DESIGN FROM RECYCLING

MANUAL

Product Development
University of Antwerp
Els Du Bois • Karine Van Doorsselaer • Lore Veelaert

GHENT UNIVERSITY
FACULTY OF ENGINEERING AND ARCHITECTURE
Kim Ragaert • Sara Hubo

AGENTSCHAP INNOVEREN & ONDERNEMEN
IWT-TETRA project 150151

context of the project

In the EU, almost 26 million tonnes of plastic waste are generated each year. Currently, about 30% is effectively recycled. 40% is validated by energy recuperation and a shocking 30% is still being dumped, although there are major regional differences [1]. The European objectives in this area are - rightly - ambitious. The Circular Economy Package that was proposed in 2015, provides for a minimal recycling rate of 55% of all plastic packaging waste by 2030.

Belgium belongs to the better students of the European class. However, to remain a leader in collecting, sorting and effectively recycling plastics, it is important to continue investing in research in order to examine innovative ways of dealing with recycled plastics.

In mechanical recycling of plastics, products are sorted, cleaned and ground as the basis for new granulate. From this granulate, it is possible to make new products with the currently used techniques (such as injection moulding or extrusion), with a much lower content of new (often oil-based) raw materials. However, the properties of these recycled plastics are not always the same as their virgin counterparts. Degradation, contamination and mixing of different types of plastics play an important role, as well as the potentially upgrading of the quality by the addition of specific additives. Unknown is often unloved. It is not so straightforward for a design to develop a product from recycled plastic.

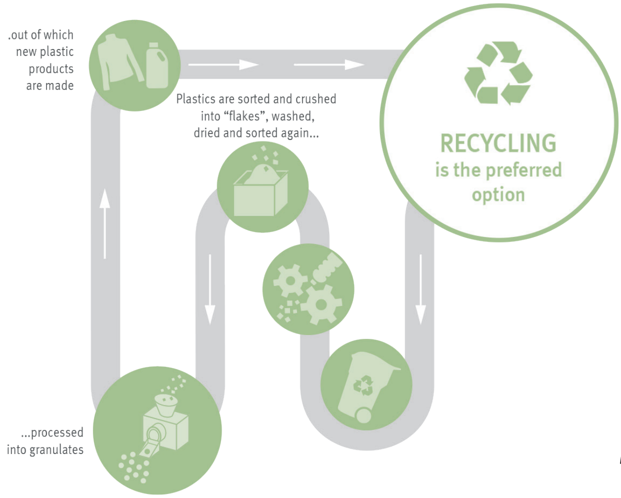


Figure based on Plastic Facts [1].

These design manuals are, just like the Determinator Box, one of the final results of the VLAIO-TETRA project Design from Recycling (project number 150151).

This research project has been conducted as an interdisciplinary collaboration between the polymer engineers of CPMT (UGent) and the designers of Product Development (UAntwerpen), supported by LCA experts of Envoc (UGent) and subcontractor Centexbel-VKC. In addition, the project also found support and validation with an active and extensive user group, composed of design agencies, recyclers, plastic processors, OVAM and Catalisti.

The aim of *Design from Recycling* is to provide Flemish SMEs with the necessary knowledge and support to design (and manufacture) more (and better) products from recycled plastics and to estimate the sustainability of these products. *Design from Recycling* is not the same as the already well-known *Design for Recycling*, which focuses on a product's recyclability during the design process.

Design from Recycling investigates to what extent a new product can be manufactured from an existing flow of recycled plastics and which design specifications it entails [2].

The bottleneck within plastics recycling is that these materials are usually reused in low-grade or extremely bulky products . However, the challenge and focus of this project lies in the use of recycled plastics in high quality products as well. *Design from Recycling* is a rather unexplored subject, where much knowledge development and knowledge transfer is still needed.

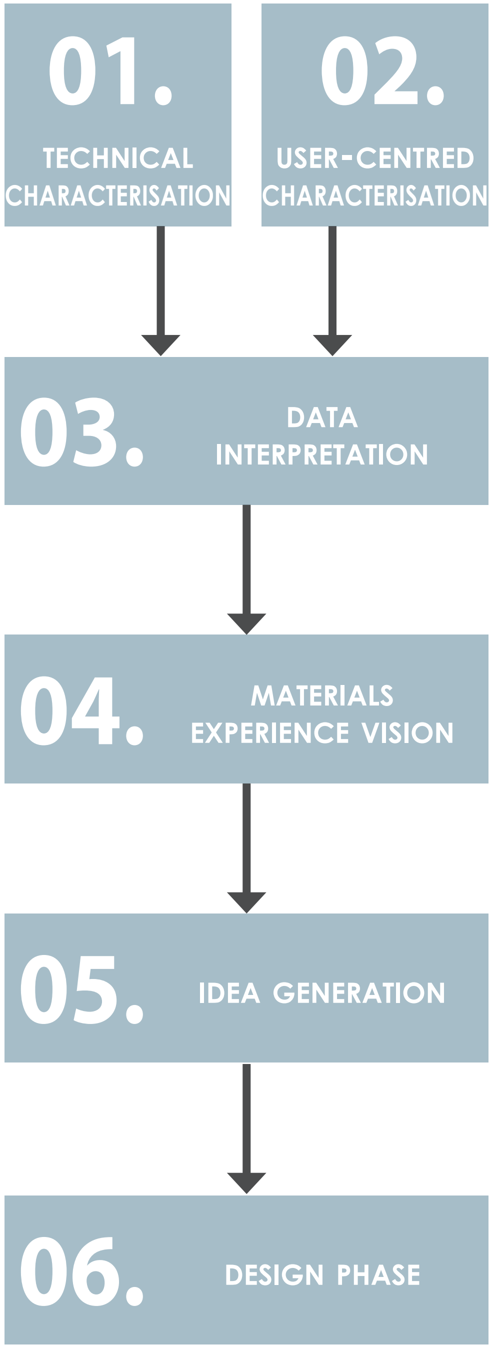
This knowledge transfer to designers is realised by tools such as the **Determinator Box** that contains this **design manual**; a guide with tips & tricks and do's & don'ts for designing with recycled plastics. The additional **design experience** booklets illustrate two cases in which this is demonstrated. Finally, the **material identity cards** contain the technical data sheets and user-centred evaluations of the fifteen recycled/ virgin materials' **determinators**.

material driven design approach

Extensive research is available concerning materials from a technical engineering perspective, which results in objective, numerical data and useful process parameters for manufacturing, through a series of normalised material tests. However, more and more attention is paid to the way consumers experience and perceive these materials (the user-centred perspective).

Therefore, the *Design from Recycling* project does not only start from a technical characterisation of a recycled material stream, but it also wants to explore and emphasize the unique identity in order to differentiate a new material on the market, instead of replacing or imitating traditional materials in existing products. This leads to the fact that new materials often fail when introduced to the market since they are not socially or culturally accepted. [2]

To support industrial design engineers in designing with recycled plastics, this research project builds upon the **Material Driven Design (MDD)** method [3], wherein a (new) material is the starting point of the design process, analogous to *Design from Recycling*. This approach aims to structure the design process and bridge both technical and experiential perspectives during different activities.



This design manual is the translation of following MDD process in six major steps, as shown on the left. First of all, the material flow is technically characterised in the lab (1) and the unique sensorial and experiential aspects of the material are evaluated by designers (2). The interpretation (3) of both steps leads to a material experience vision (or marketing slogan) for the material (4) to facilitate the idea generation (5). Finally, appropriate ideas can be further elaborated according to the design guidelines for recyclates (6).

The following pages will walk you through these steps and illustrate them with examples from several material cases.

standardised tests

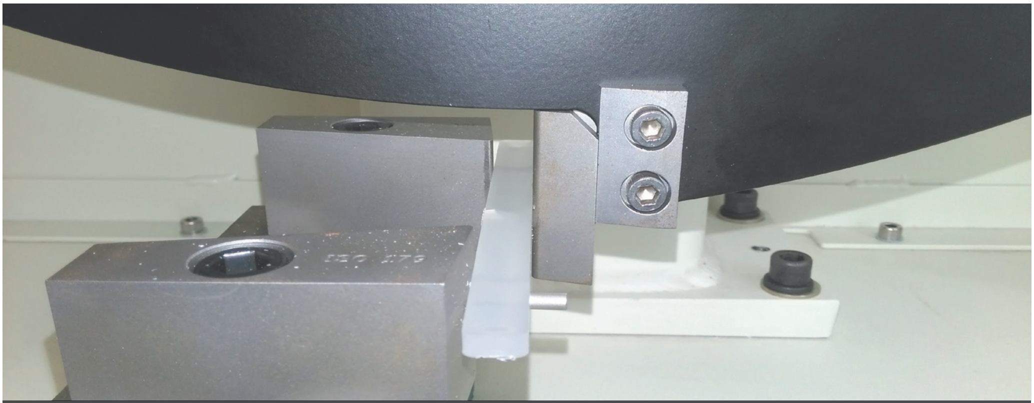
Using standardised tests, the material is physically-mechanically characterised in the lab. These test data are then summarized in a data sheet.

The **melt flow index (MFI)** is an important parameter for determining the flow behaviour of a plastic. The higher the index, the less viscous or better flowing the material is. This allows you to determine the appropriate processing technique and to detect possible degradation during processing.

Through **Fourier Transformation Infrared Spectroscopy (FTIR)** you can qualitatively determine the polymer composition of a material. In addition, the thermal analysis technique **Differential Scanning Calometry (DSC)** provides insight in the constituent components of a material (mix), besides specific information on melt and crystallization behaviour for each constituent polymer.

The thermal stability of a material can be investigated through **Thermogravimetric Analysis (TGA)**. This is important for determining the processing and user temperature.

For mechanical properties, the **impact test** is an important player, in which the resistance of a material against a sudden impact - performed with a swinging hammer - is measured. The higher the impact value, the better the resistance to impact.



impact test

Of course your designed product must also endure reality. Stress response is a key word here. Data from both a **tensile test** (whereby the material is pulled apart at a constant rate), as a bending test (where the material is pushed slowly and steadily on a holder by a stamp) are very useful.

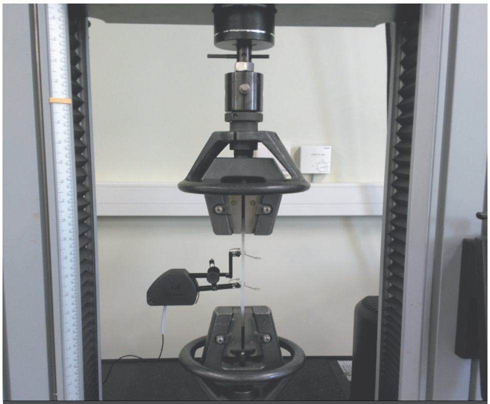
The **modulus** can be seen as a measure of the rigidity or stiffness of a plastic. The yield point shows where the material passes from an elastic to a plastic deformation.

The **elongation at break,** the **stress** and **elongation at maximum load** (also called the tensile or flexural strength) complete the palette of mechanical properties of a plastic material.

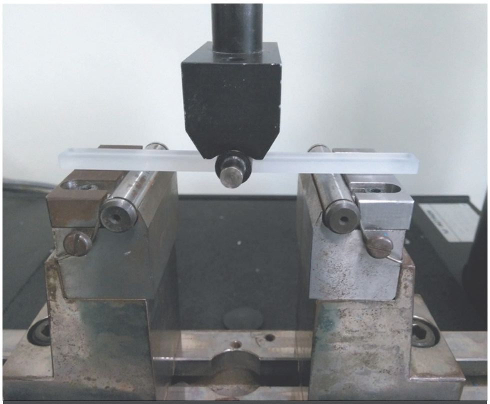
Density and **hardness** measurements provide additional information on the material properties.

Bulk density is especially important for storage, while **relative humidity** indicates show much water is present in a material. Possibly, the plastic pellets must undergo an extra drying step before processing.

In short, you can retrieve information from the data sheet of a material for a suitable design, correct processing and a safe application of the material. An empty data sheet can be found on the next page, so you can get started yourself.



tensile test



bending test

PROPERTY		UNIT	VALUES (± stdev)	COMMENTS	TEST METHOD
GENERAL					
Name		-			-
Composition		-			-
Origin		-	post-industrial/ post-consumer		-
APPEARANCE					
Colour		-			visual inspection
Transparency		-	yes/no		visual inspection
Shape		-	pellets/flakes/ grains		
PHYSICAL					
Melt Flow Rate (MFR)		g/10 min		m, T	ISO 1133: 2005
Density		g/cm³			ISO 1183-1: 2004
MECHANICAL					
Modulus	*flexural/ tensile*	MPa			ISO 527-1: 2012; ISO 178: 2001
Strength	*flexural/ tensile*	MPa			ISO 527-1: 2012; ISO 178: 2001
Yield Strength	*flexural/ tensile*	MPa			ISO 527-1: 2012; ISO 178: 2001
Strain at yield	*flexural/ tensile*	%			ISO 527-1: 2012; ISO 178: 2001
Strain at max load	*flexural/ tensile*	%			ISO 527-1: 2012; ISO 178: 2001
Strain at break	*flexural/ tensile*	%			ISO 527-1: 2012; ISO 178: 2001
Shore hardness		-		Shore A/B/D	-
Impact (notched at 23°C)		kJ/m²		specify test	ISO 179-1: 2000; ISO 180: 2000
THERMAL					
Melting temperature		°C			ISO 11357-3: 2009
User temperature (no load)		°C			
Glass transition temp.		°C			
OTHERS					
Residual humidity		%			ISO 12099: 2010
Bulk density		kg/m³			
Price		€/ton			

hands-on material tinkering

In order to create an understanding of the numbers in the data sheet and a hands-on experience with the new, recycled material, it is also advisable to take the various material samples in hand as a designer and do some destructive tests such as a fire test, machining, impact, bending and breaking.

On the one hand, different injection moulding or extrusion pieces can be used for these tests. On the other hand, a **determinator** of this material can immediately show the effect of shrink cavities, different wall thicknesses and some specific surface finishes: ranging between a beautiful gloss and a rough texture. In addition, stiffness, hardness, creep and potential hinges can be experienced and compared with other known plastics.

Finally, the most important findings can be briefly summarised to be converted to sensorial characteristics later on.

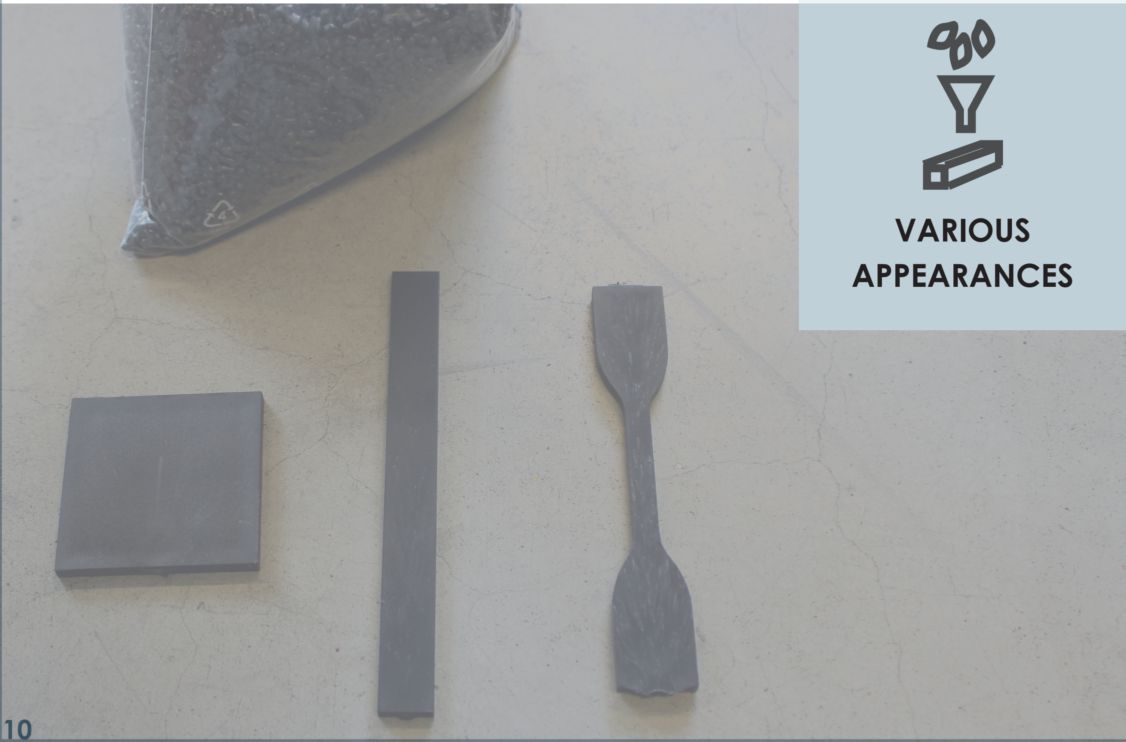
material samples

Through standardised lab tests, the characterisation of recycled plastics is relatively unambiguous on a technical level. However, a typical designers' approach is characterised by fuzzy labels and descriptions. Therefore, after the completion of the technical tests, the physical samples of the recycled materials should be passed on to the designer.

In this regard, there are four points of interest. The samples must be **product independent**. This means that they can not yet be materialised in an existing product, as this association can affect the perception of the respondent. For example, a product with sharp corners and lines can make a material appear more aggressive and harder than in a rounded product. This effect must be avoided as much as possible by comparing uniform material samples one by one. The injection moulded test bars and plates of the lab are very suitable for this purpose.

PRODUCT INDEPENDENT

VARIOUS APPEARANCES



DETERMINATOR

REFERENCE MATERIALS

The developed **determinators** in the determinator box are provided to use as an (extra) material sample. They allow you to experience and compare some sensorial characteristics such as surface gloss or flexibility.

In addition, it is important to enable a relevant comparison with similar shapes of other **reference materials**. The recycled material samples can thus be compared to known virgin plastics such as PP, HDPE, ABS, PC and PS (available in the determinator box).

Finally, it might be interesting to provide **various appearances** of each material: not only test bars or determinators, but also sprues, extrusion pieces, and even flakes or pellets so that you as a designer can also consider the origin of the material in the design process.

user-centred characterisation

Only numerical data is insufficient for designers to start the design process. Therefore, it is crucial to explore the material also from a user-centred perspective early on. Discovering the recyclate's unique experiential identity will facilitate its differentiation on the market.

In order to facilitate this user-centred characterisation, fill-in sheets are provided to generate both sensorial [4] and interpretative data. In this way, you can explore and objectify associations and emotions that are provoked by the material.

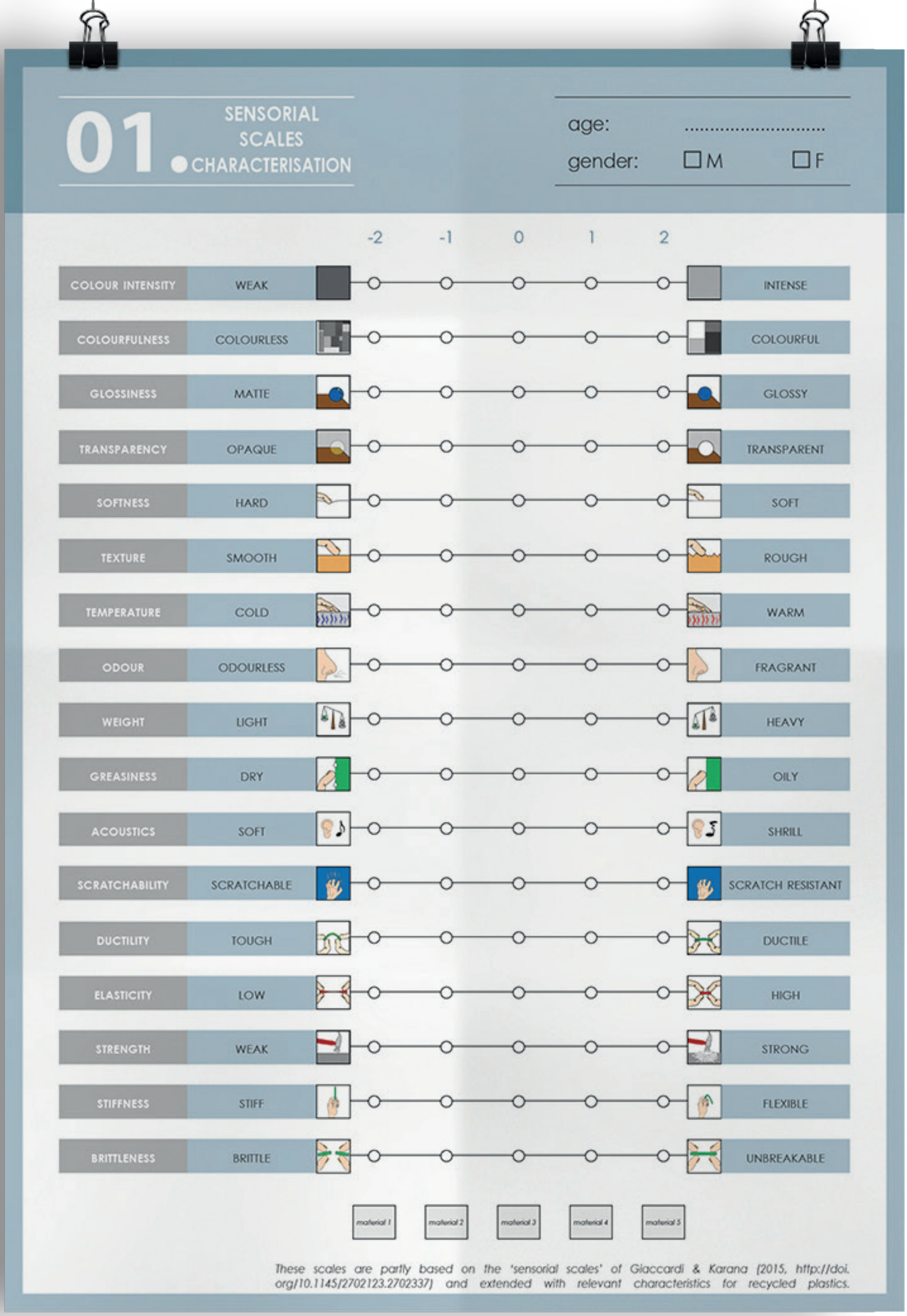
Respondents (both designers and consumers) can compare up to five different physical material samples. They are encouraged to use all their senses when testing the material (to rub, bend, break...). On average, this process takes about 15 minutes per person, and it is recommended to question at least 50 respondents if statistical processing is desired.

The fill-in sheets serve as a guidance to introducing possible material descriptions. Afterwards, you can deepen this through focus groups and interviews to discover even more meanings and emotions, specifically in the context of recycling.

IS THE MATERIAL PERCEIVED AS A RECYCLED PLASTIC? IS THE MATERIAL ASSOCIATED WITH OTHER RECYCLED MATERIALS?

DOWNLOAD THESE FILL-IN SHEETS THROUGH WWW.UANTWERPEN.BE/DESIGN-FROM-RECYCLING.

fill-in sheet sensorial scales



01. SENSORIAL SCALES CHARACTERISATION

age: ....

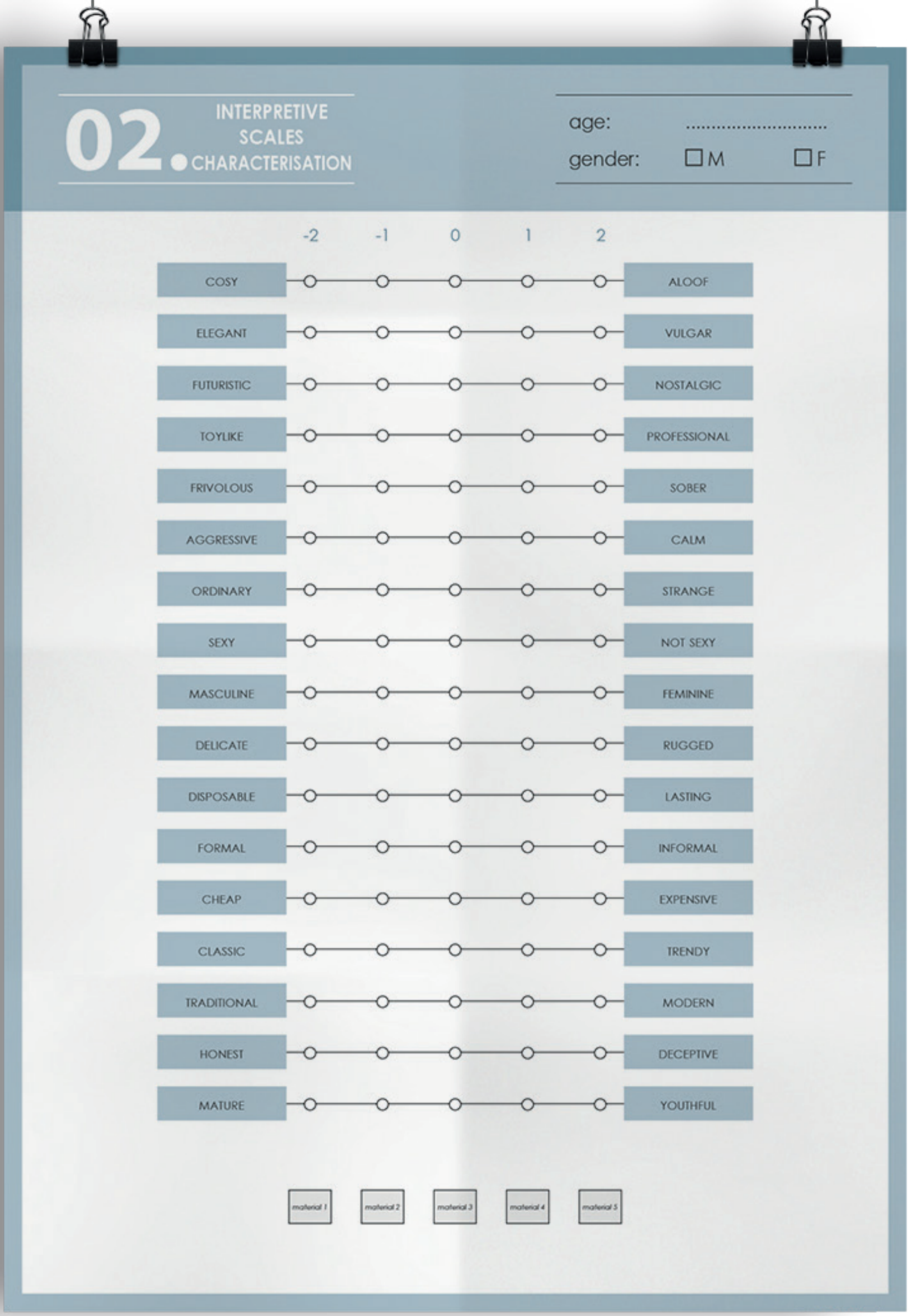
gender: ☐ M ☐ F

		-2	-1	0	1	2	
COLOUR INTENSITY	WEAK	○	○	○	○	○	INTENSE
COLOURFULNESS	COLOURLESS	○	○	○	○	○	COLOURFUL
GLOSSINESS	MATTE	○	○	○	○	○	GLOSSY
TRANSPARENCY	OPAQUE	○	○	○	○	○	TRANSPARENT
SOFTNESS	HARD	○	○	○	○	○	SOFT
TEXTURE	SMOOTH	○	○	○	○	○	ROUGH
TEMPERATURE	COLD	○	○	○	○	○	WARM
ODOUR	ODOURLESS	○	○	○	○	○	FRAGRANT
WEIGHT	LIGHT	○	○	○	○	○	HEAVY
GREASINESS	DRY	○	○	○	○	○	OILY
ACOUSTICS	SOFT	○	○	○	○	○	SHRILL
SCRATCHABILITY	SCRATCHABLE	○	○	○	○	○	SCRATCH RESISTANT
DUCTILITY	TOUGH	○	○	○	○	○	DUCTILE
ELASTICITY	LOW	○	○	○	○	○	HIGH
STRENGTH	WEAK	○	○	○	○	○	STRONG
STIFFNESS	STIFF	○	○	○	○	○	FLEXIBLE
BRITTLENESS	BRITTLE	○	○	○	○	○	UNBREAKABLE

material 1 | material 2 | material 3 | material 4 | material 5

These scales are partly based on the 'sensorial scales' of Giaccardi & Karana (2015, http://doi.org/10.1145/2702123.2702337) and extended with relevant characteristics for recycled plastics.

fill-in sheet interpretive scales


02. INTERPRETIVE SCALES CHARACTERISATION

age: ....

gender: ☐ M ☐ F

	-2	-1	0	1	2	
COSY	○	○	○	○	○	ALOOF
ELEGANT	○	○	○	○	○	VULGAR
FUTURISTIC	○	○	○	○	○	NOSTALGIC
TOYLIKE	○	○	○	○	○	PROFESSIONAL
FRIVOLOUS	○	○	○	○	○	SOBER
AGGRESSIVE	○	○	○	○	○	CALM
ORDINARY	○	○	○	○	○	STRANGE
SEXY	○	○	○	○	○	NOT SEXY
MASCULINE	○	○	○	○	○	FEMININE
DELICATE	○	○	○	○	○	RUGGED
DISPOSABLE	○	○	○	○	○	LASTING
FORMAL	○	○	○	○	○	INFORMAL
CHEAP	○	○	○	○	○	EXPENSIVE
CLASSIC	○	○	○	○	○	TRENDY
TRADITIONAL	○	○	○	○	○	MODERN
HONEST	○	○	○	○	○	DECEPTIVE
MATURE	○	○	○	○	○	YOUTHFUL

material 1 material 2 material 3 material 4 material 5

data processing

The introduced fill-in sheets for the user-centred characterisation are based on a 5-point Likert scale, ranging from -2 to 2. The collected data from different materials and from different respondents can be entered in statistical software such as Excel or SPSS. The required variables are listed below:

» Number of respondent (ordinal)

» Gender of respondent (nominal)

» Age of respondent (nominal)

» Material (ordinal)

» Different sensorial characteristics (scale)

» Different interpretive characteristics (scale)

In practice, one particular material can be analysed for all user-centred characteristics, or different materials can be compared simultaneous at a single characteristic.

Consequently, you can calculate the average value of all respondents, including the standard deviation. On the one hand, this shows whether the material is for example experienced as brittle or rather as unbreakable. On the other hand, it shows to what extent there is consensus on this.

In addition, statistical analysis can be performed to see whether the average scores differ significantly from the overall average (test value).

It is also possible to carry out analysis on subgroups such as men or women only, or based on a specific age range.

In short, based on the data of the user-centred characterisations you can objectively investigate which sensorial or interpretative characteristics are remarkable for a particular (recycled) material.

Within this project, this analysis is applied to two materials: rABS and MPO.

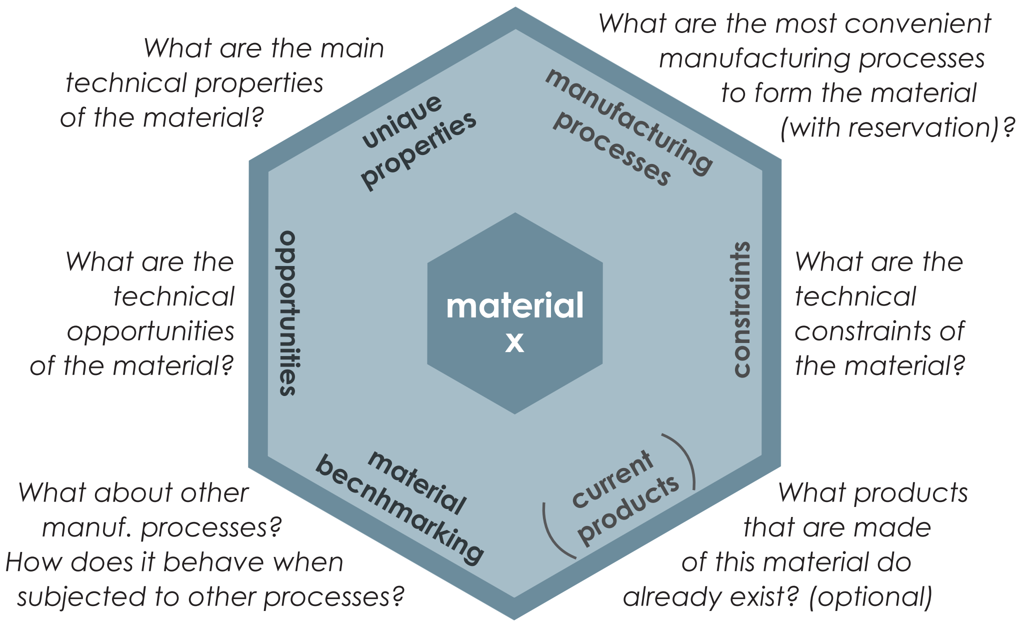
technical interpretation

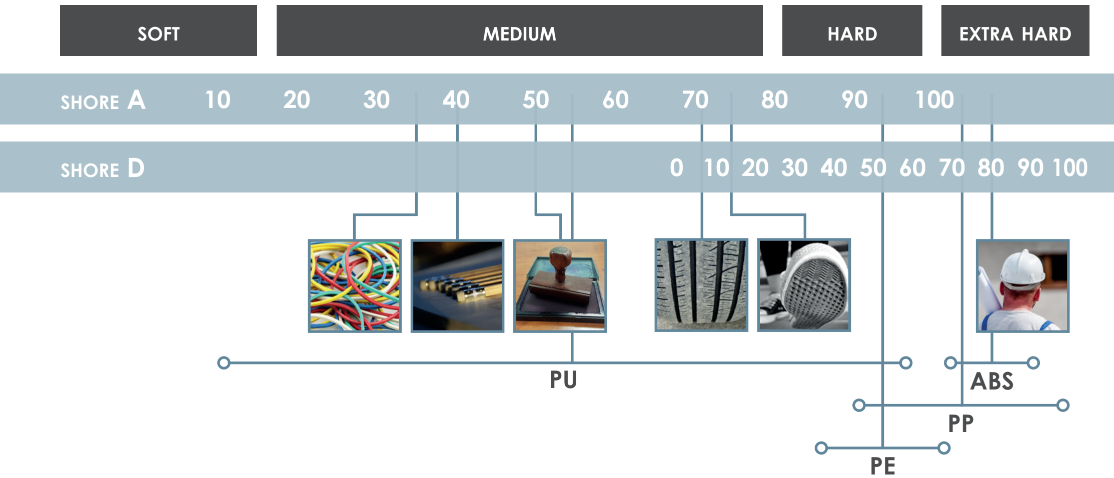
The technical data sheet of your recycled material can now be interpreted by visualising and comparing the different properties with other well-known materials. This can be done individually as well as in group.

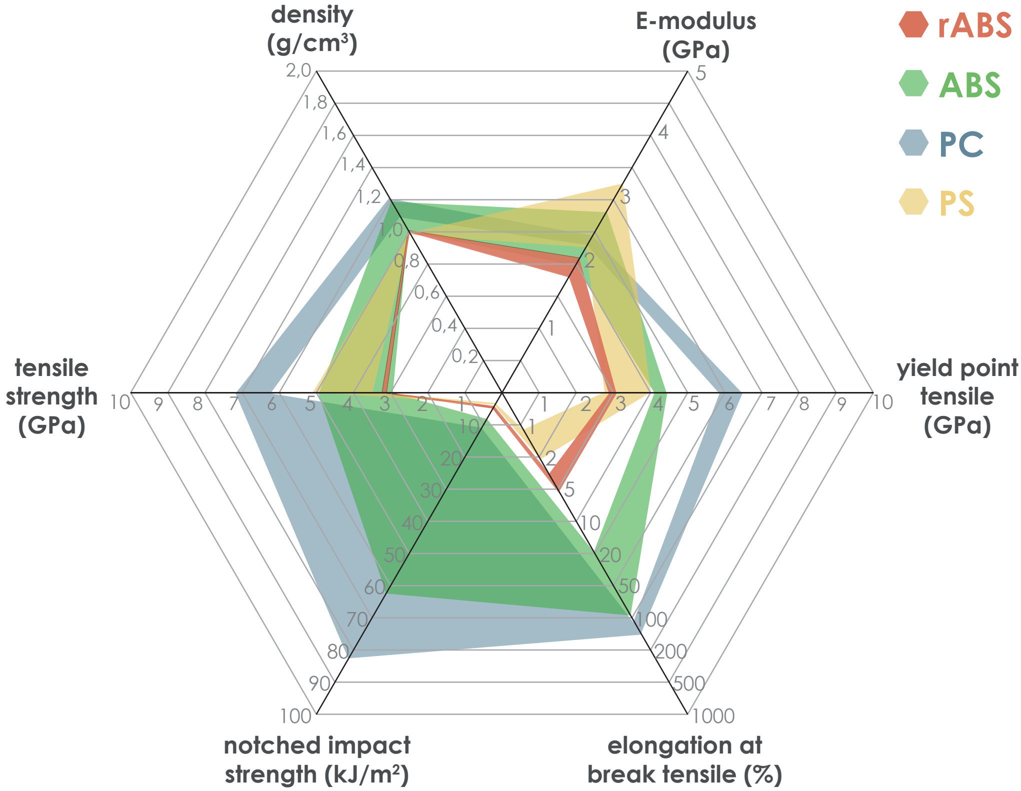
The ultimate goal of this technical interpretation is to answer the questions [3] as shown below in order to formulate the opportunities, limitations and possible processing techniques that are needed for the idea generation and design phase. These answers form the conclusion of this step and can be displayed in a **mind map** and moodboard.

For example, by using a **hardness scale** (see top right), on which different values for a property are linked to an appropriate material and a typical product application. If your recyclate has a similar value, you can instantly see what existing material is comparable and what applications it has.

If you want to visualise multiple properties at once, you can use **radar charts** to compare several materials of your choice at a glance, and find the biggest differences or similarities. The figure on the bottom right shows an example of this principle.

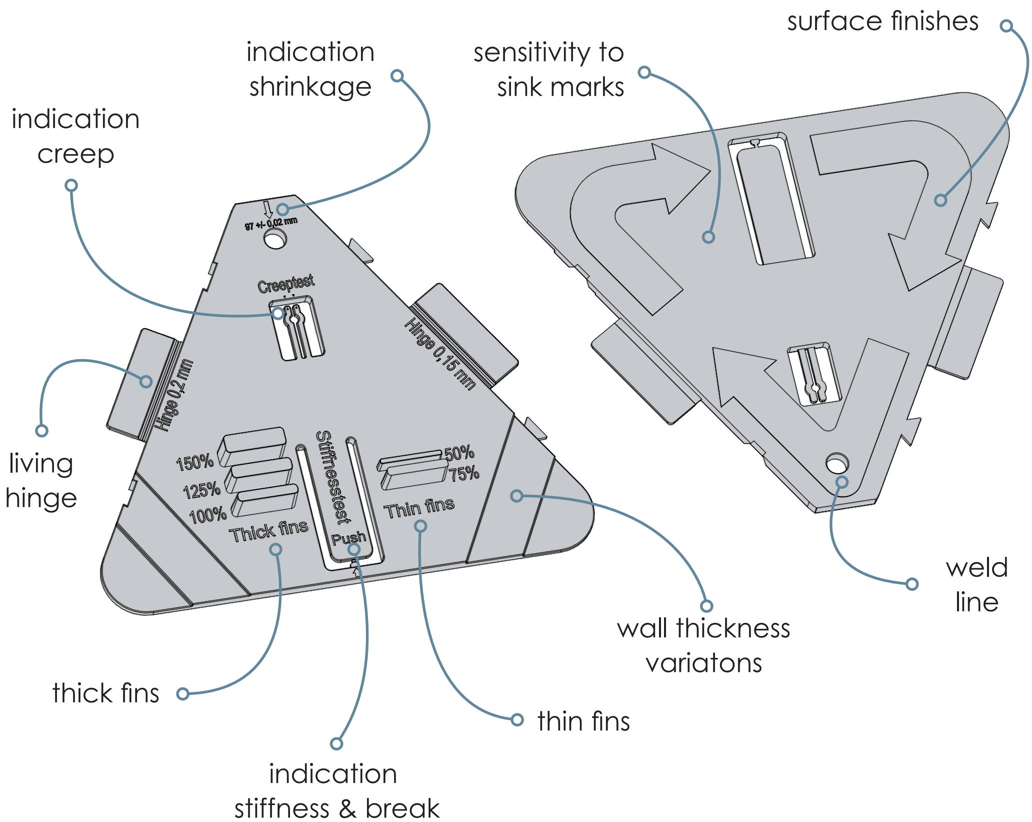


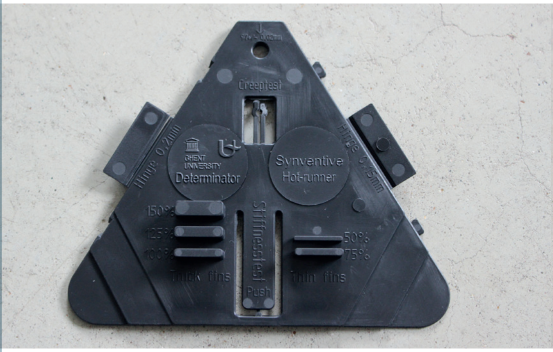

SOFT
MEDIUM
HARD
EXTRA HARD
SHORE A
10 20 30 40 50 60 70 80 90 100
SHORE D
0 10 20 30 40 50 60 70 80 90 100
PU
ABS
PP
PE

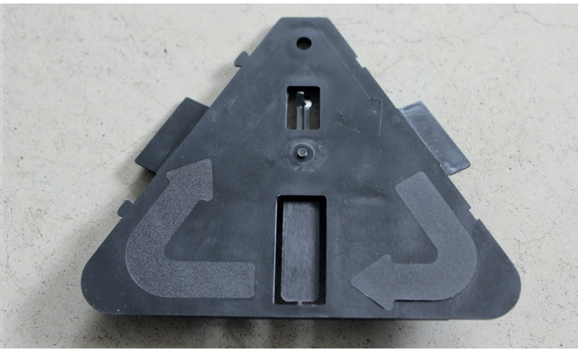

density (g/cm³)
2,0 1,8 1,6 1,4 1,2 1,0 0,8 0,6 0,4 0,2
E-modulus (GPa)
5 4 3 2 1
yield point tensile (GPa)
1 2 3 4 5 6 7 8 9 10
elongation at break tensile (%)
1 2 5 10 20 50 100 200 500 1000
notched impact strength (kJ/m²)
10 20 30 40 50 60 70 80 90 100
tensile strength (GPa)
10 9 8 7 6 5 4 3 2 1
rABS
ABS
PC
PS

determinator

Of course, you can also use the **determinators**. These visualise several material properties (e.g. stiffness), design errors (e.g. shrink cavities, warping) and user-centred characteristics (e.g. gloss, recycled perception), as described in the material identity cards.







user-centred interpretation

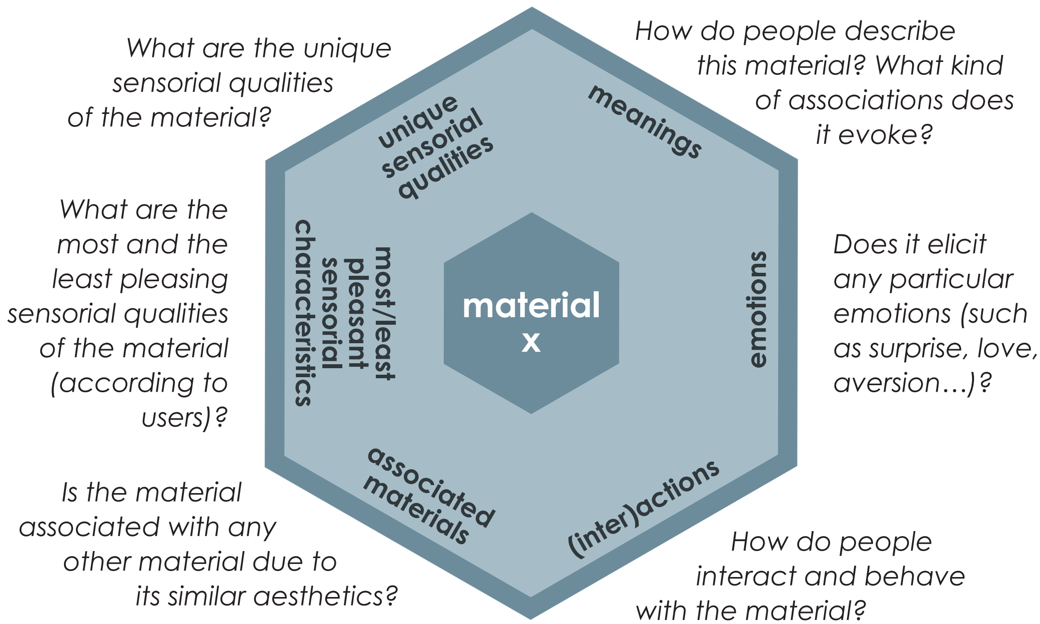
Based on the overall data generation of sensorial and interpretative characteristics with consumers (through the **fill-in sheets**), the most prominent features can be summarised.

In addition, you can deepen the understanding of the different qualities of the recycled material through **interviews** or workshops with both designers and consumers.

Based on all of these findings, you can answer the questions [3] that are shown below, in order to draw up a clear **mind map**.

Finally, a certain characteristic or opportunity can be further highlighted and explored through some **Experiential Moodboards**.

For example, the black colour that is typical for many recyclates can - depending on the chosen design or shape - also be sexy and emit sensuality, or symbolize sturdiness and strength. The light shading or imperfections can be enhanced by the use of different textures, and the black colour can also be perfectly combined with other materials!



materials experience vision

The step following the data interpretation is the synthesis of all previous phases. Summarise your findings from the technical and user-centred characterisations, guided by the accompanying questions below [3].

Next, formulate the ultimate design intention(s) that you have in mind with the material: how would you like to position the material on the market?

The fill-in tool on the bottom right illustrates, using an example of a recycled ABS material, how this statement can be formulated: "The material - does what - with whom - aiming what".

» It can be **interpretative** (meanings and associations): e.g. the material will express naturalness or elegance;

» It can be **performative**: e.g. the material will require delicate use, the materials asks to be broken;

» It can be **affective**: e.g. the material elicits fascination;

» Also, the unique role and application of the material can be expressed in a broader **context**: e.g. the material makes people aware of their consumption patterns.

In which context(s) would the material make a positive difference?

What are its unique technical/ experiential qualities to be emphasized in the final application?

What emotions would the material elicit with people?

What would it make people do?

How should the material be sensed and interpreted?

What would be the material's role in a broader context (i.e., society, planet)?

In order to formulate such a slogan, you must make a final decision about whether an established meaning is preserved or a new meaning will be exploited in a future product? It can thus be considered as the unique selling proposition of the material that you will use as an inspiration backbone during the idea generation.

The exploration towards possible visions can be visualised in various mind maps. For example, this shows that the colour black does not have to be a constraint at all, but can even fit within a certain design vision or context; such as ‘black is the new sexy’.

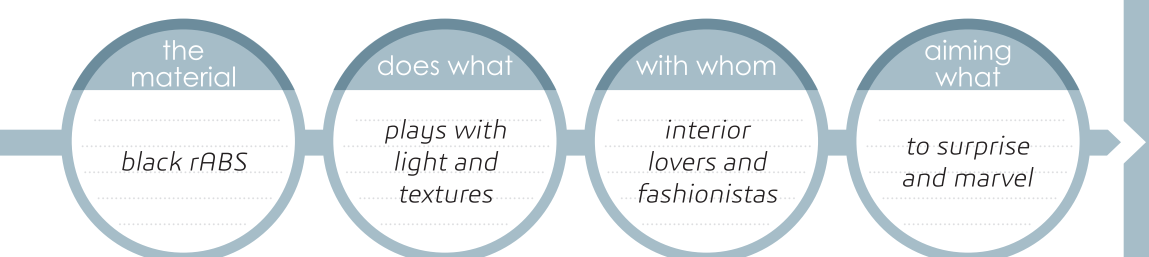
During various past design workshops within the Design from Recycling project, two global opposing design strategies emerged.

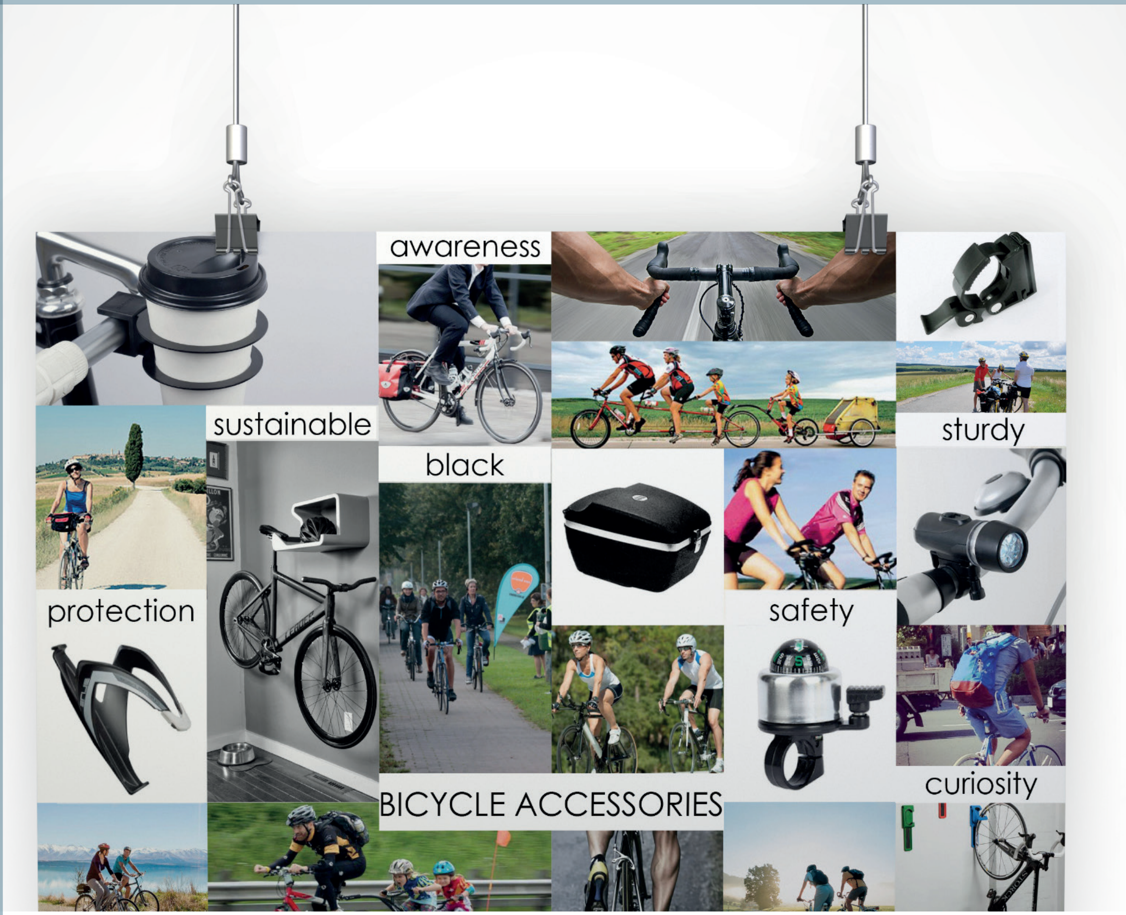
SHOW IT

On the one hand, the recycled nature of the material (unique imperfections despite mass production) can be shown and enhanced: ***show it***.

HIDE IT

On the other hand, precisely the quality of the industrial processing capabilities (just like with virgins) can be explored without emphasizing the recycling background: ***hide it***.





**moodboard composed by students of Product Development, 2017*

When choosing the set of features that you want to emphasize in your materials experience vision, you can immediately try to link this with the intended target group and/or product context.

For example, the colour black and the recycled character may suit leisure cyclists who care about the environment and are interested in bike accessories?

Create some moodboards that match your target group or that portray you chosen vision! This can come in handy later on in the idea generation.

HINT: DON'T FORGET TO TAKE A LOOK AT TRENDS AND ACTUALITY THAT YOU CAN RESPOND TO. THE GENERALLY BLACK COLOUR OF RECYCLED PLASTICS DOES NOT HAVE TO BE A CONSTRAINT!

Whirlpool Corporation

Black is the New Black

Nov 9, 2017 | Our Brands & Products

Whirlpool Corp. Design Team Predicts the Future of Color

Senior Manager of the Material, Color and Finish Studio Jessica McConnell leads a team of design detectives who scour the globe to figure out which trends are hot, which are not, and which are here to stay. "We do a great deal of research to determine what's going on in the world of design and color," said McConnell. "That involves looking at fads and trends. A fad is something we watch and monitor over time to see if it ...es and becomes a trend. We don't want to attach ourselves to fads, ...se the design and colors we choose for our major appliances have ... relevant for at least 15 years, since that's how long they're living in people's homes."

...or is the first thing a person sees when looking at an appliance and influences buying decisions, explains ...Connell. "Color is incredibly emotional," she said. "People are drawn to color for various reasons, and it's ...ually an emotional response. They might like a certain color because it means something to them."

The design team's search for the next big color starts with social and cultural trends — an investigation into the behaviors and attitudes of people. Because designers are predicting the future, they look to art, fashion and architecture to gauge where trends might be heading.

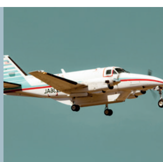
"Those industries are ahead of everybody else and much more forward thinking," said McConnell. "If you think about artists, they're just responding to feelings they have. Those feelings later become shared amongst a larger group of people, as we're all subject to the same factors. We all live in the same social context with the same politics and environmental issues. We have the same technology impacting our lives."

From Whirlpool Corporation [5]

application areas

As a first step within the idea generation process, you can define several potential application areas for recycled material, based on their technical and user-centred features.

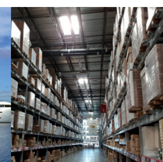
TRANSPORT & LOGISTICS


airplane


automotive

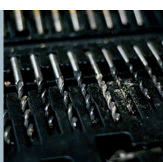

train

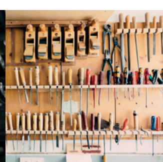

boat

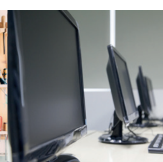

b2b packaging


container

ELECTRONICS


packaging


tools

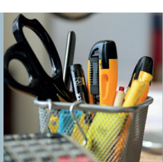


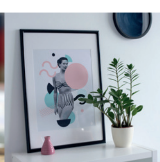
housings


installation equipment

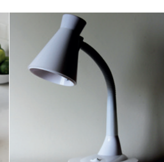

industry

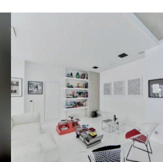
LIFESTYLE & INTERIOR

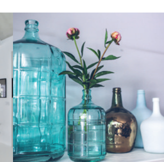

office supplies


accessories

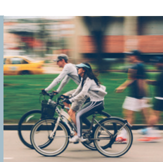

kitchen supplies


lighting

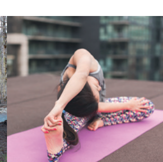

furniture

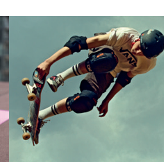

decoration

SPORTS & PLAY


bicycle accessories


trekking/ camping


fitness


protection


toys


parts

Depending on the material, you can make a selection from the visualisations below or you can identify additional application areas. These may also arise from your chosen Materials Experience Vision(s).

BOUW & CONSTRUCTIE

structural | finishing | underground | road | navy | public works

PUBLIC DOMAIN

public transport | defense | public buildings | sport | parks | security services

GARDEN

toys | pottery | furniture | tools | rain barrel | storage

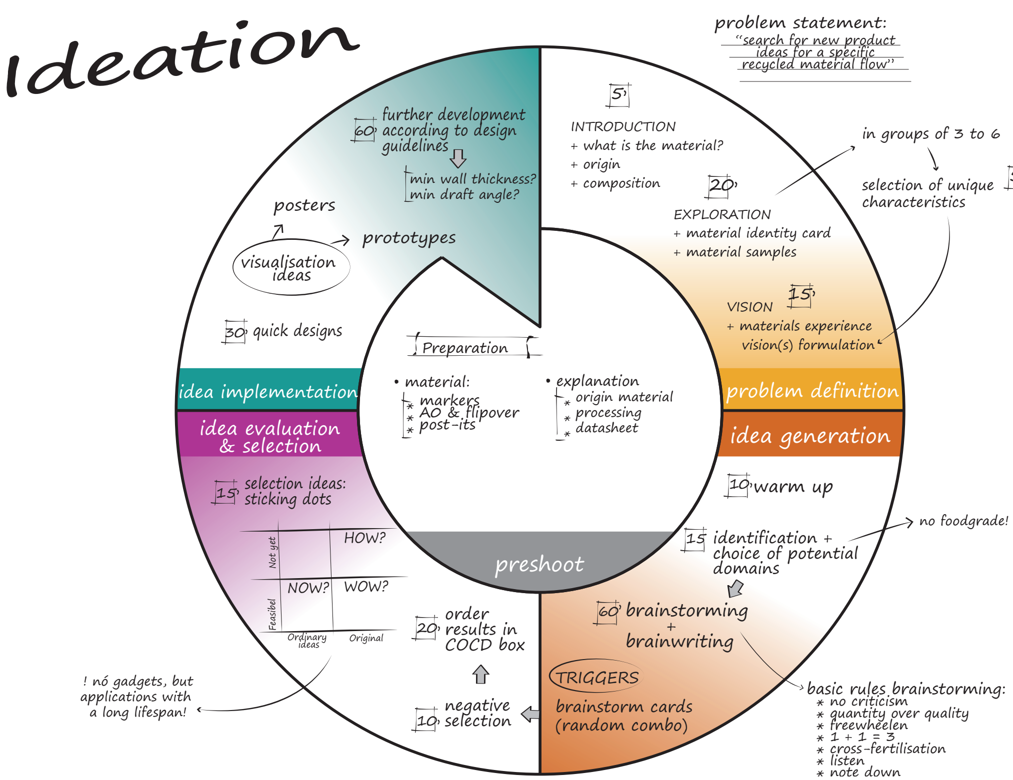
PACKAGING

crates | buckets | pallets | coils | displays | b2c

idea generation

To facilitate idea generation, you can use the **Idea2Market** tool [6] that was developed by researchers of Product Development at the University of Antwerp. This tool visualises the process from problem definition (results of previous explorations) to idea generation and idea selection. Finally, the idea implementation corresponds to the design phase at the end of this manual.

To further support brainstorming sessions, you can also prepare brainstorm cards listing different aspects of the recyclate (technical qualities, sensorial and associative characteristics, design visions, potential application areas…). Then, you can randomly combine 3 to 5 brainstorm cards to create new ideas.



idea evaluation & selection

NEGATIVE SELECTION

When your brainstorm went well, you now have a long list of product applications for the recycled material. To make this stack of ideas more comprehensible, you can easily shorten it through a **negative selection**.

Check the following elimination steps for each idea in order to end up with only useful ideas. For example, you can merge duplicate ideas right away.

Depending on the recycled material in question, a few specific negative selection criteria may be added, such as the maximum user temperature, no impact, absolute dimensional stability or other technical requirements beyond the range of recyclates.

Below, for each step some examples from past workshops are shown that were eliminated in this way.

Eliminate duplicate ideas	*street sign = traffic sign*
Eliminate ideas with food contact	*salad bowl* *disposable cutlery*
Eliminate too abstract ideas	*decor fashion store* *fire house*
Eliminate fully transparent products	*bus shelter*
Eliminate ideas that absolutely require a rich pallet of colours	*toddler toys*
Eliminate ideas with very thin wall thicknesses	*electronics*
Eliminate ideas that ...	

COCD-BOX

After finishing the diverging brainstorming sessions and negative selection, there will still be an extensive list of ideas. Therefore, we propose to use the **COCD-box** [7] to easily organise this stack for feasibility, added value and originality. This procedure takes approximately 30 minutes.

» Write down each idea on a separate post-it.

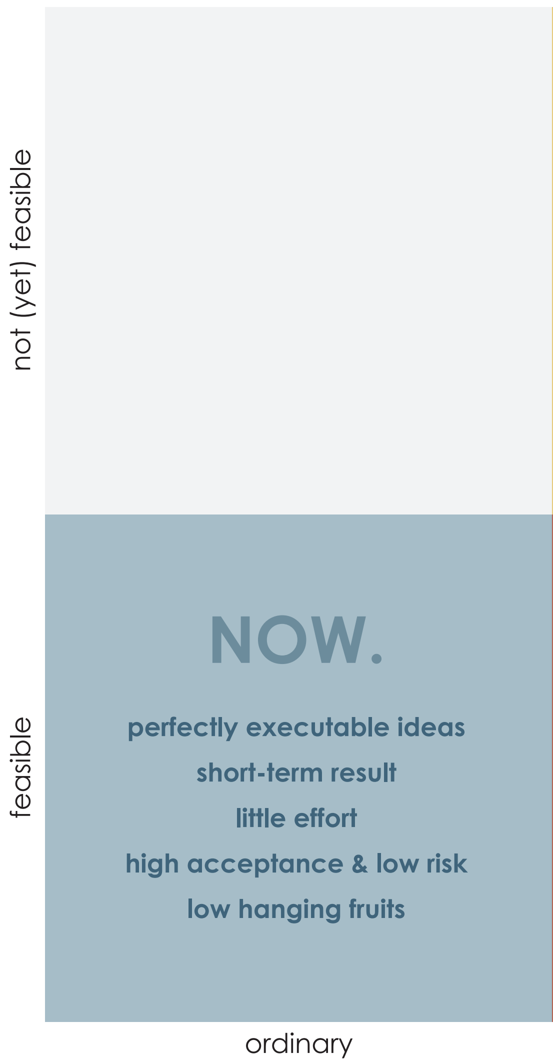
» Select each 5 favorite now, wow and how ideas and mark them with coloured stickers (blue, red and yellow respectively).

» Select in group 10 to 15 ideas with the most stickers, regardless of the colour.

» Place these ideas in the COCD-box according to the most common colour of stickers.

» Select one or more ideas in a particular category to further develop, according to the R&D possibilities and available time within the company.

» Take the red wow ideas as a starting point.



The COCD-box is based on the work of 'Centrum voor de Ontwikkeling van het Creatief Denken' [7].

HINT: SOMETIMES, IT IS REGRETTABLE THAT AN IDEA DOES NOT MAKE THE SELECTION. IF NECESSARY, GIVE A WILD CARD TO EACH PARTICIPANT TO PUSH THROUGH ONE SPECIFIC IDEA.

HOW?

ideas for the future

challenges & dreams

inspiring

vision decisive

directional

WOW!

original & executable

innovative

distinctive

activating & stimulating

breakthrough

original

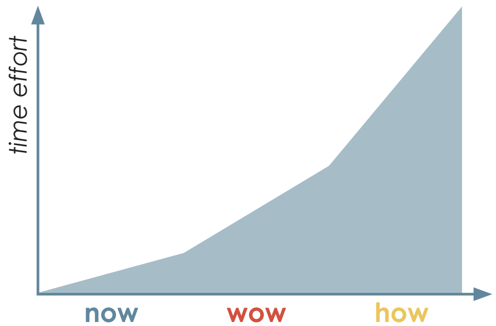
idea implementation

START DESIGN PROCESS

From the moment you have chosen a single product idea, you can follow your design process, as you are used to . Obviously, you have to take into account the technical possibilities and design guidelines of the recyclate.

The time effort of the actual design process depends on the category of the COCD-box.

Now ideas are usually simple redesigns that can be developed relatively quickly. The product must be reconsidered only from the system design phase, especially in terms of manufacturability and mould adjustments. **Wow ideas** are rather conceptual product proposals that need to be further defined, and **how ideas** can be considered as strategic triggers for a long-term innovation project within the company.



DESIGN GUIDELINES

When designing with recycled materials it is, in general, important that the design guidelines for a specific processing technique (e.g. injection moulding) are followed extra strictly. Thus, you need to provide a ‘margin’ in your design to compensate for unforeseen behaviour.

Below, some tips & tricks are listed for injection moulding with recyclates, based on the expertise of CPMT and the Design Guides for Plastics [8].

» Match the geometry of your product with the material properties by adjusting wall thicknesses, reinforcement ribs, or the size of the injection sprues.

» Consider a uniform wall thickness (or at least a gradual transition) to avoid shrink cavities and warping.

» Avoid sharp (internal) corners, even at ribs, for a proper release of the mould.

» As a result of contaminations in the recyclate, a relatively thick walled product is recommended for injection moulding to realise processability (injection moldability) and function (stiffness, strength).

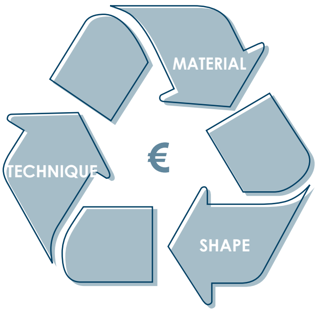
» Consider sufficient large draft angles, e.g. minimum 1° for rABS and 2° for MPO.

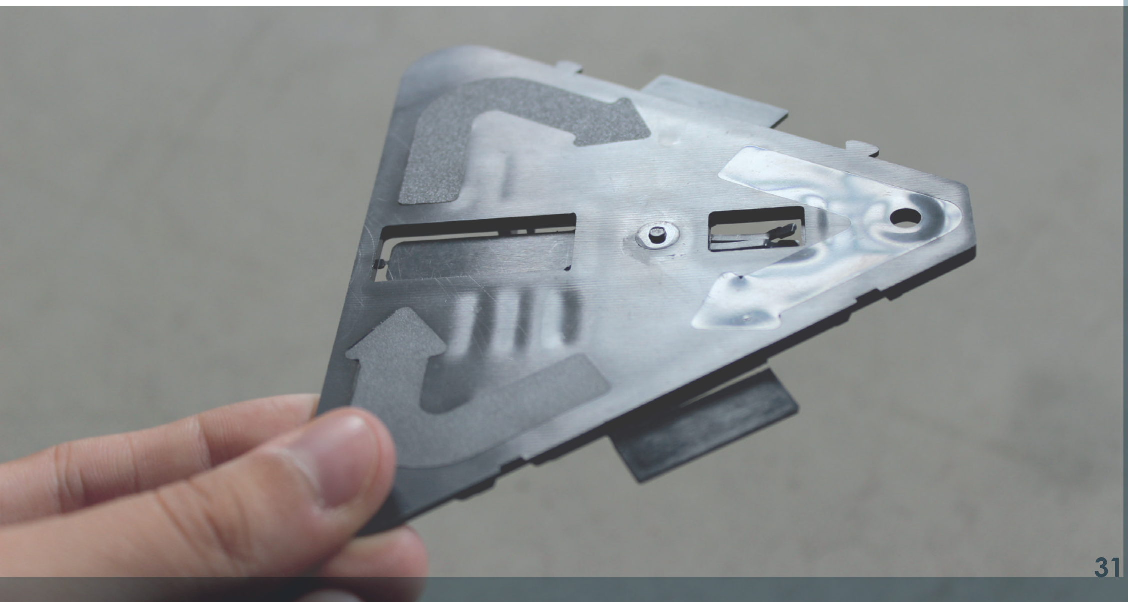
» Use a cold runner injection system with a simple flow path and sufficient ejectors.

» Hotplate welding seems to be a good connection technique for MPO, while rABS reacts well to ultrasonic welding.

When designing a product, you also have to take into account the relationship between **shape** and **technique**, in addition to the **material** itself, and always with the cost price in mind. For example, the choice for injection moulding results in different material and shape possibilities in contrast to extrusion or rotation moulding.

In addition, you can manipulate some sensorial characteristics through the physical properties. For example, the geometry has an effect on the deformability or stiffness of a product. The gloss and roughness can be influenced by the mould finishing, as the back side of the determinators shows.





eco-star

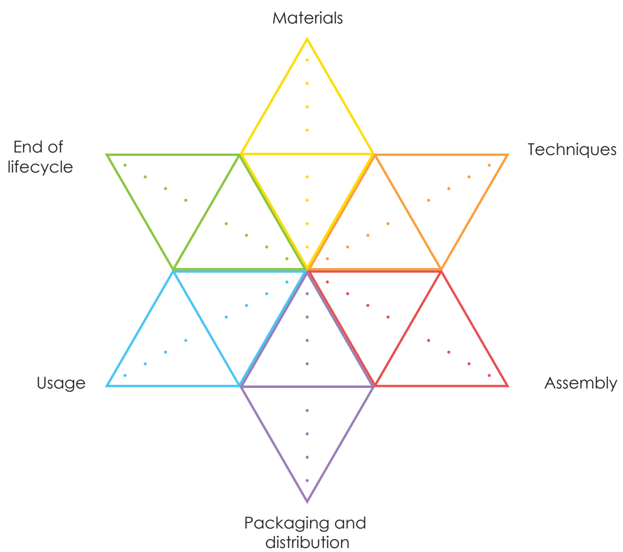
The **Eco-Star** [9] was developed by Dr. Ing Karine Van Doorsselaer of the Product Development department at Antwerp University. This qualitative tool helps you to chart and evaluate both the ecological and economic impact of a product idea or existing product.

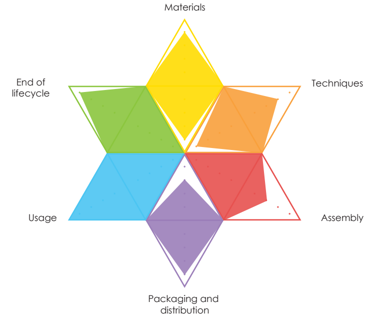
Within the Design from Recycling context, the Eco-star is an inspirational tool to qualify your proposed ideas and generate improvement points throughout its further development!

The six coloured diamonds of the Eco-Star each stand for each phase in the product life cycle. The outer triangles visualise the ecological profile, whereas the inner triangles represent the economic profile.

To start, choose five relevant statements per triangle of the table on the next page and check each of them for your product idea. Per positive answer, a part of the triangle can be coloured so that in the end the coloured Eco-Star provides a visual overview of the eco-efficiency profile. The clue is not really in the given score, but rather in the reasoning behind. Therefore, the Eco-Star contributes to the communication between the involved stakeholders and invites them for a instructive discussions!

More information about the Eco-Star can be found in chapter 5 of the book "Ecodesign: ecologisch verantwoord industrieel ontwerpen" [9].





	Ecology	Economy
Materials	» Limited amount of different materials? » Materials with low environmental impact? » Limitation of harmful excipients? » Locally available materials? » Optimised material usage? » Recycled materials? » Recyclable materials?	» Cheap materials, excipients, surface treatments? » Available materials/short delivery time? » locally available materials? » Reduction of types of materials? » Reduction of material quantity? » No oversizing? » Interesting cost of recyclates?
Techniques	» Low energy-consuming processes? » Low environmental impact technologies? » Minimal production waste? » Limited use of tools? » Local production? » Limited number of different techniques? » No toxic emissions? » Heat recovery?	» Few process steps, fast lead times? » Low power consumption? » Low consumption of excipients? » Limited additional finishing steps? » Limited production waste and valorisation of production waste? » Limited dropout?
Assembly	» Low energy consuming techniques? » Limited amount of parts? » Limited amount of actions? » Limited harmful emissions? » Standardisation? » Sustainable technology of electromechanical components?	» Fast connection technique connectivity? » Low power consumption? » Limited tools? » Limited number of parts? » Standardisation? » Cheap technology components?
Packaging & distribution	» Material with a small environm. impact? » Monomaterial? » Recycled material? » Min. quantity of packaging material? » Reusable packaging? » Recyclable packaging? » Stackable and nestable?	» No extra packaging required? » Short packing time? » Cheap packaging material? » Valorisable packaging? » Compact stacking, limited volume? » Mountable on standard reusable pallets?
Usage	» No emissions? » Low energy consumption? » Renewable energy? » Low water consumption? » Little or ecological resources? » Optimum repair/long-term availability parts? » Upgradeable (modular)? » Optimal feedback for consumers?	» Cheaply repairable (working hours)? » Availability of spare parts? » Use of standard tools? » Cheap maintenance? » Cheap resources? » Combination with service?
End-of-life	» Recyclable materials? » Disassemblable? » Reusable technical components? » Identifiable materials? » No use of incompatible inks, surface treatments, stickers?	» Feasible collection? » Cheap and fast disassembled? » Market value of recyclate? » Residual value of product? » Residual value of parts? » Large (existing) mass flow?

project staff

CPMT

Prof. dr. **Kim Ragaert** lectures materials and polymer science at Ghent University, where she holds a tenure track position in the domain of 'Sustainable Use and Recycling of Polymers and Composites'. Her research team is focused on the development of the necessary scientific tools to enable the improved mechanical recycling of polymer-based materials. Specific topics include upcycling of mixed solid plastic waste, modeling of polymer degradation, Design for and from Recycling, microfibrillar composites, WEEE plastics and recycling of multilayer packaging materials.

Sara Hubo is a senior researcher at the Centre for Polymer & Material Technologies at Ghent University. She graduated at Ghent University in 2002 as a Master in Biochemistry and has been involved in various research projects on polymer processing, more specifically defining the structure-property relationships of extruded and injection moulded (recycled) polymers.

PRODUCT DEVELOPMENT

Dr. **Els Du Bois** received her double doctorate in Product Development in 2013 at both TU Delft and Antwerp University. Currently, she works at the Department of Product Development at the University of Antwerp, Faculty of Design Sciences. Within the research group, she sets up the research line on ecodesign, and engages students in designing sustainable products and material-related designs within education.

Lore Veelaert obtained her Masters degree in Product Development in 2015 at Antwerp University. as a research assistant at the Product Development department, she worked on the Design from Recycling project, exploring and applying a design methodology to cases during several design workshops. In addition, as a teaching assistant she is also involved in both Bachelor and Master courses at Product Development.

Technologiepark Zwijnaarde 915
9052 Zwijnaarde

Kim.Ragaert@UGent.be
Sara.Hubo@UGent.be

match.ugent.be

Ambtmanstraat 1
2000 Antwerpen

Els. DuBois@uantwerpen.be
Lore.Veelaert@uantwerpen.be

www.uantwerpen.be/nl/onderzoeksgroep/productontwikkeling/

More information about the design from recycling project?
Surf to **www.uantwerpen.be/design-from-recycling**.

references

[1] PlasticsEurope, "Plastics – the Facts 2016," 2016.

[2] L. Veelaert, E. Du Bois, S. Hubo, K. Van Kets, and K. Ragaert, "Design from Recycling," in *EKSIG2017: alive, active, adaptive : International Conference on Experiential Knowledge*, 2017, pp. 129–143.

[3] E. Karana, B. Barati, V. Rognoli, and A. Zeeuw van der Laan, "Material Driven Design (MDD): A Method to Design for Material Experiences," *Int. J. Des.*, vol. 9, no. 2, 2015.

[4] E. Karana, P. Hekkert, and P. Kandachar, "Assessing material properties on sensorial scales," in *2009 ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, DETC2009, 2009, vol. 2, pp. 911–916.

[5] Whirlpool Corporation, "Black is the New Black," Our Brands & Products, 2017. [Online]. Available: http://www.whirlpoolcorp.com/black-is-the-new-black/. [Accessed: 04-Apr-2018].

[6] I. Dewit, E. Du Bois, I. Moons, and A. Jacoby, "Idea2Market: Implementing an ideation guide for product design education and innovation," *Proc. 14th Int. Conf. Eng. Prod. Des. Educ. Des. Educ. Futur. Wellbeing*, EPDE 2012, no. September, pp. 763–768, 2012.

[7] COCD – Het kennisinstituut voor creativiteit, "COCD-box," *COCD*. [Online]. Available: http://www.cocd.org/. [Accessed: 11-Oct-2017].

[8] C. Maier (Econology Ltd), "Design Guides for Plastics," 2009.

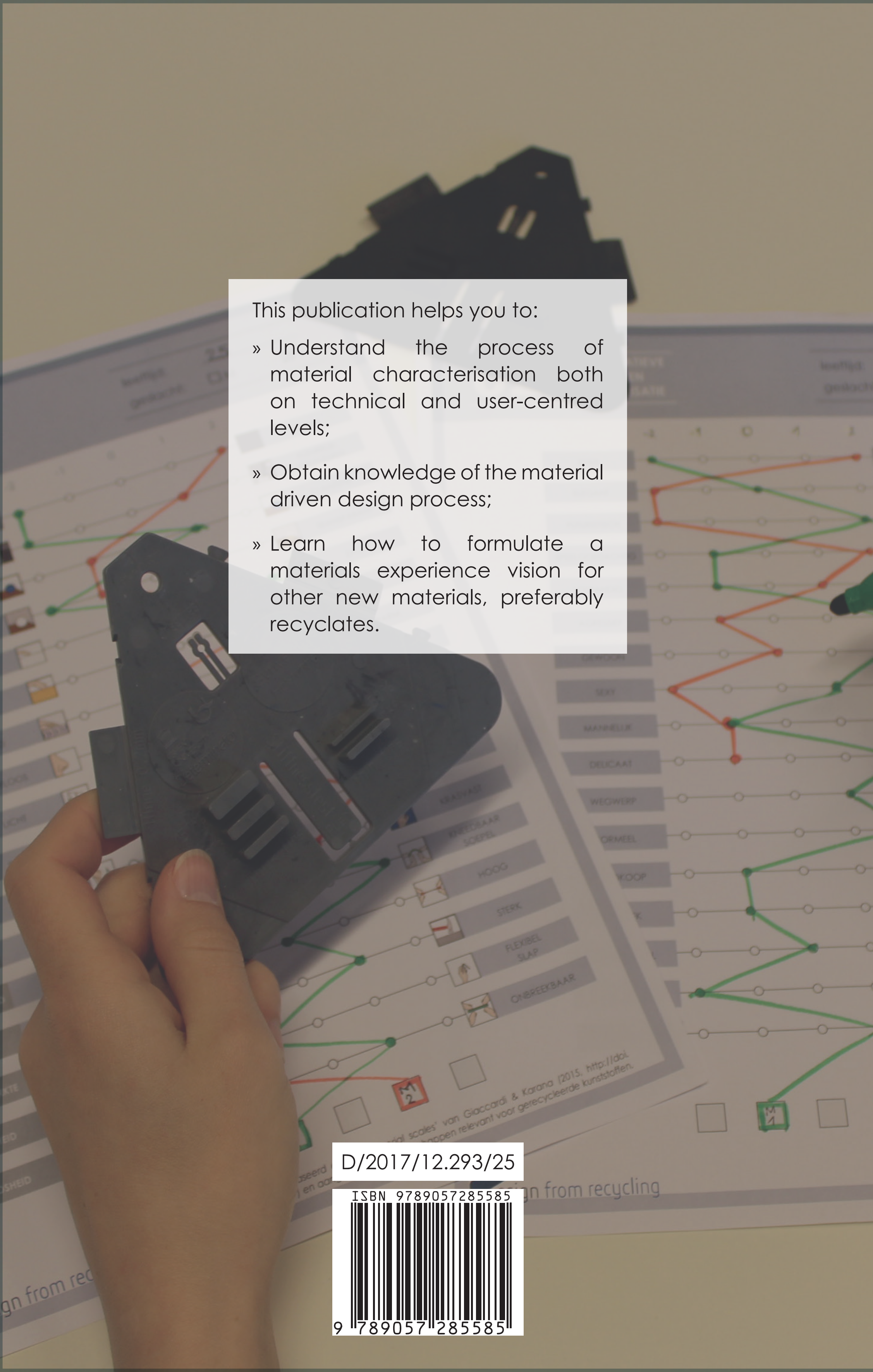
[9] K. Van Doorsselaer and E. Du Bois, *Ecodesign: ecologisch verantwoord industrieel ontwerpen*. Gent: Academia Press, 2015.

Authors: Lore Veelaert, Els Du Bois, Karine Van Doorselaer, Sara Hubo, Kim Ragaert

Final editing & design: Lore Veelaert

Images: authors & students Product Development

Stock Photos under Creative Commons CC0: pexels.com, stocksnap.io, pixabay.com



This publication helps you to:

» Understand the process of material characterisation both on technical and user-centred levels;

» Obtain knowledge of the material driven design process;

» Learn how to formulate a materials experience vision for other new materials, preferably recyclates.

D/2017/12.293/25

ISBN 9789057285585