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R∃FRAME

Circular Economy strategy FRAMEwork for sustainable SMEs

IO3: Circular Economy Implementation Framework (CE Framework)

Disclaimer:

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5.4 Manufacturing Sector

Manufacturing is defined as any industry that makes products from raw materials by the use of manual labour or machinery and that is usually carried out systematically with a division of labour. In a more limited sense, manufacturing denotes the fabrication or assembly of components into finished products on a fairly large scale. Among the most important manufacturing industries are those that produce aircraft, automobiles, chemicals, clothing, computers, consumer electronics, electrical equipment, furniture, heavy machinery, refined petroleum products, ships, steel, and tools and dies.[1]

The NACE list, the French acronym for "statistical classification of economic activities in the European Community"[2] dedicates section C (NACE Rev.2) to the Manufacturing Sector, divisions 10 to 33:

DIVISION	SECTION C — MANUFACTURING
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment

[1] Source: https://www.britannica.com/technology/manufacturing
[2] "Nomenclature statistique des activités économiques dans la Communauté européenne"

26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment

In Europe, the Manufacturing Sector is one of the oldest and most important economic sectors. Since the Industrial Revolution, the manufacturing sector has been at the forefront of the European economy. Currently (2020), the manufacturing sector accounts for 14, 247% of the European Union GDP[3] and according to Eurostat, by 2018, employed more than 29,9 million people, distributed by 2 million enterprises. But numbers are decreasing since the 90s.

The sector entered a declination period with the proliferation of new technologies, the alteration of business models to a more "service-based" economy, the ageing of the workforce and the competition of emerging markets. But more factors contributed to the decline. Energy prices and the diminishing of global resources took part in the slow growth of the manufacturing sector in Europe in the past decades. The traditional manufacturing paradigm, which has been dominated by a linear business model, has now been increasingly challenged by governments and societies. Raw materials are extracted, transported to manufacturing sites and processed into a diverse range of products. These products are then shipped to retailers, sold to customers, and users, and ultimately discharged and replaced by other products. Thus, the manufacturing sector is particularly energy and resource-intensive, with significant carbon emissions and a high dependence on resource availability. This not only puts a strain on our planet's resources but also contributes to climate change. The increasingly long and complex manufacturing value chains have been associated with an increased demand for depleting resources, high volumes of waste, and polluting emissions. Technological developments and increasing consumption trends are expected to contribute further to these adverse effects.

[3] The World Bank - Manufacturing, value added (% of GDP) - European Union - https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=EU

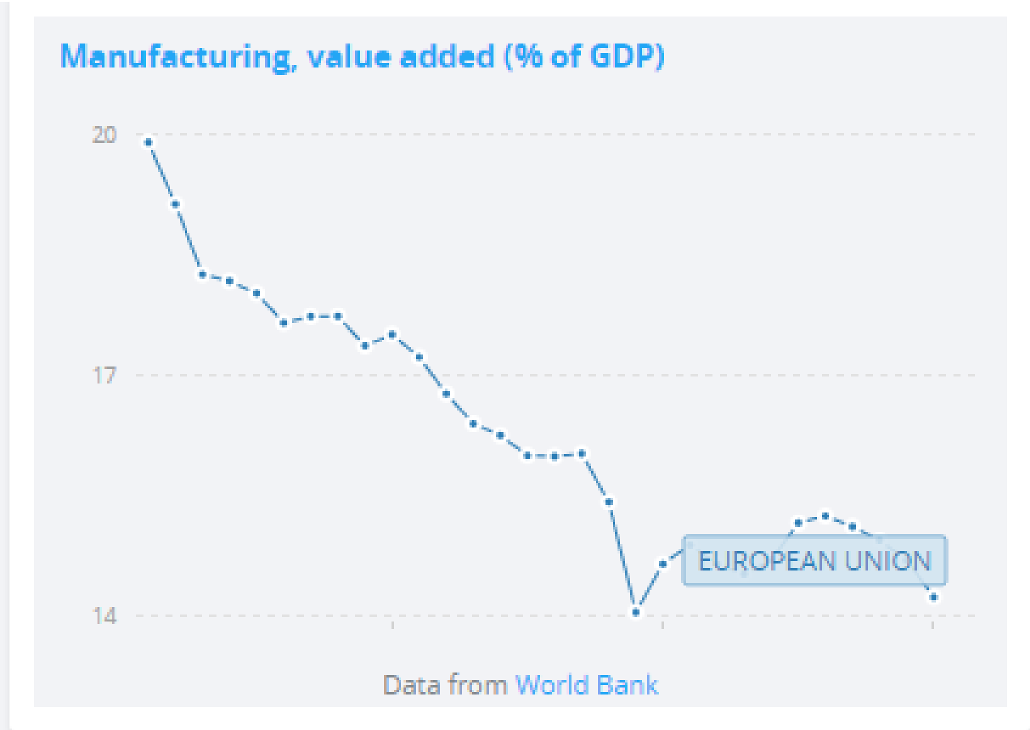

Figure 1. The World Bank - Manufacturing, value added (% of GDP) - European Union (Source: https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=EU)

EU has put concerted efforts into reviving the sector through specific categories in the Horizon 2020 program contributing, at the same time to the "greening" of the EU economy and the creation of new (green) jobs. A systemic approach is needed to address this – not only by implementing circular systems at the factory level but at the industry level. There is an increasing need to view manufacturing processes as part of a larger picture, a "system" taking into consideration a variety of levers such as business models, finance, policy, and behaviour.

The transition to a circular manufacturing sector can break this negative cycle. For this to happen, circular economy principles need to be integrated into every stage of the manufacturing system. For a long time now, European businesses have tried to compete globally by cutting labour costs, e.g. wages and social security contributions. However, the costs of materials and energy consumed in the production process are often many times higher than labour costs. Accordingly, achieving savings on energy and material consumption, which constitutes a core aim of greening businesses, will generate competitive advantages in the future. European manufacturing firms spend on average 40% of their costs on raw materials, with energy and water pushing this to 50% of total manufacturing costs. This compares to a share of only 20% for labour costs. Resource-efficient products and processes therefore positively impact the profitability of any manufacturing firm.

According to the Ellen MacArthur Foundation, the following changes are needed to move towards a circular manufacturing sector:

Materials should be kept in use while virgin material pressures should be reduced

Incremental increases in resource efficiency are still possible with the current linear economic model, but against the background of global pressure on resources and rising insecurity of supply, moving to a more circular economic model promises a much brighter future for the manufacturing companies and, per se, the European economy. Keeping resources in productive use for a longer time, using them again and again through recycling, cutting waste and reducing dependence on uncertain supplies is a direct route to improving competitiveness.

Production should occur locally and with a distributed production capacity

Distributed production, also known as distributed manufacturing, cloud producing, or local manufacturing is a form of decentralized manufacturing practised by enterprises using a network of geographically dispersed manufacturing facilities that are coordinated using information technology. This can be implemented through the establishment of local and regional manufacturing networks, the organisation of manufacturers into eco-industrial parks, the use of green scalable digital technologies and, last but not least, policy frameworks supported by global policy commitments.

Digital technology should be harnessed to simplify this process

The combination of processes and technology highly influences products (outcomes) and the waste products or undesired outputs. It's the opportunity to rethink manufacturing and the industrial network with "green" technology – zero carbon emissions goals -, big data to enhance the traceability of processes and materials, visibility and opportunities for distributed manufacturing. Product "material passports" and comprehensive environmental product foot printing by providing details of materials and processes in real-time offer information confidence to ensure high environmental and social standards throughout complex supply chains, all of which reinforce the application of circular economy practices. Other traceability technologies, such as the use of sensors, are also instrumental in supporting the development of secondary material markets and helping realize the benefits of more circular use of resources.

"Instead of only thinking about the functionality and price of making products, manufacturers should think about the whole lifecycle of their product, maximising the usage of materials and cutting out waste. Currently, many consumers still don't consider what happens to products after they've used them – it is assumed that at the point when it stops being useful, the product will be thrown out and replaced. Businesses design products to make manufacturing as easy as possible, which doesn't lead to sustainable use" (SAGE, 2020).

Circular City Funding Guide[4] suggests different measures to be introduced in the different phases of the production process to transform a linear manufacturing sector into a circular one. This implies a transition from a linear to a circular business model, no longer focusing on profit maximisation (or cost-cutting), but concentring on redesigning and/or even rethinking the conventional producer-consumer relationships, value creation activities and the structure of value chains. Circular Business Models can help slow, narrow, and even close resource loops as we transition from value chain thinking to a value cycle mindset. This is valid not only in the manufacturing sector but also in any sector of economic activity.

5.4.1 Circular Business Model 1 - Circular Supplies

It is based on supplying fully renewable, recyclable, or biodegradable resource inputs that sustain circular production and consumption systems. The value proposition focuses on the substitution of fossil, critical and scars materials. The growing demand for electronics, machinery for the automotive industry, electrical transportation, aerospace and sustainable energy technologies is responsible for the increasing use of raw materials, in particular, in the manufacturing sector. The extraction and production of these resources cause environmental and other sustainability problems. In addition, raw material extractions are getting more complicated because quality declining. Collection and recycling are being adopted but at a slow pace and much of the waste is not returned to the value chain. In a Circular Manufacturing Industry, products and parts are not thrown away or recycled in a low-grade way but, after inspection and processing, are used again in a high-quality manner. The design phase strongly influences the use and the end of a manufactured product. Ensuring that products are durable, easy to maintain and repair, and can be recycled is vital. A modular design contributes to the adaptability of the product and extends its life. During the production process, circular economy principles can be integrated by increasing the use of secondary materials - fragments of finished products that have been used and recycled and converted as a resource -, designing out waste, and creating products on-demand and on-site. Using local materials, 3D printing and robotisation are ways to optimize the production chain.

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[4] The Circular City Funding Guide supports municipalities, businesses, and other urban actors in creating circular cities. The Guide was initiated as one of the actions under the "Urban Agenda Partnership for Circular Economy". The Guide was developed by external service providers and EIB experts mobilised and funded by the "European Investment Advisory Hub". https://www.circularcityfundingguide.eu/

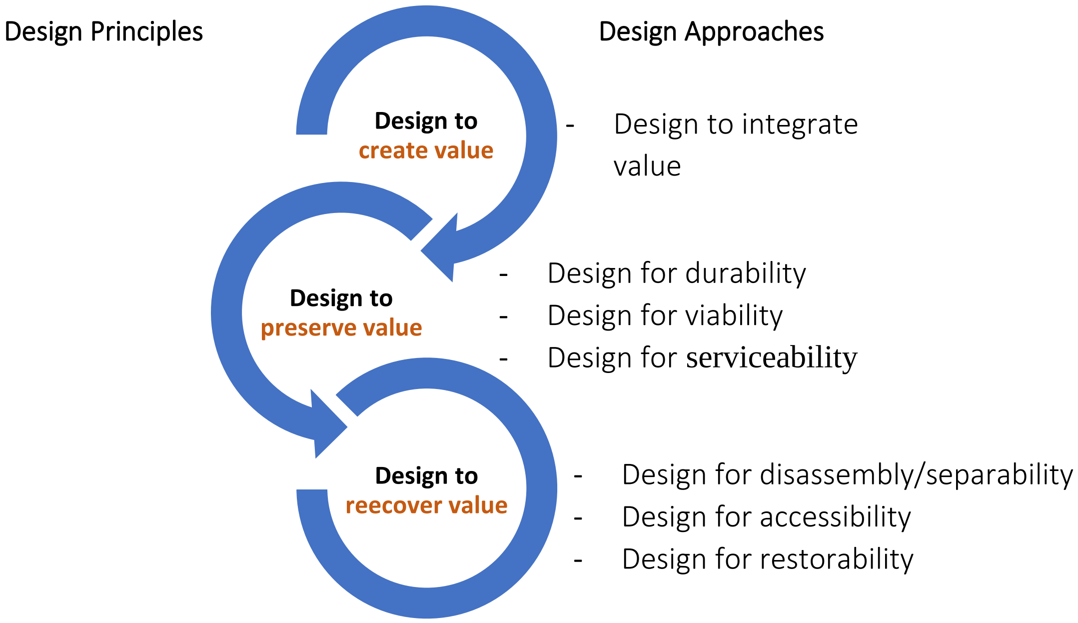

Figure 2. Design principles and approaches (Source: Adapted from UN Environment, 2018)

Relevant aspects of circular design[5]	How to incorporate it into the product	Example	
Design out of waste	Use fewer resources for producing the product	Ford investigates 3D printed parts to reduce material use and weight of components	
Design for upgrading and modularity	Allow exchange of components for updates or upgrades (e.g. standardise connections)	PuzzlePhone is built from three modular components available in different sizes and materials	
Design for reuse, repair, refurbishment, remanufacturing	Allow for disassembly through using e.g. reversible connections	Caterpillar designs parts for manufacturing e.g. an engine block with a removable sleeve in the cylinder bore	
Design based on sustainable resources	Use renewable or recycled materials	Renault uses recycled material for 36% of the total mass of a new vehicle	
Design for minimal resource use along the life cycle	Make sure the product is efficient in the use phase (e.g. no resource-intensive supplies)	Outotec dry tailings water treatment plant minimises freshwater intake during its operation	

[5] Source: Circular Economy business models in the manufacturing industry https://samfelagsabyrgd.is/assets/2020/05/circular-economy-playbook-for-manufacturing_v1-1.pdf

Design enabling high-quality recycling of materials	Limit the number of different materials, use recyclable ones and make them separable	Philips constructs light bulbs in a sandwich construction that assures separation upon crushing	PHILIPS
Design for cleaner material cycles	Substitute hazardous substances in products	Akzo Nobel created a new coating made from plant-based oils and recycled PET bottles instead of solvents	AkzoNobel
Building resilient supply chains for critical raw materials	Working on circular design, re-use and recycling	KPN introduced design criteria and set standards with suppliers. In 2019 KPN started assessing the role of critical raw materials in the supply chain of these key products. Now they develop strategies together with suppliers to mitigate risks and achieve circularity of critical raw materials. Future technology developments are monitored to keep track of changing impacts on supply chain resilience.	kpn

Good practices and Examples[6]		
3D printing VOLVO	Boost product quality and help reduce the need for a spare parts inventory	Volvo Trucks produces tough manufacturing and assembly tools in 94% less time with 3D printing
Production waste separation Ford	Integrate waste management in production process and keep waste material flows separately to enable high-quality recycling	Ford engages with suppliers to recycle aluminium scraps from car production (e.g. stamping windows into body panels). To achieve the required level of purity, Ford invested in machinery to separate, clean and shred aluminium
Remanufacturing capabilities	Develop remanufacturing capabilities to sort and repair returned equipment to extend their life cycles	Various models of Scania trucks are dismantled and remanufactured at Scania Vehicle Recycling. Parts such as engines, gearboxes and differentials are inspected and adjusted internally. They are sold

[6] *Idem*

		through local Scania workshops and distributed via the daily spare parts routine of Scania Parts Logistics

5.4.2 Circular Business Model 2 - Resource Recovery

Good practices and Examples[7]		
Incentivise product return	Provide incentives for customers to return products or components through e.g. refunds and discounts	Caterpillar uses a proprietary core management system to globally manage core returns from dealers and Caterpillar inspection facilities and determine the core credit amounts that will be refunded
Reverse logistic channels	Develop own reverse logistic channels or partner with established companies to collect components and complete products	CoremanNet, a subsidiary of Bosch, offers qualified core return solutions for the automotive spare parts market. The modular packages can be adapted to individual company requirements
Waste material management	Control waste material flows to secure high-quality material for recycling	Renault tries to maintain control over the flow of automotive waste materials and parts through its subsidiary Renault Environment that e.g. coordinates >300 demolishers in France

For materials to function in a circular economy, the 10 R-hierarchy of circularity can be applied. The R strategies correspond to different levels of value retention of the products, where "Recover" is the very final level.[8] Generally, the more value retention can be kept, the higher circularity and reduction of pressure on the environment. The value of a product at the end of its useful life determines whether it is disposed of,

[7] *Idem*
[8] *Refuse, Rethink. Reduce, Re-Use, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.*

recycled, remanufactured or handled in some other way within the recovery infrastructure. This includes separate collection and, where needed, facilities for sorting and refinement of different material streams. The product value changes over time, but the last user wants to maximize economic gains. Since the choice that is made by the last user has a significant effect on the environmental impact of the product manufactured, it is important to assess the value of the product over its lifecycle - LCA – and its end-of-life value. Innovations in robotics, optical sorting, and artificial intelligence can improve the sorting and recovery of different types of materials and collect accurate and valuable information and analyse data. On the other hand, the concept of reverse logistics facilitates the return of end-of-life products for remanufacturing or recycling, and later reintegrating into new products. Innovative companies can use the collected and sorted waste streams as feedstock in their manufacturing processes.

5.4.3 Circular Business Model 3 - Product Life Extension

Extending product value focuses on exploiting the residual value of products and delivering high-quality, long-lasting products supported by design for durability, reparability, upgradability, and modularity. Values that would otherwise be lost through wasted materials are instead maintained or even improved by repairing, upgrading, refurbishing, remanufacturing or remarketing products. However, product lifetimes have been decreasing throughout the last century. This notion of “planned obsolesce” was implemented in the manufacturing sector already in the 1930s, as a way to boost the economic recovery of the United States after the Great Depression. Planned obsolescence is a deliberate policy of producing consumer goods that rapidly become obsolete, requiring frequent replacement. Reduced material durability, limited reparability and psychological, social or emotional factors of design and fashion; are the three main ways to stimulate respective consumption and discard of products. But, when a product is in use there are different circular design strategies applicable to extend the lifetime of a) the product, b) structural elements or c) product parts. When the life cycle of a product has come to an end, this does not mean the life span of components has come to an end. A product can reach its end of use (EOU) prematurely, either due to a technical fault or because the user has no use of, or desire to keep, the product longer.

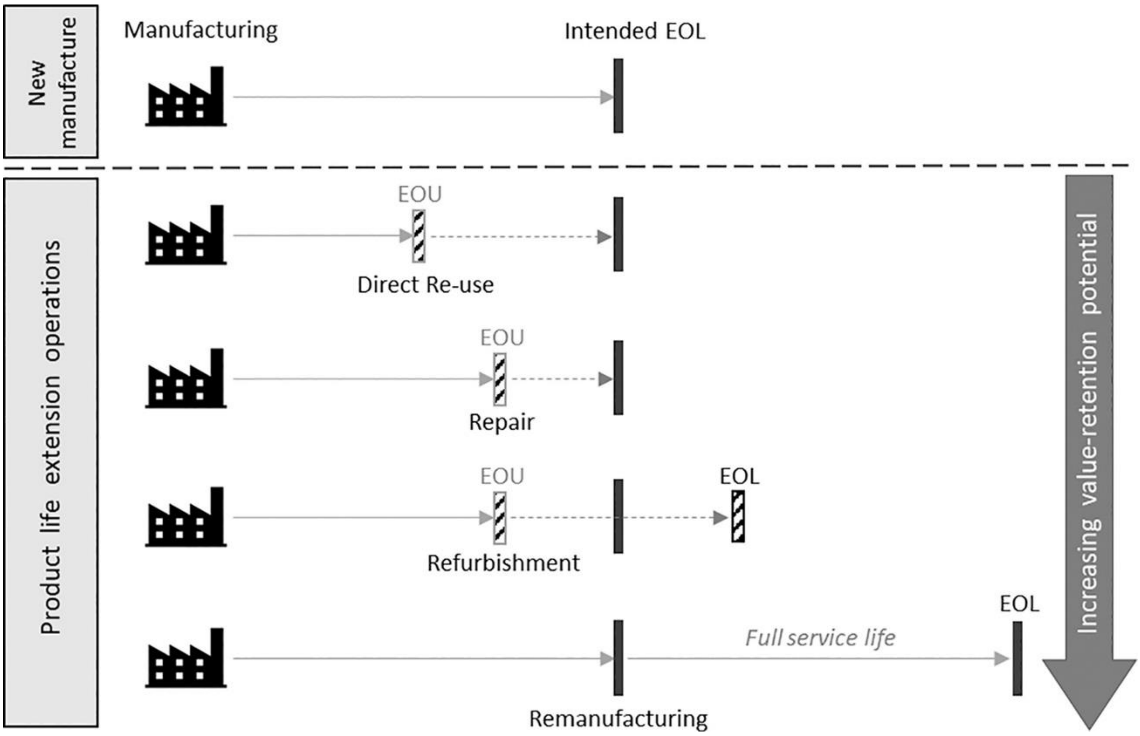

Figure 3. Graphic representation of product life extension operations (Source: Milios, 2021)

The first two level of operations - 'direct re-use' and 'repair' - make sure that the product can reach at least its intended "end of life" (EOL). The next two operations levels - 'refurbishment' and 'remanufacturing' - can effectively extend a product's lifetime beyond its intended EOL, with remanufacturing being a highly industrialised process like the original manufacturing of a product.

Good practices and Examples[9]		
Durable, ethical and smart a mobile phone designed to last FAIRPHONE	The first-ever ethical phone in the world with conflict-free minerals and Fairtrade gold in their supply chain	The company made a breakthrough in modular and repairable design to prolong the lifetime and break with the two-year cycle of the average smartphone. Repairs to the smartphone are simple and quick compared to other smartphones, spare parts are easy to get a hold of and software is relatively future proof. Its display, for example, can be replaced within minutes, for just a fraction of the cost compared to non-modular smartphones. The company had sold more than 250.000 Fairphones from its foundation in 2013 until the present.
Specialist coating Revamo	Life extension promotion and material saving	Revamo's activities can be divided into two groups. In one group, existing machine parts are repaired with laser cladding and thermal spraying and additional techniques to the specifications of new parts, or even better. Resulting in a CO2 footprint of 10-15% compared to a new part. In the second group, a coating is applied to a new product to obtain better specifications and to reduce the total cost of ownership. For a pump manufacturer, they coated the part of the pump shafts that needed to be chemically resistant and prevented the entire shaft from being made of the precious material. Other examples include coating critical machine parts to extend service life and reduce maintenance frequency.

5.4.4 Circular Business Model 4 - Sharing Platforms

It promotes bridging among producers and consumers, either individuals or organizations. The value proposition concentrates on collaboration, enabling interaction between different but interdependently actors and bringing together supply and demand, by making possible shared use/access/ownership.

[9] *Source: Manufacturing: the future is circular* https://hollandcircularhotspot.nl/wp-content/uploads/2021/06/Manufacturing-the-future-is-circular-April2021-1.pdf

Good practices and Examples[10]	Enabling technology		
Circular resource marketplace platform	Participate on a platform that facilitates the matching of required and available materials for recycling or reuse of different companies or engage in its development	Excess Materials Exchange is a pilot of a digital facilitated marketplace run by a Dutch start-up. Companies from all industries can share information on the material they want to exchange, and receive information on the value, alternative uses for/ sources of secondary materials, and environmental impact. The platform uses an Artificial Intelligence engine connecting to data of thousands of scientific papers and patents	Artificial intelligence Big data
Industrial symbiosis (IS)	Develop symbiotic partnerships with cross-industry actors designing "waste as input" streams	Kalundborg (Denmark) – Collaboration with 8 private and public partners started in the 1970s. Has about 50 symbiotic exchanges such as steam, water, or specific flows. An example of a specific flow is Novo Gro30, biomass from the pharmaceutical products that are then used as fertiliser, wastewater treatment and biogas production	Artificial intelligence Big data
Tech-enabled outcome orientation	Deploy sensors and develop smart products to generate data-enabled new business models	Michelin introduced the first "Tire Monitoring Management System" for mining tires enabled through sensors in the tires recording and transmitting pressure and temperature	Internet of Things
Data monetisation	Use data insights to reduce costs or generate revenue e.g. through predictive maintenance internally or	Siemens models the status of gas turbines with about 500 sensors in a turbine and uses data to simulate operation while AI is simulating the wear and tear of components to prompt maintenance measures	Artificial Intelligence Internet of Things

[10] *Source: Circular Economy business models in the manufacturing industry* *https://samfelagsabyrgd.is/assets/2020/05/circular-economy-playbook-for-manufacturing_v1-1.pdf*

	provided as a service to customers	to prevent downtime. Insights can be shared via the cloud	
Data visualisation tools 	Use data analytics and visualisation tools to extract insights from the pool of available data	Available plug-and-play tools are for example Tableau, Microsoft Power BI or IBM Cognos	Big data

5.4.5 Circular Business Model 5 - Product as a service

In a circular economy, products last longer and retain as much value as possible. To achieve this, additional services are required such as repair, upgrading and take-back of end-of-life products. After that, a shift from "ownership" to "use" can be attractive: a model in which the user no longer buys the product but pays for the solution. The business model is changing and with it the revenue model. Manufacturers can shift their business model from selling products to providing services under product-as-a-service contracts This business model “product-as-a-service” (PaaS) became significant over the past few years among companies enthusiastic to copy the “service-mode” of subscription revenue. Initially, PaaS was an add-on to regular products and more akin to service-as-a-service. For example, after buying a car, you’d pay an extra monthly fee for its maintenance, realizing that the car seller has access to performance data that enables improved and proactive repair. The ultimate where products are not bought but rented. Manufacturers can also facilitate the repair, remanufacturing, and re-sale of their products, to extend their life and reduce waste generation.

Product as a service offering[11]			
Offering	Ownership	Offering design	Incentives for circularity
Product-as-a service models	Lies with producing	**Operating lease:** Overarching concept, in which the lessor retains ownership of the asset, while the lessee pays for its use over a certain time	Longevity
		Full-service lease: Combines operating lease contract with additional services such as maintenance for the asset	Longevity, reparability and easy maintenance

[11] *Idem*

	company during the useful life	**Performance-based payment:** Combines operating lease with periodical fees dependent on the use or delivered the performance of the asset	Longevity, reparability, optimised use-phase consumption
		Rent: Differs from leasing in that it generally is for a shorter period. Maintenance and insurance are often included in the contract	Longevity, reparability and easy maintenance
Other product-service systems (not considered as PaaS)	Transferred to the customer sometime during the lifecycle	**Finance lease:** All the risks and rewards connected to the ownership of an asset is transferred to the lessee during the time of lease (e.g. cost for maintenance, repair, resource use during the use phase). At the end of the leasing contract, the ownership of the asset is passed over to the lessee.	No circularity incentives

5.4.6 Final advice for Manufacturers:

5.4.6.1 Assess

Firstly, identify what the enterprise is already doing. Companies are often already pursuing circular economy activities without knowing it. The REFRAME Circular Economy Self-Rate Tool can help to define the company's current capabilities. The "Circular Economy Experts Course" and the "Circular Economy Implementation Framework" provide further information and guidance on how to implement changes in the value chain.

5.4.6.2 Explore opportunities

Integrate circular design principles supported by social and environmental life cycle assessments (LCA) into innovation processes to ensure the result delivers maximum impact. This starts in the design phase – product development – optimization of circular supply chains and procurement. Reduce, reuse and recycle, extend product life, share platforms and collaborative approaches, by involving consumers in waste reduction are other ways to move towards more circular practices.

Supply chain step[12]	Circular economy opportunities
Extraction (Raw material)	Conduct sustainable sourcing, such as by using bio-based materials, reusing by-products, and preserving natural capital Use renewable energy

[12] Source: Unlocking More Value with Fewer Resources A practical guide to the circular economy https://eco.nomia.pt/contents/documentacao/unlocking-more-value-with-fewer-resources.pdf

Product manufacture	Prolong product life and use modularity in the design phase Develop industrial symbiosis to share utilities and services, etc. Optimize energy use in operations
Retail	Conduct circular logistics and procurement
Consumption	Move towards a "product as service" business model Make shared use, access and ownership of products possible Use big data to meet customer needs
End of life, waste treatment	Remanufacture, reuse, refurbish, recycle, recover Use down cycling, upcycling, closed-loop recycling

5.4.6.3 Ensure maximum triple bottom line impact

Build business cases that justify specific circular economy initiatives by combining tangible and intangible benefits considering a longer-term horizon than traditional investments. This can be implemented by 1) a Life cycle assessment (LCA), a common methodology to estimate the environmental performance. It's recommended to use LCA not only in the early project stages to be able to make the right choices (from resources to strategies) but also in later project stages to confirm targeted environmental benefits. A circular economy is often linked to the creation of (green) jobs, which is a great social impact. 2) Social life cycle assessment methodologies (social LCAs) could be useful because of their similar structure to regular LCAs. Social LCAs could help to quantify and highlight other potential social impacts. Social LCA looks at impacts on different stakeholder groups, such as, workers, consumers, local community, and society or value chain actors and; are related to diverse social themes, like fair salaries, transparency, access to resources, migration, public commitments to sustainability issues, fair competition, etc. For last, perform a 3) Life cycle costing (LCC). These principles assess not only purchase price and all associated costs but also operating costs, end-of-life costs and, potentially, costs of externalities. Overall circular economy initiatives and business models can lower input costs and, in some cases, create entirely new profit streams, build greater resilience in supply chains, and reduce exposure to material shortages and related price volatility impacts.

5.4.7 Implementation

Putting a circular strategy into practice can be achieved by the use of established processes and structures of your company to get the implementation done, such as a new product development (NPD) process. Systematic checks of your business model, not only in terms of financials but also in terms of social and environmental performance. Immediate engagement of employees and their buy-in so they can draw useful lessons and share concrete feedback from their circular economy experiences. And, last, but not least, putting the right external and internal communication strategy in place: ensure stakeholders support circular economy initiatives by communicating success stories in various creative forms of communication.

5.4.8 Lead by example and show that it can be done

A CE cannot be built alone and needs engagement from leadership and collaboration with all stakeholders and partners across sectors, governments and NGOs. Strong communication to engage employees, consumers and partners are essential for a circular economy to succeed. CE initiatives should be integrated into business strategy, communicated and executed with support from the top with priority and resources. Creative communications approaches, promotion of collaboration and transparency with external stakeholders, employers and customer engagement are also of extreme importance. The elements of an effective circular economy communication strategy are real-life examples, communication of facts and figures, calls for action, the use of creative storytelling and educational messages