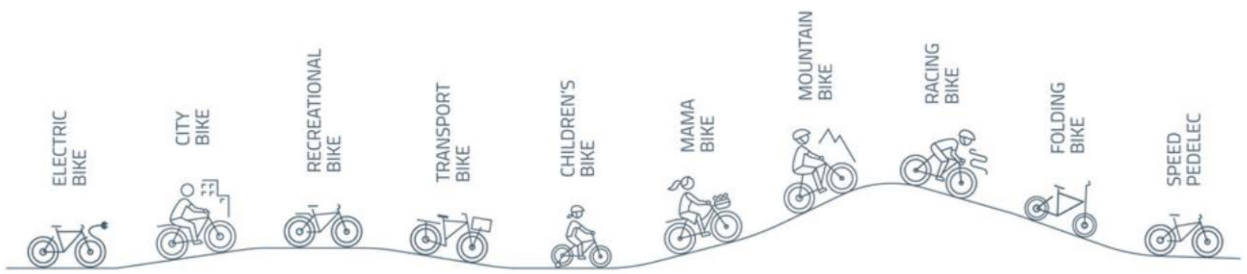
Appendix

Content

Appendix A - Portfolio

The product range of Accell consists of bicycles and bicycle part accessoires. Their bicycles are divided over 2 segments; sports & lifestyle. Accell's lifestyle brands are: Sparta, Batavus, Koga, Winora and Raleigh. The sports brands of Accell are: Haibike, Ghost and LaPierre. Thanks to their wide range brands, they can respond to the different needs and preferences of consumers in each country. This results in a very wide product range; from electric bikes to mountain bikes (or the combination of those, and from recreational bikes to folding bikes.



Koga is a premium brand with a sporty character. Since its foundation in 1974, Koga has been synonymous with the development and production of, that are both high quality and technically advanced. This international brand is built on continuous innovation and close relationship with top athletes and professional teams in the international world of competitive cycling.

KOGA

XLC (1988) is the global exclusive brand for Accell groups bicycle parts and Accessories. They develop a range of accessible and affordable parts and accessories for all kinds of bicycles; road, mountain and urban. Accessoires vary from bicycle bells to handles, and from bicycle lights to tire repair kits.

XLC x-cellent bike components

Lapierre stand for top sporting performances and top quality with a touch of french panache. They develop bikes for the the road, mountain bikes urban bikes and electric bicycles. All the LAPIERRE bikes are assembled in France by builders, who sign a Bike Pass that is delivered with each bike, and makes it possible to control quality at every stage of the assembly process.

LAPIERRE

Haibike invented the e-mountain bike (e-mtb). They produce a range of sports bikes, with a focus on e-performance models. The international product range varies from sports bike for everyday users to top quality professional racing bikes, together with special purpose racing and mountain bikes for downhill, freeride and cross country cycling.

Sparta is a Dutch brand with its origin in Apeldoorn. Sparta also used to manufacture mopeds and it was the largest producer of motorcycles in the Netherlands in the post-war years. Now they are focussed on the electric bicycle market, and considered pioneers. While working continuously on technology driven product development, they simultaneously explore new target groups and new market segments for e-bikes. The use of internet of things make the e-bike range particularly attractive to the modern city cyclist.

Batavus has been around for 116 years and is one of the strongest and best known Dutch bike brands. Bicycles from this brand are developed for a broad range of segments; electric, city, tour and child segment.

Babboe is a Dutch cargo bike brand developed for parents. Babboe sells both non-electric and electric cargo bikes with two or three wheels and is active around the globe.

Appendix B - Semi-Conducted Interviews; Interviewing employees from Accell

Interview plan (using guidelines from Adams, W.C. (2015))
Sensitize the participant
Introduce yourself
Introduce the project
Building rapport
Evoke stories
Exploring emotions - Why is that important to you, how do you feel about that?
Wrap up

Elements of attention during the interview;
General tips;
Ask: Why?
80 / 20 talking participant / interviewer talking
Embrace silence

Interview Questions
Could you give me an introduction about yourself and your position within AccellGroup?
What do you enjoy most about your job?
Can you talk me through your work process? Draw on paper immediately
Do you think about sustainability in your working method of this process?
Do you think sustainability receives enough attention within Accell?
Do you feel space to make a positive contribution to sustainability within Accell?
Besides your own job, do you have any ideas about how sustainability can play a role within the PDP?
What would help you, within the role you have at Accell, to develop a more sustainable product?

Adams, W. C. (2015). Conducting Semi-Structured Interviews. Handbook of Practical Program Evaluation, 492–505. https://doi.org/10.1002/9781119171386.ch19

Appendix C - Interview Mark Groot Wassink

B. Interview Mark Groot Wassink

My name is Martijn Stolk, master's student of strategic product design at TU Delft. Currently I am graduating in securing sustainability in the design process of Accell bicycles.

When I started to study Accell & Sustainability, I was not yet familiar with the company you founded; Roetz. Good to see cycling get a second life! Because of your experience and expertise in making the bicycle industry more sustainable, I would like to ask you some questions.

Sustainability & Cycling

What do you see as the big differences in design requirements regarding sustainability between;
Design for a linear economy (classic long life model)
Design for a circular economy (performance model)
What are the biggest challenges for the design of circular bicycles?

And what can be started tomorrow?

Sustainability & Corporate Culture

You are the founder of Roetz, now working at Auping. Do you have any tips for creating movement within a larger organization?

Sustainable design can be validated in a design process by means of (internal) quantification. Let's take as an example; plastic A is labeled 1 (highly recyclable) and plastic B is label 4 (difficult to recycle). Do you think such a validation system has potential, or takes away the creativity of the designer? In other words; bottom up strategy (providing methods that facilitate sustainable considerations) or top down (where checked for design choices)

Last question; Do you have any tips?

Appendix D - Research lifecycle bicycle

Production

The Accell production process consist of assembling bicycles from parts and painting bicycles. They do this in three main locations in the Netherlands, Hungary and Turkey. In addition, they have a number of smaller production sites in key countries, such as France and Germany, particularly for more specialised (high-end) bicycles.

The diagram [on the right page] visualizes the production flow, starting from the bike plan, ending at delivery at the customer.

1. Bicycle plan fully developed

2. Parts ordered & produced at supplier

From interviews performed with various Accell employees, it appears there are no environmental component requirements taken into account in the selection of the supplier. Focus is on reliability of delivery, on cost price and quality of materials.

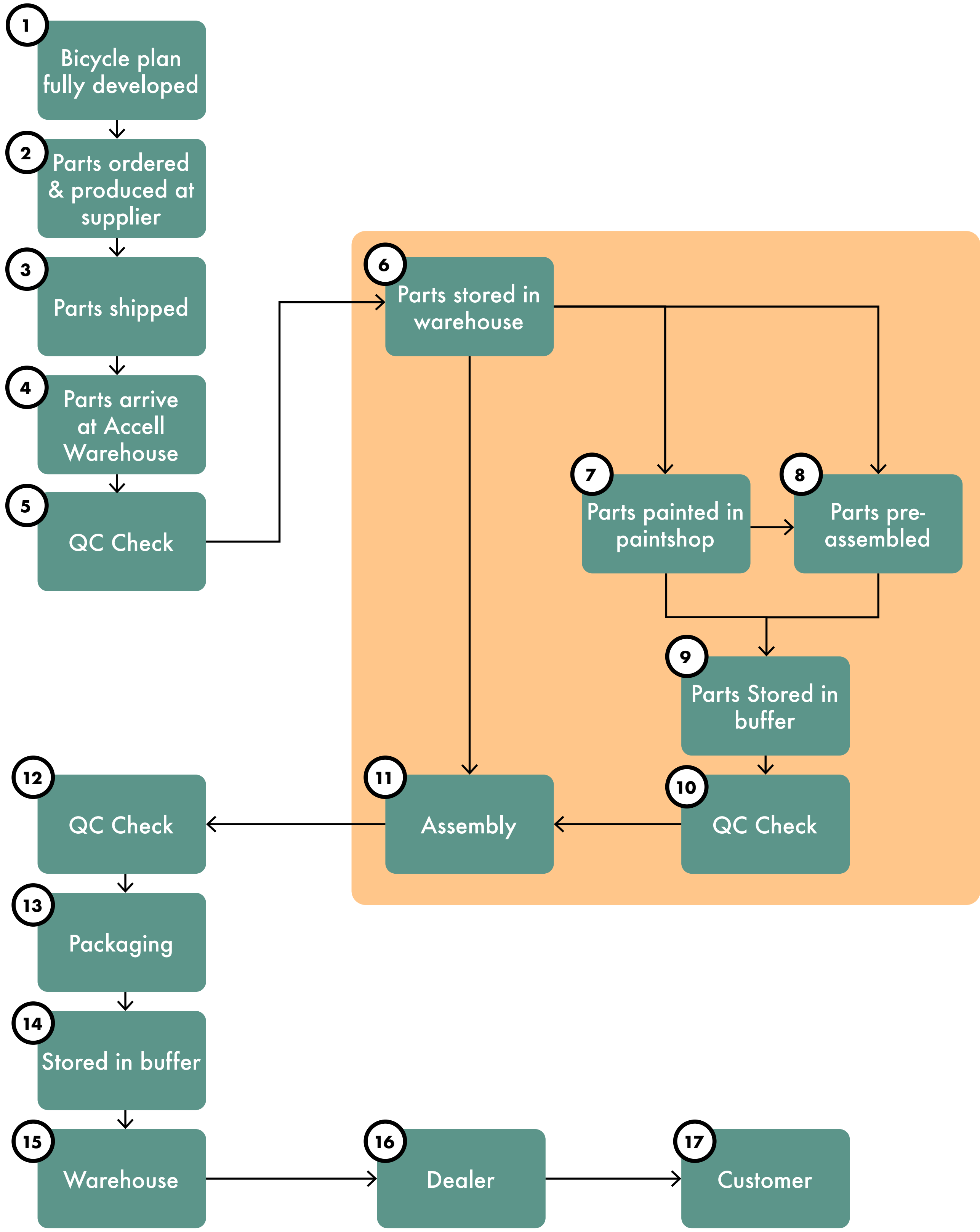
There are employees performing supplier audits, but these focus for now on human working conditions. These negotiations are tough; suppliers react fierce to for example lower working hour demands, because of fear their employees will move to alternative companies

Establishing contact with one of the main frame providers gave the insight that all the aluminium used was virgin aluminium, 0% recycled.

3. Parts shipped

Parts get shipped from all over the world to Accell. In 2019, Accell defined a new set of sustainability targets for 2025 in relation to shipping; 50% reduction of SU plastics in transport packaging from their suppliers;

Although the CO2 produced by shipping the parts is also of impact to the environment, the LCA from 2018 shows the embodied impact in the materials and assembly far exceed this.

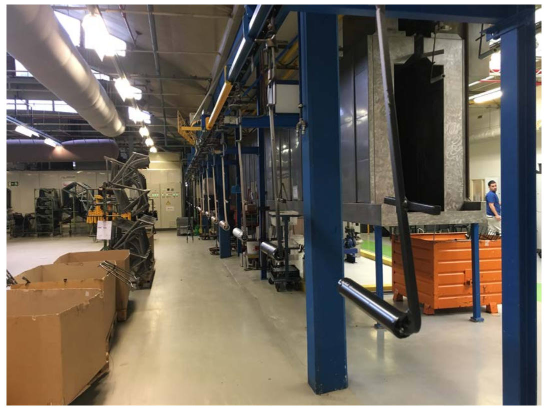


4 Parts arrive at Accell warehouse

5 QC Check

6 Parts stored in warehouse

7 Parts painted in paintshop



By hanging the components on a rail, an automated system gets the components washed, dried, and sprayed in the assigned color.

This rail moves the parts through a fully automated large scale surface treatment line and improves the paint adhesive force to the production service.

Because the paint is charged with a high voltage, the spray bends towards the bicycle parts, spilling very little paint during the proces. Next to a financial advantage, this reduces impact on the environment aswell.

8 Parts pre-assembled

9 Parts stored in the buffer

10 QC check

11 Assembly

Depending on the brand, the assembly is performed in a different manner. For Sparta and Batavus bicycles get assembled by an assembly line, consisting of multiple employees who assemble each different parts of the bicycle (up to 15 steps). With the koga bicycles, assembly is performed by a single person.

Part of the assembly includes the assembly of the wheels. All spokes are with the help of a machine attached to the rim to ensure to ensure the right tension.

12 QC Check

13 Packaging

In the sustainability targets of 2025 a target of 100% SU plastic-free packaging of Accell bicycles, parts & accessories is set for the packaging that Accell is responsible for.

14 Stored in buffer

15 Warehouse

16 Dealer

17 Customer

Use

One of the core principles of the circular economy, is creating products and systems that have a long life-time. The longer a product functions, the less products have to be produced.

The bicycle is a product that often has a second (or even third and fourth) user.

Accell does have requirements for the lifespan of a bicycle. These requirements depend on the type of bicycle, and largely on the user characteristics. Normally a bicycle is used outdoors; this means that the bicycle must function in all kinds of weather and on all road surfaces. The user can store or park the bicycle either indoor or outdoor. The parts and assemblies are produced and shipped all over the world. The products must be able to withstand these conditions.

Accell defines 5 types of bicycles;

1. Youth bicycle
2. Young adult bicycle
3. City / Tracking bicycle
4. Racing bicyle
5. Mountain bicycle

For young adult, city and trekking bicycles the expected useful lifetime is 10 years. Intensity of use differs per bicycle is high. For example, one of the users is the 'daily commuter', who lives outside the city and needs to cycle on daily bases a (long) distance to school under all weather conditions. The bicycle of the daily commuter is left outside for longer period and is not careful with his bicycle. The S-Epac (speed pedelec, bicycles with an electric motor that speeds up to 45 km/hours), is designed for a useful distance of 60.000 km.

The racing bicycle and different types of mountain bicycles are designed to last 6 years, with an expected useful distance ranging from 45000 to 25000.

End-of-use

After the bicycle has been re-used and repaired to continue offering value to various customers, it reaches the end-of-life. In the perspective of a circular economy, a more common term is end-of-use. The reasoning behind this term, is that the product won't transform into waste, but instead flow into another circular loop.

In the circular economy, there's two options left from this point.

The first is remanufacturing the components of the bicycle that still function by disassembling the bicycle and applying necessary treatments; such as sandblasting and re-painting the frame. Currently this isn't part of Accell's business. A company specialized in re-manufacturing bicycles is Roetz (more information in 2.1.2; circular strategies).

Impact on environment
At the time of writing this Thesis, Accell has no control over the End-of-Use of bicycles. Also in the recently launched leasing service of bicycles, the business model sells the bicycle after 3 years of leasing for a reduced price to a dealer. Interviews gave no insights in the end-of-use of bicycles, since this is simply not captured within the current scope of the company. What does is available is information from the LCA created in 2018. Not only contains the LCA Environmental impact from production and use, but also 'end-of-life'. The LCA mentions For all bicycles, the recycling of the metals, batteries and other waste processing reduces the environmental impact between 38% and 48%. It is not mentioned in the LCA where these numbers are based on. The data is expressed in 'eco indicator', a variable where 1000 Pt corresponds to the annual environmental footprint of an average European citizen. This indicator is outdated and replaced by three categories; Human Health, Ecosystems and Resources. But the company that performed the LCA thought the increased amount of graphs to express the impact (over these 3 categories) would create confusion by the reader, and therefore applied the subdued weighting procedure to come to one end point: the former eco-indicator. This means that the environmental impact of the categories Human Health and Ecosystems weigh 40% and Resources weighs 20% in the total impact score.

Recycling process

Interviews with Erwin de Keijzer from HKS metals and Thomas van den Haute from Sirris (belgium) gave insight in the recycling process of used bicycles. Unfortunately, both were unable to put numbers to the efficiency of recycling and the amount of material rewon. These numbers would help in determining the degree of circularity that can be achieved in the recycling process. However, they gave a detailed explanation how the bicycle processing takes form.

Collection takes place in various ways, namely the container park (environmental streets in the various municipalities) and the collection by private individuals at a scrap dealer.

When a bicycle is returned by a private individual to a municipal waste collection facility, this flow of iron (mixed metals) goes to the relevant scrap dealer / collector. This stream is often seen as a shredder pre-material.There are traders who strip this stream from the various metals such as aluminum, copper and other non-ferrous metals. Most of the times, a higher price is paid for mix metals (iron, non-iron metals) by the processor because of the larger share of non-ferrous metals. This batch is then offered at a shredder location.

The following steps are taken during the shredding process (the reduction of the streams so that post-separation can take place);

1. Shredding of the material

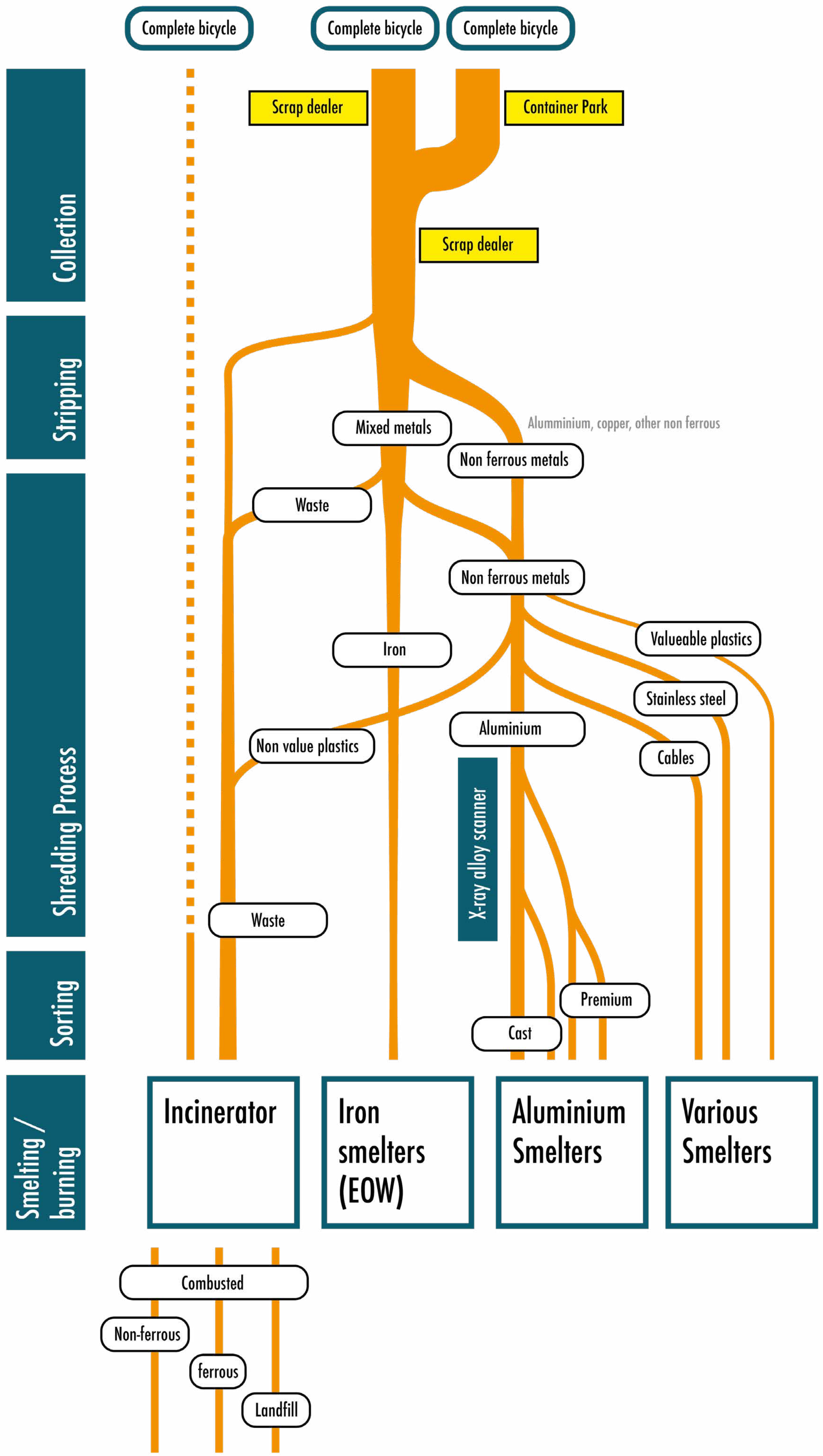
2. Separation of 'dirt'
This concerns light materials that can also contain any light non-ferrous metals.
After extraction, this dirt flow is still sieved and separated into a mineral fraction (0-10 mm) and a bigger fraction that in case of HKS goes into an eddy current. Here the non-ferrous metals are separated from the coarse dirt. These non-ferrous metals (predominantly low-alloy aluminum) are supplied to aluminum smelters.

3. Seperation Iron & Non-ferrous
After the material has been reduced, 2 material flows remain, namely iron and non-ferrous metals (which have not been extracted by the shredder installation). These currents are separated from each other by means of a magnetic roller in the shredder.
The iron is sold directly to smelters worldwide. This often goes away as EOW (End of Waste).
The Non ferrous metals together with the "heavy" dirt go through a conveyor belt line in the following processing process.

4. Seperation of Non-Ferrous
The non-ferrous metals and dirt are separated from each other by sieving technology, multiple eddy currents and color separation. Here is also a final hand sorting / check at the end. In the case of HKS Moerdijk, various flows from this bigger flow are separated from each other. For example, stainless steel, cable, aluminum and printed circuit boards are separated. The aluminum fraction is separated on alloy in a third phase by means of an X-ray separation. The premium grades are further separated here and sold directly to aluminum smelters worldwide. The cast aluminum types are sold separately to aluminum smelters worldwide. This is also often done via EOW (End of Waste).

5.Plastic seperation and incineration
The other flows, such as heavy dirt fractions, are further separated into various types of plastics. Plastics of value are separated. The final residual product goes towards incineration.

Bicycles or parts of them also go directly to incinerators. The non-ferrous and ferrous metals are also separated from each other there. There is a downgrade of the material through combustion, but the metals are not completely lost. For incineration scrap, there are several parties that do a further separation with these streams, from which also pure non-ferrous streams are created that are also supplied to smelters worldwide. These flows have a lower value because they have been burned.



Carbon composite frames

It is commonly estimated that around 30% of produced carbon fiber ends up as waste.
While the technology to recycle carbon fiber composites has existed for several years and is capable of yielding a product with mechanical properties very near that of virgin material, the composites recycling industry is relatively young and is still in the early stages of developing markets for the materials it produces from recyclate.

In the bike industry the material is used for light-weight high priced components. It takes about 20-30 labor hours to product a frame made from carbon composites.

Thermoplastic & Thermoset carbon composite frames

Thermoset uses a two-component resin that catalyzes and cross-links when heated, thermoplastics uses a resin that is re-melted.

With the production of carbon frames, the carbon fibers are kept in alignment by using a plastic matrix to achieve the properties carbon has; high strength, low weight. In the bicycle industry, two component epoxy are used as this plastic matrix. The benefits are that they are easy to shape and to mold, because of their sticky and pliable properties. Disadvantages in production is that after the two components are mixed, an irreversible reaction starts (hardening). To manage the time-sensitive nature of thermoset composite materials, the impregnated carbon must be freshly made, stored in freezers and used before a defined date.

Thermoset recycling

The most common recycling methodology for thermoset composites is pyrolysis. It is a thermic recycling process that is shown to be an efficient method for recycling carbon fiber composites in the form of both uncured prepregs scraps or as cured end-of-life objects. The pyrolytic process leads to different products in three physical states of matter. The gaseous fraction, called syngas, can be used as energy feedstock in the process itself. The oil fraction can be used as fuel or chemical feedstock. The solid residue contains substantially unharmed carbon fibers that can be isolated and recovered for the production of new composite materials, thus closing the life cycle of the composite.

In Germany for example such a recycling facility exists (CFK Valley Stade). These photos taken from the company video show the process; A bicycle frame made out of carbon reinforced fibers is put on the conveyor belt, without paint coat being removed.

During the process of pyrolytic decomposition, the thermochemical division of organic compounds takes place at temperatures of more than 500 degrees celsius. Long chained molecules are broken into smaller ones are broken through heat alone, without oxygen. The carbon fibers held together by long chain epoxy resin are split apart. High temperatures immediately send the smaller molecules into a gas phase.

Only the carbon fibers remain. These use of these fibers is not equal to the fibres used to produce bicycle frames. After processing they are used for injection molding of carbon-plastic products, saving up to 20% of weight compared to plastic products. The gases are captured end send into a special burner where they're burned to accelerate the pyrolysis process. If the process remains stable, no additional energy is needed. A built in flue gas cleaning system purifies the gases in accordance to german federal regulations.

Although this recycling methodology recovers the carbon fibers, they are 'downcycled' instead of 'recycled', serving a lower purpose than before. Furthermore, it burns the epoxy resin during the process. The resin ends to exist and toxic gases are released into the air.

Thermoplastics; Advantages and disadvantages

Using thermoplastics as a matrix instead of thermoplastics, has the potential of being 100% recycled by being able to re-use both the carbon and thermoplastic for new (bicycle) components. Although the cycling industry is not advanced yet in using thermoplastics for the production bicycle components, there are several initiatives starting up.

'Hyc-king', a taiwanese company, has successfully produced bicycle frames build from long carbon fibre reinforced thermoplastic composites. The thermoplastics raisins are created from materials as PPS, PA, PP and PC.

An even more local company; Rein4ced (Belgium) has gone a step further and is innovating the industry through the automatization of the carbon composite process. This enables them to compete with the hand work in Asia used in thermoset carbon composites. They developed a patented thermoplast composite that can be recycled and their service is available in Europe.
Accell is one of Rein4ced first clients. They initial contact was established through Haibike, and in a later stadium shifted to producing frames for the Ghost Lector. The main reason for collaboration was a characteristic of the rein4ced carbon composite; it's resistance to impact. Normally carbon fibre is sensitive to impact and although very light and strong, frangible. Because rein4ced uses next to carbon fibres also steel fibre in the composites, they claim their frame is 'unbreakable'. This partnership is very promising in the light of circular development; it is a very local company, the frames are made to last, and ultimately can be recycled. The disadvantage; at this stage the price is very dependent on volumes, which Accell cannot deliver within the current project of the Ghost Lector. Furthermore, Rein4ced is still in development phase. But potentially, because of the automated process, Rein4ced could compete with current production of frames in Asia.

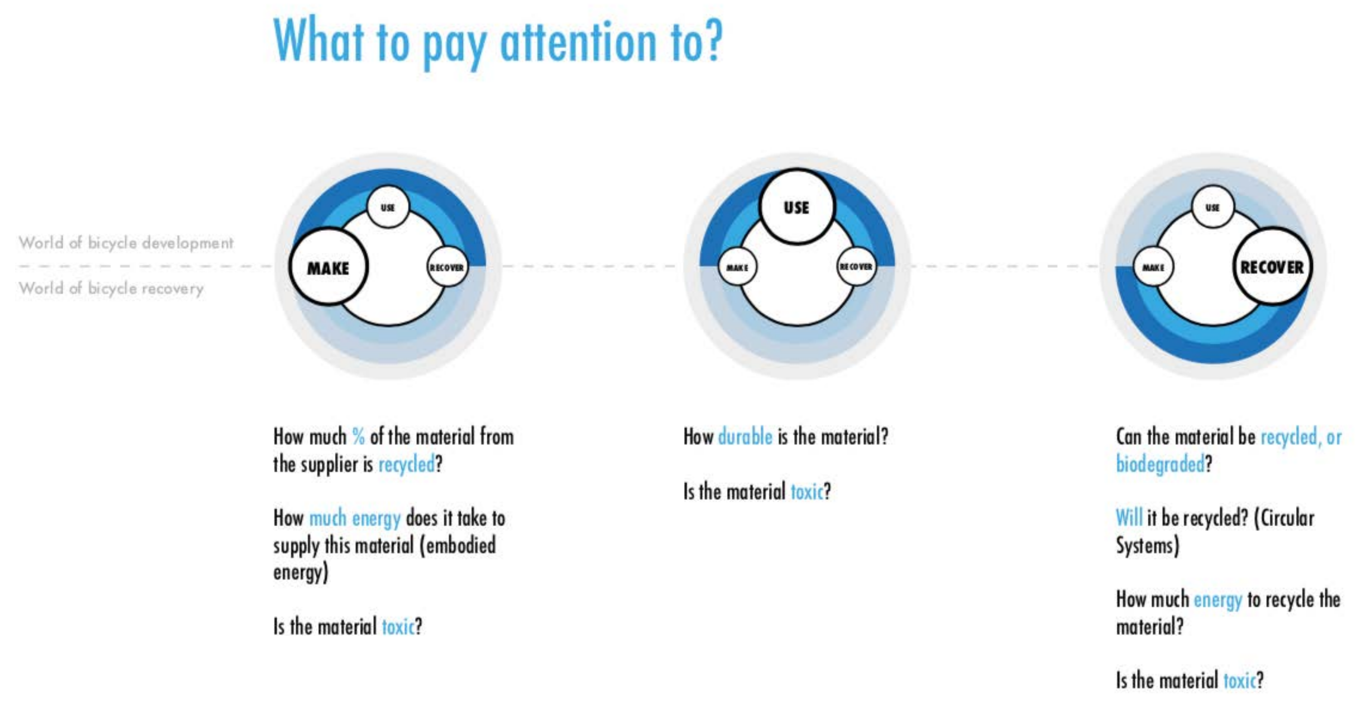
Appendix E - Circular Aspects Materials & Plastics

Do	Don't	Why?
Keep mold parts as big as possible (>>10mm)	Never mold too smal (<<10mm)	Products are shredded and grinded. Small parts produce fines = losses
Use plastics as thick as possible (>>10mm)	Never mold too smal (<<10mm)	All recyclers use density seperation technoologies, that also seperate by weight / mass
Use plastics uniformly (1 polymer per molded piece)	Try not to mold plastics around metals	Plastics are burned in the melters as they go with the recycled material
Use plastics uniformly (1 polymer per molded piece)	Avoid 2K molding of different polymers	2K molded polymers cannot be seperated
Use a limited number of polymers (ideally 1-3)	Avoid >5 polymers in a product	Too many grades in a product make recycling inefficient
Use halogen free polymers	Do not use PVC and Br-FR polymers	Softeners in PVC and bromine flameretardants are becoming frequently SVHC
Use POM unblended	Never use POM alloys (POM-ABS etc.)	POM traces produce cancerorgenic formaldehyd (0,5 ppm limit at extrusion)
Use thermoplastics for foams	Avoid elastomers and thermosets for foams	Thermosets are causing surface issues
Use rubber in a solid, bulky form	Do not use silicon rubber and foamed rubber	Rubber particles and silicone rubber contaminate surfaces
Paint your parts with thin layers	Avoid heavy coatings	Coatings are causing surface issues
For high modules use carbon fibre or talcum filled plastics	Avoid the use of glass fibre filled coatings	Traces of glass fibre reduce mechanical properties and cause wear
Connect parts with moderate forces	Avoid to connect parts permanently	Shredders must be able to seperate the individual parts of a product.
Choose virgin for very demanding parts (transparent, ...)	Do not use too strict specifications	20% of the polymer can be virgin
Choose geometries that allow easy flow paths	Avoid tight and narrow geometries	High shear rates stress and degrade the polymers
Consider more structured surfaces	Consider more structured surfaces	Traces of rubber and glass fibre reduce the quality of big surfaces

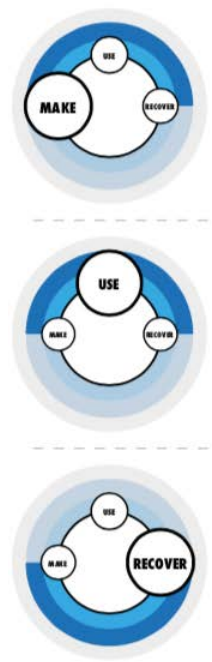
E.1 Circular Plastics do's and don'ts

	Recycle?	Downcycle?	Combust for energy recovery?	Biodegra deble?	Toxicity rating	Embodied energy primary production (^7 J/kg)	Embodied energy recycling (^7 J/kg)	Ra tio	Casting (^7 J/kg) (for metals)	Extrusion (^7 J/kg) (for metals)	Polymer extrusion energy (^7 J/kg)	Polymer molding energy (^7 J/kg)	Recycle fraction in current supply (worldwide)
Aluminium 6061	1	1	0	0	Non-toxic?	20	3,4	5,9	x	0,67	x	x	42%
Staal	1	1	0	0	Non-toxic	3,1	0,81	3,8	1,17	0,55	x	x	42%
verchroomd staal	1	1	0	0	Non-toxic	3,2	0,85	3,8	1,25	x	x	x	53%
messing	1	1	0	0	Non-toxic	7,25	1,6	4,5	1,01	0,98	x	x	38%
koper	1	1	0		Non-toxic	5,9	1,31	4,5	0,91	0,16	x	x	43%
rvs	1	1	0	0	Non-toxic	7,3	1,6	4,6	1,14	1,02	x	x	37,5%
zamac	1	1	0	0	Non-toxic	5,25	1,23	4,3	0,67	x			22%
PE	1	1	1	0	Non-toxic	8	2,65	3,0	x	x	0,62	2,2	8,4%
PP	1	1	1	0	Non-toxic	6,9	2,35	2,9	x	x	0,62	2,15	5,6%
pu schuim	0	1	1	0	Non-toxic	8,2	x						0,1%
PET	1	1	1	0	Non-toxic	8,3	2,65	3,1	x	x	0,625	2,2	8,4%
EPS	0	1	1	0	Non-toxic	12,8			x	x	x	2,2	0,7%
PC	1	1	0	0	Non-toxic	10,5	3,67	2,9	x	x	0,62	1,85	0,7%
rubber	1	1	1	0	Non-toxic	11,28	x			x	x	1,61	0,01%
PA	1	1	1	0	Non-toxic	14,5	4,3	3,4	x	x	0,625	2,15	0,71%
ABS	1	1	1	0	Non-toxic	9,2	3,25	2,8	x	x	0,62	1,85	4%
li-ion	0	1	0	0	Toxic								
karton	1	1	1	1	Non-toxic	5,2	2,2	2,4	x	x	x	x	72%

E.2 CES data on most used materials Accell



E.3 What to pay attention to?



	Thermoset Advantage	Thermoset Disdvantage	Thermoplastic Advantage	Thermoplastic Disdvantage
MAKE	Easy to shape and mold (sticky and pliable) Proven technology	Must be freshly made Expires over time Needs to be stored in freezers Toxic gases in production process	Unlimited storage life at Room temperatures Non-toxic When automated, production is faster than with thermosets	Molding process more difficult than with thermosets (stiff and springy) High melting temperature Higher pressure during molding process More expensive than thermoset production
USE			Exceptional impact resistance Safer failure mode Higher level of quality consistency	
RECOVER	Carbon is restored through the process	Toxic gases are released in recycling process Although carbon is restored, it's downcycled (serves for injection molding) Resin is used as fuel using recycling	Toxic free-recycling process. Both resin and carbon are recycled	

E.4 Thermosets and thermoplastics

Carbon Composites Recycling - Green Materials

	Thermoset				Thermoplastic	
	Carbon fiber		Glas fiber		Carbon fiber	Glas fiber
Recycling type	Thermich / chemichal recycling	chemichal recycling	Thermich / chemichal recycling	Various	Re-use material	Re-use material
Recycling option	Pyrolysis	chemichal recycling	Pyrolysis	Various	Melt & compound	Melt & compound
Rewon material	Short fibers for new composites + Gas + Oil	Short fibers for new composites + Gas + Oil	Short fibers + Gas + Oil		New material for new products	New material for new products
Value rewon material	++	++	0+		++	+
Operational costs recycling	--	--	--		0	0
Investment costs recycling	-	-	--		0	0
Technological readiness	9	9	9		4	4 / 9
Impact Environement	-	--	-		0	0

E.5 Thermoset & Thermoplastic recycling

Did you know..

It takes nearly **6 times** more energy to mine and manufacture 1 kg of vrigin aluminum than it takes for 1 kg of virgin steel

Using recycled aluminium, cuts the embodied energy by **90%**

ABS, PC, PC/ABS, PP, HIPS, PA are excellent for recycling and are recommended for use in a circular economy by the PolyCE consortium

E.6 Did you know's

Appendix F - Design for disassembly workshop 1

Understanding circularity

Basic principles

1. **Using** as many **recycled and/or reused** materials as possible
2. **Extending** the useful life of products as much as possible
3. **Collecting** as many materials and products for recycling and reuse as possible (by designing products that are easy to reuse and recycle)

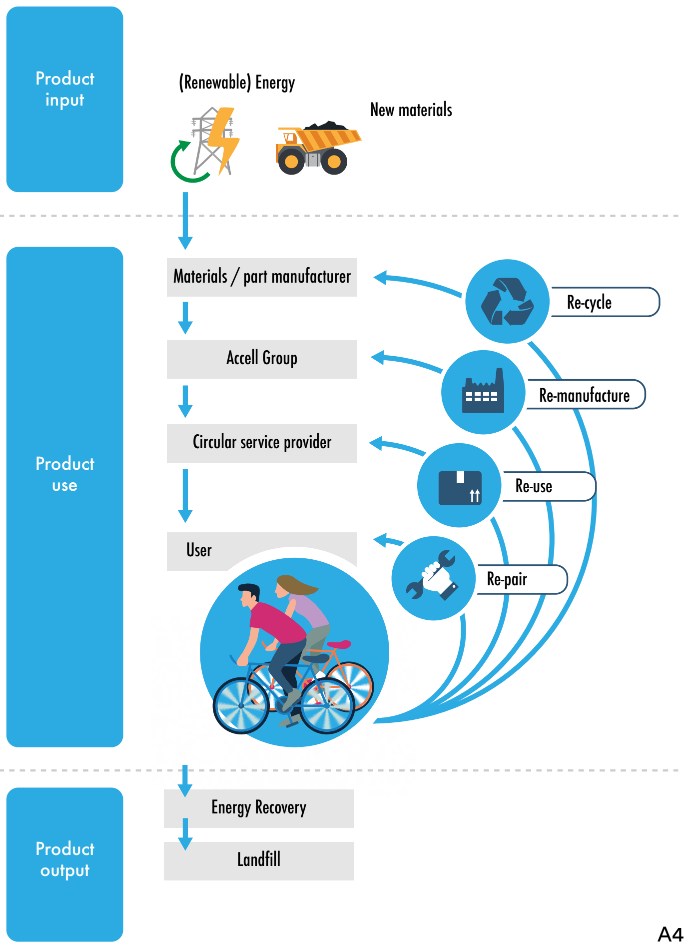
Who's responsible?

Reused goes directly back to your users

Refurbished / Re-paired comes back either to the service provider, or the user

Remanufactured goes through the manufacturing process

Recycled goes back to the materials processor



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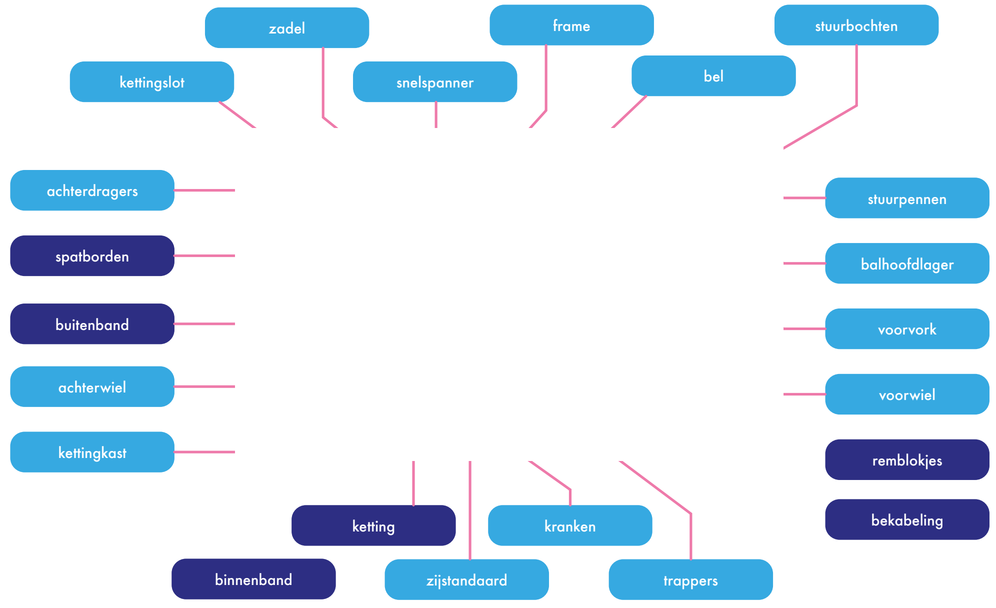
Product | Service

	Classic Long Life Model: One time sell	Classic Long Life Model: Trade-in arrangement	Hybrid Model	Access Model: Short term (<24 h)	Access Model: Long term (>24h)
Product input	Aim for reused / recycled materials to remove the need of finite resources Source materials and components as close to Heerenveen as possible, to minimise the transport footprint	Aim for reused / recycled materials to remove the need of finite resources Source materials and components as close to Heerenveen as possible, to minimise the transport footprint	Aim for reused / recycled materials to remove the need of finite resources Source materials and components as close to Heerenveen as possible, to minimise the transport footprint	Aim for reused / recycled materials to remove the need of finite resources Source materials and components as close to Heerenveen as possible, to minimise the transport footprint	Aim for reused / recycled materials to remove the need of finite resources Source materials and components as close to Heerenveen as possible, to minimise the transport footprint
Product use: Re-pair	Easy access to priority parts Low complexity of required repair tools Standardized components for accessible repairability	Easy access to priority parts Low complexity of required repair tools Standardized components for accessible repairability	Easy access to priority parts Low complexity of required repair tools	Design for repair by circular service provider The bikes should not need maintaining in the typical rental period	Easy access to priority parts Low complexity of required repair tools
Product use: Re-use			Easy to replace hybrid components components	High & easy ergonomic adaptability Design for 'rough' use Non-personal design	Design for 'normal' use
Product use: Re-manufacture		Design for standardization Design for disassembly	Design for standardization Design for disassembly	Design for standardization Design for disassembly	Design for standardization Design for disassembly
Product use: Re-cycle	Waste processor recycling - Design for disassembly by user, focus on heavy-weight parts - Non toxic material use - Easy to recycle materials	Accell recycling - Design for disassembly - Non toxic material use - Minimize variety in materials per component	Waste processor recycling - Design for disassembly by user, focus on heavy-weight parts - Non toxic material use - Easy to recycle materials	Accell recycling - Design for disassembly - Non toxic material use - Minimize variety in materials per component	Accell recycling - Design for disassembly - Non toxic material use - Minimize variety in materials per component
Product output			Energy Recovery Landfill		

Bike components

To succesfully brainstorm about circular bike development, it helps to start small. Choose a bike component and use the 'circular cycle - brainstorm' sheet to rethink it's design, using the circular principles from previous sheets.

priority parts



A4

Circular Cycle - Brainstorm

Brainstorm some of the cycles that the bike component could be designed for.

	How might this be possible for the chosen bike component?	What would be needed or is standing in my way?
IT GETS REPAIRED You design a product that can be easily repaired or upgraded to prolong use.		
IT GETS RE-USED You extend how long a product or material stays in use. This might mean offering a product as a service, as in car sharing schemes		
IT GETS REMANUFACTURED Your product returns to the manufacturer after use to have any necessary components replaced before reentering the market		
IT GETS RECYCLED You design a product that is made from pure materials, standardised to be recycled and returned to a raw natural state.		

Name of the idea:

Ideas capture

Print out as many copies as you need of the this page and invite your collaborators to flesh out the most interesting ideas following your brainstorm.

What is it and how does it work?

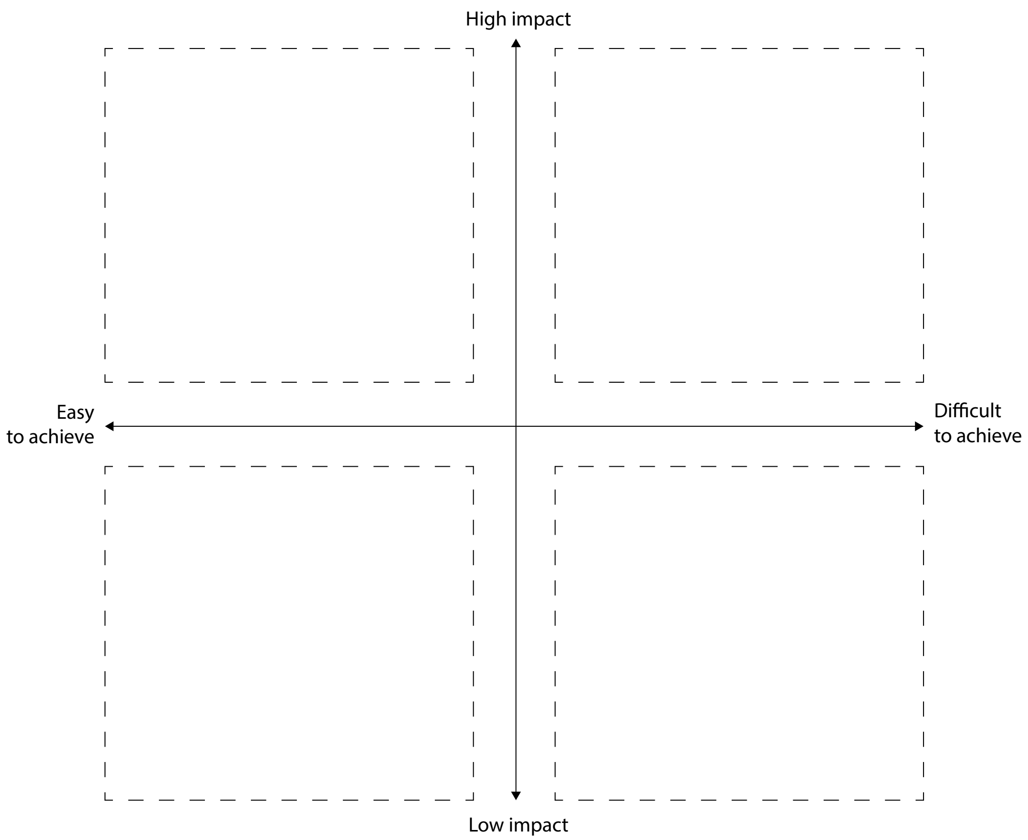
What is the desired impact? What makes it circular?

Who is it for? Are there any other users in the value chain?

A4

Concept Selection

Plot your concepts on this graph to help prioritise which ones to pursue.



A3 or bigger

Appendix G - Workshop design for disassembly

Understanding circularity

Basic principles

1. **Using** as many **recycled and/or reused** materials as possible

2. **Extending** the useful life of products as much as possible

3. **Collecting** as many materials and products for recycling and reuse as possible (by designing products that are easy to reuse and recycle)

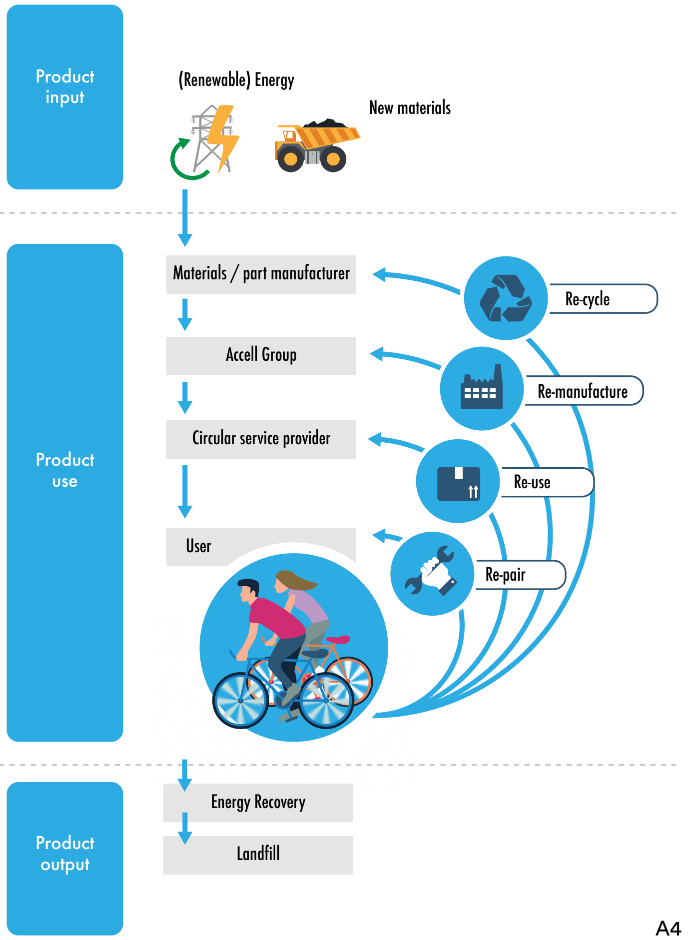
Who's responsible?

Reused goes directly back to your users

Refurbished / Re-paired comes back either to the service provider, or the user

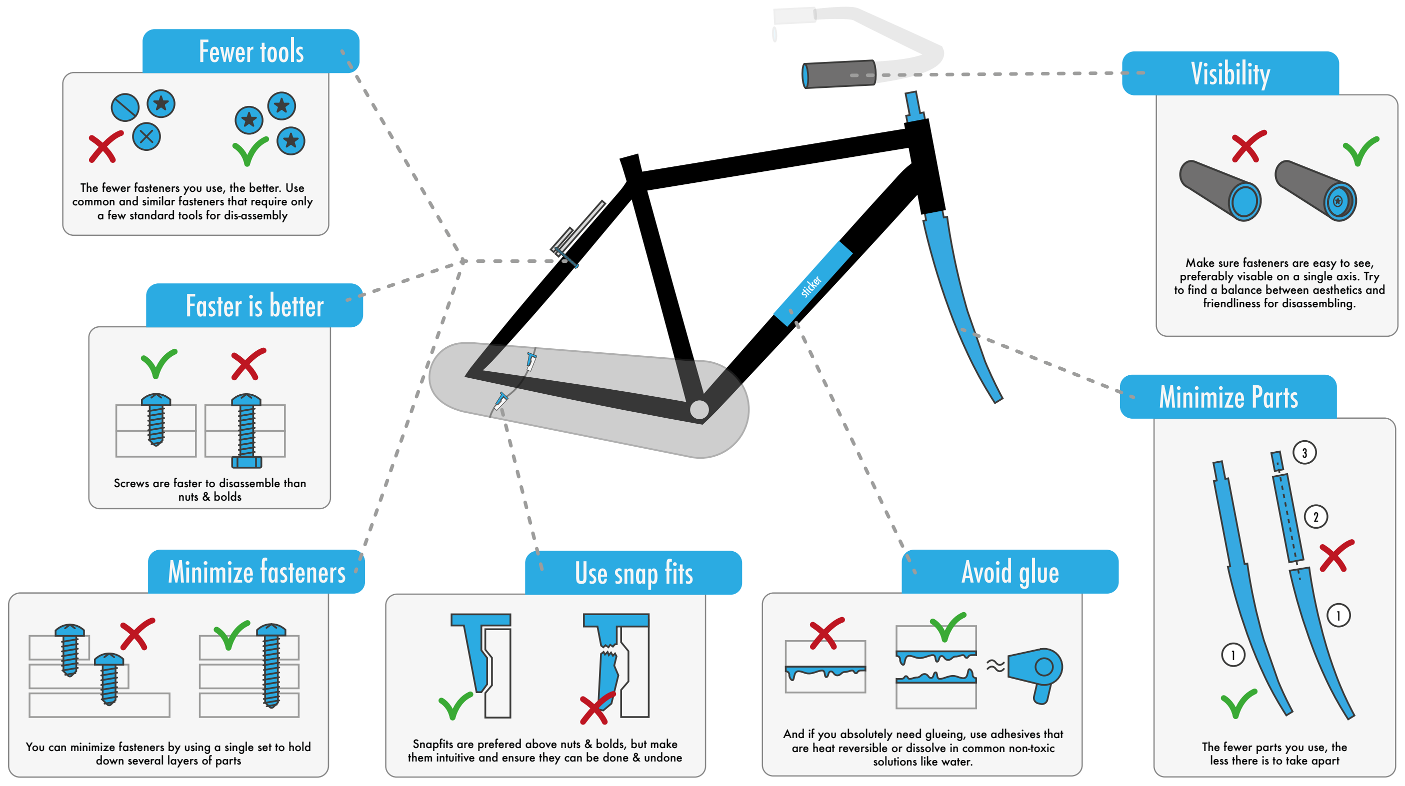
Remanufactured goes through the manufacturing process

Recycled goes back to the materials processor



A4

Understanding design for dis-assembly



Bike components

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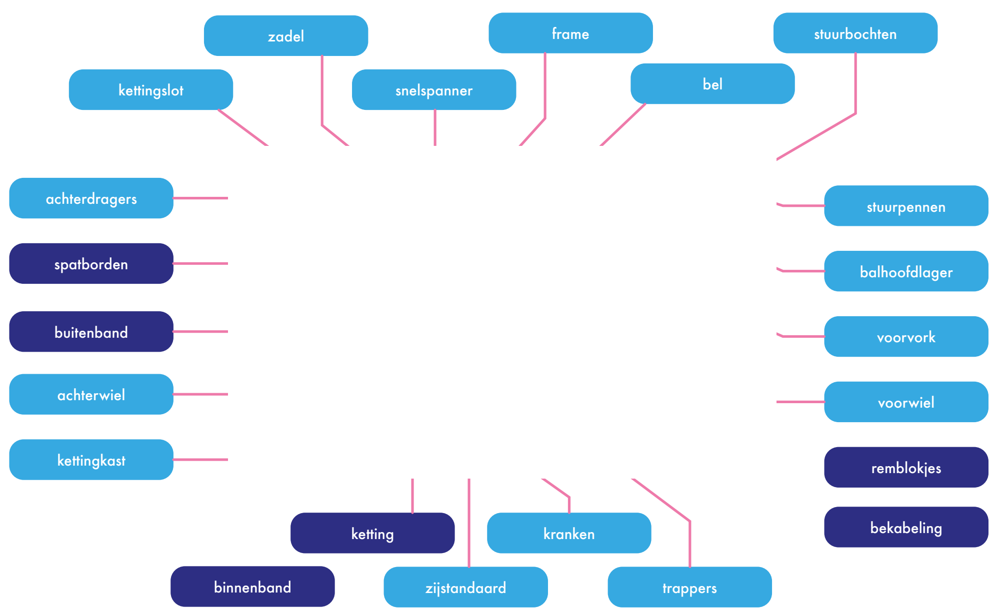
priority parts

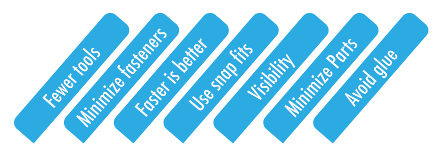


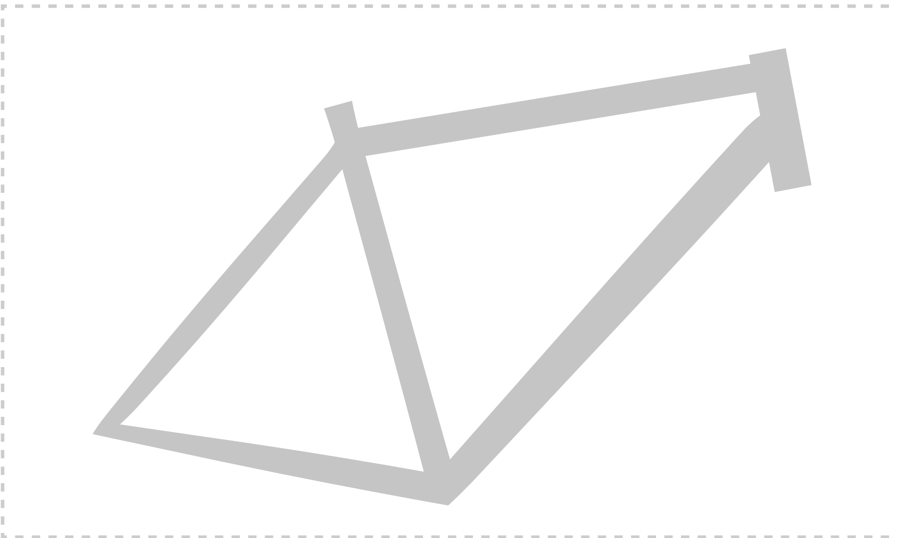
A4

Disassembly Brainstorm

First; Sketch / point out where your frame connects a particular other component.

Then, take a look at the 'design for dis-assembly sheet'. What are the best solutions? How can me make dissassembly user friendly and little time consuming?



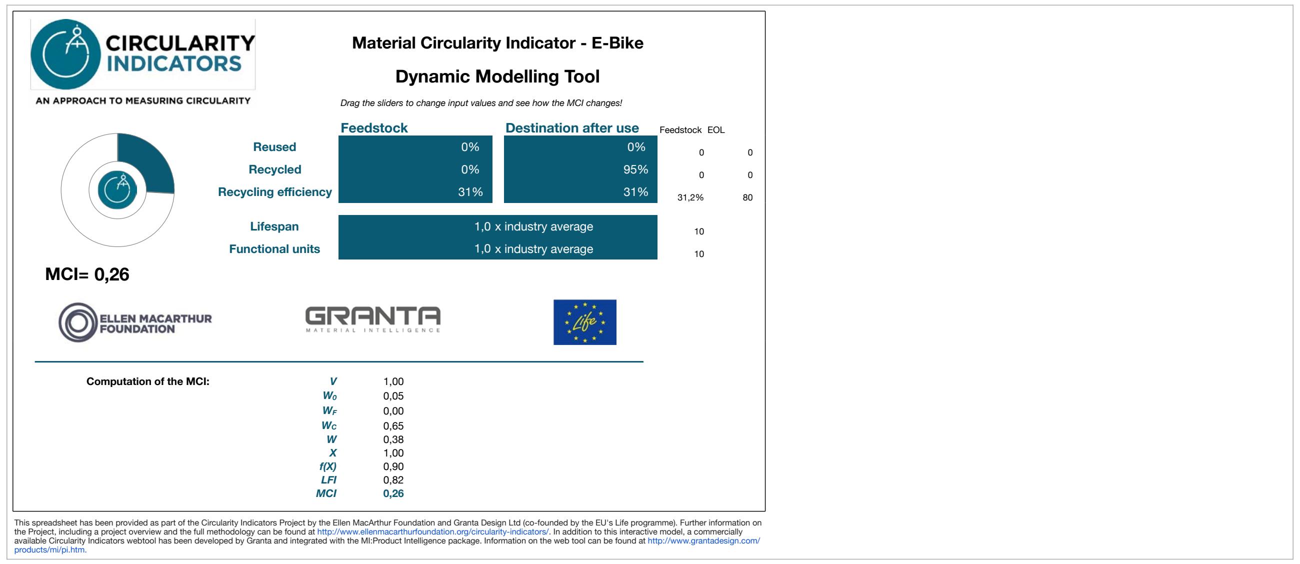


Notes

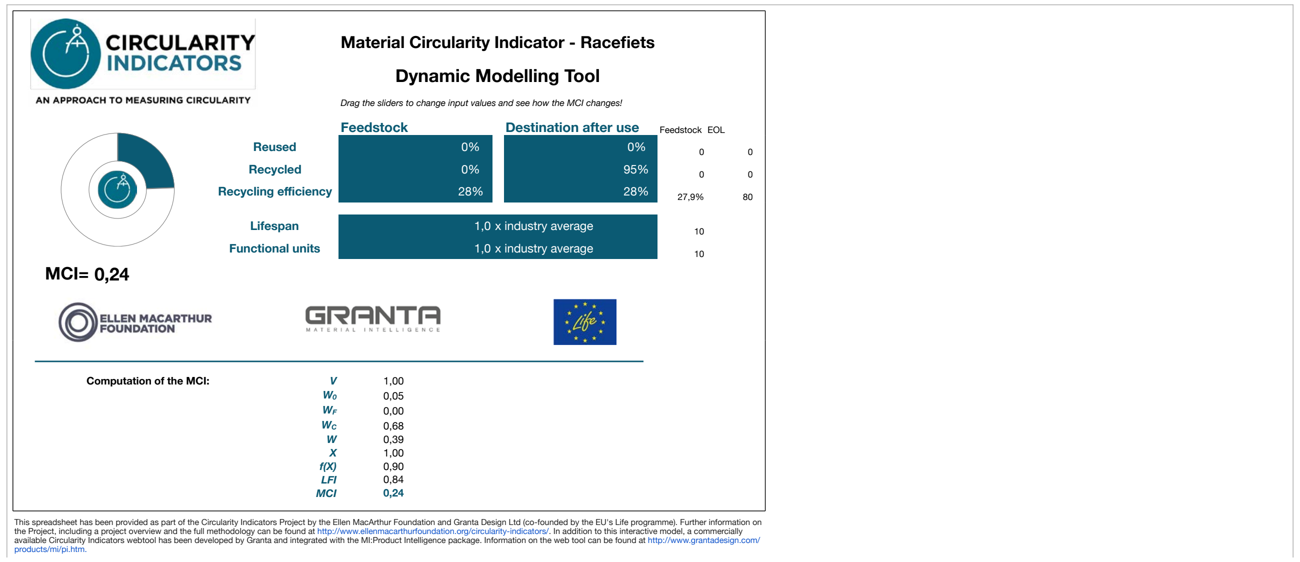
Print as many of these sheets as needed

A4

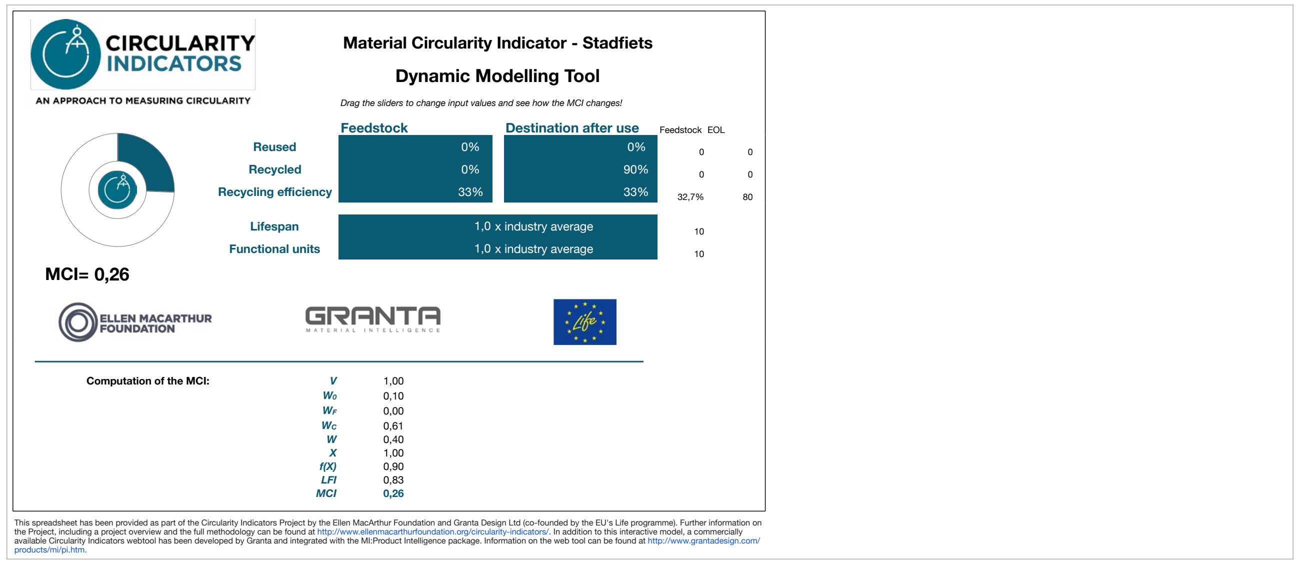
Appendix H - MCI E-bike, Racing bike & City bike



H.1 MCI E-Bike



H.2 MCI Racing bike



H.3 MCI City bike