DESIGNING WITH RECYCLED PLASTICS

GUIDELINES

Rijksdienst voor Ondernemend Nederland

PARTNERS FOR INNOVATION

NRK

This ‘Designing with Recycled Plastics handbook is the result of an MJA3 (multi-year energy agreement) project commissioned by the Netherlands Enterprise Agency (RVO) and the Dutch Federation of Rubber and Plastics Industry (NRK), initiated and implemented by Partners for Innovation in collaboration with Philips. The idea for this project originated in the working group ‘Recycled plastics and Product Design', as part of the Plastic Cycle Value Chain Agreement.

The goal of the project is to make available information from leaders in using recycled plastics in injection-moulded products. Target groups for this handbook are designers and R&D employees within OEM companies, suppliers, such as manufacturers of injection-moulding products, and design agencies.

This handbook offers background information about the entire process, from the strategic choice to use recycled plastics to communication towards consumers about products containing recycled plastics. It also contains practical design guidelines for products which can be manufactured using recycled plastics. Extensive practical examples are provided.

The foundations for this handbook were laid in a project with six Dutch leaders in the field, who brainstormed together about the content and design of the handbook over the course of two workshops. These leaders are Philips, Curver, Océ, Schoeller Allibert, AKG and Cumapol. The foundations were further supplemented by a literature search, desk research and conversations with parties involved from industry, research and education.

As part of this project, case descriptions have also been made, in which these leaders share their experiences regarding the use of recycled plastics. Videos have been recorded for all the cases and the case descriptions bundled in the case guide depicted below.

Ingeborg Gort
Abel Gerrits
Partners for Innovation, Amsterdam 2015

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FOREWORD BY THE AUTHORS

INGEBORG GORT works as a consultant for **PARTNERS FOR INNOVATION**. Her work involves initiating and delivering sustainable innovation projects in the (plastics) value chain. She is trained as an industrial designer at Delft University of Technology.
"Plastics are often seen as an environmental problem, but they are indispensable in contemporary society. Plastic products contribute to the comfort, safety and welfare of people and can make a positive contribution to reducing the environmental impact of the complete life cycle of the product. A truly sustainable plastic product is designed to be an integral component of the Circular Economy and contains no harmful substances."

ABEL GERRITS is a master's student in Industrial Design Engineering at **UNIVERSITY OF TWENTE**. As part of his graduation internship at Partners for Innovation, he worked on the development of these Guidelines and practical cases for this project.
"The research into recycled plastics and the inspiring practical examples from the leaders in the field reveal countless opportunities for using recycled plastics that fit within the Circular Economy. Designing with recycled plastics and taking account of recycling can stimulate the necessary innovation in order to increase the number of applications with recycled plastics."

FOREWORD BY THE PARTICIPANTS

EELCO SMIT is Director Sustainability at **PHILIPS INTERNATIONAL BV**: *"Plastic is an important material for Philips which is used in nearly all our products. As such, innovating with recycled plastics is an important next step in our transition to a circular economy. Our products demonstrate that recycled plastics can be used in high-quality applications without compromising on quality or design."*

DANIEL RASENBERG, Business Developer at **CURVER**: *"Post-consumer waste materials provide an excellent opportunity to reduce our carbon footprint and offer environmentally-aware consumers the products and storage solutions they are looking for. Curver will continue to innovate in order to ensure an increase in the use of post-consumer waste materials."*

TANYA NIMALASURIYA, Environmental Policy & Ecodesign expert**, JO FRENKEN**, Mechanical Engineer Research & Development and **EDWIN BOOGERT**, Mechanical Engineer Research & Development at **OCÉ**: *"Océ uses recycled plastic in a part of the varioPRINT 135. This part needs to meet strict requirements, such as fire resistance. The Océ development team looked at several possibilities and eventually opted for food-grade recycled PC+ABS for a part which is not externally visible. The experiment demonstrates that recycled plastic is suitable for high-quality technological applications. We are looking into whether use in Océ products is possible on a large scale – this will depend on the business case."*

FRANK RICHTERS, Marketing & Sales Manager at **AKG POLYMERS:** *"Recycled plastics are increasingly regarded by plastics processors and brand owners as equivalent replacements for new materials. This only holds true at absolutely consistent quality and guaranteed availability, year after year. Switching to recycled plastics is only done in close collaboration with the customer. The starting point is that there should be no concessions on product quality."*

PATRICK BREUKERS, Corporate Director Technology and **HENK DEKKERS,** Senior Development Engineer at **SCHOELLER ALLIBERT:**
"Schoeller Allibert has been designing and manufacturing its products using recycled plastics for over 40 years. It assumes that its products will be recycled from the outset. Closed loop material is recycled into high-quality input material by means of a washing process in which UV-degraded material is separated. This integrated recycling approach ensures that Schoeller Allibert uses more than 20,000 tons of regrind for returnable plastic packaging annually."

MARCO BRONS, Technical Director at **CUMAPOL:** *"With our expertise and experience gained from virgin PET production, CUMAPOL can support its customers in using recycled PET in valuable, high-quality end products. We are working towards a future characterised by a mix of mechanically and chemically recycled PET, supplemented with Biobased PET, which will mean that no new fossil fuel-based raw materials will any longer be needed."*

1. INTRODUCTION

More and more plastic waste is collected separately for recycling. This also means that more applications need to be developed for recycled plastic, or 'recyclate'. The use of recycled plastics in new products is therefore an unavoidable element in the transition from a linear to a circular economy.

In Europe and in the Netherlands, there are objectives and regulations covering the reuse of plastic waste flows.

The packaging framework agreement 2013-2022 defines objectives and targets for the reuse percentages of plastic packaging. For example, the objective is to reuse 52 percent of plastic packaging in 2022, but the hope is to achieve this percentage as early as 2017 (Rijkswaterstaat 2013).

To date, recycled plastic has still been little used in premium applications. In most cases, it is not interchangeable with virgin plastic on a one-to-one basis. It has different mechanical and/or organoleptic (odour) characteristics and is different in terms of colour. For reasons including a lack of knowledge about the use of recycled plastics and a limited range of suppliers, the possibilities of recycled plastics are currently not being optimally utilised.

This handbook demonstrates what is already possible using recycled plastics and offers a guide for the use of recycled plastics in high-end products.

2. PLASTICS IN A CIRCULAR ECONOMY

Plastic products are of great value to society. Plastics have set in train many positive developments and facilitate safety, health, comfort, food supply and welfare. Most plastics are made from fossil fuel-based raw materials such as petroleum. Currently, plastic products or packaging are often still burned at the end of their useful lives (with energy recovery). This is a linear economic model. In a circular economy, plastics and plastic products retain their value longer by reusing, repairing and eventually recycling them. The starting point is that the products and materials are specifically designed for this purpose. The illustration below shows the current situation of plastics in the circular economy in the Netherlands.

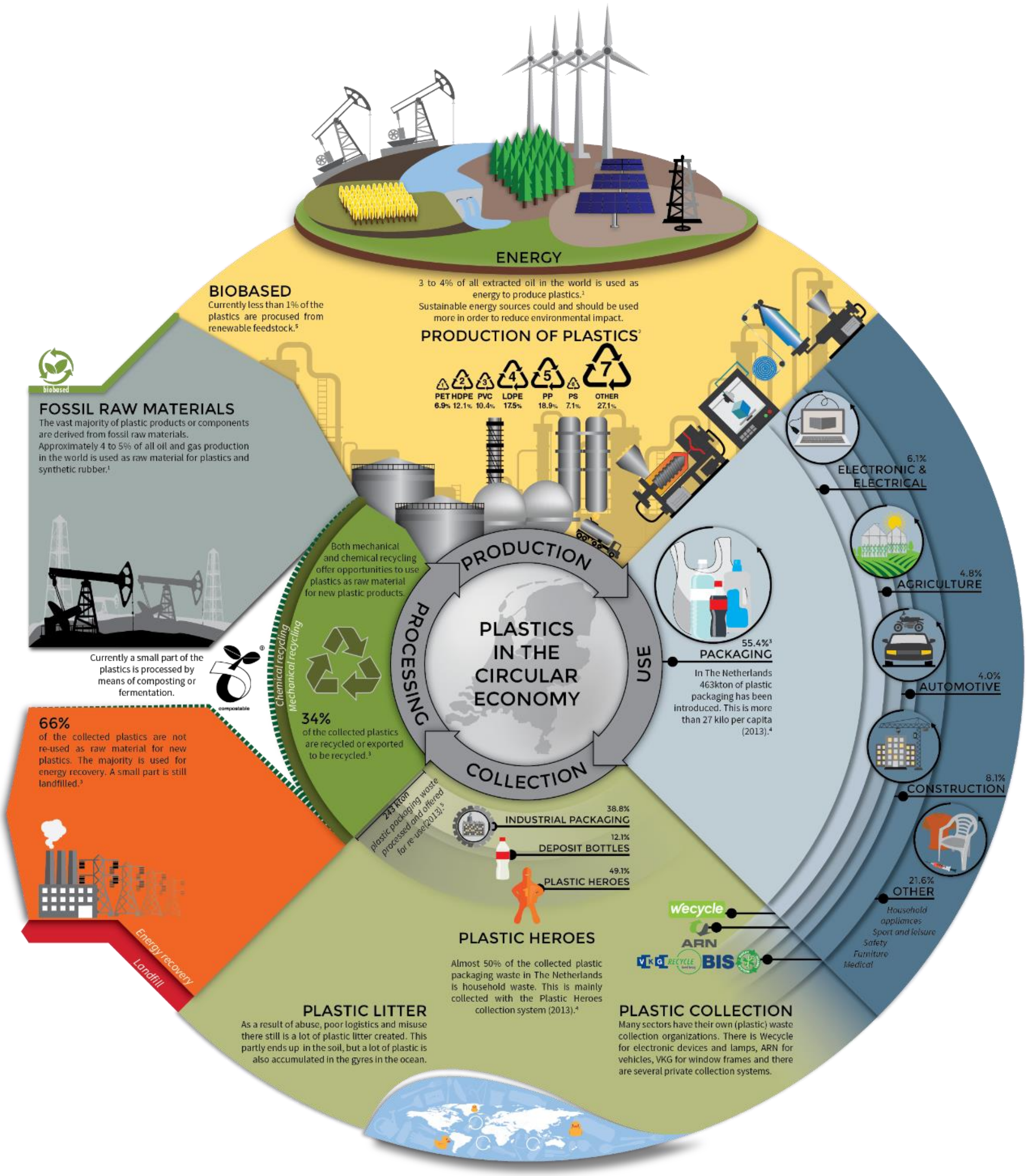


FIGURE 1: PLASTICS IN THE CIRCULAR ECONOMY (SOURCE: PARTNERS FOR INNOVATION)

2.1 PRODUCTION

At present, fossil fuel-based raw materials are primarily used for the production of plastics. Estimates vary, but if fossil fuel-based raw materials continue to be extracted at this rate, it is clear that scarcity will arise which will make the production of plastics from these sources more difficult (Prins, Slingerland et al. 2011). There are also possibilities for manufacturing plastics using renewable raw materials (biobased). These reduce the need to use fossil fuel-based raw materials, but complete replacement of fossil fuel-based raw materials with biobased raw materials is not yet feasible in the short term. At the moment, production processes using biobased raw materials still need to be scaled up and optimised. It is expected that more efficient production of biobased materials will become possible in the near future (Wolkers 2015).

It is estimated that between 3 and 4 percent of the oil and gas extracted globally is used in the production of plastics (Hopewell, Dvorak et al. 2009). In addition, energy is required to turn these plastics into products. This energy can be produced using fossil sources, but also using sustainable energy sources such as wind, water, solar and biomass.

2.2 USE

The number of applications for plastics is highly varied. In the Netherlands, packaging accounts for the largest share of the plastics used. Packagings have different functions, such as protecting and preserving products, bundling products and making them distributable, and informing users about products. On average, packagings have the shortest lifespan of all plastics applications. In many cases, the packaging is used only once and is immediately disposed of. Due to the variety of types and functions of packaging, many different types of plastics are used.

In the usage phase of plastic products, a contribution can be made to a circular economy by using products longer, reusing them, repairing them or 'refurbishing' them. In this way, they retain a high value for longer and can still be collected and recycled at a later stage.

2.3 COLLECTION

Different sectors in which plastics are used have their own collection systems. The best known in the Netherlands, the Plastic Heroes collection system for consumer packagings, has done much to increase public awareness about plastics collection. In addition, there are other collection systems, such as Wecycle (for electrical and electronic devices and light bulbs), BIS (Buizen Inzamel Systeem – tube recycling), VKG Recycling (Vereniging Kunststof Gevelelementenindustrie – plastic façade elements) and ARN (Auto Recycling Nederland – car recycling). These systems all contribute to an efficient collection of products which contain a high proportion of plastics.

Problems arise when plastics are not properly collected after disposal. This is visible to everyone in the form of litter on the street, but there are also less visible problems. A lot of plastic waste has already found its way into the ground, rivers and oceans. In spite of this, plastics are still used in applications and at locations where they cannot be properly collected after use.

For example: In scrub products and toothpastes, microplastics (plastic in the form of little balls) are sometimes used to achieve an abrasive effect. When these products are used, the microplastics can end up in your body or be flushed out with the waste water. Microplastics are hard to break down and persist in the environment for a long time (Anttonen, Halme et al. 2013).

2.4 PROCESSING

When plastics are disposed of, different processing methods are used. In the Netherlands, waste is only dumped if no other processing method is available. Many plastics end up in waste incineration, which enables energy to be recovered. However, this is not a route which fits within a circular economy, because most of the material's value is lost.

Recycling ensures that plastics can be reused as a material for new applications. In mechanical recycling, the collected waste is cleaned, crushed and reprocessed to make new plastics. In chemical recycling, a plastic is broken down into a monomer. These monomers can be used in the production process for new plastics. The more plastics remain in the circular material flow, the less new (virgin) plastics are required.

FIGURE 2: WASTE HIERARCHY, SET OUT IN DIRECTIVE 2008/98/EC

The use of compostable or biodegradable plastics made from biobased raw materials is another option. These can be digested after use, for example. This process produces compost (digestate) and biogas, which can be used to generate electricity. Compostable plastics do need to be collected and processed separately from other plastics (along with fruit, vegetables & garden waste or residual waste collection). If they are collected together with ordinary plastics, this can have negative consequences for the quality of the recycled plastics, since sorters cannot (yet) separate the biodegradable plastics.

Currently, the use of biodegradable plastics or compostable plastics is primarily suited to very specific applications, for example if these plastics end up in an organic residual flow.

Pharmafilter has developed a purification system for hospitals. In this system, various waste flows (including plastic products) are transported to an internal purification plant. Biodegradable plastic products, such as medical disposables (suitable for single use) are disposed of and ultimately digested The biogas produced in this way is used to generate electricity (Pharmafilter 2015).

3. RECYCLED PLASTICS, A STRATEGIC CHOICE!

3.1 WHY USE RECYCLED PLASTICS?

There are different motives for using recycled plastics. Usually there are several reasons which together result in a business case. A list of factors which can serve as a motivation to use recycled plastics is shown below.

COST SAVINGS: The price of recycled plastics is virtually always lower than the price of virgin commodities. In recent years, the quality of recycled plastics has increased to such an extent that it is often used as an equivalent and affordable replacement for virgin plastics in premium applications (Vraag en Aanbod 2015).

REDUCTION IN ENVIRONMENTAL IMPACT: Recycled plastics avoid the use of new materials and saves energy for production. This enables the environmental impact to be reduced. Life-Cycle Assessment studies (LCAs) reveal that recycling is virtually always the processing method with the lowest environmental impact (WRAP 2010, Deloitte 2015, NRK Recycling 2015).

REDUCTION IN THE SCARCITY OF MATERIALS: Due to the exhaustion of fossil fuel-based raw materials, it is anticipated that the price of plastics will increase and security of supply will diminish. By keeping plastics in a circular flow, fewer fossil fuel-based raw materials are required and our dependence on oil is reduced.

MARKETING CONSIDERATIONS: Consumers increasingly include sustainability in their purchasing considerations (GfK 2014). Recycled plastics can be used in communication with consumers. It can add value at product level but it can also increase the brand value of a company at corporate level (e.g. Social Plastics).

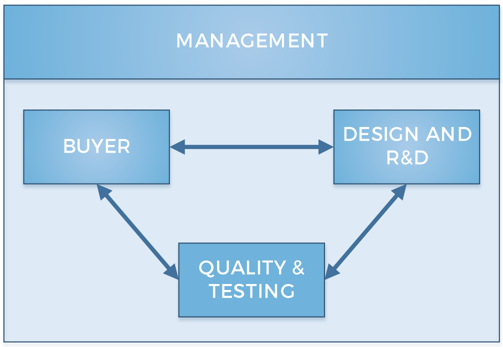
LEGISLATION, REGULATIONS AND GREEN PUBLIC PROCUREMENT: Government agencies increasingly set objectives and requirements for the use of recycled plastics. The National Waste Plan (LAP) prohibits dumping and sets requirements for the quantities of plastics that must be reused. In procurement processes, government agencies often target the use of recycled materials (IISD 2012, Ministery of Infrastructure and the Environment 2014).

CUSTOMER REQUIREMENTS: In certain sectors, attention is increasingly focused on sustainability in purchasing. In sectors in which these matters are an important factor in purchasing considerations, companies are stimulated to use recycled plastics in order to maintain and improve their competitive positions.

3.2 STAKEHOLDERS

In order to successfully use recycled plastics, the process needs to enjoy broad support within an organisation. All parties involved must be convinced of its added value. Several stakeholders who need to be involved in the switch to recycled plastics are listed below.

3.2.1 INTERNAL STAKEHOLDERS



DESIGNER AND R&D: Designers and the R&D department are often the initiators of innovation within an organisation. They can play an important role in the use of recycled plastics. With their knowledge and skills, they are able to recognise the added value of recycled plastics and incorporate them into new or existing designs.

MANAGEMENT: For the long term, it is important that a company has a sustainable strategy with a place for recycled plastics. The use of recycled plastics is a process that requires time and effort, but one that can be employed with increasing success as experience with it grows. This requires support from management, for example by including targets in policy, expressing ambitions and directing and monitoring the process.

BUYER: Recycled plastics are often purchased in small quantities and the associated specifications are often slightly more uncertain than for virgin plastics. For this reason, buyers have an important role to play in the use of recycled plastics. The collaboration between buyers, designers, manufacturers and convertors of recycled plastics is important for selecting the materials with the right properties.

QUALITY AND TESTING: Processors of recycled plastics can largely guarantee its properties and behaviour. All the same, it is important to test batches and samples in order to determine whether the material actually meets the requirements set.

3.2.2 EXTERNAL STAKEHOLDERS

COLLECTORS: Collectors of plastic waste deal with many different types of plastics. Criteria for sorting plastics include type, application and colour. The easier the collection process, the higher the potential quality of recycled plastics. . The collector therefore wants clean waste flows which can be completely separated. This is often achievable for industrial waste flows, but for consumer waste it is still trickier in many cases.

COMPOUNDERS / RECYCLERS: Recyclers and compounders of recycled plastics buy plastic (sorted and often already partially cleaned) from collectors. In consultation with final customers, they can prepare it for specific applications. Depending on the application, it may be decided to produce flakes, granulate or compounds. Intensive cooperation is required between processors and manufacturers in order to obtain recycled plastics with the correct properties.

MANUFACTURER: Because the behaviour of recycled plastics during and after production can differ with respect to virgin plastics, a manufacturer needs to be involved in the use of recycled plastics at an early stage. Good collaboration is essential from the point at which the material is tested.

DISTRIBUTOR / RETAILER: The support of retailers is necessary to sell the products manufactured using recycled plastics. Retailers and distributors often know what customers want. They can therefore help to determine where recycled plastics could be used successfully and how it should be communicated.

USER / CONSUMER: Consumer research can be important in determining whether there truly is a market for products containing recycled plastics and how they will be viewed by consumers. This research helps to set the direction for the communication strategy to be chosen.

4. WHAT ARE RECYCLED PLASTICS? AND WHAT CAN YOU DO WITH IT?

4.1 FROM WASTE TO RECYCLED PLASTICS

It is useful to understand the processes which the material has gone through before it can be used in the manufacture of new products – because with this knowledge, it is possible to exert an influence on the eventual properties of recycled plastics at an early stage of processing.

4.1.1 SOURCE AND COLLECTION

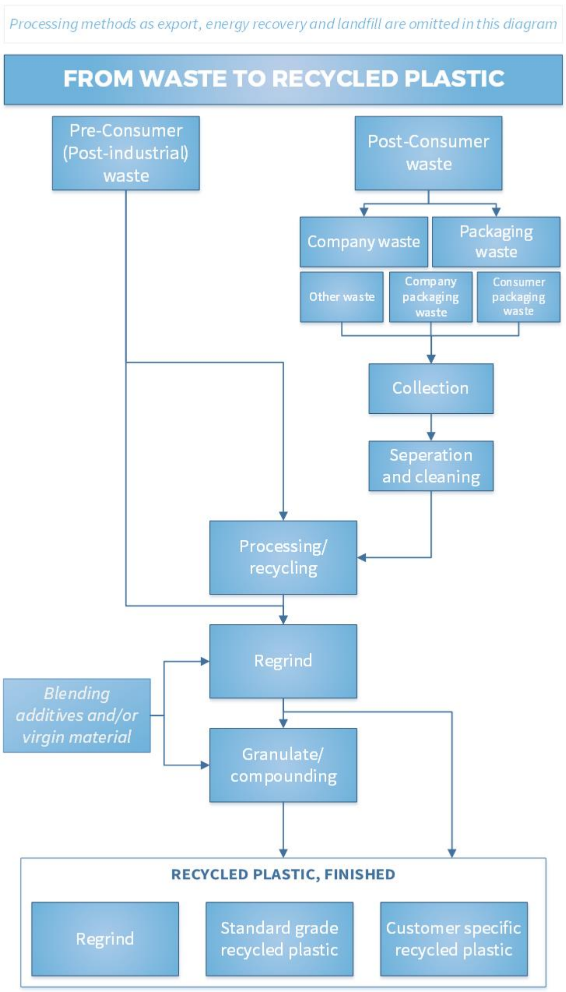


FIGURE 3: SIMPLIFIED REPRESENTATION OF THE PROCESS FROM WASTE TO RECYCLED PLASTICS

In principle, most plastic products and packagings which have been thrown away can serve as source material for recycled plastics. However, plastics blends (mixes), plastics containing lots of pigments and additives or degraded plastics are difficult to reuse for premium applications. Clean and pure mono-materials are most suitable for use as source materials for high-end applications. The source of plastic flows can give a good indication of the expected purity. Figure 3 is a simplified representation of the process from waste to recycled plastics, which is explained in brief below.

PRE-CONSUMER WASTE: Pre-consumer (or post-industrial) plastic waste are plastics obtained from a waste flow during a production process (ISO 2011). Examples are test products, failed products or products that remained unsold. These flows usually contain a single type of plastic which has not yet gone through a usage phase. As a result, the material has not yet been exposed to degradation or been affected by other substances. This means that pre-consumer waste is usually well suited to processing and has a high value.

If the manufacturer itself has a processing facility, the waste can be re-used internally. Often, crushing the plastic is sufficient and it can be mixed into virgin material directly. In many cases, the material can then be re-used in the same application as it was obtained from. However, according to ISO 14021 this is not pre-consumer waste.

The plastic waste can also be sent to *recyclers/compounders* who can often turn it into high-quality recycled plastics .

POST-CONSUMER WASTE: Post-consumer plastic waste is obtained from products and packagings which already have a life cycle behind them, i.e. they have been used. A distinction is often drawn between commercial waste and household waste.

Household packaging waste is the biggest and best-known flow of post-consumer plastic waste. It consists of many different types of plastics. It is obtained from waste generated in households and collected by means of a source-separation or post-separation system. This flow is weighed, checked and sorted by the collector and then sold to recyclers. They can turn the sorted bales into a new raw material.

Commercial plastic waste often consists of large volumes of the same type of plastic. This flow usually lends itself well to recycling. It is generally collected by private collection firms or is part of collection and processing systems set up by particular sectors.

For example: For car wrecks, the objective is that 95% of the wreck will be used for recycling or another useful application. To this end, ARN (Auto Recycling Nederland) and its chain partners have set up a recycling system. This involves the cars first being dismantled and then shredded to recover metal. Eventually, the materials are separated for reuse. The plastics recovered in this way (on average 69 kg plastic per car in 2014) are sorted into 3 classes (light/medium/heavy), each used for a different purpose.

FIGURE 4: EXAMPLE OF LIGHT FRACTION PLASTICS IN SEPARATION FROM CAR WRECKS (SOURCE: ARN)

4.1.2 RECYCLING

Both pre-consumer and post-consumer plastic waste is often taken to a recycler in order to be processed further into (high-quality) recycled plastics. The recycler can convert this waste into different types of recycled plastic, depending on the eventual application.

FLAKES: If the material collected is pure and still of sufficient quality, it is not always necessary to compound and regranulate it. Plastic flakes are only ground, washed and dusted and can then be immediately used in an injection-moulding process.

In Volkswagen heater grilles, flakes from old grilles is used (Bayer Material Science AG 2013). This involves old grilles being crushed and added to virgin material in the production of new heating grilles. Bayer provides a number of guidelines for the use of flakes mixed with virgin material:

- In most cases, 10 to 20% flake or regranulate can be mixed into virgin material without a problem
- Do not use production waste which is thermally degraded. This will significantly reduce the properties of the new material;
- Grind the waste to a size comparable to the virgin material;
- Dry the material to a moisture level comparable to the virgin material.

FIGURE 5: REUSE OF PLASTICS IN NEW COMPONENTS (SOURCE: BAYER)

STANDARD GRADES OF RECYCLED PLASTICS: Many recyclers offer several standard grades of recycled plastics which can be used for many applications. They compound the material received from collectors and use additives to ensure that the material meets the requirements for the standard grades.

GRADES FOR SPECIFIC APPLICATIONS: Recyclers are also able to develop customer-specific compounds. In this case, plastics can be compounded in partnership with the customer to produce a recycled plastic specified according to technical properties, process properties, colour, etc. The recycler can achieve this by using specific waste flows, but also by adding fillers, additives, pigments and virgin material.

Showcase AKG Polymers: Design with recycled plastics
AKG Polymers offers 7 standard grades of recycled PP. These differ from one another in the degree of flow, the presence of additives and the production method for which they have been developed. However, they can also develop grades for specific applications. The video shows how AKG Polymers develops recycled PP for premium applications.

RESIDUAL FLOW/MIXTURE A converting or production company may be left with production material which is contaminated and/or mixed and can no longer be used for high-quality applications. Often, this material is burned with energy recovery. However, sometimes it can be reprocessed one more time into flakes and used in an application with low visual and mechanical requirements.

Example: Plastic roadside posts, sheet pile walls and scaffold boards are often made of recycled plastic mixtures. Using this material means no new material is required and an additional, useful life cycle is added to the plastics flow.

FIGURE 6: SCAFFOLDING BOARDS MADE FROM RECYCLED PLASTIC (SOURCE: LANKHORST RECYCLING)

4.2 MATERIALS PROPERTIES OF RECYCLED PLASTICS

INFLUENCES ON QUALITY OF RECYCLED PLASTICS
INFLUENCES DURING USAGE PHASE
Oxidation (UV exposure)
Mechanical degradation
Chemical migration of other substances
PROCESSING INFLUENCES
Thermal degradation during: • Agglomeration • Melting
Mechanical degradation as a result of: • Forces on polymer • Shear forces
INFLUENCE OF MATERIAL USED
Purity/contamination of raw material
Additives/pigments/fillers added

Compounders and recyclers virtually always communicate the properties of recycled plastics in the Technical Data Sheets (TDS). These state properties such as melt flow index, density, tensile strength, E-modulus, impact resistance and hardness. Based on this information, an estimate can be made of the extent to which the recycled plastic is suitable for the desired application.

Due to the previous life cycle and the manufacturing processes, there are many factors that will contribute to determining the quality (see table). Plastics recyclers are often able to improve the existing properties. How recycled plastics behave with respect to virgin plastics is difficult to specify in general terms due to the countless possibilities of both virgin plastics and recycled plastics.

Several guidelines are given below about the influence of the previous life cycle and converting on the properties of recycled plastics:

DENSITY: Density can be influenced by impurities. This can have a negative impact on properties such as the stiffness or weight of a product. In HDPE, for example, impurities can negatively influence crystallisation, as a result of which the density, and hence the stiffness, turn out lower. In PP, impurities increase the density (but not the crystallinity), which means the product to be manufactured ends up being heavier than if it were made of a new polymer, which is undesirable in most cases. Density is measured using an analytical balance which can determine the weight and volume.

MECHANICAL PROPERTIES: Tensile testing is used to determine mechanical properties such as tensile strength and elasticity/stiffness. These can be reduced by the presence of contaminants or degradation of the material and due to the reduction of density in HDPE, for example (see DENSITY). Degradation can result in the polymer chains breaking or cross-linking of the polymer chains; as a result, the material can be pulled apart more easily or react in a less elastic manner.

IMPACT RESISTANCE: Clearly, the breaking of chains and degradation of the material mean that the more a plastic is converted, the more brittle it becomes. The capacity to withstand shock loads is reduced as a result. This can be tested by means of an impact test.

FATIGUE: Fatigue is caused by repetitive loads. As a result of the consequences in the preparation of the material referred to previously, fatigue can occur earlier in the usage phase for recycled plastics than for virgin material.

VISCOSITY: As a result of chain breaking, mechanical damage and thermal processes undergone by recycled plastics, its viscosity becomes lower and lower. The Melt Flow Rate (MFR, in accordance with ISO 1133) gives an impression of the viscosity. A low MFR represents a highly viscous material, which can make the injection-moulding process more difficult.

4.3 SPECIFYING PROPERTIES OF RECYCLED PLASTICS BEFORE PRODUCTION

The materials properties referred to above can be improved or adapted as required by adding additives, fillers or virgin material. In this way, the mechanical and process properties can be influenced. Visual properties can be modified by adding pigments for example.

Example: Below is an example of a specification sheet from Morssinkhof - Rymoplast showing several grades of recycled PP. It is immediately clear that there are many differences in materials specifications merely within the standard grades of reprocessed PP available.

MOPRYLENE - REPROCESSED POLYPROPYLENE morssinkhof-rymoplast

		Black			Black			Coloured			Coloured	Black	
Description	Units, norms	Z1GPMM	Z1CPMM	Z1CCPMM	Z1CPHM	Z1CCPHM	Z1CPHHM	XXGPMM	XXCCPMM	XXCPHHM	B1CCPHHM	Z1CPMM-TF20	Z1CPHM-TF20
		PP-C/PP-H	PP-C/PP-H	PP-C	PP-C/PP-H	PP-C	PP-C/PP-H	PP-C/PP-H	PP-C	PP-C/PP-H	PP high impact (modified) light shade	PP-C	PP-C
		Black/grey shade	Black/grey shade	Black	Black/grey shade	Black	Black/grey shade	Terra Cotta, Blue, Green, Grey	Terra Cotta, Blue, Green, Grey	Terra Cotta, Blue, Green, Grey	Light colored	Black/grey shade	Black/grey shade
Visual Apperance	Internal	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,50kg/l)	Regular shaped granule (0,60kg/l)	Regular shaped granule (0,60kg/l)
Processing		Extrusion and Injection moulding	Extrusion and Injection moulding	Injection Moulding	Injection Moulding	Injection Moulding	Injection Moulding	Extrusion and Injection moulding	Injection Moulding	Injection Moulding	Injection Moulding	Injection Moulding	Injection Moulding
Meltflow Index (230ºC/2,16 kg.)	g/10 min. ISO 1133	5 ± 2	6 ± 2	12 ± 4	20 ± 5	20 ± 5	30 ± 5	5 ± 2	12 ± 4	30 ± 5	35 ± 5	8 ± 2	15 ± 5
Density	g/cm³ ISO 1183	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,95 ± 0,01	0,94 ± 0,01	1,05 +/- 0,05	1,05 +/- 0,05
Ash content	%; ISO 11358	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 3	20	< 5
Recycled Polymer Content	%, Internal	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95	> 95
Melt filtration	µm; internal standard	200	300	300	300	300	300	200	300	300	200	300	300
Tensile strength	MPa; ISO 527	> 24	> 24	> 24	> 24	> 22	> 20	> 24	> 24	> 24	12--14	> 25	> 25
E-modulus	MPa; ISO 527	1250--1350	1250--1350	1100--1200	1000--1100	1000--1100	1100--1200	1250--1350	1100--1200	1000-1100	450--550	1950--2050	1950--2050
Elongation at yield	%; ISO 527	8 ± 2	10 ± 2	10 ± 2	8 ± 2	10 ± 2	10 ± 2	10 ± 2	10 ± 2	10 ± 2	20 ± 5	6 ± 2	6 ± 2
Flexural E-modulus	MPa; ISO 527	1150--1250	1150--1250	1000--1100	900--1000	900--1000	900--1000	1200--1300	1050--1250	900-1000	450--550	1700--1800	1700--1800
Charpy notched impact 23°	KJ/m², ISO 179	> 4	> 4	> 8	> 4	> 8	> 5	> 4	> 8	> 5	10--15	> 4	> 4
HDT A	ºC; ISO 75 A	> 48	> 48	> 45	> 45	> 45	> 45	> 48	> 45	> 45	> 45	> 45	> 45
Hardness	ISO 868 D	62 ± 2	62 ± 2	60 ± 2	62 ± 2	62 ± 2	62 ± 2	62 ± 2	62 ± 2	62 ± 2	50 ± 2	65 ± 2	65 ± 2

Disclaimer:
To the best of our knowledge, the data and results mentioned in this document are provided for use of general information for our customers. The values show typical average data, based on an appropriate number of individual measurements. Final determination of the suitability of any material is the sole responsibility of the user. Please note that properties can significantly be influenced by processing method, processing conditions, mould /die design and the use of additatives.

FIGURE 7: PRODUCT SPECIFICATIONS OF PP COMPOUNDS (MOPRYLENE) (SOURCE: MORSSINKHOF RHYMOPLAST)

4.3.1 MECHANICAL PROPERTIES

There are different additives which can be added in order to influence the mechanical properties of recycled plastics. Additives can improve various properties. Examples are thermal stabilisers (which increase thermal resistance), UV-absorbers (which increase the UV resistance of plastics), flame retardants (which counteract the breakdown of the material as a result of fire) and impact modifiers (which improve impact resistance). In addition, compatibilisers can be used to ensure that PET contamination in PP distributes itself in such a way that it has less impact on the mechanical properties of the PP, for example.

In this way, additives can improve properties, but can at the same time have undesirable effects on other properties. They can also influence the future suitability of plastics for recycling. How to deal with these factors is discussed in chapter 6: Designing plastic products for optimum recycling.

Example: A commonly used additive in PP is talc. This improves stiffness, dimensional stability and heat resistance. However, it also has a negative influence on impact resistance at low temperatures and oxidisation resistance. In addition, the recyclability of the plastic after use needs to be taken into account. Research has shown that up to 20% filling with talc does not have a major negative impact on properties after recycling (Wang, Bahlouli et al. 2013).

In order to improve its properties, virgin plastics can also be added to recycled plastic. The specifications of these plastics are known and they can therefore be added in particular quantities in order to adjust the specifications as required. If the same type of plastic is used, this will not generate any additional problems in terms of future recyclability.

4.3.2 OPTICAL PROPERTIES

The assumption that recycled plastics are always dark and grey is outdated. With good separation, it is already possible to add a colour hue to the material. By adding pigments in the master batch, the colour can be further specified at the processing or manufacturing stage.

Example: Old green beer crates from Grolsch are 100% recycled (Koninklijke Grolsch N.V. 2006). Flakes from old beer crates can be used in the production of new crates. Depending on the quality of the flakes, a mix is made of virgin plastic and flakes. In this way, a high percentage of recycled plastics is targeted but quality is always assured.

Adding a pigment to a recycled plastic is associated with several changes to the properties of the material. For example, depending on the colour, the density of the material can also change. This may have consequences for the separability of a product at the end of its life cycle. The influence of talc on the density is much greater because the loading factor is much higher (10% to 40% in PP). Designers can make use of this fact to promote separability.

In order to obtain high-quality coloured recycled plastics, the requirements for separation, washing and recycling are higher than for dark recycled plastics. As a result, the cost of coloured recycled plastics is higher than that of dark ones.

Example: In its Ecolife products, Curver uses Procyclen® recycled plastic from Interseroh (Interseroh Diensleistungs GmbH 2013). Interseroh offers an extensive range of colours made from 100% post-consumer waste.

FIGURE 8: CURVER ECOLIFE UNIBOXES (SOURCE: CURVER)

FIGURE 9: SEVERAL COLOURS OF PROCYCLEN® RECYCLED PLASTIC (SOURCE: PLASTICS RECYCLING OF ALBA GROUP: INTERSEROH RECYCLED RESOURCE (YOUTUBE))

4.3.3 PROCESSING PROPERTIES

Recycling can affect the melt flow rate (MFR) and the spiral flow of a plastic, which is important for its use in an injection-moulding process. Spiral flow is a measure which gives an indication of the flow behaviour in an injection-moulding machine and is partly determined by the MFR – the MFR being merely a point on the flow curve which determines the viscosity behaviour of a material. The shear tension (read: weight) at which this is measured is not by definition the shear tension during injection moulding. Two materials with the same MFR can exhibit different spiral flows. Using impact modifiers improves impact resistance and they may have some influence on the MFR, but this is a side-effect. The MFR of PP, for example can be increased (shifted) with the use of peroxide. In general, recycling has the effect of increasing the MFR because chain breakage occurs. It is not possible to adjust the MFR in PE.

Recyclers will often specify the melt flow of a type of recycled plastic and whether it is suitable for injection-moulding (and/or extrusion, for example).

Example: Cumapol, a recycler and developer of recycled PET is able to repair the length of polymer chains and even make the material stronger than virgin PET by using 'solid state polymerisation'. During this process, the material is heated with nitrogen at high temperatures and pressures in an oxygen-free environment. This removes contamination from the granulate and lengthens the polymer chains. This has an influence on the intrinsic viscosity of PET, making it suitable for reuse in PET bottles, for example.

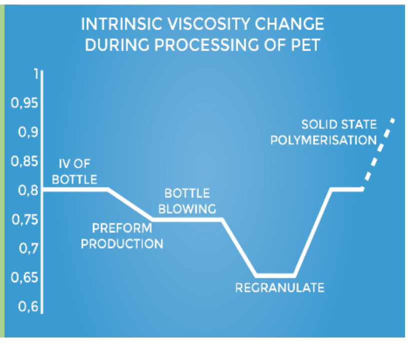


FIGURE 10: CHANGE IN INTRINSIC VISCOSITY DURING THE RECYCLING OF PET (SOURCE: CUMAPOL)

Showcase Cumapol: Design with recycled plastics
The video shows how Cumapol has designed its PET recycling process such that PET flakes from soft drinks and other bottles can be given high-value uses in various markets and applications, including food-approved applications.

4.4 BUYING AND TESTING RECYCLED PLASTICS

4.4.1 SUPPLIERS IN THE NETHERLANDS

The Netherlands has various suppliers of agglomerate, flake, compounds and regranulate. The website of the Dutch Federation of Rubber and Plastics Industry (NRK) provides an easy-to-understand summary of materials types and the form in which recycled plastics are supplied (NRK Recycling 2015).

4.4.2 EUROPEAN CERTIFICATION OF PLASTICS RECYCLERS (EUCERTPLAST)

EUCERTPLAST is a European certification for post-consumer plastics recyclers. It is aimed at promoting environmentally-friendly recycling, standardisation for recyclers, traceability and transparency around plastics recycling. It arose from the demand from buyers for greater clarity about the origins and eco-friendliness of recycled plastics.

FIGURE 11: LOGO EUCERTPLAST (SOURCE: EUCERTPLAST)

For buyers of recycled plastics, it can be useful to use Eucertplast-certified processors. These companies are certified and guarantee a reliable and high-quality recycling process. It may be advisable for plastics convertors to acquire this certification because it can be regarded as a quality mark by manufacturers. A summary of all Eucertplast certified recyclers can be found here. For more information about the Eucertplast certification system, click here (Eucertplast 2015).

4.4.3 TESTING RECYCLED PLASTICS

FIGURE 12: EQUIPMENT FOR TENSILE TEST (SOURCE: AKG POLYMERS)

The specification sheets or Technical Data Sheets (TDS) for recycled plastics do not always contain the information needed to determine whether a material meets all the requirements. They can be used for an initial screening or to decide which materials need to be tested. Technical Data Sheets from different manufacturers cannot be used to compare materials. This is because there is still considerable latitude when determining properties and also because different standards are used (e.g. ISO vs. ASTM). In order to properly compare materials, they need to be measured by a single laboratory. If all the tests cannot be performed internally, this can often be done by the supplier or in a testing facility (independent or otherwise). Here, the most important mechanical, visual, thermal and rheological tests can be performed.

Most tests used to verify materials relate to mechanical properties such as tensile strength, elongation at break and E-modulus. Tests used to ascertain these properties may include tensile tests, bend tests, hardness tests and impact tests.

Thermal or rheological properties such as heat resistance can be determined by measuring the Vicat Softening Temperature (VST) or the Heat Deflection Temperature (HDT). The Melt Flow Rate is determined using a melt indexer. Properties such as colour can be tested by means of an optical colour measure.

Appendix A provides a summary of testing facilities in the Netherlands.

4.5 APPLICATIONS WITH RECYCLED PLASTICS

Recycled plastics can already be used in many different applications. The objective must always be to use the recycled material in the highest-value application possible. The value of the application depends not only on the type of application and the visual appearance but also on the possibilities of the material.

Example: Plastic picnic tables or roadside posts are often manufactured from a mixture of different plastics. This application is often regarded as low-value. However, the application is not low-value, in view of the limitations of the 'low-value source material': it is more accurately described as a high-value application of a low-value material.

FIGURE 13: PICNIC SET MADE FROM RECYCLED PLASTIC (SOURCE: GOVAPLAST PLAY)

The above example shows that, even when the materials properties are not/no longer at a high level, there may still be a possible application which enables a reduction in the use of energy and raw materials thanks to the use of recycled plastics. However, it is important to always look for the material which best suits the application. A mono-material which has been used in a very high-value application and has barely degraded in its initial life cycle can be reused in a high-value application. It would be a waste to use it straight away in a product with lower materials requirements (such as a roadside post). If this is done properly, a material will become part of a cascading model in which it is always used in the highest-value application possible.

Very high-value products associated with very high requirements of the material, such as applications involving skin or food contact or transparent products, are still difficult to achieve using recycled plastics. Innovations are needed in order to enable these high-value applications on a large scale. In recent years, the quality and materials predictability of recycled plastics have increased. As a result, it is increasingly possible to use recycled plastics in premium products and visible applications. Figure 14 shows several applications in which recycled plastics have been used in visible components, functionally or mechanically demanding components and premium products.

TYPE OF PLASTIC	COMMON APPLICATIONS USING VIRGIN PLASTICS	APPLICATIONS WITH RECYCLED PLASTICS
PP	Packagings (bottles, crates, dairy), automotive components, garden furniture	(Food-grade) crates, tubs/punnets, boxes, automotive components, pots, flower pots, garden furniture, household products, housings for electrical devices
HDPE	Toys, tubs, crates, food packaging (milk packaging, juice bottles, shampoo bottles), refuse sacks.	(Food-grade) crates, pots, waste bins, (non-food) bottles
PET	Soft-drinks bottles/other bottles, film packagings, food tubs	Soft-drinks bottles/other bottles, fleece/other clothing, strapping, housings for electrical devices (e.g. made from PBT, obtained from PET)
LDPE	Blown film, shrink wrap, agricultural films, plastic bags, toys	(Refuse) sacks, shopping bags
PS/EPS	Disposable cups, disposable cutlery, yoghurt pots, CD sleeves, styrofoam casings, clear packagings	Insulation material, (light) switches, casings, CD sleeves (hard), styrofoam
PC	CD/DVDs, (roofing) sheets, safety glasses	Plastic profiles, housings for electrical devices
PVC	Pipes, tubes, blister packs, window frames, floor tiles	Tubes, tubs, cables, floor tiles, window frames

FIGURE 14: APPLICATIONS WITH DIFFERENT TYPES AND PERCENTAGES OF RECYCLED PLASTICS

5. HOW TO USE RECYCLELD PLASTICS IN PRODUCTS?

The development process for products incorporating recycled plastics will be more effective with a good understanding of what is possible with recycled plastics and what is not. A number of themes will be discussed here which are important for ensuring the optimum use of recycled plastics when replacing virgin material or designing a new product with recycled plastics.

5.1 INTRODUCING RECYCLED PLASTICS WITHIN YOUR COMPANY

Philips has developed a step-by-step plan for companies to make the introduction of recycled plastics easier. It identifies several points which can help in the application of recycled plastics.

1. Catalogue the use of plastics within the company

List the types and quantities of plastics used within the company. Based on this, it is possible to identify which plastics may be worth using.

2. Focus on commonly used polymers

Bulk plastics are commonly used in products, and as a result they are also widely collected and recycled. In order to guarantee a constant supply of materials, it is therefore sensible to focus on one of these types of plastics.

3. Focus on non-visible and dark parts

Although recycled plastics are available in many different colours, it is still easiest to use them in dark and/or non-visible parts. Transparent parts, food-approved products and applications with very high mechanical requirements are still difficult to achieve with recycled plastics.

4. Identify and approach suppliers

Look into potential suppliers of recycled plastics and approach them ahead of time. That way, you can benefit from their expertise at an early stage. Eucertplast is a certification system that offers a certain quality guarantee as regards the supplier.

5. Decide on the most important requirements for the product

Test the parts which are going to be manufactured using recycled plastics for all the most important properties. This means first deciding which requirements the parts must meet, and under which conditions.

Example: The bottom of a vacuum cleaner needs to be able to cope with a particular impact at a temperature of 20°C when falling out of a closet . It still needs to be able to cope with the same impact at temperatures below freezing, for example when stored in a garage.

6. Start with application in existing products

Products being introduced to the market for the first time often have strict launch dates. Often this pressure does not apply to existing products, for which components can be replaced with recycled plastics during their life cycle.

7. Design for recycled plastics

Once experience has been gained with using recycled plastics in existing products, parts can also be designed specifically for recycled plastics. Account can already be taken at this stage of product composition, masking areas and mould design, etc.

Example: Designers can deliberately use circular polymers and incorporate them into the design. Why should a paint can always have to be white? In Germany we observe that a grey can with an Injection Mould Label looks fine.

FIGURE 15: GREY CAN WITH INJECTION MOULD LABEL (SOURCE: DISCOUNTO)

8. Test moulds and components

When a product and plastic type has been selected, it is important to test them. The requirements specified under point 5 in particular need to be intensively tested.

5.2 DESIGNING WITH RECYCLED PLASTICS

In a new design which will make use of recycled plastics, the properties of the material can be taken into account from the outset. In an existing design, it is necessary to search for a material with suitable specifications. The following paragraphs provide tips and tricks on how the properties of recycled plastics can be incorporated into the design of a product.

5.2.1 FORM AND CONNECTION CHOICES WHEN INJECTION-MOULDING WITH RECYCLED PLASTICS

There are already many guidelines available relating to form and connection choices when designing injection-moulded products (GE Plastics), now SABIC IP). These guidelines are often focused on aspects such as wall thicknesses, geometry, holes, ribs, mold release and angles. Often, advice is also given about the injection-moulding settings for specific plastic types and machines.

When designing products with recycled plastics, in principle the same guidelines apply as when designing with virgin plastics. However, because there is a greater uncertainty factor in the properties and behaviour of recycled plastics, there is always the chance that the material will respond differently during injection-moulding.

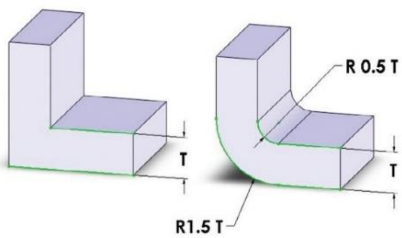


FIGURE 16: GUIDELINES FOR ANGLES IN INJECTION-MOULDING (SOURCE: PROTOMOLD)

It is therefore difficult to provide specific guidelines regarding form and connection choices with recycled plastics. In general, it is sensible to be cautious with extreme choices regarding form and connection. For example, the risk of defects with sharp transitions and angles is greater in recycled plastics than in virgin plastics, due to the uncertainty regarding the behaviour of the material. If existing moulds are used, settings such as temperature, pressure and cooling time can be used to influence the results of the injection-moulding process.

Shrinkage after injection-moulding with recycled plastics can be more pronounced (particularly in large components) than in virgin plastics. In new products designed specifically for recycled plastics, extra ribs can be added to compensate for this fact in order to support the material. When using existing moulds, the possibility of limiting shrinkage with a shorter cooling time may be investigated

5.2.2 APPLICATION

Substitution of virgin plastic

If recycled plastic is used, in most cases it will be as a replacement for the same product or component which was initially manufactured from virgin plastic. There will already be a mould for the original design. This means that recycled plastic is required with (almost) the same specifications and behaviour as the virgin material. For this reason, a particular percentage of recycled plastic is often mixed into virgin material as a blend (mix). It can also be used in an intermediate layer of a multi-layer concept.

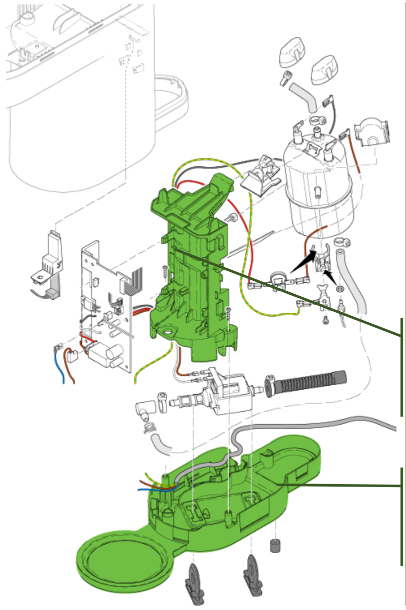
MATERIALS PROPERTIES: The materials properties of recycled plastics must match the requirements of the product manufactured using virgin plastic. The parameters for the most important requirements must be compared with the properties of the available grades of recycled plastic. If these requirements are not known, they need to be specified in consultation with the recycler or compounder of the material.

PROCESS PARAMETERS AND MOULD SUITABILITY: When substituting recycled plastic for virgin plastic, it cannot be assumed that the process parameters of the injection-moulding process will remain identical. Even though the most important mechanical and thermal properties of the material may be virtually the same, process-influencing properties (including rheological properties) can still differ. For this reason, it is advisable to perform production tests with the material to be used before initiating mass production. In addition, the mould needs to be and be able to be ventilated sufficiently in order to prevent the product having an unpleasant odour.

New/newly designed products

If a product is designed especially for the use of recycled plastics, there is greater freedom to incorporate specific properties of the material. It is also possible to make designs based on the properties of standard grades. These are often cheaper and offer a higher materials guarantee (because multiple recyclers offer comparable grades). Because there is always some uncertainty about the behaviour and properties of the material to be used, it is important to compose the critical properties at an early stage. Based on these, suitable recycled plastic can be identified. Materials tests need to be performed on this recycled plastic and the visual and tactile properties can also be tested directly.

COMPOSITION OF A PRODUCT: By building up a product according to a *'frame+covers'* principle, it is possible to investigate whether recycled plastics can be used for one part at a time. The frame can be made invisible by hiding it with one or more covers. This principle can often make it easier to use recycled plastics . One advantage is that the frame is usually a large part of a product. By attaching them to a frame, connections between parts are also limited. In this way, it is possible to examine per part whether the use of recycled plastics is feasible.



Example: In the Senseo Up from Philips, 40% post-industrial recycled (glass-fibre reinforced) PP is used in a frame on the inside of the product. The part does not come into contact with water and/or coffee and is not visible to the consumer. As a result, dark recycled plastic can be used and there are also no problems with regard to food contact (Philips 2015).

Inner frame not visible to the consumer made of 40% post-industrial recycled (glass-fibre reinforced) PP.

Base plate made of 90% recycled ABS obtained from post-consumer E-waste.

FIGURE 17: RECYCLED PLASTICS (IN FRAME AND BASE PLATE) IN THE SENSEO UP (SOURCE: PHILIPS)

Replacing a material other than plastic

In some cases, recycled plastic can serve as a substitute for a material other than plastic (wood, for example). This involves making a new design and looking closely at the properties of the other material compared to the properties of the plastic to be used.

Example: Plastic has a lot of advantages compared to wood, such as design freedom and easy upscaling for mass production. However, wood has very different materials properties, and for this reason research needs to be done into the critical properties of the wooden part. These must then be linked to a plastic with similar properties. This is less important when replacing an existing plastic product.

FIGURE 18: WOODEN AND PLASTIC ROADSIDE POSTS

5.2.3 VISUAL AND TACTILE DESIGN CONSIDERATIONS

The appearance of recycled plastics has long been an important reason why it was not used in visible and/or premium applications. However, now that the material is available in different colours and grades, much more is possible. The following paragraph describes several possibilities and difficulties in the use of recycled plastics relating to the visual appearance of a product.

VISIBILITY/INVISIBILITY: Where recycled plastics are used in non-visible parts, the consumer experience will not be affected. In such cases it is possible to save costs through the lower price of dark recycled plastics compared to virgin plastics.

Example: The Mercedes B-Class Electric Drive contains 58 parts (31.9 kilograms) of recycled and high-quality plastics (Mercedes-Benz 2014). Virtually all of these parts are invisible to the consumer and have been darkened in order to give them all the same look.

FIGURE 19: RECYCLED PLASTICS IN THE MERCEDES B-CLASS ELECTRIC DRIVE (SOURCE: MERCEDES-BENZ)

COLOUR: As stated previously in paragraph 4.3.2, different colours can now be achieved using recycled plastics. Depending on the requirements in terms of visual appearance, coloured parts can be used:

LIGHT COLOURS: In light-coloured products, impurities in the production material are visible more quickly. In order to prevent visible contamination, pure recycled plastic is therefore required. However, it is almost always impossible to eliminate very small impurities (dark dots) in the injection-moulded parts completely. Tests can reveal whether or not this is acceptable.

Océ uses parts made from PC+ABS with recycled content in its varioPRINT 135 range. In this, it uses PC from 5 gallon (18.9 litres) water bottles. By using a pure flow of recycled PC and adding this to ABS, it can obtain a light-coloured part which meets the visual requirements.

FIGURE 20: LIGHT-COLOURED RECYCLED PLASTICS IN THE VARIOPRINT 135 RANGE (SOURCE: OCÉ)

BRIGHT AND DEEP COLOURS: Very bright colours which can be achieved with virgin plastics are difficult to produce with recycled plastics. A high-gloss product is difficult to achieve, but in many cases a colour with a matt finish is possible.

Example: The Curver Ecolife NEO product range made from 100% post-consumer waste material is offered in various colours. In this way, Curver demonstrates that with good separation and preparation it is possible to manufacture premium products from 100% post-consumer waste material in different colours (Curver 2015).

FIGURE 21: CURVER ECOLIFE NEO PRODUCTS IN VARIOUS COLOURS

Showcase Curver: Design with recycled plastics
In Curver Ecolife NEO products, Curver's eco-friendly DNA is already part of the design. The video shows how it is incorporated into the design and how Curver uses 100% post-consumer waste material in various products.

DARK/BLACK COLOURS: Recycled plastics in dark or black colours are easiest to incorporate in products. It is also the cheapest, and easy to produce because it can simply be made dark using pigments.

Example: Sony uses SORPLAS™ (Sony Recycled Plastics) in several of its products. SORPLAS™ is made from 99% recycled plastics (with 1% flame retardant). Sony also uses recycled plastic which is mixed into virgin plastics (35% recycled content).

In the Handycam® FDR-AX33 (a high-end 4K camcorder), many (visible and invisible) dark parts are manufactured using SORPLAS™ and plastics with recycled content. A visible texture has been added to several of the visible parts (Sony 2015).

FIGURE 22: TOP LEFT: SONY HANDYCAM® FDR-AX33. MIDDLE LEFT: PARTS MADE FROM SORPLAS™ (99% RECYCLED PLASTICS). BOTTOM LEFT: COMPONENTS WITH (35%) RECYCLED PARTS (SOURCE: SONY)

GLOSS: It is difficult to achieve equally smooth and high-gloss surfaces with recycled plastics as with virgin plastics. High-gloss black or "piano black" is only possible with polymers when using virgin (colourless) polymer, which is then coloured black. This is because the light needs to be able to partially penetrate. This is very difficult with recycled plastics because generally-speaking it is no longer transparent. In a few cases, high-gloss can be achieved if the source material is extremely clean, but suppliers of such material are scarce. In most cases, recycled plastics will retain a matter look. Silk-gloss surfaces can be achieved with recycled plastics.

Example: The Philips PerfectCare Eco Steam Generator contains black and green parts made of both recycled plastics and virgin plastics. The parts containing recycled plastics do not have the same gloss as the surfaces made with virgin material. However, due to the contrasting effect of the black and green colours, this does not detract from the visual experience of this premium product.

FIGURE 23: PHILIPS PERFECTCARE AQUA ECO STEAM GENERATOR (SOURCE: PHILIPS)

Showcase Philips: Design with recycled plastics
In the Philips PerfectCare Eco Steam Generator, Philips incorporates as many recycled plastics as possible. The video details this process and shows which difficulties and opportunities Philips sees in the application of recycled plastics in premium products.

SURFACE FINISHING AND TEXTURE: In order to conceal visual contamination, a texture can be applied to the surface of a plastic component. A texture can contribute to the consumer experience in both visual and tactile terms. Added textures can range from a pattern to a barely visible grain which hides impurities. Click here for more information about how to add a texture to an injection-moulded product (Protomold 2011).

Example: Philips has incorporated recycled plastics in the Senseo Viva Café Eco. The top cover of the device is made of recycled PC and has a 3D corrugated structure. This is designed to hide any impurities but it also stimulates the sense of touch and sight by creating a sense of movement from every angle (Philips 2011).

FIGURE 24: TOP COVER OF THE PHILIPS SENSEO VIVA CAFÉ ECO (SOURCE: PHILIPS)

IN-MOULD LABELLING: In order to give a product a premium appearance, the use of (in-mould) labels is an option. This involves the hot polymer being injection-moulded against the label. By completely covering the parts encased by the label, little of the underlying part will be visible. As a result, requirements regarding the surface finish or colour can be made less exacting because the part is less visible. Therefore, recycled plastics can be easily used in the part. The technique doesn't need to compromise on recyclability if the label is made of the same material as the product and no harmful inks are used on the label. However, complex and double-curved shapes are hard to label using this technique.

Example: Systems Labelling has developed a label which can easily be removed from the underlying product during recycling. This helps it make white virgin PP suitable for high-value recycling because no residues of the label adhere to the plastic during the recycling process (Systems Labelling limited).

FIGURE 26: REMOVABLE IN-MOULD LABEL (R-IML) (SOURCE: SYSTEMS LABELLING)

MULTI-MATERIAL PRODUCTION: In some situations, it can be economical to use multi-material (2K/3K) injection-moulding. In this process, different materials are processed in a single production step. For example, this can involve using recycled plastic in the core of a product surrounded by virgin plastic. This production method can have an impact on the extent of suitability for recycling.

Example: Injection-moulding firm Timmerije is able to offer 2K/3K injection-moulding. This means different materials can be injection-moulded in a single production step (Timmerije B.V.) A crate like the one shown here is produced by means of 'sandwich moulding'. In this example, different recycled plastics are used on the inside (post-consumer) and the outside (post-industrial) (Sekisui Chemical Co. Ltd 2011).

FIGURE 25: TRANSPORT CRATE WITH TWO DIFFERENT TYPES OF REUSED PLASTICS (SOURCE: SEKISUI CHEMICAL CO. LTD)

ODOUR: Recycled plastics can have an unpleasant odour as a result of the degradation of a plastic, additives or migration of a substance during the previous life cycle. This can be undesirable and cause a significant reduction in the value of a product. It is possible to check whether the recycled material meets the requirements in terms of odour at the testing stage. There are also additives to mask the odour. These neutralise the odour of the recycled plastics. Click here for more information about the action of these additives (Markarian 2010).

5.3 LEGISLATION

In a number of sectors, there are supplementary legislative requirements with which recycled plastics must comply. In addition, new legislation and regulations increasingly envisage plastics in a cycle, rather than in a linear flow. The following summary is intended to provide an impression of which supplementary legislation and regulations apply to the use of recycled plastics in specific cases.

Using recycled plastics in food-contact products

In many cases, virgin plastic can be a good packaging material for foods. Recycled plastics can only be used for this application if the recycling process meets strict conditions.

EC NO. 282/2008: European Regulation (EC) No. 282/2008 prescribes the possible uses of recycled plastics which can come into contact with foods. The manufacturer must guarantee that: *the plastic input originates from a product loop which is in a closed and controlled chain ensuring that only materials and articles which have been intended for food* *contact are used and any contamination can be ruled out.* A deposit PET bottle is a good example of an application in which a product (bottle-to-bottle) can be recycled into a new food-approved application.

EFSA APPROVAL: Ultimately, the suitability of the products and the process are tested by the European Food Safety Authority (EFSA). The EFSA looks at issues relating to collection, the effectiveness of the process to reduce contamination and the described use phase. Appendix B sets out in concise form which statutory requirements firms wishing to use recycled plastics intended for food contact must fulfil. Click here for more information about 'recycled material intended for food contact' (Jetten 2012).

Example: Schoeller Allibert has an EFSA-certified recycling process for PP and HDPE (European Food Saferty Authority 2013). In this process, food-grade crates can be recycled in a closed cycle and reused in new food-grade crates. The crates are collected, cleaned in a process involving the removal of (UV) degraded material, ground into flakes and then reused as a raw material for new food-grade crates.

FIGURE 27: FOOD-APPROVED CRATE MADE FROM RECYCLED MATERIAL (SOURCE: SCHOELLER ALLIBERT)

Showcase Schoeller Allibert: Design with recycled plastics
The video shows how Schoeller Allibert ensures that returned products can be reused in new food-approved applications. It also shows how Schoeller Allibert already takes the recyclability of its products into account in the design stage.

Other legislation

REACH: REACH (Registration, Evaluation and Authorisation of CHemicals) is a European regulation on the production of and trade in chemical substances. This regulation is currently still causing problems in the recycled plastics market because it is unclear how definitions formulated in the legislation should be interpreted. This can result in recyclers having to perform a lot of administrative work before being allowed to release their products for sale. In most cases, manufacturers who only buy recycled plastics from recyclers are *'downstream users'*. They are not bound by any requirements regarding registration or other actions relating to chemical substances before the material can be used in products. Only where recycled plastics contain SVHCs (Substances of Very High Concern) is the possibility of

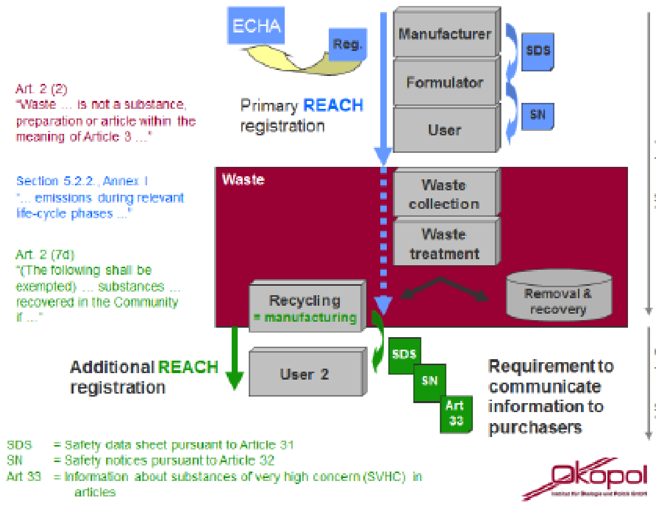


FIGURE 28: BRIEF SUMMARY OF REACH REQUIREMENTS IN THE RECYCLING OF PLASTICS (SOURCE: OKOPOL)

communicating with customers about these substances required in some cases. Click here for more extensive information about the REACH regulations (European Chemicals Agency 2010).

RoHS: RoHS (Restriction of Hazardous Substances) is a directive about restrictions on the use of particular hazardous substances (lead, mercury, cadmium, chrome VI, PBBs and PBDEs) in *electrical and electronic equipment.* Old electrical devices may still contain these substances and theoretically, therefore, must not be reused in new applications. However, many recyclers are able to guarantee that their recycled plastics do not contain hazardous substances in quantities which are prohibited under the RoHS.

Heavy metal analysis			
	RoHS	ppm	**max. 1000 (exception Cd max. 100)**

FIGURE 29: PART OF A MATERIAL SPECIFICATION SHEET FOR PROCYCLEN® HDPE BM C2 (SOURCE: ALBA GROUP)

Showcase Océ: Design with recycled plastics
Océ uses recycled plastic in parts of the varioPRINT 135 range. In doing so, it needs to comply with requirements including the RoHS guidelines. The video shows how Océ introduced recycled plastic into this product and how it guarantees that the material meets the RoHS requirements.

6.DESIGNING PLASTIC PRODUCTS FOR OPTIMUM RECYCLING

This chapter explains how the value retention of plastics after the first life cycle can be taken into account in the design phase of a product. Or to put it another way, designing for the circular economy.

6.1 DESIGNING FOR THE CIRCULAR ECONOMY

The circular economy offers a solution to the ever-growing problem of exhaustion of natural resources and increasing amount of waste. Within this concept, waste is regarded as a raw material within a technical or biological cycle.

Among other things, designing for the circular economy involves designing products in such a way that they have a long lifespan and can be properly maintained during use, can be reused when they have completed their first life cycle and can be properly recycled after disposal (Ellen MacArthur Foundation 2014). In this way, the volumes of raw materials and energy used are reduced and new business models are created in which products are increasingly offered in combination with services (Bakker 2014).

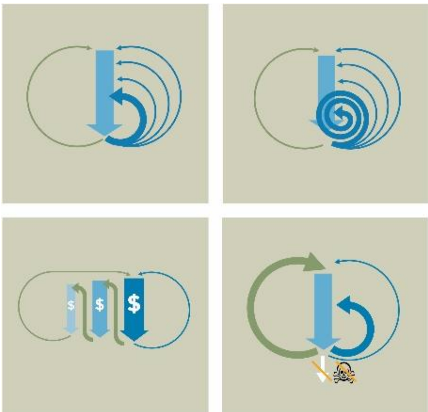


FIGURE 30: VALUE RETENTION IN A CIRCULAR ECONOMY (SOURCE: ELLEN MACARTHUR FOUNDATION)

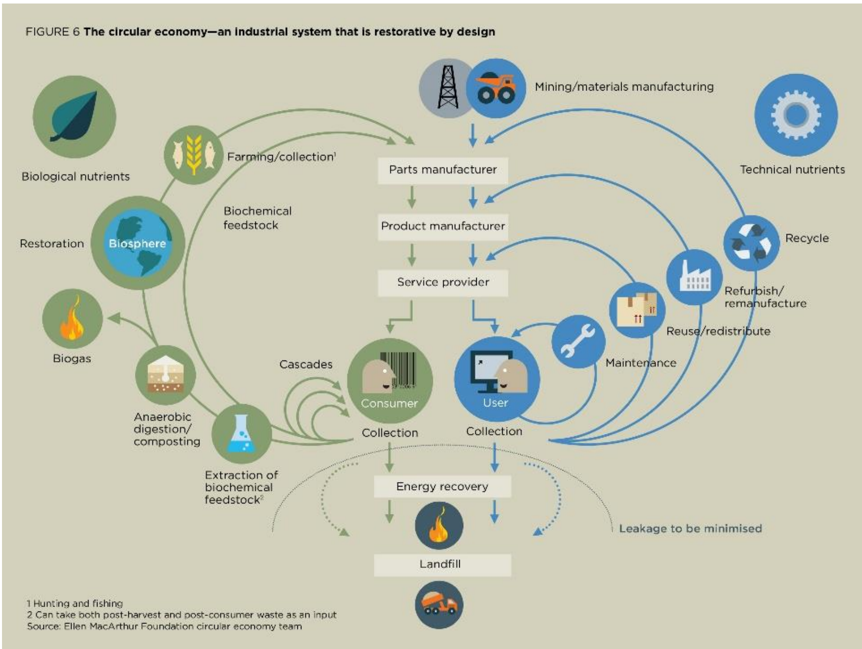


FIGURE 31: THE CIRCULAR ECONOMY (SOURCE: ELLEN MACARTHUR FOUNDATION)

In 2010, the Ellen MacArthur Foundation was founded in order to draw the attention of companies around the world to the principles of the Circular Economy. These principles result in the following aims:

1. *Maintaining the value in the original function.* Developing a product that can easily be reused means saving on materials, labour, energy and raw materials.

   Example: Toner cartridges can be reused several times in the same function after their first life cycle without major modifications. By setting up a good collection system and using design for disassembly, these products can be reused, refurbished and remanufactured.

2. *Keeping products in use for as long as possible in the circular economy.* Products have long life spans and/or gain new users after disposal by the first user. Ways of encouraging this are the use of high-quality materials, applying timeless design and preventing materials from degrading quickly (for example by using additives to counteract UV degradation).
3. *The use of plastics in cascades.* This involves plastics being recycled and used, possibly in other industries, in applications which represent a lower value. As a result, there is no need to use new materials and the plastics can remain in use longer. Design for recycling is very useful in this scenario. Design for recycling is not always the same as design for reuse, disassembly or refurbishment. Whereas screw connections are often handy in design for reuse, in design for recycling it is more effective to use only one material which does not need to be separated when recycling a product.
4. *Clean input material.* This goes without saying and means the plastic used is clean, does not contain any harmful additives, does not contain any mixed (and non-recyclable) plastics and can be collected and recycled in the correct manner. As a result, it takes fewer materials, energy and labour to prepare it for a new usage phase.

6.2 DESIGNING FOR OPTIMUM LIFE CYCLE

In an optimum life cycle, plastics undergo all the steps described above before eventually being used in the lowest-value useful application, as a raw material for energy.

The chances of a system being designed in such a way that they will actually pass through all of these steps are small. This would require intensive collaboration between the chain parties, ensuring that the materials are collected and recycled in pure form and are always used in the highest-value possible application. Designers must envision the most likely way in which a product will be recycled and take account of this in the design stage.

Example: In the Philips SlimStyle LED launched in 2015, the most likely recycling method for the bulb was anticipated in the design – shredding. As can clearly be seen in the adjacent image, various smart features have been incorporated in order to ensure that the parts can be optimally separated and reused when separated using a shredder.

Philips conducts a lot of research into the methods which can be used to design products so that they continue to represent a high value after the first life cycle. The company has investigated how the expected recycling method can be reflected in the design. Philips' research has shown that the optimum design (with the lowest environmental impact) is strongly dependent on the (expected) method used to recycle the product (Aerts, Felix et al. 2014).

FIGURE 32: PHILIPS SLIMSTYLE LED. TOP: DESIGN CHOICES WITH REFERENCE TO RECYCLABILITY. BOTTOM: SHREDDED SLIMSTYLE LEDS (SOURCE: PHILIPS)

6.3 INCORPORATING RECYCLABILITY IN DESIGN

Guidelines have already been developed to promote recyclability for different types of products and plastics. A brief summary is provided below of what can be done to aid recyclability. In addition, references are given to several studies and guidelines which discuss product and/or materials use in detail.

6.3.1 RECYCLABILITY AT PRODUCT LEVEL

The extent of recyclability of plastics can be determined at both product and materials level. If a plastic is well-suited to recycling but the product parts are not separable, the material will still not be easily recoverable. For this reason, it is important to include the recyclability of the entire product in the design considerations.

BREAK LINES AND CONNECTIONS: In many sectors it is known how most products will be recycled after disposal. This can already be anticipated at the design stage. If products will be shredded and consist of different materials, it is useful to add *break lines*. These affect the way in which a material tears. For example, the designer can locate a break line beside a screw hole in order to help separate the plastic from the screw. On the other hand, if the material is to be disassembled by hand during collection, it is effective to use simple, detachable connections.

6.3.2 RECYCLABILITY OF ELECTRONIC (HOUSEHOLD) DEVICES

Research has been carried out for Philips into ways in which the recyclability of consumer electronics and household devices can be improved in the design (Hultgren 2012). The results explain how the recyclability of the product can be improved. The most important conclusions relating to plastics in electronic devices are described here (see figure). Many of these recommendations can also be applied to other types of products.

MATERIALS

Only use materials that can be recycled
Avoid the use of (non compliant) coatings
Limit the number of different materials
Use pure materials

CONNECTIONS

Avoid fixed connections
Break-down (by shredding/disassembly) to:
- Pieces with uniform composition
- Pieces of relatively large size (>1cm)

FIGURE 33: DESIGN GUIDELINES FOR PLASTIC MATERIALS AND CONNECTIONS TO BENEFIT RECYCLABILITY (SOURCE: PHILIPS)

OVAM, the organisation for sustainable product innovation in Flanders (Belgium), has drawn up design tips for optimum recycling of products in various product categories. These provide tools for choosing the right materials for the products and using the right connections between parts in products (OVAM 2012).

6.3.3 CHOICE OF MATERIALS

The recyclability of plastics is largely a function of their purity and separability. These can be improved by paying attention to the following matters:

BLENDS: Plastics blends are mixes of different types of plastics. Generally-speaking, blends are difficult to recycle. With the exception of commonly used blends such as PC-ABS blends (which can be reused as PC-ABS blend), this causes a lot of waste in the recycling of plastics.

ADDITIVES: A high percentage of, for example, minerals (like talc) in a plastic, can also cause a change in density. Consequently, when separating (by density), they may be mistaken for a different type of plastic. This results in contamination of a batch, impacting on the quality of the recycled plastic.

COMBINATIONS OF DIFFERENT PLASTICS: If two or more plastics of similar density are used in a product, it is possible that the plastics types will be mixed during separation.

Recoup has drawn up extensive guidelines per type of plastic for the purposes of optimum recyclability.

Recoup (Recycling of Used Plastics Limited), a British organisation for plastics recycling, regularly issues new guides containing guidelines per type of plastic (for PET, HDPE, PVC, PP and PS). These clearly specify how colour, barriers, additives, closures and labels can impact on recyclability and how these can optimally be incorporated into a design (RECOUP 2015).

LABELS: Materials types can be identified by means of *SPI resin identification coding system* labels. These can be applied to the plastic components in the mould. Coding may be compulsory as part of Green Product Procurement or for Ecolabels. Sorters often use Near or Mid Infrared Detection in order to identify plastic types; for them, the code is not important. The coding can contribute to consumer awareness regarding the different types of plastics.

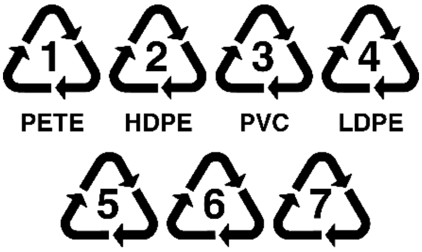


FIGURE 34: SPI RESIN IDENTIFICATION CODES FOR PLASTICS

6.3.4 TESTING THE RECYCLABILITY OF PACKAGINGS

Checking the level of recyclability of a packaging is made easy by using the RecyClass™ tool. It also provides advice on improving a packaging's design. Furthermore, RecyClass™ offers certification by an expert for using the RecyClass™ label in marketing of a packaging.

RecyClass™ (Plastics Recyclers Europe 2015) is a tool developed by Plastic Recyclers Europe which tests the recyclability of plastic packagings based on questions about the material used for the packaging, its design, the substances in the plastic and the presence of chemical components. From the answers to these questions, the test produces a score which indicates the extent to which the packaging is recyclable.

7. COMMUNICATING RECYCLED PLASTICS

Terms such as 'green marketing' or 'environmental marketing' have been in existence for decades. For consumers, it is not always clear what these claims mean. Consumers are therefore critical when considering claims such as 'sustainable', 'green' or 'socially responsible' (GfK 2014). Companies need to think carefully about how they communicate products containing recycled plastics. Based on several surveys and practical examples, we provide an impression below of which factors help determine how a product containing recycled plastics can best be communicated to a customer.

Example: The plant-bottle from Coca-Cola (partly manufactured from biobased PET) received a lot of publicity. Coca-Cola states that it learned three important lessons from the plant-bottle. *“1) PlantBottle packaging can be used as an effective marketing tool. 2) Cost improvement, not cost parity, is that matters most. 3) Support from the environmental and academic community is growing.”* (Moye 2014). Coca-Cola does not mention that the product also attracted a lot of negative publicity, when it emerged that the company had not been completely open regarding the environmental impact of the plant-bottle (van der Hoeven 2013).

Although not about the use of recycled plastics, this is an example of how communication about a 'sustainable' product can yield both positive and negative responses.

7.1 THE PERCEPTION OF RECYCLED PLASTICS IN PRODUCTS

FIGURE 35: PERSONAL TYPES AND CHARACTERISTICS ACCORDING TO THE BSR MODEL (SOURCE: SMARTAGENT)

The extent to which recycled plastics are used in communication to consumers depends very much on the *type of consumer and the function of the product.* Not all consumers want to know that recycled plastics have been incorporated into the products they buy. The function of the product also affects the degree of acceptance of recycled plastics being incorporated into products. Differences between consumers and in the degree of acceptance of products containing recycled plastics mean it is difficult to provide universal guidelines. However, it is possible to say something about how a product is perceived based on the target group and the type of product.

Influence on the perception and acceptance				
Notable product design	Much	Much	Little	Little
communication of environmental aspects	Much	Little	Little	Much
Price to quality perception equal to virgin material	Little	Much	Much	Much
Quality standards and label	Little	Much	Much	Much

In a survey performed by the Product Design Lectorate in Enschede, consumer perceptions of products containing recycled materials were studied. Based on four personality types (taken from the Brand Strategy Research (BSR) model (Smart Agent 2014)), the researchers studied how products can be developed using recycled plastics so that they *match the experience* of the user. From this it emerged that the different personality types respond differently to products containing recycled materials.

Other factors are also important for the different personality types, contributing to their acceptance of or willingness to consider purchasing products containing recycled plastics. Click here for more information and the results of this study (van Beurden 2013).

Research has also been conducted into *the relationship between the personality types and the type of products manufactured using recycled plastics*. It is clear that consumers have different requirements for different types of products in terms of the visibility, feel and odour of recycled plastics. This is often linked to the context in which the product is used (Huits 2015).

Research shows that acceptance differs by personality type and product type. Certain basic design guidelines have been drawn up which apply to combinations of product types and appearance of the material:

- In products which come into contact with food, the material must be smooth and may not contain any obvious imperfections.
- In functional products, the material may contain a few imperfections.
- In aesthetic products, the material must either not contain visible impurities or contain impurities at a level such that they provide an aesthetic value.
- In order to camouflage small imperfections, it is best to use an irregular texture.

7.2 APPEALING TO CUSTOMERS WITH RECYCLED PLASTICS

In some markets, the use of recycled plastics already goes without saying – large PET bottles, for example. Partly thanks to the separate collection system, recycled PET (rPET) is used for the production of new PET bottles (Mansveld 2015). In many cases, this is no longer even actively communicated by large brands. Other brands do communicate the use of recycled plastics, certainly if it can help boost their corporate image.

Example: Innocent®, manufacturer of healthy smoothies, presents itself as a healthy, pure and natural brand. As part of this, it uses the claim that the bottles are made of 50% rPET (Innocent). Despite the fact that large brands may use a comparable percentage of rPET, this may have added value for consumers who are interested in Innocent® because it matches what they want to communicate.

FIGURE 36: INNOCENT FRUIT JUICE PACKAGING (SOURCE: INNOCENT)

There are also companies which target a very specific target group with a small part of their range. They believe these consumers can be persuaded of the added value of the product by mentioning and promoting the use of recycled plastics. This is often used as a way of appealing to environmentally-conscious consumers.

The Curver Ecolife range is described as a product which is being 'brought to the eco-citizen' (Curver). This target group regards ecology and sustainability as important. In spite of that fact, Curver does not assume that the products are sold purely on 'sustainability'. Sustainability may be one purchasing consideration but quality and price often play a role which is at least as important.

FIGURE 39: CURVER ECOLIFE BANNER (SOURCE: CURVER)

Stabilo reserves a small part of its range for 'green' products. The use of FSC®-certified wood, the percentage of recycled plastics and Cradle2Cradle (C2C) certification are mentioned in communication about these products. In the example shown (the STABILO GREENpoint), environmental aspects are strongly promoted. The target group consists of environmentally-friendly individuals. Towards potential retailers, Stabilo emphasises that there is a group of consumers who are prepared to pay extra for environmentally-friendly products. The use of recycled plastics may be regarded as an important promotional instrument in this case.

FIGURE 38: STABILO GREENPOINT IN THE STABILO PRODUCT CATALOGUE (SOURCE: STABILO)

The above examples demonstrate how recycled plastics are actively used to promote products. Other firms do not specifically employ the use of recycled plastics as a unique selling point but do inform customers of the fact that recycled plastics have been used in the product. In these cases, consumers' attention is drawn to the use of recycled plastics but the company uses other claims to persuade them to purchase its products. A difference compared to the previous examples is that the use of recycled plastics is not specifically focused on the 'eco' aspect of recycled plastics in the products.

Example: Nike and G-Star Raw are companies who use recycled plastics in some of their products. These firms use the process of recycling 'waste materials' as a communication tool. A narrative has been created around the use of recycled plastics in their clothing, targeted on consumer awareness. The story-telling is not the main selling point. Quality and the look of the products still come first. *"I don't expect every consumer will understand how our product is made or why it is good for the oceans and the world. Most will buy it just because they really like it and feel good wearing it. That comes first. (Thecla Schaeffer, CMO at G-Star Raw)" (Lueneburger 2014).*

FIGURE 37: VISUALISATION OF PET RECYCLING PROCESS AT NIKE (SOURCE: NIKE)

7.3 INFLUENCE OF THE MARKET ON THE COMMUNICATION OF RECYCLED PLASTIC

In some sectors, manufacturers stimulate one another to incorporate recycled plastics (or other sustainability aspects) into products. This can clearly be seen in office equipment. Various (Dutch) parties in this sector have been using recycled plastics in their products for years. Different suppliers have also C2C-certified some or all of their products (C2C-Centre 2015) and communicate the use of both 'design for recycling' and 'design with recycled plastics to their customers. Because a large number of suppliers in this sector use recycled plastics in their products and actively promote this fact, competitors are also encouraged to start using it – certainly if buyers and consumers are including this as a purchasing consideration.

Recycled plastic has been used in the *automotive sector* for years. However, this is barely communicated at product level. Communication with consumers about the sustainability aspects of cars is mainly focused on CO_2 emissions. This is the most important sustainability indicator in this sector. The parts made using recycled plastics are hardly visible or not at all, because the use of (re)used raw materials may prompt negative associations in terms of quality and exclusivity. The use of recycled plastics is often only mentioned at corporate level and in annual environmental reports (Mercedes-Benz 2014).

In other sectors, the use of recycled plastics has become so commonplace that it barely warrants mention. In the *transport packaging industry*, recycled plastics have been used for a long time, particularly in non-food applications such as crates and pallets. This fact is hardly communicated by most companies. In this sector, purchasing decisions are made purely on functionality and cost. A factor may be that the emotional connection with a product is minimal and little value is attached to product perception.

7.4 COMMUNICATING RECYCLED PLASTICS AT CORPORATE LEVEL

Philips has actively been using recycled plastics in various household devices for years. The use of recycled plastics is part of a larger programme within Philips, the EcoVision programme (Philips 2012). This sets out various sustainability objectives. One of those objectives is to close the materials cycle, in which recycling and the use of recycled plastics play a prominent role. The objectives regarding the use of recycled plastics are communicated externally. This means Philips is forced to actively work towards actually achieving these objectives, but it also means the outside world knows that Philips is actively using recycled plastics.

Example: The Philips BDP9600 Blu-ray Disc player contains 50% recycled plastics (Scheijgrond 2011). The communication towards consumers does not focus on this fact but primarily on matters which affect technical performance (Philips). Only in a few Philips products which have been specifically designed as ‘Eco’ versions is the use of recycled plastics actively communicated (Philips).

FIGURE 40: PHILIPS BDP9600 BLU-RAY DISC PLAYER (SOURCE: PHILIPS)

7.5 CONSIDERATIONS WHEN COMMUNICATING RECYCLED PLASTICS

The above studies and practical examples demonstrate that communication about the use of recycled plastics is highly dependent on factors including target group, perception, market and consumer.

It is therefore sensible to ask certain questions internally in order to gain an understanding of how a product containing recycled plastics can best be communicated.

- *How is the product perceived and how is this perception influenced by the use of* recycled plastics*?* How recycled plastics are accepted by consumers depends on the type of product it is used in. A gardening tool will be perceived very differently to a colander for use in the kitchen.
- *What is the target group for the product?* Which people do you want the product to appeal to, and what do they look at when making their purchasing decisions? Could actively communicating the use of recycled plastics help?
- *What is demanded by the market?* Is the use of recycled plastics an important purchasing consideration for the customer? Does the customer want to know whether recycled plastics are used in the products?
- *What can the communication about* recycled plastics *add to the brand value and image of the company?* How do products containing recycled plastics fit with the image of the company? Despite the fact that there may not be anything to be gained directly at product level, it may still be possible to improve the company image by communicating the use of recycled plastics.

The summary below lists several opportunities and threats at product and corporate level which can be borne in mind when putting a product containing recycled plastics onto the market. These can be taken on board when determining the strategy for communicating products containing recycled plastics to customers and consumers.

	OPPORTUNITIES AND POSSIBILITIES	THREATS
Use of recycled plastics in communication at product level	• Distinctive with respect to the competition (who do not use/use less recycled plastics); • Widen the target group by appealing to 'eco-conscious' consumers; • Product may be put onto the market more cheaply (due to cheaper raw materials); • Reduction in environmental impact can be used in communication; • recycled plastics can contribute to promotion of product as a product claim (alongside claims about performance, price, etc.)	• Product may be experienced as 'inferior' or 'dirty' (particularly in products involving extensive intimate contact); • Product can be positioned in the market as premium, but may not be regarded as such by consumers; • In active communication about the use of recycled plastics in the product, there is no way back (materials guarantee required); • In some markets, acceptance is still lacking. Recycled plastics do not yet have added value here;
Use of recycled plastics in communication at corporate level	• Means of making company's CSR policy visible and promoting it; • Means of generating PR through new innovations with recycled plastics;	• Too little openness or omission of facts can result in negative publicity;

APPENDIX A: TESTING FACILITIES FOR PLASTICS IN THE NETHERLANDS

Below is a list of independent and other testing facilities in The Netherlands which are available for conducting tests with plastics and samples.

NAME	WEBSITE	CONTACT DETAILS
Polymer Science Park	*http://www.polymersciencepark.nl/faciliteiten/technieken-en-apparatuur/*	Koolwaterstofstraat 1 Ceintuurbaan 15 NL-8022 AW Zwolle +31 (0)388 53 48 10
Intertek (formerly Intertek Polychemlab) Geleen	*http://www.intertek.com/polymers/testing/mechanical/*	Koolwaterstofstraat 1 NL-6160 AP Geleen +31 (0)88 126 88 88
Protyp	*http://www.protyp.nl/Testen.html*	Borculoseweg 20 NL-7161 HA Neede +31 653 33 1368
API institute	*http://www.api-institute.com/nl/analytiek.htm*	Eerste Bokslootweg 17 NL-7821 AT Emmen +31 (0)591692117
Zuyd University of Applied Sciences/Chill **Chilllabs** **DSM Resolve**	*http://www.chillabs.com/nl/bedrijven-en-chill/faciliteiten* *http://www.dsm.com/solutions/dsm-resolve/en_US/dsm-resolve/capabilities/analysis---characterization.html*	Urmonderbaan 22 Gate 2, Building 110 NL-6167 RD Geleen +31 (0)46 702 27 82
iLAB Wageningen	*http://www.wageningenur.nl/nl/Expertises-Dienstverlening/Faciliteiten/iLAB-Wageningen/Locatie-en-faciliteiten.htm*	Bornse Weilanden 9 NL-6708 WG Wageningen +31 (0)317 48 01 96
Inholland Composieten lab	*http://www.inholland.nl/composietenlab/voor+bedrijven/faciliteiten/*	Landbergstraat 19 NL-2628 CE Delft +31 (0)15 – 257 35 92
Analyte	*http://www.analyte.nl/analyses/*	Nieuwstadterweg 5 NL-6136 KN Sittard +31 (0)46 – 452 92 29
ERT (Elastomer Research Testing B.V.)	*http://ertbv.com/nl/compoundontwikkeling/fysisch-mechanische-eigenschappen/*	Teugseweg 27 NL-7418 AM Deventer +31 (0)570 62 46 16
PTG Eindhoven **Polymer Technology Group Eindhoven BV**	*http://www.ptgeindhoven.nl/?p=about&s=analysis*	De Lismortel 31 NL-5612 AR Eindhoven +31 (0)40 – 751 76 76
Promolding BV	*http://www.promolding.nl/content.php?lan=nl&c=26*	Laan van Ypenburg 100 NL-2497 GB The Hague +31 (0)703074730

APPENDIX B: LEGISLATION ON FOOD CONTACT APPLICATIONS

A brief summary of the most important statutory requirements relating to the use of recycled plastics in food-contact applications is given below.

STATUTORY REQUIREMENT	TITLE AND BRIEF DESCRIPTION
Regulation (EC) No. 282/2008 ***Recycled plastic materials and articles intended to come into contact with foods.***	*On recycled plastic materials and articles intended to come into contact with food.* Conditions for admission to recycling process: • Closed chain • Challenge test • Quality control • Conditions for use (if applicable)
Regulation (EC) No. 1935/2004 ***General requirements for materials and articles intended to come in contact with food***	*On materials and articles intended to come in contact with food.* This sets out requirements relating to: • Permission for substances • Labelling • Existence of Declaration of Conformity (DoC) • Traceability Plastics are also named in a list of groups of materials and articles which may be subject to special measures (see no. 10/2011).
Regulation (EU) No. 10/2011 ***Requirements for plastic materials and articles intended to come into contact with food***	*On plastic materials and articles intended to come into contact with food.* • Permitted substances (including application) • Test methods • Information required for DoC • Documents/evidence required by regulator
Regulation (EC) No. 2023/2006 ***Good manufacturing practice for materials and articles intended to come into contact with food***	*On good manufacturing practice for materials and articles intended to come into contact with food.* • Quality assurance system • Careful selection of raw materials • Codified instructions and procedures • Quality assurance system • Up-to-date documentation
EFSA (European Food Safety Authority) ***Inspection institute responsible for inspecting the process in accordance with European legislation***	EFSA inspects the process in accordance with the procedure set out in *article 5 of Regulation (EC) No. 282/2008* and *articles 8 and 9 of Regulation (EC) No. 1935/2004.* The EFSA checks that the following have been demonstrated: *The plastic input originates from a product loop which is in a closed and controlled chain ensuring that only materials and articles which have been intended for food contact are used and any contamination can be ruled out.* The quality of the plastic to be recycled and the 'cleaning capacity' of the process are very important in this regard.

There are currently five companies in The Netherlands with an EFSA-approved process in which recycled plastic may be used in applications intended for food contact. They are:

COMPANY	TYPE OF PLASTIC	LINK TO EFSA REPORT ON RECYCLING PROCESS
Morssinkhof Plastics B.V.	PET	http://www.efsa.europa.eu/en/efsajournal/pub/3094
Snelcore B.V.	PET	http://www.efsa.europa.eu/en/efsajournal/pub/3462
Cumapol Emmen B.V.	PET	http://www.efsa.europa.eu/en/efsajournal/pub/3156
4PET B.V.	PET	http://www.efsa.europa.eu/en/efsajournal/pub/3399
Schoeller Arca Systems B.V.	PP and HDPE	http://www.efsa.europa.eu/en/efsajournal/pub/3187

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GLOSSARY

Abbreviation	Meaning
2K/3K	2 or 3 components (injection moulding)
ARN	Auto Recycling Nederland (Netherlands Car Recycling)
EFSA	European Food Safety Authority
EC	European Community
HDT	Heat Deflection Temperature
LAP	Landelijk AfvalbeheerPlan (National Waste Management Plan)
LCA	Life-Cycle Assessment
MFI	Melt flow index
MJA3	Multi-year agreement on energy efficiency
MSDS	Material Safety Data Sheet
NRK	Nederlandse Rubber en Kunststofindustrie (Netherlands Rubber and Plastics Industry)
R&D	Research and Development
REACH	Registration, Evaluation and Authorization of Chemicals
RoHS	Restriction of Hazardous Substances
rPET	Recycled PET
rPP	Recycled PP
RVO	Rijksdienst van Ondernemend Nederland (Netherlands Enterprise Agency)
SORPLAS™	Sony Recycled Plastics
TDS	Technical Data Sheet
VKG	Vereniging Kunststof Gevelelementenindustrie (Association of Plastic Façade Elements Industry)
VST	Vicat Softening Temperature

Definition	Notes
Flake	Ground, washed and dusted plastic.
Regranulate	Material which has been cleaned by melt purification.
Agglomerate	Compacted film material (not purified of contaminants).
Recyclate	Recyclate is the collective term for all kinds of products which are the result of a completed recycling process and can be used in a production process for semi-manufactures or end products without further processing.
Circular Economy	The circular economy is an economic system which is intended to maximise the reusability of products and raw materials and minimise value destruction – unlike in the current linear system, in which raw materials are transformed into products which are destroyed at the end of their useful lives.
Virgin fossil fuel-based plastics	Plastics which are derived directly from petrochemical raw materials such as petroleum and have not been previously used or recycled.
Biobased plastics	Plastics based on natural or 'renewable' raw materials from source material that renews itself in a limited time.
Compostable/biodegradable plastics	Plastics which degrade (catalysed by biological activity) and are broken down into natural gases, water and minerals.
Mechanical recycling	Recycling method in which collected waste is cleaned, crushed and processed to make new production materials.
Chemical recycling	Method in which the polymer molecules of which a plastic is composed are split into monomers which can be used to produce new polymers.
Life-Cycle Assessment	Life-Cycle Assessment (LCA) is a method of charting the impact of products and human activities on the environment. The outcome of an LCA study is an environmental profile: a 'score card' of environmental effects. The environmental profile shows which environmental effects play the most important role in the life cycle.

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DESIGNING WITH RECYCLED PLASTICS

Other outputs of this project are:

CASES

Inspirational examples of the use of recycled plastics in high-quality products,

supported by showcases explaining the process.

CURVER
100% post-consumer waste material in household products

PHILIPS
Recycled plastics in the PerfectCare Aqua Eco Steam Generator

OCÉ
Using recycled plastics in industrial printers

SCHOELLER ALLIBERT
Using recycled plastics in products suitable for food contact

AKG POLYMERS
Production and sale of premium polypropylene recycled plastics

CUMAPOL
Recycling and processing PET flakes into custom-made polyesters