Designing plastics circulation

- electrical and electronic products

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The purpose of the report is to drive the EEE (electrical and electronic equipment) sector towards a circular economy.

The case-examples collected for the report show how different stages of the lifecycle can be designed so that plastics circulation becomes possible and makes business sense.

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Designing plastics circulation – electrical and electronic products: table of contents

Report structure: 5-stage lifecycle model

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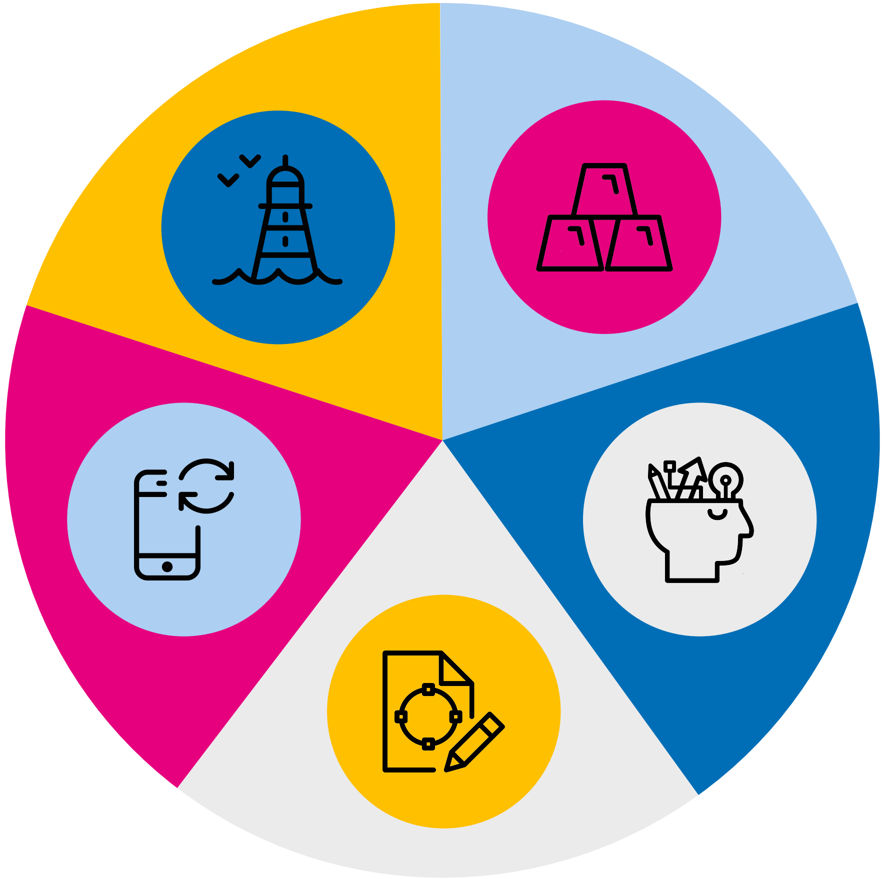

Summary of findings

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Summary of findings

Presently most electrical/electronic products (EEE) are not designed for recycling, let alone for circulation. Plastics in these products accounts for about 20% of material use, and through better design significant environmental and financial savings could be gained.

For example, using recycled plastic in a electrical/electronic product could reduce the environmental impact of a single product by over 20%. If all returned WEEE plastics would be recycled in Europe, estimated CO_2 emission reductions would be over 2.5 million metric tonnes per year [1].

(1) European Electronics Recyclers Association Position Paper: Weee Plastics Recycling Strategy Proposals 2017

(1)

Summary of findings

Technological solutions and circular design opportunities already exist, but for various reasons they haven't been implemented yet. Some challenges, such as, ease of disassembly could be resolved through better communication and sharing learnings across value chain. In addition, customers increasingly expect companies to take the lead and offer them with more sustainable choices.

Instead of creating WEEE (Waste Electrical and Electronic Equipment) we should focus on developing **CEEE** - Circular Electrical and Electronic Equipment.

The ultimate goal should be in designing and setting up a system that enables circulation. In other words, taking products back and reprocessing material back to same product over and over again.

Summary of findings: list of recommendations

Circular Design Principles

Embedding a circular economy vision and approach into the company's strategy is a first step every company could and should take. Developing and implementing circular design principles is a concrete way to execute the strategy, and it also ensures that the company is future-fit in a changing and resource-scarce business environment.

Roundtable for Plastics Circulation

Circular design can and should play an important role at each stage of the lifecycle. A roundtable – a high-level platform bringing together companies and value chain actors to create sector-wide Circular Design Principles – is crucial in order to capture economic value that is currently lost due to linear design. Taking a broader view; a great many current challenges and linear practices could be addressed through a closer value chain collaboration. Brands could learn from recyclers and take these learnings into their circular design processes and vice versa; recyclers could tailor their offerings based on the specific needs of each customer.

In addition, there are currently a number of different ways of handling and recycling plastics; there is a need to set up bigger clusters for side stream management to drive up volumes and economic viability. Various networks exist, such as WEEE Forum and Next Wave and many others, that could join forces and take the lead on this. Producer responsibility organisations in the EU member states could also be catalysts of change; for example, ESR has created an ecosystem around the WEEE industry to develop more efficient and effective collection and treatment systems in France.

Summary of findings: list of recommendations

Material identification & circular material choices
A prerequisite for the highest possible value capture is material identification. Incorrect markings on plastics have resulted in a situation whereby recyclers don’t trust the markings and therefore different types of plastics are not separated even if it were technologically possible.

Coupled with the issue of identification is the opportunity to harmonise plastics use. Going through different polymer types used in production and shifting to the most commonly used polymers is an effective way to contribute to recycling. However, this inventory should be done in collaboration with the sector, as it has a direct impact on recyclers. If recyclers knew what polymer types were coming in, they could make necessary investments in novel technologies, thus resulting in a more consistent quality of material. Furthermore, designing out chemicals and additives improves circulation opportunities significantly.

Summary of findings: list of recommendations

Legislation

A requirement for using recycled content would speed up the market transition towards circularity. In addition, requirements for circular design principles, especially reparability, modularity, upgradability, and ease of disassembly could be first encouraged in the form of sector-wide principles and gradually formulated into requirements. Removing existing barriers, such as transporting e-waste across borders within the EU, is equally important. Nordic countries are well positioned to build a Nordic Cluster of harmonisation for a take-back recycling system to support scalability.

Summary of findings: list of recommendations

Embedding environmental calculations into the decision-making process

To operate within planetary boundaries it is necessary to ensure that products are designed, manufactured and circulated in such a way as truly takes us closer to a circular economy. Calculating avoided environmental costs provides a good business case and foundation for decision-making when starting a circular journey.

Definition of Circular economy =

a restorative and regenerative industrial system, where waste and emissions are designed out through slowing, closing, and narrowing material and energy loops [(2).]

Definition of Circular design =

Based on lifecycle approach covering the whole internal process consisting of 1) R&D 2) design 3) circular business model development

(2) Adapted from: & *Martin Geissdoerfer et al. in Journal of Cleaner Production: The Circular Economy - a new sustainability paradigm? () 2017*

Chapter 1: Introduction – what is the challenge?

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Context

Design is the key to move towards a circular economy from the linear take-make-waste economic model; 80% of environmental pollution and 90% of manufacturing costs are the result of decisions made at the product design stage [3]. Presently most electrical/electronic products (EEE) are not designed for recycling, let alone for circulation. Plastics in these products account for about 20% of material use, and through better design could generate huge environmental and financial savings.
Globally the amount of e-waste is projected to grow rapidly; by 2021 there will be 52 million tonnes of e-waste (including PCs, laptops, smartphones, tablets and monitors *but* excluding a wide range of other electrical equipment such as refrigerators, lighting, measuring devices, etc.). By 2040 carbon emissions and emissions from use of the above electronics will reach 14% of total global emissions[4]. It is estimated that globally all plastic production and plastic waste incineration will generate 400 million tonnes of CO2 emissions.

The annual plastic demand in Europe is 52 million tonnes, of which plastics used in electrical and electronic products count for 6.2%. Combined with the automotive industry, these two sectors use nearly 16.3% of plastics, which equals 8.5 million tonnes per year [5]. The quantity of plastic waste from EEE sources in the EU is around 1.2 million tonnes per year[6]. According to estimates, reuse of PCR plastics in EEE is estimated below 1% (RDC Environment 2017)[7].

Using recycled plastic in an electrical/electronic product could reduce the environmental impact of a single product by over 20%[8]. Instead of WEEE (Waste Electrical and Electronic Equipment), we should focus on developing CEEE: Circular Electrical and Electronic Equipment.

(3) European Parliament: http://www.europarl.europa.eu/doceo/document/A-8-2018-0165_EN.html
(4) A New Circular Vision for Electronics - Time for a Global Reboot (2019)
(5) (5) Plastics - the facts 2018, Plastics Europe https://www.plasticseurope.org/application/files/6315/4510/9658/Plastics_the_facts_2018_AF_web.pdf
(6) European Electronics Recyclers Association Position Paper: Weee Plastics Recycling Strategy Proposals (2017)
(7) CLOSEWEEE project: Report on proposed Ecodesign Policy Concept and recommendation to strengthen Design for Recycling and the usage of post-consumer recycled plastics in new products (2018)
(8) Nordic Council of Ministers: Nordic plastic value chains - Case WEEE (Waste Electrical and Electronic Equipment) (2015)

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Circular design plays a key role in a systemic transition towards a circular economy.

The change starts with design at each lifecycle stage.

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Context

The following pages focus particularly on the crucial role of design. How can design further the sustainable use of plastic and the transition towards a circular economy? Which key factors from the design point of view enable the circulation of plastics and what hinders closing the loop?

The report introduces the concept of circular design and takes a step beyond Design for Recycling (DFR), which was called for in the previous Nordic Council of Ministers reports[(9)] as a way to improve plastics recycling and reduce the environmental impact. The ultimate goal should be designing and setting up a system that enables circulation – in other words, taking products back and reprocessing material back to the same product over and over again.

The text builds on the Nordic Programme to Reduce the Environmental impact of Plastics[(10)] and the EU Strategy for Plastics in a Circular Economy, which presents that in the future 'design and production of plastics and plastic products fully respect reuse, repair and recycling'[(11)].

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(9) Plastic Waste Markets: Overcoming barriers to better resource utilisation (2018); Nordic plastic value chains - Case WEEE (Waste Electrical and Electronic Equipment) (2015
(10) Nordic Programme to Reduce the Environmental impact of Plastics (2017)
(11) European Strategy for Plastics in a Circular Economy (2018)

Context

A number of leading brands, plastic recyclers, and experts were interviewed for this report. Their case examples show that there is huge business potential in improving plastics circulation. Customers increasingly expect companies to take the lead and offer them more sustainable choices. Moreover, these brands show that necessary changes in design principles and manufacturing processes can and should be made to keep the existing plastics in use as long as possible. Now it is time to take a leap in material flow management and scale up these circular solutions across the industry.

We would like to thank all the interviewees as well as CEO Pascal Leroy of WEEE Forum and PolyCE Project Coordinator Gergana Dimitrova of Fraunhofer Institute for Reliability and Microintegration IZM for reviewing the text.

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Context: key research questions

- What are the organisation's design principles and how are they implemented?
- In what ways design approaches and practices aim for sustainable circularity?
- How reparability, upgradability, modularity and ease of disassembly of the product have been addressed?
- What is the policy on chemicals & hazardous substances?
- What is the end-of-life strategy?
- Does the business model support the goal of decoupling growth from the use of virgin raw materials and natural resources?

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Context: list of interviewed organisations

Organisation	Area	BtB/BtC
Fujitsu	ICT software & services and IT equipment	BtB/BtC
Oticon	Hearing aids	BtC
Zen Robotics	AI based recycling technology	BtB
Dell	ICT solutions and IT equipment	BtB/BtC
Philips	Health care products, consumer electronics	BtB
Energy Authority	Legislation	BtB/BtC
Finnish Plastics Industries Federation	Plastics industry membership organisation	B2B
Ensto	Electrical solutions	BtB
Fortum	Recycler	BtB
Kuusakoski	Recycler	BtB
Plastix	Plastic recycler	BtB
Plastkretsen	Plastic recycler	BtB
Sustonable	Kitchen and bathroom panels	BtB
Volvo	Transport	BtB/BtC
Novo Nordisk	Medical products	BtC
Ohmatex	Electronic textiles	BtB
Inrego	Refurbished consumer electronics	BtC
Fisher-Lighting	LED lighting	BtB
Body-bike International	Fitness bikes	BtB
B&O	Consumer electronics	BtC
Electrolux	Consumer electronics	BtC
MatKon	Consumer electronics	BtC
Neste	Recycler	BtB

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Instead of WEEE (Waste Electrical and Electronic Equipment) we should focus on developing CEEE - Circular Electrical and Electronic Equipment.

Chapter 2: Embedding Circular Design Across the Lifecycle

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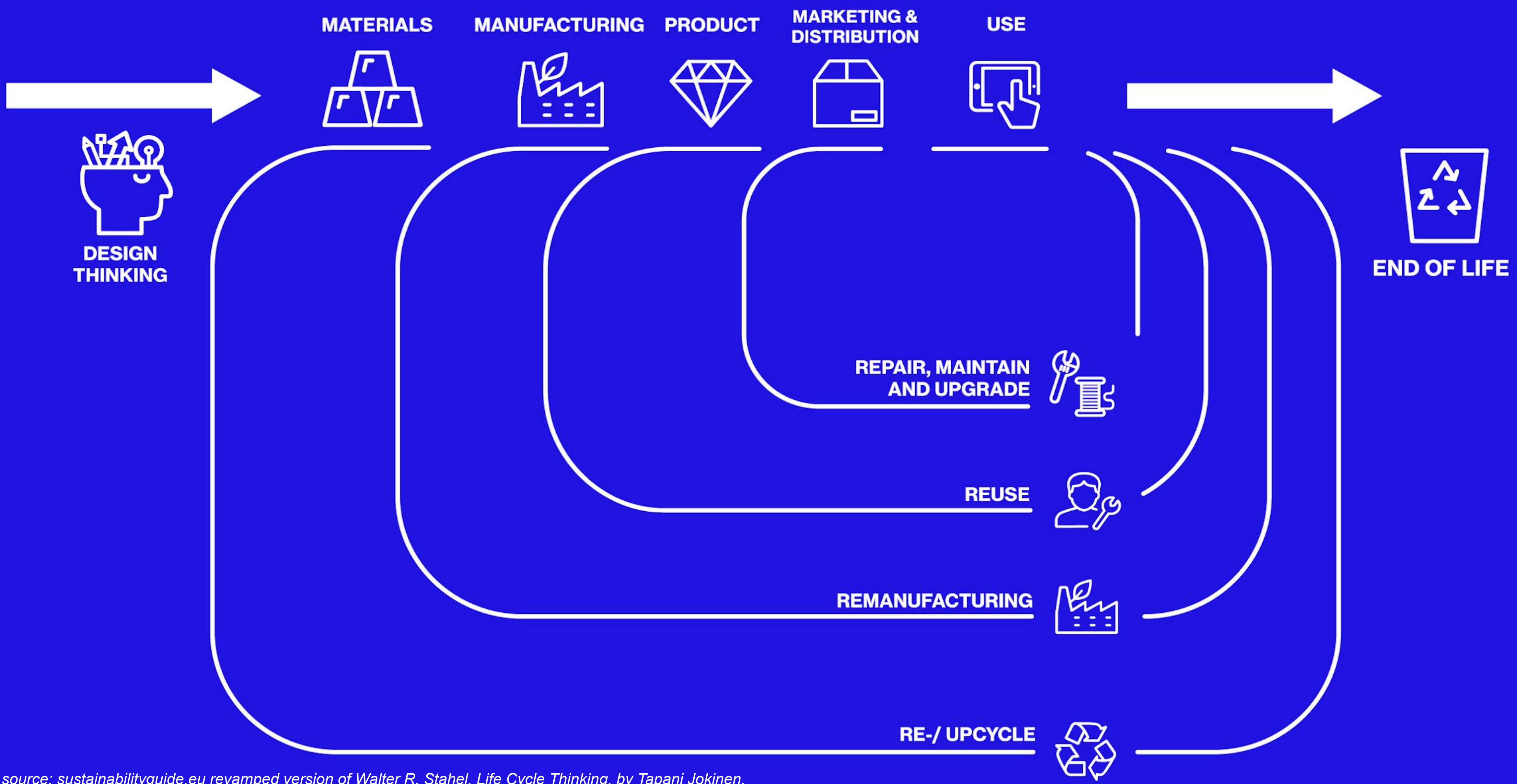
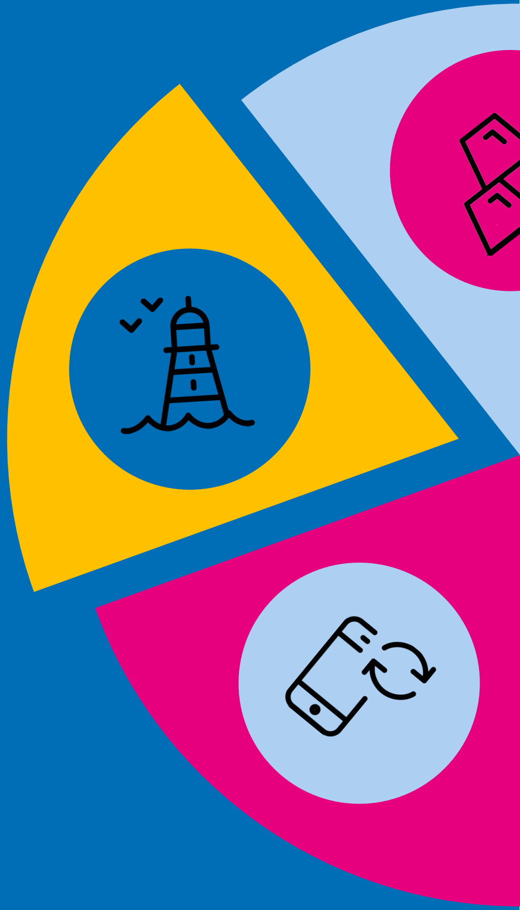


Image source: sustainabilityguide.eu revamped version of Walter R. Stahel. Life Cycle Thinking, by Tapani Jokinen.

2.1 Strategy

A company level commitment is a 'must-have' to implement all the other circularity aspects along the lifecycle



“It’s more than just environmental strategy
– it’s good business”.
- Dell

2.1. Strategy: Circular economy as a strategy

Many forerunner companies have already embedded circular economy into their strategies. This is reflected directly in the company's R&D, as the whole approach and many internal processes need to change when transitioning from a linear take-make-waste to a circular way of thinking, operating and doing business.

Traditionally, design based on linear-economy thinking mainly focuses on the **manufacturing** and **use phase** through, for example, optimal material choices, energy efficiency, functionality and aesthetics, and it is based on the linear business model of 'selling more & selling faster'.

Circular design plays a key role in a systemic transition towards a circular economy and no matter what lifecycle stage is in question, the **change starts with designing, for example, which safe and non-toxic materials are used and how the product can be easily disassembled for repair, reuse and remanufacturing.** As circular economy aims to decouple growth from the use of virgin raw materials and natural resources and eliminate pollution and waste (there is no waste in the nature, everything is raw material), circular design approach can be regarded as a tool to achieve these goals.

In this report we use the term 'circular design[12]' to describe the whole internal process consisting of 1) R&D 2) design 3) business model development. Circular design plays a key role in a systemic transition towards a circular economy. No matter what lifecycle stage is in question, the change starts with designing, for example, which safe and non-toxic materials are used and how the product can be easily disassembled for repair, reuse and remanufacturing. As circular economy aims to decouple growth from the use of virgin raw materials and natural resources, eliminating pollution and waste (there is no waste in nature; everything is raw material), a circular design approach can be regarded as a tool to achieve these goals.

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(12) Other commonly used term is eco-design although eco-design often aims for more environmentally friendly design within the current linear system and it excludes circular business model development.

2.1 Strategy: Circular economy as a strategy

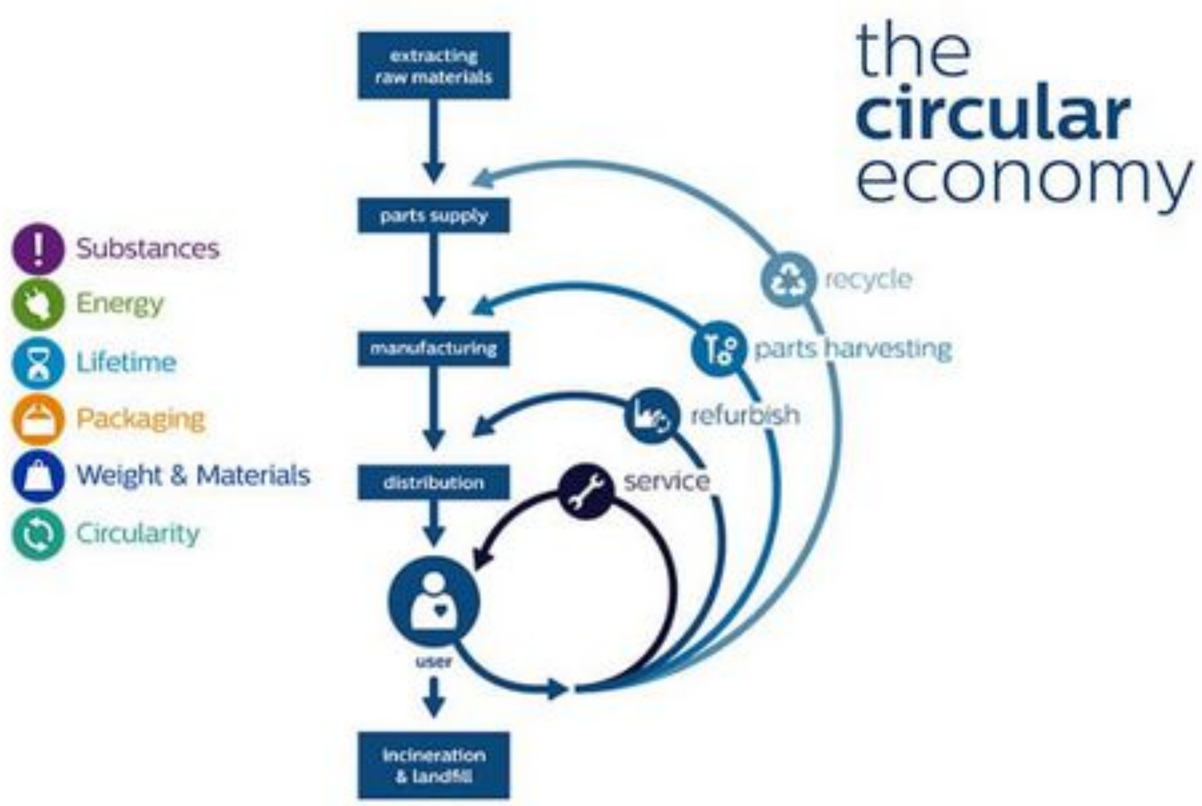
Circular design, instead, takes a lifecycle view covering materials & chemicals, manufacturing, logistics, business model, use, and end-of-life (or second life) stages. It aims for long-term value maintenance through circulating products and materials endlessly in biological (renewable materials) or technical (non-renewable) cycles using only clean energy. Why is business model development regarded as part of the circular design process? Because the product needs to be designed in a way that enables, for example, maintenance and repair services, selling the product as a service, the use of sharing platforms, and eventually taking the product back for disassembly and remanufacturing purposes.

Accordingly, circular design is much more than just design; it becomes a strategic tool steering the way business is conducted. It is necessary, therefore, to establish circular economy as a strategy at company level to maximise the business benefits of the circular design approach.

Currently there are no industry-wide circular design guidelines for electrical and electronic products which would facilitate better plastics circulation[(13)]. At the moment, the interest is in recycling valuable metals, but as the world is moving towards circularity and the amount of EEE is growing fast, plastics need to be used in a more circular fashion. Leading companies have addressed the issue by developing their own set of company-level circular or eco-design principles and processes along with concrete goals to move towards a circular way of operating, thus ensuring they are in the best position to meet the resource-scarce future. A company-level commitment is a 'must-have' in order to implement all the other circularity aspects along the lifecycle.

(13) Designing with recycled plastics guide offers info and case examples of companies using recycled plastics in their manufacturing
(2015)https://www.partnersforinnovation.com/media/Guidelines-designing-with-recycled-plastics.pdf

Case study: EcoDesign at Philips



Philips has developed an EcoDesign process with six key Green Focal Areas for improved environmental performance – Energy, Packaging, Substances, Weight & Materials, Circularity and Lifetime.
The Circularity focal area is about recovery, reuse and increasing recycled materials in the products as well as designing for easy disassembly, upgradability, recyclability and product-as-a-service business model.

Case study: EcoDesign at Philips

Image: Philips web page. Performer vacuum cleaners use recycled plastic 25-47% of parts

Philips operates both in B2B and B2C sectors. In B2B operations, Philips has set a target for closing the loop by 2020 through getting all its healthcare equipment back for remanufacturing. A target is to use only recycled plastics in inner parts of the consumer electronic products by 2025. Along with more colour options and visual quality the amount of recycled plastics can be increased to external parts.

Philips aims to shift its business model from ownership to providing solution driven services. In practice this means moving from selling to harnessing the product-as-a-service model and providing maintenance and repair services to customers.

As a result of its circular design work Philips has introduced a number of consumer lifestyle products made of recycled plastics (recycled content varying from 13%–95%), such as vacuum cleaners, coffee machines and steam iron.

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Case study:
Design for Environment at Dell

Dell XPS 13 laptop

A central part of Dell's approach is to consider sustainability at every stage of product's lifecycle – from the initial design concept to its use and eventual recycling. Dell has named the process as Design for Environment. The goal is to achieve zero waste by ensuring that every part of the product can be reused or recycled. Dell's design principles consist of six key areas:

1) Recyclability of materials.

2) Modularity: The majority of components found inside Dell products are easily removable, with standardized parts. This makes it easier to reuse or recycle them.

3) Easy disassembly: all parts are easily separable with commonly found tools.

4) Minimal glues and adhesives: Glues and adhesives can create processing challenges for recyclers, so Dell has come up with other methods, such as innovative snap fits, to accomplish the same design goals.

5) Restrictions on paints and coatings: Dell prefers integral finishes instead of exterior coatings, which can interfere with the recycling process or degrade certain plastics during processing. If paint is the only option, Dell uses paint that is compatible with recycling.

6) Single-access service door: easy access for repair and recycling.

In 2014 Dell set up a closed-loop recycled plastics supply chain. This means that Dell can recover plastics from old computers and process them into new parts for new products. Dell's closed-loop plastic parts are nowadays used in over 100 different products.

2.2 Materials & chemicals

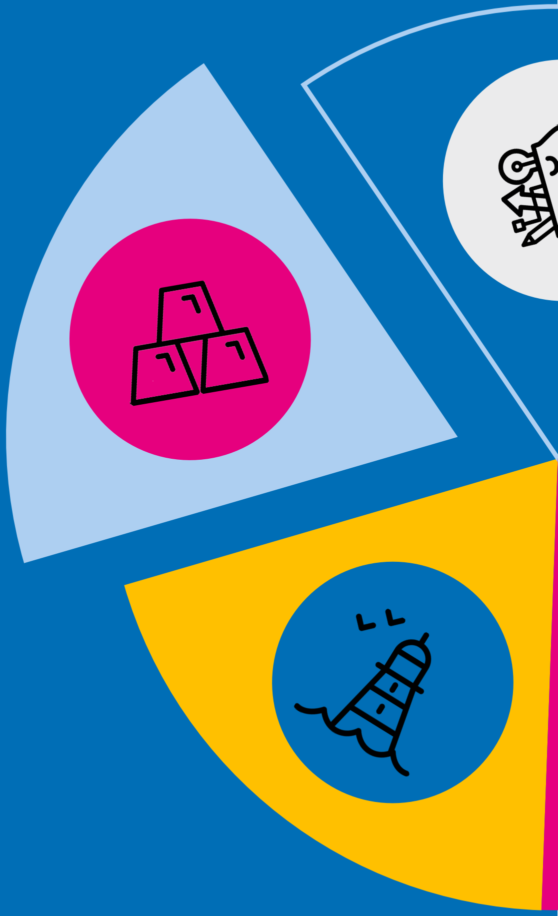
Harmonising plastic use

Material identification

Phasing out chemicals & additives

Using recycled plastic

Plastic replacing other materials



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“Manufacturers should agree on the type and amount of polymers they use in their products.”

- Energy Authority Finland

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2.2 Materials & chemicals: Harmonising plastic use

Presently there is no focus on the variety of components composition. The biggest material use in both weight and CO_2 impact is steel and the second one is plastic. This includes the thermoplastic materials PP, PS and ABS, plus smaller amounts of engineering plastics (that can be remelted and reused) and PUR, which is a thermoset material that cannot be remelted.

PUR is, for instance, used in refrigerators as a very effective insulation material but would require chemical breakdown to be recycled for use in the same application. Instead, PUR is recycled into new applications such as insulation panels and noise absorbers or as a powder for absorbing spills (e.g. oil spills) on land or in water. Thermoplastic components, on the other hand, are sorted out in the recycling process by polymer type and remelted and reused in different applications.

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2.2 Materials & chemicals: Harmonising plastic use

One of the current barriers for recyclers to processing plastics coming from electrical/electronic products is the sheer amount of different polymers.

"There are roughly around 500 000 different polymers in the world; 470 000 of them are used in technical products. This is the reason we don't process WEEE plastics." (Fortum)

One feasible solution to reduce the huge variety would be that manufacturers agree on the types of plastics and different polymers they use in their products, this would scale up more pure material stream volumes and make it financially more viable to invest in new recycling technologies.
The PolyCe[14] (Post-consumer high-tech recycled polymers for a Circular Economy) project's recommendation is to use polymers with known high recyclability rate, such as ABS, HIPS, PS, PP in parts such as housings, frames etc., which are significant also in terms of weight.

Another opportunity is to harness the platform design approach, which means that parts are standardised so that they can be used in several products. The production volume of the platform is much larger than the volume of the single product. This means that there is better economy in planning circularity, a longer lifetime, more options for repair, etc.

(14) https://www.polyce-project.eu/

Case study: Novo Nordisk harmonising plastic use

Novo Nordisk decided to use as few types of plastics in their insulin pens as possible. For one of the prefilled devices (insulin pens that are disposed of when empty), only PP and POM plastic materials were used. The two plastic types are easily separated utilising their different density. This means it is realistic to make an automatic recycling system where the pens are broken down mechanically into small pieces and then sorted in a liquid separator resulting in fairly pure material fraction that can be reused.

The major challenge in recycling is the return logistics – the diabetic patients could, for example, hand in their used pens at the pharmacy when picking up new supplies. Pharmacies (in Denmark) already receive many types of medical waste like pill boxes, unused medicine and insulin pens. But for economic (and safety) reasons the pharmacy does not sort the waste, but delivers it to an authorised waste handler. If the economic model is right (and medical products are designed with recycling in mind) pharmacies and/or the waste handlers could sort the waste products allowing for very pure material fractions.

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2.2 Materials & chemicals: material identification

Different plastic types are marked, but according to the interviewees the markings are not correct, which results in a supply chain domino effect.

“Kuusakoski bought an expensive recycling processor from Germany which could read the die cut identification code in a piece of plastics to improve separation. We started getting reclamations from our clients that the plastic we sold them didn’t correlate with the markings, which, in turn disrupted their processes. It turned out that the manufacturers’ identification codes were not correct, but they didn’t care about it. We had to stop using the processor.“ - Kuusakoski Recycling

2.2 Materials & chemicals: phasing out chemicals & additives

Apart from the basic chemical building blocks a range of other chemicals can be found in plastics. These other chemicals are referred to as additives and serve purposes such as [15].

- Functional additives (stabilisers, antistatic agents, flame retardants, plasticisers, lubricants, slip agents, curing agents, foaming agents, biocides, etc.)
- Colourants (pigments, soluble azocolourants, etc.)
- Fillers (mica, talc, kaolin, clay, calcium carbonate, barium sul- phate)
- Reinforcements (e.g. glass fibres, carbon fibres)

Furthermore, there can be residual chemicals from the production process, e.g. catalysts like antimony or uncured monomers (the basic building blocks that make up the polymer chains).

For electronic products the most common plastic types are ABS, HIPS and PC. Additives that draw attention in recycling include fire retardants (e.g. Brominated Flame Retardants or BFRs), heavy metals (e.g. lead for stabilisers and pigment, cadmium for pigment and antimony for catalysing flame retardant) and reinforcements for improved stiffness. The BRF represent the biggest challenge to recycling since they are widely present in much WEEE plastic in particular CRT (cathode ray tube) casings. The basic plastic types are simple to separate using density separation but the additives are more difficult to deal with. The WEEE directive set rules for fire protection which means that the plastics have to go through mechanical recycling as opposed to energy recovery (incineration) that can cause unwanted pollution[16] .

(15) . N. Hahladakis, C. A. Velis, R. Weber, E. Iacovidou, and P. Purnell, An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling, J. Hazard. Mater., vol. 344, pp. 179–199, 2018.

(16) L. Tange, J. Van Houwelingen, W. Hofland, F. Kohl, M. Kearns, P. Salemis, and N. Mendad, Recycling of plastics containing flame retardants in electronic waste, a technical and environmental challenge for a sustainable solution, PMI Conf., 2012.

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2.2 Materials & chemicals: phasing out chemicals & additives

Antimony is rare element in the earth crust and is mainly produced in China. Need is expected to rise in the coming years, making it more attractive to recover the antimony through the recycling process[17].

According to recyclers, various chemicals - especially a group of brominated flame retardants (BRFs) comprise one of the biggest barriers for EEE plastic recycling. Additives, such as glass fibre and heavy metals, also pose a challenge for recyclers. Phasing out chemicals and additives is to a large extent a design question. For instance, the CLOSEWEEE[18] project found that flame retardants used in TV back covers could be eliminated through changes in design, which makes recycling of back covers easier.

The PolyCe Project[19] has created a set of guidelines on the use of chemicals and additives to improve the circulation of plastics:

- **Use only common and easily recyclable plastics (ABS, PC, PC/ABS, PP, HIPS, PA).**
- **Do not use thermosets. If thermosets are necessary they should have another density than the common plastics used.**
- **Do not use elastomers. If elastomers are necessary, they should have another density than the common plastics used.**
- **Do not use halogenated polymers (e.g. PVC, PTFE).**
- **Do not use heavy-metal-based lubricants and plasticisers.**
- **Do not use polyoxymethylene (POM).**
- **Do not use silicone compounds, oils or greases.**
- **Do not use montanic acid ester.**
- **Avoid coatings (painting, lacquering, plating, galvanizing)**
- **Do not use glass fibres or carbon fibres. If reinforcement is needed, prefer talc.**
- **Avoid moulding different plastic types together by 2K or xK processes.**
- **Use one single polymer in plastic casing parts >100g.**
- **Avoid using connections that enclose a material permanently.**

(17) M. Schlummer and F. Wolff, Recovery of Polymer Additives from WEEE Plastics, CloseWEEE Workshop, Freising, 2018.
(18) CLOSEWEEE: http://closeweee.eu/
(19) A. Berwald, 'PolyCE – Deliverable 2.2 – Requirement-specific priority plastics guide', 2018.

Case study: Designing out chemicals

Hearing aid pic

Fisher-Lighting
Kartell Bourgie Lamp

Body-Bike Smart

Oticon A/S, a hearing aid manufacturer based in Copenhagen (Denmark) has enforced extra specifications, for example, a ban on the use of phthalates and natural rubber latex. Working with the restricted list ensures full transparency on the use of hazardous substances, compliance with relevant directives and the opportunity to set a higher bar than the external required or recommended standards. They are developing a risk-based approach where material compliance is not only secured by supplier declarations, but also via material analysis for high risk materials.

Fischer-Lighting has used recycled plastic in its lamp. To give plastic more strength, talc is added instead of glass fibre, which makes recycling easier.

There is a special focus on non-toxic materials at BODY-BIKE International: for example, a handle bar coming from a German supplier has to be without any toxic substances to protect the user (a lot of of skin contact) as well as the environment.

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2.2 Materials & chemicals: increasing the use of recycled plastic

According to our interviewees, using recycled plastic requires a different design approach and different processing than virgin plastic and can be challenging in the beginning. However, interviewed brands regarded this as only one R&D challenge amongst others; when there is a company level commitment to using recycled plastics, required know-how can be built along with required changes in the processes to ensure a high quality of plastic.

Another challenge to overcome is the chicken and egg problem; a situation whereby recyclers do not process plastics if there is no market for them and brands cannot buy recycled plastics because there is no supply. Big brands can take the lead on this and start working with plastic recyclers to find the right quality and make a commitment to buy the processed plastics as the car-maker Volvo has done:

"We encountered a catch 22, where we wanted reused plastics but the providers didn't have it in the right quality. Then there's the reuse business that doesn't process it as they don't think there's a market for it. Therefore we wanted to set that ambition [at least 25% recycled plastic in each new car] to show that there's a market, we want this." - Volvo

2.2 Materials & chemicals: increasing the use of recycled plastic

Besides bringing many environmental benefits, using recycled plastics also makes business sense; scaling up the volumes results in bigger savings.

"The most important driving force is that it is green, which helps improve our overall environmental performance by reducing impacts from materials, and something which is used to market certain products. But using recycled plastic can also be a cost benefit, as it is often cheaper." - Electrolux

The French ESR has created a tool called Reeecyclab for producers to evaluate the recyclability of a product, test alternatives and identify areas for improvement.

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Case study: working with recycled plastic

Electrolux vacuum cleaner pic from web site

Electrolux has established an Internal Recycling Taskforce, which includes representatives from each Electrolux sector, purchasing, R&D, production and product lines to define the commitment's scope, targets and action points. The main activities are to find reliable and high-quality material suppliers, and to identify the best opportunities within each product category for replacing virgin materials with recycled materials – either within the existing design or by adapting the design for recycled material.

Electrolux has set a target to replace virgin plastic with recycled plastic and increase the amount of recycled plastic in products to 20,000 tonnes per year. Electrolux has calculated that CO_2 emissions resulting from the production of virgin plastic are equivalent to the emissions from operations and transport activities combined, so the positive environmental impact from recycled plastic is significant.

Case study: working with recycled plastic

Sony has developed SORPLAS™, plastic made of waste optical discs and leftover film from Sony and other factories as well as post-consumer materials, such as plastic water bottles. SORPLAS is used in TVs and cameras. The flame retardant in SORPLAS is sulphur-based, which allows much higher use of recycled plastic in the product than conventional flame retardants. According to Sony, sulphur-based flame retardant does not weaken the quality of plastics, so it can be recycled several times without the loss of high quality.

At least 25 percent of the plastics used in every newly launched Volvo car will be made from recycled material from 2025 onwards. As the lifespan of the car can be long, Volvo is also using recycled plastics from other industries, for example, the packaging industry.

Plastix A/S is a sustainable cleantech plastic fibre recycling startup company that targets the niche of waste stream marine plastic pollution, such as fishing nets (HDPE) and ropes (some are PP), and helps turn it into oceans-based plastic products to supply the automotive industry, high-end furniture industry, packaging industry and brand owners.

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Case study: plastic replacing other materials

Volvo xc60 Clean Seas

Volvo uses around 200kg of plastics (16–17% of all materials used) in each car. Replacing heavier materials, like steel, with plastics makes the vehicle lighter. A lighter vehicle means less fuel consumption and smaller carbon footprint. In addition, using plastics instead of leather inside the car also means emission savings.

Ohmatex is a smart textile technology company and a good example of how the use of other materials like copper and aluminium metals for electrical conductors can be minimised when integrated into garments. Ohmatex produces electrical-conducting textiles with built-in electrodes and electrical wires based on polymer fibres. The use of metal is much less than if separate wires were used.

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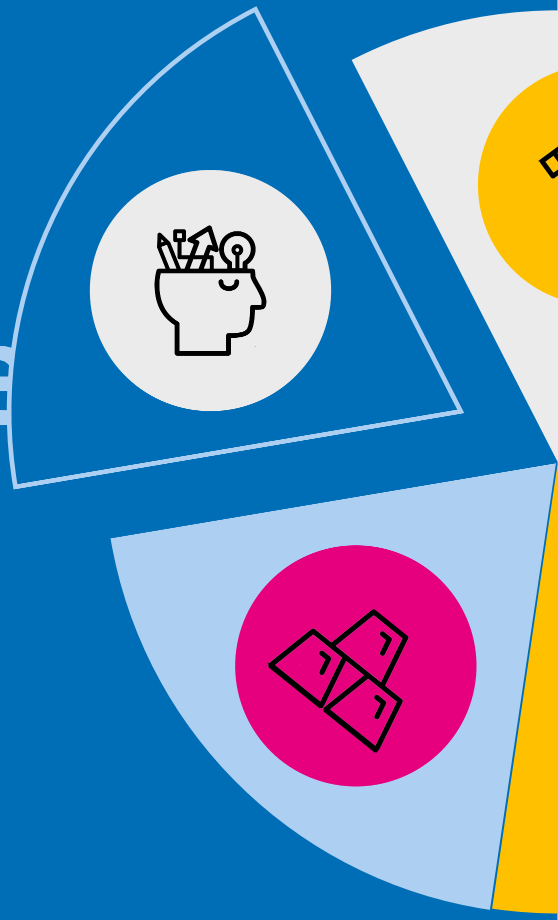
2.3 Product design – reparability, upgradability, modularity and ease of disassembly



"The point of manufacturing and design is where it all starts. Whatever they do at that point, will determine how the product will be used, re-used and re/upcycled."

- MatKon

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2.3 Product Design

Reparability, upgradability, modularity and ease of disassembly (RUMED) are circular design strategies which play a vital part in the following:

- **Extending the life-span of the product**
- **Enabling worn-out/broken parts to be replaced instead of replacing the entire product**
- **Enabling software to be upgraded without having to buy a new product**
- **Enabling remanufacturing through easy disassembly, thus being able to recover components without destroying them**

There are many business benefits for applying these RUMED strategies; from the customer perspective it creates loyalty and trust towards the brand. The overall customer experience is improved when the product is durable, spare parts and upgrades are available and repair service works seamlessly.

"The overall experience of a product that unfortunately breaks but then is quickly repaired often creates a bigger customer satisfaction than just replacing the broken product. Many customers really value the fact that the product is possible to repair and not wasted. So there's real a business advantage to provide this service." - Electrolux

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Case study: harnessing RUMED strategies

Philips offers repair manuals and software updates and sells spare parts in its online shop. They have also set up an online DIY shop, which offers guidance on repairing Philips products.

Dell has phased out glues and uses standardised snap fits for ease of disassembly. They have also standardised components for easier reuse.

Fujitsu follows 3R design principles that focus on reduce, reuse, and recycle. Fujitsu is making efforts to improve resource efficiency, which is made possible by designing products to be lighter and smaller, using recycled plastics, reducing the number of parts, enhancing ease of disassembly and improving recyclability. In addition, Fujitsu's own 3-D Virtual Product Simulator (VPS), is used during the product design process, to test the steps involved and the convenience of product assembly and disassembly before creating prototypes.

Case study: harnessing RUMED strategies

Oticon's products are designed for repair. The speakers in RITE instruments have filters to protect them from earwax and to prolong the lifetime of the speaker unit for the ear. The end users can change the filters as well. The outer plastic shell can be exchanged if it breaks. Plastic battery drawers are handled by end users when changing small batteries. They are designed with high strength material to reduce the risk of breaking, but they are also designed to break first, before more critical components get destroyed when overloaded. Battery drawers can be replaced if they are overloaded.

Fischer-Lighting supplies new LED lighting units to be retrofitted into existing lamps, easing the transition from older types of lighting sources.

BODY BIKE International produces spin bicycles for gyms. The bicycles are made from stainless steel and partially recycled plastic and are exposed to extensive wear and corrosive environment (sweat). The bicycles are therefore designed for easy disassembly to make repair easy and realistic. Old bicycles are refurbished and sold to private customers.

B&O works in close collaboration with DTU and Aalborg University on a readiness assessment, extended lifetime, improved durability and circular economy to include more design rules in their future design work. Design rules such as design for disassembly, design for reparability, design for environment, and design for reducing harmful substances are being introduced into the design stage.

2.3 Product Design: value chain collaboration

Value chain collaboration could and should be strengthened to increase plastics circulation. Bringing manufacturers and recyclers together enables mutual learning: manufacturers can improve their internal design and manufacturing processes to improve, for example, ease of disassembly of plastics, and recyclers can develop and offer tailored plastic grades for manufacturers according to specifications.

"Regarding plastic and circularity, partnering up with others is a must. In circular economy you have to do that, it is SDG 17 (the UN Sustainable Development Goal: ‘Strengthen the means of implementation and revitalise the global partnership for sustainable development’) that we relate to and discuss this with our partners. So yes, partnerships – absolutely.” - Volvo

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Case study: Learning from each other

Fujitsu organises tours for designers in their recycling centres to facilitate discussion and learning between the two parties. Designers can then apply these learnings into their design processes to promote disassembly and recycling.

Philips uses co-creation design methods with recyclers and recycled material suppliers to build common expertise on how to improve the quality of recycled plastics.

Fischer-Lighting collaborated with 3XN, a Danish architectural company, to design an award-winning lamp with recycled plastic. The plastic was supplied by Plastix A/S, a Danish cleantech recycling company specialized in converting fibres, primarily used fishnets, trawls and ropes into high-quality, virgin-like rHDPE and rPPC green plastic raw materials. This presents a solution to a substantial waste problem, contributes to a more circular economy, reduces the amount of waste to landfills, ocean plastic waste, and CO_2 emissions, as well as prevents a valuable resource from being lost. Plastix also provides consultancy services to help customers transform the high-quality material into innovative, and in this case modular, products.

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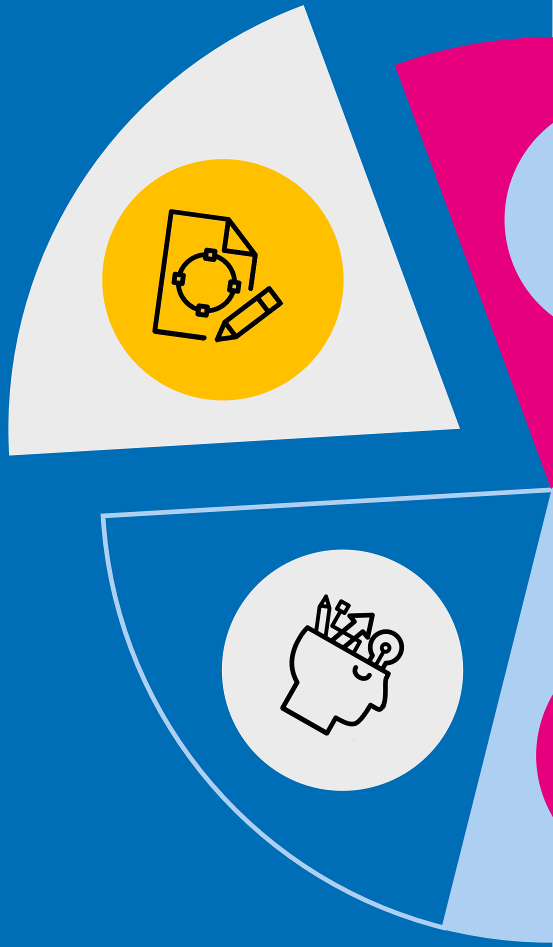
2.4 Circular Business Models



2.4 Circular Business Models

Circular business models (CBM) refer to ways of doing and developing business through decoupling growth from the increasing use of virgin raw materials and natural resources. Unlike the linear business model which is based on selling high volumes with faster purchase cycles ("sell more, sell faster") and consequently exhausting our natural ecosystems and material reserves, CBM ideally aims for one planet business logic, i.e. sustainable growth that operates within the planetary boundaries.

One way to explore this critical topic is Earth Overshoot Day[20], which calculates each year the date by which the planet's ecological resources and services have been used up (in 2018 the global Earth Overshoot Day was 1 August), and the rest of the year we operate in a growing ecological deficit. CBMs, therefore, play an important role in our effort to move towards a sustainable way of doing business.

(20)World Overshoot Day: https://www.overshootday.org/

2.4 Circular Business Models

Circular business models can be classified in the following way:

1) **Access and performance model**: in this model, the user can access and use the product without owning it, also called a 'product-service system'.
2) **Extending product value**: a business model whereby the manufacturer reuses or remanufactures old products through take-back programmes.
3) **Classic long-life model and encourage sufficiency**: focus is on long-lasting and durable products and offering maintenance/repair services to support the user's ability and willingness to keep the product in use as long as possible.
4) **Extending resource value**: this business model refers to turning waste into useful raw material and decreasing or replacing virgin material altogether.
5) **Industrial symbiosis**: this model refers to close physical proximity and collaboration between companies.

Although CBMs are often presented in the form of the above list, in reality they overlap and complement each other, thus forming 'hybrid' CBMs. For example, designing and manufacturing high-quality products (No 3: Classic long life model and encourage sufficiency) is a prerequisite for access and performance model (No 1). For the company, it is always important to explore all CBM opportunities to maximise the circularity of operations.

Case study: Moving towards a circular business model

Philips wants to move from the ownership and selling the product to access and performance model, which enables them to retain the material ownership for reuse and remanufacturing purposes.

Volvo's new mission is 'Freedom to Move' and the company wants to become a service provider creating closer relationship with the consumer. In 2018 Volvo launched M, a service providing on-demand access to cars and services through an intuitive app. Learning the user's preferences and behaviour, Volvo's software development aims to give a feeling that the car understands the user through the personalised application. Through the service model, Volvo is able to reuse and remanufacture car parts more easily.

MatKon Group consists of MatKon Refurbish, MatKon ProService and MatKon Data, and specialises in dealing with manufacturers, re-sellers and operators of electronic products (e.g. IT/IP equipment, vacuum robots, coffee machines). They offer services for the telecom industry by repairing and refurbishing used routers and TV boxes. MatKon collaborates with Kirppu (specialised flea markets, 13 stores in Denmark), where you can buy a refurbished PC with a 15% buy-back price, if returned at end-of-life. The recycle and resell concept extends the lifetime and the value of the product.

Bang & Olufsen (B&O) produces expensive high-end audio and video equipment. The B&O products represent design icons of high value and there are third party shops specialising in refurbishing used B&O products and to sell them again.

Source: Nancy M.P. Bocken et al (2016): *Product design and business model strategies for a circular economy* in **Journal of Industrial and Production Engineering**

2.5 End-of-life & reverse logistics

2.5 End-of-life

Organising reverse logistics to get products/material back for reuse and remanufacturing purposes often goes hand in hand with setting up a CBM (circular business model).

Considering the product's end-of-life as part of the design process is a crucial element of making circulation happen. For example, removing glues makes it easier to recover components.

In a linear economy companies have optimised their production lines and logistics as a one-way street being efficient in transporting products out to be sold, but taking products or materials back for reprocessing requires a different structuring of operations.

Getting products back (so called take-back programme) for reuse, remanufacturing and finally for recycling requires reverse logistics, facilities for disassembly and designing and setting up a system for remanufacturing. These operations can be performed through either by the company itself or through setting up partnerships.

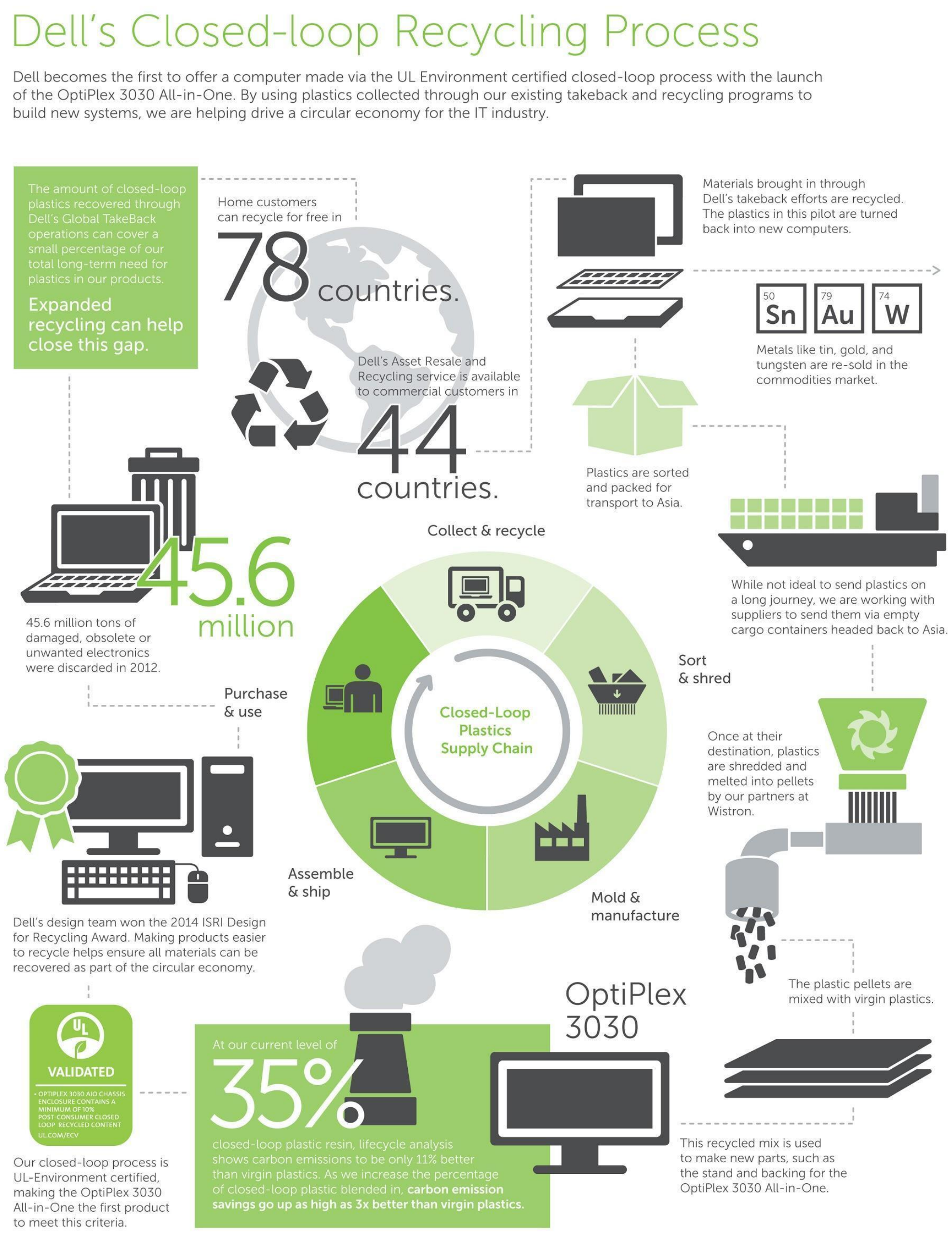
Case study: Organising end-of-life stage

Fujitsu has set up recycling centres across Japan to take-back old ICT products, where products are disassembled, sorted and recycled. Materials recognition equipment has been introduced for plastics that are difficult to discriminate between, so as to allow the complete segregation of different types of plastic. Plastics are sorted into 20 different streams for remanufacturing and recycling purposes.

Inrego has built a business based on the end-of-life stage and set up an economically feasible take-back system. Inrego extends the life-span of old computers, mobile phones and other IT equipment through buying them back, erasing all data, and repairing and upgrading them for a second life cycle. Products are then sold or rented with a warranty to customers.

Case study: Dell closed-loop plastic recycling

Dell set up a closed-loop plastic recycling process in 2014. To date Dell has used nearly 50 million kg of recycled plastic in their products[21].



(21) https://www.dell.com/learn/us/en/uscorp1/corp-comm/circular-economy?c=us&l=en&s=corp&cs=uscorp1

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Case study: Benefits of closed-loop recycling

Table 1: Natural Capital Values of Environmental Impacts: Virgin ABS & Closed-loop ABS

Environmental impact		Virgin ABS	Closed-loop ABS	Net benefit of closed-loop ABS
Human health	Human health	-$1,045,000	-$392,000	+62%
	Respiratory effects	-$186,000	-$172,000	+8%
Energy & fossil fuels	Climate change	-$1,173,000	-$686,000	+42%
	Fossil fuel depletion	-$60,000	-$21,000	+65%
Air pollution	Smog	-$538,000	-$517,000	+4%
	Air pollution	-$82,000	-$78,000	+5%
Water & land pollution	Water pollution	-$44,000	-$28,000	+36%
	Ecotoxicity	-$14,000	+134,000	+1,057%
Cumulative		**-$3,143,000**	**-$1,760,000**	**+44% +$1,383,000**

In addition to long-term value maintenance, a closed-loop system generates significant environmental benefits. In 2015 Dell conducted a study[22] which found that closed-loop ABS plastic resulted in avoided environmental costs of $1.3 million annually compared to the use of virgin ABS plastic. Accordingly, the natural capital net benefit of closed-loop ABS vs. virgin ABS was 44% (natural capital calculations include a range of environmental metrics, such as climate change, ecotoxicity, water pollution, respiratory effects, fossil fuel depletion, smog, air pollution and human health). According to the same study, avoided environmental costs would be $700 millions/per year if the entire computer sector would use recycled ABS instead of virgin ABS plastic.

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(22) https://i.dell.com/sites/doccontent/corporate/corp-comm/en/documents/circular-economy-net-benefits.pdf?newtab=true

Chapter 3:
Future of plastics

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"The Circular Economy and the UN Sustainable Development Goals will radically change the way we operate our businesses. We can, in the very near future, expect legislative frameworks requiring design for disassembly, design for recyclability, deposit and return systems, extended producer responsibility, tracking and marking systems for traceability, and perhaps even requirements of using mono-polymers, instead of mixing different types of polymers, which currently poses a barrier for recyclability." - Plastix A/S

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What will the future look like?

Given the important and manifold role of plastic in electronic/electrical products and the automotive industry, the plastic use is not going to decrease. Fossil fuel based plastic will gradually be phased out in parallel with increasing R&D and testing on biobased plastic. Of 1.2 million tonnes of WEEE plastics in the EU up to 50% could be recycled instead of the current 20%. If all returned WEEE plastics were recycled in Europe, the estimated CO_2 emission reductions would be over 2.5 million metric tonnes per year.

The first EU plastic strategy was implemented in early 2018 requiring 50% of recycled plastic in packaging material by 2025 and 55% by 2030. There could be a similar target for CEEE, which would speed up the market transition significantly.

In addition to a huge market potential, many interviewees mentioned customer demand as an important driver. No doubt this demand will only grow in the future.

"In the future there will be more demand from the consumers to have a circular economy in place for products. It will be a big movement in society." - BODY BIKE International A/S

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What will the future look like?

Whilst the case studies in this report show enormous potential for developing design practices according to circular principles, the fact is that consumers, too, need to rethink their own consumption.

“If we want to move towards a circular economy, we need to radically think about our own consumption. It has been said that this is a materialistic era on the contrary; our relationship with material is twisted. We don’t care to fix and if we don’t like the product we think that we can always do KonMari (a trend of getting rid of “stuff” at home). Back in the 70’s we still repaired products. Recycling is not a solution, it is a last resort before incineration” - Energy Authority Finland

In a similar vein, the rise of a sharing economy contributes to consumer’s role: on one hand, sharing electrical/electronic equipment increases the use rate of a single product, on the other, increased use by multiple users calls for more durable products.

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Thank you!

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