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The impacts of technological innovation on the Circular Economy and the business models

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1. Introduction

Today's businesses compete in a fast-evolving global environment. As a consequence of new arising challenges including the climate crisis, resource scarcity, technological change, and other environmental and social problems, businesses now must rethink how they operate and innovate. Significant effects are already being felt, and If we don't quickly modify our global model and systems, both people and the earth risk experiencing disastrous and permanent effects.

Presently, one of the most challenging issues that businesses must deal with is sustainability. Sustainability implies balancing economic development, environmental protection, and social well-being to fulfil the needs of the present without compromising those of future generations. In a future where population growth is constant, our current linear models of production and consumption, particularly with continuingly rising rates of consumption, will not be sustainable. Adapting to these dynamics successfully requires more than simple changes to how businesses are run now.

Technologies, which are in continuous and rapid evolution, have a key role in addressing this task. With the aid of technologies, businesses have the opportunity to use the circular economy to turn these issues into opportunities, generating financial and economic value for both the company and society. The circular economy can help firms drive innovation, open up new markets, and work towards a more sustainable global approach.

This study focuses on how circular economy is affected by innovation and new technologies and how they influence the choice of one of the five principal business models (Circular Inputs, Sharing Platforms, Product as a Service, Product Use Extension and Resource Recovery) on which circular economy is based, or the shifting from one to another, in various industries. Case studies of some important corporations who chose to apply circular economy (i.e., eRENT, Rent the Runway, Veolia, etc), are included to support the qualitative aspect of the study.

The paper also looks to the future, in fact it takes into consideration not only new technologies currently in use, but also the ones that can be applicable in the near future that are being studied and tested to exploit their full potential.

The purpose of this paper is to understand how innovation and new technologies affect companies in the transition to circular economy.

2. Where we are now: Linear Economy vs Circular Economy

The most common economic model used today is linear economy. In a linear economy, raw materials are taken, transformed into products, and after being used or consumed, they are typically disposed as non-recyclable waste, recycled, or downcycled. This classic industrial model follows a "take, make, waste" process.

The circular economy instead, which is becoming more popular, eliminates the idea of waste altogether, significantly changing how we produce and consume, and establishing a healthier ecosystem that distributes value across the economy and society. Goods and materials are maintained as long as possible in productive use, and when their useful lives are ended, they are cycled back into the system (as shown in fig.1).

True circularity requires rethinking and reworking entire value chains to create a system in which waste is completely eliminated and the aim is to add resources using regenerative approaches rather than extracting them.

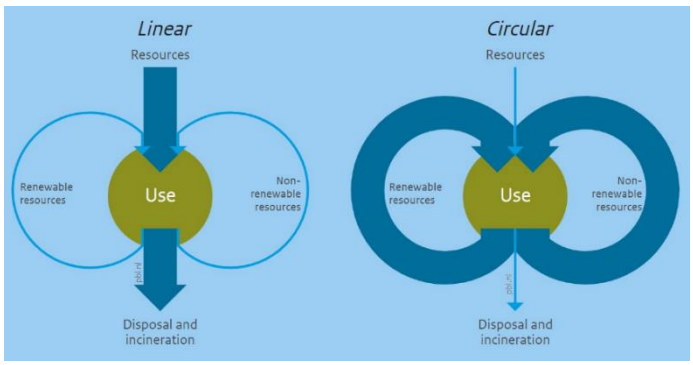

Fig.1 – Linear vs Circular Economy

Source: https://themasites.pbl.nl/o/circular-economy/

The circular economy carries the changes required to advance towards a sustainable future and has the potential to create new opportunities for companies to enter new markets with innovative products and services, setting the stage for long-term success. Businesses have a chance to re-evaluate how their operations and supply chains use resources and how it affects their cost structure. It can also boost positively trust, brand, and reputation by attracting talent or satisfying customers. In a nutshell, the circular economy can support environmental protection while helping businesses gain competitive advantage.

3. The five circular business models

The opportunity to redefine waste as a valuable resource is exploited through the use of five business models that are the foundation of the circular economy. There are four different waste types from which value can be derived:

- Wasted resources: Use of resources, such as fossil fuels and non-recyclable materials, that cannot be regenerated over time.
- Wasted capacity: Products that are not fully utilized throughout their useful life.
- Wasted lifecycles: Products reaching end of use prematurely due to poor design possibilities for reuse.
- Wasted embedded value: Components, material, and energy not recovered from waste streams.

These models give aid in transforming the traditional linear model of production and consumption into a more efficient circular model that reduces or even removes waste, pollution, and inefficiencies. Numerous public and private sector organizations have identified these models as a successful tool to implement circular economy approaches. Nevertheless, the implementation has gone more slowly than expected, and the application has not been spread fairly among the models, depending on factors such as geography, industry, business size and structure, and product type.

The business models are not mutually exclusive; they have the potential to have the strongest impact when they are combined to generate the most value.

The five circular business models are:

- Circular Inputs: use of renewable energy and bio-based or potentially completely recyclable materials.
- Sharing platforms: increased usage through shared ownership, access, or usage models.
- Product as a service: offer of product use with holding by the producer to boost resource productivity.
- Product use extension: augmentation of product use through repairing, reprocessing, upgrading, and reselling.

- Resource recovery: recovery of usable resources or energy from waste or by-products.

Circular Inputs, Product use extension and Resource recovery are more production oriented. The other two, Sharing platforms and Product as a service, are more focused on consumption and on the relationship between product and consumer. These models cover the full value chain of circularity.

The focus of Circular Inputs is on the elements used to design, procurement, and manufacturing the products. Some inputs, including renewable resources, are a link to all other models and work to minimize wasted resources.

Product Use Extension focuses on maximizing a product's use. In order to prevent wasted lifecycles and extend the useful life of products, businesses must start from the very beginning: product design and sourcing. Moreover, the Product as a Service and Sharing Platforms models are enabled by Product Use Extension. These two take it a step further by completely redefining the utility of products, such as by purchasing a service instead of the actual product (renting a designer dress instead of buying it). This encourages businesses to make the most of products' value and consumption while minimizing wasted capacities and lifecycles.

Resource recovery's task is to put embedded materials or energy back into the production cycle once a product has reached its end of use. This completes the product's life cycle from sourcing to usage and back to sourcing.

The aim of the circular economy is to completely replace the entire "take, make, waste" cycle, as already mentioned. While achieving this is a long-term goal, short-term progress can be made by focusing on localized value pools (the value pool calculates the theoretical available potential in the market for new revenues and avoided costs). Companies can concentrate on closing numerous "mini-loops" in every circular value chain loop (Fig.2). One possible scenario is the reprocessing of a waste stream from one stage of production into a usable by-product or the use of a secondary material source as the raw material for another operation.

Consider the expanding use of food production waste as a source of energy for the facility in which it is produced. Other market-related "mini-loops" help customers in reselling second-

hand goods including toys, clothing, and vehicles. These loops can break down industry barriers by allowing one company to use the waste of another industry as an input, opening up a wide range of possibilities for the five circular business models to be used throughout the global economy.

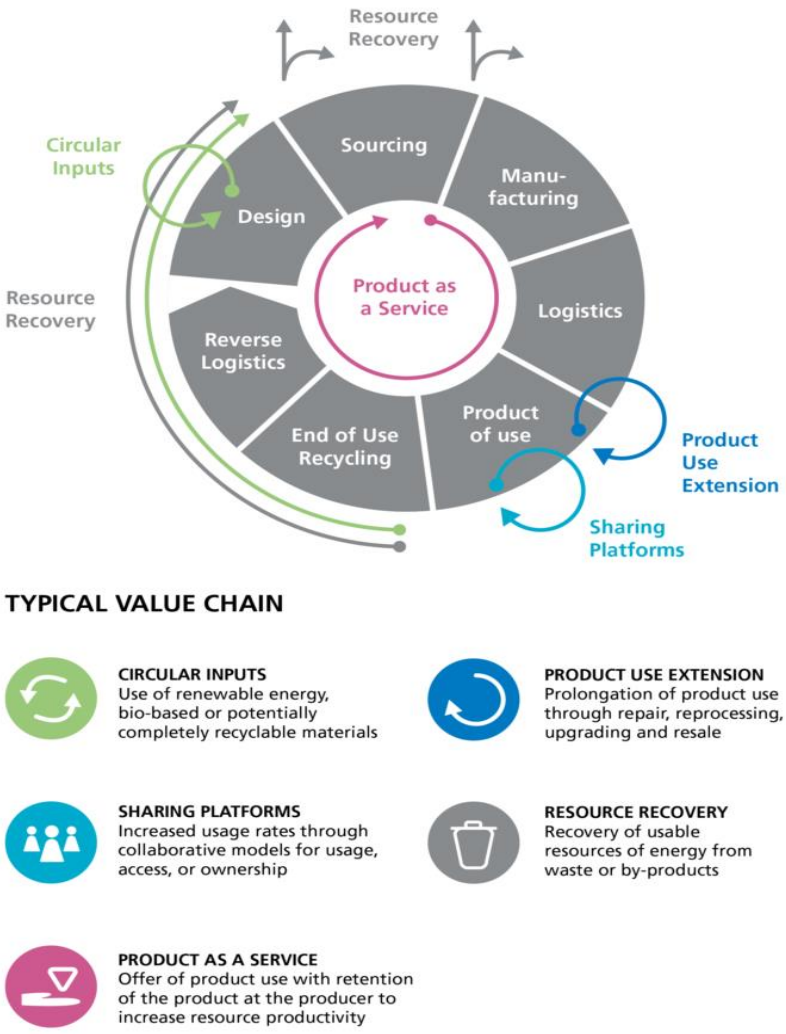

Fig.2 – Circular value loop

Source: https://esignals.fi/research/en/2021/02/22/transition-from-linear-to-circular-business-models-with-service-design-methodology-to-drive-innovation-and-growth/#79f7e3c2

3.1. Circular Inputs

Currently, circular Inputs is one of the most used circular business models by companies. An organization must shift away from a linear type of resource in its supply chain in favour of a circular one to adopt it. Three general categories can be used to classify these solutions:

- Renewable resources: Inputs that regenerate naturally and can be used continuously (e.g., water from rain or desalination processes, wind, and solar energy, etc.)
- Renewable bio-based materials: Materials derived from living organisms that are developed chemically.
- Renewable man-made materials: Engineered materials based on non-organic chemistry that can be recycled infinitely without a significant loss of quality or properties.

In the short-medium term, a company should identify and replace production inputs with circular alternatives. Yet, the ultimate goal is to fully eliminate resource loops. That being said, while the first stage of the transition to circular inputs focuses on eliminating the use of linear resources, the second stage completely gets rid of the concept of waste as part of a transformation of production systems. Currently, replacing linear raw materials, such as non-renewable or recyclable resources, with alternatives that have a less damaging impact on the environment has driven the adoption of circular inputs. Additionally, with the rising popularity of environmental sustainability in public discussion, legislation and financial supports aimed at making the economy more sustainable have emerged and became mainstream (such as the EU's ban on single-use plastics).

As a result, renewables are expected to account for almost 70% of the increase in worldwide power generation between 2017 and 2024[1], making them the energy source with the fastest rate of growth in the electrical industry. Despite this progress, we still need to drastically cut or completely remove our reliance on carbon-intensive sources like fossil fuels. Sadly, there are several factors that obstacle the adoption of renewable energy in new markets, while integrating renewable generation into the grid stays a challenge in established markets. These

[1] IEA,"Renewables 2018 Market Analysis and Forecast from 2018 to 2023"

factors include technological and financial constraints. International companies with large energy consumption have the power to set the example and should consider increasing their investments in renewable energy capacity as part of their long-term strategies.

For what concerns material innovation, media outlets have long exposed the environmental harm brought on by numerous material streams, from microplastic contamination in the recent past to chlorofluorocarbon pollution in the 1990s, raising public awareness of the need for restrictions. At the same time, the majority of industries, from cotton to rare earth minerals, have been touched by resource scarcity. As a result, there has been a significant rise in the amount of research and development being done to find new options, as well as a push from established businesses to patent and market new circular materials to be used in their upcoming products[2]. Sulapac, for example, is a Finnish packaging material manufacturing company, and alternatively to traditional single-use packaging made from petroleum-based plastic, uses biodegradable packaging solution made from wood chips and natural binders[3].

Ultimately, a material innovation needs to meet additional requirements, such as quality standards and cost parity, in addition to being circular, in order to be successful. Because of this, businesses should evaluate functionality, usability, and reusability when looking at new materials, as well as the volume required to enable them reach cost parity. Considerations related to the lifecycle may also serve in limiting any potential unintended effects on the environment, such as the higher energy intensity needed to produce reusable materials. In

Fig.3 – Material passport

Source: https://www.metabolic.nl/news/circular-economy-materials-passports/

[2] Lauren Hepler, "Why Materials Will Make or Break the Circular Economy"

[3] Sulapac, "The Ocean Friendly Straw"

support of that analysis, innovations like the material passports (fig. 3) can give information about materials throughout their lifecycle, aiding recovery at the end of use.

A material passport contains data associated with a specific product, including the characteristics of that item's materials, that facilitate the recovery, recycling, or reuse of those resources. To speed up even more the shift to more circular inputs, organizations must look beyond organizational boundaries, analyzing material flows, opportunities, and barriers. For example, circular economy engineering company called TriCiclos, used its network of recycling infrastructure to analyze waste through its waste management divisions across Latin America. Thanks to this analysis, companies like Pepsi and Coca-Cola were able to redesign their packaging and create new materials. A culture of collaboration with suppliers, partners, and customers is required to interact with the circular economy at this level[4].

Fig.4 – Nike Grind

Nike, a multinational footwear and clothing company, has achieved several successes in material innovation. In fact, it has created a collection called “Nike Grind” (fig.4) which uses its own materials and has this goal: “To reduce waste wherever we can and reuse that waste whenever we can’t”. Nike Grind generates ideas for new footwear, clothing, and surfaces in sport facilities (e.g., turf fields, indoor basket courts, tracks, etc.)[5]. Using this collection of "waste" materials (recycled athletic footwear, surplus manufacturing scraps and unused materials), the company has been able to develop new high-performance products. Over 73% of all Nike shoes and clothing are made with recycled materials, and 98.2% of production

[4] Jennifer Elks, "Nestlé, Coke, Pepsi & Unilever Join Forces to Combat Waste in Chile"

[5] Nike Grind, "More Performance. Less Waste"

waste is redirected away from landfills[6]. For example, Nike's Flyleather material has a similar appearance, feel, and even smell to regular leather, but is created with at least 50% recycled natural leather fibre from leather scraps. In addition, the material enables a cutting technique that is more effective and produces less waste than regular leather[7]. What's more impressive is that Flyknit, a new type of shoe made by Nike, contains only recycled polyester fibres. Since 1992, 130 million pounds of Nike Grind have been recycled into partners' products (fig.5)[8].

Fig.5 – Nike Grind

Source: https://nikegrind.com/

[6] Nike, "Purpose Moves Us, FY18 Nike Impact Report"

[7] Nike News, "Nike Flyleather"

[8] Nike Purpose, "Waste"

3.2.Sharing Platforms

With the help of a sharing platform, business owners can maximize their resources while also creating a community and giving clients easy access to products and services at reasonable prices. With a concentration mostly on high-value categories, such cars and accommodation, this approach has been adopted in a variety of markets and characteristics (although with comparatively lower levels of utilization by multinationals)[9]. Although the concept of sharing platforms has lately boomed because of the growth of the platform economy, there aren't many examples of scaled sharing platforms with circular concepts intentionally integrated at this time.

Large corporations often need to create new businesses or drastically change their current ones in order to test sharing platforms. It takes a lot of investigation and adaptations to get consensus on the strategy, format, functionality, and business model, especially for an established company that isn't ready to take risks. Therefore, multinational firms adopt this strategy more slowly. Contrarily, start-ups have guided the way, radically disrupting their individual sectors in the business-to-consumer market (such as local small companies and housing and transportation sharing platforms like Airbnb and ZipCar). Yet, during the past few years, sharing platforms have started to advance with significant global corporations as well. One of the biggest hotel chains in the world, Marriott [10], recently launched Homes & Villa, a competitor to Airbnb for high-end home-share rentals, and some of the major rental-vehicle businesses, like Avis[11] and Enterprise[12], currently provide "car sharing". Nowadays, sharing platforms have expanded across a wide range of industries, from fashion and accessories to coworking spaces, equipment, and tools, with many examples in the business-to-business sector. In reality, business-to-business sharing might provide major firms the best opportunities, particularly for those that maintain expensive assets with low consumption rates.

[9] Based on data from entries into the Circular Awards over a 5-year period

[10] Halah Touryala, "World's Largest Hotels 2019: Marriott Leads Again, Hyatt & Accor Rise, Forbes,

[11] Avis, https://www.avis.co.uk/

[12] Enterprise Car Club, https://www.enterprisecarclub.co.uk/gb/en/home.html

The prevalence of smartphones in emerging markets has provided a powerful launchpad for sharing services. Customers in these economies are seeking out services that are convenient, customizable, and cost saving, which is why sharing platforms are being used more and more.

Fig.6 – eRent logo

eRent (fig.6) is a start-up based in Finland that provides a Sharing Platform for equipment construction and machinery management. Through a single digital channel, the platform enables users to rent and manage various types of equipment across the country, pairing spare resources with new demand and boosting the productivity of less productive industry operations (e.g., booking equipment with rental depots at the phone). The service is a one-stop shop for complete construction sites and comprehends both heavy equipment and little tools. Thanks to a number of technologies, such as Internet of Things (IoT) tracking, eRENT customers typically save 20% on the prices of equipment and machinery[13].

[13] eRent, "Track and Rent Platform,"

3.3.Product as a service

company must modify its traditional financial expectations to take into account longer With the Product as a Service business model, products are used by customers through a lease or pay-for-use plan. This strategy brings businesses to shift its focus from volume (selling a product) to performance (selling the function of that product). An example would be the tire company Michelin's pay-by-the-mile model for cargo fleets. "With price per mile rates, you'll spend as little as possible. Our service programs keep your fleet running flawlessly, while our consistent quality helps reduce risk and performance variables. Plus, our energy-efficient tire fleet solutions save fuel and reduce emissions"[14]. The idea behind the Product as a Service models is that businesses may add value to their products by establishing long-term relationships with customers, selling additional services, monetizing consumption data, or extracting tangible value at the end of use.

The Product as a Service model has a limited adoption at scale, despite its huge potential for value creation. The shift from selling a product to selling a service is a fundamental change in a company's value proposition that introduces a series of obstacles. To start, turning a product into a service requires the design, planning, and implementation of numerous extra capabilities, ranging from customer-service desks and account managers to, at the very least, collection and reverse logistics systems. Consequently, businesses must make investments to develop these essential skills. The potential cost coming from these activities must be taken into account in the pricing strategy, which could ultimately lead to an increase in the total cost of ownership over the course of the product's use. However, worries about data ownership can put off potential clients, particularly in the business-to-business sector where operational data can provide a considerable competitive advantage.

Due to their tendency to be more flexible, less vulnerable, and better positioned to engage customers, emerging businesses are currently better positioned to deploy a Product as a Service model. Creating accounting models that are better suited to products that are utilized as services by many consumers rather than a one-time purchase by a single client, is a crucial success factor. In order to use these models, a asset lifecycles, product ownership and

[14] https://business.michelinman.com/freight-transportation/freight-transportation-services/michelin-fleet-solutions

depreciation, takeback, servicing, and an assessment of how the residual value of an asset at the end of its useful life is incorporated into accounting records. Product as a service for traditional firms and organizations focused on quarterly and annual financial performance, at scale continue to be difficulty.

Fig.7 – Rent The Runway logo

Rent The Runway (fig.7) is an e-commerce company based in the US that provides an online service for designer dress and accessory rental. High-end clothing can be rented for four to eight days for a fraction of the retail cost (10% and above), creating a completely new market. There are clothes available for weddings, galas, nights out, vacations, work, and everyday wear. In addition, Rent the Runway offers subscription plans that include free shipping, dry cleaning, and rental insurance. Customers pay a monthly subscription for these plans in order to continually update their wardrobe. Customers who use the service save money on clothing purchases, according to the business survey, and since introducing a circular packaging solution in 2015, more than 900 tons of shipping trash have been avoided[15] [16]. The company, founded in 2009, was valued at $1 billion in 2019 and had 1800 employees[17].

[15] Rent The Runway, "The Real Sustainable Fashion Movement"

[16] Samuel Hum, "How Rent The Runway Created a Multi-Million Dollar Clothing Rental Legacy," Referral Candy Blog

[17] Yola Robert, "Rent The Runway Joins the Unicorn Club at a $1 Billion Valuation"

3.4.Product Use Extension

A product's use in its targeted application is extended through design considerations, repairs, component reconditioning, upgrades, and resale on secondary markets.

Businesses that adopt the Product Use Extension business model maximize the utilization of a product for its intended function and in its original form. Think about how frequently a mobile phone is changed when all that is actually required is an update to a basic feature like the camera or battery. Product Use Extension is applied during or after the first use of the product. The item is repaired, reconditioned, updated to extend its life, or given a second use in a market for used products rather than being disposed, or at best recycled. The business model incorporates several activities such as repairing, refurbishing, and upgrading, trading in and reselling, some of which can be viewed as a business by themselves.

The fact that Product Use Extension only requires an expansion of a company's current business channels or capabilities, rather than a complete change of its present business model, means that it can, for instance, create new revenue streams through resale. Importantly, businesses may increase their contact points with their client base by encouraging customers to extend the use of products they already own. As a result, brand loyalty grows, customer centricity rises, and more product feedback can be collected.

Patagonia is the perfect example of this. According to Rick Ridgeway, Patagonia's VP of Public Engagement, "Our repair facility is the largest in North America, completing more than 70,000 repairs in 2018 alone. Furthermore, the Worn Wear platform has attracted new customers to buy Patagonia clothing at a reduced price and strengthened our brand through stronger ties to existing customers. We've been able to use the insights and data collected on broken products to improve R&D, resulting in products of higher quality and improved longevity."[18]

The main organizational barrier for implementing this business model is determining the appropriate format and scope for launching an internal exploratory venture, especially when low-value products are involved. Although those choices might not seem important at first

[18] The Circular Economy Handbook – Peter Lacy, Jessica Long, Wesley Spindler

sight, putting a Product Use Extension model into practice frequently implies gaining new skills, potential product design modifications, and financial model changes to drive away worries about declining one-time product sales. Vitsoe, for example, is a British furniture design company. This company sells a modular and upgradeable shelving system that is designed to be long-lasting and upgradeable with new shelves, drawers, and other additions and can be easily dismantled and re-built[19].

Electronics, fashion, and furniture are just a few of the areas seeing new innovations emerge. Premium brands or businesses like clothing retailer H&M, which is adopting models that shift the design criteria for clothing to focus more on quality, longevity, and the resale of used items to environmentally conscious consumers, have been the main drivers of adoption in the fashion industry. For example, H&M started an experiment for selling used clothing in Sweden. As a result, it is expected that the fashion resale industry will grow 24 times quicker than traditional retail[20].

IKEA, the world's largest manufacturer of low-cost modern furniture, is also progressing with Product Use Extension models. The business's "Second Life for Furniture" program launched in France and Belgium allows consumers to trade in used furniture for shop credit[21]. In addition, IKEA rents office furniture to businesses in Switzerland and is testing a second-hand furniture sale in the UK[22].

[19] Vitsoe, "606 Universal Shelving System"

[20] ThredUP, "2018 Resale Report,"

[21] Fast Company, "Tea Wants You to Stop Throwing Away Your Ikea Furniture,"

[22] Butler, Sarah, "Ikea to Sell Refurbished Furniture to Boost Culture of Recycling", The Guardian

Fig.8 – Schneider Electric logo

Schneider Electric (fig.8) is a French multinational that works in the energy management sector. The company, in order to update, improve, or add new features, extends the use of its switchboards by replacing switchgear components directly at the client's site. Up to 65% of the cost of new installations can be avoided by extending the useful life of equipment. To reduce waste, returned switchboards and accessories can be reused, and out-of-date parts can be recycled, reconditioned, or fixed. The switchgear housing, plugs, lights, switches, extra cabinets, cables, and wires, for example, can all be reutilized. As a result, there are fewer carbon dioxide emissions (40 tonnes, which correspond to 8 cars traveling around the world), water use (389 kiloliters, which correspond to 7 a year consumption for an average customer), and energy intensity (750,000 megajoules which correspond to 135 barrels of oil), among other benefits[23].

[23] Giovani Zaccaro, "Retrofit Versus Replace: What Should You Do with Our Power Distribution Equipment?", Schneider Electric Blog

3.5.Resource Recovery

At the conclusion of a product's use, infrastructures and techniques for recycling, upcycling, or downcycling are used to collect and process the value of the materials or energy from agricultural and industrial goods.

Resource recovery, as an extension of the conventional waste management, is the most popular business model among companies. When it comes to the value chain's final stages, resource recovery focuses on recovering materials and resources from goods that are no longer useful for their intended purposes. The recovered resource is employed in a way that keeps its value as high as possible for the longest time. For instance, steel recovered at the end of a vehicle's use is reutilized in the production of another vehicle or upcycled into higher-value applications rather than being downcycled into lower-value products. Businesses should keep in mind the "hierarchy of waste" when deciding how to add value to end-of-use products. Companies should aim at closed-loop solutions, despite the fact that they may be more challenging and not necessarily technically feasible. Reduced-quality solutions should only be considered as a last option.

Many different types of organizations have implemented Resource Recovery to this time. Everything is being recovered by businesses, including valuable metal from technological waste and plastic from packaging and cigarette butts. Given that most businesses have some kind of waste management strategy in place, this model requires little modification to current organizational frameworks and is less disruptive than others.

However, there is still a lot of unexploited potential for scaling up current solutions from boosting the standards of the output or by-products that are recycled to raising the amount of waste that is collected and processed. By using standard processes, it is only possible to recover a limited number and type of resources due to current economic conditions and technological limitations. Collection and separation stay costly, and the current waste-related infrastructure is generally unable to satisfy the quantity or quality demands of customers. Yet, as technology advances (and costs drop), data becomes more accessible, and innovative solutions automate previously labour-intensive tasks, businesses will start to focus more and more on recovering wasted resources. Due to a lack of resources, new laws requiring corporations to take

responsibility for the treatment and disposal of their products, such as Extended Producer Responsibility (EPR) fees, and growing consumer demand to address waste issues, resource recovery techniques will also be more widely adopted. For their part, businesses need to provide incentives to engage consumers, encourage product returns, and long-term change of habits. Financial incentives can be a solution, as company Apple did with its GiveBack program (for electronics products) through which customers can turn in their used products for credit and discount vouchers that can be applied towards future purchases[24].

Fig.9 – Veolia logo

Veolia (fig.9), a company that offers management solutions for water, waste and energy, assists its customers in better managing their waste and recovering valuable resources at the end of use. The company is constantly implementing new technologies for the recycling of packaging and the optimization of recycling economic models as part of this process. Recycling and material recovery account for 60% of the company's circular economy revenue. Veolia examined for Selfridges, a well-known UK department store, the store's waste streams in order to boost the amount of recycled materials and add additional waste streams. Veolia developed a method to recycle used coffee cup fibers as part of that initiative, resulting in a material that could be employed as the primary input to create the store's iconic yellow bags, raising recycling rates from 15% to 55% and achieving 100% landfill diversion[25].

[24] Apple, "Environmental Responsibility Report, 2018 Progress Report, Covering Fiscal Year 2017,"

[25] Veolia, "Selfridges-Commercial Waste"

4.Key technologies currently in use

Technology has led each of the industrial revolutions, enabling businesses to develop and massively increase levels of production and performance.

The 4th Industrial Revolution, which we are living now, (4IR) is different from any of the previous ones. While the other three had just one or few technological innovations that enabled companies to achieve an advantage in industrial productivity, this one has a range of technologies and combinations between them that are boosting transformational change across global value chains[26].

The 4IR technologies are a game-changer in the sustainability revolution because they enable businesses to separate growth and output from the usage of natural resources for the first time. These technologies offer four crucial capabilities to achieve this. They first allow for increased productivity, which leads to less waste. Second, they encourage innovation by presenting opportunities for new entrants to disrupt established markets while posing challenges for established businesses to change their course and enter new markets and business models. Thirdly, 4IR technologies improve information transparency by enabling businesses to quickly collect and analyse data to gain insightful knowledge through new levels of visibility (into equipment usage and product, energy, and material flows), connectivity (between machines, customers, and decision-makers), and flexibility (the capability to modify or adapt a device, function, or process) which are crucial to implement circular business models. Finally, they allow us to abandon the use of conventional materials that are scarce or need a lot of resources.

Currently there are 27 technologies that have a crucial role in the circular economy. These technologies are of three types: Digital, Physical and Biological.

[26] Kalus Schwab, "The Fourth Industrial Revolution: What It Means, How to Respond", World Economic Forum

4.1.Digital Technologies

Digital technologies are based on computer, electronics, and communication sciences, which take advantage of the growing amount of information and connectivity of physical resources. The Physical ones are based on basic properties of materials, energy, natural forces, and their interactions. Lastly, Biological technologies are based on biological aspects such as ecosystems and living organisms, to create goods and processes for specific use.

Digital technologies, which have 59% of adoption rate, include:

- Artificial intelligence (AI): enables machines to stimulate human intelligence and act autonomously.
- Machine learning: capability of a machine to perform new tasks after being trained on specific datasets, imitating intelligent human behaviour.
- Cloud computing: hosts web-based apps and content in a single location so that multiple devices can access it at once. Through a network connection, devices can access material and apps instantly.
- Machine vision: digital and analogue images are acquired, processed, understood, and analysed to allow the automatic extraction of data from the real environment.
- Big data analytics: examines extremely large datasets to discover patterns, trends and needs.
- Machine to machine communication (M2M): connects data, analytics, and devices with sensors and actuators. With the use of technology, information can be automatically shared between various devices or control centres without the need for human participation.
- Mobile devices: Combines software, hardware, networks, and operating systems to provide real time access to content.
- Internet of things (IOT): wireless devices with implanted sensors are used, and they interact and trigger actions.
- Block chain: uses a distributed, established network of computers that uses a shared digital system for recording transactions of assets (digital transaction ledgers) for all

parties. As a result, transparency is improved, and information sharing is protected and reliable because the data is open, auditable, and unchangeable.

- Digital twin: creates a virtual representation of a process, good, or service by combining the virtual and real world. This makes it possible to carry out predictive maintenance and build new solutions by analysing data and monitoring systems.
- Digital anchors: monitors, evaluates, communicates, and acts on data using a small computer. To authenticate the product and create a connection between it and the accompanying data stream, the computer is either attached to or integrated inside it. The technology might use barcodes, NFC tags, QR codes, or RFID tags.

4.1.1.Focus: Machine Learning

Machine learning, which is an application of AI, allows algorithms to improve and take on new tasks without any prior programming. Even the decision-making of human specialists can benefit greatly from the technology, which often utilizes neural networks. This is largely because of the enormous (and exponentially expanding) amounts of data that the technology can process quickly and accurately. Through self-learning algorithms that enable quick prototyping and testing, machine learning may assist businesses in designing circular products, components, and materials. Additionally, by utilizing predictive analytics for more accurate demand planning or by examining consumption trends to improve asset management, it can be utilized to reduce waste, resource use, and emissions.

Siemens, a leader in industrial automation, has used machine learning to improve the gas turbines' combustion processes. Their objective was to reduce emissions, which may be a challenging task that requires consideration of a variety of parameters, including gas composition, local weather, and the age of the turbine. Siemens has been able to accomplish remarkable results, sometimes even outperforming the performance of human specialists. In a series of experiments, the machine-learning system was able to further cut the nitrogen oxide emissions by an additional 20% after a human expert had manually set the turbine controls[27]. The market for machine learning has enormous potential; by 2023, it's anticipated to reach $23 billion[28]. In order to reach that value, companies must overcome multiple challenges, such as aggregation and integration of data. As for the Siemens turbine control system, large amounts of data are required to provide relevant results from machine learning. Large organizations may have access to virtual data vaults, but not all that data may be immediately useful. The majority of it needs to be "cleaned" first and a large portion of it is locked up in various formats in distinct storages.

[27] BootUP, "Sustainable Energy Management with Artificial Intelligence"

[28] Business Wire, "Machine Learning: Global $23+ Billion Market Trends & Opportunities"

4.2.Physical Technologies

Physical technologies, which have 28% of adoption rate, include:

- 3D printer: machine controlled by a computer used to create 3D objects by forming layers of material.
- Robotics: machines programmed to automatically perform a complex series of tasks. Robots can train themselves when integrated with machine learning.
- Energy storage and utilization: extends battery life, battery capacity and replaces with organic substances, chemical based raw materials.
- Energy harvesting: energy is captured from external sources such as heat, light, sound, movement and then stored.
- Nanotechnology: matter is manipulated on an atomic, molecular, or supramolecular scale.
- Spectroscopy: Analyses material based in its composition by using different spectra of electromagnetic radiation.
- Physical markers: requires a direct link to a database to aid with the authentication of a product. Products have physical markers affixed to them so that customers can verify additional information about them.
- Virtual Reality: provides an interactive, completely immersive digital reality in a computer-generated or video-enabled environment (VR), or uses wearable technology to overlay text, audio, and visuals on top of the real world (AR).
- Carbon capture and utilization: the process of removing waste carbon dioxide from big point sources (such as fossil-fuel power plants), transporting it to a storage location, and dumping it there so it won't enter the atmosphere. Utilization makes the carbon that was captured possible for new goods or procedures.
- Material Science: Utilizes expertise from various disciplines as well as chemical engineering to create new materials. It can aid in the development of goods and procedures that reduce the usage and production of dangerous substances.

4.2.1.Focus: Energy Harvesting

The process of capturing, storing, and supplying energy that would otherwise be lost as heat, light, sound, vibration, or movement is known as energy harvesting. Due to conversion efficiencies, source stability, and power-storage capacities, deployment has been fairly limited up until now. However, technology is developing, and by 2025, it is predicted that the global energy-harvesting industry would have surpassed $1 billion[29]. Applications range widely and show no lack of innovation, including IoT sensors that use solar energy to power themselves, antennas that collect radio frequency energy and convert it to direct current electricity, and an incandescent light bulb that recycles its own heat. An energy-efficient "nano-generator" developed by two top technology centres in China and the United States can be mounted on the roof of a house and used to power a temperature sensor and energy-efficient light-emitting diode (LED) lights inside[30].

Future predictions indicate that the technology will become even more important, particularly for compact and low-energy devices. The use of sensors and other electronic devices in environments where the costs associated with providing power have made certain applications challenging will be driven by IoT applications and consumer electronics[31] [32]. Buildings constitute a significant area of opportunity because they use about 30% of all energy globally[33]. If businesses could capture the wasted energy that is lost inside buildings, it might be used to power equipment that would reduce the total amount of energy needed by buildings and provide significant financial benefits to building owners.

[29] Market Watch, "Global Energy Harvesting Market 2019-Industry Analysis, Size, Share, Strategies and Forecast to 2023"

[30] Wang et al, "Efficient Scagenging of Solar and Wind Energies in a Smart City", ACS Publications

[31] Gene Frantz, Dave Freeman, and Chris Link, "TI Technology Opens New Frontiers for Perpetual Devices"

[32] Ed Sperling and Kevin Fogarty, "The Limits of Energy Harvesting", Semiconductor Engineering

[33] BP, "Energy Demand by Sector"

4.3.Biological Technologies

Biological technologies, which have 13% of adoption rate, include:

- Bio-energy: obtains energy from biomass, which includes wood, waste gas, and alcohol fuels and also from living things such as plants and animals.
- Bio-based material: new materials are derived from living organisms.
- Genetic engineering: By using biotechnology, it modifies an organism's genome.
- DNA marking: To fight counterfeiting of product, it marks items in ways that are undetectable to eyesight.
- Cellular and tissue engineering: uses the concepts of cell and tissue growth to create substitute materials that are useful or changes of current ones.
- Hydroponics and aeroponics: employs sustainable gardening techniques.

4.3.1.Focus: Bio-based materials

Bio-based materials can be formed from biopolymers and other natural fibres created partially or entirely using plant feedstock, and they can be made from plant-based materials that are compostable and recyclable and are utilized more frequently as alternatives to less sustainable resources. Mazda, a Japanese automaker, serves as an example. The corporation has begun employing bio-based plastics for its car interiors rather than conventional plastics and other materials that pose environmental risks. Mazda has created a new plastic in collaboration with Mitsubishi Chemical Corp., that can be dyed rather than painted, which reduces the need for volatile organic compounds (VOCs). The manufacturer also employs bio-fabrics for the padding of its car seats that are made entirely from plant-derived fibre, and it has started using high-strength, long-lasting bioplastics for external car parts[34]. Global plastic output is anticipated to increase deeply over the next 20 years, and most of it might be sourced from new bio-based polymers as well as from materials and chemicals made from renewable biological resources[35]. Companies planning to expand the use of this technology must take into account a number of aspects, including the product's environmental impact and potential to be recycled. Only when the proper waste management mechanisms are in place to either recycle bio-based materials back into the value chain or re-absorb them into the environment, bio-based products are considered circular. By assessing this and other criteria, a business may find that using a specific bio-based substance isn't always better for the environment than an oil-derived substitute[36].

[34] Mazda, "Bio-Based Plastics"

[35] GRID-Arendal, "Global Plastic Production"

[36] Katherine Martinko, "The Problem with Bioplastics", Treehugger

5.The impact on industries

Circular activity at the industry level comes in many different forms and volumes. Consumer-facing businesses have generally experienced the highest volumes of circular activity, frequently driven by demands from customers, governments, and workers. Particularly, the top FMCG (fast moving consumer goods) companies have set ambitious goals for the circular economy, frequently with an emphasis on reducing packaging and input waste. In addition, there has been a rise in the use of alternative materials and a dedication to the circular economy in the consumer-facing fashion sector. Rising customer demand and expectations are a clear driver for these businesses. Accenture, a company specialized in IT, services, and consulting, did a survey in 2019 which revealed that in comparison to five years before, over three-quarters of customers claimed to purchase more "environmentally friendly products". Growing public discussion about concerns like plastics and "disposable" fashion, also known as fast fashion, is motivating firms in these industries to take action. Customers are starting to put pressure on businesses-to-business (B2B) industries, like the chemical, metals, and mining industries, which are less visible to consumers. In fact, most consumers (83%) think it's critical for businesses to provide items that can be recycled or reused, and nearly half (49%) think the chemical industry, for instance, cares the least about the environment compared to eight other industries[37].

The pressure from regulatory norms is felt in other businesses. Increasing regulations for the management of products after use are pressuring businesses to place a greater emphasis on the recovery of used machines. For example, in the household industry, technicians who maintain refrigeration and air-conditioning equipment in the US are required by Environmental Protection Agency (EPA) standards to adhere to certain procedures to maximize recovery and recycling[38].

Most industries switching from linear to circular models of production and consumption, follow a dual focus applying circular models to their existing value chains while also gradually changing the way they operate today to dive into new growth sectors and capture circular value.

[37] Australian Retailers Association, "Survey Shows More Than Half of Consumers Would Pay More for Sustainable Products"

[38] United States Environmental Protection Agency, "Stationary Refrigeration Service Practice Requirements"

Resource Recovery and Circular Inputs provide the biggest opportunity for creativity and industry combination. Industries try to figure out what they should take back into their value chain and what they should redirect for reuse by others.

Unwanted plastics are being converted into better road surfaces, worn shoes are being recycled into sports floors or car interiors, and wastewater is being converted into fuel for public fleets. The potential is massive, even though technical capability, weak infrastructures, and unwanted effects prevent the circular economy from advancing.

5.1.Barriers and Enablers

The transition to a circular economy, within an organization, presents both barriers and enablers. Companies across all industries need to face various challenges such as scaling innovation, focusing on stronger supply chain circularity, and building partnerships. The four different categories of linear waste will typically be handled by circular opportunities, although their balance may vary.

For example, consumption-focused industries such as consumer electronics and goods need to focus on reducing waste coming from product use (wasted capacity) and premature disposal (wasted lifecycles). Additionally, by using service-based models to extend product life or by recovering useful material at end of use (wasted embedded values), these companies can capture value.

It's also essential to remember that customer demand will change by industry for each model. Although there is a general trend toward less consumption and greater simplicity, whether consumers are willing to switch to renting or sharing models for goods or services depends on the perceived value of the product.

According to research, these models work better with items that are less emotive and more useful (lawnmower), less expensive compared to extremely expensive (crib), or those that lack hygienic requirements for reuse (book). Consumers are also most likely to pay more for electronics products (computers, TVs, etc.), children's toys, and food and beverage packaging that are designed to be reused or recycled with over 55% preferring to pay at least a 10% premium[39].

Current industry characteristics can both facilitate and make more difficult the adoption of circular economy techniques. Consumers are used to have access to the newest products at the most affordable prices, either on-demand or delivered within days, in both the ICT and fashion industries. This causes products such as electronic apparel and clothing to shorten their lifespan. Even products with long shelf lives and high durability quickly become outmoded or unattractive. Mobile phones, for example, might technically endure for four to five years, but

[39] The Circular Economy Handbook – Peter Lacy, Jessica Long, Wesley Spindler

the demand for these devices to be updated more quickly restricts their capacity to generate enough value through disassembly and upcycling instead of resale on secondary markets.

Finally, even within a single industry, the opportunities and obstacles associated to technology and infrastructure have not been uniform. Different industries have different levels of infrastructure and technology development. For instance, recycled materials' performance and quality are a problem in the fashion business. Greater carbon circularity in the oil and gas industry depends on carbon capture technologies that haven't yet shown they can be scaled up at an affordable price.

We will now investigate what this change implies for some industries. We will look at how three distinct industries may contribute to the circular transition and how they can benefit significantly by adopting circular concepts.

5.2.Focus: Chemical Industry

The first of the three is the chemical industry. It is one of the biggest and most diverse manufacturing sectors and it creates intermediate and end products that are used by most all other sectors. The industry has been moving toward circularity as a result of decreasing non-renewable resources and severe environmental restrictions. Using sustainable inputs to produce goods and decreasing hazardous content leakage into the environment are some examples of this. Sari Dubourg, Board of Executive Directors, BASE, a German chemical company said "Across our entire portfolio, it was clear that circularity could help us minimize risks and capitalize on opportunities by changing our business models."

Challenges

Chemical companies need to cope with three major waste streams. The use of non-renewable resources as raw materials and energy sources represent the first one. By 2050, it is anticipated that around 20% of the world's oil production will be utilized to create plastic, compared to the current 8%[40]. Additionally, the chemical sector is the greatest industrial energy consumer in the world[41]. The waste produced during the production of chemicals, such as process waste, used catalysts or solvents, spilt oil, sludge, and contaminated chemical containers, makes up the second significant stream. The industry is responsible for the existence of nearly 200 of the most contaminated locations on earth, placing three million people at risk of exposure[42]. The waste produced by consumer products makes up the third significant stream. Many consumer products are made with chemicals. About 80% of the output of the chemical sector is made up of polymers, which are mostly utilized to create plastic products. Approximately 95% of the value of plastic packaging material, or between $80 billion and $120 billion in economic value, is lost each year, according to a 2016 World Economic Forum (WEF) analysis[43].

[40] Laura Parker, "Fast Facts About Plastic Pollution", National Geographic,

[41] Peter G. Levi and Jonathan M. Cullen, "Mapping Global Flows of Chemicals: From Fossil Fuel Feedstocks to Chemical Products", Environ. Sci. Technol, 2018

[42] Pure Earth, "2016 World's Worst Pollution Problems", 2016

[43] Techofunc, "Business Model & Value Chain of Chemicals Industry"

Opportunities

Numerous potential opportunities for the chemical industry have emerged as a result of the growth of the circular economy. "Circulating molecules" may be the driver for one such opportunity. Circulating molecules, as the name suggests, refers to the reuse of already-existing molecules, whether they take the form of hydrocarbons found in biomass or the chemical components of consumer goods. Currently, businesses are trying to create a new technology to exploit more the circulating molecules method in their supply chains.

The potential of reuse and recycling present another major opportunity. The same concept of reusable alternatives for PET (polyethylene terephthalate) bottles and plastic bags that has been around for a while now, can be applied to the chemical sector in various products, including automotive parts, electrical component parts, and white goods (home appliances). For what concerns recycling, it can be done mechanically by gathering and processing end products, then reintroducing their intact molecules further upstream in the value chain without altering their chemical bonds, or chemically, breaking up long-chain hydrocarbons into precursors.

The circular economy and digitalization can also be utilized by businesses in downstream industries (oil and natural gas industries). For instance, lighter materials are needed for more fuel-efficient cars, and greater insulation is needed for more energy-efficient homes. The opportunity for chemical businesses is to develop innovative strategies for holding onto a portion of the molecule's value, which has a high likelihood of success. The successful implementation of circularity downstream is anticipated to stimulate new and increased demand, with a potential rise of 26% until 2030, for more environmentally friendly chemicals[44].

Applying Technology

[44] The Circular Economy Handbook – Peter Lacy, Jessica Long, Wesley Spindler

The advance in scientific and digital fields have created new roots towards circularity.

- The molecular manufacturing technology start-up Zymergen is using big data and machine learning to rapidly create unique microorganisms for the production of plastics and other fundamental industrial materials. The platform has allowed the company to cut the time it takes to launch new items in half and raise net margin by more than 50%[45].
- Thanks to the introduction of IoT and blockchain technology, BASF is using "smart pallets" that keep track of their location, temperature, and load status to manage its supply chain more effectively[46].
- Renewable polyethylene (PE) and polypropylene (PP) from the petrochemical manufacturer SABIC are totally recyclable and use 84% less fossil fuel to manufacture than their fossil-based counterparts[47].

Obstacles

Given the complexity of the chemical business and how highly sophisticated molecular bond modification is, the shift will require a lot of time and effort. As this alteration fundamentally changes the essence of the product, adopting it is difficult and time-consuming. A number of circulating molecule technologies, such as chemical recycling and carbon utilization loops, are still not commercially viable. To fully complete the transition to a circular economy, the governments' aid is essential. Their job will be to support research and investments in this sector and implement regulations and policies. Without governments, the transition would be too costly and would take considerably more time.

[45] World Economic Forum in collaboration with Accenture, "Digital Transformation Initiative: Chemistry and Advanced Materials Industry"

[46] BASF, "BASF Invests in Smart Supply Chain Start-Up Ahrma"

[47] SABIC, "Innovations By SABIC to Minimize Food Wastage, Reduce Weight, and Lower Carbon Footprint of Packaging Materials"

5.3.Focus: Information & Communications Technology (ICT) Industry

The second industry analyzed is the ICT industry. The market has been saturated with devices that assist every area of everyday life and work over the past years. The eventual effect is a market with short innovation cycles and declining price sensitivity. Large-scale datacenters are one example of the growing technological infrastructure brought on by the rise of the cloud and big data. Infrastructure requirements will increase as technologies like artificial intelligence (AI) require more processing power, storage, and Internet bandwidth. Parallel to this, the worldwide network infrastructure needs to be updated for next generation 5G wireless networks. Additionally, the transition to a low-carbon economy combined with trends for improving user experience is now driving, and will further drive the growing volume of electronics, such as those in smart appliances, vehicles, and wind and solar power generation systems. Key raw resources including cobalt, copper, and rare earth metals will continue to see an increase in demand and price as a result.

Since value chains in this sector frequently cross the globe, they are difficult to disrupt from a circular viewpoint. Due to the geographical dispersion of the resource production and resource recovery points, this poses end-of-use issues. Further complexity is brought on by geopolitical matters, such as China's National Sword policy, which forbids the import of foreign e-waste.

Challenges

Because consumers want quick access to the newest technology at the lowest prices, ICT products have a limited lifespan. For example, in the enterprise IT sector servers are typically replaced every three to five years[48]. Two significant waste pools result from the propensity to replace older products with newer models too soon.

Wasted lifecycle is the first one. Perfectly functional hardware and devices are frequently replaced due to the rising desire for the newest innovations. Even though the potential use of

[48] SherWeb Blog, "Cost of Server Ownership: On-Premise vs. IaaS"

smartphones is significantly longer (5 years), consumers typically only utilize them for 22 months on average[49].

Embedded value is the second major waste pool. The hardware of network infrastructure, enterprise technology, and the majority of ICT devices contain precious components that are currently not being recovered. Globally, 44.7 million tons of e-waste were produced in 2016; however, only 20% of this material is now known to have been collected and recycled[50].

Opportunities

The ICT sector has many potential growth areas. The first area of possibility is demonstrated by the restoration and reuse of current ICT devices. In order to resell previously owned devices, recovery companies like Amazon Renewed, Inrego, and Laptops Direct have started to gather them. When updated with fresh software and drivers, reconditioned devices can work just as well as brand-new ones, significantly increasing their service life. For instance, sales of reconditioned smartphones increased by 13% in 2017 while those of new smartphones only increased by 3%[51]. Leasing or renting are new consumption practices that can make it easier to return products for restoration and reuse.

The second area of opportunity is the recovery of precious materials from ICT equipment at the end of their useful lives. Around 25 grams of aluminium and 15 grams of copper are found in a normal iPhone, in addition to smaller but still considerable amounts of platinum, gold, and other precious metals[52].

The third potential area is redesigning for minimal material use. Great value potential could be realized by the industry by using more intelligent designs to reduce the amount of material used in components like consumer device casings and product packaging. The use of a product can be cost-effectively extended by using circular design concepts.

[49] Torro Cases, "How to Extend the Lifespan of Your Smartphone"

[50] United Nations University, "The Global E-Waste Monitor 2017

[51] Patty Osterberg, "Electronics and the Growing Trend Towards Reuse and the Circular Economy"

[52] The Circular Economy Handbook – Peter Lacy, Jessica Long, Wesley Spindler

Applying Technology

- Apto Solutions, an asset lifecycle management company, uses an integrated approach to extend the service life of its technology before recycling it back into the economy. This prevents customers from privacy violations and recovers value from undesired assets. In 2014, Apto Solutions avoided the landfilling of 1315 metric tons of hazardous waste while also saving over 14,800 metric tons of fossil fuels and 19 million gallons of water[53].
- Fairphone, a sustainable smartphone business, built the Fairphone 2, a device projected to survive longer than the usual smartphone. The device offers simple modification, updates, and maintenance for long-term use. According to a lifecycle assessment study, the Fairphone is expected to reduce CO emissions by 30% throughout its whole lifespan[54].
- Traceability and transparency may be improved with digital solutions all along the ICT value chain. Without exposing datasets or supply chain partners to the public, the startup Circularise is building a blockchain-based communication protocol named "smart questioning" to improve value chain transparency. This ensures data reliability without requiring the revelation of private corporate or product data[55].
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Obstacles

To overcome the challenges posed by this transition, companies must find a solution to wasted lifecycles and e-waste. The first solution could be collection at end of use. Companies can offer to customers product takeback incentives, as Apple already did with its trade-in program. For the second issue, the use of robotics for product disassembly can increase the effectiveness of the recycling process and the quality of the recycled materials. Extended Producer Responsibility regulations and other global policy standards would help the growth of end-of-use practices all around the world by increasing visibility and traceability along the value chain.

[53] The Forum of Young Global Leaders in Collaboration with Accenture Strategy, "The Circulars 2016 Yearbook"

[54] Fairphone, "Impact Report Vol. 1"

[55] World Economic Forum in Collaboration with Accenture Strategy, "Harnessing the Fourth Industrial Revolution for the Circular Economy Consumer Electronics and Plastics Packaging"

5.3.Focus: Personal Mobility Industry

The third industry analyzed is the personal mobility industry. Personal mobility refers to a person's use of a private or shared vehicle for mobility. In this sector, it's crucial to mark the difference between indirect and direct circularity. The direct circular economy transformations are distinct from macrotrends (indirect circular economy) like carsharing, alternative propulsion systems, and autonomous vehicles. These macrotrends leave unsolved inefficiencies, such as indirect emissions, which have a negative effect on the environment. For example, if the travel by car is made more convenient, the number of vehicles produced and the amount of energy consumed will likely increase, consequently increasing the total distance travelled by vehicles. The adoption of direct circularity instead, specifically addresses resource utilization inefficiencies like reducing the manufacturing process's energy and material intensity[56].

The industry has made considerable progress toward circularity, with the largest improvements in fuel efficiency and emission reduction. In the next five to ten years, automakers like Land Rover, Mercedes-Benz, and others have already planned to. Another change of behaviour due to technological innovation is represented by carsharing (a model of vehicle rental where users can rent vehicles for short periods of time) and carpooling (the sharing of car journeys so that more than one person travels in a car and prevents the need for others to have to drive to a location themselves). Apps like DriveNow, Enjoy, Sharenow and others have shown a great success.

One out of every ten cars is estimated to be shared vehicles by 2030[57]. Despite the significant progress in these areas, production continues to be resource intensive, and tons of waste is being produced annually by end of use vehicles.

[56] Payton Chang, "Self-Driving Cars and Their Environmental Impact"

[57] McKinsey & Company, "Automotive Revolution-Perspective Towards 2030"

Challenges

The personal mobility sector generates waste primarily in four areas. The first one is related to manufacturing. The production process results in 20% of all GHG (greenhouse gas) emissions for internal combustion engines and up to 47% for battery electric vehicles[58]. Also, the manufacturing of a car produces about 110 kg of waste[59]. Wasted capacity represents the second area. An estimated $7 trillion worth of passenger cars are unexploited at any specific moment due to the poor utilization rates of cars, which range from 5 to 10% on average[60]. But is when they are used that vehicles have the most waste impact. The third area includes carbon, which accounts for 17% of the world's GHG emissions from transportation, as well as other wastes like microplastics shed from tires, precious metal particles released by catalytic converters (devices used to reduce the emissions from an internal combustion engine)[61], wasted embedded value not recovered from parts, and consumables (such filters, fluids, and wiper blades) changed during the life of the vehicle. Lastly, the fourth area is constituted by end of use vehicles. Private cars in Europe are estimated to be 9.7 years old on average, with 12 million vehicles being removed from the road each year[62]. Tons of potentially valuable waste are represented by this.

Opportunities

In this sector, there are three main areas of opportunity. The first is a result of the significant transition to alternative propulsion systems. In 2018, the global percentage of new sales for battery electric vehicles was 4.6%, nearly doubling from 2017. This change reveals a chance to significantly lower mobility emissions. Another exciting opportunity is ride and vehicle sharing. By 2030, 11% of automobile sales are predicted to move to the sharing economy, forcing manufacturers to modify their business strategies to remain competitive[63]. The third area of possibility is the sale and reuse of reconditioned components through after-markets. With

[58] Steel Market Development Institute, "The Importance of the Production Phase in Vehicle Life Cycle GHG Emissions"

[59] Sharon Guynup, "The Zero-Waste Factory," Scientific American

[60] David Z. Morris, "Today's Cars Are Parked 95% of the Time"

[61] https://chem.libretexts.org/

[62] Ellen MacArthur Foundation, "The Circular Economy Applied to the Automotive Industry"

[63] Electrive.com, "All-Electric Car Market Share on the Rise Worldwide"

significant environmental savings, reconditioned parts are currently sold at 50–70% of their original price. The fourth opportunity is created by lowering the resource demands from manufacturing vehicles and waste generated by production[64].

Robotics, industrial IoT, and other smart manufacturing technologies can improve production, leading to easier operations and a lower rate of reports for defective items. The Carbon emissions from the European automotive industry have decreased by more than 20% since 2008, according to the European Automobile Manufacturers' Association (ACEA) in 2018[65].

Applying Technology

- Using 3D printing in industry might reduce waste, the amount of material required, and the price of production processes by up to 90%. In 2019, a 3D-printed low speed electric vehicle, starting at $7500 was put on Asian and European markets. This vehicle is the result of a partnership between Polymer, a Chinese 3D printing materials company, and the Italian electric vehicle start-up, XEV[66].
- Thanks to the development of autonomous driving, the combination of hardware and software innovations, it's possible to move with higher fuel efficiency and less energy consumption[67].
- Vehicles can exchange data with the outside world thanks to telematics. Using telematics data and forecasts, predictive maintenance is becoming smarter. Particularly for owners of bigger vehicles and transport trucks, the ability to anticipate a servicing event might possibly result in significant material and energy savings[68].

64 Ellen MacArthur Foundation, "The Circular Economy Applied to the Automotive Industry"

65 ACEA, "Environmental Impact of Car Production Strongly Reduced Over Last Decade"

66 Green Car Congress, "Report Suggests Low-Speed Electric Vehicles Could Affect Chinese Demand for Gasoline and Disrupt Oil Prices Worldwide"

67 Meghan Brown, "Tech Trends 2019: Driverless Cars, AI, & Augmented Reality"

68 Telematics Talk, "Predictive Maintenance: The Holy Grail of Truck Telematics"

Obstacles

A big issue in this industry is the disposal of lithium-ion batteries used in electric vehicles, estimated to reach 11 million tons by 2030. The majority of those used batteries still have up to 70% of their original capacity. In fact, automakers like Tesla, Nissan, and BMW are exploring reuse possibilities for the batteries, such as employing them as stationary power sources[69]. Since the electrification and digitization of cars have raised demand for metals and minerals, second-use possibilities would also help to reduce the dangers associated with an increased supply. Around a third more lithium compounds were consumed in 2018 than in 2017, the majority of which are used in batteries.

End-of-use management has been another problem. The infrastructure needed to manage the vehicle end-of-use process is largely inadequate in developing nations, where the recycling sector is fragmented and often unregulated. Differently, most cars are decommissioned in developed countries before they reach the end of their useful lives. Despite the high rates of car recycling in these areas, the majority of the material waste streams that result is usually of low quality and are used in lower-value items and industries. Yet, there are innovative ways to address this and move away from downcycling to upcycling in the future, especially for metals and some plastics. The End of Life Vehicles Directive in Europe mandates that the industry makes sure that 95% of a vehicle's weight is reused, recycled, or reconditioned[70].

69 Electrive, "EVgo & BMW Launching 2nd-Life Battery Project"

70 Julian M. Allwood, "A Bright Future for UK Steel", The University of Cambridge

6.New technological frontiers

Together with all the technologies currently in use in the various industries, leading the path to circularity, there are other technologies that are not yet being used or are being used just marginally compared to their potential, but can give a big aid to fully exploit the potential of circular economy in the near future.

6.1.Extended Reality

Immersive technologies, which combine industry and imagination, have grown quickly during the last ten years. The virtual reality, VR, (allows users to totally immerse themselves in a speculative virtual world) and the augmented reality, AR, (combines virtual items and digital artifacts to our daily experiences in the real world), segments of the extended reality (XR) industry, are anticipated to reach more than USD 250 billion by 2028, despite not yet being widely used. Users can explore and engage with virtual environments in many ways thanks to each technology.

Both VR and AR basically are technology for creating new worlds. As a result, they can be helpful in defining and shaping a circular future. When switching from a linear to a circular business model, moving from the conceptual phase to the practical phase can be difficult. Virtual or augmented experiences can assist organizations in bridging the gap between theory and reality during the transition process. For example, an electronics manufacturer who wants to incorporate remanufacturing, might invest on a VR simulation that takes key stakeholders through a virtual factory floor. By doing so, resistance to change can be eased by emphasizing the financial, material, and energy benefits in a visually appealing manner. Environmental designers, urban planners, and other professionals involved in the construction of infrastructure may be able to use VR and AR to make important decisions involving future projects. The decision-making, design visualisation and optimization can be improved by the addition of XR components, aiding in the real-time realization of the vision. For instance, AR

may demonstrate how and where circular features like street-level refill and return stations, multi-use structures, and transport-sharing schemes might be implemented in a circular future.

VR, that needs special equipment, can help FMCG companies, fashion brands, and retail partners to powerfully and remotely visualize the advantages of shifting their worldwide producers away from traditional, damaging farming practices. Meanwhile, AR technology makes it simpler to connect with farmers in isolated rural locations because it is mostly facilitated by smartphones without the need for additional equipment. Multi-sensory virtual layering can give a unique perspective on regenerative outcomes by overlaying the biodiversity advantages of rotational grazing patterns onto land that is currently continuously grazed, hearing the sound of the return of pollinating insects into silent landscapes, revealing the return of rich texture to arid soil, and letting users taste the difference in the final crops.

In the fashion business, to address the industry's significant relationship with waste and pollution, different XR-enabled dematerialization techniques are being tested. By creating apps that enable customers to digitally try on products at home, some companies, like Gucci, Nike, and others, are tackling the high return rates faced across the sector. They can significantly lower the amount of unworn clothing sent to the landfill as well as the actual energy utilized in the transportation and processing of unwanted items.

Design is the first step in creating products with numerous use cycles. Creating methods of operation that minimize material waste is a crucial initial step, and XR-based tools can greatly facilitate this. The design, manufacture, and repair of anything (trains, planes, vehicles, electronics, etc) may be turned into waste-free by introducing digital prototypes and virtual copies.

Dematerialization is not suitable for all sectors. We cannot have virtual transportation, enhanced food, or simulated furniture, despite the circular economy's focus on shifting from ownership to service and experience models. In these circumstances, solutions are required to make sure that items are kept in use for as long as possible at their best value rather than being designed out of existence.

6.2.Blockchain

Blockchain is a distributed ledger technology (DLT), which was first considered just as a way of facilitating cryptocurrencies, that can profoundly add value to the circular economy. It is a particular type of DLT that uses informational blocks that are connected in a chain with an encrypted signature to prevent hacking. Its value can be found in accelerating and improving the a difficult business process like the sharing and updating of transactional data across network users. DLT offers a decentralyzed way of doing this. As a result, no single person can have total control over the system, guaranteeing transparency.

Blockchain is ideal to help in the circulation task. It identifies and tracks materials and components throughout the supply chain so they can be reused, remanufactured, recycled, or composted. So far, monitoring materials has been its principal role in the circular economy. A product can carry with it updated information stored on a blockchain that enables each user in the chain to make conscious decisions regarding the management of materials. This information can be linked to a GPS system or Internet of Things (IOT) sensors that track its movements and adaptations.

This enables businesses to clearly quantify their decreases in the usage of raw materials by aiding manufacturers in locating components that a blockchain may record as recycled or remanufactured, which is what Coca-Cola is already doing with its waste collectors in Africa.

This DLT can also assist the end-user in deciding how to fix or get rid of a product or its parts in the best way possible. The circular economy is made possible in practice by the detail in the stored data, which enables all partners in a product's value chain to share responsibility for its material movements. For example, Electrolux decided to start using the blockchain to record information on the best ways to disassemble refrigerators at the end of its useful life in order to recover the foam from them.

In the last years the progress on using the technology within supply chains has so far only involved pilot projects. The primary causes of this slow growth include the fact that this technology requires a level of collaborative culture at which most companies are not accustomed. A vast network of participants must cooperate in the successful use of blockchain in the circular economy, making some fundamental modifications to many aspects of their

activities. Another issue is that even with blockchain's ability to act as a gatekeeper and keep some data private, the concept of open data disturbs some.

Governmental policy is the key accelerator of this process. Significant changes might happen in the ways that businesses build their business models and products if non-renewable resources are taxed at the point of consumption and a software platform like blockchain makes this possible. Corporate strategy could better align to support a circular economy if there were financial incentives to reduce waste and polluting materials.

If blockchain can develop in a way that allows for these kinds of systems, it may be successful in permitting businesses to be fully accountable for the materials they select for their goods. The next phase of a circular economy might then be brought in as a result of blockchain technology.

7.Future business models

The potential for business model innovation today is, in many ways, limitless. Additionally, business models are now more capable than ever of evolving due to the increased prevalence of experimentation. Businesses, by using business model design, are developing innovative methods, to deliver value, that have the potential to drastically disrupt industries.

Business model design is now more than just a simple modelling exercise; it's a chance to completely rethink how a company offers, develops, and collects value. Because of increased access to technology and infrastructure, new ways of thinking, and new market opportunities, new business models are emerging more quickly than before. At all scales, from micro-enterprise to multinational, operating in every industry, reinventing business models has become as one of the most reliable methods of providing clients with something that is genuinely better than what is already available.

Business models develop depending on a variety of factors, such as fluctuations in supply and demand, consumer preferences, technological innovation, and regulatory shifts. New business models not only intersect in various ways, but they also develop at an accelerating rate. Organizations occasionally disrupt current business models by entering markets with new ones; other times, they add fresh approaches to old methods of generating, producing, and capturing value, integrating parts of various models.

There are 12 characteristics that business models of the future need to put together in different combinations. These characteristics can be understood as the driving forces behind business model design. These characteristics are:

1. Multi-layered: has the ability for various components to interact and work together to create value.
2. Participatory: allows businesses to reconsider how they interact with their clients and other stakeholders.
3. Platform-ready: offers the chance to unlock value by creating communities, empowering customers, and taking advantage of network effects.

4. Multi-capitalist: understands that value generation through a business strategy involves more capitals than only financial ones, such as intellectual, natural, relational, and many more.
5. Purposeful: builds resilience and long-term value that require cultivating a sense of purpose and truly expressing it to partners, customers, and workers.
6. Data sensible: recognises the importance of data, its sensitivity, and its owners' rights.
7. Boundary-testing: goes beyond apparent natural boundaries to create lasting value in areas that were previously thought to be outside the scope of an organization.
8. Open: enables increased collaboration and sharing, as well as the chance to profit from enhancing an ecosystem and expanding on the knowledge and understanding of others.
9. Potential enhancing: Gives people and communities the tools they need to reach their full potential.
10. Fair: In a digital context where a lack of professional competence and due diligence can cause ethical difficulties to appear in unexpected areas, the need for strong corporate ethics is even more pressing.
11. Convening: builds a community that people value.
12. Restorative: is able to fix, renew and repair.

It is easy to observe how, during the past century, technological convergence and innovative product and service design strategies have frequently created businesses of the future, that then lead new industries. For example, before the iPhone came along, a mobile web browser, music player, and messaging device that contains a GPS mapping service and also makes calls, was not available. As a result, Apple became one of the most valuable firms in the world over the past 20 years. This is the proof that business models that will prosper in the future are the ones that engage with technological innovation.

Innovation and progress in the world of economy are linked by technology. Uneven access to technology harms some individuals while benefiting others enormously. Technology might imply access to basic infrastructure or reliable power supplies and access to on-demand services and 5G data connectivity. Data is what powers the newest technological wave, which is enabled thanks to ever-increasing computing power. Data is being recognized as a new source

of potential value in the global economy, from highly effective, platform-based preference matching to productivity increasing AI. In some cases, data and technology have made room for the establishment of business models that improve quality of life. Alongside this possibility, a number of social and ethical issues including data ownership, quality, privacy, and algorithmic biases are now being addressed.

Of course, business model will also have to deal with environmental issues, which we have already largely discussed, and that represent one of the major reasons for the need of new business models.

8.Conclusion

Our consuming habits and demand are quickly approaching a critical point where they exceed the planet's capacity for safe regeneration. Throughout the past years, we have been trapped in an unsustainable system of production and consumption. Although technological progress has made it possible to use natural resources more effectively, we still take and waste more than we grow. A move to a circular economy offers businesses a significant chance to innovate, open new markets, and minimize their negative environmental effects.

This transition is not in any way simple. Although the basic idea behind circularity is straightforward, to transform waste into something useful, disrupting our current linear structures of production and consumption is a huge challenge. Companies must assess their present linear models, core assets, and customer preferences to decide how they will make the shift to the circular economy and capture the $4.5 trillion in value that is at risk. The five business models lead the path to that change thanks to physical, digital, and biological technologies that are in continuous development and are the key to this transition. This approach can be applied to any sector and depending on present waste streams, anticipated demand for natural resources, and customer preferences, each industry will shift away from its linear systems in a different way.

Fast technological innovation will cause the formation of new business models that, having specific characteristics and being able to deal with environmental issues, will be able to better exploit wasted resources, capacities, lifecycles and embedded values.

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