Inconsistent preference
respondent 11 :  Inconsistent preference
respondent 12 :  Inconsistent preference
respondent 13 :  Inconsistent preference
respondent 14 :  Inconsistent preference
respondent 15 :  Eco-system change ~ LCA (C-T-Gate) > Carbon footpri
nt > Water use > Circularity
respondent 16 :  LCA (C-T-Gate) > Water use ~ Carbon footprint > Cir
cularity > Eco-system change
respondent 17 :  LCA (C-T-Gate) > Carbon footprint > Water use > Eco
-system change > Circularity
respondent 18 :  Inconsistent preference
respondent 19 :  Circularity ~ Eco-system change ~ Carbon footprint
~ LCA (C-T-Gate) > Water use
respondent 20 :  Circularity ~ Eco-system change ~ Water use ~ Carbo
n footprint > LCA (C-T-Gate)
respondent 21 :  LCA (C-T-Gate) > Carbon footprint > Circularity > W
ater use > Eco-system change
respondent 22 :  Circularity ~ Eco-system change ~ Water use ~ Carbo
n footprint > LCA (C-T-Gate)
respondent 23 :  LCA (C-T-Gate) > Carbon footprint > Water use > Eco
-system change > Circularity
respondent 24 :  Circularity ~ Eco-system change ~ Water use ~ Carbo
n footprint ~ LCA (C-T-Gate)
respondent 25 :  Circularity ~ Eco-system change ~ Water use ~ Carbo
n footprint > LCA (C-T-Gate)
respondent 26 :  Inconsistent preference
respondent 27 :  LCA (C-T-Gate) > Carbon footprint > Eco-system chan
ge > Circularity > Water use
respondent 28 :  Inconsistent preference
respondent 29 :  Water use > Circularity ~ Eco-system change > LCA
(C-T-Gate) > Carbon footprint
respondent 30 :  LCA (C-T-Gate) > Carbon footprint > Eco-system chan
ge > Circularity > Water use
```

In [46]:

```
condorcet(results_level3Env,elements,5,Level3Env)
```

```
     A    B    C    D    E
A  NaN   16   19   12   14
B    5  NaN   12    9   13
C    7    2  NaN    7    9
D    8    4    7  NaN    8
E    8    2    6    2  NaN
```

Out[46]:

	LCA (C-T-Gate)	Carbon footprint	Water use	Eco-system change	Circularity	Score	Rank
LCA (C-T-Gate)	NaN	1	1	1	1	4.0	1.0
Carbon footprint	0	NaN	1	1	1	3.0	2.0
Water use	0	0	NaN	0	1	1.0	4.0
Eco-system change	0	0	0	NaN	1	1.0	4.0
Circularity	0	0	0	0	NaN	0.0	5.0

In [ ]:

Appendix VI – Data and assumptions

A - Business performance

Resource security

The resource security is determined by the potential volume of the material, market expectations and conversations with the purchase department of Kekkilä-BVB. For the peat materials there is enough volume, but the availability depends on the regulations for harvesting or consuming of peat. The coir materials are the most limited raw material in terms of volume, because there are other competing uses. The potential volume is projected at 60 Mm^3/year. For woodfibre the projected volume is 1138 Mm^3/year. For bark (139 Mm^3/year) and mineral wool (120 Mm^3/year) the projected volume is double the volume of coir materials. For standardised compost (15 Mm^3/year) the project volume is rather low, while the future as a circular product has a high potential. For perlite there is not expected any shortage soon, since the currently used volume is rather low. Projections for perlite are that the future volume is 16 Mm^3/year. This figures where the starting point for the discussions with the purchasers and what kind of developments and barriers are seen in the market, this then resulted in the scores as shown in the impact table.

Consistent material

The consistency is determined by the standard deviations from the test results. When many standard deviations are high, the consistency is low. When some standard deviations score high, but most do not have large deviations the score is medium. With low standard deviations the consistency of the material is high. Per material there is looked if the high standard deviations are important for the consistency or that the standard deviation is acceptable. These results are than shared with the R&D department of Kekkilä-BVB with which the validation of the data has been done.

Product development

The development of a product can be scored with High, Medium, Low. A high score means that there are many potentials to the material to be further developed. When the material can be developed on a limited scale the score is medium. A low score indicates that the product has not many development options. The longer the raw material is used in the sector, the less development is expected over time. New innovative products as Accretio and Foam have therefore a high score. The scores are validated together with R&D and Procurement specialist from Kekkilä-BVB.

Price stability

The price stability is determined by the fluctuations in the cost price over the past two years. The prices shown in table 26 are validated with the procurement department, where after the scores are determined in cooperation.

Alternative	2018	2019	2020	Score
White Peat				
Black Peat				
Accretio				
Coir pith				
Coir chips				
Coir fibre				
Woodfibre				
Bark				
Perlite				
(Standardised) Compost				
Mineral Wool				
Foam				

Table 26: Calculation prices from 2018-2020

End-of-life cost
Per alternative there is looked at the costs that have to be made for restoration of landscapes, re-use, recycling and waste. The more costs can be estimated at the end-of-life stage the higher the score. No precise numbers could be found, but there is known that peat fields have to be restored after harvesting. This also account for Accretio, but since the grow back time is estimated at 30 years the cost are assumed lower. The (standardised) compost can probably be reused again, which results in more end-of-life costs. For the inorganic materials mineral wool and foam the estimated end-of-life cost are higher than other raw materials, because of production process to make the product useable again.

Cost price
is measured with the sum of the current material cost, logistical cost and handling cost of a (raw) material. When the material is expected to be cheaper in the future this is an indicator for the product development. The cost prices of the alternatives per m^3 can be found in the effects table.

Chemical analysis
The chemical analysis shows nutrient values for many elements and characteristics. With this criteria an overall score of the chemical analysis is given, because one value outside of the boundaries could mean that the material is harmful to the plant. Results are validated with the R&D department.

Alternatives	Outliers in Chemical intern (current year)	Score
White Peat		Very low risk
Black Peat		Very low risk
Accretio		Very low risk
Coir pith		High risk
Coir chips		High risk
Coir fibre		Low risk
Woodfibre		Low risk
Bark		Low risk
Perlite		Very low risk
(Standardised) Compost		Very high risk
Mineral Wool		No risk
Foam		No risk

Table 27: Outliers in chemical analysis

Growth test
For the growth test there is looked at the scores of the performed growth test in 2019 and 2020. The mediate and bad scores are noted and on those numbers the scores are determined. Validated with the R&D department. The results can be seen in table 28. For Accretio, Perlite, Mineral wool and Foam assumptions have been made, since there was no available data. Accretio is a stabile natural material and can therefore be compared to the peat materials, woodfibre and compost. Perlite and the inorganic materials are clean materials and therefore anything can grow on those materials.

Growth test	Mediate score (#2019-2020)	Bad score (#2019-2020)	Score (1-5)
White Peat			**4**
Black Peat			**4**
Accretio			**4**
Coir pith			**3**
Coir chips			**3**
Coir fibre			**3**
Woodfibre			**4**
Bark			**3**
Perlite			**5**
(Standardised) Compost			**4**
Mineral Wool			**5**
Foam			**5**

Table 28: Mediate and bad growth test results

Weed test
Within the **weed test** the number of weeds / m^2 is measured. The more weeds are present per cubic metre the higher risk of negative effects during cultivation. The data can found in the effects table.

Biological analysis
To measure the biological characteristics of the materials is not a specific laboratory test available. In the upcoming years better measurement tools / laboratory test are expected to be able to measure the micro life within a material. For this research the score for biological analysis is based on the number of (human) pathogens and fungi present in the material and then validated with the R&D department of Kekkilä-BVB.

EC-value
The EC-value is measured in mS/cm. A value below 0.6 ms/cm is acceptable for the nutrients in (raw) material (RHP, 2018). In general the lower the EC-value the better, because than the needed nutrients can be added. The data can be found in the effects table.

pH-value
For (raw) material the acceptable pH level is different between the materials. For mixtures with materials the most accaptable range is a pH between 5.0 and 6.5 (Bos, Keijzer, Schie, Verhagen, & Zevenhoven, 2003). The pH value can be rised by adding lime to the mixture, however the pH-value cannot be brought down. In table 29 the acceptable ranges for the pH value are shown with the measured average in laboratory test. This results are then validated with the R&D department.

Alternatives	pH-range	Average	Score
White Peat	3 – 4.5		High
Black Peat	Sweden: 3 – 4.5 Baltics: 4 - 7 Germany: 3.7 – 7		High
Accretio	3.5 – 7.5		High
Coir pith	3.5 – 7.5		Medium
Coir fibre	3.5 – 7.5		Medium
Coir chips	3.5 – 8		Medium
Woodfibre	3.7 – 7		High
Bark	3.7 – 7		High
Perlite	3.7 – 7		Medium
(Standardised) Compost	No norm		Low
Mineral Wool	7		High
Foam	6		High

Table 29: pH-value ranges and averages for the alternatives

Water/air ratio

The water to air ratio is measured on 5 different pressure levels on the substrate. The ratio shows how size of the pores in the material. Small pores can fill themselves with water, where large pores have more air storage (Bos, et al., 2003). It is important to know this ratio, since than can be determined how the material behaves when water is given and how long water can be stored in the material. The pressure level on -10cm is taken as representative level for the water to air ratio. For the water content a value below the 80% is acceptable. Where for the air content the value of the mixture should be between 16-25% most of the times (Bos, et al., 2003). This can be reached by combining the materials. If both contents are within the acceptable ranges the materials has a high score. With one of the contents within range the score is medium.

Alternatives	Water content at -10 cm (%-v)	Air content at -10 cm (%-v)	Score
White Peat			**High**
Black Peat			**Medium**
Accretio			**Medium**
Coir pith			**High**
Coir chips			**Medium**
Coir fibre (50-50)			**Medium**
Woodfibre			**Medium**
Bark			**Medium**
Perlite			**Medium**
(Standardised) Compost			**Medium**
Mineral Wool			**Medium**
Foam			**Medium**

Table 30: Water and air content

WOK-analysis
In the WOK-analysis the water uptake is measured at the 50% uptake point and after 1440 minutes (24 hours). Both are necessary to analyse the Water Uptake Characteristic. RHP defined a four point scale on which the WOK results are scored: 1 = Water uptake fast, 2 = Water uptake sufficient , 3= Water uptake moderate, 4 = Water uptake slow (RHP, 2018). For the alternatives the data can be seen in the effects table. For the coir and inorganic materials assumptions have been made. For coir pith, coir fibre and foam is assumed to have a fast water uptake. For mineral wool the water uptake is assumed sufficient and the coir chips is estimated to have a moderate water uptake.

B - Social performance

Health & Safety
The health & safety score as can be seen in the effects table is determined on multiple data points. Within Kekkilä-BVB there is looked at the different suppliers and their supplier ratings. Also there is looked if the suppliers comply with the code of conduct. The procurement department is consulted for opinions about the alternatives. External sources are the Health score as estimated in the EPAGMA report (EPAGMA, 2012) and the origin of the material. The internal and external sources are used to derive at the scores, which are validated with the procurement department of Kekkilä-BVB.

Job creation
Looks into the dependence of the job market on the harvesting and production of (raw) materials. Are there many other opportunities within the area of harvesting / production locations for employment or is the region very dependent on the economic activity provided by the suppliers of the (raw) materials. For the coir materials is known that the region is very dependent on the coir production (Centre for Market Research & Social Development, 2015). Within northern Europe the peat production used to be an important job market, but with less energy being produced from peat the job creation is declining. For the other products the region is not very dependent on the production of the materials.

Environmental commitment
To look into the environmental commitment there is looked at different eco-labels and quality marks, such as RPP / local government guidelines, FSC, EU eco-label, PEFC and OMRI-listed. The scores are shown in the effects table and validated with the procurement department of Kekkilä-BVB.

C - Environmental performance

LCA (Cradle-to-gate)
The LCA from cradle-to-gate is calculated with databases from Ecochain (Ecochain, 2020), where several databases are combined to present the environmental footprint of a product. Every phase of the products supply chain is taken into account. Nevertheless is it not possible to present a LCA from cradle-to-cradle or cradle-to-grave, because of the many uncertainties, cultivation ways and global customers. The data can be seen in the effects table. For foam the the LCA value is calculated with the Idemat database (Idemat, 2020). Since the value for mineral wool could also be calculated with the Idemat database a relation between the value from Ecochain and Idemat could be established, resulting in the LCA score for Foam.

Carbon footprint
The carbon footprint data is used from the EPAGMA report (EPAGMA, 2012). For Accretio the assumption is made that is has half of the end-of-life carbon footprint then white peat. However other assumptions can also be made, since the carbon footprint of Accretio is assumed to be way lower than peat products, since there is no degradation of the material. This second value is taken into account within the scenarios. For foam the same relation with mineral wool as found between EPAGMA and Idemat is used to come at the carbon footprint value for Foam.

Water use
The water use during the harvesting and production phase is estimated and measurement along the alternatives. The data can be seen in the effects table and is validated together with the R&D and procurement department.

Eco-system change
The eco-system change value is taken as presented in the EPAGMA report (EPAGMA, 2012). For Accretio the value is assumed to be lower than wood-based materials and mineral wool. The value is lower than the peat-based material, because it is not necessary to put the field under water before harvesting. For Foam the value is compared to the ecotoxixity values for polyurethane and mineral wool in the Idemat database, whereafter the eco-system change value for Foam is determined on the relation found within the database.

Circularity
The circularity is measured by the percentage of a (raw) material that is reused or recycled at the end of the life cycle of the material. With re-use the end-product is not changed an used again within the same production process. By recycling the end-product can be used within the production process of another product. To achieve a circular economy the destination of a product has a crucial role. Within western Europe the raw materials can be fully recycled by composting and biogas production, while in the other parts of Europe (raw) materials are less likely to be reused or recycled (European Parlement, 2018). The waste management system of countries determines the ways circularity can be achieved for growing media (raw) materials.

For the natural materials the circularity at the end of the life-cycle is estimated at 100%, since at the consumer the substrate goes into the ground or is thrown away with the organic waste so it can be composted. In the landscaping department the used materials are put back into the ground as soil improvement. The residual flows from substrates in professional horticulture goes to local farmers who use the substrate as soil improvement. Mineral wool is recycled into bricks, where 90% of the used mineral wool can be used (Grodan, 2017). For Foam the circularity is estimated at 30% (Covestro, 2018), the polyurethane is in great demand for use in incinerators because of the energy released. For the future, this criterion will actually have to be filled with data reflecting the whole circularity of the life cycle and not just its end. The circularity at the beginning of the chain is assumed to be very low and a great deal of study needs to be done into the possibilities for circular substrates.

Appendix VII – Results per method and group

Within this appendix the results are presented per level 1 performance and per actor group over the different weighing methods. First the ranking of the alternatives are shown over the business performance, social performance and environmental performance. Second, the ranking is presented over the four actor groups; Growing Media company, Growing Media association / quality mark, Reseach Institution and Customers per weighing method.

A - Performance groups

Business performance

As can be seen in figure 42 the business performance ranking does not show a lot of changes. The alternatives stay within their groups of their overall score. The coir products shift tot the front of the bad scores, only bark and (standardised) compost have a worse score for the business performance. The inorganic materials all shift over the natural material and present the top 3 of products.

Ranking per method	Alternatives											
	White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Normalised	4	6	7	10	9	8	5	11	3	12	2	1
Rang reciproke	4	6	7	11	9	8	5	10	2	12	3	1
Rietveld & Ouwersloot	4	5	6	11	9	8	7	10	3	12	2	1

Figure 42: Results business performance

Social performance

The social performance results in 4 different groups of products. The peat products have the highest social score, followed closely by Accretio, Woodfibre and Bark. Perlite, (standardised) Compost, Mineral wool and Foam are the third group. The coir materials have the lowest social performance score, which is a results from the social conditions in India and Sri Lanka and the commitment these suppliers have to the environment.

Ranking per method	Alternatives											
	White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Normalised	1	1	3	10	10	10	3	3	6	6	6	6
Rang reciproke	1	1	3	10	10	10	3	3	6	6	6	6
Rietveld & Ouwersloot	1	1	3	10	10	10	3	3	6	6	6	6

Figure 43: Results social performance

Environmental performance

The environmental performance shows a completely different ranking than the overall ranking. On the environmental performance criteria Woodfibre, Accretio, Perlite and Bark score high. Followed by white peat, mineral wool and (standardised) compost. The alternatives with a low score are black peat, the coir materials and foam.

Ranking per method	Alternatives											
	White Peat	Black Peat	Accretio	Coir pith	Coir chips	Coir fibre	Woodfibre	Bark	Perlite	(Standardised) Compost	Mineral Wool	Foam
Normalised	5	8	2	10	11	9	1	4	3	7	6	12
Rang reciproke	5	8	2	10	11	9	1	4	3	7	6	12
Rietveld & Ouwersloot	5	8	3	10	11	9	1	2	4	6	7	12

Figure 44: Results environmental performance

B - Results per actor group

The results are shown for the normalised, Rietveld & Ouwersloot and Aggregate per respondent for the Rang reciproke method. Over all the different methods can be seen that small changes in ranking occur, but that the materials do not shift largely. The Rietveld & Ouwersloot method makes a bigger distribution between the preferences, which explains why most of the changes can be seen there. Between the actor groups the alternatives stay within the same range, but positions shifts. Overall white peat, woodfibre and perlite have the highest rank, followed closely by Accretio, Mineral wool and Foam. Where between the results for all the respondents a clear difference can be seen between Bark, (standardised) compost and the coir materials, the results per actor group show that (standerdised) compost and the coir materials shift in the rankings. The results for the Rang reciproke method can be seen in chapter 6.4.1. The other weighing methods with their results are shown in the tables below.

Normalised		Growing Media company	Growing media association / quality mark	Research institution	Customers
Alternatives	White Peat	1	3	2	2
	Woodfibre	2	2	1	3
	Perlite	3	1	3	1
	Accretio	4	5	4	6
	Mineral Wool	5	4	5	4
	Black Peat	6	7	7	7
	Foam	7	6	6	5
	Bark	8	8	8	8
	(Standardised) Compost	9	12	9	10
	Coir fibre	10	9	10	9
	Coir pith	11	11	12	11
	Coir chips	12	10	11	12

Table 31: Results for the actor groups over the normalised method

Rietveld & Ouwersloot		Growing Media company	Growing media association / quality mark	Research institution	Customers
Alternatives	White Peat	1	4	3	2
	Woodfibre	2	2	1	5
	Perlite	3	1	2	1
	Accretio	4	6	6	7
	Mineral Wool	5	3	5	4
	Black Peat	6	7	7	6
	Foam	7	5	4	3
	Bark	8	8	8	8
	(Standardised) Compost	9	12	10	12
	Coir fibre	10	9	9	9
	Coir pith	11	11	12	10
	Coir chips	12	10	11	11

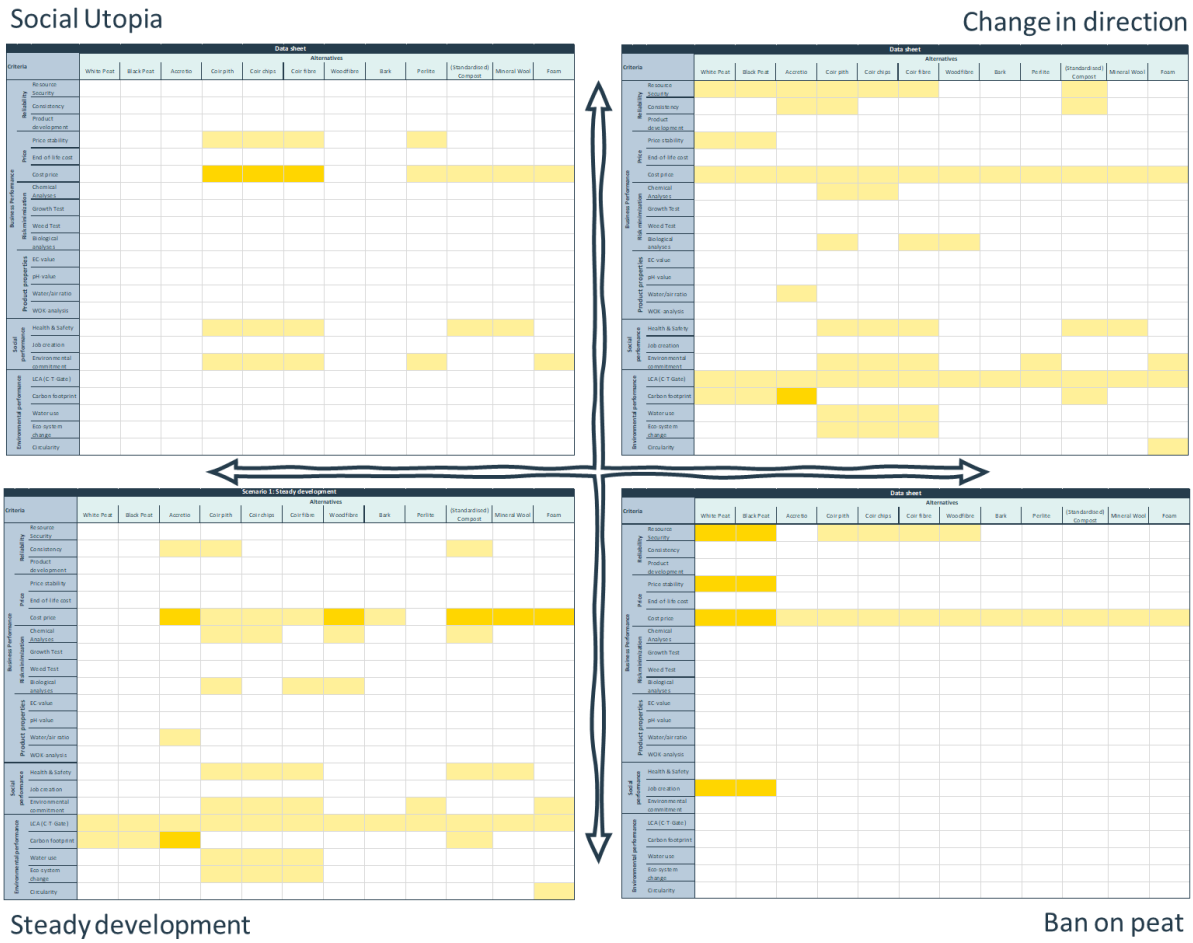
Table 32: Results for the actor groups over the Rietveld & Ouwersloot method

Aggregate per respondent		Growing Media company	Growing media association / quality mark	Research institution	Customers
Alternatives	Woodfibre	1	1	2	1
	Perlite	2	2	4	3
	White Peat	3	3	1	2
	Accretio	4	4	3	5
	Mineral Wool	5	5	6	4
	Foam	6	8	7	6
	Black Peat	7	6	5	7
	Bark	8	7	8	8
	(Standardised) Compost	9	10	9	9
	Coir fibre	10	9	10	10
	Coir chips	11	11	11	12
	Coir pith	12	12	12	11

Table 33: Results for the actor groups over the aggregate per respondent method

Appendix VIII – Operationalisation of scenarios

The operationalisation of scenarios is shown in the figure below. Light yellow represents a small change and dark yellow a big change. Within this appendix the operationalisation is discussed per scenario with the assumptions made to derive at the scenarios.



A - Steady development

- **Consistency** – Accretio, Coir pith and (standardised) compost improve by one step
- **Cost price** – Dark yellow: -10%, Light yellow +/- 5%. Coir materials to worsen 5%. Bark, (standardised) compost and mineral wool to improve by 5%.
- **Biological analysis** – Coir pith, fibre and woodibre to improve by one step.
- **Water/air ratio** – Accretio to improve by one step.
- **Health & Safety –** Coir materials, (standardised) compost and mineral wool to improve by one step.
- **Environmental commitment –** Coir materials, Perlite and Foam to improve by one step
- **LCA (C-t-gate)** – Alternatives with improvements: -10%. Others: -5%.
- **Carbon footprint** – Dark yellow: -20%. Light yellow: -10%.
- **Water use** – Coir materials: -50% due to reuse of water.
- **Eco-system change** – Coir materials: -40% due to filter for harmful substances.
- **Circularity** – Foam: 60%

B - Ban on peat

- **Resource security –** Dark yellow to worsen by two steps. Light yellow to worsen by one step.
- **Price stability –** Peat materials to worsen by one step.
- **Cost price –** Dark yellow: +20%. Light yellow: +5%, due to scarcity of the materials.
- **Job creation –** Peat materials to worsen by one step.

C - Social Utopia

- **Cost price** – Dark yellow to increase with 10%. Light yellow to increase by 5%. Due to higher social standards the cost price will increase.
- **Health & Safety** – All alternatives to improve to highest score.
- **Environmental commitment –** All alternatives to improve to highest score.

D - Change of direction

- **Resource security** – Peat and coir materials to worsen by one step. (standardised) Compost to improve by one step.
- **Consistency** – Accretio, Coir pith and (standardised) compost to improve by one step.
- **Price stability** – Peat materials to worsen by one step.
- **Cost price** – Dark yellow: +10%, Light yellow + 5%, due to scarcity of the materials
- **Chemical analysis** – Coir pith and chips and (standardised) compost to improve by one step.
- **Biological analysis** – Coir pith, fibre and woodibre to improve by one step.
- **Water/air ratio** – Accretio to improve by one step.
- **Health & Safety –** Coir materials, (standardised) compost and mineral wool to improve by one step.
- **Environmental commitment –** Coir materials, Perlite and Foam to improve by one step
- **LCA (C-t-gate)** – Alternatives with improvements: -10%. Others: -5%.
- **Carbon footprint** – Dark yellow: -20%. Light yellow: -10%.
- **Water use** – Coir materials: -50% due to reuse of water.
- **Eco-system change** – Coir materials: -40% due to filter for harmful substances.
- **Circularity** – Foam: 60%

Appendix IX – Scenario results

In chapter 7.3 the results of the scenarios are discussed along the Rang reciproke method, since this method gave small changes in ranking compared to others and the ranking was assumed to be the most trustworthy. In the tables below the results are shown per scenario over the weighing methods.

A - Scenario 1: Steady development

The results show clearly that with steady development the products that have limited develop over time shift to a lower rank, such as white peat. Between the ranking methods rather small changes occur, but the alternatives stay within their same ranges.

	Ranking per method	Normalised	Rang Reciproke	Rietveld & Ouwersloot	Agg. per respondent
Alternatives	Perlite	1	1	1	1
	Mineral Wool	2	2	3	3
	Foam	3	3	2	4
	Woodfibre	4	4	5	2
	White peat	5	5	4	6
	Accretio	6	6	6	5
	Black Peat	7	7	7	7
	(Standardised) Compost	8	8	8	9
	Bark	9	10	10	8
	Coir fibre	10	9	9	10
	Coir pith	11	11	11	11
	Coir chips	12	12	12	12

Table 34: Results scenario 1 - Steady development

B - Scenario 2: Ban on peat

In this scenario the development of the product is not taken into account. Even though the peat resources are restricted the material almost has the same score than in the current situation. With an restriction the characteristics do not change and those are good. The criteria that change due to restrictions have not a big impact on the utility of the peat products.

	Ranking per method	Normalised	Rang Reciproke	Rietveld & Ouwersloot	Agg. per respondent
Alternatives	White peat	1	4	4	3
	Perlite	2	1	1	2
	Mineral Wool	3	2	2	5
	Foam	4	3	3	6
	Woodfibre	5	5	7	1
	Accretio	6	6	5	4
	Black Peat	7	7	6	7
	Bark	8	8	8	8
	(Standardised) Compost	9	9	9	9
	Coir fibre	10	10	10	10
	Coir pith	11	12	11	11
	Coir chips	12	11	12	12

Table 35: Results scenario 2 - Ban on peat

C - Scenario 3: Social Utopia

By equalizing the social performance the shifts of ranking mainly occur at the places 9-12 between bark, (standardised) compost and the coir materials. Compost has now the lowest score where coir fibre has risen to the 6-8 place. But what the weighted sum scores mainly showed was that when the social performance is improved all alternatives are closer together and have a higher utility.

	Ranking per method	Normalised	Rang Reciproke	Rietveld & Ouwersloot	Agg. per respondent
Alternatives	Perlite	1	1	1	1
	Mineral Wool	2	2	2	2
	Foam	3	3	3	5
	White peat	4	4	4	4
	Woodfibre	5	5	7	3
	Coir fibre	6	8	8	7
	Black Peat	7	7	5	8
	Accretio	8	6	6	6
	Coir chips	9	9	9	10
	Coir pith	10	11	10	11
	Bark	11	10	11	9
	(Standardised) Compost	12	12	12	12

Table 36: Results scenario 3 - Social Utopia

D - Scenario 4: Change of direction

This scenarios combines the development of products, stricter regulations on peat and materials from far away and a social improvement for most materials. It can be seen in table 37 that the results for this scenario still show the same distribution, but that white peat has shifted towards a 6th place, where in the current situation it still scored a 1st position at some of the weighing methods. This can be explained by the development of the other products combined with a stricter regulation. In the future other alternatives will become as favoured as white peat is in the current situation, which allows for the use of more different materials in the growing media sector.

	Ranking per method	Normalised	Rang Reciproke	Rietveld & Ouwersloot	Agg. per respondent
Alternatives	Perlite	1	1	1	1
	Mineral Wool	2	2	3	3
	Foam	3	3	2	5
	Accretio	4	5	4	4
	Woodfibre	5	4	6	2
	White peat	6	6	5	6
	Black Peat	7	7	7	7
	(Standardised) Compost	8	8	8	9
	Bark	9	9	9	8
	Coir fibre	10	10	10	10
	Coir pith	11	11	11	11
	Coir chips	12	12	12	12

Table 37: Results scenario 4 - Change of direction

Appendix X – Scenario decision criteria

The decision criteria used in chapter 7.3 are shown in the tables below. Within the results of the scenarios only the outcome is shown. Within the appendix the scores over the scenarios are shown and how the decision criteria derive at the ranking of the alternatives.

A - MaxiMin

In the MaxiMin criterion (Wald, 1950) the minimum value of the scenarios is selected for each alternative. The alternatives are ranged along the hight of these values, as can be seen in table 38.

Rang reciproke		Scenario 1	Scenario 2	Scenario 3	Scenario 4	MaxiMin
Alternatives	**Perlite**	0.840	**0.790**	0.845	0.840	**0.790**
	Mineral Wool	0.815	0.766	0.820	0.815	**0.766**
	Foam	0.807	0.744	0.798	0.806	**0.744**
	Woodfibre	0.775	0.722	0.735	0.756	**0.722**
	Accretio	0.744	0.716	0.717	0.755	**0.716**
	White Peat	0.755	0.688	0.760	0.724	**0.688**
	Black Peat	0.701	0.637	0.709	0.670	**0.637**
	Bark	0.608	0.618	0.619	0.608	**0.608**
	(Standardised) Compost	0.632	0.518	0.572	0.632	**0.518**
	Coir fibre	0.616	0.469	0.700	0.603	**0.469**
	Coir chips	0.543	0.403	0.634	0.531	**0.403**
	Coir pith	0.576	0.398	0.616	0.563	**0.398**

Table 38: MaxiMin decision criterium

B - Least regret

In the regret criterion of Savage (1950) the so-called 'regret' is determined for each alternative on the scenarios. The maximum score minus the score of the alternative indicates the regret. The maximum regret value is selected per alternative, after which the materials are ranked according to the least regret.

Rang reciproke		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Least regret
Alternatives	**Perlite**	0.000	0.000	0.000	0.000	**0**
	Mineral Wool	0.025	0.024	0.025	0.025	**0.025**
	Foam	0.033	0.046	0.047	0.034	**0.047**
	Woodfibre	0.065	0.068	0.110	0.084	**0.11**
	White Peat	0.096	0.074	0.128	0.085	**0.116**
	Accretio	0.085	0.102	0.085	0.116	**0.128**
	Black Peat	0.139	0.153	0.136	0.170	**0.17**
	Bark	0.232	0.172	0.226	0.232	**0.232**
	(Standardised) Compost	0.208	0.272	0.273	0.208	**0.273**
	Coir fibre	0.224	0.321	0.145	0.237	**0.321**
	Coir chips	0.297	0.387	0.211	0.309	**0.387**
	Coir pith	0.264	0.392	0.229	0.277	**0.392**

Table 39: Least regret decision criterium

C - Optimism - Pessimism

Hurwicz (1951) uses the risk factor α, if the decision-maker does not want to run any risk then the α = 0. If the decision-maker wants to strive for the maximum benefit then it does not avoid any risk, resulting in α = 1. An α of 0.4 has been chosen because the sector is quite risk aversive, the raw materials must provide food safety and there must be no harmful substances in it. Now that the α has been determined, the score is calculated by adding the maximum value over the scenarios times α plus the minimum value over the scenarios times (1-α).

The changes in ranking have also been considered for the other α. At α = 0.5, compost and coir fibre change places. At α = 0.7 coir fibre also passes over bark. If the decision-maker strives for maximum utility, Accretio will rise above white peat for α = 0.9. At α = 1 the coir chips rise above (standardised) compost and bark.

Rang reciproke		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Hurwicz
Alternatives	**Perlite**	0.840	0.790	0.845	0.840	**0.812**
	Mineral Wool	0.815	0.766	0.820	0.815	**0.788**
	Foam	0.807	0.744	0.798	0.806	**0.769**
	Woodfibre	0.775	0.722	0.735	0.756	**0.743**
	White Peat	0.744	0.716	0.717	0.755	**0.732**
	Accretio	0.755	0.688	0.760	0.724	**0.717**
	Black Peat	0.701	0.637	0.709	0.670	**0.666**
	Bark	0.608	0.618	0.619	0.608	**0.612**
	(Standardised) Compost	0.632	0.518	0.572	0.632	**0.564**
	Coir fibre	0.616	0.469	0.700	0.603	**0.561**
	Coir chips	0.543	0.403	0.634	0.531	**0.495**
	Coir pith	0.576	0.398	0.616	0.563	**0.485**

Table 40: Optimism - Pessimism decision criterium

D - Weighted sum with uncertainty over scenarios

The weighted sum with uncertainty over the scenarios assumes an equal chance that the scenarios happen, this decision criterium is called the indifference criterion of Laplace (1825). The scores on the scenarios are added together and divided by the number of scenarios to arrive at the weighted sum score. The higher the weighted sum score, the better the alternative scores.

Rang reciproke		Scenario 1	Scenario 2	Scenario 3	Scenario 4	∑
Alternatives	**Perlite**	0.840	0.790	0.845	0.840	**0.829**
	Mineral Wool	0.815	0.766	0.820	0.815	**0.804**
	Foam	0.807	0.744	0.798	0.806	**0.789**
	Woodfibre	0.775	0.722	0.735	0.756	**0.747**
	White Peat	0.744	0.716	0.717	0.755	**0.733**
	Accretio	0.755	0.688	0.760	0.724	**0.732**
	Black Peat	0.701	0.637	0.709	0.670	**0.679**
	Bark	0.608	0.618	0.619	0.608	**0.613**
	Coir fibre	0.616	0.469	0.700	0.603	**0.597**
	(Standardised) Compost	0.632	0.518	0.572	0.632	**0.589**
	Coir pith	0.576	0.398	0.616	0.563	**0.538**
	Coir chips	0.543	0.403	0.634	0.531	**0.528**

Table 41: Indifference decision criterium

E - Weighted sum with certainty over scenarios

Where La place uses an equal chance over the scenarios there is tried to give a more represented chance to the scenarios. This assumes that there is certainty over the scenarios. For "Steady development" the chance is estimated at 40%. For the scenarios "Ban on Peat" and "Change of direction" a chance of 25% has been assumed. For "Social Utopia" this leaves a chance of 10%. This says more about the short than long term expectation. It is not possible to determine what the probability is of one scenario taking place earlier than the other.

Rang reciproke		Scenario 1	Scenario 2	Scenario 3	Scenario 4	∑
Weight		0.4	0.25	0.1	0.25	1
Alternatives	**Perlite**	0.336	0.198	0.085	0.210	**0.828**
	Mineral Wool	0.326	0.192	0.082	0.204	**0.803**
	Foam	0.323	0.186	0.080	0.202	**0.790**
	Woodfibre	0.310	0.181	0.074	0.189	**0.753**
	White Peat	0.298	0.179	0.072	0.189	**0.737**
	Accretio	0.302	0.172	0.076	0.181	**0.731**
	Black Peat	0.280	0.159	0.071	0.168	**0.678**
	Bark	0.243	0.155	0.062	0.152	**0.612**
	(Standardised) Compost	0.253	0.130	0.057	0.158	**0.598**
	Coir fibre	0.246	0.117	0.070	0.151	**0.584**
	Coir pith	0.230	0.100	0.062	0.141	**0.532**
	Coir chips	0.217	0.101	0.063	0.133	**0.514**

Table 42: Certainty over scenarios decision criterium