The development of a sustainability goal-setting and evaluation tool for packaging

to support producers and importers in their packaging development process, in order to improve the sustainability of product-packaging combinations.

Master thesis Industrial Design Engineering

Kennisinstituut Duurzaam Verpakken (KIDV)

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Nikki Groote Schaarsberg

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Duurzaam Verpakken

CIRCULARITY CHECK

RECYCLE CHECK

ENVIRONMENT IMPACT

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Nikki Groote Schaarsberg
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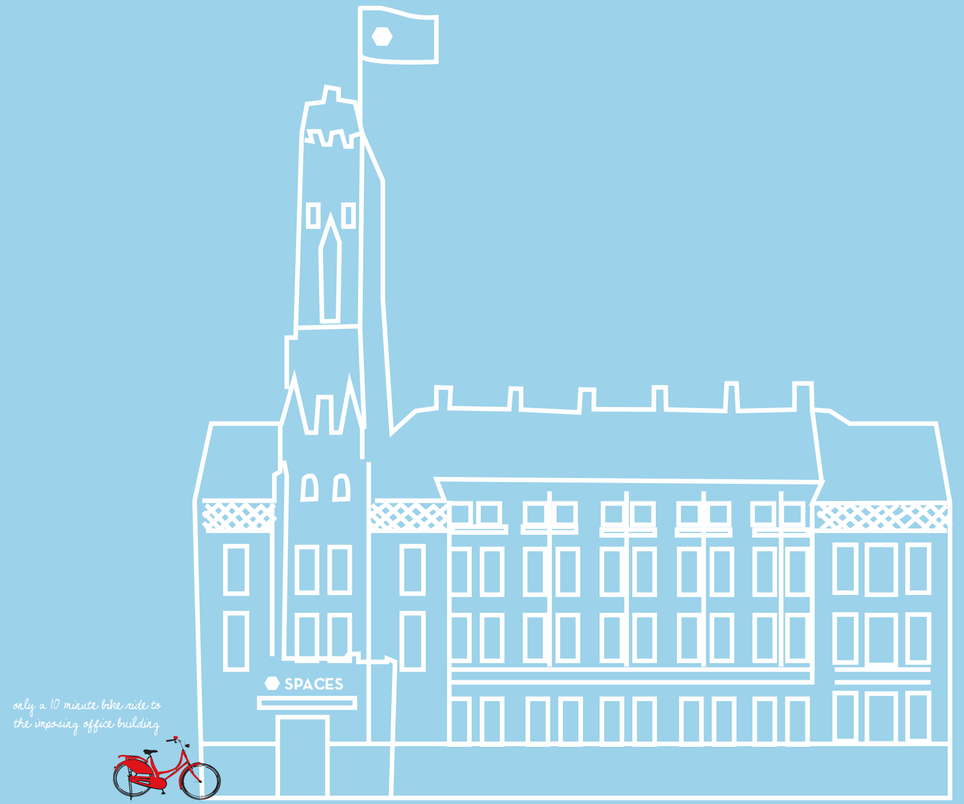
‘become more sustainable than the previous state of being’

‘sustainability is not an end-station and not the higher goal’



PREFACE

A bird's perspective at Spaces 'de Rode Olifant'

A lesson I learned in the past nine months, is that sustainability is not an end-station and not the higher goal. Moreover, you can never find the ultimate answer on what is truly sustainable. At best, you can learn what elements are influencing sustainability in a specific situation and use these learnings to become more sustainable than the previous state of being.

During my master thesis period at the KIDV, I was given the change to take a valuable viewpoint on packaging development and sustainability. Whereas normally as a packaging engineer, you are given a specific task for a specific company, the KIDV provided a whole new perspective. Located near the Malieveld in the remarkable and tall building of Spaces 'de Rode Olifant', I could take a bird's perspective on the packaging chain, regarding all stakeholders and its interests from an independent and holistic viewpoint. This gave me the opportunity to visit sorting factories, recycling facilities and a wide range of interesting producing companies.

I would like to thank the KIDV for giving me the opportunity to write my thesis on a very interesting and relevant subject. The enthusiasm, knowledge and ambitions of all employees at the KIDV helped enormously to do my master thesis project as I did. Special thanks go to Niels van Marle, my supervisor at the KIDV. Besides taking me to a very taste chocolate company already in the first week of my thesis period, he was always willing to discuss things, provide me with new insights and challenge me to always keep the interests of the end user in focus.

From the University of Twente, I would like to thank my supervisor Jos de Lange, with his always critical and challenging viewpoint and the best advice he could give, by pointing me on the magical silence working place at the KB (Royal Library, Den Haag), where I spend an uncountable number of hours writing this thesis.

The prove that packaging and waste is very much actual to a wide public was provided to me by my friends and family. I would like to thank them very much for always supporting me and listening to my stories about the unbelievably things I discovered from the waste industry.

They would always come with questions like 'where should I throw this away?' or 'why can I not separate my waste in the city of Utrecht?'. The fact that consumers are aware of packaging and waste and how to deal with it provides some hope for the future.

My neighbour that tried to throw away his ceramic oven tray in the glass bin gave me the insight that one person can never improve the whole packaging system or preserve the whole planet, but you must start somewhere.

I am grateful to you all.

Nikki

SAMENVATTING

‘Is alles circularikoek?’

Dit onderzoeksproject biedt een ontwikkelings- en implementatie-advies aan het Kennisinstituut Duurzaam Verpakken (KIDV) voor het ontwikkelen van een tool om het stellen van duurzaamheidsdoelen en het evalueren van verpakkingsalternatieven op duurzaamheid te ondersteunen. Het eerste deel van het onderzoek bestaat uit een analyse van duurzame ontwikkeling en circulaire economie en wat dit omhelst voor verpakkingsontwikkeling. Ook is onderzocht hoe de industrie hier mee omgaat en welke barrières belemmeren in het verduurzamen van verpakkingen. Een analyse van bestaande tools en richtlijnen was uitgevoerd, om uit te zoeken wat nodig is in een beoordelingstool voor duurzaam verpakken om producenten en importeurs in hun beslissingen te ondersteunen. Het tweede gedeelte richt zich op de ontwikkeling van een prototype, waar indicatoren zijn opgesteld, data is verzameld en een interface en structuur van de tool is ontworpen. Dit prototype is getest op gebruiksvriendelijkheid met verschillende actoren uit de verpakkingsindustrie om de aannames uit het onderzoek te valideren.

In een tijdperk waar bedrijven prestaties in de nabije toekomst beloven als 100% recyclebaar zijn, volledig circulair worden, CO2 neutraal produceren en waar bedrijven een ‘Plastic Pact’ tekenen en de EU een verbod op wegwerpplastic uitroept, moeten we onszelf afvragen of dit allemaal ‘circularikoek’ is, of dat dit echt realistische doelen zijn.

Een methode die toenemende belangstelling ontvangt is de Circulaire Economie (CE), zoals onderschreven door instellingen als de Ellen MacArthur Foundation en verweven in nationale, Europese en wereldwijde plannen. CE wordt vaak gezien als een operationalisering van duurzame ontwikkeling, die al onder de aandacht is sinds de publicatie van het Brundtland rapport, waar duurzame ontwikkeling is gedefinieerd als de ontwikkeling waarin de behoefte van huidige generaties wordt vervuld zonder daarbij het vermogen van toekomstige generaties om in hun behoefte te voorzien te schaden. Kernfactoren om CE te bewerkstelligen zijn: het uitbannen van afval en vervuiling door ontwerp, het sluiten van (materiaal) ketens, het optimaliseren van systeem efficiëntie, het creëren van regenererende systemen, het behouden van resource waarde en om dit alles te bereiken, het introduceren van nieuwe businessmodellen.

De vraag is wat CE en duurzame ontwikkeling betekenen voor de verpakkingsindustrie en hoe bedrijven dit zouden moeten integreren in hun verpakkingsontwikkelingsprocessen. Bovendien rest ons de vraag waarom we momenteel nog in een lineair systeem zitten, waar een groot deel van ons kunststof na recycling alleen nog kan worden gebruikt voor bermpaaltjes en anders wellicht zelfs als zwerfafval aan zijn einde komt in zee of in de natuur. Drempels die bedrijven tegenhouden om duurzaamheid te integreren op operationeel en strategisch niveau kunnen samengevat worden in het gebrek aan kennis en tools en het gebrek aan commitment en samenwerking tussen afdelingen. Ook is er een kloof aangewezen tussen wat bedrijven vandaag de dag doen aan duurzaamheid en het beoogde toekomstperspectief waarnaar wordt verlangd.

Het KIDV ondersteunt producenten en importeurs van verpakkingen hierin, door het verzamelen en delen van kennis, het samenbrengen van actoren uit de verpakkingsketen en het stimuleren van (academisch) onderzoek. Het KIDV wil producenten en importeurs ondersteunen met een tool die verpakkingsalternatieven kan beoordelen en vergelijken op meerdere aspecten van duurzaamheid.

Uit de analysefase kan geconcludeerd worden dat concrete indicatoren en tools die circulariteit in de verpakkingsindustrie bevorderen nog ontbreken. Bovendien is het complex om dit op een simpele manier te bewerkstelligen door de complexiteit en holistische aanpak die CE vereist. Voor het KIDV is daarom een beoordeling van het lineaire systeem ontwikkeld, die een startpunt biedt voor verbetering door transparant te tonen hoe efficiënt de huidige recycling (en hergebruik) systeem is. Er is geconcludeerd dat de nieuwe tool het stellen van doelen voor de toekomst en de evaluatie van een huidige situatie moet combineren om eco-efficiëntie en eco-effectiviteit tegelijkertijd te benaderen. De bevindingen uit het eerste deel van het onderzoek zijn vertaald in een theoretisch kader dat is gebruikt voor de ontwikkeling van de tool.

De tool is gebaseerd op een combinatie van het selecteren van een duurzaamheids-doelstelling en een evaluatie met behulp van de drie perspectieven om verpakkingscombinaties te evalueren op duurzaamheid. De gebruiker bepaalt zelf het raamwerk waarbinnen de drie perspectieven kunnen worden geïnterpreteerd. De 3 perspectieven worden gegeven in de door het KIDV voorgestelde: recycling module, de circulariteitsmodule en de milieu-impact module.

De recycling module is gebaseerd op de Recycle Check die door het KIDV is ontwikkeld. De milieu-impact module wordt ontwikkeld door een externe partij. Voor de circulariteitsmodule zijn vier indicatoren zijn opgesteld, die samen de efficiëntie van het huidige verpakkingssysteem kunnen bepalen. De ‘regenerate’ indicator bepaalt hoeveel verpakkingsmateriaal terugkomt in het inzamelsysteem na gebruik, waar de ‘verlies’ indicator bepaald hoe veel er van dit materiaal verloren gaat in sortering en recycling. De ‘resource value’ indicator bepaalt in welke waarde dit materiaal terugkomt in het systeem en ‘het aantal cycli’ een theoretische indicatie geeft van hoe vaak bepaalde materialen en grondstoffen hergebruikt kunnen worden in het huidige systeem.

Door de drie modules te combineren kan de gebruiker zijn keuzes in verpakkingsontwikkelingsprocessen onderbouwen, en door de visuele output van de tool te gebruiken kan dit duidelijk gecommuniceerd worden in en tussen bedrijven.

Gebruikstesten hebben aangetoond dat de tool als er nuttig gezien wordt en waardevol in het optimaliseren van verpakkingen in het huidige systeem en dat het helpt om bepaalde drempels richting verduurzaming te verlagen.

Echter, voor een transitie naar CE is meer nodig dan het optimaliseren van het huidige lineaire systeem. Bedrijven ondervinden vaak moeilijkheden in het kiezen van een juiste strategie om hun verpakkingen te verduurzamen, dus aangeraden wordt om ook hierin ondersteuning te bieden. Bovendien wordt aangeraden om te onderzoeken hoe circulariteit het best geïntegreerd kan worden in verpakkingsontwikkeling, om niet alleen ons huidige systeem te verbeteren, maar daadwerkelijk circulaire resultaten te behalen.

ABSTRACT

‘Is it all sustainababble?’

This research project provides a development and implementation guide for the Netherlands Institute Sustainable Packaging (KIDV) for a sustainability goal setting and evaluation tool. The first part of the research comprises an analysis on sustainable development and circular economy and what it implies for packaging development. Business enhancement with and barriers towards implementation of sustainability in packaging development processes are discussed. An analysis on existing tools and guidelines was executed. This to find what is needed in a tool to support producers and importers in their packaging development processes. The second part describes the development of a prototype, where indicators are defined, data is collected, and an interface and tool structure are designed. This prototype is tested by stakeholders from industry, to test the usability of the tool and to validate the synthesis from the first part of the research.

In an era where companies promise achievements in the nearby future as being 100% recyclable, becoming fully circular, producing CO2 neutral and where companies sign a ‘Plastic Pact’, we have to wonder if this is all ‘sustainababble’ or whether these are realistic goals.

A method with arising attention is the circular economy, as proposed by institutes as the Ellen Macarthur Foundation and widely adopted in national, European and global plans. CE is often seen as an operationalisation of sustainable development, which has been under awareness since the publication of the Brundtland report, where sustainable development is defined as the development which meets the needs of current generations without compromising the ability of future generations to meet their own needs. Key elements to achieve a CE: design out waste & pollution, close (material) loops, optimise system efficiency, create regenerative systems, preserve resource value and to achieve this, introduce new business models.

Questioned is what CE and sustainable development mean for the packaging industry and how companies should incorporate sustainability into their packaging development process. Moreover, one needs to wonder why we are currently stuck in a linear system, where a large amount of plastics can only be recycled into roadside posts and otherwise might end up as litter in sea or land. Barriers that are holding companies back to incorporate sustainability in operational and strategic level of packaging development are summarised to a lack of knowledge and tools and a lack of commitment and cooperation amongst departments. Moreover, a gap is indicated between what companies are doing in present-day and the desired goals that are set for the future.

The KIDV is supporting producers and importers of packaging, by collecting and sharing knowledge, bringing stakeholders from the whole chain together and stimulating (academic) research. The KIDV wants to provide industry with a tool that can assess and compare packaging alternatives on multiple perspectives of sustainability.

In the analysis phase is found that concrete indicators and tools to enhance circularity in packaging development do not yet exist, and it is complex to assess this in a simple way, due to the complexity and holistic approach that CE requires. Therefore, for the KIDV a linear system assessment is developed, which provides a starting point for improvement by transparently showing how efficient the current recycling (and reuse) system works. A conclusion was made that the new tool should combine goal setting for a desired future with evaluation of a current situation in order to address eco-efficiency and eco-effectiveness simultaneously. The findings from the first part of the research were translated into a theoretical framework for the development of the tool.

The tool is based on a combination of sustainability goal setting and a three-perspective evaluation to compare packaging combinations on their sustainability within a user-defined framework for interpretation. The three-perspective evaluation contains a recyclability module, a circularity module and an environmental impact module, as proposed by the KIDV.

The recyclability module is based on the Recycle check which is developed by the KIDV. The environmental impact module will be developed by an external party. For the circularity module, four indicators were proposed, which can together assess the system efficiency of packaging. The regenerate indicator computes how much packaging material comes back in the collection system after use, where the loss indicator shows how much material is lost in the sorting and recycling process. The resource value indicator determines in which value this material comes back in the system, and the number of cycles gives a theoretical indication on how many times specific resources can be reused in the current system.

Usability testing has shown that the tool is regarded as very helpful and valuable to achieve optimisation of packaging within the current system and that it helps overcome certain barriers towards sustainability. The visual output of the tool is remarked as helpful to clearly communicate within and between companies.

For a transition to CE more is needed than the optimisation of linear systems. Companies often experience difficulties picking the right strategy towards more sustainable packaging, so support on this aspect is recommended. Furthermore, it is recommended to investigate how circularity can be incorporated in a packaging development process, to not only improve our current system efficiency, but effectively achieve actual circular results.

GLOSSARY

Sustainability	Capable of being maintained in existence without interruption or diminution
Sustainable development	Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs
Circular Economy	A regenerative system in which we design out waste and pollution, keep the products and materials we design as long as possible in our efficient system, use them in a high value state and make sure we recover and regenerate these products and materials at the end of each service life
Eco-efficiency	Minimising the negative impact
Eco-effectiveness	Maximising the positive impact
Sustainable Packaging	Packaging that is effective in meeting its functional requirements, efficient in its use of materials, energy and water throughout its life cycle; cyclic in its use of renewable materials, and recoverable at end of life; and safe for people and the natural environment
Pack optimum	To pack, not too much, not too little, just enough
KIDV	Netherlands Institute for Sustainable Packaging
LAP3	National Waste Management
PPW	Post-consumer plastic packaging waste
MSW	Mixed municipal solid refuse waste
LCA	Life cycle assessment
C2C	Cradle to Cradle, ideology as described by Braungart and McDonough in their book 'Cradle to Cradle, remaking the way we make things'
Regenerate	Bring into renewed existence; generate again, either in the same of different property
Waste	Eliminated or discarded after use in one life cycle, might return as a new resource after recycling
Pollution	A substance that has harmful or poisonous effects on pure resource flows and/or the environment
Closing loops	The aim of keeping material, energy and economic flow in a closed system
Resource value	The quality of a resource, depending on its applicability, purity in substance and economic value
(r)PET	(Recycled) Polyethylene Terephthalate
PP	Polypropylene
PE (LDPE, HDPE)	Polyethylene (low density, high density)
Recycling	The collection, sorting and (mechanically) recycling of material into new resources
Recyclable	In theory suited for recycling

CONTENTS

INTRODUCTION

‘The aim is to close the whole chain’

As a food producer, packaging is often an element you only start to think about after you know what product you will be packing and how you want to deliver this to consumers. The functions needed to protect, preserve and consume the product are leading here. When you want to improve the sustainability of your product-packaging combination, many questions might arise. The environmental impact of packaging seems major, but when trying to reduce this impact by reducing material, either the packaging becomes very complex and difficult to recycle, or the packaging is not fulfilling its function and food waste might occur. How do you then make substantiated decisions that are fitting your company’s sustainability strategy and are supported by other team members?

For example, tomato soup can be packed in various formats, ranging from metal cans, glass bottles, glass jars with metal lids to lightweight multilayer pouches. All these packaging types fulfil the same basic function of packing the soup in a safe way. In this instance, what is better, or more sustainable? Of course, decisions can be made with a marketing perspective, thinking about what will stand out most on shelf, or with a financial perspective, deciding what will be most beneficial to the profit of a company. However, when trying to incorporate sustainability considerations as well, solutions are often not so evident.

This research aims at finding a method to support producers and importers of packaging in this matter and is thereby adapting to the request of the Netherlands Institute for Sustainable Packaging (KIDV) to develop a tool for producers and importers of packaging to evaluate packaging alternatives on multiple aspects of sustainability. Before the start of the assignment, the KIDV proposed a framework for the tool in which three aspects of sustainability are evaluated: the recyclability, the circularity and the environmental impact. For this Master thesis the focus is put mainly on the circularity pillar of this tool. Therefore, Circular Economy (CE) is chosen as the approach to sustainable development.

Developing, consolidating and sharing knowledge

The KIDV, founded in 2013, supports producers and importers of packaging, by collecting and sharing knowledge, bringing stakeholders from the packaging chain together and stimulating (academic) research. Partnership between suppliers, producers and importers of packed goods, waste processors and recyclers are essential for circularity. After all, the aim is to close the whole chain. A condition for this cooperation is that all stakeholders in the chain have access to factual knowledge about sustainable packaging based on the following principles: reduce, re-use, renew and recycle. The KIDV is responsible for the development, consolidation and sharing of that knowledge (Kennisinstituut Duurzaam Verpakken, n.d.). Over the years, the KIDV has already developed several tools to help companies towards more sustainable packaging.

Waste management structure

The KIDV is part of the Dutch waste management structure, where the Afvalfonds Verpakkingen, NederlandSchoon, Nedvang and KIDV work together to arrange the packaging and waste management in the Netherlands. Commissioned by the packaging industry, these organisations collaborate to support industry in maintaining the functioning of our packaging and waste system and provide support to make the whole industry more sustainable. Figure 1 shows the waste management structure of these companies and the role they play in in the Dutch waste management.

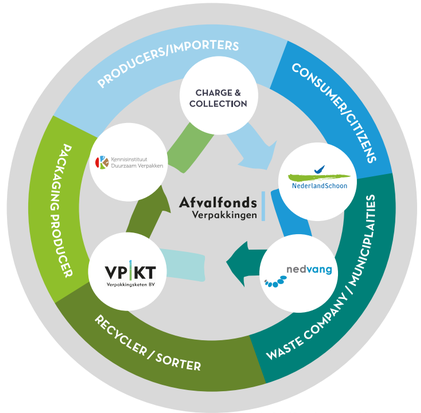


Figure 1 Waste management structure, redrawn after (Afvalfonds Verpakkingen, 2019)

Problem statement

Business enhancement with sustainability in packaging development is often challenging, either because companies do not know what is supporting sustainability and what not, or because other motives as financial and marketing perspectives are considered to be more important. Either way, there seems to be room in the packaging industry towards improvement of sustainability in product-packaging combinations and producers and importers need help in this.

The research goal

The aim is to develop a sustainability evaluation tool to support producers and importers in their packaging development process in order to improve the sustainability of their product-packaging combinations. The tool should make clear for companies what are the implications of their decisions in packaging development to the sustainability of their packaging in the current system and on a higher level what this means for the transition to a circular one.

Research approach

The research is divided into two parts. The first part explores the theoretical framework of sustainable development and the barriers that PI’s are facing in the development of sustainable packaging. From part I the design brief is formulated as depicted in the intermezzo. Part II shows the results of the development process of a prototype. Figure 2 (on the next page) shows an illustrative overview of the research approach.

Part I

First it must be clear what sustainability and sustainable development imply and how this encompasses packaging development. There are various ways to interpret sustainable development, but for this research Circular Economy (CE) is adopted as the main approach. CE is a recent phenomenon within sustainable development, which has gained momentum amongst business and research. The CE proposes a closed loop system, where economic growth and resource extraction are decoupled, creating a balanced system where development can take place within planetary boundaries. A question that rises is: why do producers and importers (PI’s) currently not take steps towards more sustainable product-packaging combinations, what are their barriers? And how might the KIDV help to overcome these barriers? To answer this question, business enhancement with sustainability is explored, after which barriers to sustainability in packaging development are designated. Current tools and guidelines that might help in sustainable packaging development are explored, to see what is missing in these tools to properly support producers and importers in the problems they currently encounter.

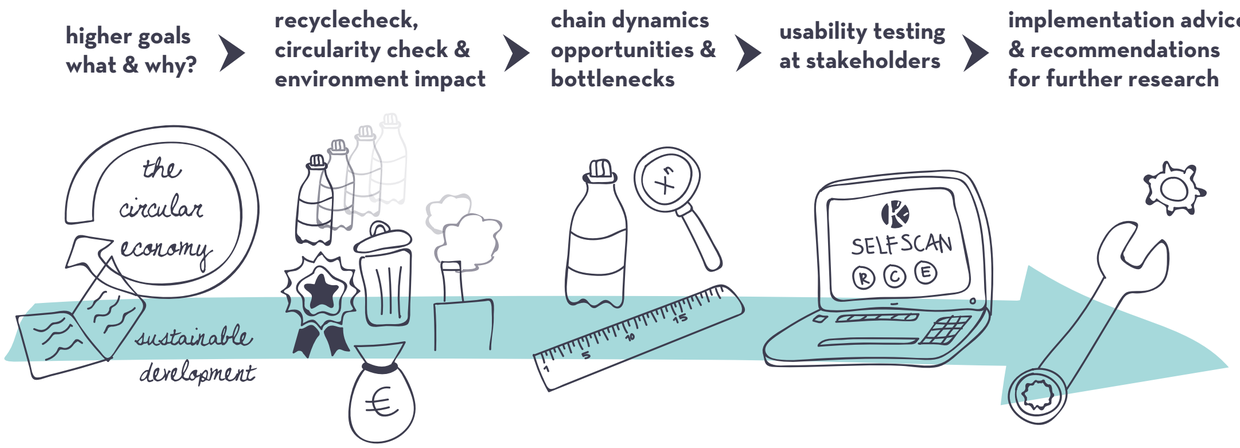


Figure 2 Overview of research approach

Intermezzo
From the analysis of part I rises the motive for the development of a sustainability evaluation tool. The intermezzo provides a condensed overview of the findings of the first part of the research and will elaborate on the requirements for the development of the tool.

Part II
Subsequently, the second part of the report will describe the development process of a prototype, to be able to give a development and implementation advice to the KIDV for the development of the tool. To validate this, a selection of producers and importers was asked to test the prototype, to inquire the functionality and usability of the tool.

The research is ended by evaluating on the outcomes of the prototype phase and how well this is aligned with the set requirements. Conclusions and recommendations for further research are provided at the end of the report.

Scope
This research is mainly focussing on the influence producers and importers have on the sustainability of product-packaging combinations. This means that the influence that other stakeholders, as consumers and government, have in the field of packaging stays out of scope. This is decided because PI's are one of the main target groups of the KIDV and are the envisioned end-users of the tool. Whereas sustainability evaluation in packaging design must be overarching and consider all packaging materials, for this thesis the scope was set more specific on plastic packaging, due to the high focus in industry, government and literature on this subject. Circular Economy is in this research the chosen approach for sustainable development, which fits the circularity pillar of the envisioned tool.

Part I: SUSTAINABILITY IN PACKAGING DEVELOPMENT

1 Sustainable development
2 Introducing the circular economy
3 Sustainability in packaging design
4 The Dutch waste system
5 Business enhancement with sustainability & circular economy
6 Barriers to sustainability - The gap
7 The field of tools & guidelines
8 Incentive for the development of a new tool

Packaging is often regarded as superfluous, as the functions it fulfils are not always noticed, and only the empty package stays behind after using/consuming the product (ten Klooster, 2002; Tim Grant, Victor Barichello, & Leanne Fitzpatrick, 2015). This results in the fact that packaging is often seen as litter. However, packaging is often an inherent and indispensable prerequisite to be able to transport, sell and use the product (Kooijman, 1990; Oude Luttikhuis, De Lange, ten Klooster, & Lutters, 2013). This makes sustainability in packaging development a vague phenomenon, strongly subjected to interpretation. To be able to define what sustainability implies for packaging, explained is what sustainable development includes in general. Moreover, the circular economy and its school of thoughts are considered. With this general overview, analysed is what this means for packaging development. The business enhancement with sustainability is examined, as well as barriers to sustainable development. Moreover, the role of the KIDV in this matter is regarded. To conclude Part I, existing tools and guidelines towards sustainable packaging are assessed, to see what the industry might need to become more sustainable.

1 SUSTAINABLE DEVELOPMENT

'Doing the right things'

As it is stated in State of the world: 'We live today in an age of 'sustainababble', a cacophonous profusion of uses of the word 'sustainable' to mean anything from environmentally better to cool' (Starke, Assadourian, Prugh, & Worldwatch, 2013). Where the Romans in ancient times meant nothing more with 'sustainable' than 'capable of being maintained in existence without interruption or diminution', nowadays the concept of sustainability and sustainable development in the environmental field is more extensive. Over time the term became less meaningful, vaguer and more unquantifiable due to extensive use and misuse.

In most literature about sustainable development, the definition as stated in the Brundtland report is cited:

'Sustainable development is development which meets the needs of current generations without compromising the ability of future generations to meet their own needs' (Brundtland et al., 1987).

1.1 Three pillars

The preservation of our planet for future generations seems like a noble aspiration. However, the needs of current generations and the construction of our current system seem to hinder this.
In our current system, economic growth is inseparably connected to environmental impact by consuming and depleting available resources. On the other hand, economic growth seems required to alleviate poverty. This proves the complexity and stratification of sustainable development. It reaches further than environmental focus, as it is accompanied by economic and social aspects. These three aspects: environment, economy and society (Carew & Mitchell, 2008; Giddings, Hopwood, & O'Brien, 2002) are also known as the three pillars of sustainable development; the triple bottom line; and the Triple-P model: people, planet and profit (Elkington, 2004) (Norman & MacDonald, 2004), depicted as the sustainability Venn diagram in Figure 3. It shows how sustainable development incorporates development that is economically, environmentally, and socially acceptable, where the circles intercept in the centre of the Venn diagram.

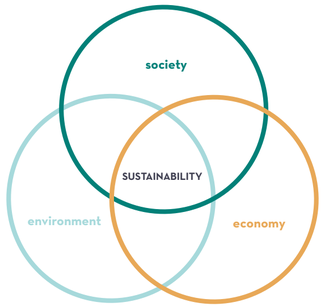


Figure 3 Sustainability Venn Diagram, based on (Elkington, 2004)

1.2 Eco-efficiency

Taking this into account, sustainability began to have its influence on development. One approach to this is eco-efficiency. Eco-efficiency assumes a one-way, linear flow of materials through industrial systems (MacArthur, 2015). 'Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing the ecological impact and resource intensity throughout the life cycle to a level at least in line with the earth's estimated carrying capacity' (World Business Council for Sustainable Development, 2000). Eco-efficiency is incapable of transforming the linear flows throughout our system. Hence, only environmental impact is minimised. For development this implies the selection of low-impact material, reduction of material usage, reduced energy consumption, reduced waste and pollution per functional unit of a product during its life cycle (Jakobsen, 1999).

1.3 Eco-effectiveness

In contrast to this appeared eco-effectiveness. Where eco-efficiency focusses on minimising the negative impact, eco-effectiveness aims at maximising the positive environmental impact (Ellen MacArthur Foundation, 2015). To measure effectiveness in relation to product development processes may be seen as "doing the right things" and measuring efficiency as "doing things right. Eco-effectiveness is improving the total impact of environment when the consumers need or demand is satisfied by alternative fulfilment of the function in question (Jakobsen, 1999). Where eco-efficiency influences the short-term performance of sustainable development, eco-effectiveness focusses on the long-term performance. One is not necessarily better than the other, it is important to address long and short term issues simultaneously (Jakobsen, 1999).

2. INTRODUCING THE CIRCULAR ECONOMY

'The aim is to keep all resources in cycles'

As an international team of researchers at the Massachusetts Institute of Technology predicted in 1972: The earth's interlocking resources – the global system of nature in which we all live – probably cannot support present rates of economic and population growth much beyond the year 2100, if that long, even with advanced technology (Meadows, Meadows, Randers, & Behrens III, 1972). Better known as the Club of Rome, these researchers also provided a message of hope: 'Man can create a society in which he can live indefinitely on earth if he imposes limits on himself and his production of material goods to achieve a state of global equilibrium with population and production in carefully selected balance.'(Meadows et al., 1972).

This vision is also carried out by others, as by the authors of 'Cradle to Cradle: Remaking the Way We Make Things': 'To consume less does not seem to be the solution, we need to consume different, produce different, in other words make our whole system different. (McDonough & Braungart, 2010). As the European Commission also states, a reduction of resource consumption can only slowdown the depletion of those resources as it cannot modify the finite nature of their stocks (European Commission, 2014b). In order to preserve our planet for future generations, system modification seems unavoidable. One of the proposed system changes is the Circular Economy (CE).

'A circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times' (MacArthur, 2015)

2.1 Definitions

This definition by the Ellen MacArthur Foundation (EMAF), is one of the most prominent CE definitions (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Schut, Crielaard, & Mesman, 2016). However, the circular economy is a concept with various understanding, and it means different things to different people. In their recent analysis of CE definitions both from academic and the grey literature, Kirchherr and colleagues reveal that a wide variety of CE conceptualizations coexist. A total of 114 definitions of CE were compared, collected from both peer-reviewed journals as well as non-peer-reviewed papers and reports. (Kirchherr, Reike, & Hekkert, 2017)

From this extensive comparative analysis, the following definition was formulated: '"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations" (Kirchherr et al., 2017). In their definition they refer to the Waste Framework Directive (European Commission, 2008), as shown in Figure 4.

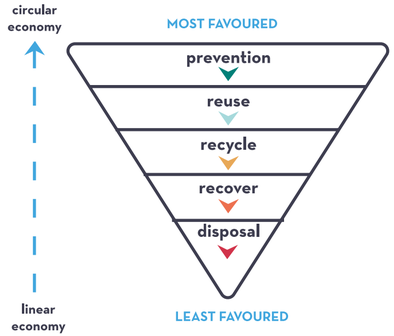


Figure 4 Waste hierarchy, R framework, based on (European Commission, 2008; Kirchherr et al., 2017)

2.2 System diagram

The R framework shows similarities with the Circular Economy System Diagram (EMF, 2013) as shown in Figure 5. Similar as in the Cradle To Cradle approach, a distinction is made between the biological and the technical cycle (MacArthur, 2015; McDonough & Braungart, 2010; Toxopeus, de Koeijer, & Meij, 2015). The aim is to keep all the resources in one of these cycles. The biological cycle aims at returning waste back to nature, therefore materials flowing through the biological cycle can be consumed by micro-organisms or animals. Materials in the technical cycle are used instead of consumed. The technical cycle is a closed-loop system of manufacturing, recovery and reuse. Materials flowing through the technical cycle are designed to remain in the system while maintaining their value.

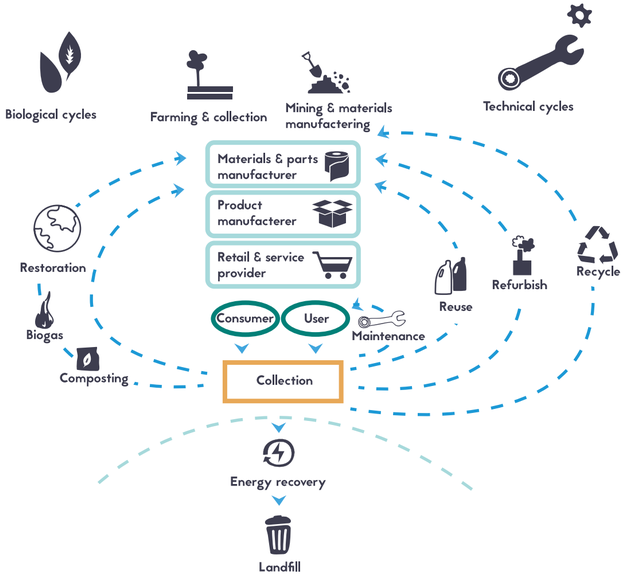


Figure 5 CE system diagram, based on (MacArthur, 2015)

A comparative evaluation of literature and organisations was executed for this thesis as well, in order to sum up findings from other research. Appendix A shows an overview of the analysis of CE definitions. From this, the most mentioned elements are translated into six elements that seem key for a CE, as shown in Figure 6

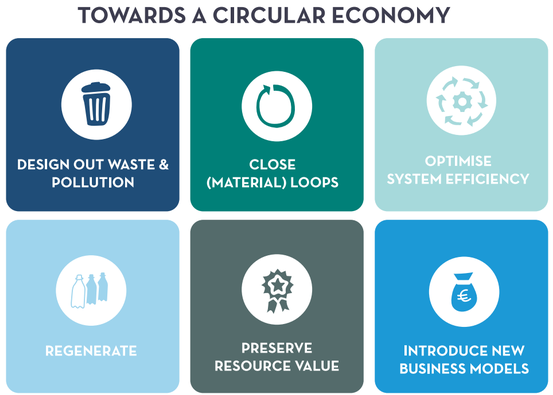


Figure 6 Key elements for a circular economy

2.3 Schools of thought

CE is not a standalone idea, as the CE model synthesises several major schools of thought. They include the functional service economy (performance economy) of Walter Stahel; the Cradle to Cradle design philosophy of William McDonough and Michael Braungart; biomimicry by Janine Benyus; the industrial ecology of Reid Lifset and Thomas Graedel; natural capitalism by Amory and Hunter Lovins and Paul Hawken; and the blue economy systems approach described by Gunter Pauli (Ellen Macarthur Foundation, n.d.). Figure 7 provides an overview of key factors of these schools of thought.

2.4 The circular gap

CE is regarded as an operationalisation for business to implement the much-discussed concept of sustainable development (Ghisellini, Cialani, & Ulgiati, 2016; Murray, Skene, & Haynes, 2017). It is important to keep in mind that CE is not an end goal for our system, as it is a method to achieve the higher goal: preserve our planet for future generations.

In theory this sounds like a reasonable methodology and a promising future perspective. However, our current system is nowhere near a 100% circular world. According to the Circularity Gap Report (De Wit, Hoogzaad, Ramkumar, Friedl, & Douma, 2018) our world economy is only 9.1% circular, leaving a massive 'Circularity Gap'. Regardless of what this metric might mean and how it is measured, it seems clear modification of our system is required.

This is also underlined by Haas and colleagues. By looking at material flows globally and in the European Union, it is estimated that only 4 gigatons per year (Gt/year) is recycled of 62 Gt/yr that is processed. Their results indicate that strategies targeting the output side (end of pipe) are limited given present proportions of flows, whereas a shift to renewable energy, a significant reduction of societal stock growth, and decisive eco-design are required to advance toward a CE (Haas, Krausmann, Wiedenhofer, & Heinz, 2015). As underlined in the research of Urbinati and others, the transition to a circular system requires companies to change and innovate their business model, transforming its existing structural and organisational conditions (Urbinati, Manfredi Latilla, & Chiaroni, 2018).

To conclude, sustainable development is needed to preserve our planet for future generations and maintain our current generation. To achieve this, system modification seems unavoidable. A proposed method for sustainable development is the Circular Economy: an economic system where we design out waste & pollution, close (material) loops, optimise system efficiency, regenerate resources and preserve their value, and introduce new business models to make this possible.

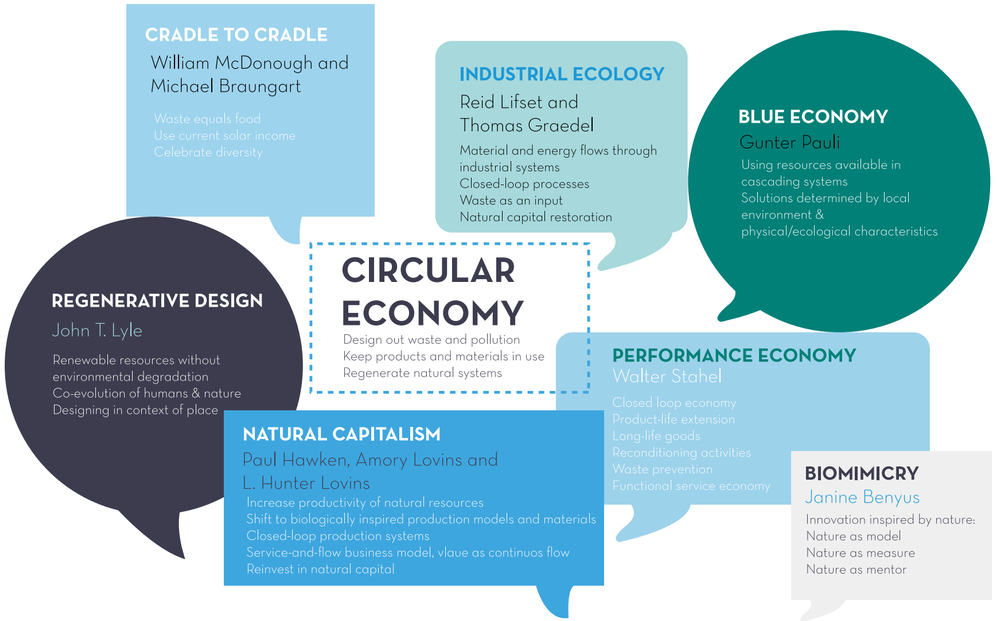
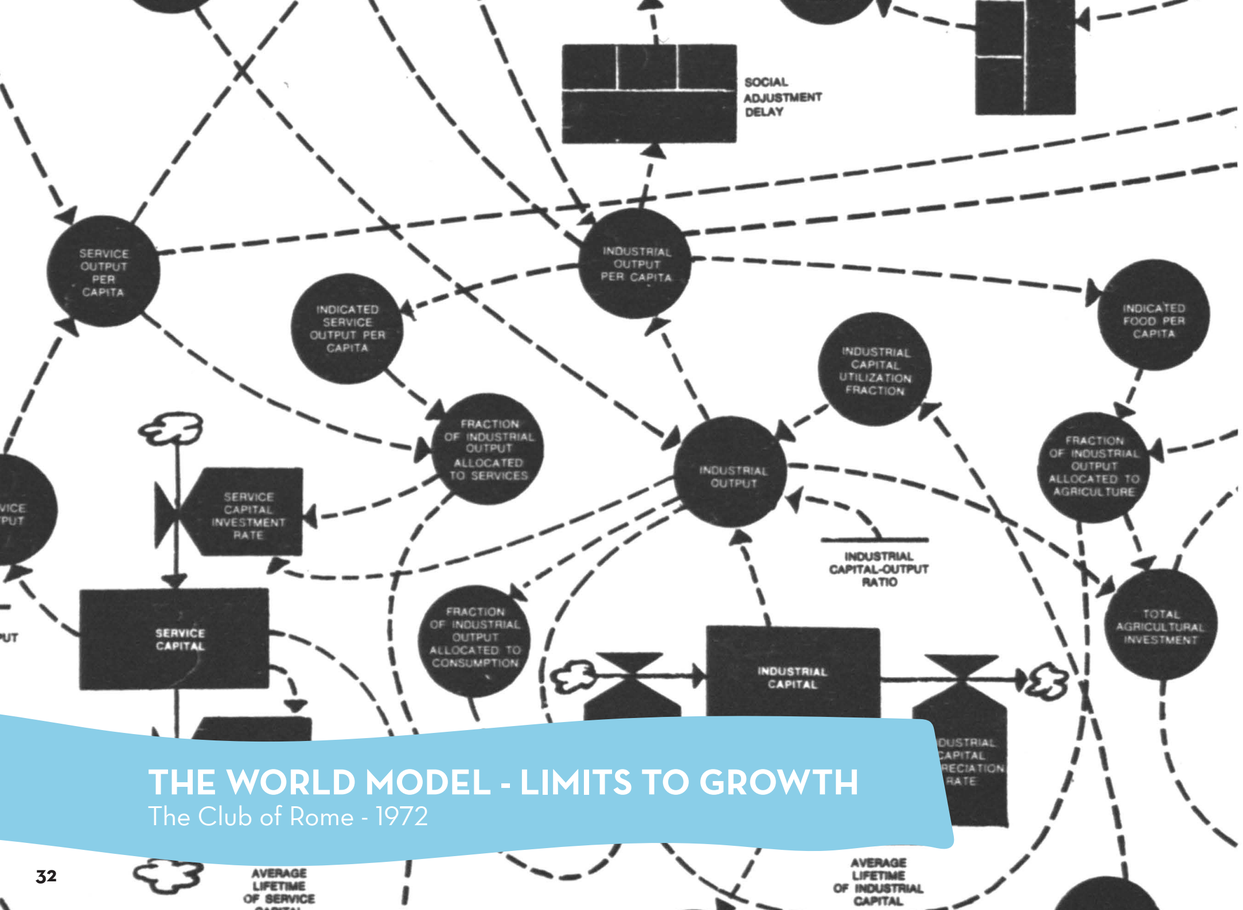
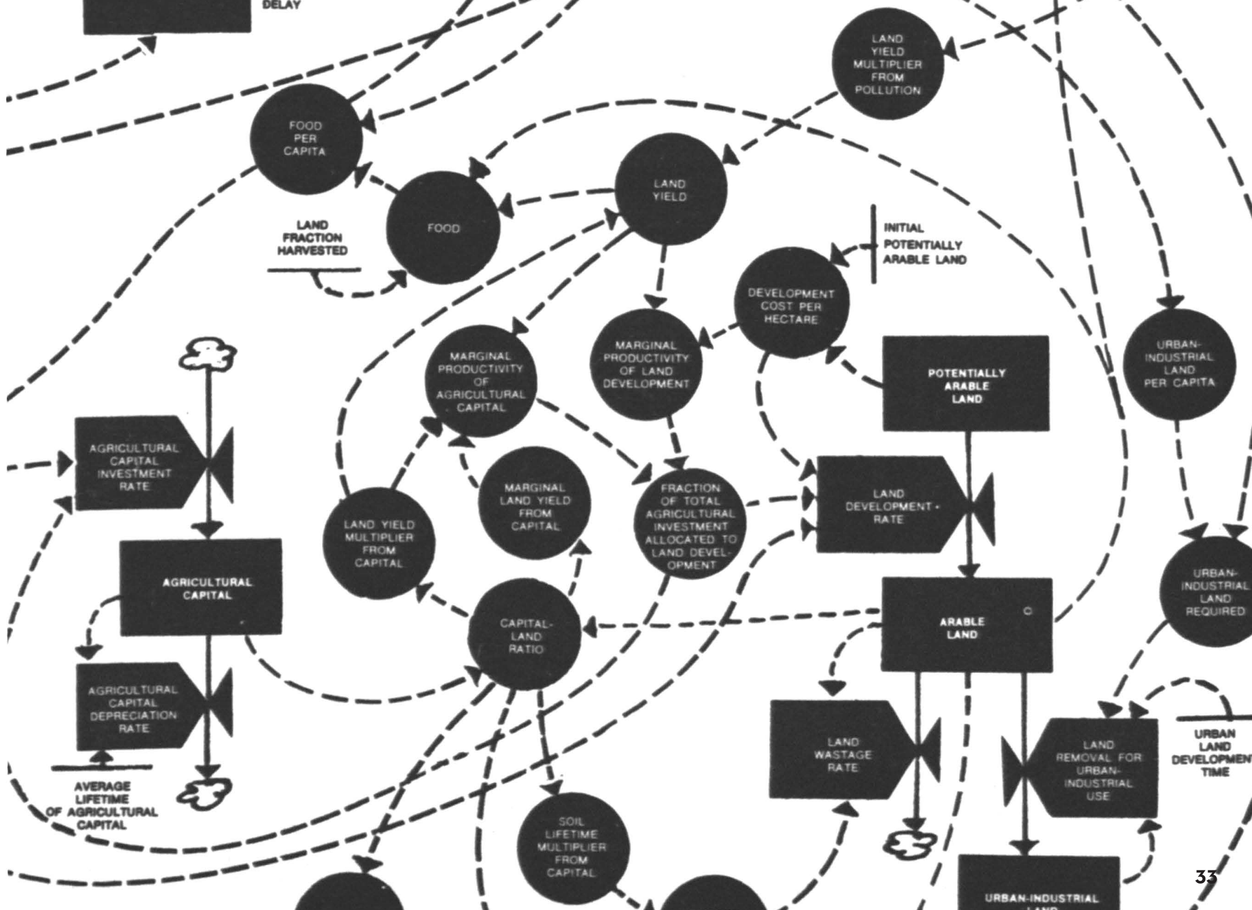


Figure 7 Schools of thought of CE





THE WORLD MODEL - LIMITS TO GROWTH

The Club of Rome - 1972

3 SUSTAINABILITY IN PACKAGING DESIGN

'Without packaging the product would rapidly decoy'

Packaging, especially when used for fast moving consumer goods (FMCG) have been considered environmentally damaging due to its material use and issues with disposal at the end of its life. Consumers seem to be almost unaware of the functions of packaging, so after separated from the product the packaging is regarded as waste. Packaging designers however have long since known the function of packaging is to deliver products to consumers in such a way that the product is protected and possibly enhanced. (Tim Grant et al., 2015). Without packaging it would be impossible to protect, distribute and deliver products in the existing supply chain. Despite this, these crucial functions sometimes seem to be used as a permit for the use of scarce resources, over-specified packaging, or using the package as billboard. (Oude Luttikhuis et al., 2013)

3.1 Functions of packaging

The need for the development of packaging was caused by the fact that the production and the consumption took place at separate places and times, and the produced goods had to be distributed and transported (Pongrácz, 2007). Packaging therefore was developed around products, to fulfil functions to the product it contains:

1. To contain the product;
2. To facilitate distribution;
3. To protect/preserve the product;
4. To facilitate use and end-of-life of product and packaging and
5. To inform about the product (and packaging) (ten Klooster, 2002).

Without a product its packaging would not exist, therefore referred is to the product-packaging combination. Without packaging, peanut butter would for example not be consumable at all, as it is a somewhat sticky substance and due to high level of oil in the product, the peanut butter would rapidly decay due to oxidation.

Figure 8 Product-packaging combination

3.2 Packaging materials and hierarchy

In packaging, a distinction can be made between primary, secondary and tertiary packaging. The primary packaging most often comes into direct contact with the product, but not in all instances. Therefore, for the primary packaging referred is to the sales unit of a product. The secondary packaging facilitates the bundling of products for distribution. The tertiary packaging bundles a large number of products for long-distance transport (ten Klooster, 2002). Figure 9 shows an example of this hierarchy in packaging.

Figure 9 Packaging hierarchy

Main materials groups that are used as packaging materials are: plastics, metals, glass, paper and board, wood (Klooster, Dirken, Lox, & Schilperoord, 2015). Each of these materials has properties to fulfil specific functions a product requires, but they all have their downsides as well. Glass for example, is suited for products that require sterilisation or pasteurisation, whereas the material is relatively heavy and fragile. Plastics on the other hand, are very light and in most instances unbreakable, but are not suited hot-filling. (Klooster et al., 2015) Table 1 shows the main advantages and disadvantages of each of the packaging materials.

Material	Advantages	Disadvantages
Glass:	Suited for sterilisation and pasteurisation Rigid Does not interact with (food) product High barrier properties Impenetrable Reusable Good recyclability	Heavy (high transport costs) Fragile Innovations go slow (mould production, high scale required, expensive)
Paper & Board	When uncoated, good recyclability Sturdiness & protection Good editability (printing & decorating)	Coating often required to fulfil packaging functions Recycling cycles not infinite
Plastics	Low price Low weight High range of possibilities in shape & looks Barrier properties Saleability Resistance to moist (Almost) unbreakable	Fossil fuel use Bad customer perception Risks on contamination
Metal	Sturdiness Conserving abilities Barrier properties (in laminate application)	High weight High energy usage in production & recycling
Wood	Sturdiness Reusable Stack ability	Not food grade Not flexible

Table 1 Advantages and disadvantages of packaging materials, based on (FNLI/CBL/NVG, 2015; Klooster et al., 2015; ten Klooster, 2002)

For this thesis, the focus lays mainly on plastics. This can be explained by the attention plastics receive in sustainability and circular economy issues, both nationwide as globally. In the implementation program of the Ministry of Infrastructure and Water management, plastics is one of the five priority chains (Ministerie van Infrastructuur en Waterstaat, 2019).

3.3 The packaging industry

The packaging industry is a network of actors that are inseparably connected to each other and to the food industry. The term 'packaging chain' is therefore frequently used, and it refers to all the links that play a role in packaged products that are brought to market (Lutters & Klooster, 2008).

A graphical overview (see Figure 10) makes the chain seem like a simplistic whole, yet it is rather complex because of wide range of options for each of the steps of the chain, and because of the potential loops involved in connection with the reuse of certain packaging or packaging components. Additionally, the use of primary, secondary and tertiary packaging complicates the chain considerably. (A. Oostendorp, M. Bode, Lutters, & Van Houten, 2006; ten Klooster, 2002)

3.4 Packaging design and development

A packaging design process has many similarities with a design process. The basic design cycle consists of: analysis, synthesis, simulation, simulation and evaluation (Roozenburg & Eekels, 1995). In the analysis phase, the problem is defined, to set up criteria of what the solution should solve. In the synthesis phase, searched is for potential solutions. In the simulation phase, determined is whether proposed solutions will satisfy the specific criteria. To end with an evaluation to which extend the goals have been achieved. Figure 11 shows a systematic overview of a packaging design

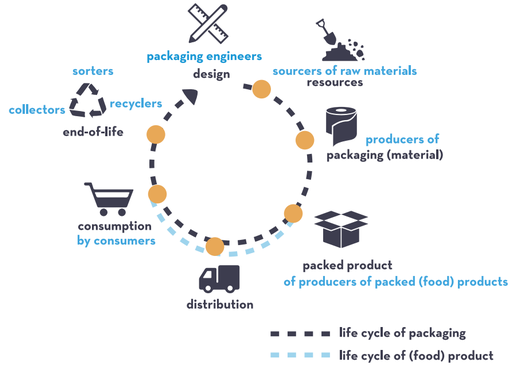


Figure 10 Integrated life cycle of product-packaging combination, based on (Oude Luttikhuis et al., 2013)

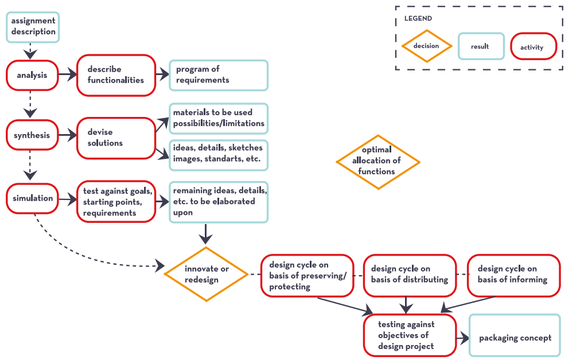


Figure 11 Packaging design method, redrawn after (ten Klooster, 2002)

process.
This process is generally not linear but iterative, which implies it is often carried out in loops (ten Klooster, 2002). This way of iterating and designing is also described by the action research model, shown in Figure 12 (Crouch & Pearce, 2013). As stated before, in packaging design the product it contains is always leading. The functional requirements the packaging must fulfil therefore always are the main starting point for development.

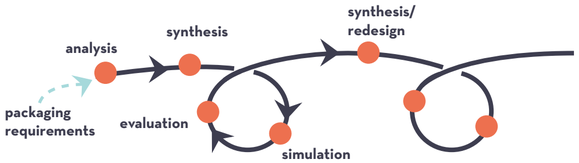


Figure 12 Action research applied to packaging design, based on (Crouch & Pearce, 2013)

3.5 Sustainable packaging development

Sustainability is often seen as a three-pillar model of environment, society and economy. For sustainable packaging development, the focus lies mainly on the environmental aspects (Koeijer, Wever, & Henseler, 2017).

Definition

According to the packaging sustainability framework by Verghese and colleagues (2012) and the Sustainable Packaging Alliance (SPA), in order to contribute to sustainable development, packaging needs to be effective in meeting its functional requirements, efficient in its use of materials, energy and water throughout its life cycle; cyclic in its use of renewable materials, and recoverable at end of life; and safe for people and the natural environment (James, Fitzpatrick, Lewis, & Sonneveld, 2005; Verghese, Horne, & Carre, 2010; Verghese, Lewis, Fitzpatrick, & Sonneveld, 2005). This definition is also adapted by the Australian Sustainable Packaging Alliance. Figure 13 shows the definition in its layered structure, from very specific at packaging component level to the more holistic layer of society.

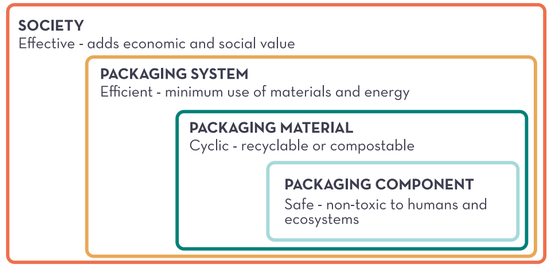


Figure 13 The four levels of sustainable packaging as defined by SPA, redrawn after (James et al., 2005)

When aiming at reducing the overall environmental impact of product-packaging combinations, research has shown that sometimes an increase of packaging (and therefore an increase of the environmental impact of packaging) leads to a decrease of the total environmental impact (Oude Luttikhuis et al., 2013; Williams & Wikström, 2011).

Pack optimum

As Kooijman stated: 'To pack, not too much, not too little, just enough' (Kooijman, 1990). This literary way of describing the optimal balance of packaging to protect a product, is also shown by the Optimum pack design, or the Soras Curve as developed by Innventia AB, shown in Figure 14. By using not enough packaging (hence, underpackaging) product loss might occur, which leads to a negative environmental impact. By using too much packaging (overpacking), the environmental impact increases unneeded due to the excess packaging weight or volume. This already shows the complexity in sustainable packaging development. Good intentions to lower the environmental impact of packaging, can easily lead to an unwanted increase in overall impact of product-packaging combinations.

Eco-efficiency

With the focus on the environmental pillar of sustainability for packaging, the main recurrent perspective on packaging is to reduce the environmental impact or eco-burden (Wever & Vogtlander, 2013). In its best case, taking the optimum pack design into account and therefore looking at minimizing the environmental impact of product-packaging combinations, but often only focussing on the impact of the packaging material itself. Looking back at the framework of sustainable development, this means focus is on the eco-efficiency of packaging. Whereas focus on the efficiency of the linear systems does lead to a minimisation of negative environmental impact, it does not result in a restored balance of inputs and outputs and thereby a circular system.

Eco-effectiveness

In order to develop sustainable packaging for circular systems, more is needed than just minimising the environmental impact of packaging. Instead of minimising, the target is to optimise products' positive environmental impact, known as eco-effectiveness. For circular packaging systems, aimed is for continuous material cycles, in which materials can be recycled without a loss of quality (Koeijer et al., 2017). Looking back at the six key elements of a circular economy, iterated is on what this implies for the packaging industry, as depicted in Figure 15.

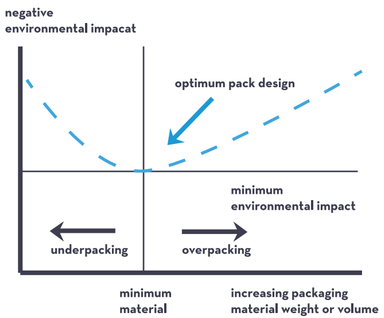


Figure 14 Optimum pack design, redrawn after (Innventia AB)

3 SUSTAINABILITY IN PACKAGING DESIGN

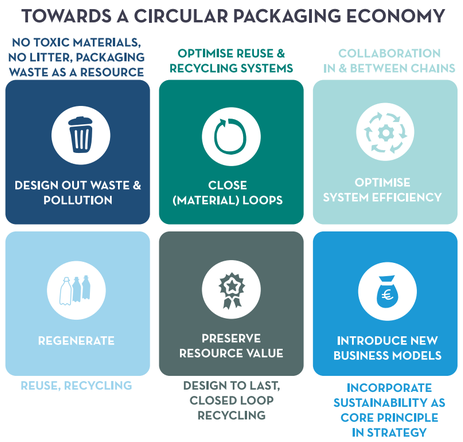


Figure 15 Circular economy implications for packaging industry

Figure 16 shows the difference between linear and circular packaging systems. Where linear systems look like a take-make-dispose system (from raw materials, to manufacturing, to recovery and landfill), circular systems are known for their closed loop structure. The problem in linear systems is the loss of quality in recycling, which causes that material streams are only partly suited to use as process inputs. In circular systems, both quality and quantity of materials are maintained throughout continuous lifecycles, balancing inputs and outputs, maintaining technical and economic quality, and eliminating material toxicity (de Koeijer, de Lange, & Wever, 2017; MacArthur, 2015; McDonough & Braungart, 2010).

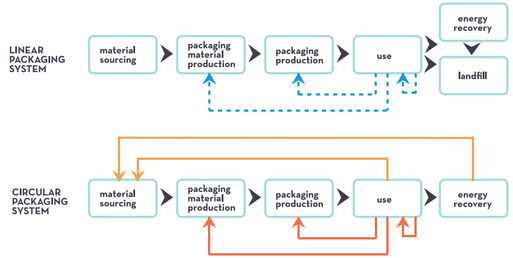


Figure 16 Linear versus circular packaging system, redrawn after (Koeijer et al., 2017)

For the transition of linear systems to circular systems, it is remarkable that a lot of focus has been put on the optimization of recycling systems. This can be partly explained by the construction of the linear system and the aim for closing loops. Where optimisation of current systems seems most obtainable, new business models and drastic system changes seem still unattainable.

Environmental lock-in

With focus of the optimisation of the end-of-chain, only part of the problem can be tackled. Regarding the environmental lock-in (Figure 17), at the stage of recycling, the environmental lock-in is already fairly high (Foxon, 2018; Koeijer et al., 2017). This means the impact a product will have is already determined for a large part and there is not a lot of room left to change this. Therefore, improvements at the start of the development cycle are therefore very relevant.

As stated by Braungart and McDonough: 'In many instances, the aim for recycling received priority over all other design considerations. The fact only, that a material is recycled, does not automatically make it environmental friendly, especially when it is not specifically designed to be recycled. The groundless adaption of superficial environmental approximations without full insight in the consequences of this, does not have to be better than doing nothing' (McDonough & Braungart, 2010).

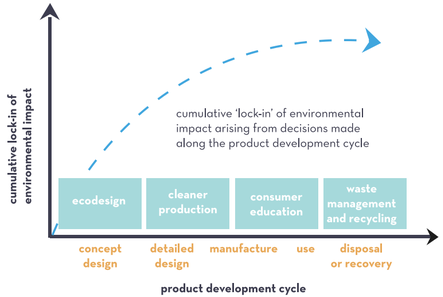


Figure 17 Conceptual representation of environmental lock-in during product development stage, based on (Koeijer et al., 2017; Lewis & Gretsakis, 2001)

The conflictive elements between eco-efficiency and eco-effectiveness

Reducing in packaging materials seems to be the first step companies have taken into making packaging more sustainable. This can be partly explained by the cost savings that companies could make by using less material. Reduce often leads to (multilayer) laminates, which are more difficult in recycling systems, but save a vast amount of material. Another explanation is the regulations regarding packaging waste (measured by weight), which addresses the need for material weight reduction (Koeijer et al., 2017).

This is underlined by Braungart and McDonough, who state that steps towards eco-efficiency can have a counter effect on the environmental impact reduction. Short term 'quick' wins towards more sustainable packaging is therefore not the optimal solution (McDonough & Braungart, 2010).

As an example to the critical note of McDonough and Braungart, fleece sweaters that are made from recycled PET bottles, look like a sustainable idea, but might lead to environmental problems, as microplastics end up in our water after washing recycled polyester in the washing machine.

Image source: Patagonia

Next to optimising recycling and reuse of packaging and materials, often based on fossil fuel and scarce recourses, alternatives arise like the use of biobased materials like bioPE and bioPET (Molenveld, Van den Oever, & Bos, 2015). These materials fit in of sustainable packaging development, because they provide an answer to the issue of scarce resources. However, their origin might be natural, in the recycling process they act the same as fossil-based materials.

Sustainability in packaging design processes

The question is how sustainability finds its way in the previous descripted packaging design and development methodology. Next to the functional requirements of a package, sustainability requirements arise. In theory, this would be already examined in the beginning of a packaging design process. In practice, it turns out that sustainability requirements do not always receive the same attention as other requirements as commercial viability (strategic fit, business case feasibility, and a limitation of commercial risks) and development aspects (timing issues, material use, and supply chain efficiency) (de Koeijer et al., 2017; Kaskinen, Neuvonen, Tarvainen, & Korhonen, 2013).

In present-day, sustainability in packaging development comes down to minimising the environmental impact of product-packaging combinations on the one side (eco-efficiency) and optimizing the product-packaging combinations and striving for circularity on the other side (eco-effectiveness). Under these two pillars a variety of aims can be placed. The aim is to minimise the use of packaging materials (and scarce resources) and interchange them where possible for biobased or recycled materials,. The aim is keep the materials we use in the system at their highest possible value, reuse packaging where possible and design them in such a way that they are easy to recycle. Above all, the functions the packaging fulfils to a product is put central, and only when those requirements are met, a packaging can be sustainable. Figure 18 shows a summative, top-down view on sustainable packaging development.

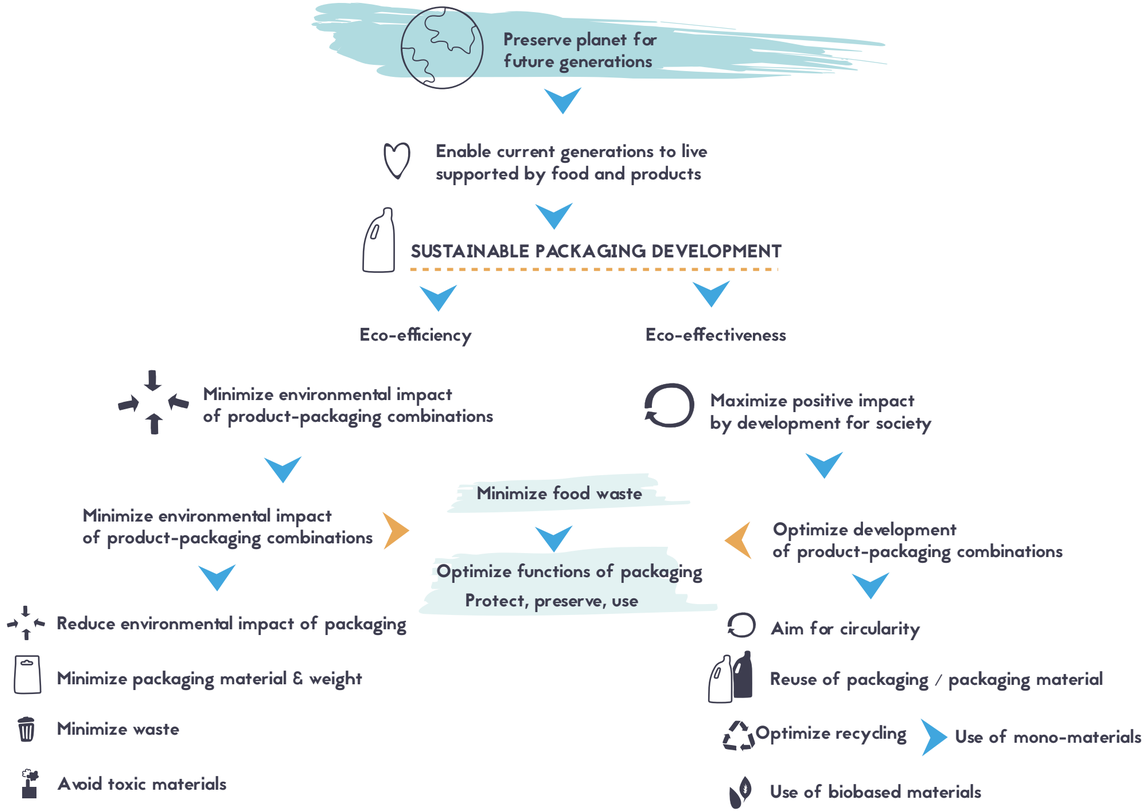


Figure 18 Sustainable packaging development, a visual summary

VERPAKKEN
Niet te veel niet te weinig juist van passe

Kooijman (1990)

4 THE DUTCH WASTE SYSTEM

‘Eventually the limitations of this system will be encountered’

In order to get a better grasp on dynamics in the life cycle of a packaging, especially where it ends up after the consumer disposes it after using/ consuming the product, this chapter describes the Dutch waste system and how packaging materials are handled in this system.

4.1 Legislation

On national level, waste management is regulated in Dutch Environmental Management Act (Ministerie van Infrastructuur en Milieu, 1979). The Dutch legislation for sustainability in packaging design can be found in the Dutch Packaging Management Decree (Staatssecretaris van Infrastructuur en Milieu, 2014). As an implementation document, the Dutch Ministery of Infrastructure and Water Management pronounced the LAP3 (national waste management plan), which describes the policies and targets for waste prevention and waste management (Ministerie van Infrastructuur en Waterstaat). In waste management and recycling, a distinction can be made between three steps. Starting with the collection of post-consumer waste from households, followed by the sorting of waste in separate waste streams and thereupon the mechanical recycling process where material streams are converted into new resources.

4.2 Waste streams

Household, or post-consumer waste can end up in several separate waste streams, as the separate collection of paper and board, glass and GFT (organic waste). For plastics three post-consumer plastic packaging waste (PPW) recycling systems are in place: separate collection from households, mechanical recovery from the mixed municipal solid refuse waste (MSW) and a deposit-refund system for large PET bottles for water and soda drinks (Brouwer et al., 2018). A schematic overview of waste stream scenarios for packaging is given in Figure 19. Municipalities can decide to execute source separation of waste or post separation, or a combination of both, which

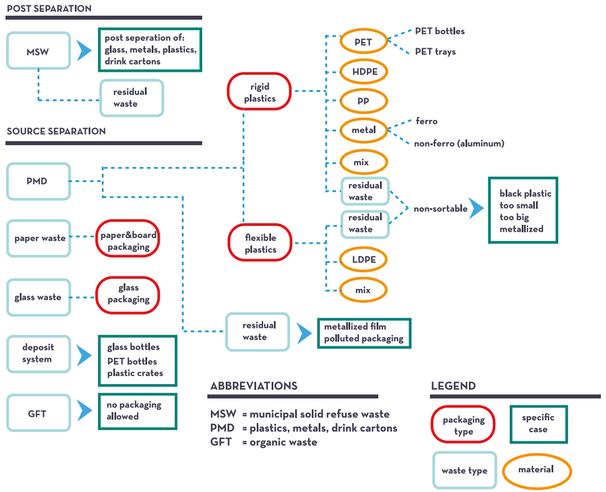


Figure 19 Schematic overview of waste streams (NL)

results in different waste systems in different parts of the Netherlands.
For each of the separate waste streams specifications is defined what is allowed in the composition of the sorting products, to guard the quality of these sorting products that are transferred to the recyclers. These specifications are called ‘DKR standards. For example, for the mixed plastics referred is to ‘DKR 350’, which states that 90% of the sorting fraction should exist of plastics that are typical for packaging (PE, PP, PS, PET), with a maximum of 10% impurities (Der Grüne Punkt, 2007).

In LAP3 is defined that the producers of packaging stay responsible for their packaging, even after it is discarded by consumers. Therefore, producers and importers of packaging pay a fee in the form of a ‘waste management contribution’ to the Afvalfonds Verpakkingen, which is used to arrange the collection, sorting and recycling of packaging in a collective way. Since January 2019, the Afvalfonds Verpakkingen provides a discount on this contribution to producers and importers that introduce rigid plastics on the Dutch market that are optimized for recycling. To define whether a packaging is optimal recyclable or not, the Recycle Check as developed by the KIDV is used. More about the Recycle Check can be read in chapter 7.5.

4.3 Recyclable versus recycled

For a packaging to be recycled, a packaging must be collected, (correctly) sorted and recycled in order to be used again, whereas being recyclable only means that a packaging theoretically is suited for recycling. For both terms, there is no clear description in what state this recycling should be. Therefore, in sustainable strategy communications and packaging (material) marketing these words are often misused, which sometimes leads to misleading statements and unfair perception within industry.

4.4 Chemical recycling

Stakeholders in the plastic packaging chain have the shared ambition to close the chain, both in the use of virgin materials as resource and in the economic value and quality of materials. By optimising existing collection and processing systems, it is possible to increase the volume and quality of recycling plastics. However, eventually the limitations of this system will be encountered. A possible solution to this might be chemical recycling. Chemical recycling makes it possible to separate different types of plastic or to separate plastic from other materials (for example through solvolysis). Chemical recycling techniques vary from the breaking down of plastic packaging materials into their smallest chemical building blocks (gasification) to the breaking down of the material into its intermediate molecular stages from the plastic production chain (depolymerisation, pyrolysis). Among other things, these various techniques offer a solution for the declining quality of the polymer chains after each cycle of mechanical recycling (Kennisinstituut Duurzaam Verpakken, 2018). Chemical recycling techniques have the potential to improve and increase the recycling of plastic packaging materials and raise the quality of the recycled content to that of virgin plastics or raw materials. The realisation of chemical recycling of plastic packaging materials at an industrial scale appears to be an ongoing process in the Netherlands, and it is out of scope of this research. As a remark, where throughout this report the term ‘recycling’ is used, referred is to mechanical recycling.

To conclude, the recycling process is divided into collection, sorting and recycling, In the Netherlands, there are different waste systems in different parts of the country, because municipalities can decide how to manage their waste streams. In general, a distinction is made between source separation of waste and post separation, after which waste can end up in mono-sorted streams or mixed waste streams. The materials that are sorted can be mechanically recycled, and chemical recycling is designated as a promising technology to expand the recycling possibilities.

5 BUSINESS ENHANCEMENT

'Such a strong focus on recycling with circular economy as the higher goal'

The theory of a phenomena and the execution in practice are often widely dispersed. The adaption of business with sustainability in packaging development is therefore explored. In this chapter is discussed how companies currently incorporate sustainability goals in their operational and strategic methodology and how CE finds its place in this, regarding both sector and company level. Next to this, this chapter also reviews a broader perspective by discussing how governmental regulations and guidelines influence the sustainability of packaging development, both on supranational and national level.

5.1 The field of actors

All actors in the packaging chain have influence on the sustainability of packaging, but for this research producers and importers of packaging have been selected as the main target group. Other actors, as consumers and governmental organisations are only shortly elaborated on. Figure 20 shows the field of actors in sustainable packaging development.

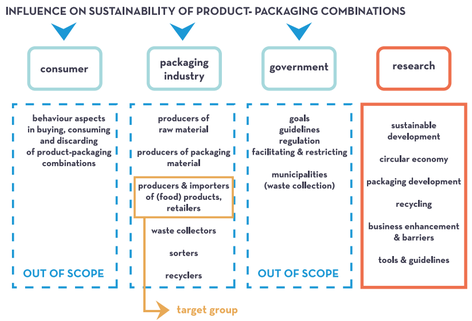


Figure 20 The field of sustainability in product-packaging combinations

5.2 The consumer

Consumers have influence on the use and end-of-life of packaging, by either performing according to the envisioned waste collection systems or deciding to discard the packaging in nature with problems as litter and plastics in the ocean as a result. For this research, the consumer stays out of scope. Mentioned should be that research have more often shown that the perception of sustainability of consumers is often not correlating with the actual sustainability of products. Moreover, recent research have shown that consumers behaviour towards recycling of packaging can be influenced by design (Borgman, Mulder-Nijkamp, & Koeijer, 2018; Geiger, Ünal, Van der Werf, & Steg, in preparation).

5.3 Supranational and national level

Governmental organisations have influence on the sustainability of product-packaging combinations by setting goals, providing guidelines and by introducing laws and regulations. In other words, governmental organisations are both facilitating and restricting.

On the level of sustainable development in general, mentioned should be the Sustainable Development Goals (SDG), as stated by the United Nations. These SDG's focus on social, economic and environmental sustainability in development. For packaging, Goal 12 seems most fitted:

'Sustainable consumption and production patterns enable efficient resource use and can reduce the impact of economic activities on the environment. To that end, this goal focuses on decoupling economic growth from resource use, and ensuring that hazardous chemicals and wastes are managed in a way that minimizes their impact on human lives and the environment.' (United Nations, 2017).

Both European and Dutch government are demanding for more sustainable product-packaging combinations. Therefore, legislation related to the sustainability of packaging has been established: the European Directive 94/62/EG (European parliament and the council of the European Union, 1994), which is translated into the Dutch Packaging Management Decree (Staatssecretaris van Infrastructuur en Milieu, 2014). In these directives the essential requirements for packaging are key.

In short, the requirements state that:

- Packaging should be as small and light as possible. However, the packaging should still fulfil the requirements for safety, hygiene and consumer acceptance
- Packaging should be suitable for either reuse, recycling or recuperation
- The presence of harmful or hazardous substances in packaging (materials) needs to be brought to a minimum

In December 2015, the European Committee published the EU action plan for Circular Economy Closing the loop', often referred to as the 'Circular Economy Package' (CEP). Part of this is the Single Use plastic proposal, where the market restriction, goals for separated collection, design guidelines, producer responsibility are defined (European Commission, 2014a).

Afflicting the Netherlands, the Plastic Pact was proposed, which was signed by 75 companies on voluntary base, agreeing on using less plastic, using more recycled content and producing 100 % recyclable plastic packaging (Staatssecretaris van infrastructuur en waterstaat, 2019).

Current developments might sound promising and new, but a lot of them find their foundation in much earlier governmental discussions. In the 'Covenant Verpakkingen 1991', environmental minister Hans Alders (PvDA) achieved a voluntary agreement where he advocated the use of less plastic, legislation to no longer providing free plastic bags, stimulating towards more recycling. On the short term this resulted in less plastic packaging on the market, but already in 1997, the agreements changed and the packaging material that was brought to Dutch market steadily grew. Only in 2016 the ban on free plastic bags was executed. Steps that government, packaging industry and municipalities should take in order to improve the sustainability of product-packaging chain in the Netherlands are stated in the Framework Agreement for Packaging 2013-2022 (Ministerie van Infrastructuur en Milieu, Vereniging Nederlandse Gemeenten, & verpakkend bedrijfsleven, 2012).

Recent development in The Netherlands is the National Agreement on the Circular Economy, where transition agendas are published to approach the transition to circular economy in a structured way (Ministerie van Infrastructuur en Waterstaat, 2019). Actors throughout the chain, from NGO's to financial institutions, governmental organisations and producing companies are collaborating in this agreement. To speed up transition to a circular plastic chain and to reduce the CO2 emissions, a transition agenda of plastics was realized, with four main directions of action:

1. prevention: do more with less plastic, reduce the waste & loss
2. more supply and demand of renewable plastics
3. better quality, more environmental efficiency
4. strategic chain collaboration

On Dutch level, the VANG policy (From Waste to Resources) is also remarkable. In this program, steps have been taken over recent years towards closing the plastic cycle. However, the policies are somewhat misleading. The focus is been laid on reducing the overall weight of the

MSW and on the increase of weight of PPW that has been collected. As stated by the Afvalfonds Verpakkingen: 'The proportion of collected and recycled plastic packaging has currently already risen to 50%'. By putting the focus mainly on the quantity of the collected plastic packaging (and the pollution that is contributing to this weight) and putting less focus on the quality of the composed materials, a closed material loop for plastics might not be easily achieved. Eventually, it is not only about regenerating all plastic packaging material, it is also about maintaining the highest resource value possible when doing so.

5.4 Sector level

A sector with large potential in applying CE principles is the Fast Moving Consumer Goods (FMCG) industry, which includes products characterized by high throughput volumes, frequent purchases and large physical volumes available at relatively low prices (MacArthur, 2015). However, a "casual interpretation" of CE can lead an industry to view it as a mere refreshing take on recycling schemes and reverse supply chains rather than a true systemic change (Webster, 2013).

To enhance the sustainability of packaging on sector level, each sector was requested to establish a plan to achieve sustainability of product-packaging combinations within the sector they operate. This request came from the Framework Agreement for packaging of 2013-2022 (Ministerie van Infrastructuur en Milieu et al., 2012). This resulted in the 'Sector Sustainabiilty Goals' for 22 sectors, in which goals are defined to realise the reduction, recycling and reuse of resources and packaging materials (Kennisinstituut Duurzaam Verpakken, 2019a).

5.5 Company level

To begin with, there are different company profiles and they all have their own approach and connection to sustainable development. As an example, a small brand owner only has a guiding role in the packaging development and the actual development is done via partners or co-packers. These external stakeholders largely determine the type of packaging and must provide the required information, only the final decision is in hands of the brand owner.

In contrast, food processing companies often have their production and research and development department indoors. Here, different departments are involved throughout the stages of a development process. Departments as marketing, packaging development, product development, purchase and production are all involved in this process. These sorts of companies often have sustainability incorporated in their company strategy, only on operational level aspects as costs and quality often receive priority.

Researchers have explored what is incorporated in the strategy and activities of companies. In their research, Stewart and colleagues analysed circular economy related activities reported by companies in their corporate sustainability reports. From this can be concluded that CE has started to be integrated into the corporate sustainability agenda of companies. Where the majority of activities are oriented toward the main product and packaging, focusing on end of life management and sourcing strategies, less or almost nihil focus is put on circular product design and business model strategies (Stewart & Niero, 2018). This end-of-life management is merely focusing on the optimising of the current recycling system.

Indecipherable is why there is such a strong focus on recycling when circular economy is the higher goal. This can be partly explained by the fact that product life extension is not a viable option (except for returnable packaging) whereas focusing on material use extension certainly is. One way of doing this is improving the recyclability of the packaging material, which depends on both its technical recyclability, that is, the ease with which it can be reprocessed and used to manufacture new products, and on the availability of facilities to collect, sort and reprocess the material (Niero, Hauschild, Hoffmeyer, & Olsen, 2017; Verghese et al., 2010).

To conclude this chapter, both on supranational and national level there are guidelines and frameworks in place in the form of regulations and agreements that support industry in sustainable packaging development. Planned actions towards more sustainability in packaging development are merely directed in the area of the reduction of material use and the optimal reuse and recycling of resources and packaging materials. CE is beginning to find its place in the corporate sustainability agenda of companies, whereas most actions are still focussing on the optimisation of our current system. The recycling system receives a lot of attention and the quantity of plastic packaging that is being put on the market and recycled is leading here.

6 BARRIERS TO SUSTAINABLILITY - THE GAP

'We tend to forget the base of our current situation'

In literature it seems evident that steps towards more sustainability need to be taken in order to preserve our planet for future generations. As the previous chapter has shown, there are ambitions and agreements of companies, sectors and governmental organisations towards more sustainability in packaging development. In practice this appears to be complex to implement and achieve. A question that rises is: why do producers and importers (PI's) currently not take steps towards more sustainability in packaging development? This chapter will explore the barriers that companies face and moreover will try to define a gap between what is done in present day and what is desired as a goal for the future.

6.1 Misalignment

According to De Koeijer and colleagues, there is a misalignment between operational and strategic levels of sustainability processes (de Koeijer et al., 2017). In their research, the alignment of the strategic and the operational level of packaging development in relation to the integration of sustainability is regarded. As an outcome of this research, they indicated factors that potentially influence the implementation of sustainability considerations in packaging development processes, as shown in Table 2.

Their research used interrelations between actors, decisions, actions and trade-offs, and decision-making criteria to find enablers and barriers in the alignment of strategic and operational levels of sustainable packaging development (de Koeijer et al., 2017). Regarding their findings, barriers to sustainability considerations in packaging development processes can be summarized to a lack of knowledge and tools and a lack of commitment and cooperation amongst departments.

		Barriers
Internal	**Strategic**	Lack of management commitment and support Avoidant sustainability ambition Commercial disadvantage Attitude towards change Mere focus on incremental product innovation Organizational complexities
Internal	**Operational**	Conflict with functional requirements Additional workload Additional costs Supply chain complexities Lack of suited tools Lack of cooperation among departments: limited involvement of marketing and sales; gap between environmental proponents and executors Limited experience
External	**Strategic**	-
External	**Operational**	Competitive disadvantage Customer resistance to design changes

Table 2 Factors that potentially influence the implementation of sustainability considerations in packaging development processes (de Koeijer et al., 2017)

It is striking that packaging developers seem to have little influence on decision making in packaging development processes (de Koeijer et al., 2017), whereas they are actually the designated actor within a development team to consider the whole life cycle of a product-packaging combination. When elements from different expertise are not considered in sustainable development, sustainability decisions are often based on incomplete and precarious models of the life cycle of a product-packaging combination, that in result lead to sub-optimisation (Luttikhuis, de Lange, Lutters, & ten Klooster, 2014).

According to the EASAC (European Academies Science Advisory Council), companies may lack the information, confidence and capacity to move to CE solutions due to a lack of indicators and targets, awareness on alternative circular options and economic benefits, and the existence of skills gaps in the workforce and lack of CE programmes at all levels of education (Huhtala, 2015). Consistently, without an evaluation framework or support from the industry, CE initiatives are not sustained (Saidani, Yannou, Leroy, Cluzel, & Kendall, 2019).

6.2 The gap

Next to the misalignment between operational and strategic level of sustainability considerations within companies and the lack of knowledge of, and tools for sustainable packaging development, a gap can be indicated between what companies are doing in present day and the desired situation that we want to achieve in the future. To clearly define what this gap is, the current state of being must be explored, followed by what we want to achieve in the future. Subsequently, the gap can be determined.

The previous chapter regarded the current state of being on the level of goals and agreements towards more sustainability in packaging development. This has shown that CE is starting to be incorporated in sustainability agendas, but that current actions are mostly focussing on the optimisation of the recycling system. With CE as the desired goal for the future and the optimisation actions of our linear system in present day, a gap between these two points becomes clear, as shown in Figure 21.

We can evaluate the current state of being in present day, whereas goals need to be made for a desired future by using a future perspective. If we use these future goals to make operationalisation plans for present day, we cannot immediately apply these to our current situation. Although the gap is now somewhat clear, the method of bridging this gap is, nonetheless.

This leaves us with the question what we should do now to make steps for the desired situation in the future. We tend to forget the base of our current situation and thereby it becomes very difficult to achieve a desired goal in the future. Looking the other way around, if we keep on using our current situation as the way to go, and try to optimise this, then we will not

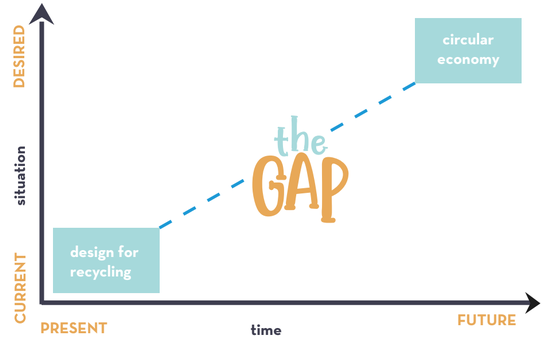


Figure 21 The gap between present day and the desired future, based on (Kennisinstituut Duurzaam Verpakken, 2019b)

reach the desired goal either. Starting by optimising what we are already doing will help to set a few steps towards the edge of the gap but cannot completely bridge it. Therefore, next to optimisation our current situation, other activities are required to genuinely achieve the desired goal. This brings us back to the findings from chapter 1, where is stated that for sustainable development, we need to change the way we do think in order to preserve our planet for future generations and where CE is described as the methodology to achieve this.

To help PI's in enhancing sustainability of product-packaging combinations, it is concluded that they might benefit from support in improving the cooperation and commitment amongst departments and enriching their knowledge on sustainable packaging development. An evaluative framework is designated to support and sustain CE initiatives within companies. It is underlined that companies should consider the whole life cycle of a product-packaging combination in order to make substantiated decisions. With a hiatus between our current situation and the desired goal in the future, support should aim at bridging this gap.

7 FIELD OF TOOLS AND GUIDELINES

'A goal-driven approach versus a tool-driven approach'

While the need for sustainable development is recognized by industry, the translation of long-term goals on strategic levels of sustainability into operational approaches for sustainable packaging development is not evident. Multiple barriers are obstructing the implementation of sustainability considerations in development processes, with a lack of knowledge, tools and support designated as the main factors. A wide range of tools and techniques for improving and assessing sustainability is available, yet none is tailored for the development of product-packaging combinations (Koeijer et al., 2017; Oude Luttikhuis et al., 2013). Therefore, an analysis on current tools and guidelines is used to discover what is missing in these tools to support producers and importers in enhancing the sustainability of product-packaging combinations, specifically in decision making processes.

Existing models and tools can be divided into two variants: generative and evaluative ones. Generative tools (ideation and design tools) are aimed at integrating environmental considerations into the development process. This is most relevant during the earlier phases of development. We can sub-divide this in protocol- and diagram-type models. During the later stages of the development process, evaluation of a product's sustainability and life cycle is more relevant, using evaluative (assessment) tools (Koeijer et al., 2017).

7.1 Protocol-type models

Protocol-type models provide support during the beginning of development processes, often in the appearance of principles, guidelines and checklists. Two rather known and similar frameworks are Cradle to Cradle (C2C) and Circular Economy (CE). Both replace the linear take-make-dispose pattern and eco-efficiency with the strive for eco-effectiveness: optimising a products' positive environmental impact, where waste equals food (Koeijer et al., 2017; MacArthur, 2015; McDonough & Braungart, 2010). Another widely used guideline is the Design for Environment (DfE) framework, which is the overarching term for a variety of principles and guidelines, as: The Twelve Principles of Green Engineering and the Ten Golden Rules. These focus on material and energy efficiency, the elimination of hazardous substances and minimization of material diversity.

The flexibility and adaptability of protocol-type models make them often the go-to type model for design & marketing teams, especially suited for front-end phase of development processes. As a con, protocol-type models can limit innovation and are insufficient when completely new solutions arise. Moreover, disadvantage is that background knowledge is needed to use protocol-type models in a good way. Protocols struggle in the trade-off between flexibility and accuracy (Koeijer et al., 2017).

7.2 Diagram-type models:

Diagram-type models display a development process as a cycle or chain of steps, as the packaging design process. These models are generic and the application for packaging is unclear. Existing models have a lack of proper integration of actors beyond product-packaging development teams, such as managerial decision makers, suppliers and consumers. This makes diagram-type models not suited for use in cross-functional teams. Models with a specific focus on sustainability considerations for circular packaging development are rare (Koeijer et al., 2017).

7.3 Evaluation-type models:

Where both protocol- and diagram-type models are used in the beginning of development processes, evaluative tools are used in later stages of development. One widespread phenomenon in sustainable assessment is the LCA (Life Cycle Assessment) approach. LCA's are effective in determining the environmental impact of packaging in all steps of the chain (Sonneveld, 2000). LCA outcomes can be used both internally for product evaluation and optimisation and externally as communication to consumers or to use as competitive feature of a product (Sonneveld, Verghese, Fitzpatrick, & Lewis, 2018).

However, LCA's seem to be missing some context for PI's to make substantiated decisions when developing packaging for circular systems. Moreover, the amount of time and effort that are required for an LCA are often regarded as a big hurdle for companies. For LCA's, reliable data is needed and all assumptions and methodology in the assessment must be transparent to interpret the results in an appropriate way. Moreover, expert knowledge and software are required to properly execute a LCA, which is often not present at PI's (Oude Luttikhuis et al., 2013).

Examples of LCA tools to assess the environmental impact of packaging are PIQET (Verghese et al., 2010), COMPASS (Sustainable Packaging Coalition (SPC), 2012),PackageSmart (Earthshift, 2014) and Envpack (Ligthart, Thoden van Velzen, & Brouwer, 2018). Envpack is an LCA tool developed for educational use, funded by the Top Institute Food & Nutrition, KIDV and TNO. Like the other LCA-based packaging tools, Envpack uses the cradle-to grave approach. Product-packaging combinations are taken into account in this tool and for example food waste is included in the assessment (Ligthart et al., 2018).

It is important to be aware of the fact that in any case, an LCA study can never define whether one product-packaging combination is sustainable or not. At best, it is possible to assess whether one packaging design is more sustainable than another, either because it fulfils the same needs at a lower eco-burden or because it fulfils more needs at the same eco-burden (Wever & Vogtlander, 2013).

One of the main issues of the assessment method itself is the limited focus on integrated product-packaging combinations. When for example product losses are not taken into account in an LCA of packaging, the validity of the results is limited (Koeijer et al., 2017). Moreover, by separately considering packaging from its product the functions packaging fulfils are ignored.

The eco-costs/value ratio model of Wever and Vogtlander overcomes this problem by including the value created in product-packaging combinations in the assessment, next to environmental assessment. This leads to a more eco-effective assessment (Wever & Vogtlander, 2013).

An interesting comparison is made by Rossi and colleagues, who compare the evaluative approach of the LCA methodology with the protocol-type C2C methodology. As they state, C2C adopts a goal-driven approach, whereas LCA uses a tool-driven approach. This implies that when using the LCA method, stakeholders are inspired to make improvements to the product/packaging based on the conclusions generated by the LCA study. In contrast, when using the C2C approach, the goals that need be achieved are first established, after which tools and metrics needed to evaluate progress towards those goals are developed (Rossi, Charon, Wing, & Ewell, 2006).

In the context of a case study for the Carlsberg Circular Community, Niero and fellow researcher proposed a framework in which C2C and LCA methods are combined to support packaging development for circular systems by addressing eco-efficiency and eco-effectiveness simultaneously (Niero et al., 2017). This might be relevant for the development of an evaluation tool that aims at supporting transition to CE.

7 FIELD OF TOOLS AND GUIDELINES

7.4 Circularity assessment tools and indicators

Next to the previous described generative and evaluative tools and models, specific focus is put on the availability of circularity assessment tools and indicators. Most of these circular assessment tools focus on circularity on product level, which makes them not specifically suited for packaging or product-packaging combinations. Hence, products are most often designed for more durability than packaging, making the assessment less applicable to more fast flowing goods like packaging for FMCG. Striking is that most circularity tools and indicators look at circularity on micro-level, taking meso- or macro-level not into account. This is remarkable, because circularity is not something one company can achieve, more emphasis on a chain perspective would be valuable.

Several literature exists that compares different CE frameworks and assessment methods to find alignments and misalignments between them. From this analysis, it is possible to conclude that the main disagreements relate to what principles and criteria of circularity are used in the proposals (Camacho-Otero & Ordoñez, 2017).

Two aspects are relevant for a circularity assessment: it should contribute to closing the material loops and keep resources for future generations. On the other hand, circularity assessment should allow companies to understand what natural resources they depend on and what internal opportunities they have from waste streams. Such sort of assessment could support in strategies towards circularity (Camacho-Otero & Ordoñez, 2017).

In academic research, several examples can be found of literature that collects and compares different circular economy indicators and assessment tool, as the research of Linder and colleagues . (Linder, Sarasini, & Loon, 2017) and the one of Saidani and others (Saidani et al., 2019). Build upon their research, Table 3 was put together, which is by no extend complete but aims at providing an overview in order to learn from this and to see if elements of this can be used in the KIDV tool.

Organisation / researchers	What sort of indicators/assessment	How it works	Remarks
Ellen MacArthur Foundation & Granta Design	Material Circularity Indicator (MCI)	Measures how restorative the material flows of a product or company are	MCI gives value between 0 and 1 where higher values indicate a higher circularity
GSES	Circular product footprint indicator	Circular product footprint: Amount of recycled material & virgin material in a product	
VBDO	Circular performance on company level, Key performance indicators (KPI's)	Strategy and governance (targets, accountability), Implementation (revenue, product design, procurement), Innovation (circular business models, budget, partnerships), Communication and engagement (customers, stakeholders, raising awareness)	Benchmark circular business practice ranking. In 2015 47 companies were ranked on how good they scored on each of the 4 segments, outcome is a percentage of total score.
Viktoria Swedish ICT (Linder et al., 2017)	Metric for quantifying product-level circularity	Ratio of recirculated economic value to total product value (using value chain cost as estimator)	Output is a circularity metric between 0 and 1 (0% to 100% recirculated parts), limited to measure degree of recirculated direct material in de product weighted by direct costs, including material and labour costs.
Circle economy & PGGM	Circle assessment on 7 key elements; score companies on current circular thinking & educate on opportunities	7 key elements: collaborate to create joint value, design for the future, rethink the business model, incorporate digital technology, use waste as a resource, prioritise regenerative resources, preserve and extend what's already made	Output are radar plots, score between A+, A, B, C, D Key opportunities and key challenges Examples of strategies and companies that use these strategies
ResCoM (IDEAL&CO)	Circularity calculator. Decision making tool and methodology to support manufacturers in transition to closed-loop industrial systems	BOM* or product info, costs of product stages, what percentage of product/part enters specific cycles (remanufacturing, refurbishment, recycling)	Output is potential mass and value flows of a product, percentages on 4 performance indices: circularity, value capture, recycled content, reuse index
(Maio & Rem, 2015)	Circular economy index;	The ratio of the material value produced by the recycler (market value) by the intrinsic material value entering the recycling facility	Index measures recycling rates, excluding all other circular economy effects and loops
(Vogtlander, Scheepens, Bocken, & Peck, 2017)	EVR: Eco-cost value ratio	EVR is computed by analysing the costs, the eco-costs and the (customer perceived) value,	Eco-cost is based on LCA, not really a CE assessment, but more nuanced than normal LCA by incorporating value
WeSustain (Ecopreneur & MVO Nederland)	Questionnaire to assess circularity on company level	By filling in the extensive list, the tool computes indicators on design, procurement, manufacturing, delivery, use, recovery, sustainability in percentages.	Could be used as checklist but strongly subjected to interpretation of questions and input by user

Table 3 Overview of circularity indicators and assessment

7.5 KIDV tools

Where the KIDV focusses on the collecting, sharing and together bringing of knowledge, the approach for KIDV tools is most often bottom-up, helping producers and importers with the first steps towards more sustainable packaging. The KIDV has developed some tools and guidelines for PI's, focussing on specific areas of sustainable packaging. The 7 main guidelines for sustainable packaging (Appendix B) is an example of a protocol-type model. An evaluative tool of KIDV is the Recycle-check, shown in Appendix C. the KIDV mainly provides knowledge sources, services and interactive support, combined with accessible knowledge on the website. A self-assessment tool is not available yet.
The Recycle-Check is a decision tree tool to one of the many choices that packaging designers, but also marketers and buyers have to make if they bring a new product or packaging on the market. The user will be asked a short series of questions about the material and packaging components that affect the sorting and recycling. The questions should be answered with yes or no. Background information is provided for each question on the different aspects of sorting and recycling. The Recycle-check focuses at the entire packaging, for example a bottle with cap and label or sleeve, or a bowl with lid and label. Currently, only a Recycle check is available for rigid plastics, but the other material groups (as flexibles, paper & board, glass) are developed.

An example of KIDV's informative tools are the factsheets that help enrich knowledge on specific fields of packaging development, often about nuanced and difficult subjects like bio-degradable plastic packaging or chemical recycling.

A service that the KIDV provides is the 'Quickscan', where two packaging experts of the KIDV screen the packaging portfolio of a company to see which product-packaging combinations might need adaption to improve its sustainability.

7.6 Evaluation on target group needs and existing tools

As described in chapter 6, producers and importers of packaging experience barriers in sustainable packaging development. There is a need for a packaging-specific tool, to enrich knowledge on sustainability in packaging development and to support communication and commitment amongst departments and stakeholders in order to achieve improvement of sustainability of product-packaging combinations and on a higher level, to support the transition to CE. Looking back at the gap as defined in chapter 6, evaluative tools as the LCA approach can evaluate and compare packaging alternatives in a current system. Protocol-type tools might be able to support in bridging the gap, but no clear guidelines are available yet. A combination of goal setting with a future perspective and evaluation of the current situation in one tool would be a good way to combine an eco-efficient and eco-effective approach and it might support producers and importers of packaging to bridge this gap.

To conclude, existing tools and guidelines to support sustainability in development have been assessed, where a distinction can be made between protocol-type tools and evaluative tools. Where some tools are not specifically suited to be used in sustainable packaging development, other tools are very applicable for packaging, but require a vast amount of knowledge or experience to use them in a proper way. No specific tool was found that combines assessment of eco-efficiency and eco-effectiveness, which leads to the incentive for the development of a new tool. The new tool should combine goal setting for a desired future with evaluation of a current situation.

8 INCENTIVE FOR THE DEVELOPMENT OF A NEW TOOL

'Provide a nuanced view'

As analysed in the previous chapter, there are several models and tools to support in sustainable (packaging) development, but these all seem to be missing aspects to be fully suited for the given task. The KIDV requests an evaluative tool for PI's, that helps in sustainable development processes of packaging. The tool should address the barriers and gap that companies are facing in present day, in order to support sustainable development in the current situation and help in transitioning to CE. The tool needs to be suited for use by a variety of companies that are involved in packaging development, from small brand-owners to larger food producing companies.

8.1 KIDV tool proposition

The KIDV proposed a tool with 3 modules, that all assess a certain aspect of sustainability. Starting with the Recycle-check, followed by a so-called 'circularity check' and an environmental impact assessment, based on existing LCA knowledge. The KIDV already developed the Recycle-check for rigid plastics and plans to use an external expert to develop the environmental impact module of the tool. For this research, the focus is therefore put on the development of the circularity module of the tool.

The framework of the tool with 3 modules, as proposed by KIDV, is in line with findings from literature. As proposed by Niero and colleagues, a combination of assessment methods for both eco-efficiency and eco-effectiveness would be very valuable. By combining LCA and C2C methodologies into one tool, both environmental impact as closing resource loops and preserving material quantities and qualities can be assessed (Niero & Hauschild, 2017). A tool that uses both goal setting towards more sustainability in packaging development and evaluation of achievements of these goals, would challenge users to clearly define a sustainable strategy for packaging and would enable users to interpret the output of the tool in a substantiated way.

8.2 The current situation and needs

The most common existing tool for assessing sustainability is an LCA, but this is often regarded as too complex or not robust enough to provide a clear view on sustainability without the risk of varieties in results due to interpretation. Moreover, the LCA methodology focusses mainly on the environmental impact of packaging, resulting in eco-efficient development and neglecting other aspects crucial for transitioning to CE, like material recapturing and value redemption. For transition to a circular economy, closing (material) cycles is key, both on quality and quantity level. This requires high-quality collection, sorting and recycling of materials, which has to be considered in packaging design. As a result, structured packaging development for circular systems requires models and tools which address this from the perspective of design and marketing teams (Koeijer et al., 2017).

As addressed in chapter 6, there are some barriers towards sustainability for producers and importers, and current tools for sustainability in packaging development seem to be lacking enough guidance to overcome these. The lack of knowledge and commitment amongst department are selected as the main issues that could be supported with the new tool. The tool requires a combination of goal setting for sustainable development and an evaluation of the current sustainability of packaging. The evaluation of packaging should exist of three perspectives on sustainability: recyclability, circularity and environmental impact. By combining goal setting and evaluation, the tool should provide producers and importers of packaging with a nuanced view on sustainable packaging development to enrich their knowledge. The output of the tool should provide companies with an overarching framework that can be used in decision making in packaging development processes and communication in multidisciplinary teams towards more sustainable product-packaging combinations.

The aim is:
To develop a sustainability goal setting and evaluation tool for producers and importers of packaging, to support them in improving the sustainability of their product-packaging combinations.

8.3 The state of circularity

It is imperative to determine the current state of circularity so that one can have a benchmark against which to track improvements (Haas et al., 2015). Looking at the knowledge of PI's on the current system and its problems, there is plenty to gain before transition to a circular economy seems viable. Providing insights into the issues of our current linear system might support short term optimisation, to speed up the transition to a more circular one. Currently, communication about recyclability, process yield, and environmental impact are often fuzzy. By showing PI's more transparent data, an honest perspective can be provided, which helps in the improvement process.

8.4 The need for suited indicators

Whereas a large variety of existing sustainability and circularity indicators were found in literature, carefully must be selected what indicators seem most relevant to reach the envisioned result towards PI's. As remarked by Bell and Morse:

'Dealing with the humongous number of available sustainable development indicators, allege that now we have developed so many indicators that we are having to ask ourselves, what exactly are we measuring' (Bell & Morse, 2008).

In order to assess packaging on its recyclability, circularity and environmental impact, indicators are required to assess these specific elements. Whereas the Recycle-check is a given fact and the environmental impact tool is something the KIDV wants to outsource to an external party that has expertise in LCA methodology, in this research most focus lays on the circularity-check. This is also the part where most fuzziness in literature exists. Research into sustainable assessment methods and (circularity) indicators have been used to find what are the requirements of indicators to be used in sustainability assessment.

Conceptual simplicity

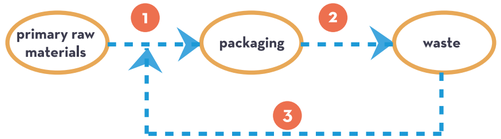
According to Di Maio and Rem, indicators need conceptual simplicity, whereas there is always a compromise between this and the cost of evaluation and the degree to which the indicator is in parallel with current policy targets (Maio & Rem, 2015). From literature review was derived that conceptual simplicity is crucial for indicators, as it provides an indicator with robustness and reliability. This to make sure that different studies will reach similar results, with little room for alternative interpretation (Maio & Rem, 2015). Because of the social contexts within which a circularity metric is to be used, it is also important that it is robust against opportunistic behaviour. There are plausible incentives for firms to try to present circularity values that are as high as possible (Linder et al., 2017).

Indicator for recycling efficiency

Di Maio and Rem regard the lack of an effective key performance indicator for stimulating the recycling industry as a fundamental issue. The mass recycling rates do have conceptual simplicity and are easily obtained. However, these mass recycling rates do not include the quality of recycling volumes and the applicability of this recycled materials for new purposes. This has brought an inaccurate and misleading indicator, which contributed to wrong decision making and to poor innovation in industry (Maio & Rem, 2015). Changing the metric used to assess recycling for circular systems is also underlined by Brouwer and colleagues, who introduce a different

approach to define the recycling yield. The 'net recycling yield' does not only look at collection and sorting of post-consumer-waste (PCW), but also takes the actual (mechanical) recycling step into account (Brouwer et al., 2018).

This indicates the importance of transparent indicators that are consistently computed from clearly defined measurement points and definitions. Figure 22 shows the measurement points as described above, for a more honest reflection upon recycling efficiency, as recommended by Maio and Rem.



1 Resource efficiency of production
2 Resource efficiency of collection
3 Resource efficiency of recycling

Figure 22 Material flow and resource efficiencies, redrawn after (Maio & Rem, 2015)

Separating indicators

Indicators can be used individually, as part of a set, or in the form of a composite index that combines individual indicator scores into a single number. Such a single aggregated number can be very useful in communicating information on general sustainability to the public and to decision makers. Possible disadvantages are that the methods to achieve an aggregation are often subjective and that every index contains hidden assumptions and simplifications. Therefore, such combined indicators need to be used judiciously. An important lesson learned from literature is that it is recommended not to combine different aspects into one integral indicator. It is better to assess each phenomenon with a separate indicator, improving the reproducibility and interpretation. As an example, Linder and colleagues developed a product-level circularity metric, with a very narrow focus. Toxicity, environmental impact etcetera are not incorporated, their advice is to use other metrics on the side (Linder et al., 2017).

Units

For the unit of expressing resource efficiency, literature recommends to use the economic value (Linder et al., 2017; Maio & Rem, 2015) because most targets in governmental and corporate reports are expressed in terms of economic values. This makes indicators expressed in economic value better aligned with policies and strategies (Di Maio, Rem, Baldé, & Polder, 2017). Subsequently, where mass only represents only quantity, economic value can represent both quantity and quality.

To help producers and importers of packaging to improve the sustainability of their product-packaging combinations, a sustainability goal setting and evaluation tool should be developed. Whereas potential barriers to sustainability are defined as a lack of knowledge, experience and support amongst departments, the tool should address these factors. To approach this, learnings from tool- and indicator research will be considered. Assessment methods need robust indicators, that are transparent in the way they are computed, have a high repeatability, low change of different results due to variation in interpretation and well-chosen units to express results in.

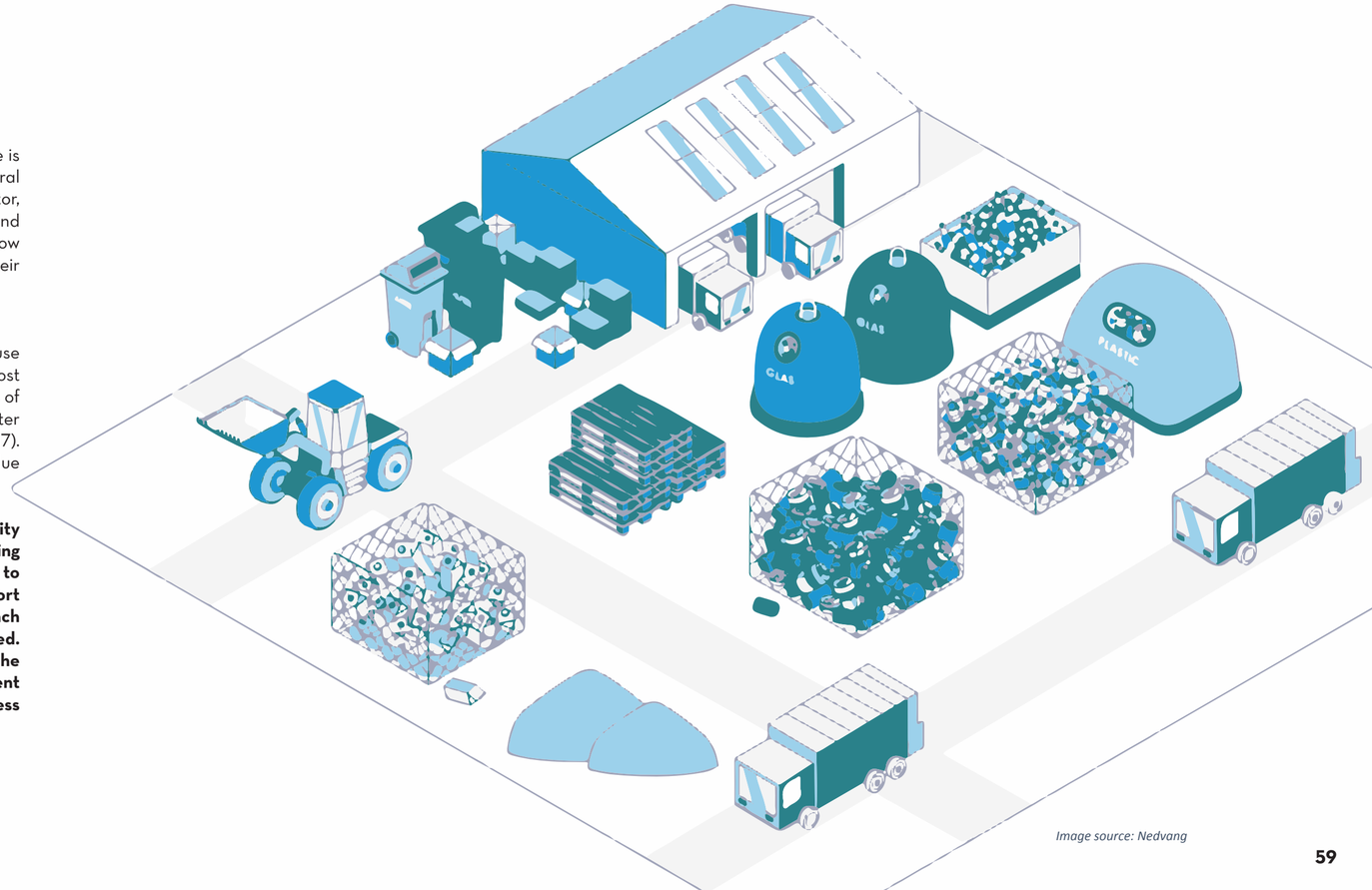


Image source: Nedvang

INTERMEZZO: REQUIREMENTS

Recaps
Usability requirements
Technical requirements

‘This intermezzo will summarize the findings of the first part of the research’

RECAPS

The theoretical framework

After exploring the theoretical field of sustainability in packaging development and Circular Economy as an approach to sustainable development, an incentive for the development of a tool for producers and importers of packaging was formulated. This intermezzo will summarize the findings of the first part of the research, in order to come up with requirements for the development of the tool, which will be described in the second part of this report. In this specification, requirements are divided into requirements focusing on user aspects and requirements focusing on the technical functioning of the tool.

Circular Economy is gaining widespread attention as an approach to sustainable development. Research has however shown that producers and importers of packaging are experiencing barriers towards improving the sustainability of their product-packaging combinations. Moreover, a challenge lays in the translation of desired future goals into concrete actions for present-day development. The KIDV can adapt to this by developing a tool where sustainability goal setting and evaluation are combined to support producers and importers of packaging in improving the sustainability of their product-packaging combinations.

Figure 23 shows the theoretical framework for the tool with sustainability goal setting and evaluation of packaging as defined in the first part of the report. As depicted here, there are two approaches to sustainable development, defined as eco-efficiency and eco-effectiveness. Where eco-efficiency aims at reducing the negative impact, affecting the short-term performance of sustainable development, eco-effectives focuses on the long-term performance and tries to maximise the positive impact. The difficulty lays in the fact that one is not necessarily better than the other, it is important to address long and short-term issues simultaneously.

Dilemmas might arise here. When for example tried is to optimise the recyclability of a packaging, light-weight multilayer packaging material can be substituted for a monolayer material, that might be heavier to create the same barrier properties. This modification has as a result that the minimisation of packaging material and/or weight might not be possible.

For PI's to decide on these dilemmas within packaging development it is therefore important to first set sustainability goals. After this, the evaluation of a packaging can be interpreted by reflecting on these goals. This evaluation part consists of three perspectives, as proposed by the KIDV: the recyclability, the circularity and the environmental impact. When a company chooses 'optimise recyclability' as the main goal, then the results of the recyclability (and circularity) module of the tool will be leading in the evaluation of a packaging.

The recyclability module is already developed by the KIDV and for the environmental impact module, an external expert will be consulted. The tool will be developed with the help of the theoretical framework as described above. The next part of this research focusses mainly on the development of the circularity module. For this module, the six elements of CE as depicted in the framework can be used as a starting point for developing indicators. To further specify what is required to develop the tool, requirements are formulated.

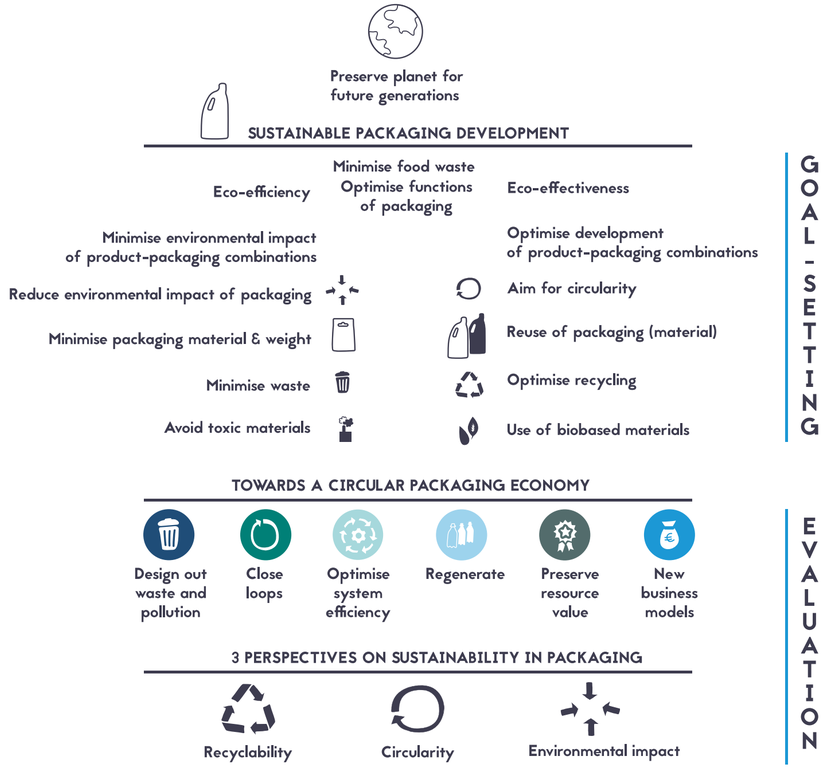


Figure 23 Goal setting and evaluation of sustainable packaging

USABILITY REQUIREMENTS

The tool needs to:

The tool needs to:

- Be suited for producers and importers to use (packaging engineers, procurement, marketeers, designers)
- Encourage to think about sustainability strategy in packaging development
- Make aware of basic functioning of packaging; to not lose out of sight during use of tool
- Have optimal reuse of information throughout 3 modules
- Provide a guidance to make dilemmas in sustainable packaging design negotiable
- Enrich the knowledge of PI's on chain dynamics and on what goes wrong in current chain
- Enrich the knowledge of PI's on sustainability within packaging development (recyclability, circularity, environmental impact)
- Balance trade-offs of simplicity in use and accuracy in output
- Be transparent in shown indicators and data
- Provide information where needed on aspects as terminology, indicators (user testing will be used to find what is needed)
- Provide users with visual output that can be used in communication with other stakeholders

TECHNICAL REQUIREMENTS

The tool needs to:

- Be specifically focused on the Dutch market (where possible EU oriented)
- Be a web-based tool for self-assessment
- Have validated data as resource for system
- Communicate assumptions in indicators and/or missing data clearly
- Be developed for rigid plastic packaging at first
- Be futureproof to incorporate material streams of flexible plastic, paper and board, metal and glass packaging.
- Have pre-set input (average values of packaging weight as guideline (and to prevent input errors)
- Provide KIDV with clear insights in user input & results
- Be adaptable for innovation in packaging
- Be future proof
- Use the input from Recycle check (rigid plastic) as input/switchboard
- Be able to save case studies; to enhance comparative evaluation
- Incorporate relevant allocation (LCA), recycling energy, costs and emissions

TTrade-off in requirements

Notable is that there seems to be a trade-off in the tool between simplicity for the user (effort) and accuracy of the output (result), as shown in Figure 24. In the development process of the tool, it is therefore important to strike a fair balance between these potentially contradicting aspects, to find the sweet spot. User testing in the prototype phase and reflection upon these requirements during further development is required to ensure this alignment.

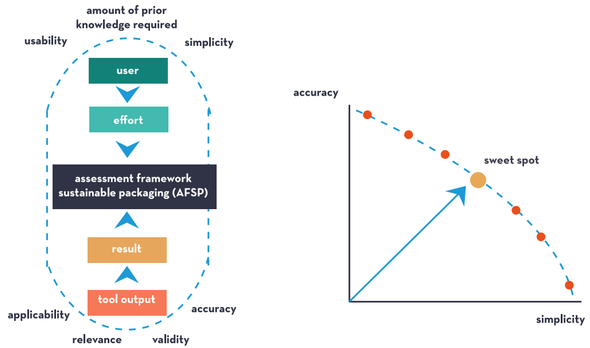
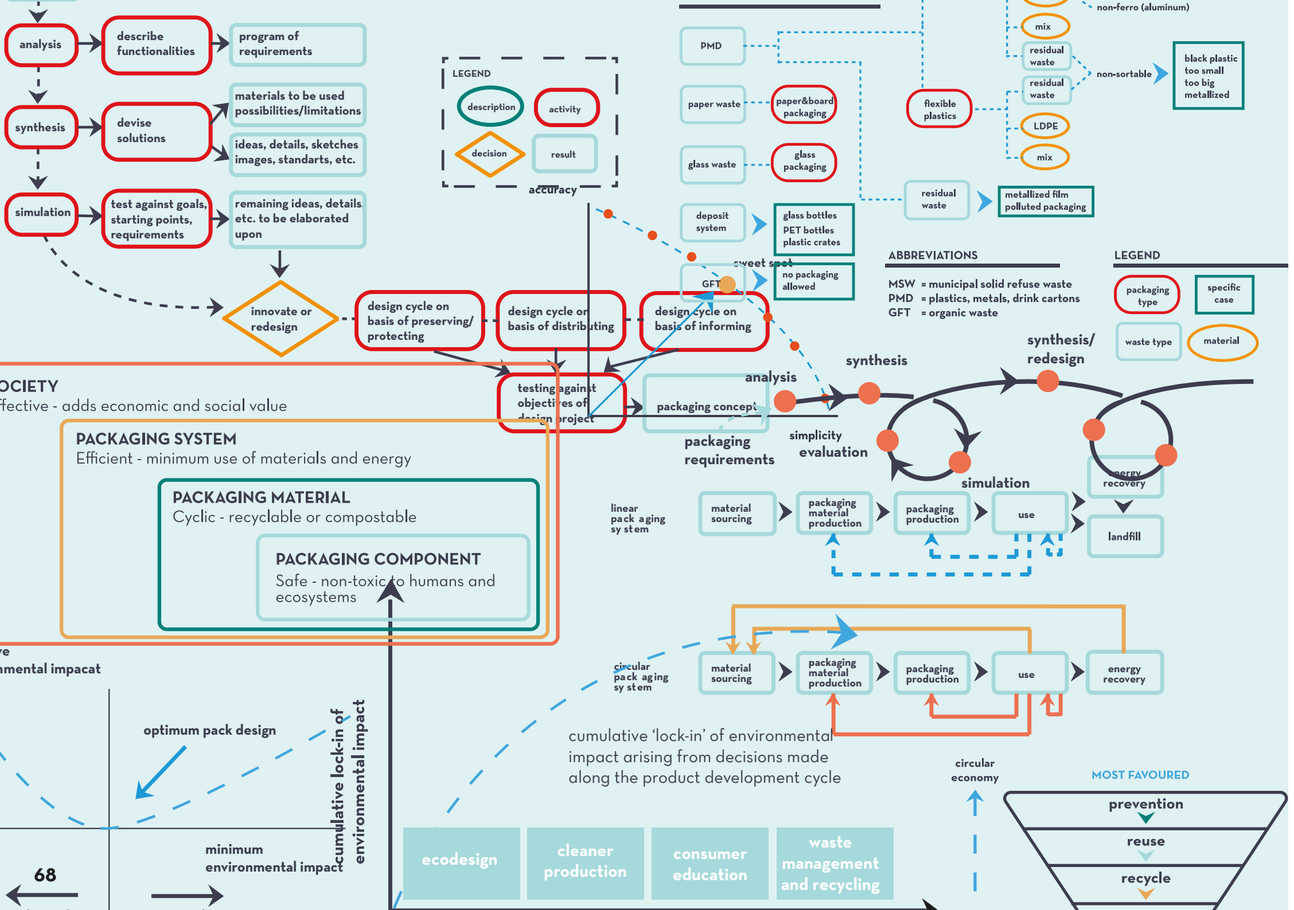


Figure 24 Requirements for tool divided into simplicity in use and accuracy in output

PART II: DEVELOPMENT OF THE TOOL

After defining what sustainable development implies for packaging, explored is how business enhances this and what barriers are encountered. Existing tools, guidelines and indicators are contemplated to find what is missing in these tools to support producers and importers of packaging to enhance sustainability in packaging development. The motive of KIDV for the development of a new tool is formulated, from which a list of functional requirements was defined. In the second phase of this report, elaborated is on the development of a test version of the tool in order to come up with an implementation advice for KIDV to develop it.



9 APPROACH

To be able to give a substantiated implementation advice to the KIDV for the development of the tool, a first exploring version of the tool was made. The technical concept was tested to detect system boundaries, to validate whether third parties where fitted to deliver data and to see to which extend the tool could be build. For this, only minimal but necessary functionalities where incorporated.

First, the indicators are formulated, after which data is gathered to compute these indicators. The visual interface and structure of the tool as used in the prototype are debated, after which a user test is executed to see how the envisioned target group of the tool experiences the tool. From this, system boundaries and implementation aspects are compiled. Finally, implications for further research are discussed. This test phase was twofold, testing both the feasibility and usability of the tool. Therefore, the delivered product to the KIDV was something between a proof of concept (POC) and a prototype (Figure 25)

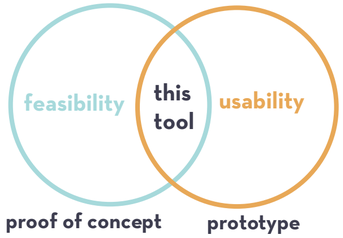


Figure 25 The AFSP: Prototype versus Proof of Concept

10 DEVELOPMENT OF INDICATORS FOR EVALUATION

'We need to assess both quantity and quality of resources'

To define how we can best evaluate sustainable performance, with specific attention to recyclability, circularity and environmental impact, we first need sharp definitions of what PI's should know about these three perspectives to support their decisions in development processes for sustainable product-packaging combinations. This is done for each of the three modules within the tool. As the focus is put on circularity module of the tool, this chapter elaborates on indicators to evaluate on the circularity of packaging.

10.1 Recyclability

With recycling referred is to the process of collecting waste, sorting this and afterwards (mechanically) recycling the material into resources that can be used again in new production processes. It is important to note here that a lot of packaging (materials) can be recycled, only their design is not always optimal for recycling. For plastics for example, colours, labels or glues can disturb recycling, but this does not immediately mean that the material is not recycled. Therefore, in the Recycle Check, the KIDV makes a distinction between optimal and sub-optimal recycling. The Recycle Check can be found in Appendix C.

10.2 Circularity

There is a need to define CE indicators that are relevant for PI's of packaging. According to literature, there is a need for robust, transparent, easy to compute indicators, with a high reproducibility and a low risk of differences in outcomes due to interpretability. Also found is that it is recommended to use a selection of indicators next to each other, instead of trying to fit all elements within one integral indicator. The indicators need a balance between accuracy and simplicity. In order to define CE, the definition of CE is used:

CE includes new business models, where the take-make-waste system is replaced with reducing, reusing, recycling and recovering materials. With this, creating environmental quality, economic prosperity and social equity to the benefit of current and future generations. This described system is restorative and regenerative by design and aims to keep products, components and materials in use at their highest utility and value at all times (Kirchherr et al., 2017; MacArthur, 2015).

From this, decided is that for PI's, it is most relevant to look at the micro-level of CE, which implies the circularity of resources within a company. Where environmental quality will be assessed in the environmental impact module, focus of the circularity check is on the preservation of quantity and quality of materials within the linear system. This to track the performance of packaging combinations in current reuse and recycling systems. This adapts to the request of KIDV to develop an 'as is' assessment, looking bottom-up at the linear system, to see how efficient current systems are to find optimisation aspects that PI's can immediately adapt to. It is key to be aware of the implications to this approach, because it means actual transition to a circular economy cannot be assessed.

In order to see how regenerative packaging is, an indicator is required that expresses this: a regenerate indicator. This indicator should express how much of a packaging returns into the system after a cycle in the product-packaging combination life cycle. To define this, we need information of how much of a specific unit is put on the market, in order to see how much is lost when it comes back in waste collection. After waste collection, waste is sorted and recycled, here it is important to know how much loss appears hear. What is the amount of packaging material lost in sorting and recycling? From the throughput material that is maintained after the sorting and recycling, we want to know what the quality is, in order words: the resource value. As stated by Eriksen and others: 'To correctly assess the ability to close plastic loops via recycling, both plastic quantities and qualities need to be evaluated' (Eriksen, Damgaard, Boldrin, & Astrup, 2019).

To sum up, we need to assess both quality and quantity of the resources that are maintained in the system, and we need to express how much resources are lost in system processes. This is in contrast with current indicators as the recycling yield, which only looks at the quantity of material that is sorted in sorting systems.

Whereas the indicators as described above provide an indication of a resource that flows through one cycle of production, distribution, use, dispose, collection, sorting and recycling, some resources might be able to do much more than one cycle. Therefore, proposed is to provide users with a theoretical number of the amount of cycles that a (packaging) material can make. Whereas some materials can almost infinitely be recycled, as glass and metals, paper only has about 7 cycles before the paper fibres become too short to produce a decent paper material. Moreover, plastic can have multiple cycles, only after one cycle it might be that the material cannot be used in the same application anymore. Therefore, the number of cycles shows whether this is in the own chain, or in a different chain. The number of cycles indicator is merely based on knowledge that is available at the KIDV and is therefore a somewhat substantiated assumption, more than a truly validated indicator.

The number of cycles integrates the difference between closed-loop recycling (remade into the same product) and open-loop recycling (made into another product). Figure 26 shows the recycling scenario's, where also quality is expressed, as proposed by Huysman and colleagues (Huysman, De Schaepmeester, Ragaert, Dewulf, & De Meester, 2017). In this figure, post-consumer packaging material is referred to as 'plastic waste'.

This does not immediately mean that this material is lost, it solely means that it is collected in waste-collection.

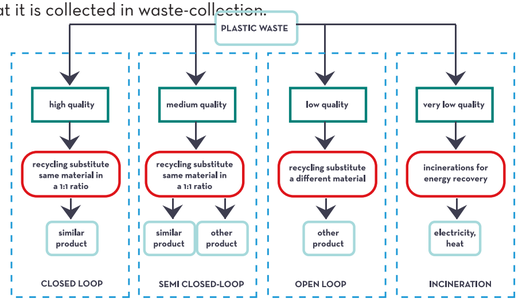


Figure 26 Plastic waste scenarios, redrawn after (Huysman et al., 2015)

These waste stream scenarios influence the quality of plastic, which depends on a wide range of properties such as physical and chemical composition, mechanical strength, colour, odour, additive concentration and content of toxic chemicals. As such, a single and unique parameter cannot be applied to represent the quality for all possible application types (Eriksen et al., 2019). Moreover, resource value is not a linear number if we look at the technical quality of recycled materials. For example, the quality of rPET is influenced by glue residues, caps and labels. After one cycle, the amount of small polluting particles increases. For a mixed content of virgin PET and rPET, this is a stable value, for 100% rPET, this amount is growing. This influences production efficiency, for 100% rPET the risk of production errors gets bigger, because of a less stable plastic (Thoden van Velzen,

10 DEVELOPMENT OF INDICATORS FOR EVALUATION

Brouwer, & Molenveld, 2016).
This makes the translation of the resource value into a single indicator difficult. Looking at the technical quality and application methods, it is not a linear number but a changing matter over multiple cycles. Multiple approaches can be taken. Brouwer and Thoden van Velzen proposed the assessment of polymer purity as resource value indicator for plastic material (Brouwer et al., 2018). Three issues arise here. The first issue is that the polymer purity of for example Polypropylene (PP) might be high, after one cycle of being suited for food packaging, the applicability immediately decreases to non-food and often thick-walled application. The second issue is that this indicator can only be computed after very specific research of samples and large differences in quality might occur in different sorting facilities because of extra separating steps in the process. As a third issue, this indicator would only be applicable for plastic packaging, which would mean a different indicator would be needed to compute the resource value of other packaging materials. As proposed by Dia Maio and Rem, quality of resources can also be expressed in market prices of resources (Maio & Rem, 2015). This value could be compared to the market prices of virgin resources, using an open available information source as 'Vraag & Aanbod' (Vraag & Aanbod, 2019). The resource value could then be calculated by defining the ratio of material value produced by recycler (market value) divided by the intrinsic material value.

In a circular system, assumed and required is that resource values stay stable throughout multiple life cycles. This makes it relevant for the circularity assessment to monitor if quality is stable or whether it declines. Therefore, it is recommended to assess the value of a resource after one cycle. If the quality of a resource declines after a cycle, it cannot be regarded as fully circular. In the current plastic industry this is always the case, as recycled content is nearly always regarded as less valuable than virgin content, caused by lower polymer purity and resulting in less application options.

By regarding the economic value of a resource, automatically the purity and application options are assessed. Moreover, the economic value adapts quickly to question and demands, making it an easy to compute indicator and easy adaptable to changes in the market.

To summarize, the circularity module within the tool needs a regenerate indicator (1), which measures how much material comes back in waste collection after one life cycle, a loss indicator (2) which shows how much of this material is lost in sorting and recycling, a resource value (3) indicator which indicates what is the quality of this material and a theoretical number of cycles (4) which provides a theoretical estimation of how much cycles the package can make before turning to actual waste/incineration.

In formula:

$$(1)\ \text{Regenerate indicator} = \frac{\text{collect indicator}}{\text{input indicator}} \times 100\%$$

$$(2)\ \text{Loss indicator} = \frac{(\text{collect indicator} - \text{recycle indicator})}{\text{collect indicator}} \times 100\%$$

$$(3)\ \text{Resource value} = \frac{\text{material value produced by recycler}}{\text{intrinsic material value}} \times 100\%$$

$$(4)\ \text{Number of cycles} = \text{theoretical number}^*$$

***To compute this number for each of the materials, KIDV knowledge and communication of sorters and recyclers needs to be collected. Further research might be able to validate this theoretical numbers.**

Image source: www.ecobirdy.com

A critical side note
Preserving quality in plastic recycling seems to be crucial for closing loops for the plastic industry and there are ways to indicate whether a plastic packaging can be recycled with a high, medium or low quality. However, high quality in plastic as a resource is not as black-and white as it seems. As an example, the 'Eco-bird chair', fully made of recycled plastics. This is a product with a proposed long life, almost indestructible and suited for reuse. According to the assessment method as described above, this would be a very low value application of resources, almost at the level of the well-known and favourite example of the roadside post. But critically regarded, is this designer chair a lower value application than a plastic cucumber sleeve or a shampoo bottle? And should we say this is far from circular because the plastic is used in a different way than it was in its original shape, meaning it is open loop recycled? This question reaches further than the scope of this thesis, but it is a perspective to keep in mind.

10 DEVELOPMENT OF INDICATORS FOR EVALUATION

10.3 Environmental impact

The environmental impact module provides the tool with an LCA aspect to assess the eco-efficiency of packaging, next to the more eco-effective assessment of resource regeneration and quality. In this module PI's can compare results, to make the difficult decisions of high recyclability versus low environmental impact. The LCA module will be developed by an external party as selected by KIDV, still some crucial elements are discussed for the development of this module.

For complete LCA studies, it is recommended to follow the ISO 14044:2006. This specifies requirements and provides guidelines for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA and its limitations (International Organisation for Standardization (ISO), 2006). For the KIDV tool, a simplified LCA methodology will be followed, which means that not all requirements from this ISO standard can be met. It is important to communicate this to the users of the tool.

For an LCA tool, factors like use of (scarce) resources and energy, emissions to air, water and soil (in CO2 equivalents), preferably divided into the separate steps in a life cycle: resource, production, distribution, end-of-life are relevant. A simplistic display of the calculation system of an LCA is given in Figure 27.

Moreover, for the users of the tool it is key that assumptions and settings are clearly communicated, so it is evident how the tool comes to the given results. For example, in LCA, three approaches can be taken for allocation.

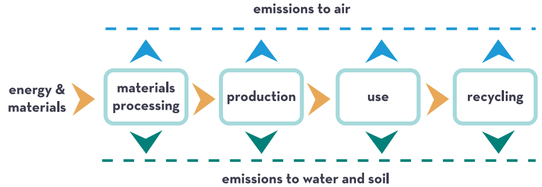


Figure 27 Basic calculation system of LCA, redrawn after (Wever & Vogtlander, 2013)

This has influence on the results, because recycling benefits can be either allocated to one or more steps in a chain.
Allocation option 1 is: Recycled content 100/0, where no credits are given for the use of recycled content). Approach 2: Avoided Burden 0/100 Approach, where all credits are provided to the user of recycled content and no credits are given for being optimal recyclable. Option 3: Shared Burden or 50/50 Approach, where both ends of the life cycle get even credits (Vendries et al., 2018). These allocation assumptions should be stated in the tool, so users know where certain values are based on. Moreover, assumptions on the level of supply chain configurations beyond the packaging itself, such as the length of the supply chain, mode of transport, reverse logistics and energy mix should be communicated. The assumptions mentioned here are by no means exhaustive, but as the environmental impact module will be developed by an external party, a full list would be out of scope of this research.

It would be valuable if the environmental impact module could take product loss/food waste into account in its assessment, because this is something that would be forgotten if packaging would be assessed as a stand-alone object but is crucial in the sustainability of product-packaging combinations. For this, required are product compositions, as the ingredients can then be integrated in the inventory (Ligthart et al., 2018). Moreover, fair input of functional units to compare packaging alternatives is required. Two packaging alternatives can only fairly be compared if they both fulfil the same functional unit.
In this chapter is discussed how each of the three modules within the tools should evaluate packaging on sustainability. The recyclability is assessed by using the Recycle check as developed by the KIDV. For the circularity module, four formulas are defined, which can together give an indication of the circularity of a packaging within the current recycling system, by evaluating on the quantity and quality of regenerated resources. As defined in the requirement and aim of the tool, this is important to show PI's how efficient their packaging combinations are in the current systems, to find optimisation aspects that they can immediately adapt to. The environmental impact module will adapt to a simplified version of existing LCA methodology, using indicators as water use, energy use and emissions in CO2 equivalents. Communication to users of assumptions and used methodology is noted as crucial.

11 DATA COLLECTION

‘Connect scientific research and the producing industry’

The circularity of packaging within the current system can be evaluated by using the four indicators as defined in chapter 10. To compute these indicators, validated data of the Dutch system is required. The tool needs input from packaging input in chain, (waste) collection, sorting and recycling. It is important to be aware of which data source is used for this and what are the implications of each source. The interests that lay behind these measurements might influence the data immensely, which might result in a biased outcome. This chapter will discuss the measuring points needed for validated data, after which data sources are compared to see with of the sources is most suited to deliver data for the tool.

11.1 Measuring points

The moment of measuring in a life cycle of packaging is defining the data outcome. Figure 28 shows the envisioned points of measuring to collect the suited data for computing the indicators. It is recommended to use a measurement point on the moment where product-packaging combinations are put to market, after which a measurement should take place on the moment of collection. Subsequently, a measurement point should take place after the sorting of the collected material, followed by a measurement moment after the actual recycling of the sorting products. By combining these measurement points, the regenerate and loss indicators as proposed for the circularity module can be computed.

11.2 Data source comparison

During the data selection process in the research period, several companies that have obtained data of the Dutch packaging recycling system have been consulted. Table 4 shows the data sources that are compared on their advantages and disadvantages and the sort of data they can possibly provide.

Data source	Sort of data	Advantages	Disadvantages
CBS (based on research (Di Maio et al., 2017)	Netherlands system of national accounts Generic information amount of material put on the market and amount of material collected	Robust Open accessible Yearly update Consistent Independent monitoring	Very generic No specific data per type of material stream No specific sorting & recycling data Information from some municipalities is missing
Wageningen Food and Biobased Research (WFBR) (Brouwer et al., 2018)	Quality and quantity of collected post-consumer plastic waste, drinking cartons, metals	Very specific data Independent research	Data of 2014 and 2017 available, consistency in data input for future not secured No specific data for paper & board, glass
Afvalfonds (Afvalfonds Verpakkingen, 2017)	Material streams per municipality, measured on moment of collection in weight. Information from sorting facilities about composition of waste	Collaboration Afvalfonds and KIDV should be possible Yearly open publication: Monitoringsrapportage’	Incentives, focus on quantity, not on quality Only have data on main categories (plastic, not specific on sorts of plastic)
Municipalities	Measure mass of waste streams after collection	Obligated to provide transparent data, input for Wastetool Nedvang	Incentives for as low as possible collection rates of solid municipal waste (SMW) Do not look at quality of PMD, only quantity (VANG policy)
Nedvang	Wastetool (as filled in by municipalities)	Collaboration of Nedvang & KIDV should be possible	Not very specific data Not open accessible Only collection data

Table 4 Data comparison

11.3 The data provider

For the prototype, chosen is to use the data of the research of Wageningen Food and Biobased Research (WFBR), where the Dutch PPW recycling network has been elaborately assessed. Both packaging types and materials have been described, from household potential to polymeric composition of the recycled milled goods. Material flow analysis, data reconciliation and process technological parameters have been used to analyse the composition of 173 samples of PPW (Brouwer et al., 2018).

Figure 28 Measuring points in a packaging life cycle

11 DATA COLLECTION

The research of WFBR provides transparent data of the collection, sorting and recycling of plastic packaging waste, regarding both the weight of the material flow as the output quality. This in contrast to for example the data from the Afvalfonds Verpakkingen, provided in their yearly monitoring rapportage of packaging waste (Afvalfonds Verpakkingen, 2017), where only collection and sorting data is communicated and only material quantities are regarded.

Although WFBR has executed very relevant research for industry, direct application of this knowledge is not available for PI's to use in their decision making and packaging design optimisation. Therefore, it is very valuable to use this data and translate it in a practical, interactive and visual way so that industry can use these findings. This also adapts to the aim of KIDV to connect scientific research and the producing industry.

Subsequently, it is important to consider what are the implications of chosen data source for the development of the tool and the future of the tool. The most recent data is from 2017, which is suited to develop the tool now, because no drastic changes have been made to collection, sorting and/or recycling systems. However, research and thereby data updates are required in the future to keep the tool up to date. One example that will be very relevant in the nearby future is the recycling plant of 4PET where the aim is to recycle PET trays. In the data of 2017, PET trays could not be recycled, but were already collected separately. This implies that the regenerate indicator shows a fair number, only afterwards the loss indicator shows 100% loss, because none of the trays is recycled. When the 4PET tray recycling will be up and running, changes in the tool datasheet need to be made.

Moreover, for the development of the other material streams in the tool (as paper and board, glass, metals, rigid plastics) it is important to be aware that the research of WFBR does not have all this information, only generic data. Whereas the research does have specific information on flexible plastic packaging, metals and drinking cartons, because they are also collected in the PMD, for the other materials, either more generic Afvalfonds data should be used, or further research is required to provide the tool with specific data. Appendix E shows the full list of packaging materials that are monitored by WFBR and could be used in the tool.

11.4 Dummy data

For the development of the prototype, a selection of dummy data was put together in collaboration with Marieke Brouwer, using her database to see to which extend the model is suited for using in the KIDV tool. As an example, a calculation for the regenerate and loss indicator is executed using the dummy data, for both transparent and coloured PET bottles. For now, bottles smaller than 0,5 litres and bottles bigger than 0,5 litres are assessed as a cumulative, but with the data of WFBR, this could also be shown separately. Table 5 shows the data used in these calculations.

Regenerate = (collect indicator / input indicator) x 100%
For PET bottles transparent this implies: (9575 / 14856) x 100% = 64 %
For PET bottles coloured this implies: (1868 / 3063) x 100% = 61%

Loss = ((collect indicator – recycle indicator) / collect indicator) x 100%
For PET bottles transparent this implies: ((9575-6885) / 9575) x 100% = 28%
For PET bottles coloured this implies: ((1868-1208) / 1868) x 100% = 35%

Material PET (rigid)	Input chain (consumer packaging)	Collection (post-consumer waste)	Sorting product (PET bottle)	Recycle product Sink fraction
PET bottle transparent < or equal to 0.5 l	10291	Source separation 5344 MSW* separation 948 MSW not separated 3999	Source 4040 MSW 663	Source 3604 MSW 591
PET bottle Transparent >0.5 l	4566	Source separation 2979 MSW separation 304 MSW not separated 1283	Source 2707 MSW 202	Source 2503 MSW 187
Cumulative PET bottle transparent	14856	9575 (source + MSW)	7612	6885
PET bottle coloured < equal to 0.5 l	2467	Source separation 1362 MSW separation 212 MSW not separated 893	Source 905 MSW 116	Source 827 MSW 106
PET bottle coloured >0.5 l	596	Source separation 223 MSW separation 71 MSW not separated 302	Source 161 MSW 26	Source 150 MSW 24
Cumulative PET bottle coloured	3063	1868 (source + MSW)	1208	1107

Table 5 Data on PET bottles (2017), units in ton

***MSW = Municipal solid waste**

To conclude this chapter, data of the Dutch waste systems from a research by Wageningen Food and Biobased Research will be used for the circularity indicators of the tool. This is decided because this data was most elaborate and reliable. Using this data for the tool can be regarded as very valuable because it gives the opportunity to translate extensive research findings into practical, accessible information for the packaging industry. Connecting scientific research and the producing industry aligns well with the aims of the KIDV.

12 FROM FINDINGS TO FRAMEWORK

'From fuzzy elements to simple representation'

A theoretic framework was defined in which the sustainability goal setting and evaluation of packaging on three perspectives of sustainability are combined to support PI's in their packaging development process, in order to improve the sustainability of product-packaging combinations. For the circularity module, four indicators are proposed and data from the Dutch waste system is collected to compute them. The next step in the development is the translation of theory and data into an accessible and applicable design for the tool. The visual appearance of the tool should be simple and clear for PI's to easily use and interpret the tool. This chapter shows how all elements come together in the construction of the tool and it shows the rationale behind the visual interface of the tool.

12.1 Combining the elements

To recapitulate the previous chapters and show how this comes together in the construction of the tool, a summative overview is provided in Figure 29. The elements of the overarching framework for sustainable packaging development as created in chapter 3 is used to select the goal-setting options for the tool. The recyclability module is filled in by the Recycle check of the KIDV, which will be converted into an online interactive tool for the test phase. The circularity module will be based on the four indicators of circularity as proposed in chapter 10, computed by the data which was gathered in chapter 11. The environmental impact tool will be outsourced to an external party. For the test phase of the tool, an existing simplified LCA is used, based on (RDC Environment & Fost Plus) to demonstrate its basic functioning.

Figure 29 Construction elements of the tool

12.2 Visual language

A visual language is created for the tool, to make the translation of complex and fuzzy elements into a simple and accessible representation. The aim is here that the tool looks appealing to PI's to use it, and that it still looks trustworthy and robust, adapting to other communication and tools of the KIDV. Figure 30 on the next page shows the visual elements.

The colour scheme that is used adapts to the colours of the KIDV identity, to make the design look as familiar as possible. The three perspectives on sustainability are all given an own identity, by providing them with a logo and a colour scheme. For the non-verbal aspect of the logo arrows are used, that provide the user with visual information on what each module is doing. For the recyclability, the arrows represent the typical recycling icon, making a triangular shape. For the circularity module the arrow makes a round shape, representing of course the circular flow of things. For the environmental impact module, the arrows are all facing towards each other, creating an impact zone. The name of the modules is placed in the centre of these arrow shapes.

The arrows are also used to show the overarching aim of the modules: evaluating packaging combinations. This is communicated by putting the arrows around the different packaging material groups. The silhouettes of the packaging groups that are used, are part of the KIDV identity and are also part of the KIDV logo. For communication purposes of the indicators that are used in the tool, several icons were designed.

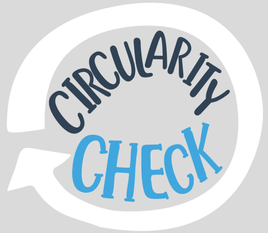
12.3 The circularity machine

As was stated before, the KIDV tool uses very relevant data from research by WFBR, which is not directly applicable for industry when it is remains in immense data sheets filled with numbers and abbreviations. To make it accessible for PI's, this data must be translated in a practical, interactive and visual way so that industry can use it as valuable information to enrich their knowledge. As a result, the recycling data from WFBR is translated into the circularity machine (Figure 30). The circularity machine is an interactive visual representation of the four indicators. The coloured circles around the indicator icons represent calculated percentages, which interactively show the user how high or low a certain packaging combination is scoring by rotating and moving during calculation.

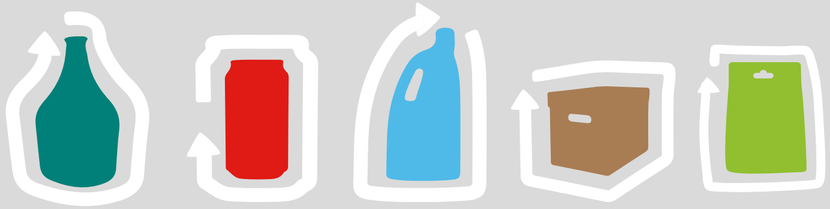
12.4 Development approach

For the development of the prototype, Adobe InDesign was used to make a first interactive version of the tool. Although this version was suited for navigating through the pages, it did not provide potential users with a true grasp of the interactive web-based tool that was envisioned. Therefore, the KIDV provided the opportunity to work with a web-development expert to build a first draft of the web-based tool. In collaboration with Floriaan Post (Mechanical Engineer), the static structure and graphic elements were transformed into a working prototype, suited to be used in a usability testing phase.

In this chapter the translation of the theoretical framework, indicators and data into a visual appearance is made. This step is crucial, because it translates complex and fuzzy elements into a simple and accessible representation. The tool should look appealing to PI's to use it, and still look trustworthy and robust, adapting to other communication and tools of the KIDV. For the prototype of the tool, a visual identity is designed, which is in line with the brand identity of the KIDV. These elements were used to design a structural interface for the prototype, which is transformed into a web-based tool in collaboration with a web-developer.



Logo of the three modules



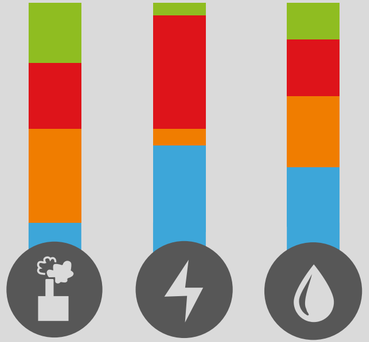
Arrow applied to packaging silhouettes

Figure 30 Visual elements for the tool

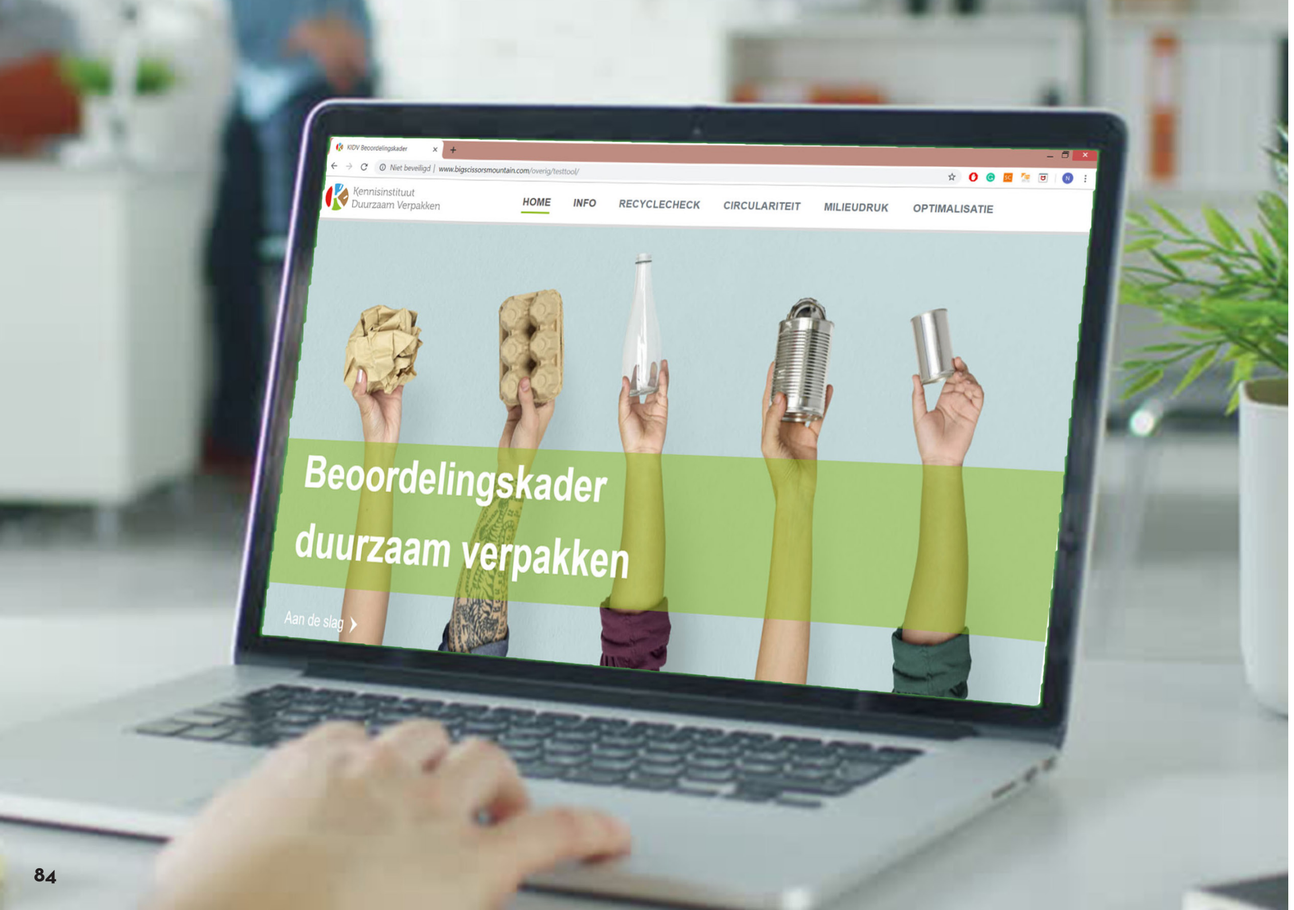
The circularity machine

Recycle Check icon

The KIDV logo, used as design inspiration



Environmental impact icon



13 STRUCTURE OF THE TOOL

After the definition and computing of indicators with available data, a visual interface was developed. As the functional requirements state, the information and data output of the tool needs to be visualised in such a way that it is easily to read for users, with a balance between simplicity and accuracy. Moreover, the interface should be built up in such a way that elements can be used as communication tools within multidisciplinary teams in their decision making towards more sustainable packaging. This chapter discusses the structure of the tool and specific interface elements that are used in the test phase of the tool. Figure 31 shows the structure of the tool.

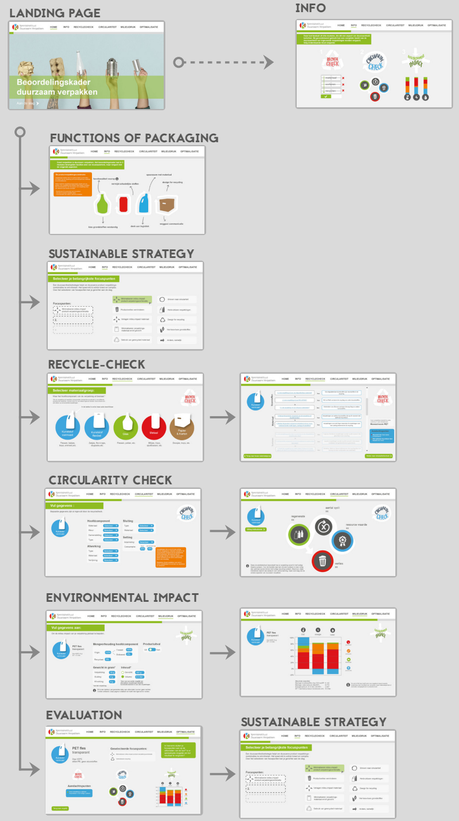


Figure 31 Structure of the tool

Figure 32 Landing page

The landing page of the tool (Evaluation Framework Sustainable Packaging, in Dutch Beoordelingskader Duurzaam Verpakken) shows the different modules within the tool on the top, only the user cannot access these pages yet. This way, the user will have to follow the envisioned order in using the tool. A grey navigation balk will track progress and will be filled with a green colour when more modules are filled in (Figure 32).

Goed verpakken is duurzaam verpakken. Het beoordelingskader laat in 3 modules belangrijke facetten zien van duurzaamheid, maar vergeet niet de volgende aspecten:

De productverpakkingscombinatie

Verpakkingen hebben direct en indirect impact op het milieu. De impact van de verpakking zelf wordt bepaald door materiaal- en productiekeuzes.

Indirect biedt de verpakking toegevoegde waarde aan een product. Een verpakking kan hierdoor milieu-impact vermijden door het beschermen van het product. Een verpakking moet dus allereerst zijn functies vervullen:

- Beschermen & conserveren van het product
- Gebruik & transport mogelijk maken
- Communicatie over inhoud, gebruik & afvalfase

Figure 33 Functional requirements of packaging

The functional requirements of a packaging are key; therefore, the user is made aware of the key principles of packaging with the use of an informative slide. Used for this are the '7 tips for sustainable packaging' by the KIDV in a new graphic display (Figure 33).

**Deze tool bestaat uit drie modules, die elk een aspect van duurzaamheid belichten. Bij gecombineerd gebruik kan een completer beeld van de duurzaamheid van ingevoerde verpakkingen worden vergaard.
Volg onderstaande invul-volgorde:**

Figure 34 Information for user

Next, a user guide on how to use the three modules is placed. This explains that the user should start with defining the sustainable packaging strategy of the company, before starting with the recycle check, followed by the circularity check and ending with the environmental impact. Generic information that applies to all modules within the tool can be stated here, as the fact that the tool is an as-is assessment for consumer packaging that ends up in household separate waste (Figure 34). Moreover, a disclaimer should be placed here that the data calculated in this tool are indicative. The results cannot be used in external publications and the KIDV may not be held liable.

Kennisinstituut Duurzaam Verpakken
HOME INFO RECYCLECHECK CIRCULARITEIT MILIEUDRUK OPTIMALISATIE

Selecteer je belangrijkste focuspunten

Een duurzaamheidsstrategie helpt om duurzame product-verpakkings-combinaties te ontwikkelen. Het speelveld is echter breed en complex. Door het selecteren van focuspunten kan je gerichter aan de slag.

Figure 35 Focus point selection

The next page requests the user to select (a maximum of) three focus points. This page is crucial, as it lets users think about a sustainable strategy for packaging. Either the company already has a clear strategy, or the company still has to make one. Either way, the user sets its own framework for assessment with the selection of focus points. When for example the minimising of environmental impact of product-packaging combinations is selected as focus, the user will regard the outcome of the tool in a much different way than when optimize recycling is selected. For the first example, the user will find the results of a laminated pouch rather interesting, because the environmental impact will be relatively low. In the second example, the user might more easily choose for a glass bottle or a metal can, because they score high on recyclability (Figure 35).

Figure 36 Input Recycle-check

After the educational and informational pages, the user can start a new assessment project by the selection of a main material group. In this first version only rigid plastic packaging is available to be chosen (Figure 36).

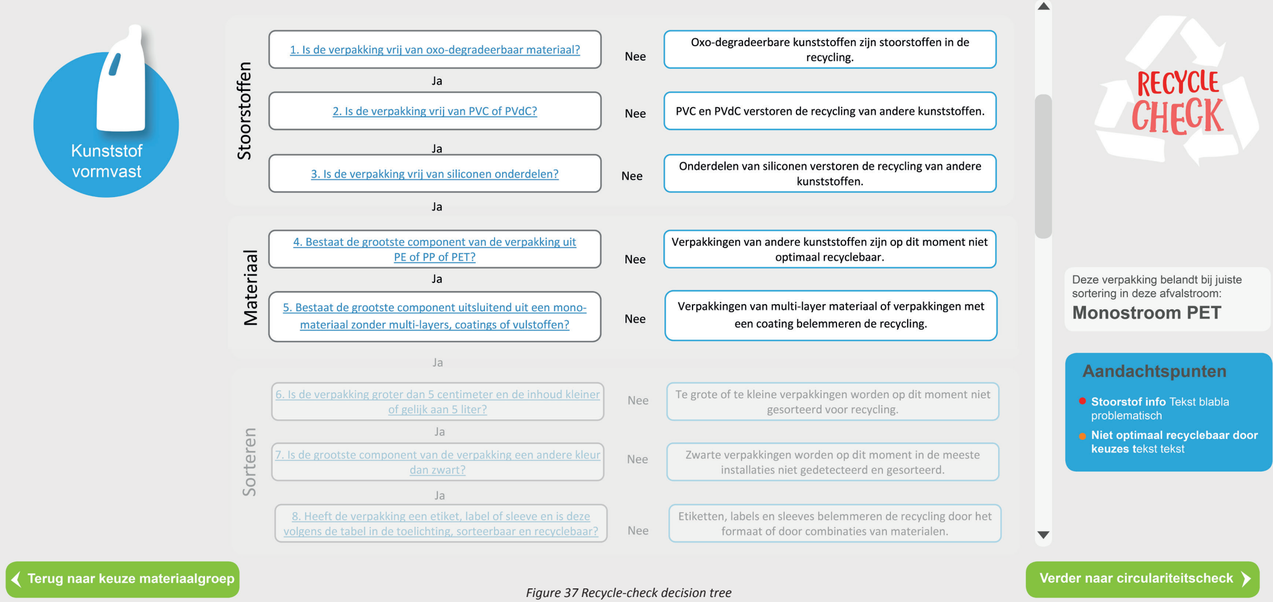


Figure 37 Recycle-check decision tree

The recycle check page shows the recycle check as developed by KIDV, only here it is a more interactive decision tree. The idea is that the user fills in yes or no on each question, hereby defining whether the packaging combination they fill in is optimal recyclable or not. When a no is answered, a 'point of attention' will appear on the right, indicating that the user should perhaps change something about the packaging combinations to optimize recycling. This module works as a switchboard, remembering what the user fills in, so the system can decide in which waste stream the packaging will end up. This is used as input for the next tool, the circularity check. For the prototype, this interactive smart system is not tested, as it is out of scope for this testing phase (Figure 37).

Vul gegevens :

Bepaalde gegevens zijn al ingevuld door de recyclecheck.

Hoofdcomponent

Materiaal: Selecteer
Kleur: Selecteer
Samenstelling: Selecteer
Type: Selecteer

Afwerking

Type: Selecteer
Materiaal: Selecteer
Verlijming: Selecteer

Sluiting

Type: Selecteer
Materiaal: Selecteer

Setting

Inzameling: Selecteer
Consumptie: thuis 60% | out-of-home 40%

Verpakkingen die in out-of-home setting worden weggegooid, belanden meestal in het ongescheiden restafval dat als bedrijfsafval wordt behandeld. Dit betekent dat het percentage dat hier is ingevuld vrijwel zeker wordt verbrand en dus niet in aanmerking komt voor recycling.

Raadpleeg design guidelines voor out-of-home verpakkingen om de kans op zwerfafval te verkleinen.

Figure 38 Input Circularity Check

The circularity check needs a separate input page before showing the actual tool. In the input page, the user fills in more specific information about the packaging, as material of labels, caps, etcetera. Moreover, whether there is a specific deposit system in place to collect the packaging or if a packaging can be reused. All these inputs are matters that influence the circularity of a packaging within the current linear system. Here a note for the user should be placed that the circularity check assesses the efficiency of the linear system, and thereby does not provide indicators for a circular economy. This is very important for the user to be aware of, because it will influence the way the results are interpret (Figure 38).

Kennisinstituut Duurzaam Verpakken
HOME INFO RECYCLECHECK CIRCULARITEIT MILIEUDRUK OPTIMALISATIE

Uitleg indicatoren

Deze circulariteitscheck beoordeelt hoe je verpakking scoort in het huidige lineaire systeem. Voor de transitie naar een circulair systeem is meer nodig dan optimaal scoren binnen het huidige recycling systeem. Beschouw deze indicatoren daarom als startpunt voor verduurzaming, maar overweeg ook de andere aspecten van duurzaam verpakken.

Figure 39 Circularity check

The circularity check itself is an interactive machine, with the four indicators: regenerate indicator (showing the recycling yield), the loss indicator (showing the waste in sorting and recycling), the resource value (showing the quality of the throughput material) and the number of cycles (showing the theoretical number of cycles that the material can have as a resource. It is crucial that the meaning and computing of these indicators is explained here. The option of system tweaking might be nice here for the user to see what changes in their packaging would do to the overall score. Only small modifications should be possible, like changing the colour of the material or changing the main mono-material. This system tweaking will not affect the main case which is already filled in Figure 39).

Vul gegevens aan:

Om de milieu-impact van je verpakking globaal te bepalen.

PET fles
transparant

Dop HDPE (4 g)
EP = 0.5 liter

Mengverhouding hoofdcomponent

Virgin: 100%
Fossiel: 100%
Biobased: 0%
Recyclaat: 0%

Productuitval

Uit Aan

Gewicht in gram*

Verpakking: 30 g
Sluiting: 4 g
Afwerking: 0 g

*van één verpakking

Inhoud*

Gewicht: 500 g
Volume: 0.5 liter

*Voer voor een eerlijk vergelijk van alternatieve verpakkingen dezelfde functionele eenheid in voor alle verpakkingen

Dit is een testtool met generieke data, aan uitkomsten kunnen geen rechten worden ontleend. Deze pagina is statisch en hoeft niet ingevuld te worden.

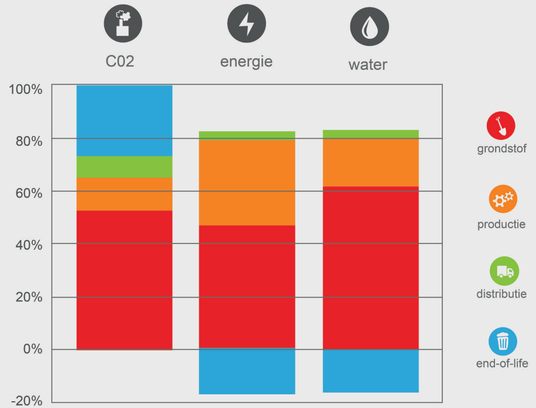
Figure 40 Input environmental impact

For the input page of the environment impact module (Figure 40), it is important to incorporate some pre-sets in the dashboard of the tool, to prevent input errors, to make it easier to compare an alternative where no specific data is available and to benchmark good practices in industry. For example, a wine bottle that weights 800 grams is far above average in material use, by using benchmarking this comes to light. This idea adapts to the research of Ten Klooster and colleagues that proposes key figures in the packaging industry to support reasonable material reduction in sustainable packaging design (Klooster ten, Koeijer de, & Lange de, 2018; Verschoor, Klooster ten, Korhonen, & Ylipoti, 2018).

Kennisinstituut Duurzaam Verpakken
HOME INFO RECYCLECHECK CIRCULARITEIT MILIEUDRUK OPTIMALISATIE

PET fles
transparant

Dop HDPE (4 g)
EP = 0.5 liter



Absolute waarden

Bijdrage broeikaseffect (kg C02-eq/EP	0.142
Bijdrage waterverbruik (liter/EP)	0.772
Energieverbruik (H & NH) (MJ/EP)	2.907
EP = eenheid product (functional unit)	0.5 liter

De end-of-life fase heeft soms een negatieve impact-waarde, omdat deze dan het effect van vermeden virgin materiaalgebruik of vermeden energiegebruik in productie toont.

Figure 41 Environmental impact

The environmental impact works similar like existing LCA tools. A distinction between different steps in a life cycle should be shown as the sourcing of raw materials, production, distribution and end-of-life (Figure 41).

PET fles
transparant

Dop HDPE
etiket PE, geen stoorstoffen

Geselecteerde focuspunten:

- Minimaliseren milieu-impact product-verpakkingscombinatie
- Optimaliseren recycling

In hoeverre sluiten je focuspunten aan op de uitkomsten van de tool? Is er optimalisatie mogelijk om het resultaat te vergroten?

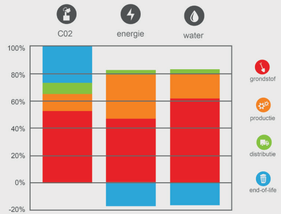
RECYCLE CHECK

Aandachtspunten

- Deze verpakking is optimaal recyclebaar in het huidige systeem

CIRCULARITY CHECK

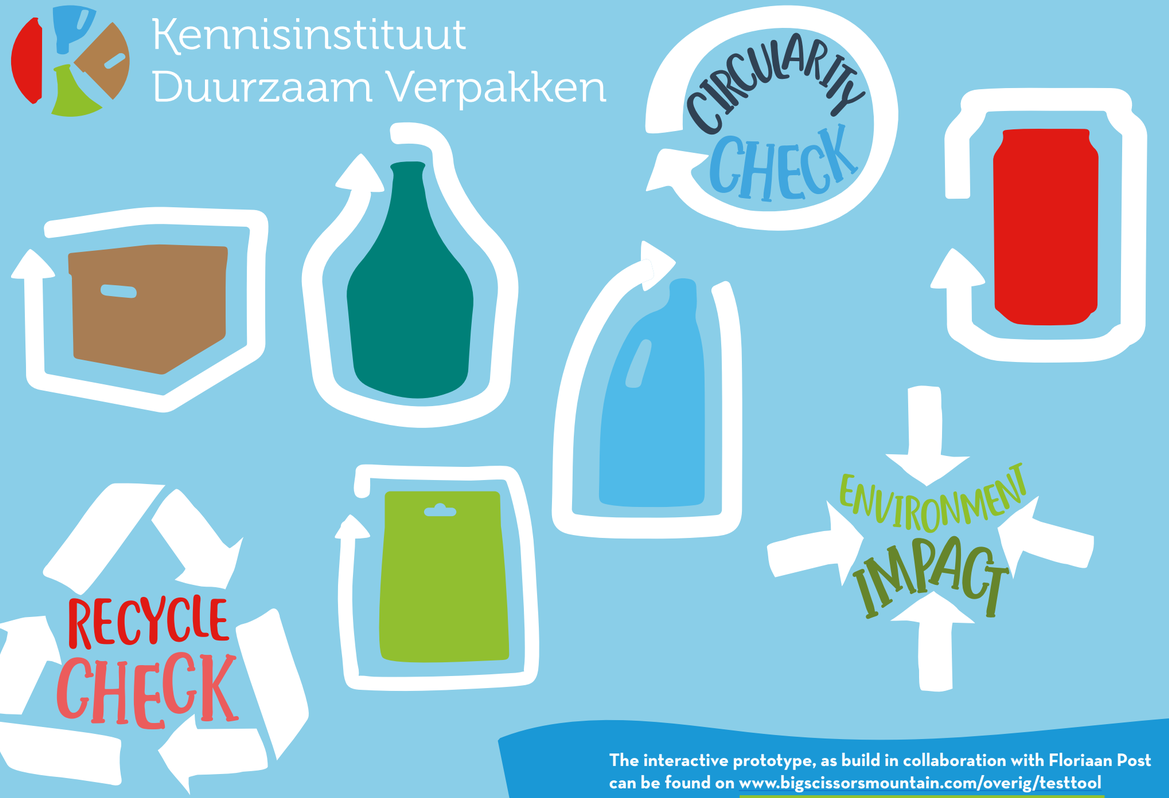
ENVIRONMENT IMPACT



Terug naar vergelijk

Figure 42 Evaluation page

After walking through the tool, an overview of outcomes of the tool is presented, which could be helpful in communication of different stakeholders within a company or in communication with external parties as suppliers. Moreover, this overview could help in decision making, because it can be supportive for packaging engineers to talk with other functions within the development team as marketeers and buyers. By showing elements that are important for sustainability of packaging within the linear system in a visual way, it will be easier to communicate the issues and possible solutions (Figure 42).



The interactive prototype, as build in collaboration with Floriaan Post can be found on www.bigscissorsmountain.com/overig/testtool

14 SYSTEM BOUNDARIES

'The tool is mainly an as is assessment'

To evaluate on the development process of the prototype, system boundaries that are encountered during the development process are discussed. The tool cannot give the ultimate answer on sustainable packaging, there are some system boundaries. Moreover, not every aspect could be fully validated. Some assumptions are necessary to make the tool feasible.

14.1 Dutch linear system

The focus of the tool is the Dutch system, where only consumer packaging and waste is considered. Other countries in the EU have similar waste sorting and recycling systems, so in the future these countries might be added to the tool.

For this moment, the tool assesses the circularity of the linear system with a strong focus on reuse and recycling. It could be stated that the tool is some sort of pre-dashboard of an LCA assessment. Hence, the circularity check determines how much material comes back after one cycle and determines in which quality this material comes back and how many times it can be used. These indicators can be used to make the LCA more exact.

The tool is mainly an 'as is' assessment, which means that it looks at how good the current system works. Future scenarios, which can be referred to as 'what if' scenarios are not implemented in the current settings. It could be very valuable to add scenario's like the use of chemical recycling on large scale into the assessment framework. Moreover, energy transitions could have a large influence on the output of the tool, so incorporating this for future scenarios could be relevant. It could also be interesting to see how good packaging is scoring with policies as a reference (for example: 50% of all packaging should be recycled).

14.2 Data

The data that is used as input for the circularity check and environmental impact, is validated data from a research by Wageningen Food & Bio based Research (WFBR). From this research, an extensive data list of rigid and flexible packaging is available. Moreover, data of drinking cartons and metal packaging is available. Appendix E shows the full list of available data.

A system boundary for now is that for the other material streams, only generic data is available. Within this research, there are also some assumptions that have influence of the output data. WFBR uses generic sorting and recycling systems. Optimisation of these systems or innovation towards new systems have a large influence on the output. The current tool does not take this into account. When for example an extra flake separating step is incorporated in the process, the quality of the output will be much higher.

Moreover, aspects like the sink/float ratio are not completely integral. There are always some losses of material that end up in the sink/float product of another material, which will be recycled into something, but not into the original material stream. These nuances are not considered for calculating the indicators.

14.3 Indicators & assessment

When looking back at the system diagram of a CE, the AFSP mainly assesses the efficiency of the technical cycle. The biological cycle is not considered, apart from resources that are extracted from the biological cycle and end up in the technical cycle, like biobased materials that are recyclable in the technical systems and food leftovers that end up in the technical cycle. This mainly influences the output of the environmental impact check.

The indicator 'number of cycles' is not a fully validated number; in most instances this is an assumption based on the system knowledge of the KIDV. Therefore, this is a theoretical number, a rule of thumb.

Despite the fact that it would be very valuable to make a summative visual output of the three tools into one visual (as depicted in Figure 43), this is rather complex to achieve. The translation of a combination of indicators into one indicator is rather risky, because a lot of nuance is lost. Decent normalisation of all indicators is required to provide a validated cumulative indicator.

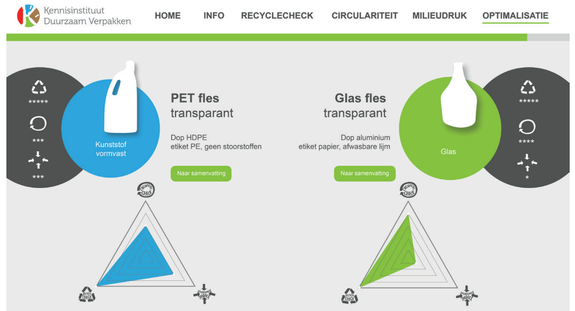


Figure 43 Comparative overview of tools

For packaging combinations with multiple components of different materials, like a cornflake box of paperboard combined with a flowwrap bag of plastic, it would be valuable for the user to combine the results in a cumulative output. This might be feasible for the environmental impact of these components, but for the other tools this is not feasible.

14.4 Innovations

Innovations on material and packaging level are not integrated in the current data set, so when a company wishes to compare existing packaging options to innovative ones, this is not feasible yet. It would be possible to provide users with the ability to fill in the required information to evaluate new packaging types next to existing ones. The implementation advice will further elaborate on what is needed to integrate this in the tool.

To conclude, the request of the KIDV to develop a sustainability assessment tool to compare packaging alternatives on recyclability, circularity and environmental impact is feasible, but with some important remarks to the methodology and promised output of the tool. With the approach followed, the linear packaging system can be assessed on efficiency, with focus on recyclability and environmental impact. This provides a more transparent depiction of system characteristics and boundaries that are currently occurring but does not provide users with an answer on how to become 100% circular.

PART III: VALIDATION & IMPLEMENTATION

The thesis work on the sustainability goal setting and evaluation tool for packaging can be seen as the start and as navigating work for the tool that the KIDV will develop in the further course of 2019. To see whether the development of the tool is achievable, a prototype was conducted. With the help of this, an implementation guide is written for the KIDV, which will help in the further development process of the tool. Moreover, reflected is to which extend the tool requirements are met when this methodology is followed.

15 USABILITY TEST

Where the tool is already tested on the feasibility and complexity by building the prototype, the usability of the tool is examined in this chapter. The test setup will be explained, after which a summary of test results is provided, followed by an evaluation to discuss to which extend the requirements of the tool are met.

15.1 Aim of test

The user aspect of testing the tool is to see whether the tool can support PI's in knowledge enrichment on packaging chain dynamics and can improve communication and commitment throughout departments in design and decision-making processes throughout packaging development. The test will be used to find out to which extend users understand the three modules, to see if there is enough information provided to use the tool independently. Moreover, to which extend PI's can compare results of packaging assessments in a substantiated way? Can actual improvement be made on the sustainability of product-packaging combinations by using the tool?

15.2 Test setup

After the development of the prototype version of the tool, a user test was set up. In order to obtain a complete representation of the usability of the tool, a variety of test users was selected. These test users all play a different role in the packaging industry. This variety fits the wide range of companies that appeal for support of the KIDV.

The stakeholders that were selected and agreed upon testing the tool were: Marqt, Superunie, Tony Chocolonely, Remia, Friesland Campina, Burg Groep. The role of the test users within these companies varied, because not all companies have their own packaging development department. This resulted in test users that are in a packaging engineer role, but also test users that are in a sourcing or marketing role within their company. This mirrors the broad range of envisioned users of the tool. Table 6 shows an overview of the participating company and the function of the participants within these companies.

Company name	Sort of company	Function of participant
Marqt	Retailer	Impact & Quality manager
Superunie	Retail organisation	Process Manager sustainable trading
Tony Choco-lonely	Small to medium enterprise	Marketing Sourcing & Quality Sourcing
Friesland Campina	Big company with R&D	Packaging engineer
Burg Groep	Big company with R&D	Sustainability & Quality
Remia	Big company with R&D	Packaging Engineer Sourcing

Table 6 Participants in usability test

In the test tool, only a selection of packaging samples is embedded. Based on the Recycle check of rigid plastic packaging that was already published, the prototype was developed. The sample packaging selection exists of trays and bottles, based on the materials PP, PE and PET, as shown in Figure 44. These three materials are selected, because these are the three mono-materials that are sorted as separated waste streams in the sorting installations.

A predefined list of questions was formulated to get a structured way of working through the test and communicate with users (Appendix J). Scope of the questions is: current sustainability actions within company, dilemmas in sustainable packaging development, experience with sustainability assessment tools. After testing the tool, questions focus on usability of the tool, comprehensiveness, expected use intensity.

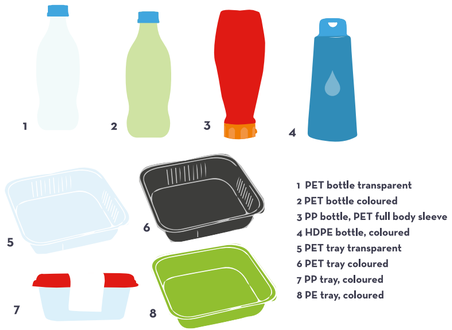


Figure 44 Sample packaging, rigid plastics

15.3 Test results

The most important statements from test users was put into the summative overview in Figure 45. This already gives an indication to which extend the envisioned requirements of the tool are met according to its users.

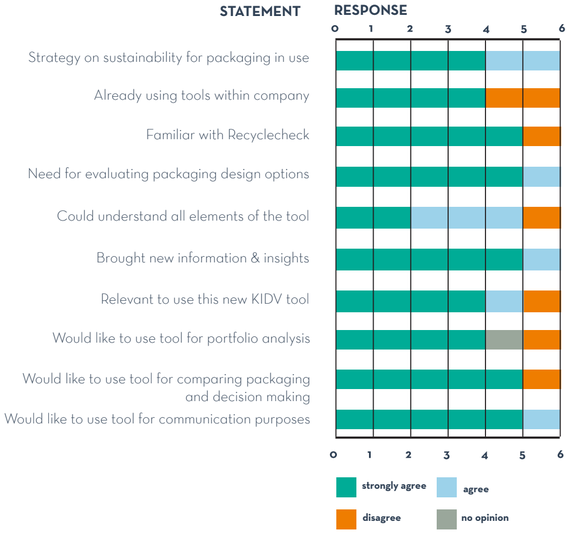


Figure 45 Summative overview of test response

15 USABILITY TEST

The results from the open questions provide more specific feedback on the use of the tool. Appendix K-P show the interview reports of all participants. The results are summarised below.

What are companies' activities around sustainability?
Four of the six participating companies mention that a sustainability strategy for packaging is in place, whereas the other two participants mention the lack of a clear strategy. This enormously influenced the way the tool was perceived. Users with a clear strategy could place the assessment elements in their own referencing, whereas the other participants had more difficulty interpreting the results and making decision based on this.

What are the dilemmas your company is facing towards sustainability?
Most barriers to sustainability that are mentioned are focussing on the operational level of a company. Participants mention difficulty to switch to packaging alternatives due to machinery and functional requirements. Often mentioned is the cost aspect of modifying processes and design decisions, which is seen as a high barrier for sustainable development. Moreover, willingness throughout departments is mentioned, where communication and knowledge are bottlenecks.

Is the company currently using tools to help with sustainability?
Generally, companies refer to available results of LCA tools, that are mostly not specifically executed for their product portfolio. The Recycle Check of the KIDV is often mentioned as a tool that is used, only one participant did not use the Recycle Check before. Only one company has an own assessment framework in place to support in decision making in packaging development processes.

What is your first reaction after using the tool?
Participants found the visualisation of information output very valuable. Often mentioned is the added value the tool output will bring to multidisciplinary team meetings, because of its well-balanced character between simplicity and completeness. The interactive elements of the tool are rewarded for their clear and fun way of showing the results.

To which extend does the tool support communication and decision making towards more sustainable packaging?
From most test sessions could be concluded that the visualisation is very helpful in communication amongst departments. The decision making is strongly connected to the strategy a company has towards sustainability in packaging development. Users defined the visual outcomes as valuable in supporting this decision making.

In what context and in what frequency are you expecting to use the tool?
All participants indicated to be expecting to use the tool in the future for future development processes. Some supported this statement with the remark that they would like to assess their whole existing packaging portfolio with the tool as a starting point for future development.

Is there anything you missed or did not like about the tool?
There were some remarks about the complexity of the information required to provide input to the tool. Some participants were not familiar with the Recycle check, which resulted in high difficulty to walk through this part of the tool. After one sample package, other samples were experienced to be more easily to fill in. A valid comment was that it would be valuable when the product-packaging combination is more integrated in the tool.

Besides the results from the questions, some results from the author's observations during the case study are worth mentioning.
Additional background information should be available for new users, but more advanced users should also be able to use the tool without information pop-ups at every page.

Concluded can be that overall, the user tests have shown positive results. The incentives for the development of a new sustainability assessment tool was confirmed by several stakeholders. Moreover, the approach that was taken for the tool connected to the wishes of its envisioned users.

16 EVALUATION

To evaluate the results of the usability testing and the development of the prototype, the requirements that were set for the tool were reflected. For the evaluation of the usability requirements, referred is to the results of the user testing and the evaluation of the technical requirements is based on the development of the prototype. Moreover, this chapter looks back at the gap between present-day activities and future goals, to see to which extend the tool might help in bridging this.

16.1 Usability requirements

The usability requirements stated that the tool should be suited for use by producers and importers of packaging (packaging engineers, buyers, marketeers etc). By the selection of multiple test users from different companies, with different roles within these companies, concluded can be that the tool is suited to be used by different users of a packaging development team. Mentioned should be that the information dependency of users varied enormously between packaging engineers and roles that have less extensive knowledge on packaging as marketeers and buyers. To make the tool flexible and suited for different users, it is recommended to provide background information in a subtle way, so it is always there but not bothering the more experienced user. Users were triggered to think about the sustainability strategy of their company due to the 'focus point' page. The communication aspect as required, can be concluded to be achieved. The visual output pages of the tool were often remarked by the users as very helpful, expounding and the perfect ending of their effort put into the assessment modules.

In the requirements a desired balance between simplicity and accuracy was described. It is not possible to draw a validated conclusion on this after executing 6 usability tests. As a first indication, it can be concluded that 5 out of 6 users stated that their knowledge was enriched, and the output was still understandable enough. Only for one user, the output was not detailed enough to add value to the knowledge within the company that was already available. From this we can conclude that the tool is suited to enrich knowledge and stimulate companies to start their optimisation of sustainability of packaging, but for the companies that are already further in this process, the tool does not offer that much. The KIDV should test this balance again with more users after the tool is further developed.

16.2 Technical requirements (functionality)

In order to evaluate on the functioning of the tool, the technical requirements are regarded. First, proven is that validated data can be obtained from existing research to compute the indicators as proposed in this research. There were some assumptions that needed to be made in order to make a simplified model of reality, but if these are clearly communicated, these do not harm the functioning of the tool.

In this case, it is assumed that the data of WFBR of 2017 is representative for the current Dutch waste system and that this data is applicable to all plastic packaging that is entered in the tool. For the integration of other packaging materials in the tool, some small modifications might be needed, but in broad sense, the tool as developed for rigid plastic packaging can be extended to flexible plastics, paper and board, metals and glass. The 'number of cycles' indicator as used in the circularity module is for a large extent based on assumptions and could only be estimated based on knowledge available at the KIDV of the current recycling system. The environmental impact module is based on the Pack4ecodesign module of Fost Plus and RDC Environment. For the test phase it is assumed that the actual tool will use a similar approach.

Not all envisioned functions could be incorporated and thereby tested in the prototype of the tool. First of all, users could not fill all information of a packaging combination, as labels, caps and sleeves are not integrated in the prototype. One of the more complex functions is the interaction between the different modules within the tool. Where the requirements state that information from the tools should be transferred to the other tools, so the user only has to fill in new information at each tool, this could not optimally be tested in the prototype. Furthermore, users could not compare more packaging cases interactively, as the prototype did not have these functions yet. Comparison was simulated by static mock-up pages of two packaging alternatives, which did provide users with the basic idea of comparison.

16.3 Looking back at the gap

In this research, a gap was defined between what we are doing in the current situation and the desired goal that is set for the future. From this was concluded that support for PI's should aim at bridging this gap, where starting by optimising what we are already doing would help to set a few steps towards the edge of the gap but cannot completely bridge it. It was therefore proposed that next to optimisation of our current situation, other activities are required to genuinely achieve the desired goal. CE was depicted as an approach to achieve this. Looking back at this, we need to conclude that the tool is not really bridging the gap. The tool seems to be a valuable way of thinking about sustainability goals and useful to evaluate packaging alternatives in the current system, but the tool certainly does not help producers and importers to start doing completely different activities towards a CE. This is partly due to the approach of the circularity module, which is much more of a linear system, instead of a circular system evaluation. Moreover, looking at what is provided in the tool after the goal setting and three-perspective evaluation, users might not even be truly sure what actions they should take next in present-day. Perhaps it is not the role of the KIDV to precisely steer producers and importers in a certain direction, but some advice and/or support could be valuable.

After evaluation of the requirements that were set for the tool, it can be concluded that the tool seems to be technical feasible, with some system boundaries to consider and some assumptions that are made. When integrating the usability output features, the tool should be valuable and understandable for the end user. The findings are used to formulate an implementation advice to the KIDV, to ensure these aspects can be incorporated in the development of the tool.

17 IMPLEMENTATION ADVICE

From the development phase it is encountered that both on technical aspects as on usability, the development of a sustainability goal setting and evaluation tool for packaging seems feasible, with some restrictions and assumptions. The KIDV should consider the following aspects for the development of the tool and the implementation of it.

17.1 Functioning of tool

The tool requires a reading guide on how to use the modules of the tool and how to interpret results. Moreover, a holistic view on sustainable packaging design should be provided to users, which they should see before going in-depth into the assessment. Otherwise, there is the risk that users will focus too much on for example recyclability. A disclaimer should be used to make sure that users are aware of the indicative approach of the tool. The tool does not provide completely exact data or true answers, and users should not use the output of the tool in this way.

Both from user input as from literature came clear that it is crucial that the functional requirements a packaging needs to fulfil to pack and protect a product are incorporated in the tool. Advised is therefore, that the user needs to fill in the requirement specification of the packaging to be assessed. This does not have to be very extensive, but at least some basics about the product to pack, as envisioned shelf life, filling methods and the viscosity of the product.

For the Recycle Check, it is key that the user can find all background information needed to work through the decision tree. Instant feedback is valuable for users, so it is recommended to show points of attention on the side, so that when packaging features are sub-optimal for recycling, this is immediately shown. For this, a traffic sign colour indication can be used (red, orange, green). This way, implications of design choices are transparently shown.

User tests have shown that it is crucial that the circularity check contains enough explanatory guidance. The indicators that are shown are relevant for users, but for this the interpretation of users is key. Users like to tweak their packaging in the tool to see how they can optimise the outcome of the tool, therefore instant tweaking with fast visual output is recommended. Moreover, providing attention points like the recycle check are required for users to modify their packaging design.

The environmental impact is of great interest to its users. Whereas 'minimizing CO2 footprint' is often stated in sustainability strategies, it is recommended to use CO2 equivalents for the output of this module. Crucial for this part of the tool is that users fill in the same functional unit for all packaging they want to compare. Hence, comparing a glass bottle to a PET one is only fair if both pack the same volume of liquid. It is recommended to use key figures for packaging, to prevent input errors in unity (hence 500 grams versus 0.5 kg).

17.2 Indicators

This research has provided the current selection of indicators presented in the tool. By carefully selecting the data that is used for the tool, these indicators show a reasonably fair view on the current system. However, the KIDV should clearly communicate on how to use and interpret the tool and its results, so that misuse of indicators can be prevented. This can be incorporated in a disclaimer. It is recommended to keep monitoring development on circular economy assessment, as expected is that these phenomena will further develop and measuring methods might evolve to become more exact. An integral indicator of circularity would be valuable, but for now this is not recommended as it would decrease the transparency of information communicated to users and the risk of losing nuance is rather high.

17.3 Data

The data determines for a large extend the outcomes of the modules within the tool. The data itself is strongly subjected to measuring methods. WFBR uses generic sorting and recycling methods for their data collection. Hence, when there is a large-scale innovation/improvement of these systems, this might have a vast influence on the recycling yield. It is recommended that the KIDV keeps an eye on certain innovations, so that data keeps validated.

17.4 User

As it was described in chapter 14.4, the KIDV should take some aspects into account considering usability. User tests have shown that some users need a lot of background information, where others have plenty background knowledge available to fill in the tool independently. With this finding, concluded can be that the tool should be flexible for multiple sorts of users. It is recommended to use as little pop-up information buttons as needed but provide the user with the ability to find background information where needed.

The visual aspects of the tool have proven to be crucial, because users indicated that these visual outputs would be very helpful to communicate with both internal and external stakeholders. It is recommended to use visual output like the prototype, because these were regarded as very clear and helpful. The interactive elements in these played a vital role in this, because it made the users feel the impact much more than just the still images. Further research into interface design and data visualisation might be helpful here.

17.5 Incorporating innovations

It is recommended to look for a way to incorporate room for innovation on the tool. One way of doing is, is by providing users the opportunity to contact suppliers of the new packaging innovations to provide them with data, so they can use this as input for the tool. The risk here is that suppliers might be less exact in their data as other packaging from EcoInvent data, but if it is clearly communicated that users are responsible for this and that the outcome of the tool is purely indicative, this would be doable. The Recycle Check and circularity module are suited to evaluate new innovations, as they would simply assess in what theoretic existing waste stream a new packaging would end up. This means that suppliers would solely have to provide information about environmental impact aspects as the energy use, water use and submission of CO2 equivalents.

17.6 Beyond the Dutch borders

It might be very valuable to incorporate other countries as pre-set within the tool. Here it is important to compare where data comes from, who measured it and in what way. For the data of recycling efficiency, cooperation with Universities and governmental organisations in EU and on global scale would be very valuable. There are already some comparable researches in other countries, as the research in Italy (Mastellone, Cremiato, Zaccariello, & Lotito, 2017) and the research in Belgium (Huysman et al., 2015).

17.7 Dynamics between goal setting and evaluation

It should be noted that there are dynamics between the goal setting and the evaluation modules of the tool. In the prototype tool, there are two use scenarios. Either the user already has defined a clear goal, and uses the tool to evaluate on the packaging with the help of the 3 perspectives, Or the user does not have clear goals yet and first fills in some guesstimated goals, after which the evaluation modules bring more perspective to the

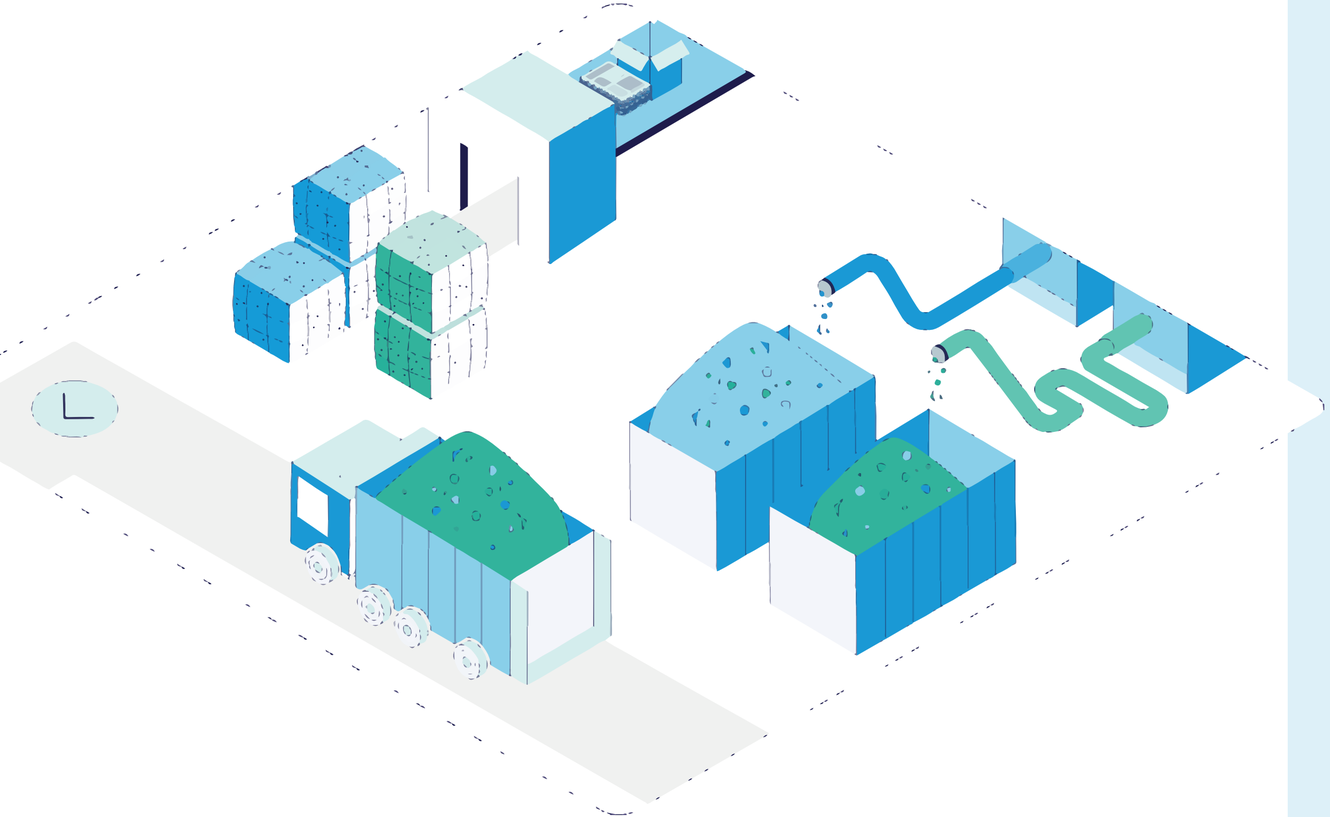
aspects that influence the sustainability of a packaging, after which the user reflects on the goals and changes the goal-setting. It cannot be defined which route would be more valuable, assumed is that this depends on the experience of the user of the tool. For the KIDV it would be valuable if there would be a way to monitor which goals are selected in the goal-setting phase and the KIDV might be able to take a steering role in this. The tool could propose certain settings to users, as the 'Plastic Pact' goals, to show users how they are scoring towards those goals. The tool could then put a lot of producers and importers on one line, letting them work on the same goals.

17.8 Design focus

For the users it might be valuable to have more design focus within the tool, as currently the tool is mainly an evaluative assessment tool. When the user could switch between evaluation and design, the tool might be able to provide users with design suggestions. As an example, the tool could already state that when a PET bottle is selected, a PET sleeve is not a good idea, because of the recyclability. Moreover, when the user selects that the product will be hot filled into the packaging, the system might give an alarm that a certain plastic might not be a good idea, and that glass might be better.

Bring the nuanced story, do not give the ultimate answer, create a sense of how small of big impact is, how circular or linear things are, educate users on the current packaging system, but let them think about alternatives as well. Try to not stand in the way for innovation. Users should be provided with the ability to learn about the system, to interpret results in the right way and to compare packaging alternatives in an honest way.

'to successfully implement CE models, a synergy between sustainable packaging development, new business models, system cooperation, behaviour and willingness of all stakeholders must be achieved.



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DISCUSSION

Interpretation of the results

In hindsight of this research, reflected should be on all steps of the process, to critically look at the process and results. The assessment framework sustainable packaging provides an assessment method for producers and importers of packaging, to enhance decision making in packaging development processes to enhance and improve sustainability in product-packaging combinations. The model is, like every other model, imperfect, oversimplified, and unfinished. However, decisions cannot wait for perfect models and total understanding. It is key to indicate where these imperfections and oversimplifications lie, to propose starting points for further research and improvement of the tool.

As a defining system boundary, the tool only looks at the system efficiency of the current linear, Dutch system. This implies that the tool is not directly valid for other countries, and most companies do not produce for only one country. The big question however is, can and should we use linear methods to achieve circular results? This approach is mainly chosen to fit the wishes and requirements of the KIDV to provide producers and importers with a first guide towards more sustainability and circularity within their development processes. A more holistic approach, with guidelines and strategic considerations would be very valuable, however this was not requested by the KIDV. This does not reduce the value of the tool that was currently developed, only interpretations of results from the tool should be taken very carefully, to not transfer a wrong image.

Research in a wider context

To put things in a broader perspective, the sustainability assessment as described, especially the circularity check and its indicators, are solely one element in the overall CE transition. To successfully implement CE models, a synergy between sustainable packaging development, new business models, system cooperation, behaviour and willingness of all stakeholders must be achieved. Circular indicators as a standalone device do not achieve anything, they first have to be translated into suitable actions to successfully achieve the transition to a CE. Where current actions are mainly focussing on the optimization of the recycling industry, because this is how our current system mainly looks, we have to start wondering what the next more drastic steps will be. Further research is required to discover and define what this will be.

As a start, more focus on the assessment of product-packaging combinations as an integrated development process is recommended. For now, this was regarded as too complex by the KIDV, but this seems to be the only reasonable thing to do to really support industry. Hence, to improve the sustainability of product-packaging combination, producers and importers can do more than just optimize their packaging design by material choices to improve recyclability and lower the environmental impact. Transition towards CE needs a holistic approach and cannot be achieved by just optimising packaging materials.

CONCLUSIONS

This research project provides an approach to develop a sustainability goal setting and evaluation tool to support producers and importers in their packaging development process, to improve the sustainability of product-packaging combinations. Part I of this report discusses Circular Economy as an approach to sustainable packaging development. Subsequently, barriers that producers and importers are facing in the development of sustainable packaging are explored. This resulted in the incentive for the development of the tool, which was translated into a theoretical framework and a requirement specification in the intermezzo. In Part II, a prototype of the tool was developed, which was tested on usability with stakeholders from industry. From an evaluation on this process and results, an implementation advice was provided to the KIDV. This chapter will discuss the findings of this research, leading to the conclusion of this thesis.

To preserve our planet for future generations and sustain our current generations, we need to handle our resources with care and harmonise our innovation, production and consumption through sustainable development. An approach to sustainable development is the Circular Economy: an economic system where we design out waste and pollution, close (material) loops, optimise system efficiency, regenerate resources and preserve their value, and introduce new business models to make this possible.

In present-day, sustainability in packaging development comes down to minimising the environmental impact of product-packaging combinations on the one side (eco-efficiency) and optimising the product-packaging combinations and striving for circularity on the other side (eco-effectiveness). Under these two pillars comes the aim to minimise the use of packaging materials (and scarce resources), interchange them where possible for biobased or recycled materials, keep the materials we use in the system at their highest possible value, reuse packaging where possible and design them in such a way that they are easy to recycle. Above all, the functions the packaging fulfils to a product is put central, and only when those requirements are met, a packaging can be sustainable.

Both on supranational and national level there are guidelines and frameworks in place that support industry in sustainable packaging development. CE is beginning to find its place in the corporate sustainability agenda of companies, whereas most actions are still focussing on the optimisation of our current system. The recycling system receives a lot of attention and the quantity of plastic packaging that is being put on the market and recycled is leading here. Research has concluded that companies might be experiencing barriers to sustainability, as a lack of knowledge, experience and support amongst departments. Moreover, a gap is identified between what companies are doing currently and what is desired for the future. The translation of future goals into present-day actions seems complex but crucial to bridge this gap. For PI's to decide on dilemmas within packaging development it is therefore important to first set sustainability goals. After this, the evaluation of a packaging can be interpreted by reflecting on these goals.

From this arose the incentive: To develop a sustainability goal setting and evaluation tool to support producers and importers in their packaging development process, in order to improve the sustainability of product-packaging combinations.

The KIDV proposed to use a three-perspective evaluation: the recyclability, the circularity and the environmental impact. The recyclability is assessed by using the Recycle check as developed by the KIDV. The circularity module gives an indication of the circularity of a packaging within the current recycling system, by using four indicators. The regenerate indicator measures how much material comes back in waste collection after one life cycle, the loss indicator shows how much of this material is lost in sorting and recycling, the resource value indicator indicates what is the quality of this material and the theoretical number of cycles provides a theoretical estimation of how much cycles the package can make before turning to actual waste/incineration. The environmental impact module will adapt to a simplified version of existing LCA methodology and will be developed by an external party.

Data of the Dutch waste systems from research by Wageningen Food and Biobased Research are used for the circularity indicators of the tool. This was decided because this data was most elaborate and reliable. Using this data for the tool gives the opportunity to translate extensive research findings into practical, accessible information for the packaging industry. Connecting scientific research and the producing industry aligns well with the aims of the KIDV.

For the prototype of the tool, a visual identity is designed, in line with the brand identity of the KIDV. The theoretical framework is translated into a visual appearance, which is transformed into a web-based tool in collaboration with a web-developer.

The prototype of the tool was used in usability testing with stakeholders from the packaging industry, which showed that the tool could provide valuable support to PI's in sustainable packaging development processes. It can be concluded that the tool seems to be technical feasible, with some system boundaries to consider and some assumptions that are made. When integrating usability features, the tool should be valuable and understandable for the end user.

After evaluating on the prototype, we need to conclude that the tool is not really bridging the gap. The tool seems to be a valuable way of thinking about sustainability goals and useful to evaluate packaging alternatives in the current system, but the tool certainly does not help producers and importers to start doing completely different activities towards a CE. This is partly due to the approach of the circularity module, which is much more a linear system evaluation, instead of a circular system evaluation. Moreover, looking at what is provided in the tool after the goal setting and three-perspective evaluation, users might not even be truly sure what actions they should take next, in present-day. Perhaps it is not the role of the KIDV to precisely steer producers and importers in a certain direction and lead actions, but some advice and/or support could be valuable here.

The all-defining answer on what is most sustainable, can never been given. Tools can at best provide a comparative approach, by comparing two or more packaging alternatives, to see what the better option is. Still then, the sustainability of packaging is such a nuanced case, as it is always integrated with the actual product and the functions it should fulfil. What seems sustainable on the short-term, because it has a low impact on the environment and does not use too much material, might turn out to be not sustainable at all at the long term, because material ends up in nature or can only be incinerated after waste collection.

The main, recurrent element which should never get out of focus is the higher goal of a Circular Economy and sustainable development. The aim is to produce, consume, develop, innovate and live in a conscious way, to not only successfully provide life to our current generations, but also preserve our planet for future generations.

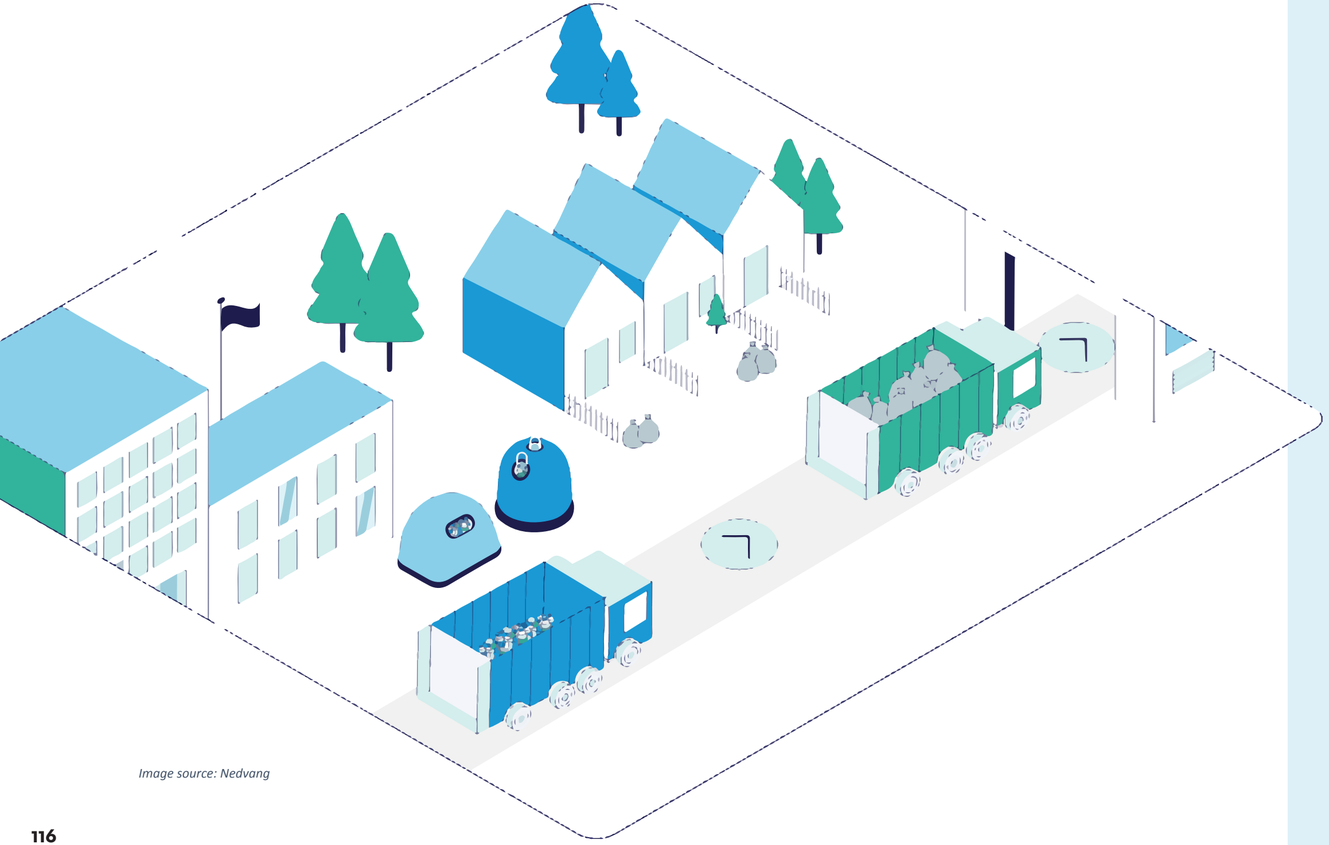

Image source: Nedvang

RECOMMENDATIONS

This thesis has been conducted from a specific scope and request from the KIDV. The result has been concluded to meet the KIDV's need for a sustainability evaluation tool for packaging, focused on supporting producers and importers of packaging in the improvement of the sustainability of product-packaging combinations. The research results can be further improved upon and reach beyond the scope of this thesis. This chapter provides recommendations for further development of the KIDV tool and brings recommendations for further research.

For the KIDV

First, it is crucial that a company has a clear strategy on sustainability within packaging development, as it gives them the ability to put the output of the tool in their own evaluation framework. Whereas this strategy defining is often experienced as complex and difficult, companies will benefit by support in this part of development and the KIDV could play a major role in this. It is recommended that the KIDV keeps track of what tool users fill in in the goal-setting phase. Moreover, the KIDV could provide users with predefined goal-settings as the 'Plastic Pact' setting or using agreements from the sector sustainability agreements as pre-setting. The KIDV could perhaps even take a role as moderator, which can support users when a combination of goals is selected that would not contribute to improvement of sustainability.

The balance between accuracy of output and flexibility and simplicity for its users will always have to be kept in mind. In order to support industry in improving the sustainability of product-packaging combinations, the tool needs to be simple in use and flexible to be used in different packaging scenarios. On the other hand, the tool needs to provide valid output and enough accuracy to be relevant for use in current and future development projects. The KIDV should keep this balance in mind and re-evaluate this aspect during and after the next development phase of the tool. Usability testing is a good approach to evaluate on this.

As a follow-up, it is recommended to test the adaptability of the tool in strategic and operational functioning of companies. Do they use the tool, and if not, does it depend on the information provided, the representation of the information, the knowledge of PI's, or are there other factors playing a role?

Implications for further research

It is recommended to asses product-packaging combination as an assembly, because packaging is not a stand-alone object. From the statute of 'Stichting Afvalfonds Verpakkingen' can be abstracted that the advising role of the KIDV has to focus on product-packaging combinations. This does not mean that the KIDV has knowledge of food or non-food products, but aims it's advising role on the quality requirements of packaging for the functions packaging fulfils towards the product, as food safety and protection against damage (Bruijnes, 2018). Therefore, a crucial requirement is that the tool supports industry in assessing not only sustainable packaging alternatives but makes sure PI's focus on sustainable product-packaging combinations.

This research took a bottom-up approach to sustainable development and circular economy. By assessing the efficiency of the linear system, optimisation aspects could be found to make the first steps towards closing loops. The definition of CE is somewhat ambiguous, and no indicators do yet exist that can assess the actual (future) circularity of products and materials, so this would be an interesting aspect for further research. Particularly, what CE implies for packaging and what industry should do to achieve a successful transition to a CE.

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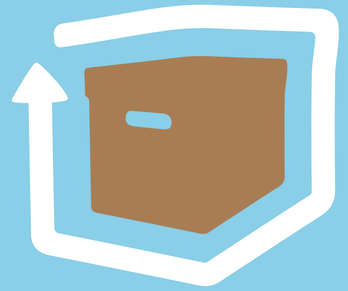

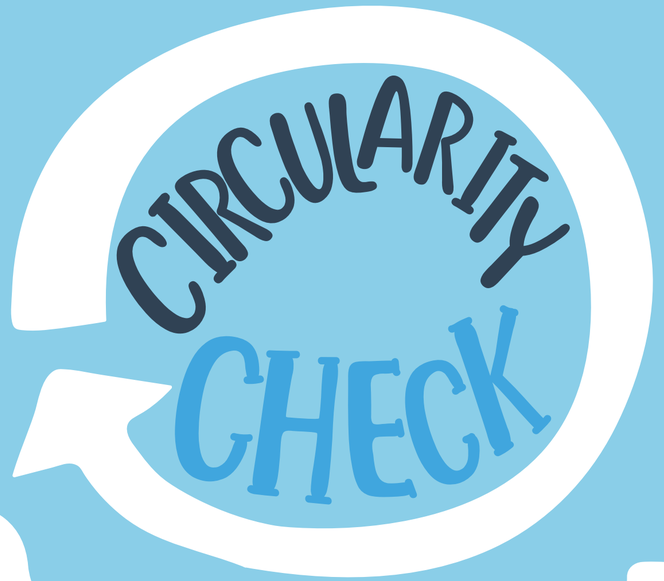

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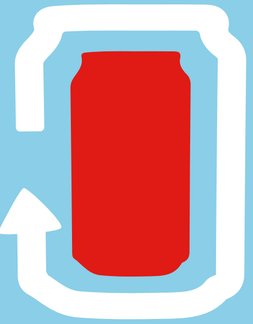

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APPENDIX

APPENDIX A Circular Economy definitions analysis

Organisation	Definition of Circular Economy (CE)
Ellen MacaArthur Foundation	Design out waste & pollution Keep products and materials in use Regenerate natural system An industrial economy that is restorative or regenerative by design
Ceha, A. 2018	Regenerative system in which resource input and waste, emission and energy leakage are minimized by slowing, closing and narrowing material and energy loops
Viktoria Swedish ICT	Closed loop product, resource and material cycles Improve resource efficiency Keep resources in use for as long as possible Extract maximum value of resources
Circle Economy	7 principles: Prioritize regenerative resources, Design for the future, Preserve & extend what's already made, Rethink the business model, Use waste as a resource, Collaborate to create joint value, Incorporate digital technology
Kama 2015 / Su et al. 2013	A self-sufficient economic regime conducted through closed loops of materials
Mathews et al. 2011	A closed cycle of material and energy flows
Yuan et al. 2006	The core of CE is the circular (closed flow) of materials
Geng et al. 2013	A CE is an industrial system focused on closing the loop for material and energy flows
JIE, 2015	In a circular economy, resources are kept in use for as long as possible, extracting their maximum value
Linder and Williander, 2015	An economy in which the conceptual logic for value creation is based on utilizing economic value retained in products after use
Haas et al. 2015	CE aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows
EC 2015	An economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized
Di Maio et al. 2015	CE models maintain the added value in products for as long as possible and minimize waste. They keep resources within the economy when products no longer serve their functions so that materials can be used again and therefore generate more value. Create more value through business models. Decouple economic growth from material input
Webster 2015	A circular economy is one that is restorative by design, and which aims to keep products, components, and materials at their highest utility and value at all times.
Nancy M. P. Bocken, de Pauw, Bakker, & van der Grinten, 2016	Design and business model strategies that are slowing, closing, and narrowing the resource loops
The Green Alliance	Better systems for resource efficiency and security. The circular economy captures and retains materials in the system, so today's goods are remanufactured or reused to become tomorrow's goods, rather than sent to landfill.
Rijksoverheid	Economic system that is based on the reusability of products and materials and on the preserving of natural resources. Value creation in every step of the system.
Afvalfonds	Focus on recycle percentages, 'in fact, the material flows of paper/cardboard, metals & wood are circular, glass is almost circular'
Het Groene Brein	A CE is an economic system based on minimizing the use of resources by reusing products, parts and resources. A system with closed loops where products loose as little value as possible, renewable energy sources are used and system thinking is central.
Kirchher, Reike, Hekkert	An economic system that replaces end-of-life concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. Enabled by novel business models and responsible consumers.
Plastics recyclers Europe	Society keeps resources in use for as long as possible, extracts the maximum value from them whilst in use, then recovers and regenerates products and materials at the end of each service life."

Organisation	Closing loops	Regenerate	Maximum resource value	System efficiency	Economic & business	Design out waste & pollution
Ellen MacaArthur Foundation	X	X	X	X		X
Ceha, A. 2018	X	X		X		
Viktoria Swedish ICT	X		X	X		
Circle Economy		X	X	X	X	X
Kama 2015 / Su et al. 2013	X	X		X	X	
Mathews et al. 2011	X					
Yuan et al. 2006	X					
Geng et al. 2013	X					
JIE, 2015	X		X			
Linder and Williander, 2015	X		X		X	
Haas et al. 2015	X					X
EC 2015	X		X			X
Di Maio et al. 2015	X	X	X		X	X
Webster 2015		X	X			
Nancy M. P. Bocken, de Pauw, Bakker, & van der Grinten, 2016	X				X	
The Green Alliance	X	X		X		X
Rijksoverheid	X	X	X	X	X	
Afvalfonds	X	X				
Het Groene Brein	X	X	X	X		X
Kirchher, Reike, Hekkert		X		X	X	X
Plastics Recyclers Europe		X	X			

APPENDIX B 7 tips for sustainable packaging

Netherlands Institute
for Sustainable Packaging

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Good packaging is sustainable packaging 7 tips from KIDV

1 Always put the functionality of the packaging first.

In most cases, the product has a more significant environmental impact than its packaging. A good packaging protects the product against damage and spoilage and helps consumers dose the product carefully, so they can get the most out of the product.

Intended effect: the valuable product is not lost.

2 Avoid the use of harmful substances in packaging materials.

For example, avoid using inks that contain mineral oils and other harmful substances.

Intended effect: preventing harmful substances from ending up in the environment and in (recycled) materials.

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Netherlands Institute
for Sustainable Packaging

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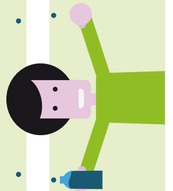


2 Avoid the use of harmful substances in packaging materials.

For example, avoid using inks that contain mineral oils and other harmful substances.

Intended effect: preventing harmful substances from ending up in the environment and in (recycled) materials.

3 Use materials sparingly.

Use as little material as possible or ensure that the packaging can be reused. During production, keep material losses to a minimum.

Intended effect: more efficient use of raw materials and to reduce the amount of waste.

4 Create a clean material stream that can be recycled easily.

Whenever possible, use a single type of material per packaging component and ensure that consumers can easily separate the different components. Also make sure that consumers can empty the packaging completely, so no product residue is left in the packaging.

Intended effect: proper separation and recycling of packaging waste, so it can be used to produce raw materials for new packaging materials and products.

5 If possible, use recycled or renewable raw materials.

This ensures that materials can be used for as long as possible and it reduces the need for virgin materials.

Intended effect: further closing the material chain.

6 Keep logistical efficiency in mind when developing packaging.

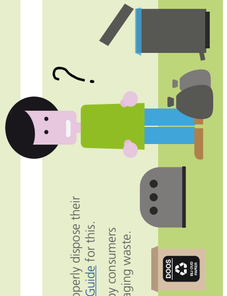
Keep the empty space in transport units to a minimum, so the energy requirements per transported product are as low as possible. Design packaging materials that limit the risk of product damage to a minimum.

Intended effect: reduced energy usage, pollution and product loss during transport.

7 Include information on the packaging concerning the proper disposal behaviour for consumers.

Make sure that consumers know how to properly dispose their packaging waste. You can use the Disposal Guide for this.

Intended effect: proper waste separation by consumers makes it easier to reuse and/or recycle packaging waste.



Netherlands Institute for Sustainable Packaging

KIDV RECYCLE CHECK

RIGID PLASTIC PACKAGING

VERSION 2019
20 NOVEMBER 2018

Netherlands Institute for Sustainable Packaging

Rigid plastic packaging materials

The decision tree on the next page will help you determine whether a packaging is easily recyclable or not. Each question comes with its own background information and clarification. Read this information carefully before answering each question. You can consult this information by clicking on the questions.

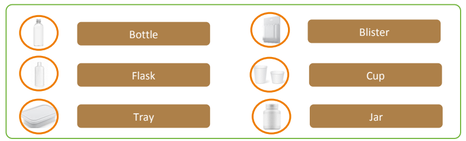


IMAGE 1: EXAMPLES OF RIGID PLASTIC PACKAGING MATERIALS

When evaluating the packaging, it is important to look at the integral packaging as it is disposed of (separately) by the user. The survey also mentions "the largest component of the packaging." This is usually the part of the packaging that holds the product itself. Both aspects are explained in the image below. Integral packaging: the container (green), the cap/lid (blue) and the label (white). In these examples, the largest component of each packaging is shown in green.

IMAGE 2: RIGID PLASTIC PACKAGING: MAIN COMPONENT SHOWN IN GREEN

There are also rigid plastic packaging materials that are not included in the recycle check, because they must be disposed of as part of the residual waste stream. This includes packaging materials for medication or small chemical waste, as well as for example paint, glue or caulk.

IMAGE 3: EXAMPLE BLISTER, SMALL CHEMICAL WASTE, CAULK CONTAINERS

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APPENDIX C

Recycle Check for rigid plastics

Netherlands Institute for Sustainable Packaging

Decision tree

Beforehand

a. Is it a rigid plastic packaging?
- No → This recycle check is only designed for rigid plastic packaging materials; the KIDV is developing separate recycle checks for other packaging materials.
- Yes

b. Is it a packaging for medical products or one that should be disposed of as part of the small chemical or residual waste stream?
- No → Packaging materials for medication or those that should be disposed of in the small chemical or residual waste streams are not part of this Recycle Check. Click here for more
- Yes

Interferents

1. Is the packaging free of oxo-degradable material?
- No → Oxo-degradable plastics are interferents in the recycling process.
- Yes

2. Is the packaging free of PVC or PVdC?
- No → PVC and PVdC interfere with the recycling of other plastics.
- Yes

3. Is the packaging free of silicone components?
- No → Silicone components interfere with the recycling of other plastics.
- Yes

Material

4. Does the largest component of the packaging consist of PE or PP or PET?
- No → Packaging materials made from other types of plastic are currently not optimally recyclable.
- Yes

5. Does the largest component consist exclusively of a mono-material without multi-layers, coatings or fillers?
- No → Packaging materials made from multi-layer materials or those with a coating impede the recycling process.
- Yes

Sorting

6. Is the packaging larger than 5 centimetres and is it's volume smaller than or equal to 5 litres?
- No → Packaging materials that are too large or too small are currently not sorted for recycling.
- Yes

7. Does the largest component of the packaging have a colour other than black?
- No → Most sorting facilities currently do not detect or sort black packaging materials.
- Yes

8. Does the packaging have a label or sleeve and is it sortable and recyclable according to the table in the clarification?
- No → Labels and sleeves impede the recycling process due to their size or the combination of materials used.
- Yes

Recycling

9. Is the packaging free of hotmelt and non-washable adhesives?
- No → Non-washable adhesives and hotmelt impede the recycling process.
- Yes

10. Is the packaging free of enclosed metal components?
- No → Enclosed metal components impede the recycling of plastic.
- Yes

11. Is the packaging free of opaque PET?
- No → The dye in the packaging material impedes the recycling process.
- Yes

12. Is the packaging not a PET tray?
- No → This type of packaging material is only recycled on a limited scale at the moment.
- Yes

The packaging is easily recyclable.

Tip: To help consumers dispose of the packaging correctly, it is advisable to include a disposal logo on the packaging. Go to www.wegeconwijzer.nl for more information.

APPENDIX D Interview notes WFBR, Marieke Brouwer

January 10th 2019,
Marieke Brouwer, Niels van Marle, Nikki Groote SchaarsbergHet model van Marieke
Model is only reflecting on consumer waste, amount in Kton
Number is a combination of source separation and separation after collection, calculations are in these 2 separate streams.

Model uses a basic set-up of sorting and recyclng facilities, a different set-up would have big influence on the sorting efficiency and the quality of the recycling output

For example, more flake separating steps placed after each other would show a higher quality in output.

One separation step would have a 50/50 separation, if you would do the same batch again, it would show a much cleaner separation.

Numbers of Nedvang are used for the amount of PMD that is collected, this is rough data, including pollution.

Next to this, data of sorting facilities is used, for PET, PP, PE, Mix, focusing on the weight of the bales (Nedvang)

Insights from Suez & Schönmacher are obtained for the sorting distribution
CBS provides waste data (MSW)

The separation facilities that separate MSW provided info as well

Assumption is made that 6% of the PMD is rejected at the sorting facility.

WFBR research: average composition, made corrections for pollution etc.

The research scheme: the number at the recycling step shows higher amounts than the sorting steps, because there are also non-packaging resources in the recycling step.

Just like black colour, white colour also has an influence on the recycling product, because when colouring this after recycling, the colour would get more pastel-like

Producers almost always ask for transparent material, because then they can completely determine the colour

Packaging types are separated into percentages, how much is a cap, how much is a label, how much is a bottle in percentages of the weight

Transfer coefficient sink/float of shredded material

From the collection of consumer waste, there is 38% from PMD,
20% from MSW, 80% of MSW is not separated.

PET bottle that has a deposit system is not incorporated into this model, different data available. 5 Kton large PET bottle is collected in consumer waste, 28 Kton from deposit system.

The future proofness of this data: in the future more consumer plastic waste will be collected, quality is going down a little bit, but the output of recycled material is the same. VANG Policy has influence, because focus on weight instead of quality.

APPENDIX E List of materials monitored by WFBR research

E - List of materials monitored by WFBR research

PET bottle clear ≤ 0.5 litre
PET bottle coloured ≤ 0.5 litre
PET bottle clear > 0.5 litre
PET bottle coloured > 0.5 litre
PE beverage bottles
PP beverage bottles
PS beverage bottles
Misc. beverage bottles
PET non-beverage bottles
PE non-beverage bottles
PP non-beverage bottles
Misc. non-beverage bottles
PET thermoforms & rigids
PE thermoforms & rigids
PP thermoforms & rigids
PVC thermoforms & rigids
PS thermoforms & rigids
Carriage bags (PE) > A4
Carriage bags (PE) < A4
PET flexible packages > A4
PET flexible packages < A4
PE flexible packages > A4
PE flexible packages < A4
PP flexible packages > A4
PP flexible packages < A4
PVC flexible packages > A4
PVC flexible packages < A4
PS flexible packages > A4
PS flexible packages < A4
Rigid packages made from non-NIR identifiable plastics
Flexible packages made from non-NIR identifiable plastics > A4
Flexible packages made from non-NIR identifiable plastics < A4
Misc. plastics (PC, PLA, etc.)
Laminated flexible packages and blisters ---> bijna allemaal laminaatfolies, heel klein beetje door-drukstrips voor kauwgom en medicijnen (zie ook laminaten rapport van mijn collega's).
EPS trays
EPS blocks
Silicone tubes
PET non-packages
PE rigid non-packages
PE film non-packages
PP non-packages
PVC non-packages
PS non-packages
non-NIR identifiable non-packages

APPENDIX F Interview Afvalfonds Verpakken, data collection

Gesprek Afvalfonds 20-11-2018 (In Dutch)
Coen Bertens, Niels van Marle, Nikki Groote Schaarsberg
Duidelijk onderscheid huishoudelijk afval & bedrijfsafval
Afvalfonds grotere inzage huishoudelijk afval, industrial waste slechts globale cijfers.
Meetpunt collect: Nedvang via wastetool (gegevens van gemeenten)

8 stromen gedefinieerd
- Inkomend bedrijf
- Inkomend gemeente
- Inkomend andere afvalbedrijven
- Stroom naar recycler
- Stroom naar energie
- Naar andere afvalbedrijven
- Glas geaccepteerd door recycler
- Glas naar energie

Meetpunt sortering: info van sorteerders
Wat er wordt afgeleverd aan poort van recylers (PET, PP, PE, mix)
Meetpunt recycling: alleen van glasketen info
In data uitsplitsing materiaalstroom PMD – plastic, metaal, drankkarton
Eenheid van data = gewichten

Vanuit afvalfonds belangrijk dat data niet traceerbaar is, en dat het in zekere zin geabstraheerd is, zodat niet alles terug te rekenen valt tot gevoelige informatie
Recyclers geven vaak aan dat input vanuit sorteerders vervuild is (20/30% wordt genoemd)
Afvalfonds neemt jaarlijks 1100 monsters, 1 monster is zo'n 20% van een baal, hier wordt dan gekeken naar kwaliteit van baal
EU doelstellingen om meetpunt na recycler te leggen is nog ter discussie, dus nog niet geïmplementeerd in NL
Aandachtspunt zijn correcties in monitoring, op meetmoment van sortering (niet verpakkingen, vervuiling).
Strenge controles op monitoring & meten, http cyclos
Belangen en gevoeligheden hebben invloed op betrouwbaarheid van data & uitkomsten data
Gemeenten hebben belangen bij de metingen van collectie (zo laag mogelijke gewichten), sorteerders belangen bij meetmoment sortering (zo hoog mogelijk rendement in sorteringsproces)
Monitoringsrapportages jaarlijks, input van 2017 mogelijk te gebruiken in eerste dummie (vertrouwelijk)
Inbrengen project afstemmingsoverleg Afvalfonds (Chris, Kees)

APPENDIX G Interview TU Delft - Resources & Recycling

H – Interview TU Delft – Resources & Recycling
Notities 16-11 Gesprek Peter Rem TU Delft (In Dutch)
Systemen van virgin polymeren & recyclesysteem niet op elkaar aangesloten, competitiestrijd, belemmering, deels door niet gestandaardiseerd systeem. Opstelling van normen vanuit virgin polymeren waar recyclaat niet aan kan voldoen.

De voordelen van € als eenheid voor berekeningen model
- Als kunststof fysieke eigenschap mist: daalt waarde, of meer materiaal nodig om zelfde effect te bereiken
- Prijs marktwerking ingebakend – als aanbod materiaal groter is dan de vraag daalt de prijs

Prijs recycled plastic daalt als er geen vraag is voor toepassing
Juist ook waardevol om massa & € als eenheden naast elkaar te laten zien, omdat hier vaak grote verschillen in zitten. Een kleine fractie kan nog een hoge waarde hebben na 1e cyclus, een zwaar materiaal als staal kan lage waarde hebben.
Bij gebruik van data spelen jaar en land een belangrijke rol. Wat in het ene land een stressed resource is (bv water) is in een ander land momenteel geen probleem.

Transparantie bij aannames is heel belangrijk. Dat is precies wat er vaak mis gaat bij LCA's, waarbij data gepubliceerd wordt zonder daarbij duidelijk de aannames te vermelden.

Voor welke situatie doet het model een assessment? Momenteel de transitie van lineaire naar circulaire economie.

Relevant voor milieudrukindicator: mogelijkheid om met geschatte getallen voor 2025 te rekenen.

Wanneer de energiemix in 2025 totaal anders is heeft dit grote invloed op de impact die het model weergeeft.
Ook de stand van technologie kan in de toekomst anders zijn en ook dit heeft grote invloed op bv recycle efficiency.
Vb laminaat 300 · voor 1400 €/kg
Versus mono materiaal 700 · 2500 €/kg
m· dikte / prijs / kilo's
prijs / m· goede indicator

Data CBS:
Sector besteding binnen andere sectoren (matrix)
Dashboard input circulariteitscheck
Onderbouwing om food waste niet als kwantificeerbare data mee te nemen
- Food waste heeft een grote impact op het totale cijfer
- Data moeilijk verdedigbaar, groot risico op verkeerd/anders interpreteren

Daarom raadzamer om bijvoorbeeld aan te geven acceptabel/niet acceptabele verpakking
Een verpakking met 30% productverlies is niet acceptabel, dat kan als food for thought worden meegegeven aan de gebruiker (kwalitatief ipv kwantitatief)

Positief van tool:
Discussies op gang brengen, kaders schetsen: transparantie
Daarom is het geven van 1 getal gevaarlijk, maar een combinatie van indicatoren kan wel

Met beperkte info > gebruiker duiden op problematiek
Een complexere, meer uitgewerkte variant (versio 2.0) zou mogelijk wel 1 getal kunnen geven, dat is nu niet haalbaar & wenselijk

De eerste gebruikers zullen zich moeten beseffen dat ze werken met een engine in ontwikkeling
Jan Paul van Soest (CvOE, LCA expert, pragmatisch) waardevol als adviesgever voor back-end van de engine
Nog terugkoppeling met Peter Rem na overleg met Di Maio over mogelijk gebruik CBS data
Mogelijk maart Master Thesis student uit Bologna focus op datagebruik

APPENDIX H Interview questions usability test

Gebruikerstest Beoordelingskader Duurzaam Verpakken
Structuur:
- **Inleidend gesprek; vragen**
- **Testen van tool**
- **Reflectie**

Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?

Wat doet bedrijf aan duurzaamheid/verduurzaming?

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?

Welke vragen zou je graag beantwoord zien in een beoordelingstool voor duurzaamheid

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?

Hoe vaak denk je de tool te gaan gebruiken? (Welke andere mensen in bedrijf tool gebruiken? (functies)

Extra: bekend met recyclecheck?
(Deze voorkennis heeft waarschijnlijk invloed op hoe soepel die wordt doorlopen, eventueel pdf met achtergrondinfo nodig)

Testen van tool
Inleiding: Alleen vormvaste kunststoffen staan erin, beperkte keuze-mogelijkheid.?]
Doel van testtool is gebruiksvriendelijkheid, kennisoverdracht testen, werking modulariteit,

Reflectie:
Eerste reactie? ...

Wat heb je geleerd, wat kan je met deze informatie?

In hoeverre helpt het jou en bedrijf om stappen te zetten?

Helpt het om genoemde dilemma's op het gebied van duurzaamheid te verhelpen?

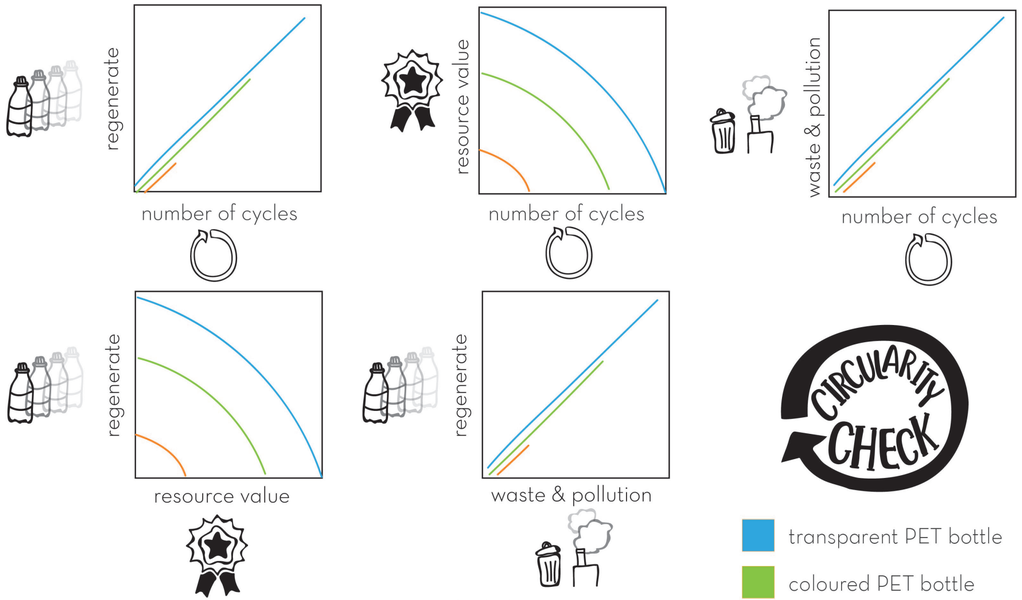
Welke stappen zou je naar aanleiding van deze tool zetten?

Wat ontbreekt er naar jouw idee?

Wat heb je nodig om verduurzamingsstappen te zetten en onderbouwen?

APPENDIX I

Iterations on indicators



closing loops = (material x regenerate - waste)$^{\text{number of cycles}}$ x resource value

regenerate = amount of material that is collected, sorted, recycled

waste = amount of material that is lost in sorting & recycling process

CIRCULARITY CHECK

transparent PET bottle

coloured PET bottle

black PET bottle

Kennisinstituut Duurzaam Verpakken

Transparent PET bottle 0,5 L

M= 100 kg clear PET

Cap (HD)PE

Material profile transparent PET

Rx = 0.92
Wx = 0.05
X^n = 2

Input: 100 kg clear PET. 92 kg is collected, sorted & recycled. From this 92 kg collected PET, 5 kg is lost
Output after one cycle (n=1) = 87 kg

CL = ( **)**

closing loops = (regenerate - waste)$^{\text{number of cycles}}$ x resource value

regenerate = amount of material that is collected, sorted, recycled

waste = amount of material that is lost in sorting & recycling process

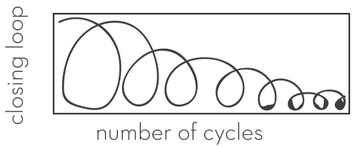
CL = (M · Rx - Wx) ^n x RV
CL = (M · 0.92 - 0.05) ^2 x RV =
CL = (M · 0.92 - 0.05) ^3 x RV =
CL = (M · 0.92 - 0.05) ^4 x RV =
CL = (M · 0.92 - 0.05) ^5 x RV =

RV influenced by colour & number of cycles.

RV (n=1) = 0,9
RV (n=2)= 0,9
RV (n=3)= 0,9
RV (n=4)= 0,4
RV (n=5)= 0,1

CL = closing loop formula
M = material input
Rx = regenerate indicator
Rx = R_{own} + R_{other} + R_{energy}
Wx = waste indicator
X^n = where n is number of cycles
CL = (M · Rx - Wx)^n x RV

Material stream gets smaller after more cycles



Data per material needed to generate:

Rx
Wx
RV
X^n

APPENDIX J Interview usability test - Remia

K – Interview usability testing - Remia (In Dutch)
Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?
Judith van Voorthuizen – Verpakkingstechnoloog (Industrial Design Engineering UT, packaging)
Willem Landman – Inkoop
Samen ook 'team duurzaamheid' als extra taak

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Bezig met ontwikkelen van duurzaamheidstrategie
Al uitgevoerd: Quickscan, doorlichten van verpakkingsportfolio, bekend met recyclecheck
Opmerking; Remia als familiebedrijf -

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?
Gebruikers zijn samen verantwoordelijk voor verpakkingsportfolio en verduurzaming, opstellen van strategie,

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
Focus voornamelijk op recyclebaarheid, circulariteit te ver weg en niet echt haalbaar op dit moment voor Remia. Want: herbruikbaarheid kan niet echt, en eigen materialen zijn na 1 cyclus ook niet meer geschikt voor voeding
Tegenstrijdigheid; labels moeten volgens recyclecheck zo klein mogelijk zijn, maar voor wetgeving voedsel en warenautoriteit mag de tekst erop weer niet te klein zijn en moet je allemaal verplichte informatie vermelden

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?
Verwerkbaarheid (fles moet knijpbaar zijn, mag niet te dun zijn, warm afvullen, houdbaarheid, etc)
Uitstraling; rPET dof, viezig als je er mayonaise in stopt
Kosten

Remia beschouwd samenvattings pagina als zeer waardevol, samenvattende representatie van verpakkingsafwegingen. Wat naar hun idee nog ontbreekt is ergens een reminder: wat zijn de functionele eisen waar de verpakking aan moet voldoen
Alles in 1 pagina op te slaan, te printen (pdf rapoortje), dit is een goed praatmodel voor afstemming met bv marketing – hiervoor is de radarplot ook heel waardevol, maar hier mag je dan echt niet vergeten waar verpakking aan moet voldoen -
Verder
EU focus (of nog breder)
Bedrijfsafval meenemen in data

Gebruik van tool evaluatie vs design
Juist dat laatste is handig als mensen er niet veel verstand van hebben
Dan maakt het systeem alvast slimme keuzes voor ze

Voor nu: Tool levert goede handvaten, goed communicatiemiddel (goede praatplaatjes), visualisatie van data heel waardevol

RV & milieudruk koppelen? Kan dat?

Remia merkt op; verantwoordelijkheid wordt nu sterk bij PI's neergelegd, maar naar idee van Remia toch ook juist stappen te maken bij sorteerders & recyclers, recyclebaar zijn, dat is iets van de producent, maar dat het daadwerkelijk gebeurd, dat is aan de sorteerder

Beleid & focus heeft veel invloed op interpretatie van resultaten (en daarnaast dus ook de eisen die je aan je verpakking stelt, want een houdbaarheid van 12 maanden is anders dan 3 maand – export van saus lastiger, warm transport, vervorming van kunststof.)

Verwachting is dat Remia de tool regelmatig gaat gebruiken, zeker in het begin. Handig om het hele verpakkingsportfolio een keer door te lichten en in aart te brengen. Handleiding voor gebruik is wel handig, zeker als collega's die iets minder van verpakking weten (als bv wordt marketing genoemd) de tool gaan gebruiken.

APPENDIX K Interview usability test - Marqt

L – Interview usability testing - Marqt (In Dutch)
Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?
Ariane Kaper, impact & kwaliteit + stagiair voedingsmiddelentechnologie

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Beleid verpakkingen focust zich vooral op gezondheid, food waste tegengaan en zo min mogelijk verpakken & zo min mogelijk verpakkingsmateriaal gebruiken – voorkeur voor papier en rPET 'bijna alles is wel in ofwel papier ofwel rPET te verpakken', voor andere keuzes moet een goede reden zijn.

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?
Impact & kwaliteit, verpakkingsontwikkeling gebeurt nooit bij Marqt zelf, ofwel bij producenten van eigen merken die in Marqt liggen, of van huismerk producten, in overeenstemming.

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
Belangrijkste dilemma dat wordt genoemd zijn kosten. Voorbeeld van aluminium bakje (voor ready-meals) waar ze eigenlijk wel vanaf willen, maar de alternatieven zijn zo veel duurder, de klant heeft niet de bereidheid om daar voor te betalen.
Ander voorbeeld, groente afdeling, kunststof tasjes verruild voor papieren zakken, qua inkoop duurder, en klant denkt ook nog dat die minder stevig zijn waardoor ze er vaak 2 omheen doen en ze dus ook nog sneller op gaan.
Geprobeerd om groente en fruit onverpakt te verkopen, maar met het oog op logistiek, klimaat in winkels en handeling, was dit geen succes, veel productuitval.
Ook schapruimte wordt genoemd, collomoduul standaarden, het moet wel allemaal in hetzelfde kratje passen, aanpassingen zijn altijd veel werk, dit is een barrière om verduurzamingsstappen te nemen. Ook de esthetica speelt mee, het moet er wel lekker uitzien, het product moet wel verkocht worden.

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?
Bovengenoemde voorbeelden, kosten, haalbaarheid, bereidheid van klant, hoeveelheid werk

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?
Momenteel gebruikt Marqt basis LCA's van elke materiaalgroep (glas, papier/karton, kunststof PP, PET, PE, metaal) als richtlijn ordegrootte.

Hoe vaak denk je de tool te gaan gebruiken? (Welke andere mensen in bedrijf tool gebruiken? (functies)
Meer als achteraf check, eerder gebruikt door de leveranciers en producenten van Marqt dan wij zelf, wellicht wel als extra check (maar meer geïnteresseerd in de uitkomsten van de tools.)
Niet bekend met recyclecheck, daarom veel informatie nodig om de tool te doorlopen.

Reflectie:
Erg veel voorkennis nodig, meer uitleg nodig om er soepel doorheen te lopen.

Wat heb je geleerd, wat kan je met deze informatie?
Met nodige extra uitleg, meer inzicht gekregen in huidige dynamiek keten. Bv dat PET trays op dit moment nog helemaal niet gerecycled worden.

In hoeverre helpt het jou en bedrijf om stappen te zetten?
Heel fijn om visueel bewijs te krijgen van dingen die we onbewust al als vuistregels gebruiken. Dat bepaalde kunststof verpakkingen bijvoorbeeld net zo goed uit de test komen (omdat milieu-indruk lager ligt dan glas, dat vinden we belangrijk)

Wat ontbreekt er naar jouw idee?
Meer uitleg zou fijn zijn, maar dan vooral voor de producenten van ons. Wij willen liever gewoon direct de radarplot zien, met de meer diepgaande grafieken daar dan achter.

Gevaar kan zijn dat de radarplot, omdat het nu een score van 1-5 geeft, al snel niet genuanceerd wordt vergeleken. Als glas een 5 scoort en kunststof een 4, dan wordt de 4 als prima ervaren, verbetering blijft dan ook uit.

Uit deze testsessie kan worden geconcludeerd dat de visuele output als waardevol communicatiemiddel wordt gezien, het laat snel aan andere partijen zijn waar overwegingen op gebaseerd zijn, het vat fijn samen. Vooral als producenten een keuze maken en deze naar Marqt toe onderbouwt met een 'rapport' uit een van de tools. 'Omdat die optie dan waarschijnlijk ook gewoon het goedkoopst is', aldus Marqt.

APPENDIX L

Interview usability test - Burg Groep

M - Interview usability testing – Burg Groep (In Dutch)
Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?
Mees Bakker, thesis student – science, business, innovation VU Amsterdam

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Strategic vison for 2035: 100% renewable resources, responsible product use, energy neutral production, transparency and openness

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?
Research into innovation of primary packaging
Developing ambitions & strategy

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
Produceren voor private label, stakeholders doen aanvraag van product-verpakkingscombinaties
Maar als producent verantwoordelijk voor duurzaamheid van deze producten, afvalbeheerbijdrage

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?
Bepaalde productgroepen gestopt, deels omdat ze minder goed liepen, maar ook omdat ze niet aansloten bij duurzaamheidsvisie voor 2035

Welke vragen zou je graag beantwoord zien in een beoordelingstool voor duurzaamheid
Sterk de behoefte om verpakkingen te vergelijken

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?
Quickscan uitgevoerd met KIDV

Hoe vaak denk je de tool te gaan gebruiken? (Welke andere mensen in bedrijf tool gebruiken? (functies)
Duurzaamheidsmanager, bij nieuwe innovaties en om te kijken wat startpunt is (portfolio doorlichten)
Als er vragen komen vanuit bedrijfsleven, kan Burg Groep advies uitdragen, als kennispartij

Ervaring met invullen recychecleck

Reflectie:
Eerste reactie?
Meer uitlegplaatjes zouden fijn zijn, bv bij afwerking: wat is een etiket, wat is een sleeve, wat is een full body sleeve? Dit is vaak bekend, maar dus niet bij elke gebruiker

Wat heb je geleerd, wat kan je met deze informatie?
Best demotiverend om te zien hoe het ervoor staat, en eigenlijk kan je nooit een volle driehoek halen,

In hoeverre helpt het jou en bedrijf om stappen te zetten?
Heel waardevol om meer inzichtelijk te krijgen wat er mee speelt, er zijn altijd voor en tegens, goed dat je dat terug ziet, helpt zeker om verpakkingen te vergelijken

Helpt het om genoemde dilemma's op het gebied van duurzaamheid te verhelpen?
Dit is een sterk communicatiemiddel waarmee we naar onze klanten kunnen stappen, sneller over de streep trekken om bepaalde keuzes te maken

Welke stappen zou je naar aanleiding van deze tool zetten?
Bij Burg Groep lijken verpakkingen heel sterk op elkaar, kleine nuances, dus om daartussen te kiezen heb je veel detaillering nodig in de tool

Wat ontbreekt er naar jouw idee?
Meer detail, bv semi-opaak (wel gekleurd, maar je kan er wel doorheen kijken)

Hoe vaak denk je de tool te gaan gebruiken?
Eerst huidige portfolio bekijken, waar staan we nu? Vervolgens gebruiken voor eigen innovatie, maar ook om vragen vanuit klanten te beoordelen op duurzaamheid.
N – Interview usability testing – Friesland Campina (In Dutch)

APPENDIX M

Interview usability test - Friesland Campina

Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?
Friesland Campina
Tim Mulder, Packaging engineer

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Portfolio analyse, doelen per divisie, strategie schrijven, keuzes maken aan de hand hiervan, LCA's om ze te onderbouwen.
Verduurzamingsstappen kunnen bij FC alleen vanuit een vraag vanuit 'business' worden gestart. Nu duurzaamheid in strategie is verwerkt, kan dat.

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
De alignment tussen verschillende afdelingen en divisies is lastig. Targets verschillen per afdeling, en deze zijn niet goed met elkaar afgestemd. Financieel krijgt altijd voorrang. Harde data helpt wel om soms opties te onderbouwen.

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?
Financieel & geen vraag vanuit business

Welke vragen zou je graag beantwoord zien in een beoordelingstool voor duurzaamheid
Op global level (wereldwijd) waarde die materiaal behoudt

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?
Respackt (eigen LCA tool) om zowel losstaande verpakkingen als hele portfolio's door te lichten

Extra: bekend met recyclecheck? Ja

Reflectie:
Fijn om de recyclecheck digitaal te doorlopen, dat is een stuk fijner dan in een pdfje. Zou waardevol zijn als er integratie met Afvalfonds zou kunnen zijn, dat gebruikers het bij jullie invullen en direct kunnen corresponderen naar Afvalfonds.

Wat heb je geleerd, wat kan je met deze informatie?
Wel even wat uitleg nodig bij de indicatoren, theoretisch aantal cycli niet zo relevant. Vooral resource value interessant, maar dan wel op wereldwijd niveau, daar hebben we voor alleen NL niet zo veel aan.

In hoeverre helpt het jou en bedrijf om stappen te zetten?
FC heeft al eigen LCA tool, die veel uitgebreider is dan deze, dus dat voegt niet iets toe. Recyclecheck digitaal voegt wel iets toe, vooral als je daar ook een 'rapport' van zou kunnen downloaden als bewijs naar Afvalfonds.

De getoonde data is wel sterk afhankelijk van strategie, als reuse belangrijker wordt dan recycle, dan slaan de uitkomsten wel volledig om.
De verlies indicatoren zeggen weinig, voor gevoel buiten macht van FC, meer een probleem van sorteerders en recyclers. Als je al transparant PET hebt gekozen, en er is alsnog verlies, dan kan je daar verder niet veel meer aan doen.
Wat kan ik dan nog doen om circulariteit te verhogen? Welke indicatoren moet ik dan aanpakken? Hier meer hulp bij zou fijn zijn, dus niet alleen evaluatie van ontwerpkeuzes, maar ook sturende richting, wat kunnen we doen?
Voor grotere bedrijven is toch vooral de resource value van belang, maar dan wel grensoverschrijdend, dus niet alleen voor NL, maar juist internationaal. Die heeft FC zelf al 'redelijk scherp' naar eigen zeggen.
Meer details van andere stromen zou ook fijn zijn, in welke stromen belanden materialen en wat betekent dit?

APPENDIX N

Interview usability test - Superunie

O – Interview usability testing – Superunie (In Dutch)
Inleidend gesprek:
Wie zit aan tafel; functie binnen bedrijf?
Cindy Verhoeven, Milieutechnoloog
Procesmanager Duurzame Handel

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Duurzaamheid van verpakkingen zat niet in beleidsplan, op dit moment bezig met strategie van duurzaamheid op verpakkingsniveau – ERP systeem gekoppeld aan specs van verpakkingen taxanomy van verpakkingen,

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?
Procesmanager bevind zich in de driehoek tussen inkoper, technoloog en marketeer

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
Inkopers leggen vraag neer bij leveranciers, niet altijd 'eerlijk' antwoord, moeilijk te bepalen wat nou beter is, moeten zelf verpakkingen toetsen op basis van huidige specs, data niet goed, leveranciers leveren info aan voor ERP systeem, zowel voor ingrediënten als verpakking, was in het verleden niet goed gestructureerd, niet alles stond in zelfde format (kunststof, plastic, meerdere benamingen etc)

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?
Nieuwe taxonomy gekoppeld aan ERP systeem, nieuwe verpakkingen moeten daar in het juiste format in, maar duurt dus wel een tijdje (oude producten stonden meer ongestructureerd)

Analyse van bestaande verpakkingen handig

Bekend met recyclecheck, al Quickscan uitgevoerd

Testen van tool

Reflectie:
Met de extra uitleg erbij wel duidelijk, maar zonder dat is het heel lastig om het te begrijpen
Stappen moeten duidelijker worden, verwachting is dat de inkoper het verschil tussen circulariteit en milieudruk niet weet.
Zou fijn zijn als de focuspunten meer gelaagdheid hebben, toelichting 'in het ideaalplaatje neem je al deze punten mee, praktijk weerbarstig'

Superunie vult focuspunten van CBL in (gewicht verminderen, gerecycled materiaal gebruiken, hernieuwbare grondstoffen)
Mist het stoplicht van Quickscan (wellicht te verwerken in recyclecheck, Cindy wil ook groene dingen zien die goed gaan)
Cycli indicator vaag, is dat als flesje? Of als iets anders? (hier is de uitleg bij, eigen keten, andere keten)
Duidelijker als resource value & cycli omgedraaid worden, dan zie je de waarde die het regenerate materiaal nog heeft
Wil exacter weten hoe dat verlies tot stand komt, waar zit dat m in (sortering & recycling)

Mist een soort eindconclusie, wat gaan we dus doen? Strategie?

APPENDIX O

Interview usability test - Tony Chocolonely

P – Interview usability testing – Tony Chocolonely (In Dutch)
Inleidend gesprek: Wie zit aan tafel; functie binnen bedrijf?
Berend,Marketing,Liese,-Sources,- Kwaliteit, Joost, Inkoop

Wat doet bedrijf aan duurzaamheid/verduurzaming?
Sterke focus op impact maken in de chocoladebranche, eigen CO2 impact zo klein mogelijk

Welke rol speelt gebruiker in verduurzaming binnen bedrijf?
Binnen Tony is iedereen bezig met impact maken, inkoop richt zich vooral op eerlijke koop, marketing richt zich op hoe dit verhaal wordt overgebracht in de industrie

Welke dilemma's ervaar je binnen jouw bedrijf op het gebied van verduurzaming?
Subjectieve meningen van leveranciers, moeilijk te peilen wat nu beter is, en wat gevalideerd is
Perceptie van de consument is ook vaak anders dan dat echt waar is
Uiteindelijk is de operationele haalbaarheid ook belangrijk, en de kosten die hieraan verbonden zijn

Welke factoren hebben meegespeeld om wel/niet duurzaamheidsstappen te zetten in het verleden?
Willen graag stappen zetten, maar weten nog niet zo goed wat de juiste zijn, en met drastische veranderingen [die impact hebben op productie, product, alles wacht je dan toch liever tot je zeker weet dat het de beste optie is

Welke vragen zou je graag beantwoord zien in een beoordelingstool voor duurzaamheid
We willen graag de opties van leveranciers eerlijk kunnen vergelijken, zodat het allemaal wat objectiever wordt, we willen ook aan onze consumenten kunnen laten zien welke afwegingen we maken en waarom we voor dingen kiezen – als dat dan kunststof is (omdat het het beste is), dan kunnen we dat onderbouwen en uitleggen zodat de consument het begrijpt

Hebben jullie eerder duurzaamheidstools gebruikt? (Of nog in gebruik), ervaringen?
Nee – student van UT heeft een keer een LCA uitgevoerd, verder niet

Hoe vaak denk je de tool te gaan gebruiken? (Welke andere mensen in bedrijf tool gebruiken? (functies)
Bij elke nieuwe innovatiestap even peilen – verwacht is dat vooral sourcing (inkoop) de tool gaat gebruiken, dit dan vergelijken met wat leveranciers ons vertellen Nog niet bekend met recyclecheck.
Reflectie:
Eerste reactie?
Tony heeft erover nagedacht om zelf zo'n soort tool te maken, maar nu ze zien hoe tijdsintensief dit is, voor je er iets aan hebt, die ambitie niet meer echt. Graag de KIDV tool gebruiken.

Als we een verpakking met 2 componenten willen vergelijken met een verpakking met 1 component, hoe werkt dit? Mogen we dan waardes bij elkaar optellen?

Wat heb je geleerd, wat kan je met deze informatie?
Op dit moment nog niet heel handig voor ons, omdat we geen vormvaste kunststoffen hebben. Maar de tools zijn straks wel heel relevant, laat duidelijk de overwegingen zien die we moeten maken

In hoeverre helpt het jou en bedrijf om stappen te zetten?
Helpt straks heel erg, zowel om onze eigen kennis te vergroten zodat we beter kunnen plaatsen wat leveranciers ons aan info verstrekken, anderzijds wellicht ook om te communiceren naar onze consumenten.

Helpt het om genoemde dilemma's op het gebied van duurzaamheid te verhelpen?
Ja, zie bovenstaand

Welke stappen zou je naar aanleiding van deze tool zetten?
We zouden dan bv wel voor kunststof kiezen ipv papier & alu als hieruit blijkt dat dat veel duurzamer is

Wat ontbreekt er naar jouw idee?
Nieuwe innovaties (bv paperwise, iets specifieks) staan er natuurlijk niet in, terwijl dat vaak is waar we naar kijken, een samenwerking met leveranciers van specifieke materialen zou dus waardevol zijn om de tool verder te vullen met info – dat je als gebruiker een aanvraag kan plaatsen bij een leverancier van een materiaal om de specificaties aan te leveren zodat de tool dit mee kan nemen.
Ook een toekomstvisie zou fijn zijn, zodat we als Tony's zien wat eraan zit te komen, wat gaat er gebeuren in het systeem, wat is de verwachting? Bv dat PET trays nu nog niet gerecycled kunnen worden maar straks wel

Hoe vaak denk je de tool te gaan gebruiken?
Bij elke innovatiestap en als nulmeting

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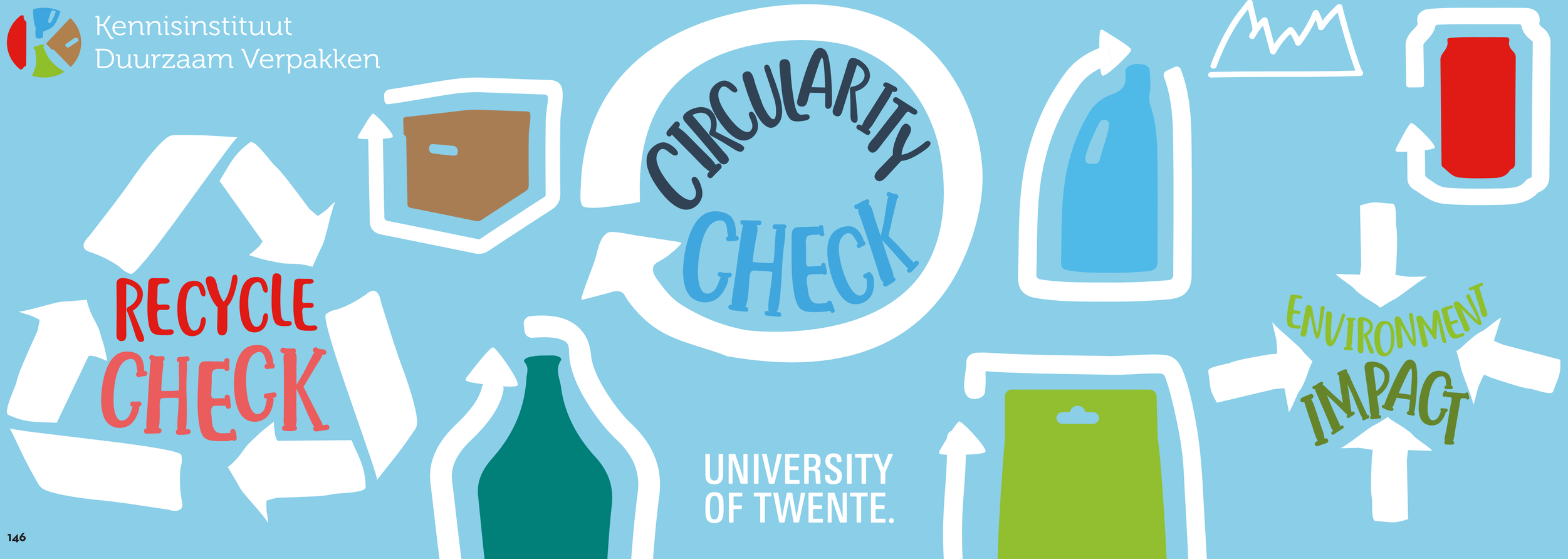

As a food producer, packaging is often an element you only start to think about after you know what product you will be packing and how you want to deliver this to consumers. The functions needed to protect, preserve and consume the product are leading here. When you want to improve the sustainability of your product-packaging combination, many questions might arise. The environmental impact of packaging seems major, but when trying to reduce this impact by reducing material, either the packaging becomes very complex and difficult to recycle, or the packaging is not fulfilling its function and food waste might occur. How do you then make substantiated decisions that are fitting your company's sustainability strategy and are supported by other team members?

This report is the result of a Master thesis that has been conducted to obtain the Master of Science (MSc) degree in Industrial Design Engineering at the University of Twente in the Netherlands. The research project has been performed at The Netherlands Institute for Sustainable Packaging (KIDV). This research aims at finding a method to support producers and importers of packaging in this matter and is thereby adapting to the request of the KIDV to develop a tool for producers and importers of packaging to evaluate packaging alternatives on multiple aspects of sustainability.

UNIVERSITY OF TWENTE.

Kennisinstituut Duurzaam Verpakken

BIG SCISSORS MOUNTAIN