Closing the Loop for a Circular Economy: CIRCit Workbook 5

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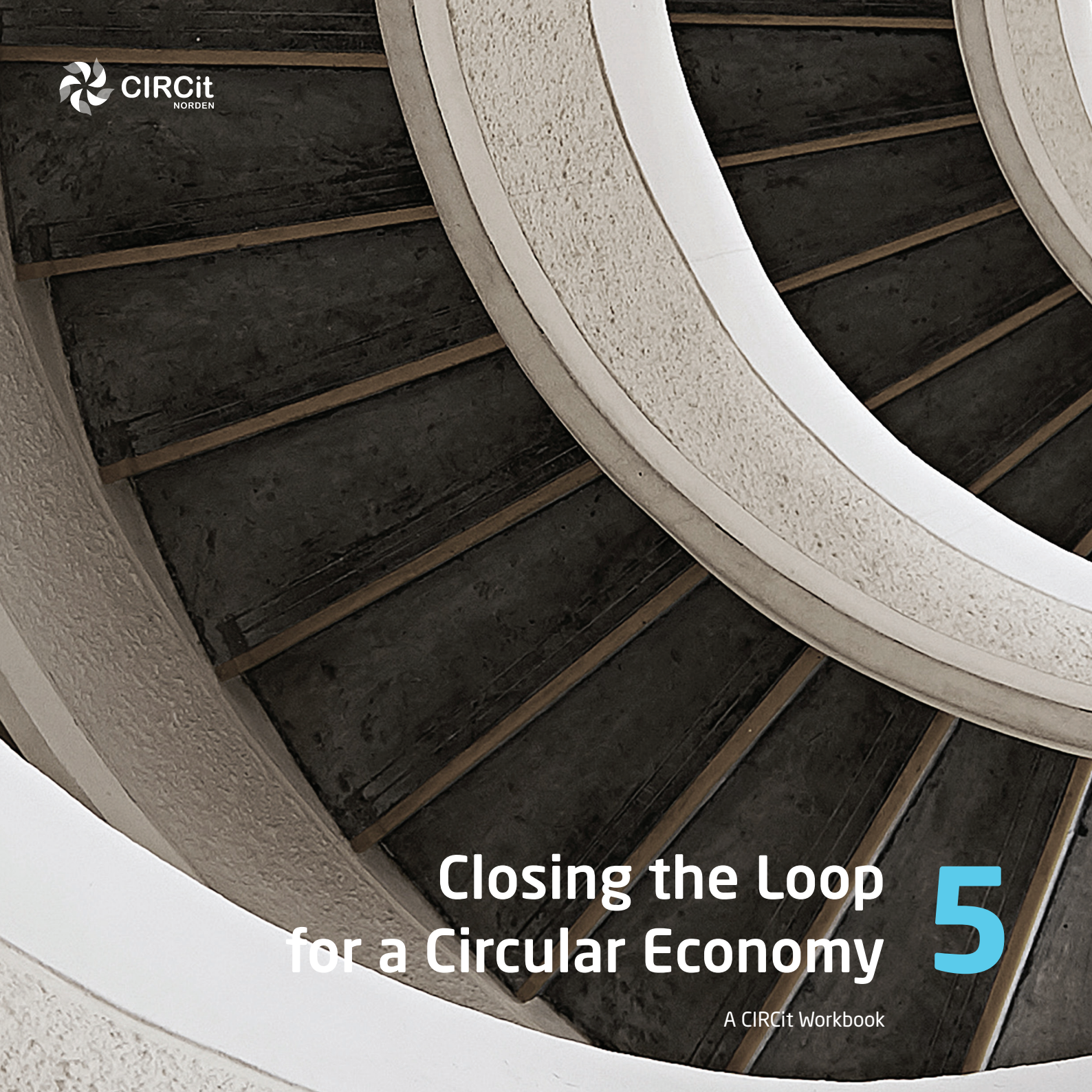

CIRCit NORDEN

Closing the Loop for a Circular Economy

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A CIRCit Workbook

1 **Circular Economy Sustainability Screening** A support for decision-making through the sustainability screening of alternative circular solutions in terms of environmental, social and business potential. e-ISBN: 978-87-7475-601-9

2 **Circular Economy Business Modelling** A guide to the creation of circular business models based on a step-by-step approach, best practice and success cases.
e-ISBN: 978-87-7475-603-3

3 **Circular Product Design and Development** An approach to assess product circularity and a set of circular design guidelines for early product development.
e-ISBN: 978-87-7475-605-7

4 **Smart Circular Economy** A look at how digitalisation and smart products can play a role in facilitating the transition to a Circular Economy.
e-ISBN: 978-87-7475-607-1

5 **Closing the Loop for a Circular Economy** An assessment tool and guidelines to support the identification of the best circular strategy for products at end-of-use.
e-ISBN: 978-87-7475-609-5

6 **Collaborating and Networking for a Circular Economy** An approach to support circular value chain configurations, seeking innovation through collaboration.
e-ISBN: 978-87-7475-611-8

What are we exploring in this workbook?

How well is your company poised to take back products at end-of-use or end-of-life? Do you have a way in which to assess the value, the condition and the potential of used products and a clear strategy of how to decide the relevant route for a product's components, depending on their condition? This workbook provides a way to tackle these questions and provides guidelines to support the identification of the best circular strategy, given an existing product and existing end-of-life and end-of-use infrastructure.

Closing the Loop for a Circular Economy
A workbook in the CIRCit Series

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E-book version and more information at www.circitnord.com

In this workbook

Photo Sven Read, Unsplash

Introduction to Circular Economy

What is Circular Economy?
Circular Economy is a concept, based on the principle of decoupling value creation from resource consumption. The basic idea of Circular Economy is to move away from the so-called linear mindset, where value creation is based on the 'take-make-use-dispose' dogma.

Circular Economy has the potential to achieve maximum value by increasing resource productivity, enhancing energy efficiency, lowering resource consumption and decreasing waste. To do this, we should continue to extract value from resources for as long as possible, by extending their productive lifetimes. This means, for example, increasingly enjoying product and service offerings that are not necessarily based on one-time ownership, and not necessarily based on single-lifetime products.

On first thought, many might equate Circular Economy to recycling of old and used products and materials. And indeed, *material recirculation* is a possibility, whether it be via recycling, cascading or recovering. Alternatively, and more valuable again, one could consider *product recirculation*, by applying tactics such as upgrade, repair & maintenance, reuse or remanufacturing. Even greater potential could also be achieved, by rethinking whole new ways of generating value, via integrated product/service business approaches, shared-access products, or new service offerings for long life products.

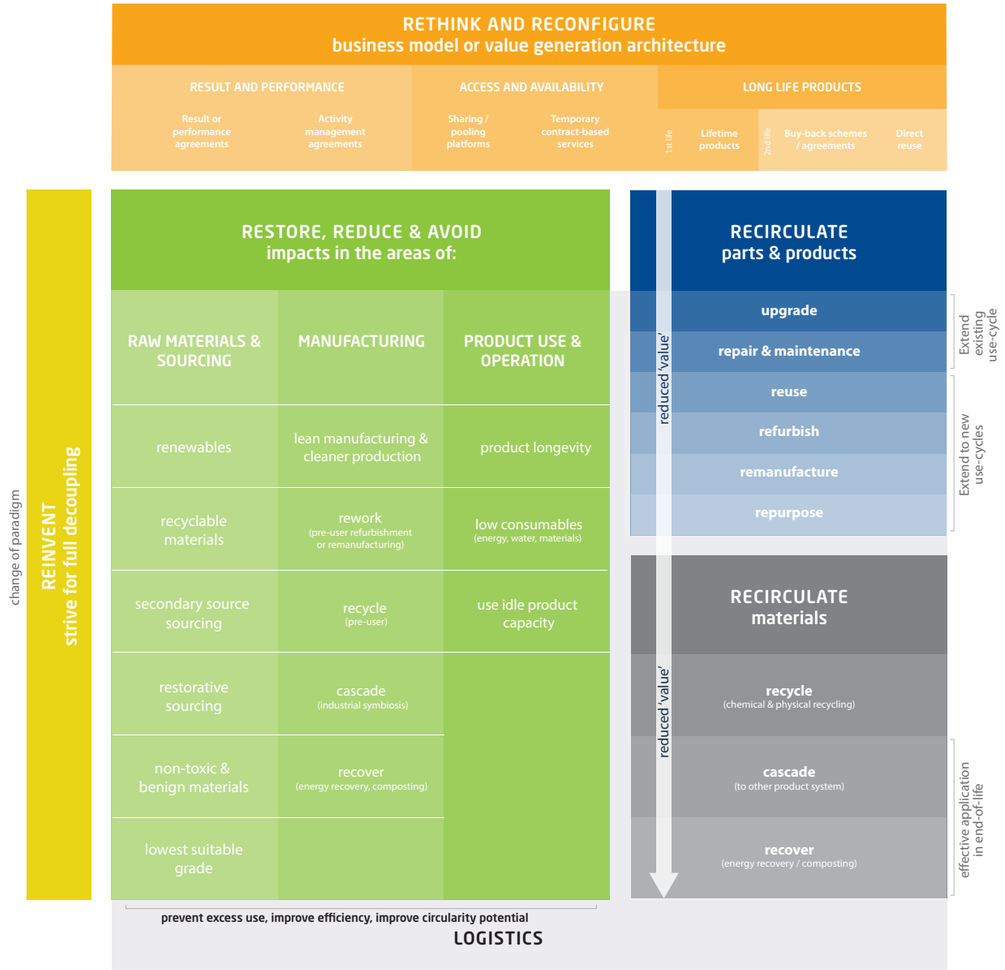
70+
participating Nordic companies

Achieving a Circular Economy requires a fundamental shift in mindset through business model, product design, support of the active product life cycle and closing the product loop, when the user no longer has a need for it. At the core of a Circular Economy lies collaboration, within and across value chains and with different societal stakeholders than we've maybe been used to.

And there's no use being circular, if the outcome is less sustainable than the starting point. Therefore we need to be able to estimate the sustainability benefits and drawbacks of our actions.

For many companies, there will be obvious low-hanging fruits, such as reduction of single-use packaging in the production facility, or making small design changes to the product, to ease its disassembly at end-of-life. But for most, there will be a necessity to re-think the way in which business is done, materials and components are sourced, and new types of solutions are developed and marketed, in order to achieve maximum value and circularity from the resources used.

The good news is that there are increasing numbers of examples, in all types of business sectors and within civil society, in general. Circular Economy is a movement that is currently under rapid development, and the many necessary components to shift our mindset from a linear to a circular economy are increasingly manifesting themselves.



*The **Circular Strategies Scanner** can help you to map which strategy or strategies are already being implemented by your company and to identify opportunities of complementary strategies to maximise the value created for as fewer resources as possible. We will refer to this Scanner throughout the six workbooks.*

Photo Nick Jio, Unsplash

How to make the transition

The basic concept of Circular Economy is easy to grasp for many. It is appealing from a business perspective, as it connects good business sense to good environmental stewardship. After all, which business would not like to reduce the consumption of cardboard boxes in internal production shipping; fully utilise its logistics capacity; or make its product easier to produce, maintain and upgrade?

The tricky part for many companies, however, is in knowing which steps to take first. How ready is your customer and the market in general, to embrace circularity and what role can your company play? Are there drivers or barriers to be found in the way in which regulations are composed in your area of operation – and if so, are there ways of exploiting the drivers or removing the barriers? Should we design the product for upgrade, or should we develop a new business for leasing? Should we make a new partnership for materials sourcing, or should we be better at monitoring our product in-use? As with many new phenomena and business trends, it is often easier to admire and envy the existing good case examples than it is to actually get started on the journey within one's own business.

This workbook is one in a series of six proposed areas to begin the transition to a Circular Economy.

Circular Economy Sustainability Screening | Circular Economy Business Modelling | Circular Product Design and Development | Smart Circular Economy | Closing the Loop for a Circular Economy | Collaborating and Networking for a Circular Economy

Introduction to CIRCit

The CIRCit research project was a 3½-year research project, spanning the five Nordic countries, Denmark, Norway, Finland, Iceland and Sweden. Using a number of action research methods, CIRCit's objective was to support the Nordic industry to discover and implement the opportunities of Circular Economy, through the development, testing and implementation of science-based tools.

The project spanned six main areas, corresponding to the workbooks that you are currently reading, as follows.

Circular Economy Sustainability Screening

This workbook supports decision-making by providing sustainability screening of alternative circular solutions in terms of environmental, social and business potential.

Circular Economy Business Modelling

This workbook supports the creation of circular business models, based on a step-by-step approach, best practice and success cases.

Circular Product Design and Development

This workbook presents an approach for assessing product circularity in the conceptual design stage, plus practical design guidelines to support early product development decisions.

Smart Circular Economy

This workbook helps to evaluate how digitalisation and smart products can play a role in facilitating the transition to a Circular Economy.

Closing the Loop for a Circular Economy

This workbook provides an assessment tool and guidelines to support the identification of the best circular strategy for products, taken back at end-of-use.

Collaborating and Networking for a Circular Economy

This workbook presents an approach to support various circular value chain configurations, seeking innovation through stakeholder collaboration.

Closing the Loop for a Circular Economy

This workbook helps to identify and evaluate options for closing the loop of products and parts that are already out on the market. It is intended as a decision support, to help to alter linear flows into circular ones.

Expected outcomes

- An overview of recirculation options within circular strategies.
- Insights into options, regarding what to do with products that have reached end-of-use or end-of-life, and how to retain value. Nine recirculation strategies are provided.
- A procedure for evaluating suitable recirculation approaches.

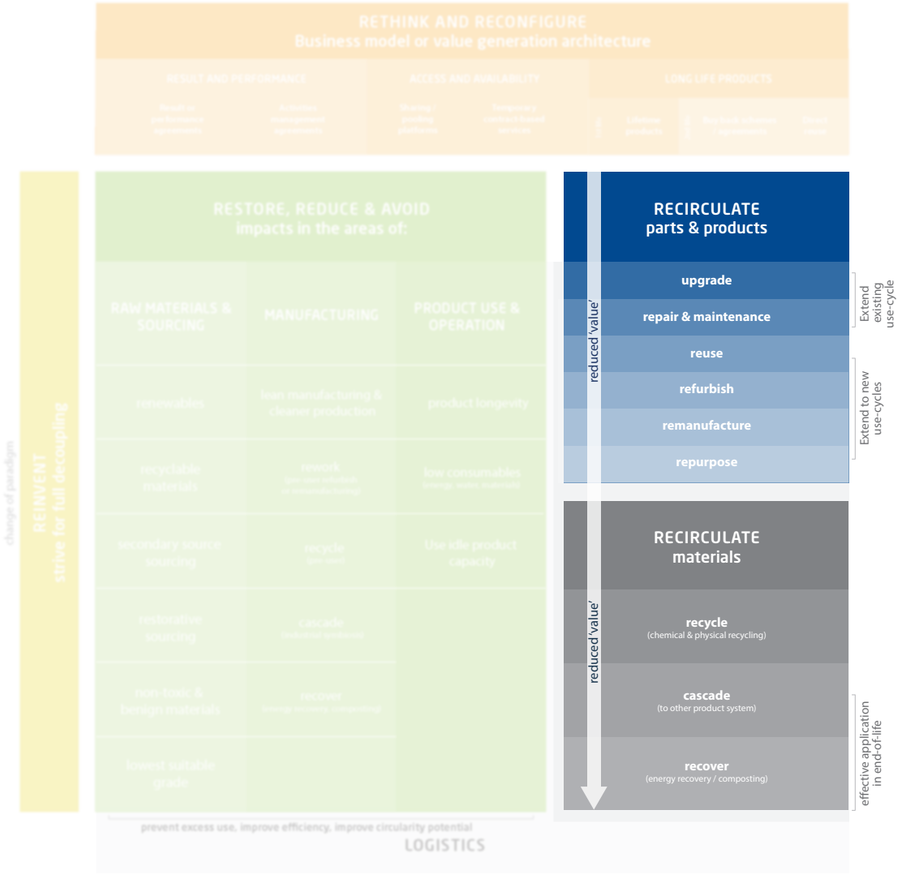
Who can use this workbook?

This workbook is intended to help companies that want to establish recirculation of existing products.

Two different starting points are expected. Firstly, companies with a portfolio of products may want to find out which should be prioritised for recirculation, and which recirculation strategy should be preferred. Secondly, companies that have already identified a specific product to recirculate can get help to evaluate different recirculation strategies.

To activate the full potential of the decision support in this workbook, it is recommended that a wide variety of functions be represented, including people from the company involved in environmental management and general management, plus any colleagues connected to sustainability and/or circular economy. It is also relevant to consider involving aftersales, to support the transition to circularity.

Manufacturing companies are the main target of this workbook. Private or public organisations that offer treatment of discarded products can also benefit from understanding how to identify prioritised options for closing the loop.



These nine recirculation strategies from the *Circular Strategies Scanner* form the backbone of all closing the loop strategies for a company and will be described in detail, in the next pages.

1 Nine recirculation strategies

Nine options to close the loop
Linear product life cycles depend on the availability of resources from start to finish. Resources are taken, used for a limited time and then disposed.

Circular Economy fosters the recognition that the linear economic model is unsustainable. In addition to new business ideas and new product development processes, there needs to be found a solution for existing products that are currently being used, and which are approaching a stage when they are not fully functional, either temporarily or permanently.

Closing the product cycle for existing products includes strategies to recirculate products or parts, as the first option, or recirculating materials, as the last resort:

- **Recirculate products or parts:**
  - Extend existing use-cycles
    - 1. Upgrade
    - 2. Repair and maintenance
  - Extend to new use-cycles
    - 3. Reuse
    - 4. Refurbish
    - 5. Remanufacture
    - 6. Repurpose
- **Recirculate materials:**
  - Effective application at end-of-life
    - 7. Recycle
    - 8. Cascade
    - 9. Recover

Recirculating products or parts seeks to extend functionality to additional use-cycles, without significantly changing the structure.

Where recirculating products or parts is not possible and the end of a use-cycle also becomes the end of the actual life cycle of a product, material recirculation strategies are the next priority, to attempt to retain value. In this part of the workbook, the nine prioritised recirculation strategies are presented, together with a description of their purposes, general background, benefits and limitations.

Note that strategies for recirculation are linked, among others, to aspects of design and business modelling. Separate workbooks are dedicated to these aspects.

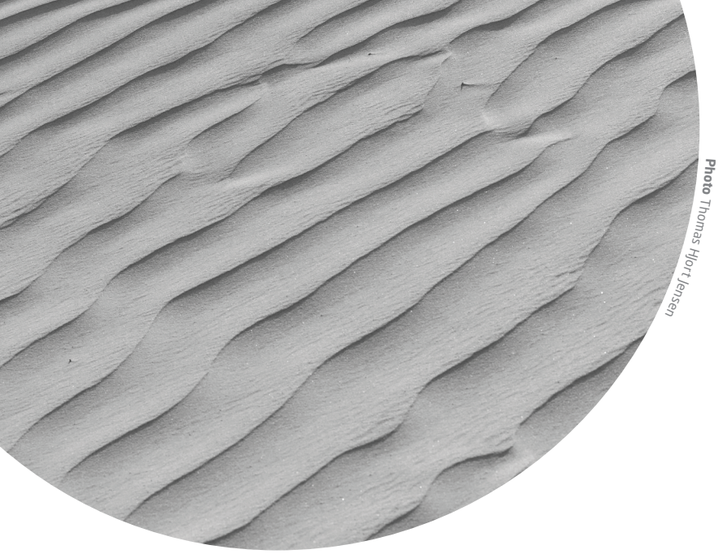


Photo *Thomas Hjort Jensen*

For each of the following nine strategies, we map out a simplified process-step approach, each of which is adapted from IPR (2018).

Recirculate products and parts

Extend to new use-cycles with the purpose of capturing (residual) value or to reduce value loss from continued use of products and parts.

Recirculating products and parts means that both material- and processing value, embodied in the product at beginning-of-life, can be retained. The strategies located in this part of the *circular strategies scanner* therefore have a high potential to reduce resource demand.

Many processes to recirculate products and parts are already established for specific sectors, but not for all. What is not currently feasible may be developed in a few years' time, as there is currently great attention on recirculation strategies. Keep an eye on this for your sector.

Recirculation strategies for products and parts include a variety of requirements. Among them is that there is a demand on the market for the recirculated product or part, otherwise we may waste resources in preparing it for such.

Simply put, recirculating products and parts is a preferred option, when the question:

"Is there a demand for the value of a product?"

... can be answered with:

Yes, if the product can be updated or modernised (check section on **upgrade**).

Yes, the product can be used as is (check section on **reuse**).

Yes, if the product is repaired to provide full functionality (check section on **repair**).

Yes, if the product is refurbished to provide restored functionality (check section on **refurbishment**).

Yes, if the product is remanufactured to provide restored functionality (check section on **remanufacturing**).

Yes, for a limited set of properties in another use-cycle (check section on **repurpose**).

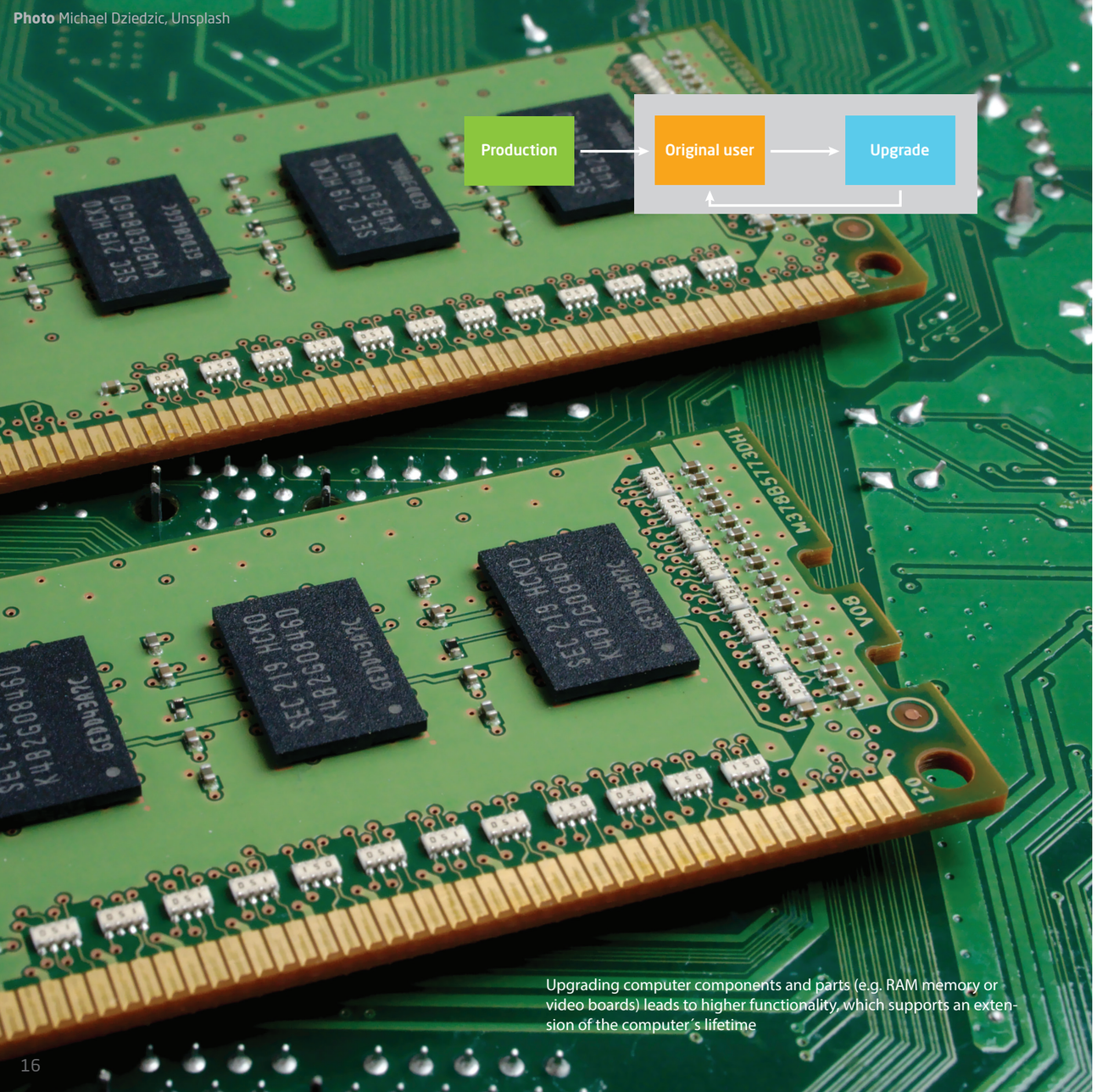
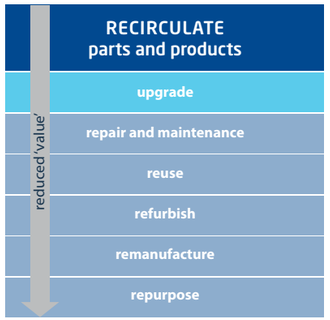
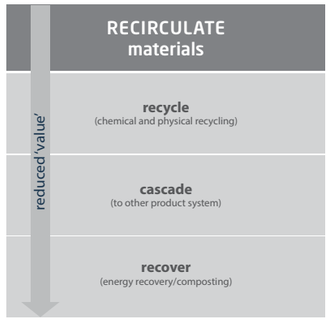


Photo Michael Dziedzic, Unsplash

Upgrading computer components and parts (e.g. RAM memory or video boards) leads to higher functionality, which supports an extension of the computer´s lifetime





UPGRADE: Update, modernise, renew, retrofit, rebuild

Purpose: To extend an existing use-cycle by adding value or expanding functions in respect to previous versions.

Upgrade can refer to aesthetical upgrades, which implies changes in the exterior to adapt to changed preferences, or functional upgrades of hardware and software.

Upgrade strategies are established in various sectors.

Upgrade as a circular strategy is suitable for products that are essentially functional, but do not meet evolving quality and performance requirements customary in the market. This is a strategy suitable to meet customer demands in markets with short innovation cycles, due to technological change and development, but also for markets with fast changes, due to fashion and trends, including clothing and furniture.

Application areas

Information and communication technology (ICT) is a typical example for a market where products are decommissioned after a period that is shorter than their service life. Users demand up-to-date versions of products, even if previously used products are still fully functional. Therefore, products might reach their end-of-use not due to wear or failure, but are decommissioned when a new version is released.

This applies also for products that include ICT to control functions, for example household appliances and industrial applications with a programmable logic controller (PLC).

Software upgrades as a specific strategy are made available for subscribers of a proprietary product or registered users and include new versions with significant changes and extended functionality. In some cases, software upgrades also require hardware upgrades. Newer versions of operating systems for smart phones are rolled-out to existing products where possible, but limitations apply if storage or performance requirements are not met.

How to
Exchange parts that are perceived as outdated and replace with items that provide required features. For example, add increased storage capacity for electronic devices.

Software upgrades for appliances are available for private consumers (phones, TV-sets, washing machines) and for industrial applications (PLC's). For furniture, replacement and add-on covers are available as well as fittings.

Products that are based on a modular design offer planned options for upgrades. If upgrades were not envisioned at the design stage of an existing product, replacing or adding functionalities with an upgraded version might be difficult to implement, due to limitations of space or if parts are hardwired or fixed permanently, as this would imply a risk of damaging the product during the upgrade process.

Aesthetical upgrades are offered for products such as furniture (e.g. covers for upholstered sofas, or as refacing drawerfronts for kitchen cabinets). They are offered for modular furniture that is designed for upgrade or that meets standard dimensions and uses standard fittings, (e.g. cabinet units).

Benefits
The upgrade strategy extends product value through enhancing the function of an existing product to even beyond its original design condition and reducing value loss, by enabling continued use of parts and products.

Customers of upgraded products purchase up-to-date versions that are functional, for lower costs, compared to latest versions.

For a manufacturer of products, offering upgrades to existing products provides an opportunity to reconnect with customers and establish a more long-term relationship.

Additionally, it offers access to new market segments, e.g. customers who prefer used products due to affordability.

Consider also
If hardware parts or parts are physically removed to perform an upgrade, a separate recirculation for these items should be investigated, either as parts for a different application or as recirculated materials.

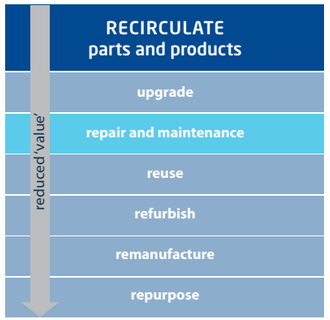
Upgrades of products that are not designed for this strategy can still be possible, even if this requires a greater effort to remove and replace outdated parts.

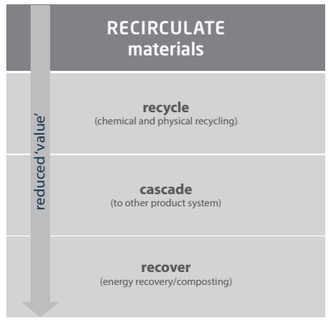
Options to update products and parts still need to consider quality and design requirements.

The number of consecutive upgrades that can be performed on a product is limited.

Photo IFIXIT

Fairphone has developed smartphones that are easy to repair: key components (e.g. battery and screen) are easily accessible and visual cues inside help with replacing parts and modules.





REPAIR & MAINTENANCE: Corrective, condition based, predictive and prescriptive maintenance

Purpose: Extend an existing use-cycle by countering wear-and-tear and correcting faulty parts of a defective product, to return it to its original functionality. Partial disassembly of products is envisioned and a limited warranty for the repaired part may be issued.

Regular maintenance is often stipulated in the terms of guarantee for investment goods, which includes exchange of wear parts and consumables. Traditionally, maintenance would be performed periodically, regardless of the actual state of a product and whether or not parts needed to be replaced. Modern and advanced options that include information collected from sensors and counters can be used to adapt maintenance intervals to actual demand. Workbook 4 describes this approach and related benefits in detail.

Repair as a part of maintenance may involve the restoration or replacement of faulty parts. It is an activity that must be performed when a part is not functioning, or not functioning reliably, resulting in the necessity to replace or fix parts.

Repairs can be performed as part of a planned maintenance activity, or when the state of a product requires it.

There are three main approaches to repairing a product, which may be combined if some parts are repaired by the customer, the original manufacturer, or by third parties, due to special tools or safety issues.

Repair approach 1: Industrial repair by manufacturers

For companies that offer repair and maintenance services, this can be a core part of their revenue streams. Some products are made intentionally difficult to repair by the owner, for one of the following reasons:

- the product includes parts that can cause direct harm to the user in case of non-professional repair, either through physical damage or exposure to chemicals.
- products whose operation and maintenance can be dangerous or lead to safety concerns, e.g. large products or products for critical

applications such as traffic vehicles.
- the structure of the product is too complex to be repaired by the customers.
- products are difficult to repair for a consumer because of a high risk of damaging the product or allowing a repair that can lead to a future failure.
- products that need special tools and a special environment.
- warranty issues.

It is worth noting that there is large focus on planned obsolescence, for which reason such repair strategies are often viewed with scepticism.

Repair approach 2: Repair by third party

A third party specialises in repairs as an offering. The manufacturing company might receive revenue from selling spare parts and collaboration with (even endorsement of) the specialist.

Repairs are performed by local repair shops, which can reduce the effort for travelling or transport of goods between the user and the manufacturer. Many professional services are often expensive and more B2B-driven.

Repair approach 3: Domestic repair

Customers invest their own time and costs for spare parts, tools and the actual repair activity. The manufacturing company might obtain revenue from selling spare parts, tools, updates and upgrades. Domestic repairs can extend the use-cycle of products, beyond a mandatory warranty period. These generally target a customer segment that would otherwise not purchase a product. However, all concerns about safety and warranties must be solved.

How

Spare part kits including tools and guidelines can be developed for existing products based on aftersales service experience, for example for replacing parts that can be accessed easily on the outside of a product (covers, handles). Instructions can also be supported with photos and clips on the manufacturer's website.

Repair shops can be certified by the manufacturer on completion of training.

Benefits

The use-cycle of products is extended. Manufacturers and dealers stay in contact with customers and receive indications about the state of the product, depending on the type of spare parts kits that are ordered. Manufacturers and dealers can potentially gain contact with new owners of products that have been resold.

Considerations

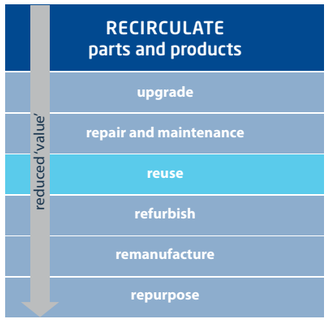
For some products, repair is not intended, as evolution of products happens fast, and older versions do not provide an up-to-date range of features (outdated products).

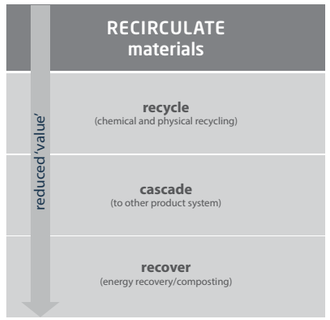
If customers understand that paying for a service and repair can be cheaper than regularly buying new products, they might stop buying new products altogether.

Broken or worn products can be used to recover spare parts and are otherwise directed to material recirculation, where possible. Occasionally, there is a trade-off that needs to be investigated, case-by-case, to find the optimum use-cycle of a product. For instance, by keeping energy-using products in use for a longer time through repair, the same rate of new and more energy efficient products will not be demanded. This is potentially more resource demanding and can lead to additional emissions, if the product is operated with electricity from a grid with a high share of fossil fuels (e.g. energy using products (EuP) that have been sold secondhand to a user in Estonia, where fossil fuel contribution is 80%, contribute to higher emissions during the use phase).

Photo Kelvyn Ornettte Sol Marte, Unsplash

Reuse of parts is a good strategy for the maintenance of larger and complex products, such as transportation systems.





REUSE: The second or multiple use of the same product after end-of-use, without significant repair or other intervention

Purpose: Extend to new use-cycle by reusing a part or a product which is discarded or not in use, but still in good condition and can fulfil its original function in a different use context (new customer/user).

Reuse strategies may involve a minimum amount of condition monitoring such as cleaning or repackaging. No warranties are provided, and no disassembly is involved. Return and resale of second-hand goods is available for some brands through stores, such as Patagonia and Bergans.

How

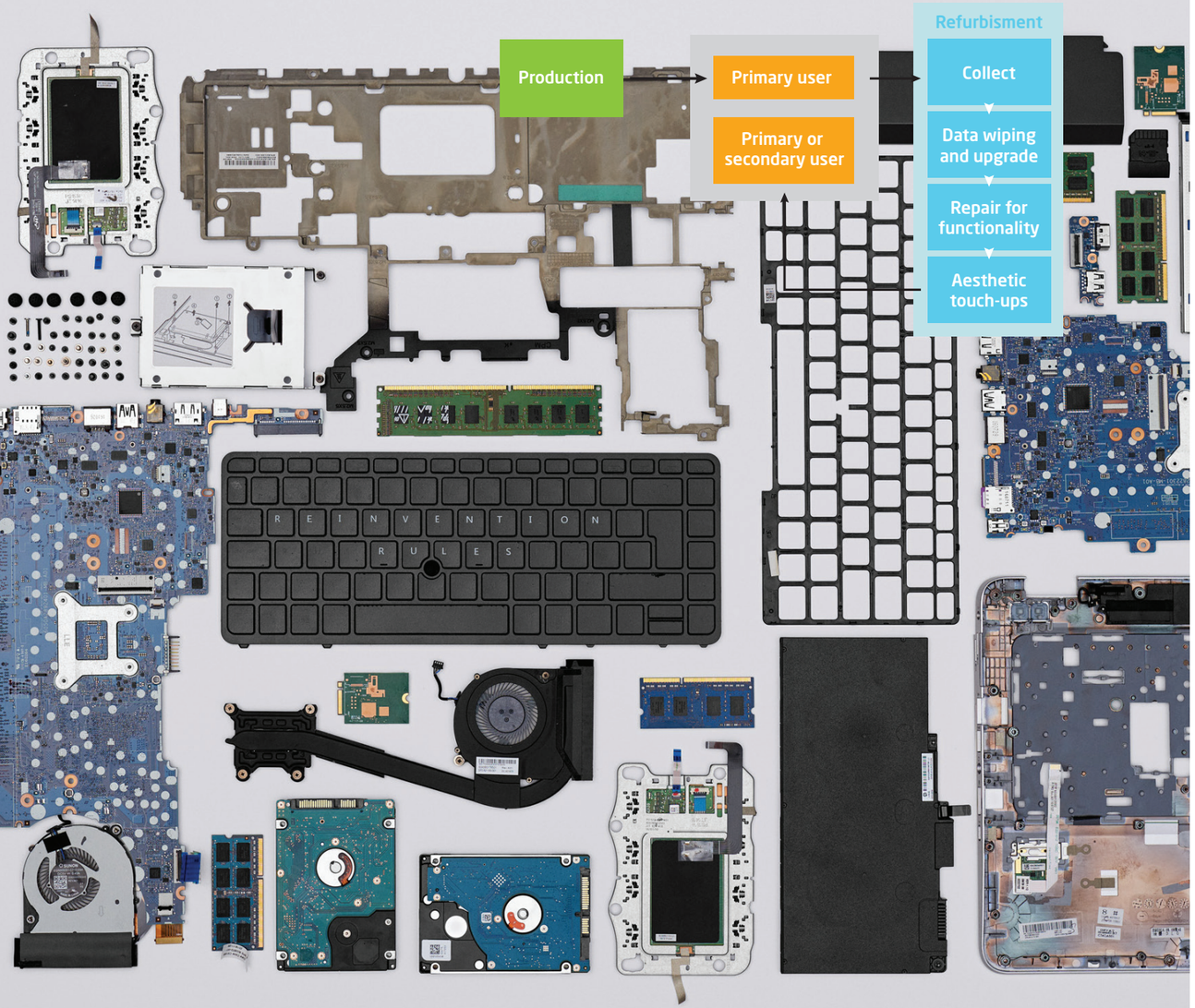
Redistribution of existing, preowned products to new users, which is also called service life extension. Use-cycles are added, one after another. Users exchange products between them, based on their needs. The manufacturer is not necessarily involved or informed. Examples in non-industrialised contexts include online selling platforms, such as Ebay. Similar platforms, specialised for investment goods and equipment are established, e.g. Autoscout24 for cars or Machineseeker for capital equipment.

Benefits

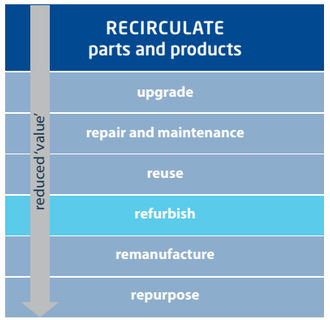
Reuse redistributes used products and extends the service life of the existing products, which reduces the number of products that had to be produced in the first place and (1) saves all the resources and values placed into extraction and production of a new product including energy, work, time and material, (2) reduces the waste stream, and (3) saves time, resource and energy used in repairing, remanufacturing, or recycling the old ones.

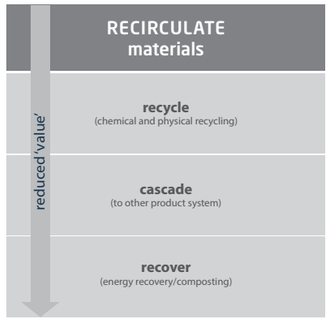
Considerations: In reuse, the product is still in working condition and able to fulfil its original function, maybe involving a minimum amount of cleaning and repackaging. No warranties are provided, and no disassembly is envisioned. Reuse does not include upgrades and can lead to an extended use of products that are not up-to-date, regarding energy efficiency or contents of hazardous substances that were regulated after the initial user purchased the product.

Photo Courtesy of Inrego



Inrego is a global supplier of refurbished IT equipment, giving tens of thousands of IT products per month a second life.





REFURBISH: Recondition, retrofit, refresh, remodel

Purpose: Extend to new use-cycles by returning a part or product which is discarded or not in use at the current owner to a satisfactory working condition. The working condition may be inferior to the original specification.

Refurbishment does not claim that products are returned to as-new conditions and the actual condition is often less clearly specified, compared to remanufacturing.

Refurbishing activities may include cleaning, repairing, resurfacing, repainting, resleeving of products and/or parts. Partial disassembly is envisioned to replace or repair specific parts.
In the case of traditional product sales, a warranty for all major parts may be issued, which will be limited, in comparison to newly manufactured equivalent.

Refurbishment includes restoring a returned product, after a certain period of use, to satisfactory mechanical specifications and operating condition, within the bounds of what is considered acceptable. Refurbishment is achieved by rebuilding or repairing major parts that are close to failure, often when there are no reported or apparent faults in those parts.

How

Products are typically returned to a central facility, visually inspected and functionally tested. Necessary repairs (including assembly and disassembly) are then performed for the purpose of resale or redistribution.

The device might be cosmetically enhanced, and protective coating might be applied. In the disassembly, parts of a specific product are kept together and, after cleaning, inspecting and replacing of the severely worn or broken parts with new parts, the product is reassembled with most of its original parts, to reach near-original condition.

Refurbishment can be achieved via different approaches:

- Original equipment manufacturer (OEM): products arriving from service centres, trade-ins from retailers or end-of-lease contracts.
- Contracted centres: approved contracted centres are used to refurbish products on behalf of the OEM. In other words, the OEM maintains ownership of the products but does not perform the actual remanufacturing itself.
- Independent centres: the OEM has little or no contact with the product and the independent centres buy or collect products or parts from the market as input for their processes.

Benefits

Refurbished products are suitable for customers who expect a use-cycle with limited duration, for example, customers who need complementary items for existing equipment.

Consider also

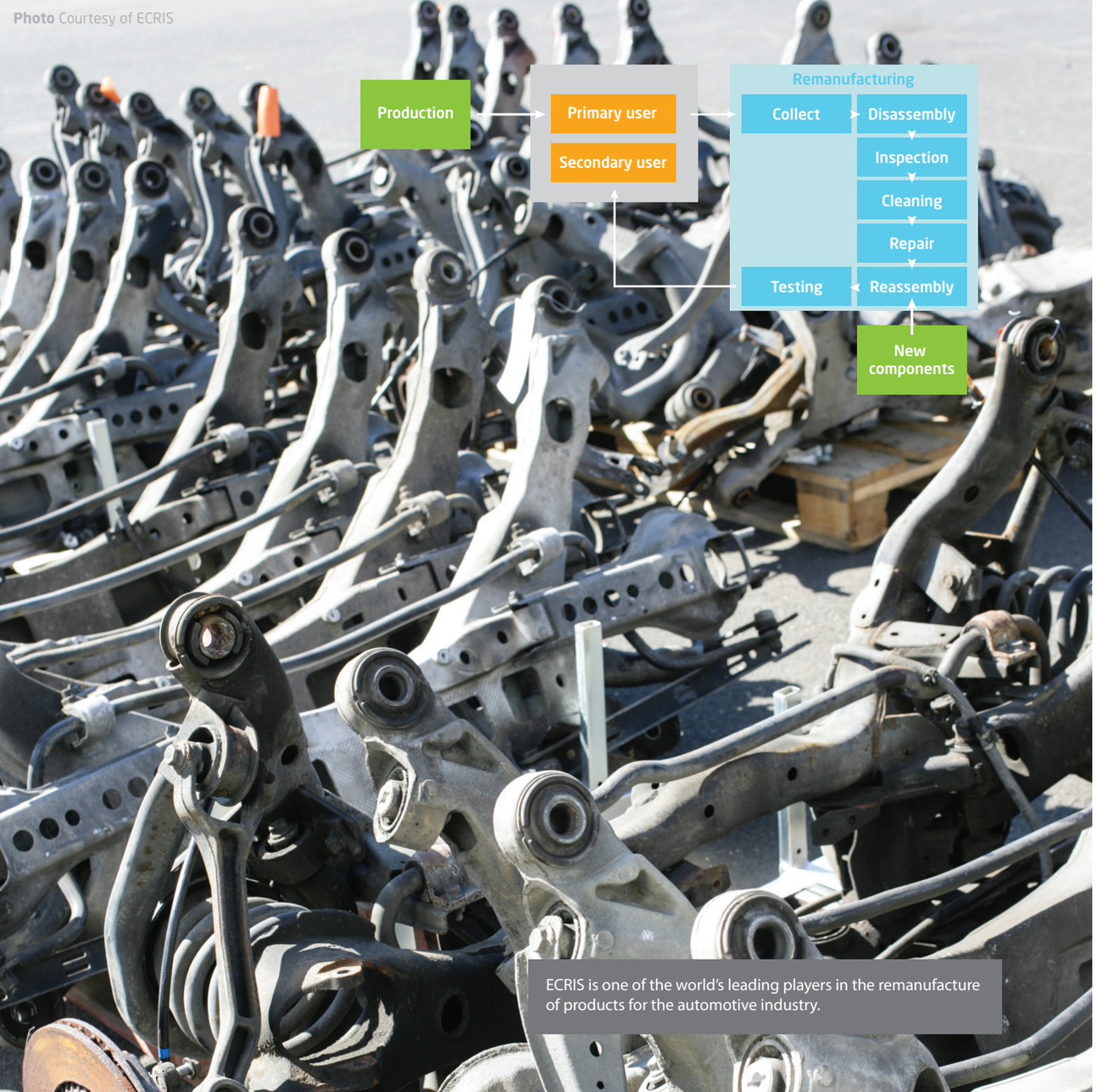
The main difference from remanufacturing is that refurbishment is usually less rigorous, less costly, involves less disassembly and reassembly and involves a lower production volume.

Refurbished products can be an attractive option as peripheral complements to products that are reaching the end of a use-cycle, e.g. refurbished batteries can be used in electric vehicles that have been in service for several years and will potentially be retired within a relatively short time period.

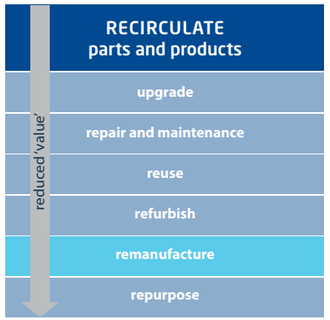
Refurbished products and parts can also be an attractive option for products that are no longer produced, but still sought by a small customer base. A refurbisher in Finland purchases used iPhones from companies and private individuals, refurbishes them and returns them to service with a 12-month comprehensive warranty. Phones sold to the refurbisher may either be fully functional or in an inoperable condition.

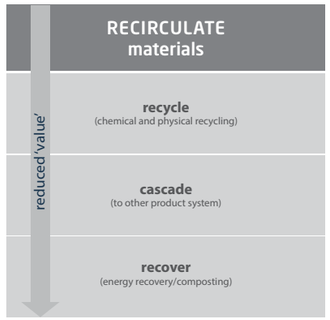
Refurbishment includes a technical analysis on the phones, which indicates their condition. Customers of refurbished phones can choose between different levels of refurbishment; older models are offered with scratches and wear, at lower prices, to attract customers who accept products that are functional but visibly used.

Additionally, phones are examined for signs of water damage and other interior faults. According to the refurbisher, phones can nearly always be extended to a new use-cycle, at least partially; they can either be used to supply spare parts or be refurbished for resale. Phones that are unfit for the domestic market are sent abroad via other recycling services. Unusable phones and unusable parts are taken to electronic waste disposal points.



ECRIS is one of the world's leading players in the remanufacture of products for the automotive industry.





REMANUFACTURE: Rebuild and restore to as-new or higher performance

Purpose: Extend to new use-cycles by returning a product that is discarded or not in use, to at least OEM performance specification and quality.

In the case of traditional product sales, a warranty that is at least equal to that of a newly manufactured equivalent may be issued.

Remanufacturing to an industrial standard means collecting and returning used products, disassembling, sorting, cleaning, inspection, repairing and reconditioning, assembly, testing and finally combining and upgrading them with new parts to make a product that both looks and performs at least equal as new, and thereafter selling them as new.

The remanufactured product might have equivalent or even higher performance and functionality and might be used by the same or a new user. Remanufacturing includes testing each part regarding safety and performance. Parts that do not meet the criteria are not recirculated; parts that perform better than required from a new part are reassembled without charging a premium.

In some cases, remanufacturing includes a step to improve the performance and reliability of remanufactured products. For example, a remanufacturer of pumps in Sweden adds a composite layer on the surface to improve the efficiency. In another example, a Dutch remanufacturer of electromechanical motors replaces bearings that have been identified as a key failure point with more durable ones. In both cases, remanufacturers use their knowledge about design and about typical wear and failure issues to improve the product.

Full warranties and guarantees are given in connection with remanufacturing. Remanufacturing takes place in an industrial environment.

Cases from remanufacturing report substantial energy and material savings. Therefore, remanufacturing provides companies economic advantage compared to brand new ones.

Remanufacturing is a very good option for highly material intensive, very expensive and very specialised products.

For users of such custom products, it is also reported that remanufactured products are often available faster than newly manufactured ones, reducing the risk of downtimes in production.

There are also a number of barriers for remanufacturing, as follows:

- Critical volumes of the same kind of product are required, to enable a successful remanufacturing facility and the collection and transportation of such products can implicate high costs and emissions, lowering potential benefits.
- Consumers might mistrust remanufactured products, perceiving them as no longer 'new'.
- Infrastructure is required for product collection and storage.
- There is a risk that sales of the company's new products will decrease and the loss of these sales will be greater than the profit from sales of remanufactured products, known as market cannibalisation.
- When products are sold and the initial warranty period is over, buyers decide how to further handle them. OEMs do not necessarily know when a product has been resold, who currently owns a product, or how it is used. This can make it difficult to access products that could be suitable for remanufacturing. Independent centres, not involved in the original sale of a product, would need to find suitable input for the remanufacturing process.
- Uncertainty about (and variation within) the quality of the products or parts returning for remanufacture mean that the remanufacturing process needs to be flexible and adaptable.

How

Remanufacturing can be organised via various means:

- OEM: products arriving from service centres, trade-ins from retailers or end-of-lease contracts.
- Contracted remanufacturers: approved contracted centres are used to remanufacture products on behalf of OEMs. In other words, the OEM maintains ownership of the products but does not perform the actual remanufacturing itself.
- Independent remanufacturers: the OEM has little or no contact with the product, and it buys or collects products, parts or components from the market as input for its processes.

Benefits

Some companies sell remanufactured parts via their aftersales services, which can be a faster source of parts delivery than providing replacements produced from virgin raw materials.

The main driver for many companies is profitability, as the cost to produce through remanufacturing is lower, due to reduced cost of materials, parts, energy and labour. Other drivers include competitiveness and pricing policy. For example, the price of the used product prior to remanufacturing might be 0–20% of the new price, whereas the remanufactured product retails at 40–60% of the new price.

Consider also

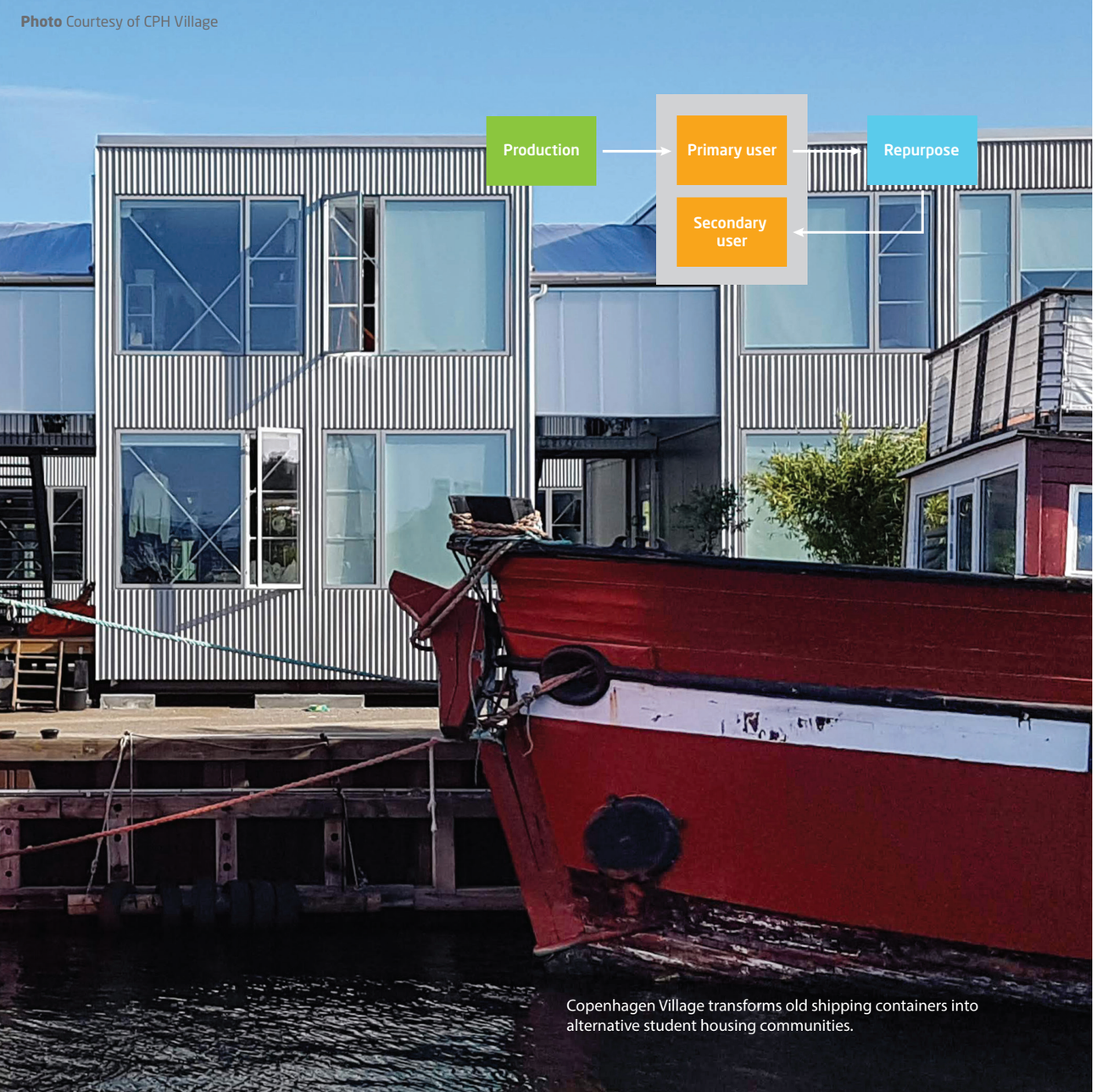
Regulatory aspects or standards may require adjustments to remanufactured products and parts, to meet new demands (e.g. chemicals or energy).

Keeping old products in use carries the risk of preventing new, more efficient products from entering the market.

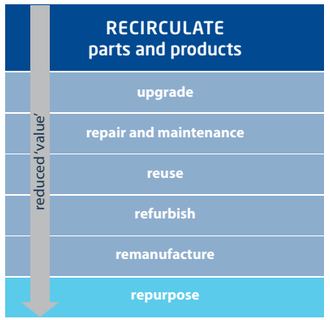
Example from the Nordic countries: Structural parts from used cars can be removed at end-of-use, when the car is written-off. Vehicle scrappers apply a procedure of testing, cleaning, replacing wear-parts and reassembling parts that are then available for the aftersales market, through authorised repair shops. Parts for remanufacturing are selected, based on experience regarding sales volumes and demand.

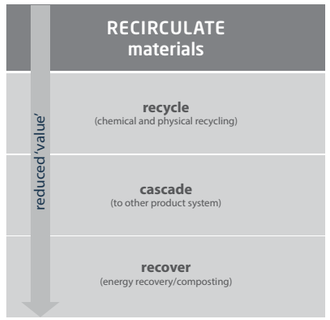
The disassembly company ECRIS AB in Jönköping was developed based on a research project collaboration between the automotive company, Volvo Car Corporation; a large-scale recycling company, Stena Metall; and vehicle scrapping company, Jönköpings Bildemontering, as the main stakeholders. Today, ECRIS provides remanufactured parts for the aftersales market and also offers the range *Genuine Classic Parts (GPC)*, for older, discontinued Volvo car models.

Photo Courtesy of CPH Village



Copenhagen Village transforms old shipping containers into alternative student housing communities.





REPURPOSE: Finding alternate use

Purpose: Repurpose means extending a discarded product or its parts to new use-cycles, by finding different functional uses.

Repurposing generally implies that a limited set of the initial product or part properties is used in a further use-cycle. This could be the shell of the product, specific parts, and maybe also aesthetic features related to the design, where applicable.

An example of an emerging area for repurposing is that of traction batteries from electric vehicles, which are repurposed for use in stationary applications, in combination with solar panels. A main advantage is that demand and supply of energy can be aligned and home owners or utility companies can utilise solar panels to a higher extent. This benefits local distribution networks, when the users are connected to the grid. Users in sparsely populated and remote locations, such as islands in the Atlantic, avoid using fossil fuelled diesel generators as backup.

Numerous established repurposing examples can be found related to buildings and developed properties. One example of this is in the repurposing of shipping containers into housing solutions, e.g. Copenhagen Village, which transforms old shipping containers into alternative student housing communities.

How

Parts that are not used in a new use-cycle are removed, where necessary. New features are added to adapt to a new use-cycle.

Benefits

Existing large-scale properties and assets can be used with reduced effort for production and construction.

Consider also

Parts that are not transferred to a new use-cycle should be considered in a dedicated separate recirculation, e.g. fittings and other parts that were specific for the initial use-cycle, but removed to enable the repurposing, will themselves become available as parts or materials for recirculating.

Photo Courtesy of CPH Village

Recirculate materials

Effective application of end-of-life of materials, with the purpose of capturing (residual) value or to reduce value loss from continued use of materials.

Introduction

Recirculating materials can be the preferred option when a product or part is broken or worn so much that it is considered to be beyond repair. This strategy can also be adopted for energy-using-products that should be replaced by more modern, efficient versions. And it can be an option for products that contain hazardous substances, which are restricted and should be removed from the market.

Supporting processes to establish recirculation of materials are established to enable effective capturing of residual value, for example dismantling and separation of products to extract clean fractions that can be used as high-quality raw materials.

Recirculating materials means that the structure and functionality of a product or part is lost, due to the transformation process that is applied.

Transformations can be mechanical, thermal or chemical. All op-tions here are related to losses of input material and processing effort. This can be used as an advantage, if products are no longer in demand or have to be removed due, for example, to policy requirements that were established after the initial use-cycle started.

Recirculation of materials is also frequently utilised for production residues and as a common materials pool for a multitude of products and parts that are sufficiently similar.

Infrastructure for processing is most frequently shared or outsourced and the processing can become more efficient, when it is performed for larger flows.

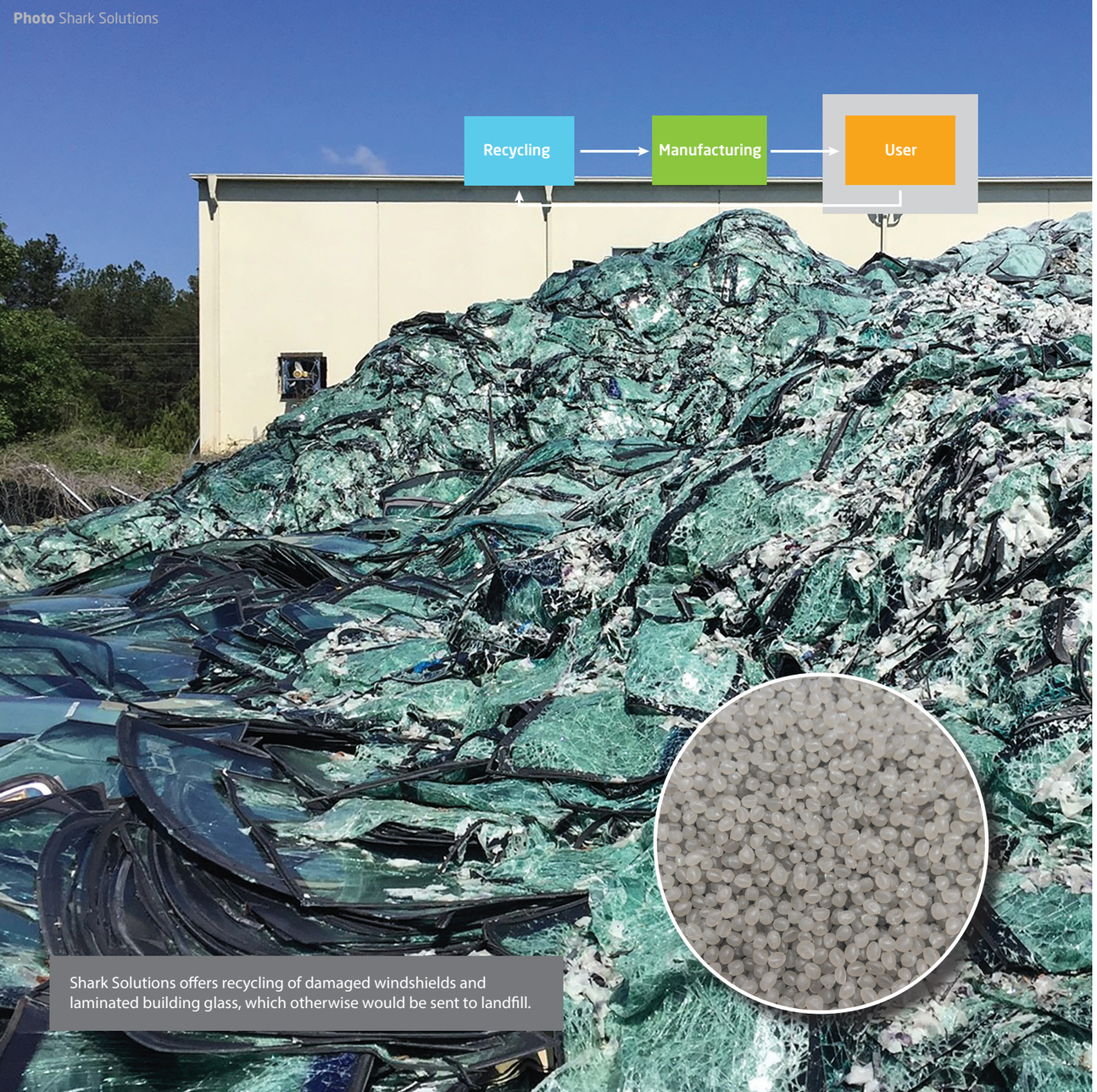
While global scale is established for sourcing of virgin raw materials, recirculation of materials is mostly established on regional scales.

Processing of materials is more related to materials processing from natural resources, with screening and separation processes using physical and chemical properties of materials and neglecting functions of products in current use-cycles.

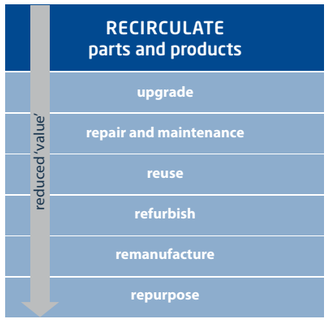
Closed product cycles are an important contribution to recovery of materials of limited availability, and especially materials that are required for key applications in Europe, such as renewable energy or transport.

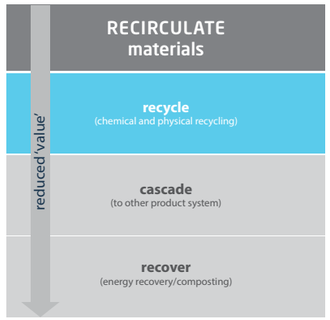
The supply risk for rare-earth elements, antimony and phosphorus is especially high. Closed product cycles are a way to reduce the demand. In 2017, a list of 27 materials were categorised as critical raw materials (CRM). For more information, see also www.circitnord.com.

A list is also provided in the CIRCit toolbox.



Shark Solutions offers recycling of damaged windshields and laminated building glass, which otherwise would be sent to landfill.





RECYCLE: Reprocessing materials to recover some of its properties

Purpose: Extend the lifespan of materials by processing them, in order to obtain the same or comparable quality for a wide variety of new applications.

Recycling includes any recovery operation by which material is reprocessed into products, materials or elements and substances that are retrieved through chemical or metallurgical processes, whether for their original or other purposes.

Recycling implies that the initial structure of a product is broken down and a new structure is formed. This can be the same as was established for the previous use-cycle (e.g. bottle-to-bottle or can-to-can recycling for beverage containers), but also a different use-cycle (e.g. PET bottle to polyester fabric).

How

Typical recycling steps include the following:

1. Collect discarded products locally and store.
2. Transport the products to central processing facilities, which costs and requires energy.
3. Where possible, extract the parts that can be recirculated as parts. The easier it is to remove decent quality working parts and the higher the value of the part in the overall product, the higher the likelihood that this can be implemented.
4. Separate those parts that are already of a decent quality and any hazardous materials.
5. Feed the rest into the deeper recycling process.
6. Shred everything.
7. Classify it. Classifying divides this output into a material mix that can be processed in the following sorting phase. The output is mostly classified by particle size. At the end of the process, there will be at least two different classes, which are distinguished by at least one dimension.

8. Sort. This could be achieved by density, with a magnetic or electric field, or by using other physical or mechanical characteristics of the material you want to separate. The chosen mechanism depends on the material mix.

9. Extract suitable materials from the process. From an economic and environmental point-of-view, it is beneficial if the materials are of high value and do not simply replace deadweight, which can be sourced in abundance from primary sources.

10. Restart this process, from step 5, for as long as it is economically feasible. In most cases, the separation of smaller parts requires a different machine from the one used previously. Certain processes will be more expensive because increasingly complex machines and processes will be needed to sort and separate the shredded materials.

11. Residues are sent to safe disposal, or where possible to recovery of specific compounds and substances.

Benefits

Safe and efficient recycling systems are a basic requirement for a circular economy, but they are not the first choice. Cases for which it is crucial to have advanced systems in place include:

- products and parts that are not in demand on the market; and
- products and parts that should not be transferred to a new use-cycle, due to low energy efficiency or the presence of substances and compounds that cannot be put on the market, due to changed legal requirements for authorisation and registration of hazardous substances.

Consider also

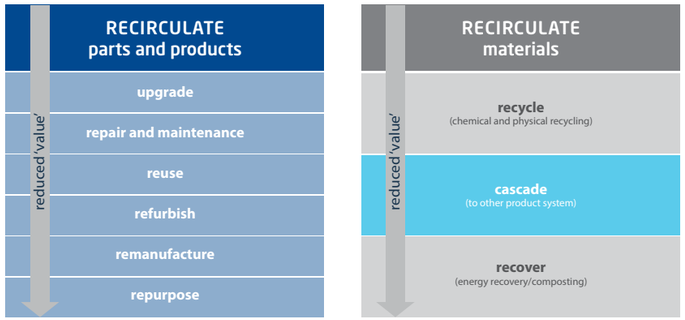
Recycling is challenged by the variety of materials used in the products (multimaterial) and by products' complexity, which may require advanced recycling technology for materials separation. If valuable materials are dispersed in a complex product, efficient separation requires high effort. However, critical raw materials and valuable constituents might be available in higher concentration than in natural mineral deposits.

Information on efficiency of recycling processes is not always transparent and needs to be evaluated carefully on a case-by-case basis.

Moreover, low volumes and concentrations of materials are economically infeasible for recycling.

Photo Kolar.io, Unsplash

Mondi Group optimises the use of virgin and recycled wood fibre by applying the cascading use principle.



CASCADE: Finding alternative uses for materials, accepting declining quality of properties

Purpose: A subsequent use that significantly transforms the chemical or physical nature of the material.

Cascading can, in short, be characterised as repurposing of materials, accepting declining levels of mechanical properties. The cascading process results in a material that is not suitable to be returned to the initial use-cycle.

Cascading offers options to retain the value added to products, before reverting to the option of energy recovery, in a subsequent step.

Typical examples include filling and insulation material for construction applications, which can be produced from used textiles that are not suitable to produce clothes. Outdoor furniture from recycled mixed plastics is robust and long-lasting. Biomass can be used in a metallurgical process as a reducing agent, which also means that more than the calorific value is retained.

Cascading is typically practiced in applications that require large flows. Cascading means that product materials are reused to extend resource timelines. However, in cascading, a new application usually has a lower demand for resource quality.

In a cascade strategy, a material starts its use-cycle at the highest quality possible and the quality of the material naturally declines over time. Every step of the cascade has a certain lifetime.

In accordance with the cascading strategy, the resource should be used in a new application, before the quality falls too low.

It is worth noting that quality decline is not necessarily the result of natural processes, over time. A decline in quality can also occur due to potential impurities of the materials to be cascaded (e.g. non-separation of post-consumer plastics into different polymers before cascading).

An additional influencing factor is the treatment strategy of products and materials at the end-of-use and end-of-life stages in earlier use-cycles. Products and parts might be considered to be unsuitable for separate recirculation

Photo by Javier Granadal, Unsplash

of products, due to the high effort required for separation. Similarly, recycling of materials to provide inputs for the original application requires clean and separate fractions to avoid a decline in structural properties.

In general, the process for cascading follows a similar structure as the recycling process (see steps 1-11 in previous strategy description).

Due to material mixes and insufficient efficiency of treatment processes, not all fractions provided during the procedure are suitable for a high-level recycling. In particular, fractions that are considered as residues can still contain constituents that are suitable for specific use-cycles.

The parameters to evaluate material quality are highly product dependent. As an example, textile products that are not suitable for applications where they are visible can be used on the inside of furniture. Where tear strength has deteriorated, fibres still keep their heat retention potential and are thus suitable as insulation material.

Benefits

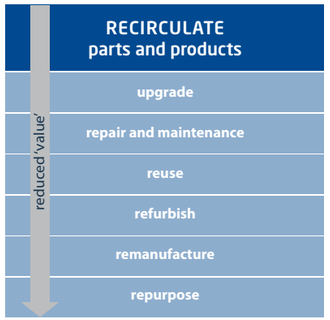
Cascading can be used to retain the value of large material fractions that are not suitable for other applications and would otherwise be treated as waste.

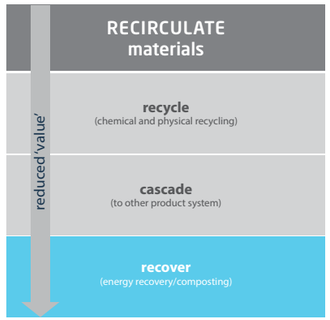
Consider also

Treatment steps in cascading can be described as non-reversible, if fractions are mixed to provide a specific property. In this case, it is preferable if the resulting product has a long-lasting use-cycle. As an example, outdoor furniture and equipment for roadworks made from mixed plastics fractions that are considered to be too difficult to recycle are robust and highly wear resistant. One the other hand, they can hardly be repaired once they are broken and are only suitable for energy recovery as a final additional use-cycle.

Photo Andreas Dress, Unsplash

The Danish town of Roskilde's waste-to-energy plant is extremely efficient, utilising up to 95% of the energy recovered from waste incineration.





RECOVER: Achieving energy or nutrients from the product or part, when all other options fail

Purpose: Recover energy or nutrients from composting or processing materials.

This includes the processes of incineration, pyrolysis and anaerobic digestion for the recovery of energy, and composting for the recovery of nutrients.

Energy and nutrient recovery should be limited to products, parts and materials that are not suitable for material recycling or cascading, either because processes for material recycling are not established, because there is no demand for secondary materials for any application, or because the demand is not meeting available supply.

Only a limited range of the initial material properties are extended to another use-cycle, for example, the calorific value that is used in energy recovery processes, or nutrients that are used when biomass is used for composting.

For energy recovery, it is essential that materials have a sufficient calorific value so the recovered energy covers and exceeds effort for logistics and flue gas treatment, as well as handling of solid residues.

Pyrolysis is suitable to produce gases, liquid and solid fuels, which can be used as process materials in another use-cycle.

Anaerobic digestion results in methane and solid residues, which need to be stabilised further to recover nutrients. These residues can then be applied to soils and contribute to closing the loop for nitrogen and phosphorus, among others.

Composting also results in a nutrient-rich product that can be applied on soils.

How

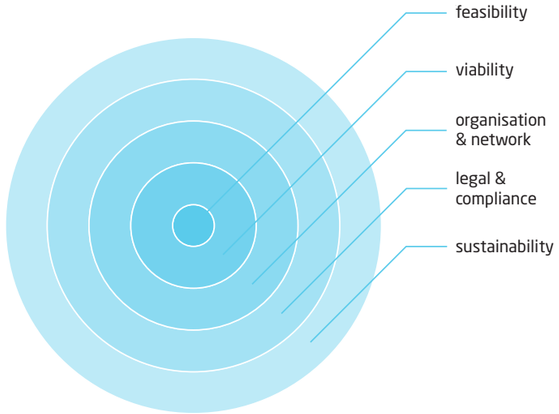
Collect, process (homogenise) and treat products and materials. Recovery processes might use similar steps as recycling or cascading, but aim to recover specific substances and fractions.

Benefits
Recovery processes are suitable to separate mixed fractions and extend the use-cycle for specific fractions.

Residues of biodegradable short-life products, which are not suitable for human consumption or as animal feed, can be used to provide a valuable and high-demand supply of nutrients.

Fractions with high calorific values can be used in energy recovery processes as fuel and replace natural raw materials, which are then available for other applications that utilise a wider set of properties.

Consider also
The processes described here are originally developed for waste treatment with the aim of separating and treating unwanted flows. Therefore, they are also designed to allow for a safe treatment of potentially hazardous residues.



2 Choosing recirculation strategy

Evaluating recirculation strategies from a market and product perspective

Having understood the nine recirculation strategies detailed in Part 1 of the workbook, Part 2 will help you to evaluate and choose a recirculation strategy for a given product.

This evaluation and choice can be achieved by considering the market- and product-oriented suitability of the recirculation strategies. Thereafter, an evaluation of the implementation potential is recommended.

Market & product decision tree
The decision tree will help you to evaluate the recirculation strategies from a combined market/product perspective, helping to identify which strategy best fits for the product under consideration.

Evaluation of the implementation potential
Having identified the potential recirculation strategies for the product under consideration, the next step is to evaluate the candidate recirculation strategies, with respect to requirements for implementation in the current context.

There are five evaluation criteria for the choice of recirculation strategy: feasibility; viability; organisation & network; legal & compliance; and sustainability. The order of these criteria (from feasibility through sustainability) implies an order of application, but not necessarily of importance. For an effective application of the evaluation to various cases, it is therefore recommended to work from the inside-out.

The evaluation of *feasibility* and *viability* adds more information about whether the recirculation strategy can be implemented with the expected benefits, or if the effort for the recirculation strategy considered surpasses positive outcomes. Recirculation processes thus have to be both technically feasible and viable, as a prerequisite.

Additionally, the resulting product, part or material must be actually used for a specific purpose that could not easily be satisfied, otherwise. When materials

that result from recycling or cascading compete with other bulk materials for generic applications (for example as ballast), the potential sustainability gains will be low.

An in-depth account of sustainability aspects related to Circular Economy is provided in Workbook 1, which is dedicated to sustainability screening.

General background information needs to be collected or estimated in preparation for an informed evaluation. It is recommended to identify and collect data describing both products and parts, and about recirculation strategies, in as much depth as possible.

While not all data may be available for all types of products in a quantitative form, initial indicative conclusions can be used to support the evaluation.

Ideally, the following information can be used for the evaluation:

- Bills of materials for products and parts, including presence of critical raw materials and high-value constituents.
- Assembly instructions for products and parts, with information regarding joining technologies.
- Availability of service processes for retro-logistics including collection, storage and transport.
- Disposal options and related environmental impact and regulation.
- Liabilities for products and parts that are recirculated, incl. warranty and producer responsibility.
- Demand for and availability of other stakeholders and network partners required and available to establish a closed loop.

Where data are not available in a quantitative form, the evaluation can be used to identify information gaps and indicate further requirements to confirm preliminary options for recirculation.

Feasibility addresses the potential of a recirculation strategy to be implemented in practice, based on the technical properties of a product, part or material and based on the performance and capacity of treatment processes.

Feasibility can be related to the item for which a recirculation strategy is planned and will then include sub-aspects, such as the assessment of the condition, according to industry standards.

Feasibility is also related to the process that needs to be implemented and whether it requires conditions, for example temperature and pressure, which can be provided on a sufficiently large scale.

For recirculation of products and parts, technical feasibility requires that the condition of a product can be assessed for safe application in an additional use-cycle, according to industrial standards.

If there are reservations due to lack of testing methods or reduced functionality, the product can be used to a certain, but more limited extent. Examples include reuse as-is without warranty, or refurbishment to working condition, with limited warranty.

Viability addresses the necessary effort to implement a recirculation strategy that is technically feasible. It can be assessed based on necessary tools for inspection, separation, cleaning, and the time required to perform handling processes.

Moreover, transport to a location where treatment is performed needs to be considered, as well as the need for storage of products intended for additional use-cycles.

Feasibility and viability are evaluated together, to understand if a product, part or material is in principle suitable for recirculation, and if the recirculation has the potential to contribute positively, from a sustainability perspective.

Organisation & network addresses whether there are any particular partners and networks needed to implement recirculation.

The need to establish a specific network for a particular recirculation strategy can be evaluated by mapping competences and expected volumes available in-house, considering whether they are sufficient in scope, competency, technology and capacity, to execute an independent recirculation strategy.

Alternatively, service providers will be needed for specific recirculation activities. Even competitors with similar challenges can become network partners, if individual volumes are limited. Moreover, buyers of used products can be introduced, to secure demand.

Existing networks and value chains also offer an opportunity to connect to and use their infrastructure, thus reducing organisational effort for establishing and implementing a recirculation. Workbook 6 focuses on the area of value chain collaboration and can be a good source of inspiration for the considerations to take when creating a collaborative network.

Legal & compliance aspects need to be evaluated thoroughly and can be related to specific cases. For sectors where safety critical functions have to be provided, recirculation of products and parts may be restricted, for example if the product contains chemicals that have become restricted subsequent to the product's initial release onto the market.

If legally required warranty durations and scopes cannot be met by a specific recirculation strategy, this can be seen as an exclusion criterion, even if an additional use-cycle is technically feasible and viable.

If end-of-use items have to be shipped across national borders to implement a specific recirculation strategy, it is necessary to establish whether permits for such can be obtained.

For some sectors, such as food packaging or medical equipment, specific regulations limit or prevent the use of secondary parts or materials, as they are seen as a safety risk; such aspects must also be checked and addressed.

If there are regulations regarding chemical content that must be applied for items placed on the market, it is required to establish for recirculation of products how regulations address products that were compliant when they were placed on the market in the first instance, but not with more recent versions. While continued use at the current owner is usually permitted to avoid retroactive effects, when products and parts enter a new use-cycle and are placed on the market, the regulatory authority might require that they comply with current legislation. This should be double checked, on a case-by-case basis.

To some extent, a similar effect needs to be addressed when energy-related products are recirculated as products or parts.

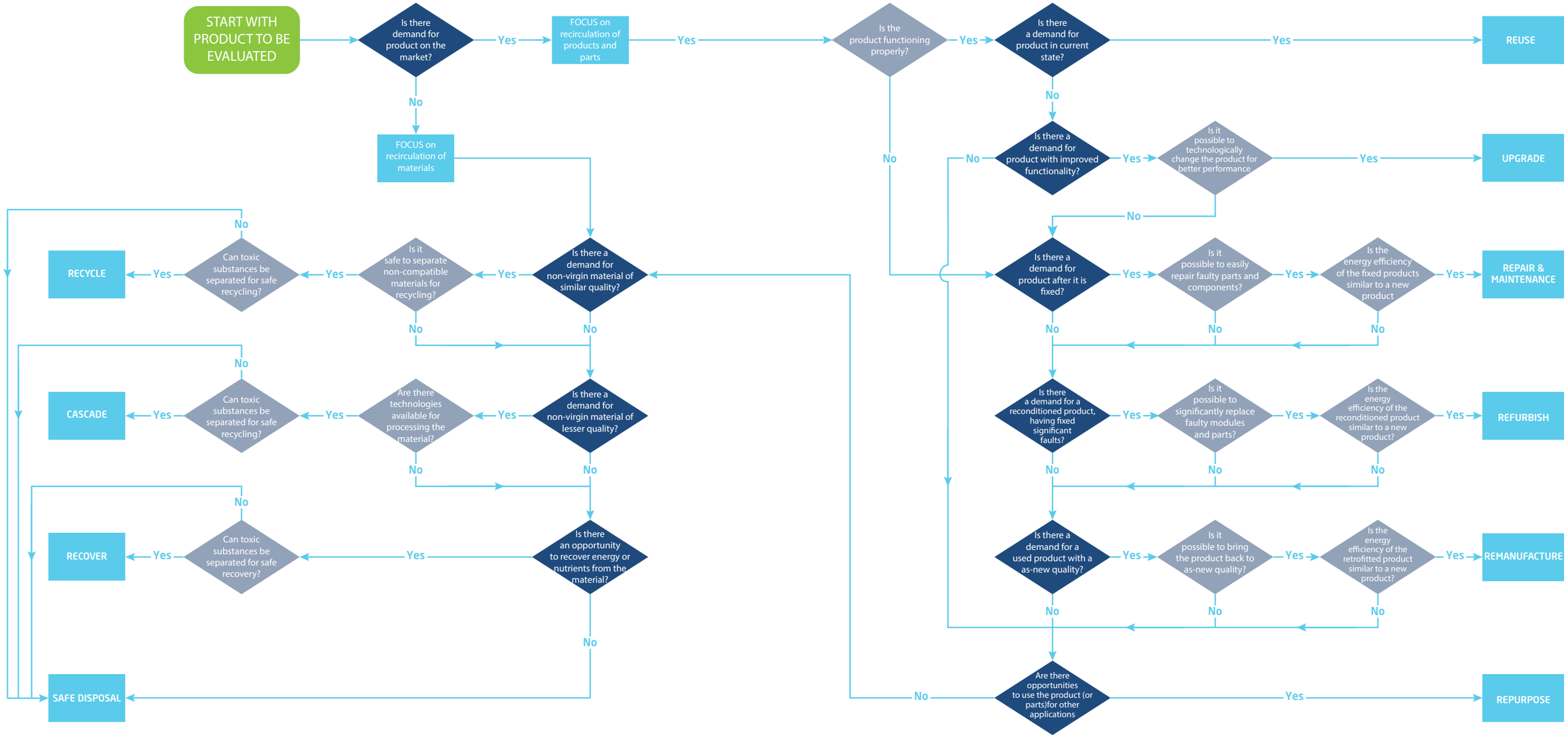
Moreover, safe treatment must be established for residues that cannot be recirculated, for example damaged wear-parts that are removed for remanufacturing, or mixed materials for which no demand on the market can be established.

Sustainability

Contribution to sustainability is the ultimate goal for all recirculation processes. The outer-most ring in the evaluation model relates to the potential contribution of a recirculation strategy to sustainability, understood from a triple bottom line (social, environmental, economic) perspective.

The evaluation of areas related to the technical aspects can be used to reveal whether a planned recirculation has a potential to reduce resource demand, which is a prerequisite for environmental sustainability. Recirculation is intended as a measure to reduce demand for virgin raw materials, which has a direct relation to energy usage and emissions from mining and processing. Thus, a potential to contribute to environmental sustainability is expected.

Recirculation that requires high effort may well end up having a lower environmental and economical sustainability potential, already from a process perspective.


START WITH PRODUCT TO BE EVALUATED
Is there demand for product on the market?
Yes
No
FOCUS on recirculation of products and parts
FOCUS on recirculation of materials
Is the product functioning properly?
Is there a demand for product in current state?
REUSE
Is there a demand for product with improved functionality?
Is it possible to technologically change the product for better performance
UPGRADE
Is there a demand for product after it is fixed?
Is it possible to easily repair faulty parts and components?
Is the energy efficiency of the fixed products similar to a new product
REPAIR & MAINTENANCE
Is there a demand for a reconditioned product, having fixed significant faults?
Is it possible to significantly replace faulty modules and parts?
Is the energy efficiency of the reconditioned product similar to a new product?
REFURBISH
Is there a demand for a used product with a as-new quality?
Is it possible to bring the product back to as-new quality?
Is the energy efficiency of the retrofitted product similar to a new product?
REMANUFACTURE
Are there opportunities to use the product (or parts)for other applications
REPURPOSE
Is there a demand for non-virgin material of similar quality?
Is it safe to separate non-compatible materials for recycling?
Can toxic substances be separated for safe recycling?
RECYCLE
Is there a demand for non-virgin material of lesser quality?
Are there technologies available for processing the material?
Can toxic substances be separated for safe recycling?
CASCADE
Is there an opportunity to recover energy or nutrients from the material?
Can toxic substances be separated for safe recovery?
RECOVER
SAFE DISPOSAL

What now?

Resource effectiveness has been identified as an important contribution of recirculation strategies to sustainable development. Existing products that are already on the market and have reached a stage, where they are no longer reliable, not performing satisfactorily, or are not functioning at all, offer additional opportunities as a source of secondary products, parts or materials.

Closing the product cycle is a relevant approach for industry to retain value that has been created at some stage in the economy, while similarly avoiding that valuable land is used as landfill for discarded goods. Benefits and drawbacks can be explored to identify potential uses and therefore propose different recirculation strategies.

The overall evaluation of recirculation strategies for products, regarding their contribution to a sustainable circular economy, needs to consider aspects related to the product and what contributes to its value. This will provide a first indication of which recirculation strategy is in principle applicable, following the descriptions in this workbook.

Equipped with a thorough overview of recirculation strategies; a decision-support to evaluate the market- and product-related suitability of considered recirculation strategies; and a method to evaluate the implementation potential of chosen strategies, the next step is to begin to investigate how to pilot such a strategy. Workbook 1 provides a structured process and methodology to follow, in order to carry out a sustainability screening of the candidate recirculation strategy, based on a database of sustainability performance indicators.

And Workbook 6 provides support regarding how to go about identifying value chain partners and collaborative opportunities, to achieve especially the recirculation strategies that focus on keeping products and parts in circulation.

The CIRCit website (**www.circitnord.com**) provides additional tools and examples, to help guide you with the next steps in closing the loop for a sustainable Circular Economy.

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Nordic
Green Growth

This workbook provides an assessment tool and guidelines to support the identification of the best circular strategy for products, taken back at the end of use.

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