Circular Design Guidebook

A material selection method
for the Electronic, Electrical, and Appliance industries

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Foreword

To strike the balance between economic growth and protection of our mother Earth becomes more crucial for all of us. Boosting profits is no longer the sole business performance indicator. Civil Society and public stakeholders expect businesses to accept their role to support environmental development, lower their impact and carbon footprint while staying committed to the improvement of their surrounding communities. Instead of linear economy, circular economy should be the driving force in the future in all of the sectors. The core thinking of circular economy is to use the resources efficiently, to expand the life of the products and to make them more recyclable. In addition to defining the concept of circular economy, this guidebook also explains how to redesign the production.

Dr. Thomas Prinz

Director General, German Institute Taipei

Human activity is responsible for rising carbon emissions and depleting the earth's natural resources at an unsustainable rate. Without a change in habits and business models, we are on the path to irreversible climate change. The only solution for the economy is a wholesale switch to circular business models that reduce as much as possible the use of natural resources and close production loops. This guidebook provides an excellent introduction to the circular economy and how to go about redesigning business models and incorporating circular thinking into every aspect of supply chains.

Freddie Höglund

CEO of European Chamber of Commerce Taiwan

Foreword

In recent years, the term "circular economy" has gained a significant presence and has become a central piece not only between academics and Industries but also integrated in numerous policies in industrialised countries, like the EU Circular economy package. Most countries have recognised that the great environmental and societal challenges of our time can only be mastered by a fundamental change in our economic systems. Both the 2030 Agenda for Sustainable Development with its 17 SDGs as well as the Paris Agreement make clear statements and set clear goals for such a transformation.

A circular economy is a system that creates value by designing out waste and keeping products, materials and components in use for longer. However, design of the products on its own is not enough, and designing a circular system also requires new business models that consumers can embrace, capture new opportunities, reverse logistics and infrastructure to collect and treat the products to recover materials and components, policies and favourable system conditions to shift incentives.

This Guidebook is meant to inspire designers and provide them with resourceful examples and tools but is also offer an easy to read guide for a wider pubic.

Dr. Federico Magalini

Managing Director of Sofies

The Circular Design Guidebook comes at an opportune moment – just as both the digital economy and the circular economy have become ever more relevant, touching everyday lives in ever more ways. Innovations, both in technology and in business models, are taking place at speed and scale to achieve global sustainability goals.

For a sustainable transition from a linear to a circular economy, product design plays a crucial, yet often underestimated, role that impacts all stages of production, use, and recycling. Product designers thus have the power, already at the design stage of a product, to influence its pathways, whether linear or circular.

This guidebook offers a valuable framework for product designers, introducing the resource constraints in a linear economy and the opportunities of a circular economy. It goes beyond the purely theoretical, providing instead, practical strategies and actionable insights through examples and case studies. What I found especially valuable is the systematic life-cycle approach on material selection that intrinsically promotes product circulation, rather than focussing on recyclable materials alone.

I hope the Circular Design Guidebook becomes a go-to resource for product designers and inspires a leap towards greater circularity of products by design.

Deepali Sinha Khetriwal

Co-founder of E[co]work

Contents

3 Material Selection from a Sustainability Perspective

Appendix

Material Selection Toolkit

1

From Linear to Circular

As a key solution to sustainable development, how does a circular economy affect the future of electrical and electronic products?

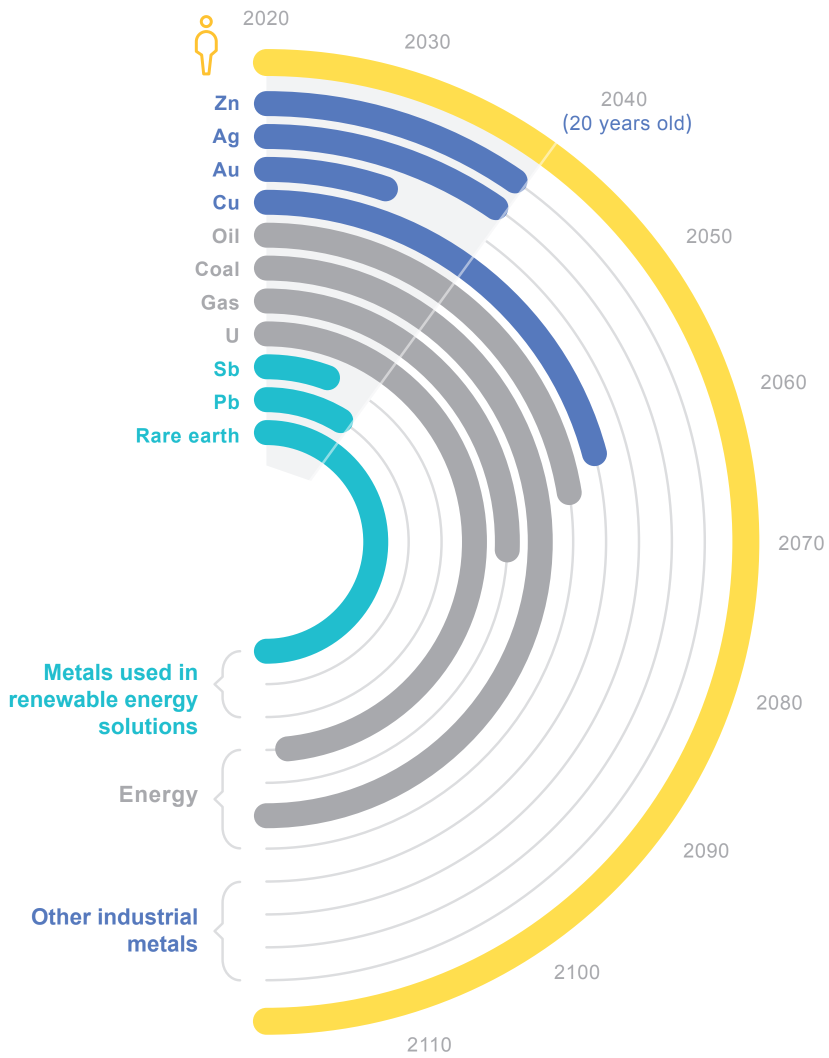
Resources are Limited

The global demand for key raw materials are mainly from five industries: energy, transportation, healthcare, defense, and electronics[1]. Due to the continuous population growth and the rapid development of technology, the resource demands of these industries have been constantly increasing.

In response to the climate crisis, the energy industry is replacing fossil fuels with renewable energy, and developing solar and wind power generation, and energy storage technologies. As a result, the demand for rare earth metals is increasing, and the types of resources required by the electronics industry have continued to increase alongside the evolution of technology. For example, the number of raw material types required for chip production has grown from just 20 in the 1990s, to over 60 by 2014[2].

However, the stock of natural resources will not be enough for this increasing demand. According to a United States Geological Survey (USGS)[3], for a baby born in 2020, by the time he reaches his 20th birthday, mineral resources such as zinc, gold, and silver – all of which are important for the production of electrical and electronic products – will have been completely exploited.

Therefore, with the pressure of future resource shortages, the electrical and electronics industry must seek alternative materials and business models, in order to continue to meet market demands.



▲ Exhaustion Date of Natural Resources

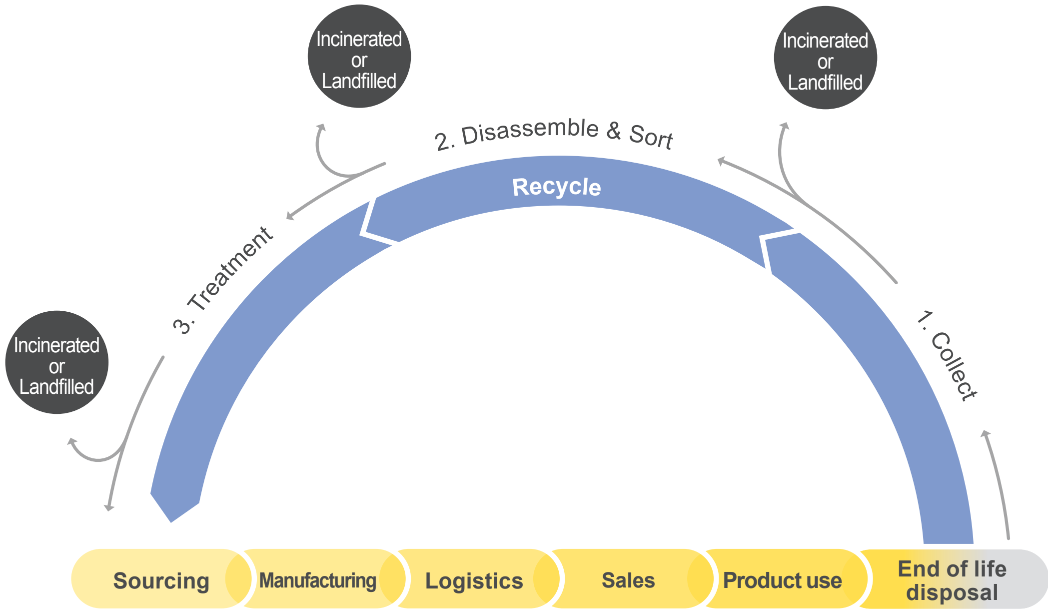
1. Access to critical materials, Andrew Stretton, Lydia Harriss, 2019.
2. Critical Metals Handbook, Gus Gunn et al., 2014.
3. World energy resources, Clerici, A., & Alimonti, G., 2015. Guidelines for Application of the United Nations Framework Classification for Resources (UNFC) to Uranium and Thorium Resources, UNECE, 2017., Antimony Statistics and Information, USGS, 2021, Lead Statistics and Information, USGS, 2021, Rare Earths Statistics and Information, USGS, 2021, Zinc Statistics and Information, USGS, 2021, Silver Statistics and Information, USGS, 2021

All Endings are Also Beginnings

As we are facing a natural resource shortage, if the large amount of waste accumulated from the “take→make→dispose” linear-economy behaviour of the past 200 years could be converted into resources, perhaps it can help to relieve our demand for natural resources.

When a product leaves the user’s hands and reaches the end of its value chain, it usually goes through a series of processes like “collect,” “disassemble and sort”, and “treatment” to become usable resources. Various roles, such as collectors, and recyclers, collaborate closely in the process to create this recycling industry.

Recycling is a behaviour driven by economic interests, which means the collected items must have sufficient economic value if they are to achieve large-scale reuse in the market. In other words, if the material is recyclable and reusable, and the original product can be easily disassembled, cleaned, and sorted, while also being of a sufficient quantity, its reuse as a resource can possibly be achieved.



▲ Recycling industry’s value chain

The Journey From Waste to Resources

Many countries give guidance on resource reuse through government policies, and these policies can be divided into three distinct time periods:

Waste Management (1950s Onwards)

Since the industrial development from the 1950s caused serious damage to the planet, international conventions have been established to address various environmental issues. For example, the Basel Convention places strict controls on the cross-border transportation of hazardous waste. Developed through the 2000s, the Waste Electrical and Electronic Equipment directive (WEEE) followed the Extended Producer Responsibility (EPR) regulations, requiring electrical and electronic equipment brands to consider the recycling issues that happen at the end of the product life cycle.

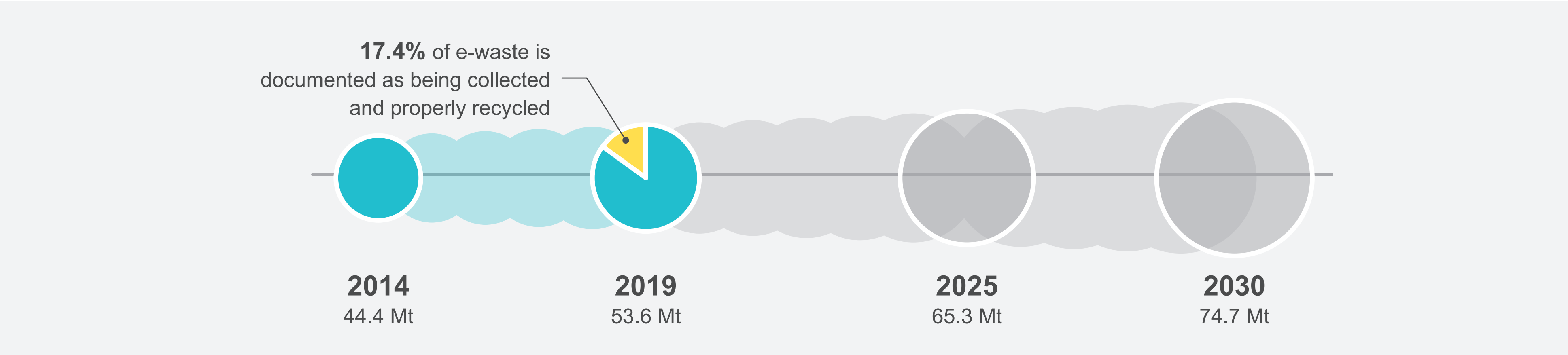
Source Management (2000s Onwards)

After the 2000s, in order to avoid illegal or incorrect dismantling of e-waste, the design of products and the choice of raw materials had to be improved. The Restriction of Hazardous Substances directive (RoHS) stipulates that electrical and electronic equipment should not contain specified chemical substances, and resources should be effectively managed to prevent contamination.

Resource Recovery (After 2005)

International policies for resource recovery have been continually proposed. In 2005, Japan issued a progress report for the first phase of "The Fundamental Plan for Establishing a Sound Material-Cycle Society".

However, while greater consideration about waste management could lead to an improvement in recycling rate, it cannot keep up with the amount of waste generated. According to a report by the International Telecommunication Union (ITU)[4], in 2019 the electronic waste (e-waste) produced globally was estimated to be 53.6 million metric tons, of which only 17.4% was recycled. Looking at current consumption trends, it is expected that the amount of e-waste will exceed 74.7 million metric tons by 2030, and as consumption continues to rise, we will face even harder challenges. The way we look at waste, or rather "misplaced resources", needs to change.



▲ Global E-waste Generated by year(Unit: Mt)

4. The Global E-waste Monitor 2020, The International Telecommunication Union, 2020.

Defining a Circular Economy

In recent years, attempts have been made to come up with solutions to fight against global warming, climate change, and the reduction of energy and resource consumption. A "circular economy" has been taken as a key pathway to sustainable development. A circular economy is an economic development model which, through regenerative and restorative designs, aims to decouple resource consumption from economic growth. It consists of the following principles:

1. **Change begins at the source**

   Instead of taking remedial action to deal with waste and pollution, a circular economy advocates designing them out of the system at the beginning. From the initial phase of the product design, we need to consider relationships with society, the environment, and its users, as well as the business model, through the product's entire life cycle.

2. **A change of perspective – Waste is a resource**

   In nature there is no concept of waste. In the same way, waste from one industry may be considered a resource for another industry. A circular economy considers all output of manufacturing, logistics, and end-user usage as resources, in order to maximize utilization and reconsider all possibilities.

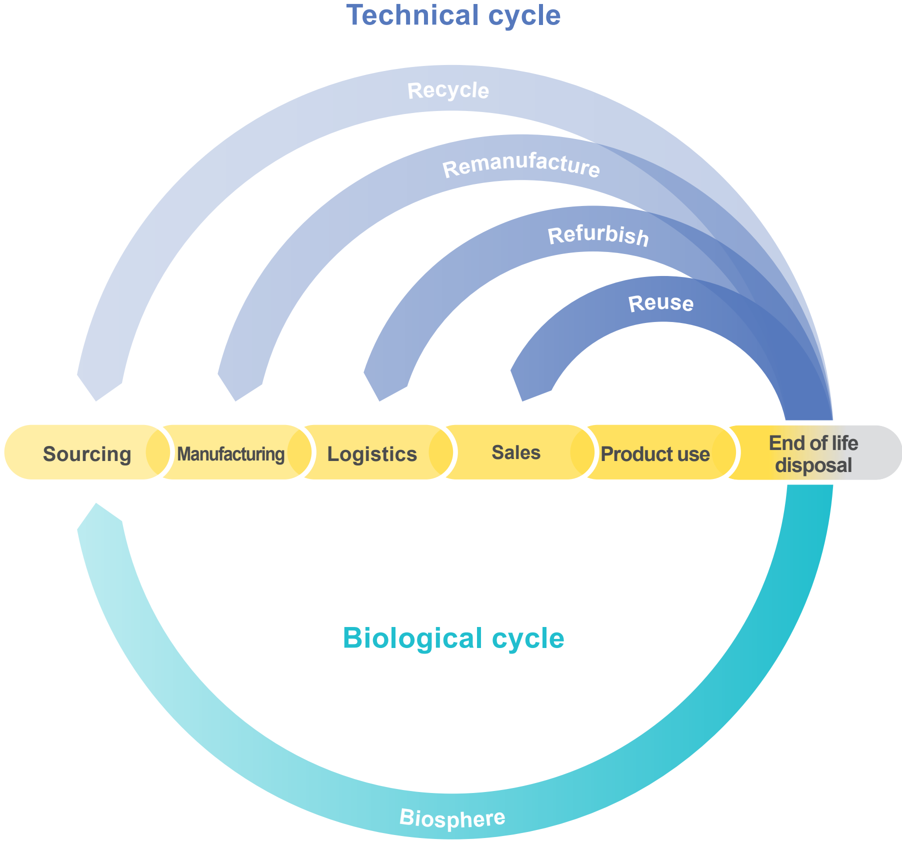
3. **Maintain high-value utilization**

   Business models that offer reuse, refurbishment, remanufacturing, and even sharing, before the end of the product life cycle, are encouraged first and foremost, in order to maintain a high product value. In addition, a focus on durability to extend a product's lifetime, thereby maximizing resource effectiveness.

4. **Circular path thinking**

   Based on the nature of its material, the product's regenerative path can be divided into the following two cycles:

   - Biological cycle: Applicable to organic substances that biodegrade quickly and can be returned to the ecosystem, for example as agricultural food or livestock excrement etc.
   - Technical cycle: When natural resources are used in industrial products (e.g. electronic devices which are made from various metals and plastics), they become difficult to return to their original forms. It is therefore desirable that these products are used as long as possible through reuse, refurbishment, remanufacturing, etc., and that they are finally recycled properly in order to reduce the waste of natural resources.



▲ Circular Economy Butterfly Diagram

According to the assessment of Ellen MacArthur Foundation and the McKinsey & Company in 2015[5], a circular economy could save up to €540 billion per year in material costs, and generate an annual net economic benefit of €1.8 trillion in Europe by 2030.

5. Growth Within: A Circular Economy Vision for a Competitive Europe. McKinsey, and the Ellen Macarthur Foundation. 2015.

Evolution of Sustainability – Goals and Strategies

Goals of governments and organizations

International oversight of the electronics industry continues to increase, with an aspiration of moving towards a circular economy. For example, in 2015 the European Union published “An EU action plan for the Circular Economy”, and in 2018 the U.S. EPEAT ecolabel increased the proportion of recycled materials used in electronic products. With these policies and standards, it’s no longer just regional regulation, but is gradually expanding to other markets around the world.

Next Step: Return the Right to Repair to Consumers

As the understanding of “sustainability” has gradually changed, consumers’ attention has focused more on the later stage of a product’s use where it has not yet become “waste”, giving birth to “Right to Repair” legislation. The Right to Repair requires brand owners to extend their product warranties, and offer spare component supply and repair services for the duration of the warranty period.

In 2019, the EU amended the Ecodesign Directive to include the right to repair products. This was also included in the EU Circular Economy Action Plan of the European Green Deal (2020 version), promoting market mechanisms for recycled materials, and reducing the consumption of raw materials.

Brand Strategy of Early Deployment

Major international brands have demonstrated their willingness, and are in recent years trying to turn circular economy strategies into practical actions. During the production of this guidebook (2020), we selected 14 leading brands from global analyst firms[6] (e.g. IDC, IHS Markit, Gartner), and analyzed their CSR reports. We found that all the global electronic brands in the market are consistently moving towards strategies like product maintenance, modular designs and designing for disassembly, and using recycled materials. In addition, they are exploring methods for extending product life cycles, while also enabling take-back systems to properly collect and recycle used products.

Certification for IT products

EPEAT

A new optional item added in the 2018 edition: Products or accessories containing more than 10% ITE-derived post-consumer recycled plastic.

TCO Certified Edge

Display products must use at least 85% recycled plastic, while all-in-one PCs must use at least 50% post-consumer recycled plastic.

European Union

WEEE

- In August 2018, the management scope was expanded to apply to all EEE(electrical and electronic equipment) products.
- From 2019 onwards, all countries in Europe must achieve a recycling rate of 65%.

Ecodesign Directive

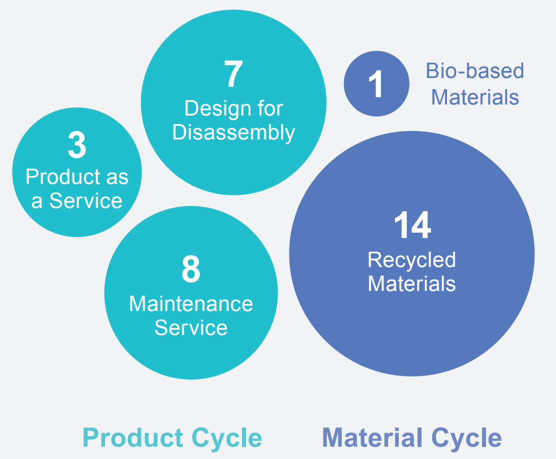
In 2021, some home appliances will formally implement the Right to Repair Act. Manufacturers need to ensure that they can provide spare parts for repairs for at least seven to ten years.

Industry Coalition

Circular Electronics Partnership

In 2021, major international organizations and the electronics industry supply chain jointly issued a roadmap outlining six pathways, as well as defining the target processes for 2023, 2027, and 2030. It will include the definition of circular electronic products, standardizing secondary materials, establishing a tracking platform etc.

▲ International standards and trends



▲ Commitment totals, out of 14 brands, according to the CSR reports

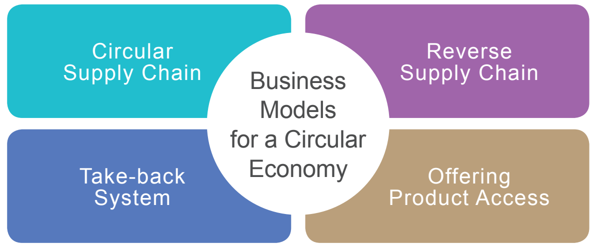
6. Gartner Says Worldwide PC Shipments Grew 2.3% in 4Q19 and 0.6% for the Year, Gartner, 2020. Global smartphone shipments finish 2019 with a 2.2 percent decline; Samsung retains market leadership, The IHS Markit, 2020.Vendor Data Overview, IDC, 2020.

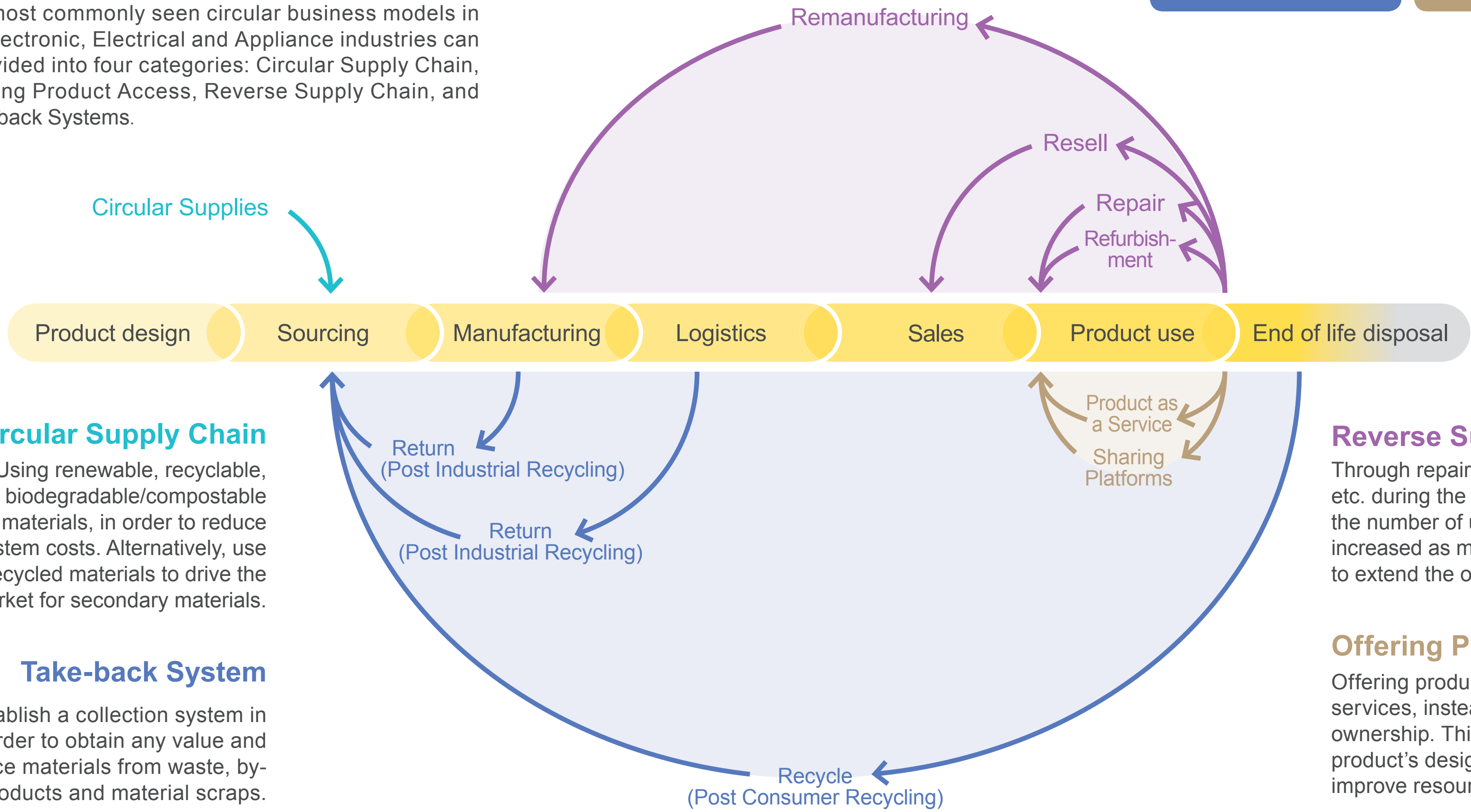
Circular Economy Business Models

In addition to policies, business is also an important force to promote change in the world. When developing business models based on the idea of “decoupling value creation from resource consumption”, companies need to enlist the cooperation of more partners in the value chain. This will result in a “circular business model” that is different to those that came before.

The most commonly seen circular business models in the Electronic, Electrical and Appliance industries can be divided into four categories: Circular Supply Chain, Offering Product Access, Reverse Supply Chain, and Take-back Systems.

The establishment of a circular economy business model requires strategic thinking about circular design, in order to reposition the companies in the market, and to develop a new business blueprint.





Circular Supply Chain

Using renewable, recyclable, or biodegradable/compostable materials, in order to reduce system costs. Alternatively, use recycled materials to drive the market for secondary materials.

Take-back System

Establish a collection system in order to obtain any value and scarce materials from waste, by-products and material scraps.

Reverse Supply Chain

Through repair, remanufacturing, etc. during the product use phase, the number of use-cycles can be increased as much as possible in order to extend the overall product lifetime.

Offering Product Access

Offering product access or services, instead of selling product ownership. This can change a product’s design direction and improve resource effectiveness.

2

Circular Design

The establishment of a circular economy business model is achieved by "circular design." This chapter will introduce five circular design strategies, and analyze how they relate to the value chain and business models.

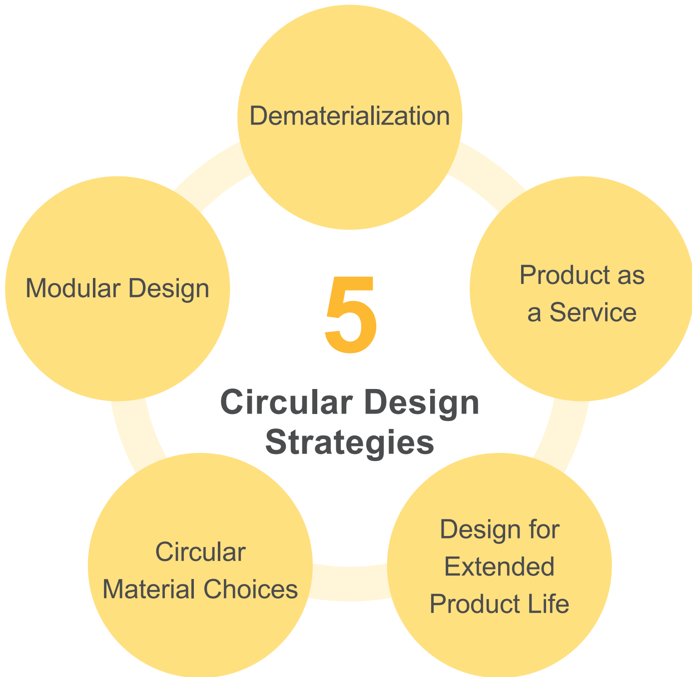
Five strategies for achieving circular design

> **"The next big thing in design is circular."**
> Tim Brown, CEO of the world-renowned design firm IDEO

It requires system-wide thinking in order to build "circularity."The scope of a design should consider the overall lifecycle of a product, servicing, the business model, and even the entire supply chain and all necessary stakeholders. Many international organizations have attempted to come up with common strategies, such as the Circular Design Guide in 2017. Launched by the leading design firm IDEO in collaboration with the Ellen MacArthur Foundation, it looks at the concept of a circular economy through design thinking.

Our guidebook refers to researches published by leading international organizations and academic researchers, and then explores five circular design strategies applicable to the electronic, electrical, and appliance industries. These include Dematerialization, Product as a Service, Design for Extended Product Life, Circular Material Choices, Modular Design. The guidebook explains each strategy in relation to the Electronic, Electrical and Appliance industries, and provides designers examples to enable circular design thinking in order to create more elegant, effective and sustainable solutions.

In the following section, we will introduce these strategies using circular business model diagrams, and discuss how companies can implement these strategies in product design.



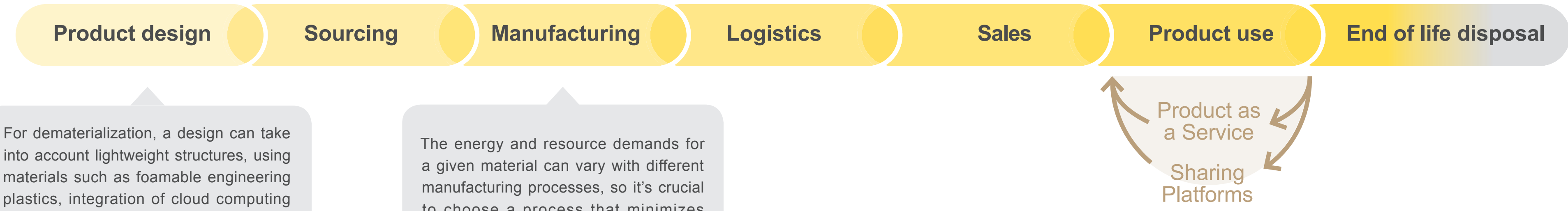
▲ Circular Design Strategies

Circular Design Strategies

Dematerialization

Reducing the resource requirements of a product means using as few materials as possible to provide an effective solution. It can be transforming a product from physical to virtual, or optimizing the design to use only the smallest amount of physical materials to manufacture.

Sharing Platforms, and Product as a Service, are both used to meet market demands, increase the utilization rate of products and materials, and achieve the purpose of dematerialization.



For dematerialization, a design can take into account lightweight structures, using materials such as foamable engineering plastics, integration of cloud computing such as Google's Chromebook, or product virtualization such as Netflix.

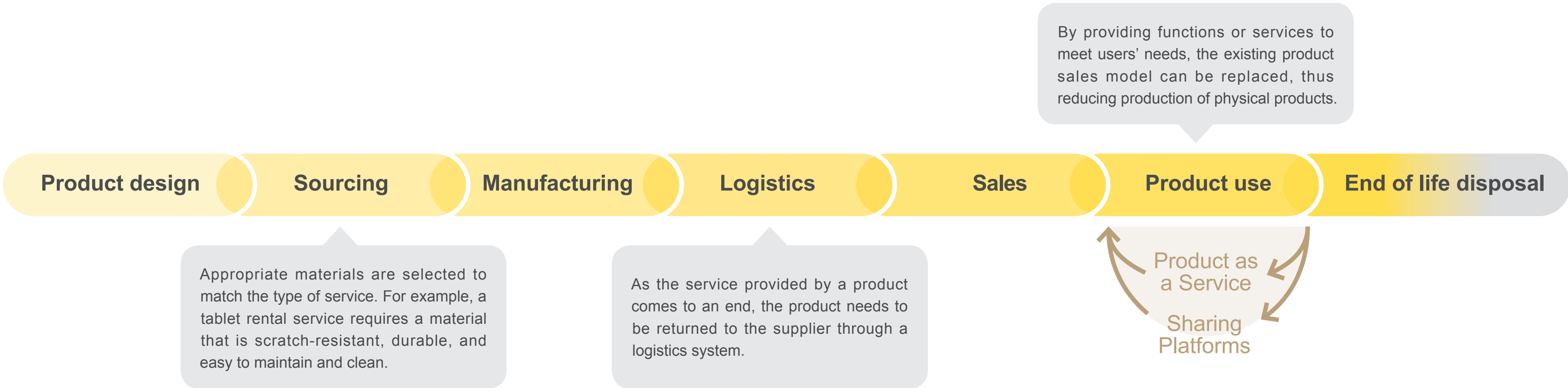
The energy and resource demands for a given material can vary with different manufacturing processes, so it's crucial to choose a process that minimizes energy and resource waste.

Offering Product Access

Circular Design Strategies

Product as a Service

Instead of product ownership, in many cases, customers only need the rights to use a product for a period of time. In this way, businesses no longer profit from the number of products sold, but instead are committed to improving both product durability and the quality of aftermarket servicing. This avoids the need for mass production of consumer products, and improves overall customer satisfaction.
In recent years, new forms of business models have been developed based on this concept, such as leasing, subscribing, or sharing, which offer customers a variety of products and services, instead of selling items permanently.

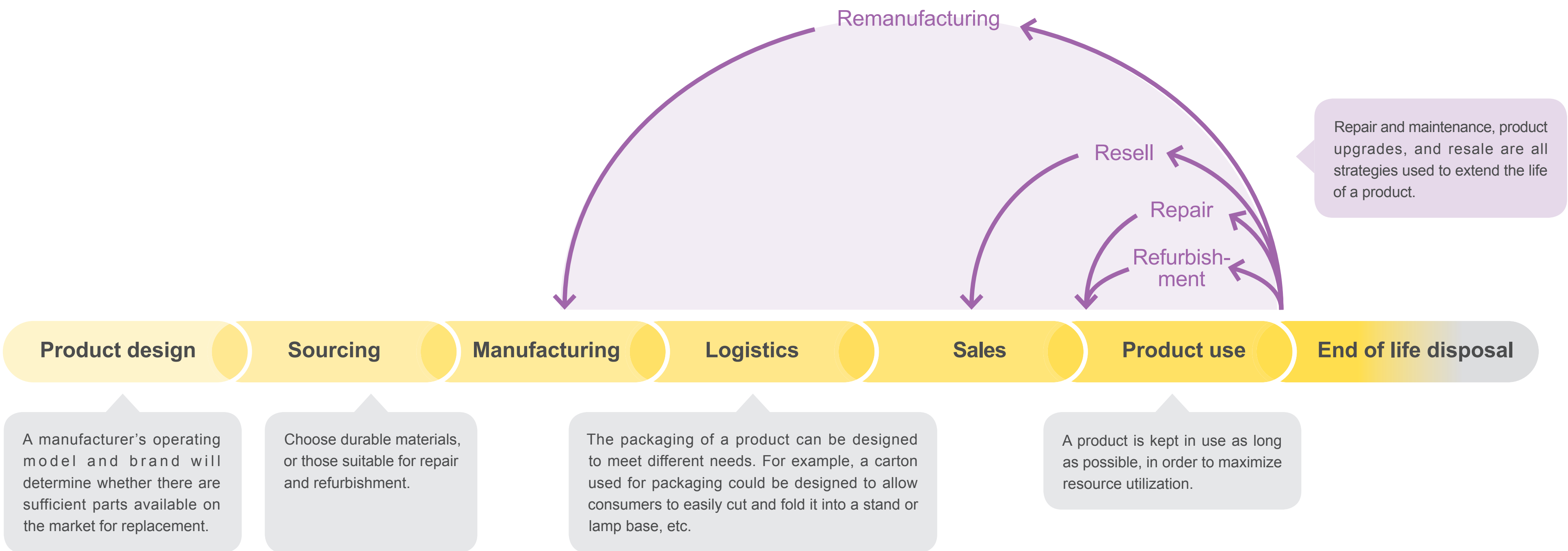


Offering Product Access

Circular Design Strategies

Design for Extended Product Life

A design should be able to satisfy the changing needs of users over time, maximising a product's value, and prolonging its lifespan. This strategy includes a variety of measures such as designing for both physical and emotional durability, making the products and individual parts maintainable, upgradeable, easy to repair, remanufacture, refurbish, etc. It can even allow for repurposing, reuse, or reselling, in order to increase the use-cycles of the product before it reaches the end of its lifetime.

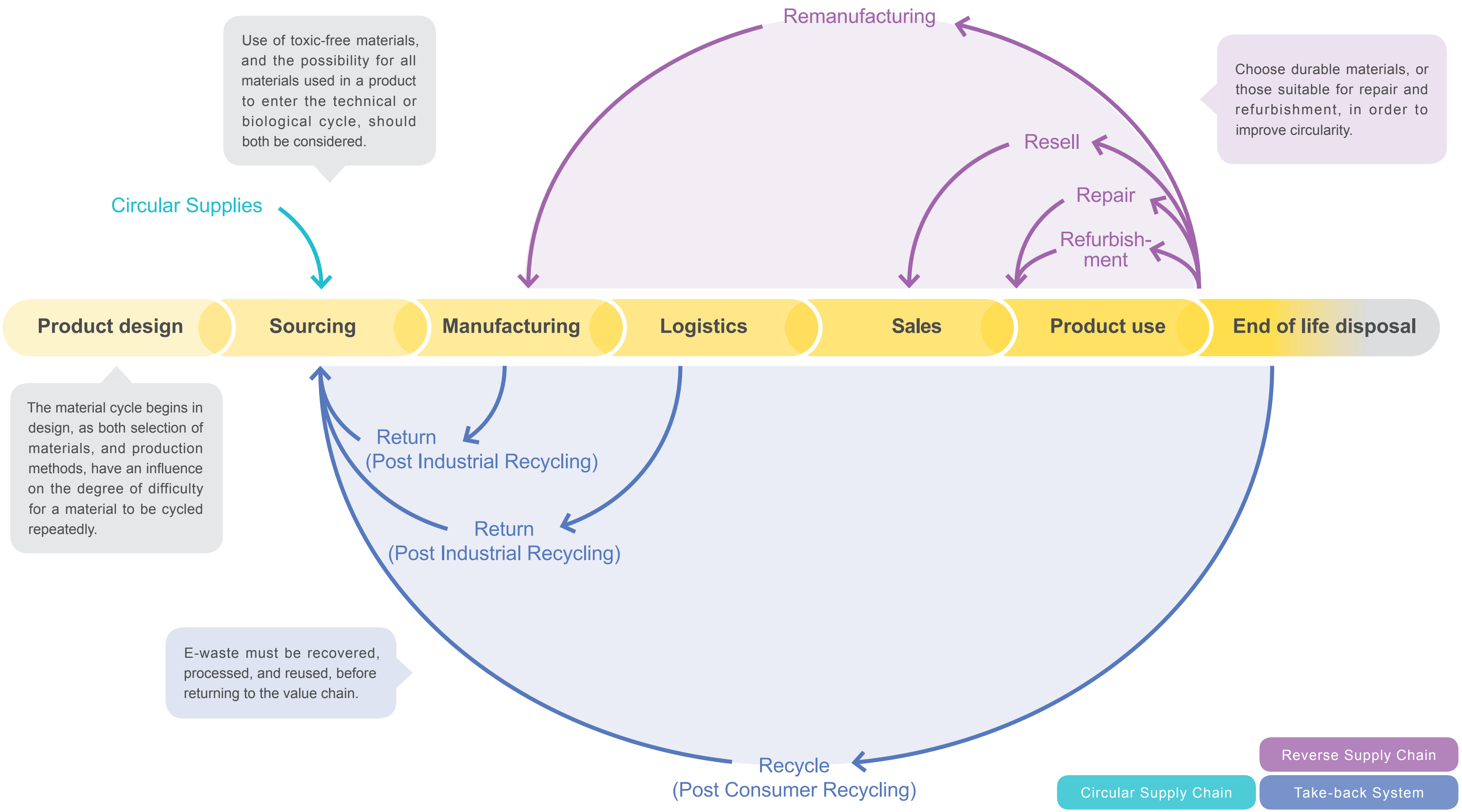


Reverse Supply Chain

Circular Design Strategies

Circular Material Choices

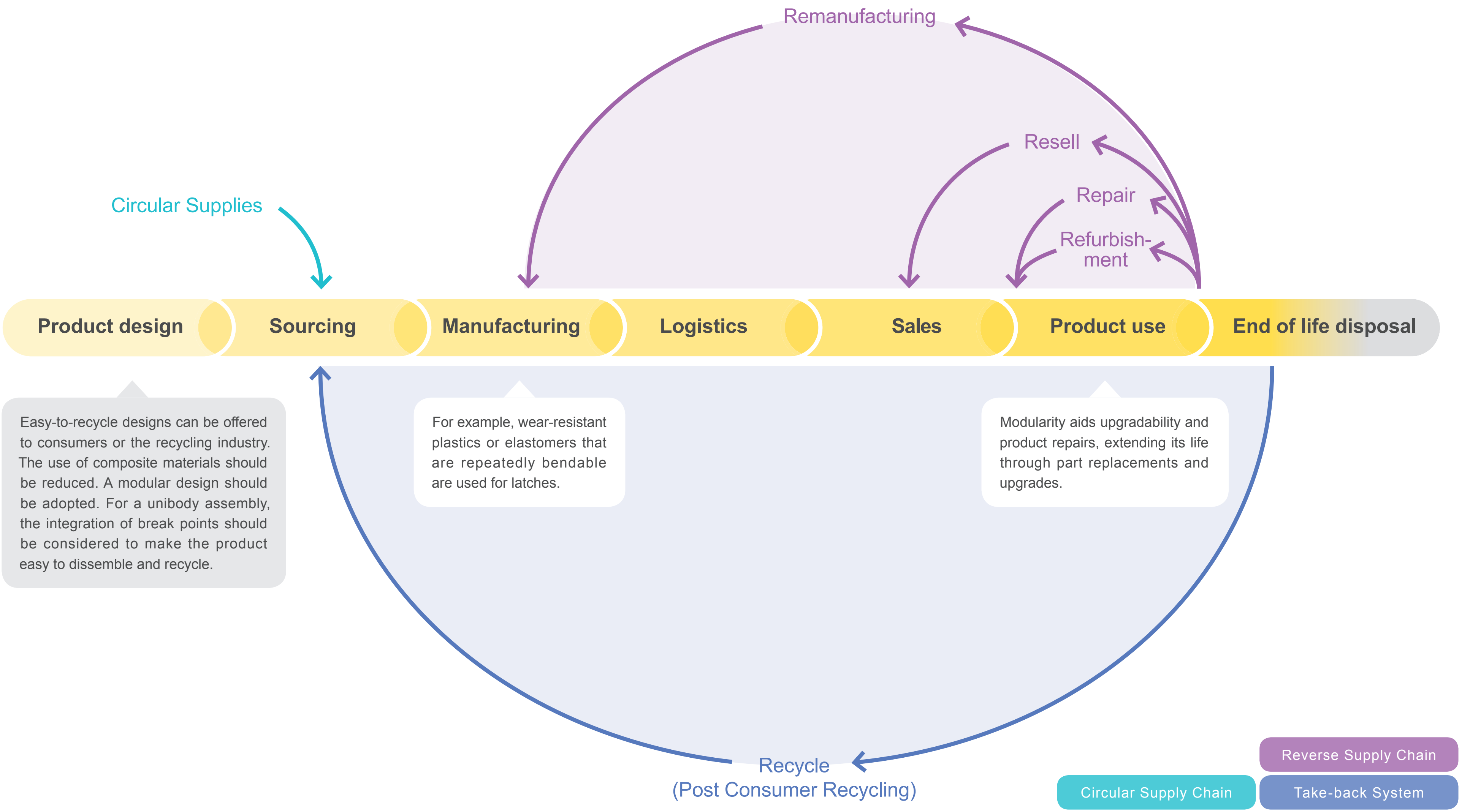
The goal of material selection is to ensure that the material is harmless to the environment and the human body, while at the same time keeping its resources in the value chain as much as possible. Materials should not only be easy to recycle, but also easy to repair and refurbish during the product use stage.



Circular Design Strategies

Modular Design

A modular design enables parts removal and easy disassembly of a product. This reduces the cost and workload of replacing components when they're damaged. It's an effective strategy to make the product easy to upgrade, repair, and remanufacture. Such a strategy can also include the use of modular components as much as possible, in order to meet diverse market needs. Sharing component specifications, to achieve either cross-brand or cross-product-line part replacement, can also increase the utilization rate of parts in the overall market.



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Material Selection from a Sustainability Perspective

As far as physical products are concerned, the implementation of all circular design strategies requires "material selection." This chapter introduces a systematic material selection process, to help designers quickly open the door to circularity and sustainability.

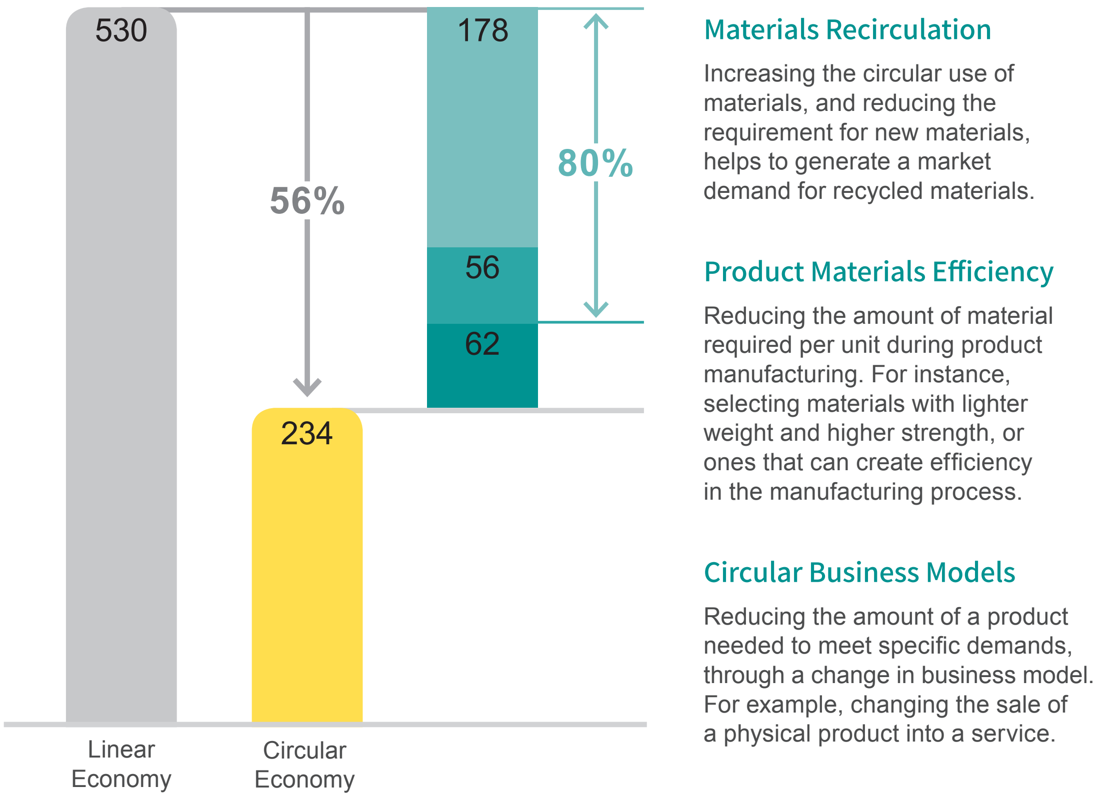
Start from Material Selection

Correct material selection can yield an 80% impact – “Material Selection” as the first step to circular design.

When designing a physical product, material selection could have multiple downstream impacts. Not only does it affect the product’s circularity, but also the energy and resource effectiveness of the products, and even the scale of the recycled materials market.

Taking the impact of carbon emissions as an example, according to an estimate in a 2018 joint study by Material Economics and multiple EU climate organizations[7], carbon emissions could be reduced by 56% by 2050 if a circular economy model is introduced in the production of major industrial raw materials.

Nearly 80% of the stated total carbon reduction can be achieved by combining material recirculation and material efficiency. Neither of these strategies could be implemented without a "good material selection," which just goes to show how important material selection is.



▲ EU emissions reductions potential from circular economy, 2050 (Mt of carbon dioxide per year)

7. The Circular Economy – A Powerful Force For Climate Mitigation, Material Economics, 2018.

Key aspects of Material Selection

How can we ensure a successful material selection? This guidebook identifies two key aspects:

1. Circularity Throughout the Lifecycle

It's important to select not just "recyclable materials", but also "materials benefiting product circulation". Even if all components of a cell phone are made of "recyclable" materials, such as metals and most plastics, the cellphone may still sit in a drawer at home at the end of its life, or be rejected by recyclers because of its insufficient value after disassembly. Therefore, to help ensure circularity, it's important to maintain the "value" of a "product" throughout its life cycle, via circular design strategies and material selection.

2. Moving Towards a More Comprehensive Approach to Sustainability

Is the best material one that improves the circularity of a product? Not necessarily. Pragmatically speaking, apart from circularity, electronic products must also comply with increasingly stringent safety regulations, energy efficiency requirements, and green certifications. Therefore, indicators such as carbon footprint, water footprint, and conflict minerals, should be taken into account as well. These indicators, although beyond the scope of circularity, are important elements for humans on the path to sustainable living. If these issues are not taken into account, the results of material selection evaluations may end up being infeasible in reality.

How to integrate these diversified and complicated elements, while also making the process clear and easy to implement, is a key challenge in the process of material selection.

It's important to select not just "recyclable materials", but "materials benefiting product circulation".

▲ Relationship between circularity and other issues

Material Selection Process – Introduction

In response to the aspects just discussed, this guidebook provides a material selection process, with worksheets that comprise these three key features:

- **Product Life Cycle as a Framework**

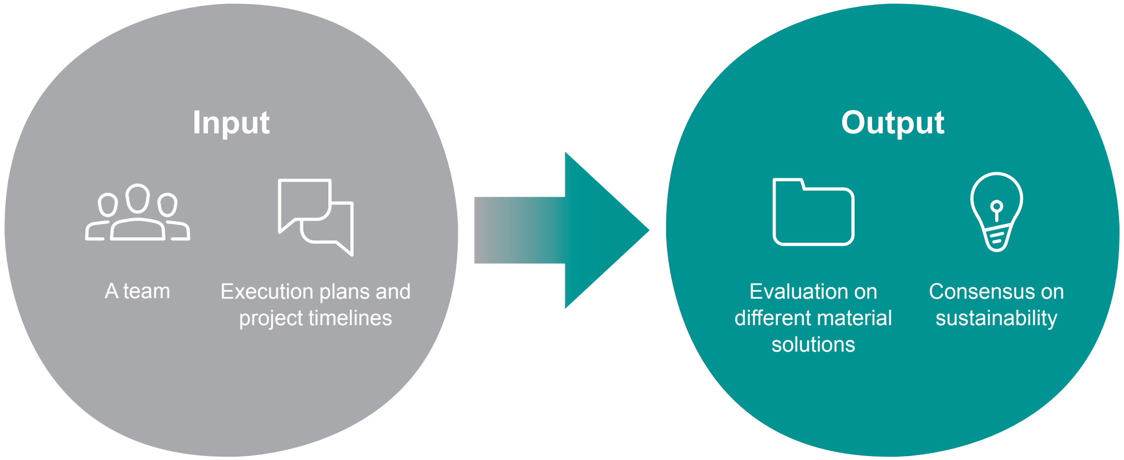
  Systematically assess the impacts at each stage of the product's life cycle, including raw materials, manufacturing, logistics, usage, and disposall.

- **Evaluation Criteria and Quantitative Indicators**

  When it is difficult to take all indicators into consideration, it is important to consider which evaluation criteria and quantitative indicators are most important to the product, and to justify that choice.

- **A Scalable Framework for Sustainability Indicators**

  A scalable categorization framework primarily covers indicators pertaining to circularity and the environment. Meanwhile, more sustainability indicators can be integrated at any time, as one sees fit.



Project Timeline Suggetion

It can vary based on the business needs and resource availability, could be a 1-day workshop or a 1-3 month process to develop a prototype.

Material Selection Process – Overview

1 Preparation

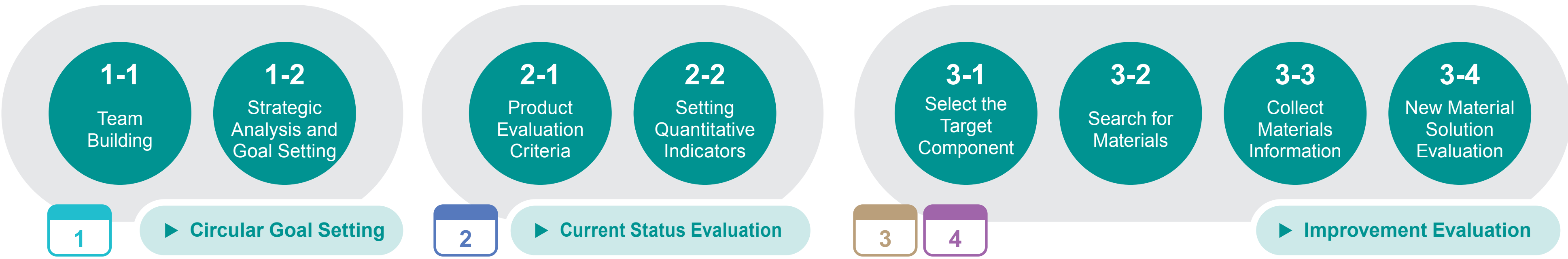
Build a cross-functional project team, then work together to conduct a strategic analysis, and set product goals using worksheet 1.

2 Setting Indicators for Evaluation

With worksheet 2, the team will choose product evaluation criteria and quantitative indicators, then complete a current status evaluation.

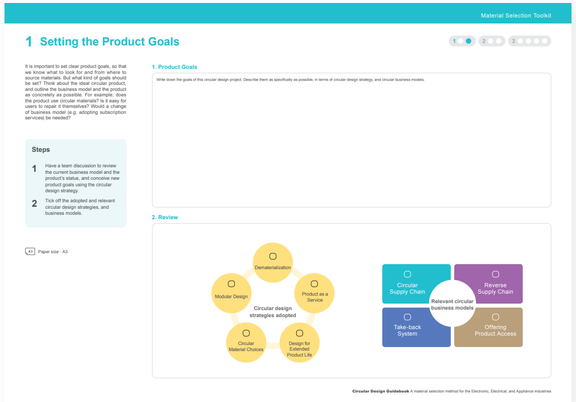
3 New Material Evaluation

Combining the use of worksheet 3 and worksheet 4, the team will select a target component, search for materials, collect information, and then make a new evaluation to compare to the current status evaluation completed previously.

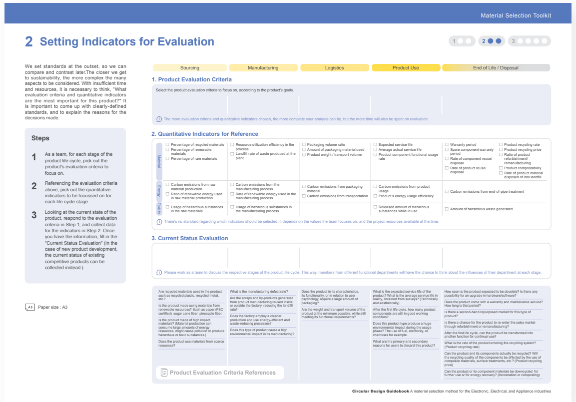


Material Selection Toolkit

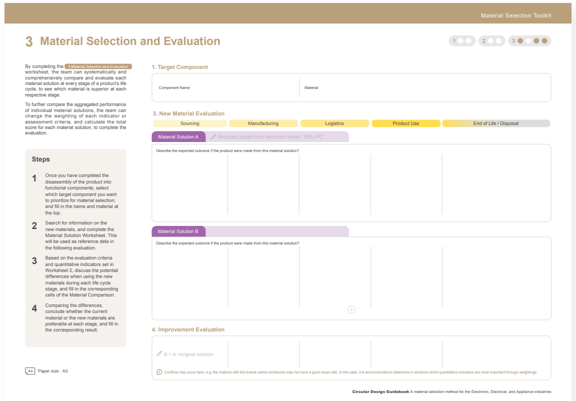
1 Worksheet 1
Setting the Product Goals



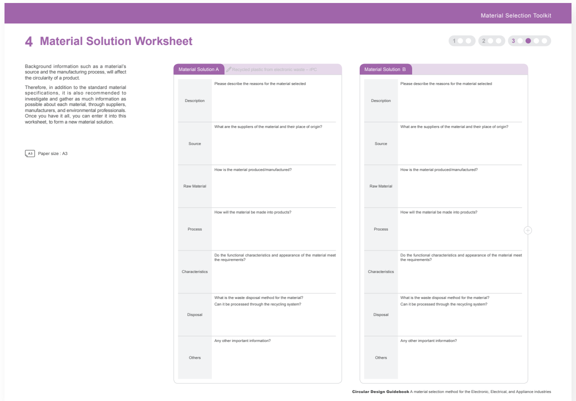
2 Worksheet 2
Setting Indicators for Evaluation



3 Worksheet 3
Material Selection and Evaluation



4 Worksheet 4
Material Solution Worksheet



▲ Material selection toolkit

1 Preparation

1-1 Team Building

To ensure all expertise is taken into consideration, and the best solutions are implemented for material selection, it is critical to form a cross-functional project team. While every company has different organizational structures, we recommend forming a project team with at least four different roles – strategy planning, product design and manufacturing, professional sustainability service, and project management.

The Importance of Multifaceted Considerations

As an example, using bio-based engineering plastics for the outer casing of a product will raise costs, and may discourage companies from adopting them. However, a new material may offer a significant improvement in carbon emissions, and may be eligible for policy subsidies. Alternatively, it may be able to penetrate specific markets such as the green procurement of the Japanese government. This hidden advantage may be overlooked by a purely cost-driven procurement department, but might be noticed by marketing, legal, or environmental experts. This is why an integrated perspective is important.

Strategy Planning Function

Providing strategic thinking on products and business models, from the perspectives of marketing, policy, environmental, and trends. The marketing department is one example.

Product Design and Manufacturing Function

Providing advice on procurement, technology, and manufacturing feasibility. For example, the production department.

Professional Sustainability Service Function

Providing expertise in policy, industry, circular materials, and disposal, this can be an internal dedicated staff member or an external consultant.

Project Management Function

Integrating resources and opinions, leading project direction, and schedule management. This is likely a project manager.

▲ The four types of roles

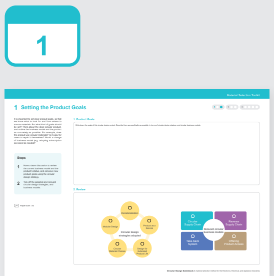
1-2 Strategic Analysis and Goal Setting

After the team has been formed, the team members can work together to conduct strategic analysis and set product goals.

It is important to set clear product goals so that we know what to look for, and from where to source materials. But what kind of goals should be set? Think about the ideal circular product, and outline the business model as concretely as possible. For example, does the product use circular materials? Is it easy for users to repair it themselves? Would a change of business model (e.g. adopting subscription services) be needed?

If it involves significant changes to the business model, it may take a longer time for a company to implement it, as it would likely require a series of processes, internal communications, or workshops.

This guidebook focuses on the implementation of material selection once specific goals have been defined, rather than getting into a discussion on business models. This step is therefore presented in a simplified manner.

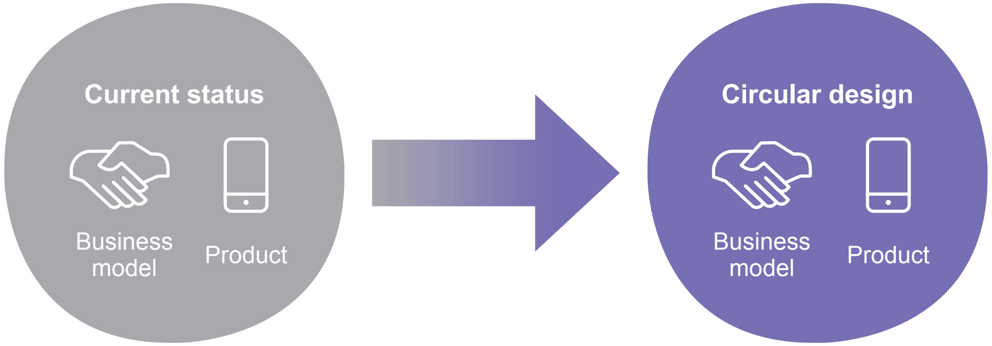


Circular Design Strategy Adoption

Review the current business model and the current product status. Use the circular design strategies in Chapter 2 of this guidebook, to come up with new product goals.

Product Goals Setting

Describe the goal as specifically as possible, in terms of both a circular design strategy and a circular business model. Put the result in the 1-Setting the Product Goals section.



Hints

1. What is the existing business model? How do the existing products create value?
2. What new values can be created through the spirit and paradigms of the circular design strategy? What are the opportunities?
3. Is it necessary to change the existing business model?
4. Does the product have a new function, purpose, or change in life cycle?

Examples

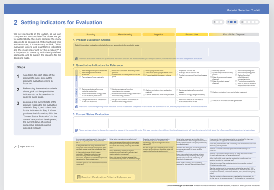
1. Establish a circular supply chain, use recycled materials whenever possible, and ensure the manufacturing process is sustainable and toxic-free.
2. Design for Extended Product Life– a product easy to repair and refurbish, with a higher secondary market value.
3. Products with a recycling plan, to enable reselling for other specific purposes after they are discarded or replaced. (E.g. a discarded cell phone could be used as a sensor device with wi-fi capability.)
4. Products specifically designed for a B2B subscription rental model.

2 Setting Indicators for Evaluation

2-1 Product Evaluation Criteria

After setting the product goals, worksheet **2-Setting Indicators for Evaluation** is used next. Read the product evaluation criteria for each life cycle stage. These evaluation criteria are presented in the form of questions. The team can choose to answer those directly related to the goals, considering how well the product currently meets those goals.

2



Sourcing	Manufacturing	Logistics

Select the relevant evaluation criteria according to the circular product's goals.

Sourcing	Manufacturing	Logistics
• Are recycled materials used in the product, such as recycled plastic, recycled metal, etc.?	• Are the scraps and by-products generated from product manufacturing reused inside or outside the factory, reducing the landfill rate? • Does the factory employ a cleaner production process, such as using energy-efficient and waste-reducing processes? • Does this type of product cause a high environmental impact in its manufacturing?	• Does the product in its characteristics, its functionality, or in relation to user psychology, require a large amount of packaging? • Are the weight and transport volume of the product at the minimum possible, while still meeting its functional requirements?

ⓘ The more evaluation criteria and quantitative indicators chosen, the more complete your analysis can be, but the more time will also be spent on evaluation.

Select all those related to the product's goals

Product Evaluation Criteria

Sourcing	Manufacturing	Logistics
Are recycled materials used in the product, such as recycled plastic, recycled metal, etc.?	What is the manufacturing defect rate?	Does the product in its characteristics, its functionality, or in relation to user psychology, require a large amount of packaging?
Is the product made using materials from renewable resources? Such as paper (FSC certified), sugar cane fiber, pineapple fiber.	Are the scraps and by-products generated from product manufacturing reused inside or outside the factory, reducing the landfill rate?	Are the weight and transport volume of the product at the minimum possible, while still meeting its functional requirements?
Is the product made of high impact materials? (Material production can consume large amounts of energy resources, might cause pollution or produce hazardous or toxic substances.)	Does the factory employ a cleaner production, such as using energy-efficient and waste-reducing processes?	
Does the product use materials from scarce resources?	Does this type of product cause a high environmental impact in its manufacturing?	

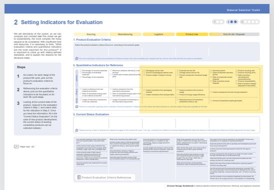
▲ Setting product evaluation criteria

2-2 Setting Quantitative Indicators

To evaluate performance in each respective life cycle stage more precisely, we need to set quantitative indicators. The actual research and evaluation required involves complicated data collection, and empirical judgment. Therefore, this guidebook provides a set of circular quantitative indicators, and the indicators correspond to a classification framework of "materials, energy, toxicity". The guidebook also includes the very important indicators for carbon emissions and renewable energy, which will help the team promptly pick out the indicators needed, and take command of the overall selection process.

The team can choose indicators by referring to the chosen Product Evaluation Criteria in section 2-1, and collect data for the product indicators. They can then fill in the “Current Status Evaluation” part of the **2-**Setting Indicators for Evaluation worksheet with the answers to 2-1, and the data from 2-2. For a broader sustainability perspective, this framework can also be systematically expanded to include other sustainability indicators. For example, in the “Material” category, the team could insert the indicator “Conflict Mineral Usage Amount.”

2



	Logistics	Product Use	End of Life / Disposal	
Material	☐ Packaging volume ratio ☑ Amount of packaging material used ☑ Product weight / transport volume	☑ Expected service life ☐ Average actual service life ☐ Product component functional usage rate	☑ Warranty period ☑ Spare component warranty period ☐ Rate of component reuse/ disposal ☐ Rate of product reuse/ disposal	☑ Product recycling rate ☐ Product recycling price ☐ Ratio of product refurbishment/ remanufacturing ☐ Product compostability ☐ Rate of product material disposed of into landfill
Energy	☐ Carbon emissions from packaging material ☐ Carbon emissions from transportation	☐ Carbon emissions from product usage ☐ Product’s energy usage efficiency	☐ Carbon emissions from end-of-pipe treatment	
Toxicity		☐ Released amount of hazardous substances while in use	☐ Amount of hazardous waste generated	

▲ Example:Setting quantitative indicators

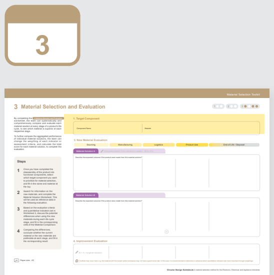
3 New Material Evaluation

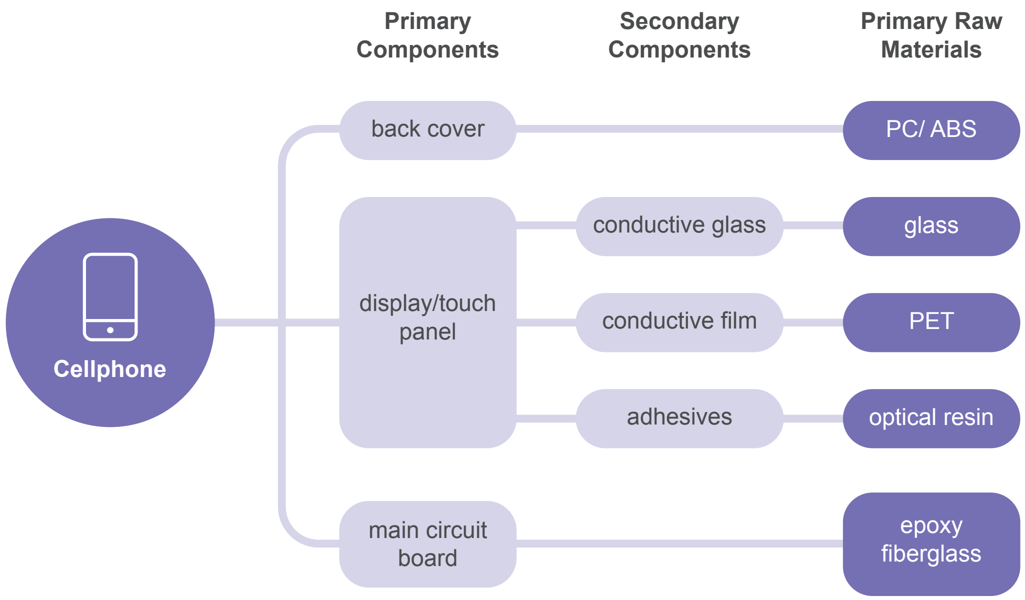
3-1 Select the target component

To go through the material selection process, all components of the product need to be disassembled and analyzed individually. If it's an existing product, we can refer to its Bill of Materials (BOM).

Based on the product goals set in Step 1, select the highest priority component for material selection, and fill in the **3**-Material Selection and Evaluation worksheet. For example, if you would like to increase the amount of recycled materials used, you can start by prioritizing the component which accounts for a larger percentage of weight. Depending on different situations, this could be determined by factors such as the difficulty of implementation, volume percentage, price, risk level, etc.

The disassembly process is shown in the diagram showing a simplified BOM explosion. From left to right, the product can be disassembled into primary components, which are further disassembled into secondary components, and finally down to the smallest component that can possibly be disassembled. This becomes an analysis to determine exactly what materials it is made from.





▲ Simplified BOM explosion: cellphone

3-2 Search for Materials

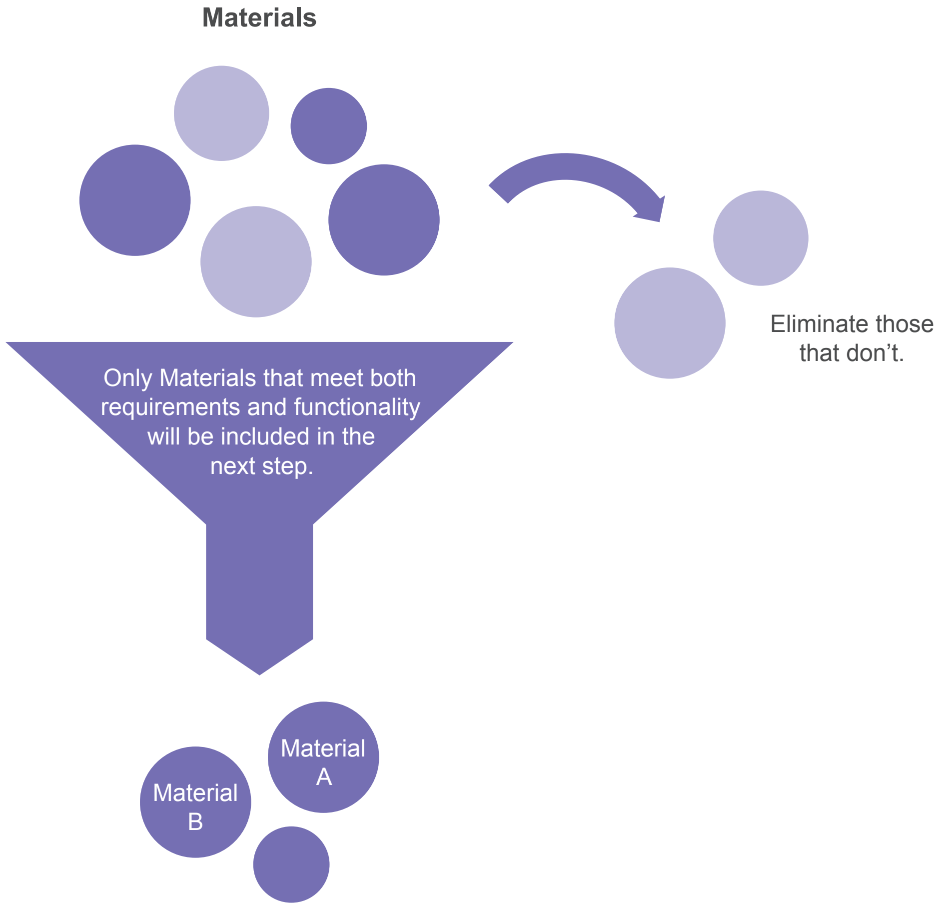
Referring to the goals set previously, a search is now performed in order to produce a list of suitable materials.

Sources may range from existing suppliers, to material databases, material libraries, etc.

Point for Consideration: Functions and Requirements First

There is a high probability that new materials will create more waste, if they do not fully meet both the functions and requirements. For example, compostable plastic as a packaging material may degrade more quickly due to the moisture and high temperature in the environment (e.g. transportation or storage). This would leave the product without proper protection.

Products are created to meet demands. By choosing materials that users like and find useful, products are less likely to be discarded, and will maintain the highest possible value.



▲ Search for materials

3-3 Collecting Materials Information

After deciding on several candidate materials, information on these materials should be collected. This "background information" – such as the material's source, and the manufacturing process – will affect the circularity of a product manufactured with these materials. Therefore, in addition to the standard material specifications, it is also recommended to investigate and gather as much information as possible about each material, through suppliers, manufacturers, and material and environmental professionals. Once you have it all, you can enter it into the **4-Material Solution Worksheet** to form a new material solution.

4

Example A — *Recycled plastic from electronic waste – rPC*

Description	Please describe the reasons for the material selected *Choosing plastics from electronic waste treatment plants to maximize the percentage of recycled PC.*
Source	What are the suppliers of the material and their place of origin? *OO Eco Corp./Taiwan*
Raw Material	How is the material produced/manufactured? *After crushing, processing and sorting, it is made into recycled plastic pellets.*
Process	How will the material be made into products? *Products are made primarily through injection moulding.*
Charact-eristics	Do the functional characteristics and appearance of the material meet the requirements? *This recycled material is mostly only available in black.*
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? *The material can be recycled and remanufactured, and with an autonomous recycling system, cycling can be achieved effectively.*
Others	Any other important information? *Recycled material originates from discarded wafer shipping boxes, which is a plus in the EPEAT.*

Example B — *Recycled Aluminum*

Description	Please describe the reasons for the material selected *Recycled aluminum reduces carbon emissions from mining new aluminum.*
Source	What are the suppliers of the material and their place of origin? *XX Metal/Indian*
Raw Material	How is the material produced/manufactured? *After remelting and adjusting the composition, it is made into recycled aluminum ingots or briquettes.*
Process	How will the material be made into products? *Extrusion, die casting, CNC*
Charact-eristics	Do the functional characteristics and appearance of the material meet the requirements? *Through CNC machinery and a process adjustment, there is close to no difference from virgin aluminum.*
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? *Materials are recyclable and can usually be processed in recycling systems.*
Others	Any other important information? *Materials from some recycling plants are polluted; mind for the possible presence of lead or other hazardous substances.*

▲ Example: Material Solution Worksheet

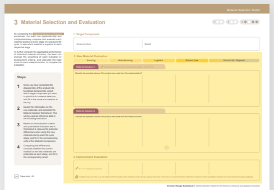
3-4 New Material Solution Evaluation

Referring to the completed **4-Material Solution Worksheet** and referring to the evaluation criteria and quantitative indicators set in Step 2, the team is to complete the evaluation by replacing the target component with a new material, in order to finally conclude the whole material selection process.

By completing the **3-Material Selection and Evaluation** worksheet, the team can systematically and comprehensively compare and evaluate each material solution at every stage of a product's life cycle, to see which material is superior at each respective stage.

To further compare the aggregated performance of individual material solutions, the team can set the weighting of each indicator or assessment criteria. They can then calculate the total score for each material solution.

3



Example A — Recycled plastic from electronic waste - rPC

Describe the expected outcome if the product were made from this material solution?

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• It is estimated that the rPC back cover accounts for a 10% of the total weight. • Carbon emissions per unit weight of raw material production decreased by about 70%. • 7% reduction in overall product's carbon emissions.	• No significant change.	• No significant change.	• No significant change in the expected service life. • No significant change in reasons for disposal.	• No significant change in warranty period, component replacement term and product recycling rate.

Example B — Recycled Aluminum

Describe the expected outcome if the product were made from this material solution?

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• It is estimated that the recycled aluminum back cover accounts for 20% of the total weight. • Carbon emissions per unit weight of raw material production decreased by about 92%. • 18.4% reduction in overall product's carbon emissions.	• Processing temperature increased.	• The total weight of the product is expected to increase by 10%.	• No significant change in the expected service life. • No significant change in reasons for disposal, but the surface is prone to scratches, which may lead to replacement by users due to external abrasions.	• The warranty period, component replacement term, and product recycling rate may be slightly higher, because of the higher recycling value of aluminum compared to plastic.

Improvement Evaluation

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
B>A>original solution	B<A=original solution	B<A=original solution	B<A=original solution	B>A=original solution

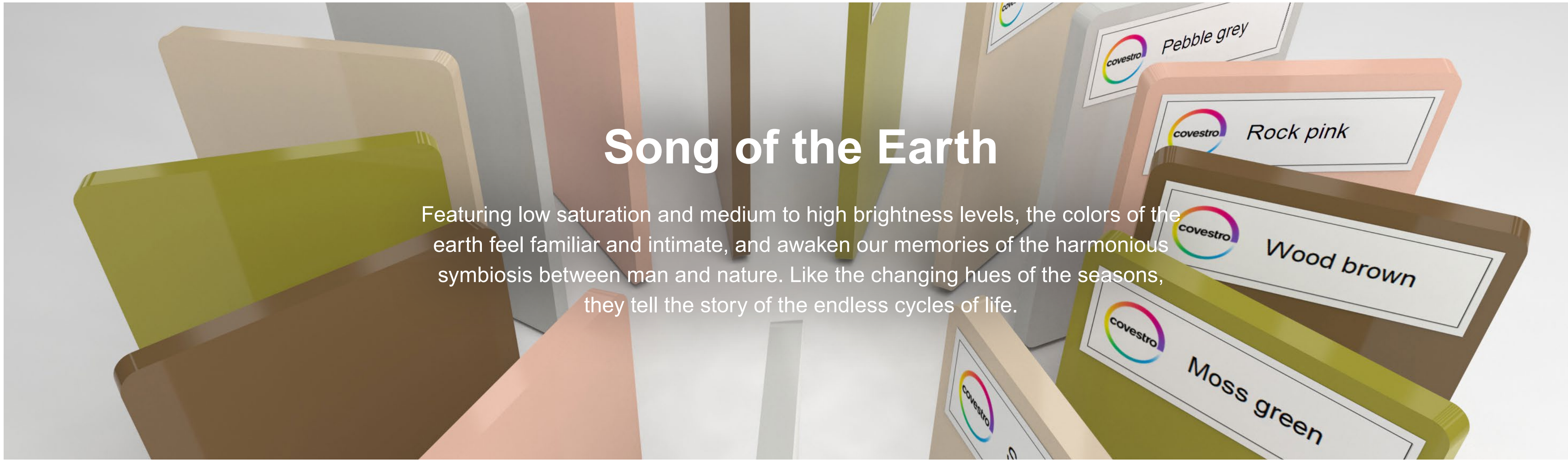
▲ Example: Improvement Evaluation

Appendix

More Circular Design Cases

Brand	Product / Service	URL
Epson	PaperLab	https://global.epson.com/innovation/paperlab/
eRENT	Track & Rent Platform	https://www.erent.fi/en/
Gerrard Street	Modular headphones	https://gerrardstreet.nl/en/#subscribe
Gomi	Turn plastic waste into products	https://www.gomi.design
Grover	Subscribe to the latest technology	https://www.grover.com/uk-en
Moriondo	A Monthly Sustainable Coffee Subscription Service	https://moriondocoffee.com
Signify	Lighting Services	https://www.signify.com/global
Sogee48	Second-hand device platform	https://sogee48.com
Valtavalo	Lighting Services	https://valtavalo.fi/
Zuora	SaaS platform	https://www.zuora.com
GEM	Urban mine	http://www.gemchina.com/xunhuanchanyelian/
Aihuishou	Device recycling platform	https://www.aihuishou.com
Homeapp123	Appliance rental platform	https://homeapp123.com.tw

Defining the Colors of Sustainability in Asia-Pacific



Song of the Earth

Featuring low saturation and medium to high brightness levels, the colors of the earth feel familiar and intimate, and awaken our memories of the harmonious symbiosis between man and nature. Like the changing hues of the seasons, they tell the story of the endless cycles of life.

Wood brown
RAL 060 70 20

Sand white
RAL 070 80 10

Moss green
RAL 120 70 20

Rock pink
RAL 030 70 20

Pebble grey
RAL 000 80 00

Covestro has partnered with the Color & Imaging Institute, Art & Science Research Center at Tsinghua University to create aesthetic design solutions for sustainable materials based on their characteristics through consumer surveys, expert interviews, big data mining and design industry research. "Song of the Earth" is the first phase result of the research. Want to learn more? Contact cmf-design@covestro.com.

Manufacturing Process Case Study

Thermal management for network devices: Metal replacement/weight reduction solution(2K solution)

Existing solution

Die-casting process, high processing temperature (700°C) , 2nd deburring operation, then machining to meet required dimensions, and finally surface painting.

2K solution

Polycarbonate injection molding of the 1st shot with a high thermal conductivity PC , then molding the 2nd shot with a lower thermal conductivity PC, using 2K technology.

Lower processing temperature (300°C), no 2nd operation or painting process required.

▲ 2K solution

Existing solution	Die-casting aluminum
Description	Please describe the reasons for choosing the material
Source	What are the suppliers of the material and their origins?
Raw Material	How is the material produced/manufactured? *Die-casting aluminum: casting aluminum oxide to bars*
Process	How will the material be made into products? *Die-casting: processing temperature 700°C, needs deburring, machining and painting, etc. (E.g. a 2nd operation.)*
Charac-teristics	Do the functional characteristics and appearance of the material meet the requirements? *Corrodes easily.*
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? *Die-casting aluminum: re-casting reject products (NG), then put them into the next production cycle.*
Others	Any other important information? *High material density, high manufacturing energy consumption, high product defect rate.*

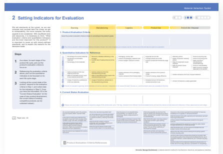
2K solution	Polycarbonate injection molding
Description	Please describe the reasons for choosing the material *Light weight; low energy consumption; high design freedom; high production efficiency, easy to recycle; very low defect rate*
Source	What are the suppliers of the material and their origins? *Covestro global*
Raw Material	How is the material produced/manufactured? *Thermal conductive PC: thermal plastic compounding*
Process	How will the material be made into products? *Polycarbonate injection molding of the 1st shot with high thermal conductivity PC, then molding the 2nd shot with low thermal conductivity PC, using 2K technology.*
Charac-teristics	Do the functional characteristics and appearance of the material meet the requirements? *Better able to visualize surface quality with a thermal conductive PC, higher design freedom with variable surface finishes, no corrosion*
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? *Thermal conductive PC: can put a certain percentage into the next production cycle.*
Others	Any other important information? *Potential weight saving of up to 30%-50%* *Product processing: 60% less energy consumption than die-casting aluminum* *Material recycling: 75% less energy consumption than die-casting aluminum*

▲ Manufacturing Process Case Study - Material Solution Worksheet

An evaluation of two material solutions, adhering to stated evaluation criteria and quantitative indicators.

This case only shows the "manufacturing" stage.

By completing the 3-Material Selection and Evaluation worksheet, the team can systematically and comprehensively compare and evaluate each material solution, at every stage of a product's life cycle.



Setting Indicators for Evaluation

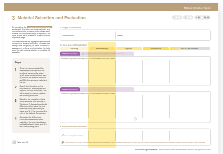
Manufacturing

Product Evaluation Criteria

- Does the factory employ a cleaner production and use energy-efficient and waste-reducing processes?
- Does this type of product cause a high environmental impact in its manufacturing?

Quantitative Indicators for Reference

Material	• Density • Tooling life • Defect rate
Energy	• Energy consumption (processing temperature and cycle time)
Toxicity	None



Material Selection and Evaluation

▲ Manufacturing Process Case Study - Evaluation criteria and quantitative indicators.

Existing solution — Die-casting aluminum

Describe the expected outcome if the product were made from this material solution?

- More waste from machining, high temperature environment, high energy consumption
- Density 2.5g/cm, more material used, higher defect rate; shorter tooling life (limited to 0.1 million)
- High energy consumption (higher processing temperature, longer cycle time); more carbon dioxide emissions

2K solution — Polycarbonate injection molding

Describe the expected outcome if the product were made from this material solution?

- Thermal conductive PC: low odor, low energy consumption
- Density: 1.4g/cm, less material used, low defect rate; longer tooling life (up to one million)
- Product processing: 60% less energy consumption than die-casting aluminum. Material recycling: 75% less energy consumption than die-casting aluminum

Improvement Evaluation: Existing solution < 2Ksolution

▲ Manufacturing Process Case Study Improvement Evaluation

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Material Selection Toolkit

1 Setting the Product Goals

It is important to set clear product goals, so that we know what to look for and from where to source materials. But what kind of goals should be set? Think about the ideal circular product, and outline the business model and the product as concretely as possible. For example, does the product use circular materials? Is it easy for users to repair it themselves? Would a change of business model (e.g. adopting subscription services) be needed?

Steps

1 Have a team discussion to review the current business model and the product's status, and conceive new product goals using the circular design strategy.

2 Tick off the adopted and relevant circular design strategies, and business models.

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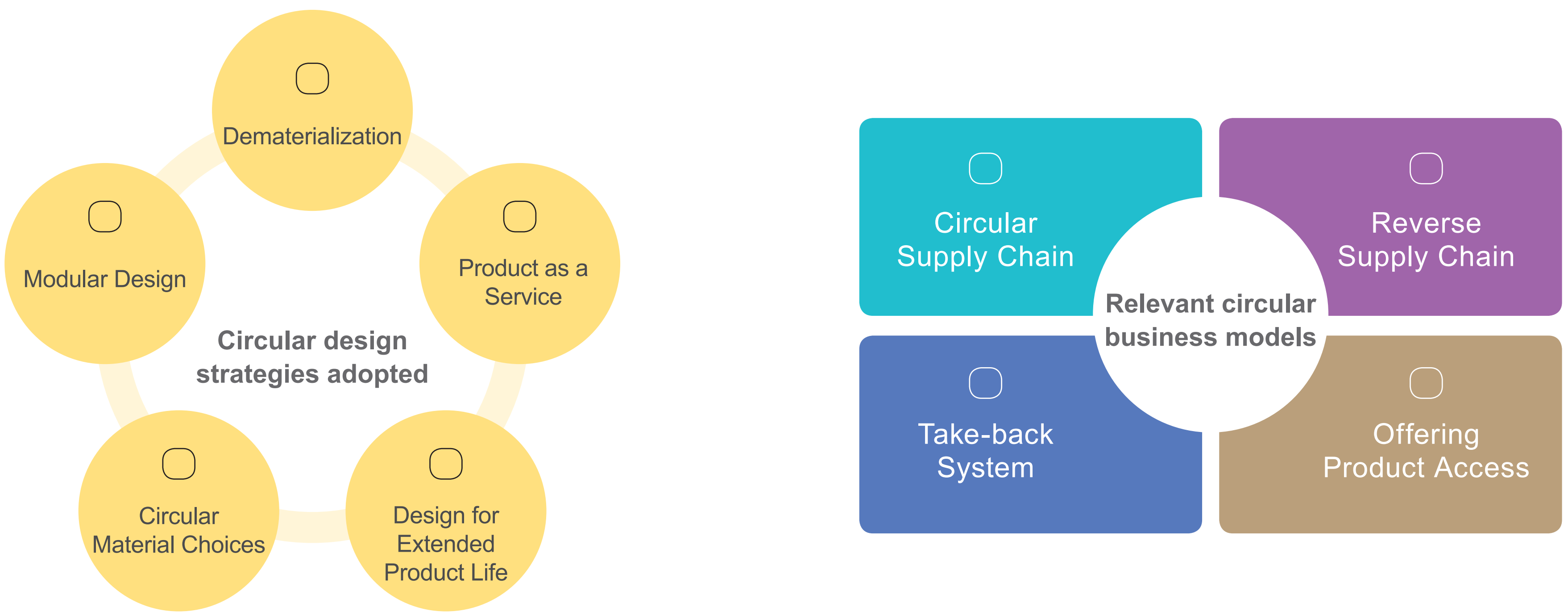
1. Product Goals

Write down the goals of this circular design project. Describe them as specifically as possible, in terms of circular design strategy, and circular business models.

2. Review



2 Setting Indicators for Evaluation

1 2 3

We set standards at the outset, so we can compare and contrast later.The closer we get to sustainability, the more complex the many aspects to be considered. With insufficient time and resources, it is necessary to think, "What evaluation criteria and quantitative indicators are the most important for this product?" It is important to come up with clearly-defined standards, and to explain the reasons for the decisions made.

Steps

1. As a team, for each stage of the product life cycle, pick out the product's evaluation criteria to focus on.
2. Referencing the evaluation criteria above, pick out the quantitative indicators to be focussed on for each life cycle stage.
3. Looking at the current state of the product, respond to the evaluation criteria in Step 1, and collect data for the indicators in Step 2. Once you have the information, fill in the "Current Status Evaluation" (In the case of new product development, the current status of existing competitive products can be collected instead.)

A3 Paper size : A3

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal

1. Product Evaluation Criteria

Select the product evaluation criteria to focus on, according to the product's goals.

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal

ⓘ The more evaluation criteria and quantitative indicators chosen, the more complete your analysis can be, but the more time will also be spent on evaluation.

2. Quantitative Indicators for Reference

	Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal	
Material	☐ Percentage of recycled materials ☐ Percentage of renewable materials ☐ Percentage of rare materials	☐ Resource utilization efficiency in the process ☐ Landfill rate of waste produced at the plant	☐ Packaging volume ratio ☐ Amount of packaging material used ☐ Product weight / transport volume	☐ Expected service life ☐ Average actual service life ☐ Product component functional usage rate	☐ Warranty period ☐ Spare component warranty period ☐ Rate of component reuse/ disposal ☐ Rate of product reuse/ disposal	☐ Product recycling rate ☐ Product recycling price ☐ Ratio of product refurbishment/ remanufacturing ☐ Product compostability ☐ Rate of product material disposed of into landfill
Energy	☐ Carbon emissions from raw material production ☐ Ratio of renewable energy used in raw material production	☐ Carbon emissions from the manufacturing process ☐ Rate of renewable energy used in the manufacturing process	☐ Carbon emissions from packaging material ☐ Carbon emissions from transportation	☐ Carbon emissions from product usage ☐ Product's energy usage efficiency	☐ Carbon emissions from end-of-pipe treatment	
Toxicity	☐ Usage of hazardous substances in the raw materials	☐ Usage of hazardous substances in the manufacturing process		☐ Released amount of hazardous substances while in use	☐ Amount of hazardous waste generated	

ⓘ There's no standard regarding which indicators should be selected; it depends on the values the team focuses on, and the project resources available at the time.

3. Current Status Evaluation

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal

ⓘ Please work as a team to discuss the respective stages of the product life cycle. This way, members from different functional departments will have the chance to think about the influences of their department at each stage.

Product Evaluation Criteria References

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
Are recycled materials used in the product, such as recycled plastic, recycled metal, etc.? Is the product made using materials from renewable resources? Such as paper (FSC certified), sugar cane fiber, pineapple fiber. Is the product made of high impact materials? (Material production can consume large amounts of energy resources, might cause pollution or produce hazardous or toxic substances.) Does the product use materials from scarce resources?	What is the manufacturing defect rate? Are the scraps and by-products generated from product manufacturing reused inside or outside the factory, reducing the landfill rate? Does the factory employ a cleaner production and use energy-efficient and waste-reducing processes? Does this type of product cause a high environmental impact in its manufacturing?	Does the product in its characteristics, its functionality, or in relation to user psychology, require a large amount of packaging? Are the weight and transport volume of the product at the minimum possible, while still meeting its functional requirements?	What is the expected service life of the product? What is the average service life in reality, obtained from surveys? (Technically and aesthetically) After the first life cycle, how many product components are still in good working condition? Does this product type produce a huge environmental impact during the usage phase? The use of fuel, electricity, or chemicals for example. What are the primary and secondary reasons for users to discard this product?	How soon is the product expected to be obsolete? Is there any possibility for an upgrade in hardware/software? Does the product come with a warranty and maintenance service? How long is that period? Is there a second-hand/repurposed market for this type of product? Is there a chance for the product to re-enter the sales market through refurbishment or remanufacturing? After the first life cycle, can the product be transformed into another function for continual use? What is the rate of the product entering the recycling system? (Product recycling rate) Can the product and its components actually be recycled? Will the recycling quality of the components be affected by the use of composite materials, surface treatments, etc.? (Product recycling price) Can the product or its component materials be downcycled, for further use or for energy recovery? (Incineration or composting)

3 Material Selection and Evaluation

1 2 3

By completing the 3-Material Selection and Evaluation worksheet, the team can systematically and comprehensively compare and evaluate each material solution at every stage of a product's life cycle, to see which material is superior at each respective stage.

To further compare the aggregated performance of individual material solutions, the team can change the weighting of each indicator or assessment criteria, and calculate the total score for each material solution, to complete the evaluation.

Steps

1 Once you have completed the disassembly of the product into functional components, select which target component you want to prioritize for material selection, and fill in the name and material at the top.

2 Search for information on the new materials, and complete the Material Solution Worksheet. This will be used as reference data in the following evaluation.

3 Based on the evaluation criteria and quantitative indicators set in Worksheet 2, discuss the potential differences when using the new materials during each life cycle stage, and fill in the corresponding cells of the Material Comparison.

4 Comparing the differences, conclude whether the current material or the new materials are preferable at each stage, and fill in the corresponding result.

A3 Paper size : A3

1. Target Component

Component Name	Material

3. New Material Evaluation

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal

Material Solution A Recycled plastic from electronic waste - 50% rPC

Describe the expected outcome if the product were made from this material solution?

Material Solution B

Describe the expected outcome if the product were made from this material solution?

4. Improvement Evaluation

B > A >original solution

Conflicts may occur here, e.g. the material with the lowest carbon emissions may not have a good reuse rate. In this case, it is recommended to determine in advance which quantitative indicators are more important through weightings.

4 Material Solution Worksheet

Background information such as a material's source and the manufacturing process, will affect the circularity of a product.

Therefore, in addition to the standard material specifications, it is also recommended to investigate and gather as much information as possible about each material, through suppliers, manufacturers, and environmental professionals. Once you have it all, you can enter it into this worksheet, to form a new material solution.

A3 Paper size : A3

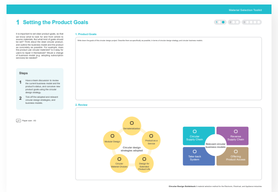
Material Solution A Recycled plastic from electronic waste – rPC

Description	Please describe the reasons for the material selected
Source	What are the suppliers of the material and their place of origin?
Raw Material	How is the material produced/manufactured?
Process	How will the material be made into products?
Characteristics	Do the functional characteristics and appearance of the material meet the requirements?
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system?
Others	Any other important information?

Material Solution B

Description	Please describe the reasons for the material selected
Source	What are the suppliers of the material and their place of origin?
Raw Material	How is the material produced/manufactured?
Process	How will the material be made into products?
Characteristics	Do the functional characteristics and appearance of the material meet the requirements?
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system?
Others	Any other important information?

1. Setting the Product Goals



Product Goals

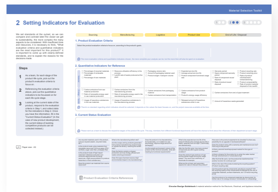
Write down the goals of this circular design project. Describe them as specifically as possible, in terms of circular design strategy, and circular business models.

1. A cell phone that uses a circular supply chain, adopts more recycled materials whenever possible, and uses a sustainable, toxic-free manufacturing process.
2. A cell phone designed for the Design for Extended Product Life, easy to repair and refurbish, and with a higher second-hand market value.

Product Evaluation Criteria

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• Are recycled materials used in the product, such as recycled plastic, recycled metal, etc.?	• Are the scraps and by-products generated from product manufacturing reused inside or outside the factory, reducing the landfill rate? • Does the factory employ a cleaner production and use energy-efficient and waste-reducing processes? • Does this type of product cause a high environmental impact in its manufacturing?	• Does the product in its characteristics, its functionality, or in relation to user psychology, require a large amount of packaging? • Are the weight and transport volume of the product at the minimum possible, while still meeting its functional requirements?	• What is the expected service life of the product? What is the average service life in reality, obtained from surveys? (Technically and aesthetically) • What are the primary and secondary reasons for users to discard this product?	• Does the product come with a warranty and maintenance service? How long is that period? • Is there a second-hand/repurposed market for this type of product? • Is there a chance for the product to re-enter the sales market through refurbishment or remanufacturing? • What is the rate of the product entering the recycling system? (product recycling rate)

2. Setting Indicators for Evaluation



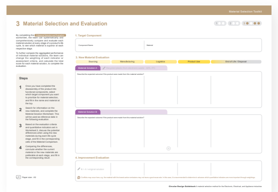
Quantitative Indicators for Reference

	Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
Material	☑ Percentage of recycled materials ☐ Percentage of renewable materials ☐ Percentage of rare materials	☐ Resource utilization efficiency in the process ☑ Landfill rate of waste produced at the plant	☐ Packaging volume ratio ☑ Amount of packaging material used ☑ Product weight / transport volume	☑ Expected service life ☐ Average actual service life ☐ Product component functional usage rate	☑ Warranty period ☑ Spare component warranty period ☐ Rate of component reuse/ disposal ☐ Rate of product reuse/ disposal ☑ Product recycling rate ☐ Product recycling price ☐ Ratio of product refurbishment/ remanufacturing ☐ Product compostability ☐ Rate of product material disposed of into landfill
Energy	☑ Carbon emissions from raw material production ☐ Ratio of renewable energy used in raw material production	☐ Carbon emissions from the manufacturing process ☐ Rate of renewable energy used in the manufacturing process	☐ Carbon emissions from packaging material ☐ Carbon emissions from transportation	☐ Carbon emissions from product usage ☐ Product's energy usage efficiency	☐ Carbon emissions from end-of-pipe treatment
Toxicity	☐ Usage of hazardous substances in the raw materials	☑ Usage of hazardous substances in the manufacturing process		☐ Released amount of hazardous substances while in use	☐ Amount of hazardous waste generated

Current Status Evaluation

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• Overall percentage of recycled material in the cellphone = 0%. • Carbon emissions from raw material production have not been calculated.	• The usage of hazardous substances complies with international standards. • 25% of plants on the supply chain attained a 10% or less waste landfill rate.	• The product weighs 550g. • The printed carton accounts for the majority of the packaging material's weight, about 250g. • The basic strength of the product itself is sufficient. The product should be resistant to shocks and impacts, and is able to withstand excessive moisture during transportation.	• The expected service life is 3 years. • The main reason for disposal is that consumers tend to buy new cell phones with better hardware performance.	• The product is warrantied for one year. • The expected period for provision of replacement spare parts is five years from the date of launch. • The estimated product recycling rate is less than 10%. • The product demonstrates a good value in the secondary market for reuse with the potential of refurbishment before sold to specific markets.

3. Material Selection and Evaluation



Target Component

Component Name: Cellphone back cover | Material: PC/ABS

Material Solution A Recycled plastic from electronic waste - 50% rPC

Describe the expected outcome if the product were made from this material solution?

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• It is estimated that the rPC back cover accounts for a 10% of the total weight. • Carbon emissions per unit weight of raw material production decreased by about 70%. • 7% reduction in overall product's carbon emissions.	• No significant change.	• No significant change.	• No significant change in the expected service life. • No significant change in reasons for disposal.	• No significant change in warranty period, component replacement term, and product recycling rate.

Material Solution B 90% Recycled Aluminum

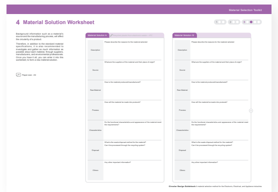
Describe the expected outcome if the product were made from this material solution?

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
• It is estimated that the recycled aluminum back cover accounts for 20% of the total weight. • Carbon emissions per unit weight of raw material production decreased by about 92%. • 18.4% reduction in overall product's carbon emissions.	• Processing temperature increased.	• The total weight of the product is expected to increase by 10%.	• No significant change in the expected service life. • No significant change in the reasons for disposal, but the surface is prone to scratches, which may lead to replacement by users due to external abrasions.	• The warranty period, component replacement term, and product recycling rate may be slightly higher, because of the higher recycling value of aluminum compared to plastic.

Improvement Evaluation

Sourcing	Manufacturing	Logistics	Product Use	End of Life / Disposal
B>A>original solution	B<A=original solution	B<A=original solution	B<A=original solution	B>A=original solution

4. Material Solution Worksheet



Material Solution A	Recycled plastic from electronic waste – rPC
Description	Please describe the reasons for the material selected Choosing plastics from electronic waste treatment plants to maximize the percentage of recycled PC.
Source	What are the suppliers of the material and their place of origin? OO Eco Corp. /Taiwan
Raw Material	How is the material produced/manufactured? After crushing, processing and sorting, it is made into recycled plastic pellets.
Process	How will the material be made into products? Products are made primarily through injection moulding.
Characteristics	Do the functional characteristics and appearance of the material meet the requirements? This recycled material is mostly only available in black.
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? The material can be recycled and remanufactured, and with an autonomous recycling system, cycling can be achieved effectively.
Others	Any other important information? Recycled material originates from discarded wafer shipping boxes, which is a plus in the EPEAT.

Material Solution B	Recycled Aluminum
Description	Please describe the reasons for the material selected Recycled aluminum reduces carbon emissions from mining new aluminum.
Source	What are the suppliers of the material and their place of origin? XX Metal /Indian
Raw Material	How is the material produced/manufactured? After remelting and adjusting the composition, it is made into recycled aluminum ingots or briquettes.
Process	How will the material be made into products? Extrusion, die casting, CNC
Characteristics	Do the functional characteristics and appearance of the material meet the requirements? Through CNC machinery and a process adjustment, there is close to no difference from virgin aluminum.
Disposal	What is the waste disposal method for the material? Can it be processed through the recycling system? Materials are recyclable and can usually be processed in recycling systems.
Others	Any other important information? Materials from some recycling plants are polluted; watch for the possible presence of lead or other hazardous substances.

Circular Design Guidebook

A material selection method for the Electronic, Electrical, and Appliance industries