Danfoss Sustainability Paper No. 2

Decarbonization Explained

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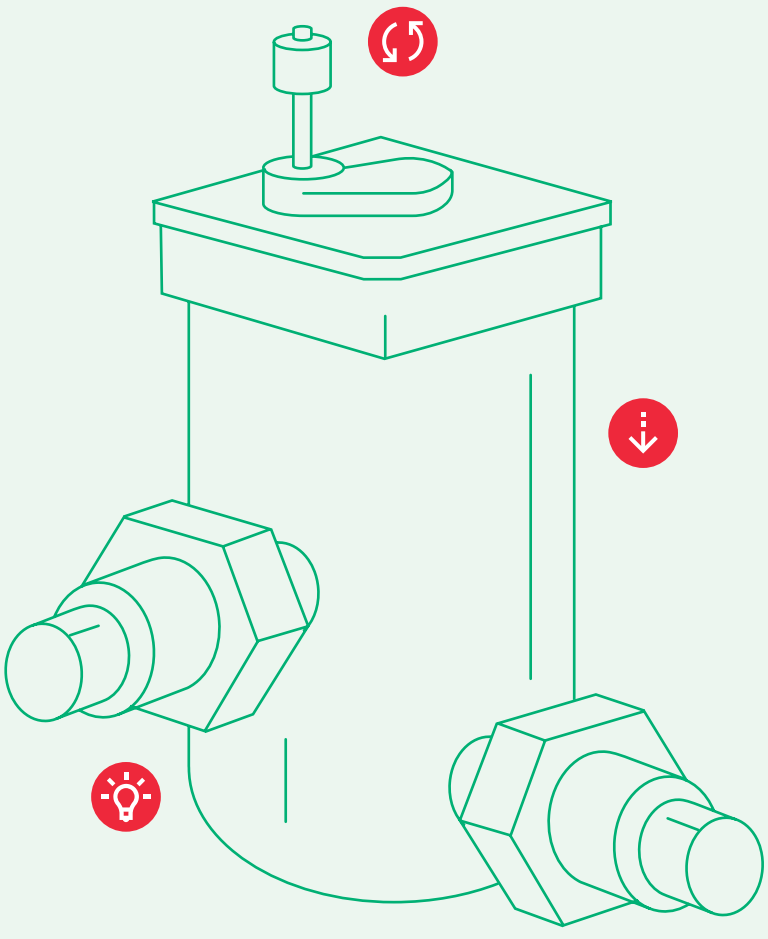
Circularity in action

A framework for sustainability in product innovation



Executive summary

Today, 96.8% of the world's resources are not cycled back into the global economy at end of life.[1] At the same time, the global population consumes 1.75 times the resources that the Earth can regenerate[2] and resource extraction is projected to increase by 60% by 2060.[3] In the current linear model of "take-make-waste", a vast majority of our natural resources are not utilized efficiently.

The circular economy has the potential to unlock $4.5 trillion of economic opportunity through increased resource efficiency and sparking innovation, including new business models on reuse, repair, remanufacturing, and product-as-a-service.[4] According to the Ellen MacArthur Foundation (EMF), a circular economy can boost Europe's resource productivity, generate cost savings of €600 billion a year, and €1.8 trillion more in other economic benefits.[5] And that's just Europe. Imagine the economic and environmental potential at a global scale.

As key raw materials become increasingly scarce and more costly to extract and contest, keeping resources in circulation is critical. This makes the transition from a linear system of "take-make-waste" to a circular one - where resources are kept in circulation, waste and pollution are avoided, and nature is regenerated - even more essential.

As we seek to address these challenges, we have a tremendous opportunity to succeed by looking into how we produce our products today. **It all starts with innovation. To engineer the products for tomorrow, circularity must be an integrated part of the innovation cycle from the beginning.** Embedding circularity principles into research and development (R&D) enables organizations to reengineer pipelines of more resource-efficient, circular, and sustainable technologies for the future. By redesigning products with circularity in mind, we can achieve the biggest impact at scale. Putting the right tools in place for product innovation is key to bring about this change.

While pursuing circularity in product development unlocks many exciting opportunities, it also involves navigating **complex design trade-offs** across the lifecycle of a product. Therefore, it is important to equip innovation organizations with a toolbox that enables the understanding of the impact of sustainable design choices, from material selection to carbon emissions. A holistic approach is key, with focus on sustainability and circularity at a systems level.

Circularity is not only an environmental imperative. It is also a business imperative that drives innovation, reduces costs, and opens up new revenue streams.

To close the circularity gap, transparency across systems and value chains is important for collective progress. In this paper, we present the Danfoss Circularity Framework - product innovation toolbox, cases, and learnings, with the aim of sparking industry **engagement and enhancing circularity practices through shared insights, continuous improvement, and collaboration.**

It all starts with innovation and design

A more circular economy starts with innovation and the design of products. Design can be a force of change from linear to a more circular economy. Waste – in the form of materials waste and stemming from traditional business models – is ultimately the result of design decisions. Circular and sustainable innovation is one of the important levers to address waste and increase resource efficiency.[6]

Up to **80% of products' environmental impacts are determined at the design phase**.[7] Circularity decisions – such as the type of material, assembly method, business model, and expected lifespan – made during the early design stages significantly influence a product's sustainability and circularity performance over the product lifecycle many years into the future. The average lifecycle of industrial components ranges on the order of years, and decades in some cases. Changing technology takes time. This is why we start with product innovation.

Circular product design and decarbonization go hand-in-hand

To date, efforts to tackle the crisis have been focused on the transition to renewable energy, which addresses 55% of global greenhouse gas (GHG) emissions. Circularity is needed to complete the picture of emissions reductions through how we make and use products.[3] The Ellen MacArthur Foundation estimates that 45% of GHG emissions reductions needed to reach Net Zero can be reduced through circularity.[8]

Implementing circular product design practices can ensure that substantial emissions are avoided from the get-go. Embedding circularity and the relevant tools within new product development is a necessary part of the equation of tackling product-related value chain emissions, and at the same time, continuing to engineer the more sustainable products needed for the green transition.

The role of regulation in circular product design

Regulation plays a crucial role in driving the transition to a circular economy by setting frameworks, metrics and thresholds that encourage sustainable practices. Recent regulatory developments are key to reshaping how products are designed, ensuring they prioritize resource efficiency, durability, repairability, and recyclability, which are essential for achieving circularity and addressing environmental and economic challenges.

Circular design has steadily increased in importance on the political agenda over the last decade. In 2020, the European Commission launched their second comprehensive Circularity Action Plan. With this action plan, new legislative initiatives will shape the future market for manufacturers, with focus on material efficiency and recirculation of resources. Additionally, regulations on waste minimization and recycling, packaging, extended producer responsibility, and the right to repair are being introduced.

Circularity has become a global policy trend, both because of its important role in the green transition and to stabilize supply chains. This is evident from regulations and directives such as the recently adopted Ecodesign for Sustainable Products Regulation (ESPR), which significantly widens the scope of the current Ecodesign Directive[9], the directive for electrical and electronic waste (WEEE)[10], the critical raw materials act[11], and the EU taxonomy including circular economy.[12]

"Innovation is the driving force behind the transition from the linear economy of "take-make-waste" to a circular one, where resources and products are used as efficiently as possible."

Frances Iris Lu
Vice President
Head of Sustainability & ESG
Danfoss

The challenge of measuring circularity

Circular economy is highly complex. At present, there is no universal consensus on approaches and methods to design products for circularity, nor a common metric to quantify circularity, although steps, such as the Material Circularity Indicator (MCI)[13], have been taken. This poses a major challenge to companies in quantifying and measuring circularity progress and performance. To this end, it is important to identify which aspects of circular design lead to a greater sustainability impact.

There are a growing number of standards and frameworks both in Europe and internationally. Current challenges and limitations include, guidance that is not fully operable, leaving room for interpretation, and the selective use of circularity indicators. Often, what is most easily measured is prioritized. This has resulted in disproportionate focus on recycling, over, for instance, refurbishment, remanufacturing, reuse, and accessibility and disassembly of critical components for repair and preventive maintenance, important loops in the Ellen MacArthur Foundation's butterfly diagram, ensuring a continuous flow of materials in a circular economy. To build effective frameworks and measurements with the intended sustainability impact, we must take a holistic approach to circularity.

Circular design tools and metrics are essential to enable more circular product designs. However, companies face another challenge in identifying and selecting the right tools. Research has shown that while more than 92 approaches exist for circular business model innovation, only five were regularly applied in companies.[14] Selecting the appropriate approach and the right tools from the existing range poses a challenge.[15]

By selecting tools that provide a holistic assessment of circularity, with a range of qualitative and quantitative indicators, and putting a focus on metrics across all circularity loops, significant advancements can be achieved in the design of new products.

A disproportionate focus

Often, what is most easily measured is prioritized. This has resulted in disproportionate focus on recycling, over, for instance, repair, remanufacturing and design for disassembly.

Adopting the loops of the EMF butterfly diagram

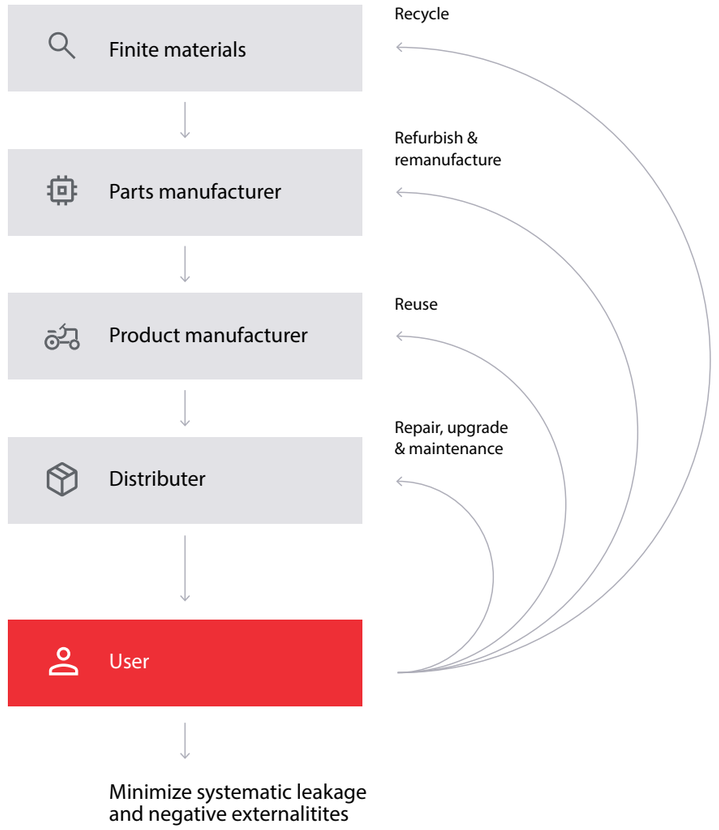


Figure 1: As a Member of the Ellen McArthur Foundation, we embrace 'thinking in systems' - circularity is not a one product or one company job. It requires engaging with stakeholders across the entire value chain to engineer the right solutions.

To guide our transformation, the technical cycle of the Ellen MacArthur butterfly diagram has been adopted. As both a part and product manufacturer we have broad presence in the butterfly diagram. The inner loops are where most value can be captured as more of the value embedded in a product is retained.

Circularity at every level

One of Danfoss' three step-change initiatives on sustainability is circularity, due to its importance in the transition to a low-carbon and circular society, as well as for the pivotal role the manufacturing industry can play in it.

By placing circularity at heart of Danfoss sustainability ambition, we aim to drive the operational changes needed to deliver sustainable **long-term value creation.**

At Danfoss, we engineer products and solutions that enable us to do more with less – by using resources smarter and more efficiently – both in our operations and our products. To operationalize this principle for circularity, we have developed a framework and tools to embed circularity in our existing innovation process and enable engineers and product design teams to make the right decisions from an early point in the design phase.

Promoting sustainable and circular design within the manufacturing sector isn´t a one-size-fits all approach, yet best practices are emerging. We follow the steps recommended for implementing circular product design in an organization (EN 45560).[16] First is formalizing our mission to deliver the best circular products to our customers into clear goals. Our goals embed circularity in all innovation with a target on newly developed products, while continuously scaling existing circular initiatives by increasing circular business revenues.

Step-change initiative 1

Decarbonization

CO_2

Step-change initiative 2

Circularity

Step-change initiative 3

Diversity, Equity & Inclusion

DE&I

Cascading circularity

Building on existing standards and frameworks, we have developed a robust, holistic framework, which empowers informed decision-making on sustainability and circularity during innovation and product design.

We are pleased to share this framework and invite for feedback and open dialogue with organizations and companies. **By disclosing our approach in this paper, we seek to continuously enhance global circularity practices through transparency, shared insights, and collaboration.**

Levels of circular product design		Implementation
Goals	Circular Goals defined as part of strategy.	**25%** increase of circular business revenues by 2030 from a 2023 baseline. **80%** of newly developed products launched are covered by Danfoss circularity approach by 2030.
Strategies	Identify and optimize circular strategies relevant for our markets.	**3 Principles** Rethink, Reduce, & Recirculate with **10 strategies.**
Guidelines	Determine the applicable circular product enablers for each strategy.	The strategies consist of **30 guidelines** for product design.
Design	Translate the circular attributes into specific circular design requirements and track progress.	Tools implemented into the new product development process.

Figure 2: Levels of circular product design and their implementation in Danfoss.

A framework for action

To solve the challenge of embedding and measuring circularity in innovation, Danfoss has developed 10 Sustainability Strategies, which are important inputs during new product development. The identified strategies are divided into 3 guiding principles: Rethink, Reduce, and Recirculate. The three principles, together with the ten strategies, capture the product lifecycle.

Consideration of one aspect in isolation does not secure circularity – only through a holistic view of the product from design to end-of-life can we unlock the full circularity potential. The three guiding principles ensure that sustainable design strategies promotes the circular loops, as well as efficient resource use throughout a product's lifetime:

Rethink involves fundamentally reassessing the product design and business model at the early stages of design innovation. This includes aspects such as changing the product design to improve disassembly and modularity to retain long-term value or rethinking the business model by shifting from selling a product to providing a service, transforming the circular value of the product.

Reduce is often connected to the manufacturing stage of the product and includes strategies that lower the environmental impact of the product. This includes design and sourcing to decrease (virgin) material and energy consumption and to reduce waste and increase energy efficiency during manufacturing, logistics and packaging.

Recirculate looks towards the end of a product´s life, to retain the most value from products, components, and materials. Divided into two aspects, this includes product and component lifetime extension through reuse, repair, and remanufacturing, or material recycling at end of life.

The three principles and ten underlying sustainable strategies are visualized in the Danfoss Sustainability Strategies Wheel, building on research papers that were part of the CIRCit Nord project and Danish Design Center´s Circular strategies wheel.[17,18]

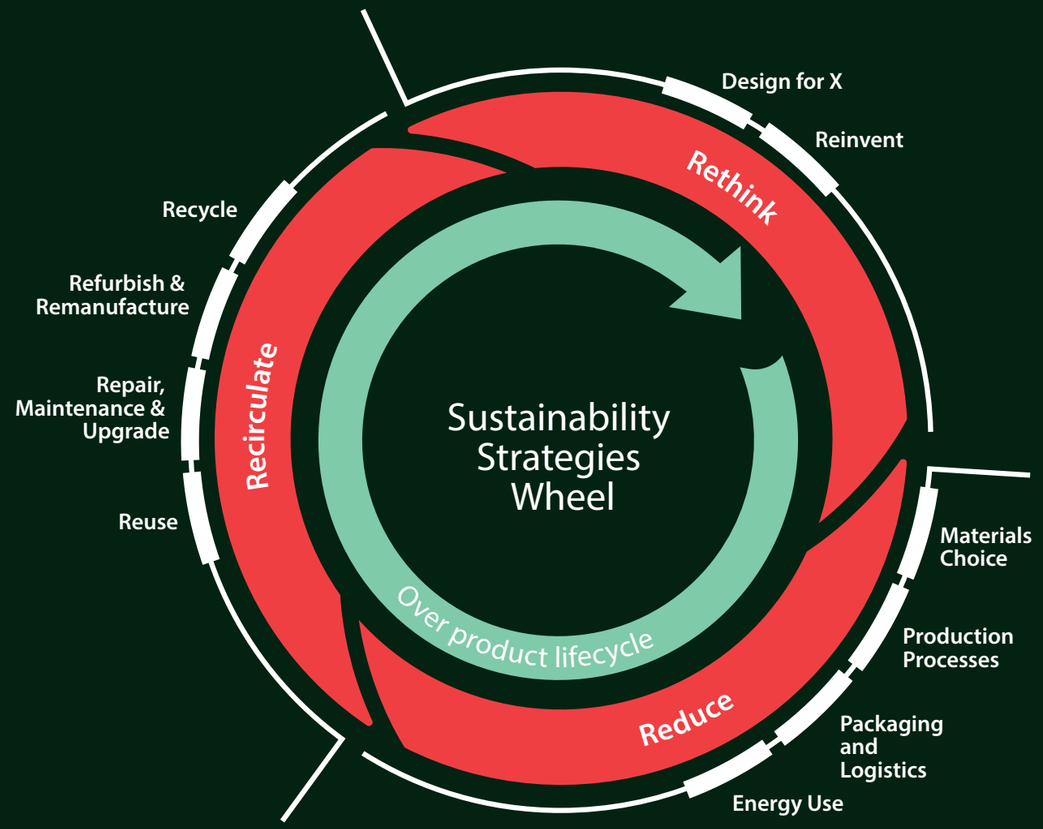


Figure 3: Danfoss Sustainability strategies wheel.

The sustainability strategies

The 10 sustainability strategies have 30 targeted guidelines that, when implemented in product development, promote circular design. These 30 guidelines have been identified as the most relevant for a global industrial company, such as Danfoss, through pilots and co-creation across the organization. As knowledge on circularity evolves, the design strategies and recommended guidelines will be kept up to date to continually elevate the lifecycle of our products.

The 3 overarching principles, with the 10 Sustainability Strategies and underlying 30 guidelines are described below.

These circularity principles, strategies and guidelines have formed the basis of the Danfoss Sustainable Design Guide. The purpose of this guide is to operationalize circularity, by providing explanations, practical guidance, and examples to the product development teams across the organization and around the world.

Principle 1

Design and reinvent

Design for X – an umbrella strategy that covers design principles that are crucial to ensure opportunities for end-of-life value creation. It involves the following three guidelines: **1** Designing for disassembly, **2** durability, and **3** modularity.

Reinvent – concerns **4** rethinking the business model behind the product, **5** designing towards dematerialization and digitalization, 6 adding complementary functions and capabilities.

Principle 2

Minimize energy consumption

Materials choice – 7 prioritize minimizing material use while favoring high recycled and renewable content, **8** select low carbon materials, **9** minimize material complexity by promoting use of similar material grades, **10** consider material abundance to avoid critical raw materials and scarce materials, **11** select non-hazardous materials.

Production processes – 12 repair and reuse products not meeting quality requirements during production, **13** consider low consumption manufacturing processes (energy efficiency, renewable energy, water consumption), **14** reduce waste, and **15** find use of waste streams.

Packaging & logistics – 16 selection of materials for packaging and logistics options that have improved sustainability profile by considering aspects such as recycled content, recyclability, reduction of packaging volume, efficient design etc.

Energy Use – 17 looking into ways to reduce the energy consumption during use always striving to be better than the industry standard and **18** optimize the energy demand in a system level.

Principle 3

Close the loop

Reuse – 19 Consider compatibility with old products, **20** enable reusability of parts or components of the products.

Refurbish & remanufacture – 21 Enable accessibility of critical components, and **22** ensure product and materials traceability. **23** Enable the refurbishment or remanufacturing of products so that they can create continued value.

Repair, maintenance & upgrade – 24 making repairs and maintenance possible, **25** making sure spare parts are available, **26** use standard components, and **27** make the product upgradable.

Recycle – 28 provide repair and recycling manuals, **29** avoid material combinations that complicate recycling, and **30** ensure recyclability of the product and components at the end of life.

"Our Sustainability Strategies Wheel is a great example of how we can put the Danfoss sustainability and circularity strategy into action by integrating it into our key innovation processes."

Torben Christensen
Chief Sustainability Officer &
Head of Global Services
Danfoss

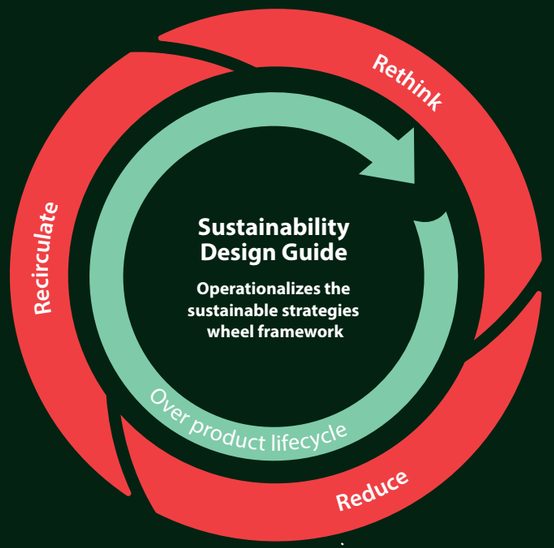
Engineering the tools for circularity

We measure what we value, which is why Danfoss seeks to assess circularity holistically. No single indicator can measure the multifaceted aspects of circularity. The Danfoss Sustainable Design Guide is supported by a suite of quantitative and qualitative tools and guides, that each contribute to an informed decision-making process.

Given the breadth of Danfoss´ product portfolio, the importance of each of the 30 guidelines varies from product to product. It is therefore important that the toolbox supports product development teams in navigating the nuances of circular design. Not all circular strategies will be applied every time, but R&D teams are equipped to optimize circularity performance on the aspects that are most relevant for the specific product in hand.

A need for a comprehensive circularity toolbox

We measure what we value, which is why we seek to holistically assess circularity. No single indicator can measure the multifaceted aspects of circularity.



RE:CIRC
Qualitatively assesses the sustainability performance and identifies high-impact areas for product improvements.

Carbon footprint tool
Calculates the lifecycle carbon footprint of the product.

Green material guide
Guidance on carbon footprint and circularity potential of materials.

Circularity index tool
Quantitively measures the circularity potential related to material and component efficiency.

Sustainable packaging tool
Measures the sustainability of packaging concepts with an index.

Danfoss negative list
Bans or restricts the use of chemical substances in Danfoss' products.

Figure 4: Danfoss sustainability toolbox.

Case 1: Modularity enabling maintenance and remanufacturing of pumps

The modular design of our Series 90 and H1 High Power Pumps ensures ease of adaptation for diverse applications, allowing configuration of pumps to meet a broad range of customer needs. This same modular flexibility has now enabled a robust circular aftermarket strategy centred around remanufacturing, where pumps are returned to their original performance standards. The versatility of the Series 90 and H1 design demonstrates how sustainability potential can be unlocked with strategic product design.

In Brazil we trained and authorized our distributor Mecanizza to remanufacture Series 90 High Power Pumps. The pumps are applied in sugar cane harvesters and instead of repairs, the Remanufacturing offering has been a way to recirculate the pumps in a manner that significantly reduces downtime of the machine during the harvest season. The pumps re-enter the supply chain as good as new and with a new warranty including updated serial numbers for tracking purpose. The remanufactured products undergo rigorous testing to meet the same standards as our new products, reinforcing our promise of delivering sustainable high-quality products. Moreover, we are in the process to expand our Remanufacturing business further.

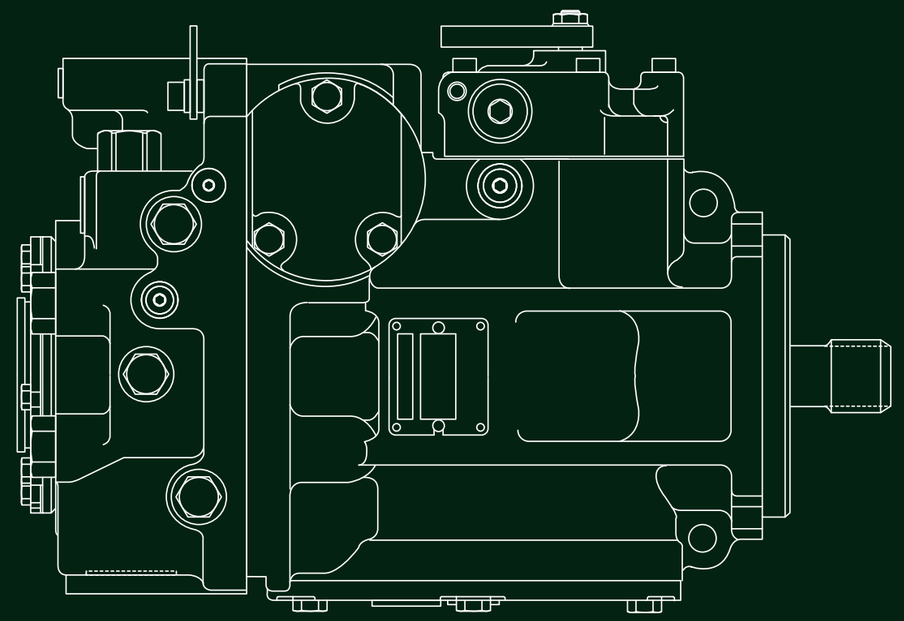


Figure 5: The Danfoss Series 90 High Power Pump converts input torque into hydraulic power. Its modular design allows for versatile applications and supports sustainability by enabling remanufacturing to original performance standards.

During implementation, we have a series of workshops with innovation teams across Danfoss, where we apply the tools and investigate first hand, what opportunities exist in improving the circularity of our products from the design.

RE:CIRC

Our qualitative assessment tool, RE:CIRC, has been tailored to assess the 30 guidelines across all product development efforts. Drawing on insights from existing research[19], RE:CIRC assesses the circularity and sustainability performance of a product, providing R&D teams with the foundation to make informed design decisions. RE: CIRC assess each of the 30 guidelines based on both relevance and the current level of fulfilment, identifying where the greatest potential for improvement lies.

This in turn advances improvements in the next steps of the innovation process and enables continuous improvement in design. The RE: CIRC tool, including the guidelines and thresholds for fulfilment, has additionally been third party validated.

Together with RE: CIRC, additional tools to support robust and objective quantitative metrics and calculation have been developed.

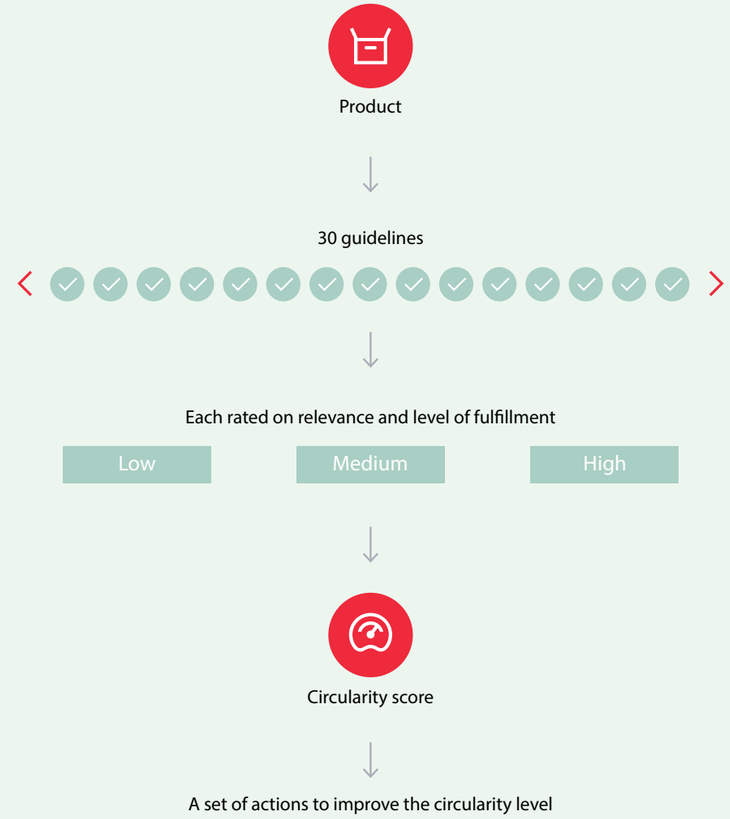


Figure 6: The RE:CIRC assesment model

Circularity index tool

One such tool is the Danfoss Circularity Index, which quantifies the circularity of a product´s material flow. The Danfoss Circularity Index draws on the work from the EMF's Materials Circularity indicator and the World Business Council for Sustainable Development's (WBCSD) circularity metrics.[20,13] Focusing on material efficiency, such as recycled content, recyclability, reusability, reused content, materials scarcity and lifetime, the circularity index calculates the circularity of each product based on the Bill of Materials (BOM) and user defined input.

For example, products manufactured using only virgin materials and ending up in landfill at the end of life will score poorly in the index. On the other hand, a product that contains no virgin feedstock, and is completely and efficiently recycled, or where components are reused will score high. The result is an absolute value that can be used as a common circularity measure across Danfoss to enable benchmarking between products and across product generations.

The Danfoss Circularity Index weighs several factors, such as critical raw materials. The EU Critical Raw Materials list, enriched with additional materials with increased scarcity, is used to assess the use of materials that are economically, strategically, and geographically important. It is essential we design with extra care to avoid or minimize waste of these materials.

Danfoss negative list

Materials, resources, and chemicals are essential to achieving circular, world-class quality products. Concerning health and environmental properties of chemicals and materials, the Danfoss Negative List is the foundation of our efforts to reduce the use of harmful substances in our production and products.

The Danfoss Negative List is based on current legislation, supplemented with selected substances for which Danfoss has adopted additional restrictions. These include substances that are identified as hindering circularity of products and solutions.

Green materials guide

The green materials guide has been developed to select low carbon materials with high circularity potential early in the product development process. It guides the selection of materials with lower carbon footprint and increased potential for recycling.

Carbon footprint tool

The carbon footprint tool has been developed to be used in product development to measure products' CO_2 performance and contribution to value chain emissions reductions throughout a product's lifetime. The carbon footprint tool also serves as the link between circularity and decarbonization. It is based on a quantitative assessment to validate the climate impact of circular design and serves to confirm that circularity choices also contribute to our overarching sustainability targets. The carbon footprint tool is rooted in our Life Cycle Assessment (LCA) model.

Sustainable packaging tool

The sustainable packaging tool helps teams to decide on the most optimal packaging option, by assessing 9 sustainability related parameters, including carbon footprint, recycled content, recyclability, reduced material use, hazardous substances and many more. With a list of more than 40 different packaging materials, and predefined properties for each of them, the tool helps balance the tradeoffs and it generates a final score based on assessment of all the different aspects.

The sustainability toolbox in symphony

To achieve a systemic approach to sustainability in innovation and product design, the entire toolbox must be used in conjunction. For instance, the carbon footprint model can indicate emission reductions related to circularity but may fall short on aspects such as disassembly. Considering all aspects, and both qualitative and quantitative metrics, is important for a complete assessment to maximize positive sustainability impact in the product portfolio.

Case 2: Reducing energy and material use

During the development of iC7 series drives, a range of initiatives led to improved design and more focus on sustainability. For the iC7 series, circularity and reduced carbon emission go hand-in-hand. The aluminum content weighed 73% less than previous generation of drives, leading to a proportional reduction in the use of virgin materials. The packaging was changed from Styrofoam to cardboard, without compromising protection during transport. At the same time, the iC7 series promises an even higher energy effi¬ciency potential, reducing system energy consumption over its lifetime.

Danfoss' DrivePro® services complement these advancements by optimizing drive performance and extending drive lifetime. For example, DrivePro® Site Assessment and DrivePro® Start-up ensure reduced energy consumption and CO2 emission, from the start. DrivePro® Remote Monitoring reduces emissions from unnecessary travel and ensures faster response times. DrivePro® Spare Parts and DrivePro® Preventive Maintenance extend product lifetimes. These services maximize circularity value, optimize energy and resource usage, and reduce waste, enhancing sustainable operations for customers.

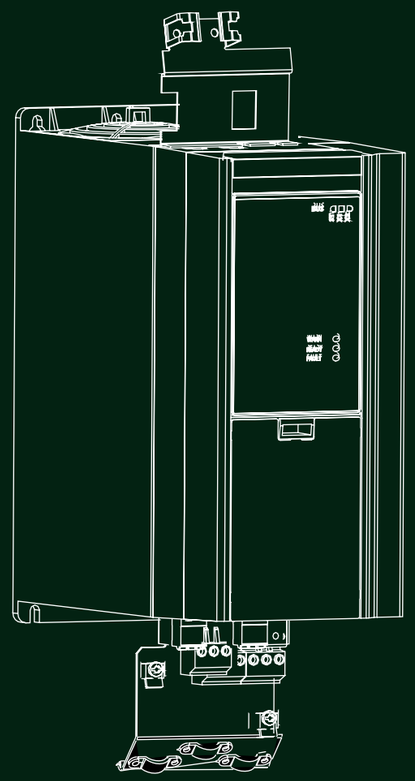


Figure 7: The iC7 series AC drives control the speed and torque of electric motors and thus save energy. Designed for superior performance, compact size, and reliability, these drives enhance system efficiency.

Achieving circularity impact

Designing for circularity across a product's lifetime involves a web of opportunities, constraints, and trade-offs. Optimizing for one circular design guideline may inadvertently impact another -- for example, a compact, durable design may compromise the ability to repair and recycle at end-of-life. These nuances underscore that **the design phase is a decisive moment for securing fact-driven decision making for sustainable product design.**

Empowering R&D teams to make informed decisions when faced with design choices and trade-offs is key to achieve impactful circularity. Our toolbox, including RE:CIRC, is based on an underlying circularity hierarchy that prioritizes high-impact initiatives. It draws on existing standards to support harmonization and standardization. A clear and consistent circularity hierarchy is important to achieve a systems-level approach that avoids the pitfall of cherry-picking circular practices that only appear advantageous.

The circularity hierarchy

Danfoss divides circular economy initiatives in four tiers (refer to Figure 8); The three top tiers align with commonly accepted circularity hierarchy from standards[17] and the prioritisation from the EMF's butterfly diagram. The fourth tier is included to promote circular initiatives within production processes and logistics – aspects of which are important to a manufacturer. The 30 product guidelines are mapped across these tiers and weighed accordingly, providing a uniform approach to prioritizing circularity initiatives across tools and guides.

Like RE:CIRC, the circularity hierarchy is also third party validated.

Sustainability must be balanced with factors such as quality, cost, customer needs, regulations, and market constraints. This requires holistic measures and a robust methodology. A clear prioritization of circular initiatives as foundation ensures that our design decisions align with the broadest array of these factors. **There are always opportunities, trade-offs, and compromises when striking the balance between design factors. By utilizing structured and holistic frameworks in the innovation process, we inform the design choices that can drive product portfolios towards becoming even more environmentally and commercially sustainable.**

Prioritising circular design strategies

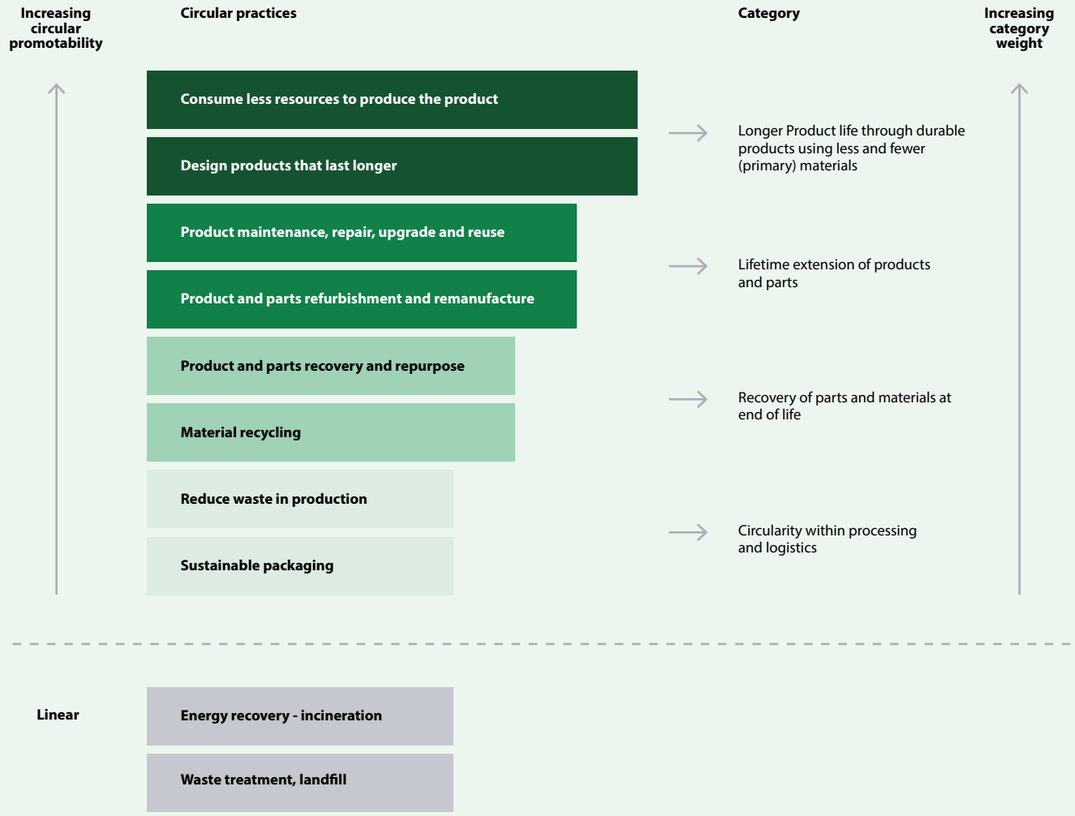


Figure 8: The material value hierarchy, inspired from FprEN 45560[13] guides our design decision making towards maximize material efficiency by keeping materials at their highest value. This hierarchy illustrates value loss or additional resources needed from top to bottom, ensuring we prioritize high-value material recovery, when designing new products.

Integrating circularity in innovation and product development

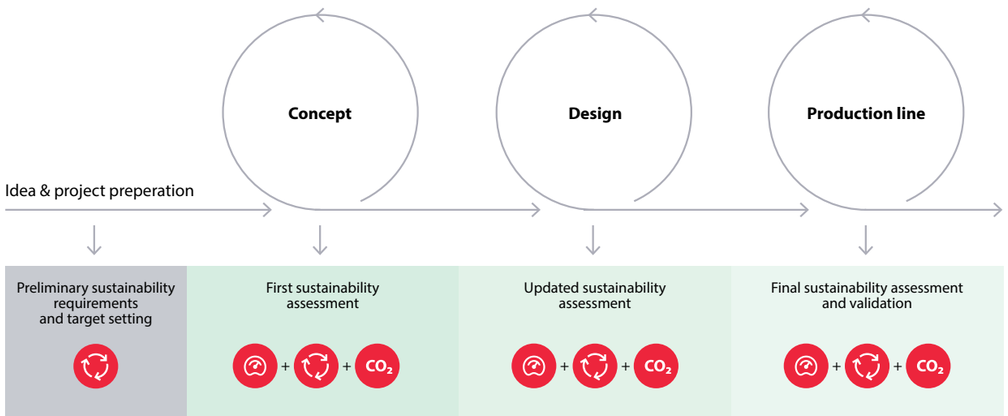
Danfoss allocates approximately 5% of annual turnover to innovation and R&D. Embedding circularity into an already strong investment in innovation yields high potential.

The product sustainability and circularity toolbox has been integrated into the company-wide innovation management tool, which structures and guides continuous improvement in product development.

The sustainability assessment is conducted at key milestones throughout the product development cycle.

At the beginning of a project, a preliminary assessment of the Sustainability Strategies is conducted, and targets are set for circularity and decarbonization. As the design is refined, the assessment is updated to reflect improvements made in high-impact areas. Prior to launching the new product, a final assessment is performed to verify that targets are met, and improvements have been made.

These assessments are an integrated part of the business cases for product development. This allows us to encourage and track all improvements – commercial, technical, and sustainability – throughout the innovation process. By delivering sustainability metrics alongside technical and financial performance, we promote widespread adoption of sustainability in innovation efforts. Circularity, carbon, and compliance assessments are required in the stage gate model for product innovation.



Circularity Index tool - Quantitively measures the circularity potential related to material and component efficiency.

RE:CIRC - Qualitatively assesses the sustainability performance and identifies high-impact areas for product improvements.

Carbon footprint tool - Calculates the lifecycle carbon footprint of the product

Figure 9: Integrating sustainability tools in the Danfoss innovation process.

Operationalizing circularity on a global scale

Operationalizing circularity is not an easy task. Governance, resources, and skills need to be in place to navigate the circular loops and put the sustainability strategies that guide our decision-making to work. Through our journey of integrating sustainability in the innovation process, we have identified four key learnings:

1. **Provide tools & resources**
Provide tools that assess and measure sustainability holistically. Allocate resources and define roles and responsibilities across the organization.

2. **Implement early**
The earlier sustainability is assessed the higher potential for positive impact on the product design. Integrating the tools in the concept development phase.

3. **Train & support**
Ensure proper training and capacity building on sustainability topics. Make tools available and provide support when needed.

4. **Track**
Integrate wanted sustainability assessment in the existing performance management systems to ensure that they are conducted across the company and tracked against targets.

Partnering to shape the future

Transparency and a culture of sharing are important to bring about continuous improvement and more sustainable and circular products. Similarly, circular business models, such as takeback, remanufacturing, and refurbishing all require close collaboration across the value chain.

At Danfoss, we have taken the first steps on this journey towards systematically improving product circularity, and we hope to engage business partners along the way. Sustainable innovation is challenging when standing alone, as circular initiatives in product design often create value across the value chain. Many Danfoss products are critical in other technologies, and their use phase is often downstream. We believe that collaborative partnerships to innovate are key to create value and impact throughout the lifecycle of a product.

Case 3: Circular value generation through systemwide collaboration

Data gathering and analysis are important levers to further the circularity of existing and new products. Digitalization and IoT solutions are already now enabling new business models, including at Danfoss, such as pay as you save, predictive performance, leasing, and service contracts.

One example of this is the system-wide service collaboration on Refrigeration-as-a-Service. Danfoss has teamed up with ANEO Retail in a joint venture to make the food retail industry more sustainable. It offers customers a worry-free transition to the most efficient refrigeration and freezer systems on the market, without the need for high, upfront investment. With maintenance, service, and extended warranty, this collaboration makes sure to keep the systems at the highest value and only repair and maintain when needed.

Sensors, data collection, and analysis are all important levers for circularity, and they need to be integrated in the product design. This requires a holistic approach when developing such systems solutions. Collaboration across the entire value chain is needed to secure that all areas of the business, service, sustainability, and product are considered.

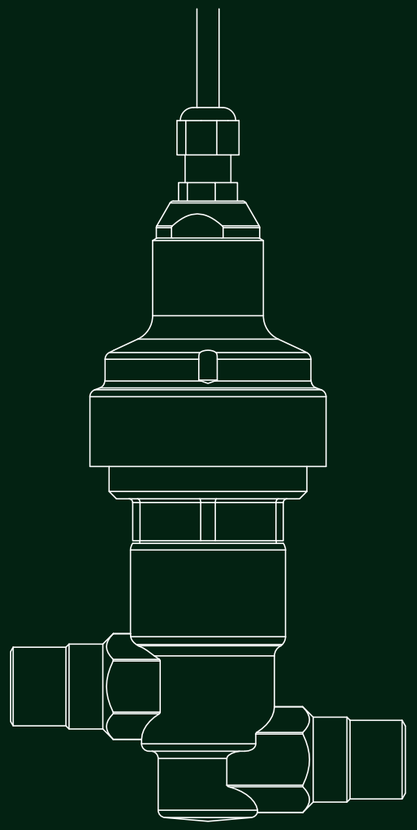


Figure 10: The CCMT electronically operated valve is designed specifically for CO_2 systems, essential for the shift towards greener, low-GWP solutions for food retail cooling systems. CO_2 can be effectively used in supermarkets, enabling both environmentally friendly and energy-saving systems in all types of stores.

Key takeaways

Circularity	Circularity is a business imperative in the manufacturing industry because it maximizes resource efficiency, reduces waste, and drives growth through new business models.
Decarbonization	Circularity is a crucial lever for decarbonization, enabling significant emission reductions at a system level.
A clear framework	A clear and comprehensive circularity framework needs to be in place that makes use of all the circular loops without disproportionate focus in some, like recycling. Companies should focus on system level changes.
Innovation	Circularity can drive the innovation process by bringing new insights to the assessment of design opportunities, trade-offs, and decisions.
The tools	Achieving impactful circularity requires a comprehensive toolbox and tangible metrics by making use of a mix of qualitative and quantitative indicators.
Evolving and learning	Implementing circularity in product design is a must-win battle, and industry alignment is essential. There is a need to harmonize and build upon existing standards and frameworks and be transparent as we continuously improve.

The path ahead

We believe that by sharing our learnings and fostering open, industry-wide dialogue, we can collectively advance the journey toward a more circular and sustainable future. As we navigate the complexities of sustainable innovation, it is crucial that we remain transparent, share knowledge, and refine our practices together.

We invite stakeholders to join us in this endeavour. By embracing circularity and integrating it into our core innovation processes, we can collectively lead the way to a more circular economy.

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Circularity Lead at Danfoss

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A sustainability thought leadership series to provide insights into our sustainability projects and learnings and share best practice with industry peers and sustainability professionals.

We are committed to become our customers' preferred decarbonization partner, but we cannot do it in isolation. To systemically drive down emissions in the entire value chain for scope 1, 2 and 3, we need to learn from each others' sustainability journeys across industries and sectors.

We are all part of the same chain. Let's accelerate the green transition together.