



Circular economy – the design perspective.  
From theory to implementation







# Executive summary

Circular economy starts on the drawing board. Only when designers, manufactures, producers, and purchasers understand the environmental and social impacts throughout the life cycle of material selection and design, we will be able to achieve a true circular economy. Today, only 12 percent of materials used in Europe comes from recycling<sup>1</sup>, but with better understanding of material use and design for circularity we can work together to increase this number.

The growth of our societies and the companies within them can in large be ascribed to the utilization of raw materials. We need materials to produce the goods to build the wind-mills, the electrical cars and ferries that we need for a low-carbon future, but we also need to develop an industry that can provide sustainable materials that are ethically sourced, produced with low emissions, longer lasting and recyclable. Our planet can only produce, renew and supply a finite amount of resources, and even in cases where there is abundance, extraction and mining come with a footprint. This implies that we need to use our materials more efficiently and ensure that we keep them in the loop for as long as possible.

The European Union (EU) has undertaken an ambitious strategy in form of the European Green Deal, which aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where

there are no net emissions of greenhouse gases and where economic growth is decoupled from resource use. In March 2020, the EU presented its Circular Economy Action Plan – a future-oriented agenda for achieving a cleaner and more competitive Europe. The Action Plan aims at accelerating the transformational change required by the Green Deal, while building on circular economy principles<sup>2</sup>.

As an aluminium producer, we take great interest in material selection and design. In this paper we want to share with you the knowledge and insights we have gained from our work with customers across the manufacturing industry in order to better understand the role of design in general and aluminium in particular to develop a greener manufacturing industry. Whether you are a designer, engineer, architect or sustainability practitioner, we hope this paper will provide new perspectives and knowledge on how to achieve circular economy in your work. Our purpose is to create a more viable society by developing natural resources into products and solutions in innovative and efficient ways.

We need to collaborate across the entire value chain to make it happen.

Are you with us?

<sup>1</sup> [https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=cej\\_srm030&plugin=1](https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=cej_srm030&plugin=1)  
<sup>2</sup> [https://ec.europa.eu/environment/circular-economy/pdf/new\\_circular\\_economy\\_action\\_plan.pdf](https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf)



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# Circular economy

The circular economy provides solutions for how to create more out of less.

Since the industrial revolution and up to now, the use of raw materials has followed the principle of “supply and demand”. Economic theory describes the relationship between the quantity of a commodity that producers wish to sell at various prices and the quantity that consumers wish to buy<sup>3</sup>. For raw materials, however, the problem is that there is only a finite amount, meaning that when there is less of something, prices do not only go up, but we have to use less and start looking for ways to develop alternative materials.

From 1970 to 2017 the annual global extraction of materials tripled, and it continues to grow day by day, which poses a major risk to our environment. According to the UN<sup>4</sup>, about half of the world’s total greenhouse gas emissions and more than 90 percent of biodiversity loss and water stress can be ascribed to resource extraction and processing of materials, fuels and food. It becomes increasingly clear that today’s linear economic model of “take, make, use and dispose” is reaching its physical limits and must be replaced. But with what exactly?

A shift towards a greener economy is needed. The transition offers an opportunity to expand sustainable and labor intensive economic activity. Circular economy provides solutions for how to create more value out of less resources and offers great opportunities for innovation and business creation for those who master it, for instance, there is a significant potential in global markets for low-emission technologies, sustainable products and services. The circular economy also offers vast opportunities for new activities and jobs<sup>5</sup>.

## **Taking the leap from a linear to a circular economy**

Today, our economy remains too linear and dependent on the extraction, trade and the conversion of raw materials into goods, and finally, the disposition of the product as waste or emissions. While a linear economy harvests, produces, uses and disposes materials (what is often referred to as cradle-to-grave), a circular economy strives to reduce resource use, losses and waste to a minimum, keeping resources in circulation as long as possible and ultimately recovering and regenerating materials and products. Thus, circular economy is much more than recycling and use of renewable resources. It means having better designed products which can easily be dismantled and effectively recycled, and then put into use again and again (cradle-to-cradle).

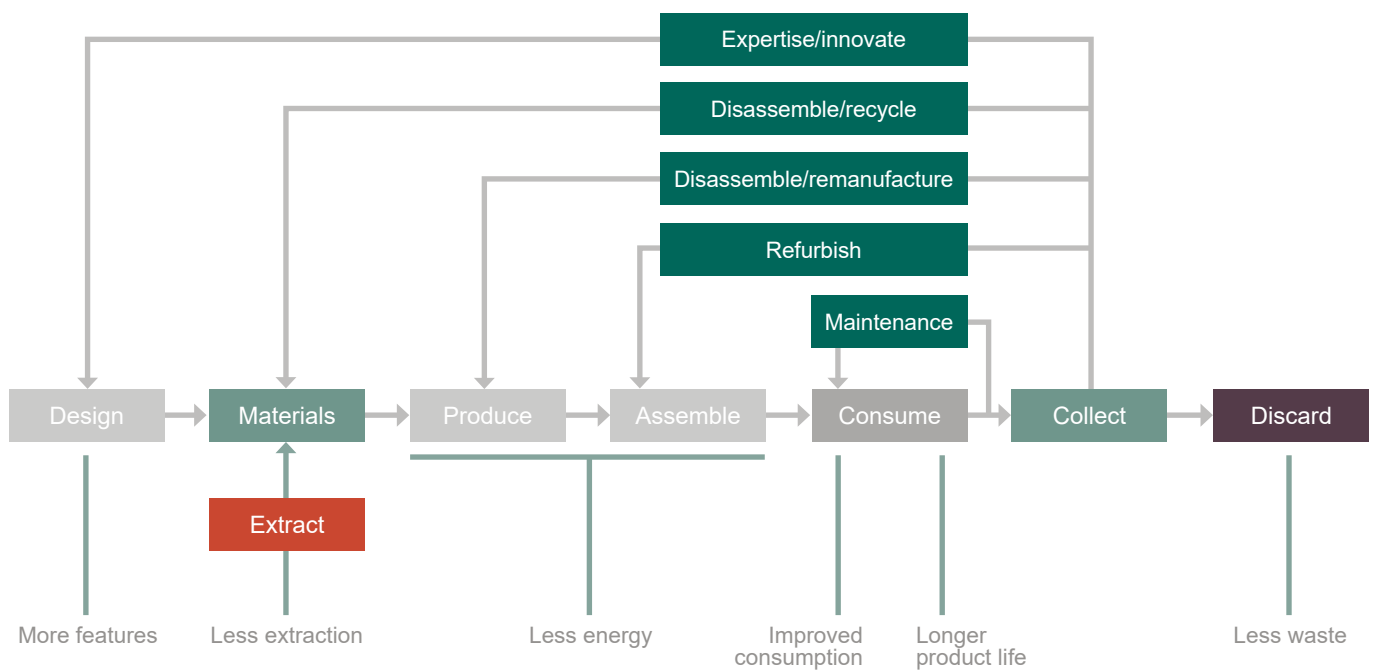
<sup>3</sup> <https://www.britannica.com/topic/supply-and-demand>

<sup>4</sup> <https://www.unenvironment.org/news-and-stories/press-release/un-calls-urgent-rethink-resource-use-skyrockets>

<sup>5</sup> European Commission (2019). “The European Green Deal”.

*"Circular economy is defined as an economic system aimed at eliminating waste and the continual use of resources."*

#### CIRCULAR ECONOMY FLOW



#### LINEAR ECONOMY FLOW





# The Circular Economy Action Plan

In March 2020, the European Union presented its Circular Economy Action Plan, which provides a future-oriented agenda for achieving a cleaner and more competitive Europe in co-creation with economic actors, consumers, citizens and civil society organizations. The Action Plan aims at accelerating the transformational change required by the Green Deal, while building on circular economy actions implemented since 2015.

In short, the plan presents a set of interrelated initiatives to establish a strong and coherent product policy framework that will make sustainable products, services and business

models the norm while at the same time transforming consumption patterns so that no waste is produced in the first place.

Today, many products break down too quickly, cannot be easily reused, repaired or recycled, and many of them are made for single use only. However, the circular economy and greener solutions can be implemented in products, services and industries, and in both small- and large-scale operations, and it all starts at the drawing board. Below we take a closer look at seven concepts that can help organizations achieve circularity.





## 7 concepts to achieve circularity<sup>6</sup>

The full application of circular economy is diverse within the Hydro organization, due to the broad mix of products and solutions, including energy, billets, rolled products, building systems and extrusions. Here's seven concepts that can help organizations looking to achieve circularity.

### Concept 1 – Refuse and Rethink

The first concept is about changing behavior and the way we think about products, by forgoing certain products or using them more intensively. Before using or producing something, pause for a moment and reconsider the need for materials or the types of materials used. On a larger scale, the concept includes rethinking business models and service delivery models, see how new ways of working can improve functionality, service level and footprint. Platforms for sharing cars or tools ensure that those products are used more intensively. One shared electric drill could be enough for 10 households instead of them each buying their own drill.

### Concept 2 – Reduce

Reduce is about manufacturing products more efficiently or making them more efficient to use, or why not both? By designing and making products using materials more efficiently, and by making them more resource efficient in the use-phase, we can limit the need for raw materials and thereby reduce the product environmental footprint. One example of efficient products reducing the need for new resources are water recycling showers.

### Concept 3 – better and longer lifetime

This concept is related to design and is about using a finished product better and longer. Better designed products improve performance and durability, they age better and add value. Moreover, products that have integrated or embedded dismantling and recycling in the design and development phase will provide benefits at end of life. Dismantling will be faster and easier, which leads to better segregation of parts and materials. Recycling starts at the drawing board, implying that we should consider the repair and re-use of the product already at the initial phase. Questions for designers to ask themselves: Can this product be repaired, by whom, and is it possible to use the product or its materials again?

<sup>6</sup> Rood and Kishna (2019), Outline of the Circular Economy. PBL Netherlands Environmental Assessment Agency, The Hague.

### Concept 4 – Re-use me

Re-use is defined as the action or practice of using an item, whether for its original purpose (conventional re-use) or to fulfil a different function (creative re-use or repurposing). The ‘re-use me’ concept is about extending a product’s life cycle. Materials that would otherwise be wasted or discarded are either kept for alternative use or improved, such as through re-manufacturing, repairing, upgrading and re-marketing.

By extending the lifespan of products for as long as possible, companies can keep material out of landfill while also discovering new sources of revenue. ‘Re-use me’ challenges companies to design products for modular use, modification, easier disassembly or deconstruction, such as the IKEA DELAKTIG modular sofa. The advantage is that it becomes easier to separate and recycle materials in the future.

### RE-USE ME

“Re-use me” is about extending the product life cycle. It is about going the extra mile. Materials that would otherwise be wasted or discarded are either kept for alternative use or improved, such as through re-manufacturing, repairing, upgrading or re-marketing. By extending the lifespan of products for as long as possible, companies can keep material out of the landfill while also discovering new sources of revenue.

Some companies have their own re-manufacturing activities or ask external companies to do it for them, so it is key for Hydro engineers and designers to understand what use the component that is designed today might have in the future. This helps to reduce costs, waste, greenhouse gas emissions and raw material needs on the long run.

- **Alternative or modular** use of the object.  
The IKEA Delaktig sofa is a perfect example.
- **Inverted supply chain**, with re-manufacturing or refitting after materials and components are returned.

“Re-use me” challenges you to design products for modular use, modification, easier disassembly or deconstruction, such as for a window. The advantage is that it becomes easier to re-use, and then separate and recycle the materials in the future.





## Concept 5 – Recycling: Go for the closed loop

We can distinguish between two main recycling principles: open-loop and closed-loop recycling. **Open-loop recycling** uses materials that can be recycled but which will downgrade at each cycle. That does not make it bad, but such materials cannot be re-used endlessly because something is intrinsically lost at every cycle. Concrete, bricks, paper and wood are some examples. Plastic can usually be recycled only a few times. Closed-loop recycling on the other hand, uses and re-uses materials that can be continuously recycled, without loss of qualities and with less energy or resources. Aluminium is one such material, and also other metals and glass.

As aluminium can be recycled many times, we refer to it as a **permanent material**. Aluminium is 100 percent recyclable, it can be recycled again and again without losing its characteristics and has a very high return-rate from the time the end of life phase is reached. Producing recycled aluminium from post-consumer scrap only requires five percent of the energy it takes to produce primary aluminium. That is why it is important to ensure that all post-consumer aluminium scrap can go back into the loop.

### OPEN- OR CLOSED-LOOP RECYCLING

#### OPEN-LOOP RECYCLING

This uses materials that can be recycled, but which will "downgrade" at each cycle. That does not make it bad, but such materials cannot be re-used endlessly because something is intrinsically lost at every cycle. Concrete, bricks, paper and wood are examples. Plastics can usually be recycled only a few times.

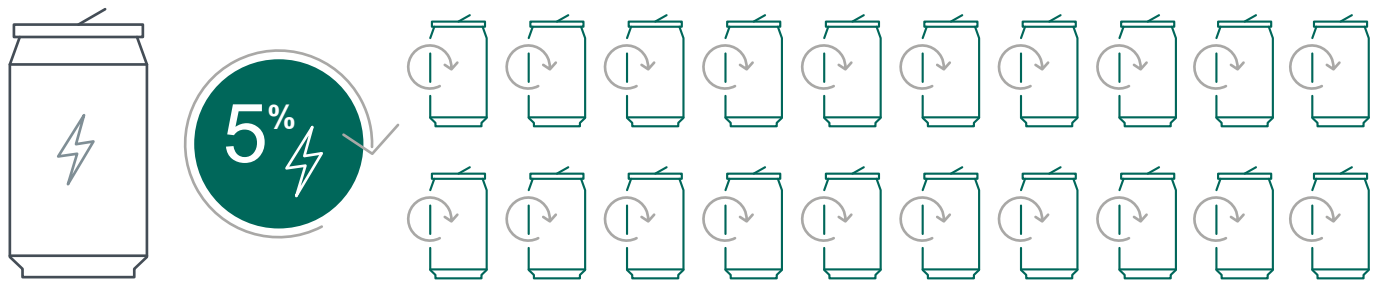


#### CLOSED-LOOP RECYCLING

This uses and re-uses materials that can be continuously recycled, without loss of qualities and with less energy or resources. Aluminium is one. Others include glass and other fellow metals. Closed loop has a strong focus on supply chain sustainability.



<sup>7</sup> Aluminium estimated recovery rate >95 percent for building and construction sector in Europe



### Concept 6 – Take-back

Recycling a product into something new is nice, but recycling for the same use is even better. We call this the ‘take-back’ concept. For aluminium, advantages include less segregation of alloy qualities, less carbon footprint, perfect proof of recyclability, shorter and stable supply chain and reduction of leakage of scrap to other applications and/or regions. Recycling is a comprehensive process, but by take-back the process is simplified, and quality is higher<sup>8</sup>.

### Concept 7 – Renting and leasing with services

Leasing cars is familiar to most of us, but what if we could use a similar concept for some of our finished products? The idea could also be adopted for larger and more complex objects such as building materials and energy infrastructure. How about renting windows, facade structures or even elevators? This would mean a business disruption of the traditional manufacturing industry which would transform not only the financing of projects and products, but also the operating model of companies providing such services. Today, several companies offer their customers to rent products that they need and through the lifetime of use, purchase maintenance, spare parts and services. By providing the product only for the time needed, not only is the initial investment cost reduced for renters, but the physical product can be re-deployed and re-used time and time again for other customers. Also, this would generate revenues for companies, and we can call it “product as a service”.

<sup>8</sup> Hydro is one of the partners in AUF (Aluminium und Umwelt im Fenster- und Fassadenbau) which is a non-profit association in Germany that promotes the closed-loop recycling of aluminium profiles used in buildings. The association contributes toward saving primary resources and consequently, reducing the associated environmental impacts. AUF supports the collection of post-consumer profiles mainly used in windows, doors and curtain walls from buildings at their end of life, and the collection of pre-consumer scrap for profile manufactures in Germany. The profiles collected in this way are then recycled into new profiles, with no change in quality or performance compared to profiles produced with primary aluminium.





## IKEA DELAKTIG – circular economy and aluminium

"I would hope to see the bed or sofa in 20 years being used in a completely unexpected functionality – one that I did not predict myself in the first place. That would be success," says industrial designer Tom Dixon.

IKEA, the world's largest furniture retailer, invited Tom Dixon to discuss doing something special. Both brought ideas to the table. Aluminium brought them together.

Something special turned into IKEA DELAKTIG, a product platform based on circular-economic principles. In simpler words, it is modular furniture that can be disassembled and rearranged into completely different pieces of furniture.

"Aluminium is the catalyst behind DELAKTIG," says IKEA's creative leader James Futcher.

"Initially, there were many ideas being discussed and then Tom presented this idea of challenging the way sofas are made today. And we saw that aluminium could help us make a platform that was changeable over time as your life changes," says Futcher. "We also wanted to use a strong long-lasting material that you could easily add things to."

"This is where the idea of an open-source sofa was born. Once we started to work with the material, we could quite easily see the possibilities of how to use the grooves in the aluminium for fitting products on to."

### Naturally anodised finish

Aluminium is the right material for DELAKTIG because it is light and strong, and because adding features is easy once the metal has been extruded into a profile. "It also looks good," says Futcher.

The finish for the frame is a naturally anodised process. This extra layer on the surface of the aluminium makes it more scratch-resistant and protects it from corrosion. Window frames typically use natural anodising for the finish.

Using aluminium also gives you the opportunity to make a strong knock-down construction," says Futcher. "It will last for a long time and can be handed down in generations."

And that's the idea: That DELAKTIG products can be reused instead of being thrown away. That a sofa can be turned into a chair, a chair into a bed. And so on.

# Design for recycling

The key to a circular economy is planning for a product's life cycle already at the drawing board. What if products were designed to be re-used instead of being thrown away?

In a circular economy, design comes first. This emphasizes the importance of good design, focusing on respecting the resources while reusing other materials. Today, too many products cannot be recycled because they are too difficult or expensive to take apart. To create a circular economy, we need to start with design and material selection, choosing recyclable materials and designing products in a way that makes them easy to send back into the loop.

There are generally three things that you should know about sustainable design. The first is material selection and understanding how to choose a sustainable material. Make sure to carefully assess the carbon footprint from a life cycle point of view. How much of the material is required compared to another material to obtain the same effect, such as strength? How long will the product last and what is the maintenance required? You can find more information about material selection in chapter 2.

Secondly, design for recycling implies easy repair and re-use. You should make sure to ask yourself: Can this product be repaired? By whom? Can I use the product or its material again? Finally, production and knowing how to assemble the product is key. Know that similar materials do not need to be separated, which improves the recycling rate. For mixed-material combinations, mechanical fasteners such as bolts, screws, snap-fit and interlock joints make it easy to disassemble and recycle the product when it is no longer in use.

## Design concepts for circular economy

While respecting the fundamental goals of design, sustainable design aims to reduce the negative impact of a product or a solution on the environment and people's health. There is a consensus that sustainable design extends to the whole life cycle of the object and works to reduce consumption of non-renewable resources, minimize waste, allow re-use, improve recycling and ultimately increase the overall quality of a product.

Until recently, the inclusion of sustainability or environmental considerations was not an integrated part of product design and production. However, the world is changing, and professionals today embed those aspects in their products. The best way to embrace and implement sustainability in design is when industrial designers, engineers and architects collaborate. Therefore, in the following we propose three different concepts that are centered around recognized and tangible principles used today by experienced designers and product engineers: ten principles for good design, ten golden rules for EcoDesign and ten advices for Design for Disassembly.



## DESIGN CONCEPTS



### principles for Good Design

- is innovative
- makes a product useful
- is aesthetic
- makes a product understandable
- is unobtrusive
- is honest
- is long-lasting
- is thorough down to the last detail
- is environmentally friendly
- is as little design as possible



### golden rules for EcoDesign

- toxicity
- housekeeping
- weight
- energy
- upgrading
- lifetime
- protection
- information
- mix
- construction



### advice for Design for Disassembly

- know the field
- document
- document more
- simple tooling
- limit materials
- limit permanent fixes
- clever markings
- easy access to parts
- avoid dangerous stuff
- modularity

# Ten principles for good design – Dieter Rams

Already in the 1970's, renowned German designer Dieter Rams (2009)<sup>9</sup> introduced the idea of sustainable development and of obsolescence being a crime in design, through his ten principles for good design:

1. Good design is **innovative**. The possibilities for progression are not by any means exhausted. Technological development is always offering new opportunities for original designs. But imaginative design always develops in tandem with improving technology and can never be an end in itself.
2. Good design makes a product **useful**. A product is bought to be used. It has to satisfy not only functional, but also psychological and aesthetic criteria. Good design emphasises the usefulness of a product while disregarding anything that could detract from it.
3. Good design is **aesthetic**. The aesthetic quality of a product is integral to its usefulness because products are used every day and have an effect on people and their well-being. Only well-executed products can be beautiful.
4. Good design makes a product **understandable**. It clarifies the product's structure. Better still, it can make the product clearly express its function by making use of the user's intuition. At best, it is self-explanatory.
5. Good design is **unobtrusive**. Products fulfilling a purpose are like tools. They are neither decorative objects nor works of art. Their design should therefore be both neutral and restrained, to leave room for the user's self-expression.
6. Good design is **honest**. It does not make a product appear more innovative, powerful or valuable than it really is. It does not attempt to manipulate the consumer with promises that cannot be kept.
7. Good design is **long-lasting**. It avoids being fashionable and therefore never appears antiquated. Unlike fashionable design, it lasts many years – even in today's throw-away society.
8. Good design is **thorough** down to the last detail. Nothing must be arbitrary or left to chance. Care and accuracy in the design process show respect toward the consumer.
9. Good design is **environmentally friendly**. Design makes an important contribution to the preservation of the environment. It conserves resources and minimises physical and visual pollution throughout the lifecycle of the product.
10. Good design is **as little design as possible**. Less, but better – because it concentrates on the essential aspects and the products are not burdened with non-essentials. Back to purity, back to simplicity.

<sup>9</sup> Rams, D. (2009). Dieter Rams: ten principles for good design. From Vitsoe.com: <http://www.vitsoe.com/en/gb/about/dieterams/gooddesign>











## Vaan R4 – the world's fully recyclable yacht

In 2019, the Dutch start-up Vaan presented the world's most sustainable luxury sailing yacht to the market. The Vaan R4 is a catamaran made almost entirely of circular materials, including recycled aluminium from Hydro.

"One of the biggest industry challenges today is that many of the products designed and produced are too difficult or expensive to take apart and recycle when they are no longer in use. We are proud to work with a visionary company like Vaan to address these challenges, and to contribute to the first fully recyclable yacht. The yacht is built with our 100 percent recycled aluminium, consisting of 75 percent post-consumer scrap," says Marijn Rietveld, Director Offshore and Marine in Hydro.

The new yacht addresses one of the biggest challenges of modern production, specifically: how to make sustainable products. In the leisure boat industry, few boats are recycled when they are no longer in use. Every year, 78,000 boats are scrapped and burned in in Europe, causing large CO<sub>2</sub> emissions. Less than three percent are being dismantled.

The Vaan yacht is made from circular materials that can be recycled when it is no longer in use. A key material in the Vaan R4 is the Hydro 75R alloy, made of minimum 75 percent recycled post-consumer metal, which is now used at sea for the first time.

### Designed for disassembly

To improve the percentage of materials that go back into recycling, products need to be designed with a full life cycle perspective in mind starting at the drawing board. This idea is new to the marine leisure boat industry, with the Vaan R4 representing a future-oriented approach.

"The yacht industry is quite a traditional industry where sustainability is not a top priority, which is why we wanted to make a luxury yacht with no negative impact to the environment. Developing a truly circular solution requires collaboration along the entire value chain. Hydro's expertise has been invaluable in making this a truly circular product with recycled aluminium," says Igor Kluin, founder and CEO of Vaan.

In addition to aluminium, the yacht is made of other natural materials, such as lyocell (an alternative to silk), a plant-based alternative for leather made of pineapple leaves, cork, linen, and certified wood.

# Ten golden rules for EcoDesign

## – Luttrupp and Lagerstedt

Conrad Luttrupp at KTH Royal Institute of Technology and Jessica Lagerstedt's at Lund University have developed '10 Golden Rules in EcoDesign' to help product designers integrate environmental demands into the product development process. These rules also embrace the properties and qualities of aluminium profiles, making aluminium a wise selection for sustainable products. The ten golden rules are:

1. **Toxicity:** limit the use of toxic substances and, where such substances are essential, try to arrange closed material loops.
2. **Housekeeping:** review your routines to minimise energy and resource consumption in production and transport.
3. **Weight:** choose materials and designs that minimise the weight of the product.
4. **Energy:** think about how the end product will be used and try to minimise the user's energy and resource consumption.
5. **Upgrading:** design the product to allow upgrading and repair, especially for long lifespan and system-dependent products.
6. **Lifetime:** optimise the product for its intended working life.
7. **Protection:** invest in durable materials and surface treatments to protect the product.
8. **Information:** prepare for upgrading, repair and recycling through accessibility, labelling, modular construction and manuals.
9. **Mix:** mixing materials affects recyclability. Try to use as few materials as possible in simple forms.
10. **Construction:** use as few joining elements as possible, and avoid the unnecessary use of screws and bonding, and look for intelligent geometric solutions.





*Through uniting experts we can develop products that can be recycled and go back into the loop – starting already at the drawing board. This chair is made out of 100 per cent recyclable aluminium and was designed by Tom Dixon for Hydro.*

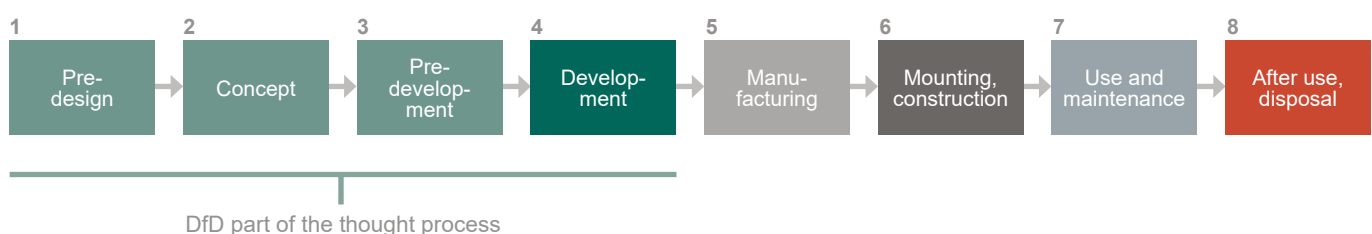
# Ten tips for Design for Disassembly

Design for Disassembly (DfD) is a design approach that considers a future need to disassemble the product for repair, improvement, refurbish or recycling. Alongside with the ‘take-back’ approach, DfD is the perfect application of applying circular economy on a product level. Products (from a simple chair to buildings) that follow this approach are intentionally designed for material recovery, value retention and possible next or alternative use. Here are the ten tips for how to design for disassembly:

1. **Know the field:** visiting recycling facilities and talking to specialists, strippers, repair companies and the like will give valuable insight and information.
2. **Document:** create documents on materials, design and processes. Prepare your bill of materials and communicate it accordingly, so the stripper knows what he or she will have in hands.
3. **Document more:** provide a disassembly or deconstruction manual, especially when specific or delicate operations are required. Bare careful to mention any hazard that could occur during operations.
4. **Simple tooling:** whenever possible, unless security and safety is involved, favor standard tooling and limit fasteners types and dimensions.
5. **Limit materials:** limiting materials make a product easier to sort and recycle once disassembled.
6. **Limit permanent fixes:** glues and sealants make the separation and recycling more difficult, and some of them will actually increase the ecological risk.
7. **Clever markings:** labelling and markings of connections and materials contribute to efficient disassembly, reassembly and deconstruction.
8. **Easy access to parts:** easy access to parts will make operations faster and safer, for instance by allowing space for tooling insertion and movements.
9. **Avoid dangerous stuff:** select materials using the precautionary principle, with consideration for future impacts. Choose materials that are not harmful for people or the environment, that have high quality and will retain value for recycling or reuse.
10. **Modularity:** using elements, shapes and materials that endorse interchangeability, modularity and standardisation will facilitate product durability, maintenance, reuse and repair.

## DESIGN FOR DISASSEMBLY (DFD) IN A DESIGN PROCESS

Thinking of DfD works best when it is included in the product design from its earliest stages:





*“Design for Disassembly (DfD) is the process of designing products so that they can easily, cost-effectively and rapidly be taken apart at the end of the product’s life, so that components can be reused and/or recycled”*

**Concept: the CHALLENGES of DfD are when? How and by whom will disassembly happen?  
Ask yourself or your customer the following questions:**

- *Will the product need to be repaired or maintained?*
- *Which parts may need a replacement?*
- *Who will repair and maintain it?*
- *Can the experience be easy and intuitive?*
- *Can the product be retaken, refurbished and resold?*
- *How far should we disassemble?*
- *If it must be discarded, how can we facilitate its disassembly into easily recyclable components?”*

To embed DfD in a design process, we advise the following:

- Ask your customer about dismantling and after-use
- Ask the “Challenges questions” (see frame above)
- Put a goal statement at the beginning of the process:  
*“The design of this solution will endorse DfD in order to allow efficient manufacturing, mounting, use, re-use, reduce weight, make repairs and maintenance easier and faster, and which will ultimately favor economics and environment. It will be documented accordingly.*
- Add DfD in your product checklist design reviews





*We are aluminium*

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Hydro is a fully integrated aluminium company with 35,000 employees in 40 countries. Rooted in more than a century of experience in renewable energy, technology and innovation, Hydro is engaged in the entire aluminium value chain, from bauxite, alumina and energy to primary aluminium, rolled and extruded products and recycling.