Circular economy – the life cycle approach. 
From theory to implementation
Executive summary

Circular economy starts on the drawing board. Only when designers, manufacturers, 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\(^1\), 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 windmills, 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 Commission (EU Commission) has undertaken an ambitious strategy in form of the European Green Deal, which aims to transform the EU Commission 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 Commission 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\(^2\).

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?

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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. 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, 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.

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).

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3 https://www.britannica.com/topic/supply-and-demand
"Circular economy is defined as an economic system aimed at eliminating waste and the continual use of resources."

CIRCULAR ECONOMY FLOW

LINEAR ECONOMY FLOW
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

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?
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 fulfill 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\(^7\) 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.

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**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.

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\(^7\) 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.

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”.

8 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.
“Did you know that nearly 75% of all aluminium ever produced is still in use?”
Life cycle analysis

With the new EU Green Deal, measuring the life cycle impacts of products and materials will become increasingly more important and may become a requirement by law. The new EU circular economy action plan, launched in March 2020, announces initiatives along the entire life cycle of products, targeting for example their design, promoting circular economy processes, fostering sustainable consumption, and aiming to ensure that the resources used are kept in the EU economy for as long as possible.⁹

In addition to increasing recycled content in products and reducing carbon and environmental footprints, the Circular Economy Action Plan sets out to reward products based on their different sustainability performance, including by linking high performance levels to incentives. This means there is a need to measure and benchmark the sustainability of products throughout their life cycle. Examples are tools for reducing emissions from construction and buildings is using Level(s) to integrate life cycle assessment in public procurement and the EU sustainable finance framework and exploring the appropriateness of setting of carbon reduction targets and the potential of carbon storage.

Tools and processes that evaluate the full life cycle impacts of products and services will become increasingly important for those looking to make environmentally sound choices in design, material use and purchasing. Both methodology and regulations are increasingly moving towards accounting for and publishing life cycle impacts.

Life cycle assessments, so called LCAs, are good decision-making tools when selecting materials and design options for products and services. LCAs take into account all emissions and energy consumptions for each and every step in the life cycle of a building or a product and calculates the total environmental impact.

The new EU circular economy action plan will amongst other things look at environmental footprint, and the Product Environmental Footprint (PEF) will likely be considered as reference methodology to be used in legislation.
Life cycle assessment (LCA) methodology

Life Cycle Assessment (LCA), also known as Life Cycle Analysis, is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product’s manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave).

LCA addresses the environmental aspects and potential environmental impacts throughout a product’s life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal. The purpose of performing an LCA is to document the environmental and climate impacts associated with the product and its life cycle, and to support decision making to improve the environmental performance of the product.

LCA can assist in identifying opportunities to improve the environmental performance of products at various points in their life cycle, informing decision-makers in industry, government or non-government organizations or the selection of relevant indicators of environmental performance, including measurement techniques. LCA results can also be used in marketing such as eco-labelling, environmental claims, or producing environmental product declarations (EPDs).

An LCA study according to ISO 14044:2006 consists of four main steps: scoping, inventory analysis, impact assessment and data interpretation.

The scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. For some products cradle-to-grave is the scope selected, others include recycling and thus cradle-to-cradle life cycle assessment is applied.10

Product Environmental Footprint (PEF)

Product Environmental Footprint guide (PEF) is a somehow type of life cycle assessment methodology developed by the European Commission's Joint Research Center (JRC) and has been developed in the context of the European Commission's 2020 strategy – “A Resource-Efficient Europe.”

The PEF is a multi-criteria measure of the environmental performance of a product or service throughout its life cycle and is produced for the purpose of seeking to reduce the environmental impacts of goods and services, taking into account supply chain activities, from extraction of raw materials, through production and use, to final waste management. For different product categories there are different rules to be applied which should make sure that the aspects that matter the most in each product category are not ignored. The approach is still in its testing phase.11

Environmental Product Declaration (EPD)

An Environmental Product Declaration (EPD) is an independently verified and registered document that communicates transparent and comparable information about the life cycle environmental impact of products. An EPD is defined by the International Organization for Standardization (ISO) as a declaration that quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. Companies implement EPD’s in order to improve their sustainability goals, and to demonstrate a commitment to the environment to customers. An EPD is a so-called Type III environmental declaration in accordance with ISO 14025, and developed out of demand for a standard of comparison between different products. Although EPD’s are primarily intended to facilitate business-to-business transactions, they may also be beneficial to consumers who are environmentally focused when choosing goods or services.

EPDs show the most significant environmental aspects of a particular type of product, showing objective and verifiable information about the environmental impacts of the product/service. For the construction sector in Europe, the EN 15804 Standard defines how companies should work to create their EPD.

EPDs give you the environmental impact of the material from these impact categories like:

- GWP – Global warming potential, in kg CO2 equivalents per kg (or other functional unit) of product
- ODP – Depletion potential of the stratospheric ozone layer
- POCP – Formation potential of tropospheric photochemical oxidants
- AP – Acidification potential of land and water
- EP – Eutrophication potential
- ADPM – Abiotic depletion potential for non-fossil resources
- ADPE – Abiotic depletion potential for fossil resources

In addition to environmental impacts from the product life cycle, an EPD can also express what happens with the product at the end of its useful life, for example when the building is torn down and materials are sorted. An EPD shows how much can be sorted, recycled and subsequently and turned into new products.

For those looking for comparisons of products using independently verified EPDs, common databases such as Öko-baudat, GABI, EPD Norge, InData Network and Environdec are renowned sources. The EPD is normally valid for three years, or five years for construction products.
The aluminium life cycle

From mining bauxite to tailor-made products and recycling – as a fully integrated aluminium company, we create value throughout the entire life cycle. Aluminium has a life cycle that few other metals can match. It is corrosion resistant and can be recycled over and over again, requiring just a fraction of the energy used to produce the primary metal. This makes aluminium an excellent building material – reshaped and repurposed to meet the needs and challenges of different times and products.

"Did you know that our new climate strategy – “30 by 2030” – calls for a 30% reduction of own CO2 emissions throughout the aluminium value chain by 2030. We will do this through greener sourcing, greener production and greener products."
1. Bauxite Mining

Aluminium production starts with the raw material bauxite, which contains 15-25 percent aluminium and is mostly found in a belt around the equator. There are around 29 billion tonnes of known reserves of bauxite and at the current rate of extraction, these reserves will last us more than 100 years. There are, however, vast undiscovered resources that may extend the time perspective to 250-340 years.

2. Alumina Refining

Using the Bayer process, alumina (aluminium oxide) is extracted from bauxite in a refinery. The alumina is then used to produce the primary metal at a ratio of 2:1 (2 tonnes of alumina = 1 tonne of aluminium).

3. Primary Production

The aluminium atom in alumina is bonded to oxygen and needs to be broken by electrolysis to produce aluminium metal. This is done in large production lines and is an energy-intensive process, requiring a lot of electricity. Using renewable power and continuously improving our production methods, is an important means to meet our goal of being carbon neutral in a life cycle perspective by 2020.

4. Fabrication

Hydro supplies the market with over 3 million tonnes of casthouse products annually, making us a leading supplier of extrusion ingot, sheet ingot, foundry alloys and high-purity aluminium with a global presence. The most common uses of primary aluminium are extruding, rolling and casting:

- **Extruding**
  Extrusion allows for shaping aluminium into almost any form imaginable using ready-made or tailored profiles.

- **Rolling**
  The aluminium foil you use in your kitchen is a good example of a rolled aluminium product. Given its extreme malleability, aluminium can be rolled from 60 cm to 2 mm and further processed into foil as thin as 0.006 mm and still be completely impermeable to light, aroma and taste.

- **Casting**
  Creating an alloy with another metal changes the properties of aluminium, adding strength, brilliance and/or ductility. Our casthouse products, such as extrusion ingots, sheet ingots, foundry alloys, wire rods and high purity aluminium, are used in automotive, transport, buildings, heat transfer, electronics and aviation.

5. Recycling

Recycling aluminium takes only 5% of the energy required for producing the primary metal. Also, aluminium doesn’t deteriorate from recycling and 75 percent of all aluminium ever produced is still in use. Our goal is to grow faster than the market in recycling and take a leading position also in the recycling part of the aluminium value chain.
Labelling, certifications and standards

Voluntary sustainability standards systems are market-based tools, designed to address the most pressing social and environmental challenges of our time. There are a range of different standards that a company can follow, and many of them have a proven track-record of delivering impacts at a global scale on the sustainability issues that matter most, such as ISO, Cradle to Cradle® or the aluminium specific ASI certifications.

ISO 14044
ISO is an independent, non-governmental international organization with a membership of 164 national standard bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant international standards that support innovation and provide solutions to global challenges. The ISO 14000 series is developed by ISO to help organizations to reduce their impact on the environment. The ISO 14044 standard covers LCA studies and life cycle inventory (LCI) studies. ISO 14044 specifies requirements and provides guidelines for LCA including: definition of the goal and scope of the LCA, the inventory analysis, impact assessment (LCIA), interpretation, reporting and critical review of the LCA, as well as limitations of the LCA and conditions for use of value choices and optional elements.13

Cradle to Cradle®
The Cradle to Cradle Certified Product Standard is rooted in the Cradle to Cradle® design principles established by William McDonough and Dr. Michael Braungart. Standard requirements are developed through a stakeholder engagement process with input from technical experts, market leaders and the public. To receive certification, products are assessed for environmental and social performance across five critical sustainability categories: material health, material re-use, renewable energy and carbon management, water stewardship, and social fairness. A product is assigned an achievement level for each category: Basic, Bronze, Silver, Gold, Platinum.14

ASI
The Aluminium Stewardship Initiative (ASI) is an industry-led initiative to drive sustainability across the entire aluminium value chain. Certification to the ASI Standards enables the aluminium industry, as well as the users of aluminium, to demonstrate their commitment to social, environmental and ethical standards. The ASI certification scheme enables producers and industry users of aluminium to demonstrate in a credible way that they uphold the highest environmental, social and ethical standards and are applicable to the entire aluminium value chain, from bauxite mining over refining and smelting to material conversion. The standards also apply to industrial users of aluminium, such as the automotive industry and the packaging materials sectors.

BS 8001
The British Standard Institution (BSI) is the national standards body of the United Kingdom. The BS 8001 guiding principles set out by BSI as a practical framework to help guide organizations to simplify and identify what is relevant to them when transitioning to a circular economy. BS 8001 is the first practical framework and guidance of its kind for organizations to implement the principles of the circular economy and has been written in way so that it can be used wherever they are in the world. It is intended to apply to any organization, regardless of location, size, sector and type. Based on six simple principles, it will ensure implementation in projects or concepts. These six include15 Systems Thinking, Innovation, Stewardship, Partnership, Value Optimization and Transparency.16

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13 https://www.iso.org/standard/38498.html
15 Adapted from BS 8001
In 2011, Hydro became the first producer in the world to receive a C2C Silver certificate for our light poles. The products are designed to reduce waste. Hydro also established a system in which we take the light poles back for recycling at the end of their life-cycle. By incorporating circularity, we use less raw materials in the supply chain. When using C2C certified light poles from Hydro, you receive a guarantee that the light poles are 100 percent recyclable, made with renewable energy, in compliance with strict water use guidelines, and that they are manufactured in an environment where social responsibility is the standard.
Next steps

Initiatives to trigger circularity

There is no magic formula or fixed set of actions to make a project or product circular. There are indeed many ways to do it, by putting the right initiatives together. Some require small efforts while others are more challenging.

Until a few years ago, circularity was quite difficult to measure, and the analysis were mainly based on assumptions, an un-coordinated approach. Today, several certifications or standards are existing that can give a performance on circularity features (like Cradle-to-Cradle® certification or ASI), while additional standards and framework are being currently developed (internationally and at a national level), to include circularity assessments.
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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.