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STRATEGIES FOR THE CIRCULAR ECONOMY

CIRCULAR DISTRICTS AND NETWORKS

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PREFACE

The circular economy has recently received considerable attention, as it represents an effective and valid option for aligning production systems and sustainable strategies with worldwide environmental and social objectives. The circular economy allows businesses to create efficient reverse system solutions by adopting the principles of reduce, reuse, and recycle, as described in the well-known waste pyramid proposed by the Ellen McCarthy Foundation. Although several circular economy systems models and frameworks have been built upon the original waste pyramid, new emerging mega trends like sophistication of products and consumers' needs, digital transformation, Covid-19 outbreaks, worldwide raw material shortages, international crises, and global warming impose urgent and comprehensive updates of those models and frameworks with new ingredients.

This book seeks to achieve such goals by proposing a new and original learning path, starting from an analysis of the strategies available for firms and policy makers relative to circular economy systems and develops a circular economy cascade, which is an evolution of the traditional waste pyramid model. Next, the book proposes the concept of circular districts to the scientific community and the business world and applies the related framework to case studies and practical applications. Therefore, this book allows professionals, executives, and business leaders to gain fresh and original knowledge about various aspects of circular economy systems, including: selecting and implementing the right circular economy strategies, evaluating the available public mechanisms to support circular economy projects and appropriate of the highest possible value, identifying the proper circular network to put a circular economy into execution, understanding the role of digital technologies to shift from traditional to smart circular economy systems, and realizing the opportunities that both firms and policy makers have when sponsoring the implementation of circular districts.

Considering that this book contains new strategic developments in the circular economy area, it allows scholars and Ph.D. students to identify new research avenues and possible future projects in the field. Furthermore, the book provides inspiration for managers, practitioners, and policy makers to develop modern circular economy systems by properly evaluating and including all applicable business ingredients. Finally, this book perfectly fits with graduate and post-graduate program content, thereby allowing students to recognize the best paths to properly integrate the circular economy within corporate and functional strategies.

As mentioned, this book focuses on two approaches available to firms to shape successful circular strategies: circular economy cascade and circular districts. Hence, the book is organized into 3 parts and 8 chapters in total, through which readers will become acquainted with the critical aspects, driving factors, opportunities, and challenges linked to these two paradigms.

The first part comprises 5 chapters. Chapter 1 provides an analysis of the circular economy strategies and proposes an evolution of the traditional waste pyramid with the circular economy cascade. The latter includes an evaluation of both the product life cycle and the returns' residual value to select the proper circular economy strategy. Chapter 2 makes a comprehensive analysis of the stakeholders interacting in circular economy systems, including firms, supply chains, consumers, policy makers, institutions, and governments. It explores the critical criteria for selecting the right stakeholders and implementing the most efficient and effective circular economy networks. Chapter 3 proposes a link between the circular economy strategies and the public mechanisms available to support its implementation and management to enable circular economy projects to be pursued even when the related output is not economically appealing. Chapter 4 analyzes the strategic options that firms have to appropriate of the economic value inherent a circular economy framework, also using recent technologies like blockchain. Chapter 5 crosses traditional circular economy systems with new mega trends like digital transformation, smart cities, and omnichannel strategies; hence, this chapter derives fresh ideas and insights to rethink traditional circular economy systems and reinvent the business models accordingly.

The second part of this book comprises one chapter that explores the business and entrepreneurial potential linked to the shift from the circular economy thinking to the green circular districts thinking. It shows how circular districts can be an effective option for the worldwide energy transition by developing and using green technologies and clean solutions. Therefore, this chapter opens the discussion around the creation of green circular districts and leaves tools with which readers can evaluate both the economic and environmental feasibility of such projects.

Finally, the book ends with the third part, which comprises two chapters giving details on two business cases that apply the new concepts and paradigms proposed throughout the book, specifically circular economy cascade and green circular districts.

Overall, this work analyses the circular economy approaches by discussing both the opportunities and the difficulties that firms face in reshaping the corporate strategies by considering circular economy principles using modern and original frameworks. The evolution from circular economy to circular districts reveals the motivation to redesign circular economy systems by taking a district perspective, including green technology advancements and progresses, as well as atypical business models and new industrial collaborations.

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Part I

Chapter 1
CIRCULAR ECONOMY STRATEGIES AND APPROACHES

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ABSTRACT: *This chapter introduces the links between the circular economy and waste pyramid to develop the waste cascade and identify the strategies and practices that firms can adopt to implement a successful circular system. Among the various blocks of the waste cascade, the chapter focuses on "Reduction, Reuse, and Recycling", as those have a direct and strategic link to circular economy. Within each of these blocks, the chapter offers genuine insights on how circular economy can reshape the firms' strategies and provide an original source of business opportunities.*

1.1. Circular economy and the waste cascade

The current debate on the circular economy involving the scientific community, institutions, and business has become very popular due to the fantastic opportunities that it offers as well as today's emerging challenges in terms of environmental restrictions and global warming. The circular economy emerges as a new paradigm for firms and countries to promote the diffusion of new production models and sustainable consumption behaviors. In fact, the circular economy assumes a shift from a linear economy to a circular one that is guaranteed through both process and product innovations followed by new marketing strategies and organizational structures.

The literature has identified the circular economy within the triple "reduction, reuse, and recycle" concepts, which are key ingredients of the new strategic paradigm. The need to adopt a circular economy model is linked to the principles of environmental sustainability, social inclusion, and business convenience. Therefore, the circular economy requires a high level of knowledge that involves multiple stakeholders and that seeks to optimize various aspects of business at the same time. By focusing on reduction, reuse, and recycle, the new production models move away from traditional linear systems that are mostly based on cost reduction and product differentiation with a focus on the forward activities that create value for customers and for society at large. These targets, which are indeed fully valid and have the merit to be part of the corporate strategy, require the adoption of circular systems that incorporate backward flows and integrate them with traditional forward activities.

According to the Ellen MacArthur Foundation (2015), the circular economy paradigm identifies traditional production and business models by sponsoring the rational management of resources and finding new paths for the creation of value, also including social and environmental spheres [1]. Hence, the circular economy literature [2] has developed the triple "reduction, reuse, and recycle" paradigm as follows:

- Reduction: This principle is highly inspired by the traditional industrial paradigms of mass production and lean production that were based on efficiency linked to different drivers. Applied to the circular economy, the principle of efficiency it is based on the minimization of inputs to pursue a minimal utilization of virgin raw materials while using and appropriating the residual value of waste and returns.
- Reuse: Some of the components that return back through the backward flows can be directly reused to make either new products or refurbished products. When firms invest in product reusability, the circular economy aims at extending their product lifecycle.
- Recycling: The principle of recycling links to firms' capability to recover material from waste and inject them into production processes. The circular economy approach can then include recycling operations to reacquire the traditional properties of a product or to use the recycling material for other types of applications.

In waste management, reduction, reuse, and recycling are the blocks of the waste management pyramid [3], which is elaborated in the *waste cascade* in Figure 1. The figure indicates an order of actions to identify and construct a sustainable strategy by showing the stages of waste management to be undertaken according to sustainability targets, product value, usage opportunities, and product lifecycle. Therefore, the waste cascade guides toward a sustainable strategy by obtaining the maximum value from products

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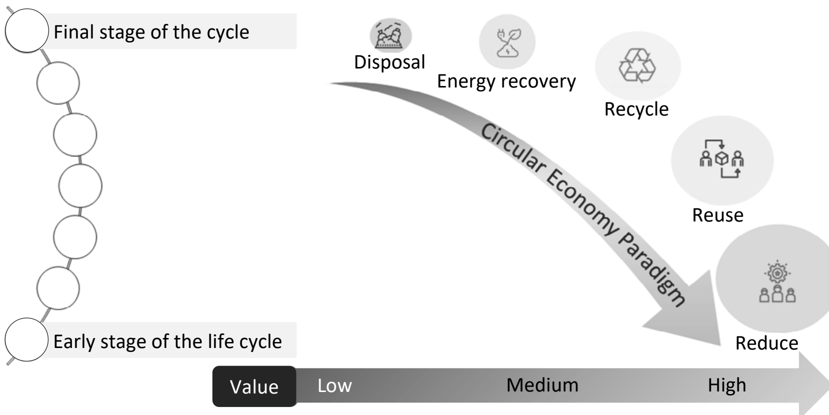
[1] MacArthur, E., Zumwinkel, K., & Stuchtey, M.R. (2015). Growth within: A circular economy vision for a competitive Europe. Ellen MacArthur Foundation.

[2] Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11-32.

[3] Carter, C.R., & Ellram, L.M. (1998). Reverse logistics: A review of the literature and framework for future investigation. *Journal of Business Logistics*, *19*(1), 85.

while reducing the amount of waste in the lifecycle and optimizing the circular economy practices through the analysis of possible usages. Within the cascade, the blocks for reduction, reuse, and recycle directly link to the implementation of circular economy systems, while the others require the implementation of other types of sustainable practices and strategies.

Figure 1. The waste cascade.



1.2. The "Reduction" principle

Reduction is linked to the concept of eco-efficiency, which basically signifies "doing more with less" [4]. In fact, eco-efficiency is linked to the concept of creating more goods and services while using fewer resources and creating less waste and pollution [5]. In this sense, the circular economy can be very beneficial by reducing the amount of natural resources consumed; decreasing energy use, emissions, and waste by cutting the amount of toxic waste created or emitted; and decreasing the amount of virgin materials to be used. To be effective, eco-efficiency should be measured. Several indicators have been proposed for this purpose in the past, like utilization and consumption. Specifically, some indicators are the domestic extraction of raw materials comparative to the demand and the reduction of water con-

[4] McDonough, W., & Braungart, M. (2010). *Cradle to cradle: Remaking the way we make things*. North point press.

[5] Yu, Y., Chen, D., Zhu, B., & Hu, S. (2013). Eco-efficiency trends in China, 1978-2010: Decoupling environmental pressure from economic growth. *Ecological Indicators*, *24*, 177-184.

sumption by changing the production processes. Therefore, the reaction-related eco-efficiency that firms are able to reach leads to sustainable development, which requires indicators expressed in ratios and linked to internal and external resources, the product lifecycles, and the performance of logistics and procurement as well as indicators linked to input consumption and natural resource utilization. Cabeza et al. (2013) reviewed the low carbon and low energy consumption material in the building sector[6]. According to their review, the energy performance of a building depends on the energy spent in making the materials rather than the energy consumption of the building *per se* during the lifecycle. In this sense, the analysis of eco-efficiency requires two major ingredients: The economic value added and the environmental impact. According to Gavrilescu (2004), the best way to capture the economic value created is represented by the net present value (NPV) and the internal rate of return (IRR)[7]. Furthermore, the environmental impact can be measured according to the abiotic resources depletion potential (ADP), the global warming potential (GWP), the ozone layer depletion potential (ODP), photochemical oxidation potential (POCP), human toxicity potential (HTP), ecological toxicity potential (ETP), the acidification potential (AP), and the eutrophication potential (EP). Then, the eco-efficiency can be computed according to two indicators:

$$Economic\ Added\ Value = \frac{Market\ value\ of\ products}{Cost\ of\ raw\ material\ and\ energy}$$

$$Environmental\ Impact\ Ratio = \frac{Environmental\ impact}{Environmental\ credits}$$

The Economic Added Value informs on the value that a firm obtains when selling products in comparison to the cost of inputs (e.g., raw material, energy). In contrast, the Environmental Impact Ratio informs on the negative impact that products have to the environment in comparison to the benefits obtainable from the circular economy. Then, the eco-efficiency can be computed as:

$$Eco-efficiency\ indicator = \frac{Economic\ Added\ Value}{Environmental\ Impact\ Ratio}$$

[6] Cabeza, L.F., Barreneche, C., Miró, L., Morera, J.M., Bartolí, E., & Fernández, A.I. (2013). Low carbon and low embodied energy materials in buildings: A review. *Renewable and Sustainable Energy Reviews*, *23*, 536-542.

[7] Gavrilescu, M. (2014). Biorefinery systems: An overview. Bioenergy Research: Advances and Applications. 1, 219-241.

The eco-efficiency indicator reflects the earlier mentioned definition "doing more with less", which can be obtained, for example, by reducing the cost of raw materials or the environmental impact.

1.3. The "Reuse" principle for materials

The *Reuse* principle refers to materials when the collected outcomes are perceived – in many instances – as waste to get rid of. In fact, the materials do not necessarily have any residual value for consumers though they take up capacity and capabilities of firms. Instead, materials can be reused by extending their purposes for the same types of applications or assigning them for alternative application and use. The main challenge that customers must face is recognizing the benefits of reusing some materials for different industries and sectors. The use of materials, which is different from recycling (which we will come back to later), refers to handling materials with the purpose of diverting them from a waste stream. Reusers, therefore, keep materials out of waste by either avoiding processing them or making negligible production steps. The use of materials is then linked to several collection programs that can bring various benefits. First, environmental benefits can be observed in terms of fewer resources, energy, and labor compared to other tasks like recycling; benefits are also linked to the local community, since society at large needs materials for people's basic needs such as food, buildings, and clothing. Furthermore, reusing materials instead of using virgin materials means there is less burden on economic systems as a whole.

According to Sherman (2019), the reuse principle requires connecting the circular economy to two types of sustainable operations: The physical space (warehouse or storefront) to store the materials and products available for reuse as well as brokering and listing the related services[8]. In fact, these two sustainable operations have been highly successful in the United States for many years by leading to the following collection options for material waste:

- Industrial materials exchange services. Waste exchange programs can be linked to the reuse principle for both material and goods; it consists of a platform for firms, even across different industries, on which reusable "waste" can be exchanged with other firms that can use those items or materials for their industrial purposes. Therefore, the platforms of

[8] Sherman, R. (2019). Before You Recycle, Choose to Reuse, NC State Extension Publications, Sept. 18th.

these types of programs must be populated with information on available waste and surplus of materials, which can be visible to other firms through social media and interaction points like newsletters, webpages, and catalogues. The firms can either contact and exchange with each other directly or formalize the circularity through an exchange service.
– Individual materials exchanges. In North Carolina, local governments have acquired competences in managing ad hoc waste material to be reused, such as paint or pallets, and operate them on a continuous basis.

According to Sherman (2019), the materials listed in waste exchanges typically include the following items: Acids and alkalis, construction materials, containers and pallets, discontinued products, durables and electronics, glass, metals and metal sludge, oil and wax, other inorganic and organic chemicals, paint and coatings, plastic and rubber, solvents, surplus equipment, textiles and leather, unused supplies, and wood and paper.

Indeed, the analysis of the materials to be reused depends on the sector from which the materials are collected. As an example, Blander (2019) made a comprehensive analysis of the materials that can be collected through the circular economy and be reused for further applications in the construction industry[9]. The analysis started by selecting the materials and distinguishing between reusable materials and recyclable materials. The sorting tasks that were carried out to make such a distinction led to valuable and well-identifiable outcomes of circular economy systems. Accordingly, the materials in the building and construction sector can be considered within that circular economy system and must be carefully evaluated and classified. Among them, the most important material waste that can be reused are:

– **Drywall.** Drywall is a very complicated material since it can be contaminated with other materials and substances, which make it not properly usable or easy to treat. However, being able to collect the drywall material in good enough condition allows construction companies to fully reuse it.
– **Wood.** Wood is one of the most frequently reused materials in the construction industry, since its structure is unaltered even after a demolition. Therefore, instead of considering it as a waste material to be disposed of, wood can be reused to make floors and furniture. Generally speaking, wood collected from the circular economy of the construction industry is in good condition, although it may require some processing when it is used as composite materials.

[9] Blander, A. (2019). When a building comes down, where do its materials go? Metropolis. https://metropolismag.com/viewpoints/recycling-demolition-building-materials/.

- **Plastic.** Buildings and their construction require a high quantity of plastic that can be found in different parts, like in packaging or piping. Indeed, as with other industrial applications, the plastic collected from the construction industry can offer several opportunities. For example, plastic materials can be reused for packaging or in landscaping, making new drainage pipes, or floor ducts and flooring.
- **Aggregate.** The aggregate coming from the circular economy system of the construction sector can be used either for recycling—a compacted mass of fragments or particles—or for reuse purposes like making concrete or as backfill material. Surely, the aggregate material from the construction industry should never be sent to landfills.
- **Glass.** The construction industry is characterized by a high amount of glass material that is obtained by the circular economy activities on a certain site. The material can be fully reused after some processing due to its fragility; however, glass material is almost guaranteed to be fully reusable. Rather than only focusing on the traditional applications of glass material, construction companies can use it also to manufacture bricks, aggregate, and as decoration material. Although the properties that make glass material very appealing as a subject in circular economy systems, collecting and recovering glass can be an expensive process, especially when it is contaminated and requires atypical processing before being treated and reused.
- **Insulation.** The circular economy in the construction sector allows for collecting a lot of material for insulation, which is highly reusable. Examples of insulation material reuse are the simple reuse of the off-cuts and the removal of possible contaminants like nails. While the possible reuse applications are feasible, the circular process behind it could be more expensive than the insulation material itself, which is cheap when purchased as a virgin material. Furthermore, the insulation material is exposed to a high risk of contamination, making the restoring process very expensive.
- **Other possibilities.** Other types of construction materials can also be collected through the circular economy. For example, steel is also present when demolishing buildings and can be used as a waste material for reinforcing the infrastructure of new buildings. Furthermore, the concrete resulting from a demolition can be reused to make new pavement, while untreated timber can be used as mulch for improving both soil moisture and fertility.

This example of the construction industry gives a deep reflection on the heterogeneity that waste materials have even when coming from the same source (e.g., demolishing a building). The managerial challenge that firms face consists of implementing and coordinating circular economy systems that are able to manage these material types simultaneously, though each material has its own peculiarities and characteristics and might require special treatments. Hence, the increasing complexity of material waste will make the implementation and the optimization of a circular economy extremely difficult and challenging.

1.4. The "Reuse" principle for goods

Whenever the "Reuse" principle refers to goods, society at large should be reengineered to identify the best methods and the principal actors involved in that process. Within local communities, various forms of informal collections take place, where people can make their used products available to other social clusters (e.g., the collection of clothes for charity) or simply making them available to everyone. It is common to see waste collection points and/or drop-off points managed by volunteers who promote the reuse of products that still have a residual value. Society at large needs a certain capacity to accommodate and manage circular economy systems. Relative to the reuse principle linked to products, the following collection options can be identified [10]:

– Swap shops. Swap shops have been engineered with the purpose of collecting "things" that people would have normally discarded and making them available to others at little or no cost. Swap shops can be created and managed either by firms or by local authorities. In the former, they are designed as areas that collect any type of materials and products, also acting through differentiated waste. In the latter, local authorities and governments set up swap shops at landfills or collection centers to let the public drop off non-hazardous reusable items and also pick up things they can use.
– Surplus stores. Surplus stores accept items that have reached their end-of-use stage, like furniture and office equipment, and make them available to the public either for free or for small amounts. In most cases, *surplus* stores are operated by large and public institutions such as universities. However, surplus stores can be also managed by the government at a high level by providing used equipment, vehicles, and supplies for public institutions and local governments.
– Scrap exchanges. Scrap exchanges accept industrial scrap or printer overruns and distribute them for free or sell them at a nominal cost to

[10] Sherman R. (2019). *Ibidem*.

schools, day-care centers, senior centers, and nonprofit organizations with arts programming. The scrap materials can be used in art and drama classes and in a variety of arts and crafts programs. Schools and other organizations can contact businesses directly to obtain scrap materials or they can use a scrap exchange.
- Secondhand stores. In many countries, the circular economy made by secondhand stores is very common. These collection options can be either private or non-profit organizations that can target specific social outcomes, like gathering donations for local schools and hospitals, or manage the collection of secondhand goods in a more traditional way, according to people's voluntary actions and ethical behaviors. In this sense, secondhand stores are not classical waste reduction options but rather outlets for products that can be reused instead of discarded.

The physical platforms identified by Sherman (2019) have been followed and complemented by digital transformation processes and have opened the way for sharing economy options in this direction. In fact, sharing economy platforms provide a peer-to-peer means for connecting secondhand product users with the providers. According to Belk (2014), "Sharing is a phenomenon as old as humankind, while collaborative consumption and the sharing economy are phenomena born of the Internet age" [11]. This emerging trend is possible thanks to digital technologies as well as innovative corporate strategies and business models through which collaborative consumption becomes possible and is exemplified by using online platforms for obtaining, giving, and sharing access to goods and services. Furthermore, sharing can happen by either giving access through ownership or by transferring ownership, which happens through swapping, donations, or purchasing used goods [12]. Therefore, the circular economy definitely depends on the collaborative intentions on the sharing platforms, which leads to continuous contributions and heavy use of the platforms' resources. Ek Styvén and Mariani (2020) undertook both supply-side and demand-side perspectives when identifying the proper sharing economy option for used products and argued the existence of three drivers helping to adopt the best peer-to-peer platform [13], specifically: 1. Technology:

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[11] Belk, R. (2014). You are what you can access: Sharing and collaborative consumption online. *Journal of Business Research*, *67*(8), 1595-1600.

[12] Hamari, J., Sjöklint, M., & Ukkonen, A. (2016). The sharing economy: Why people participate in collaborative consumption. *Journal of the Association for Information Science and Technology*, *67*(9), 2047-2059.

[13] Ek Styvén, M., & Mariani, M.M. (2020). Understanding the intention to buy

Technological advancement, mostly through the development of digital technologies, the Internet, online services, and digital platforms, allow society at large to rent, lend, swap, donate, or purchase used goods; 2. Supply of used products: A market for used products can exist if there is an industry for it and related competition along with a network of consumers that supports the supply-side and creates the structure; 3. Social and psychological drivers: A project based on the circular economy for used products starts from the analysis of social and psychological factors that push and drive people to interact on sharing platforms and underpinning unconventional behaviors like lending and renting mechanisms or transferring of ownership through swapping, donating, or purchasing used goods. These factors represent both the antecedents and the drivers of any circular economy system based on used products.

1.5. The “Recycling” principle

“Recycling” is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products. Firms adopting recycling must have the facilities and capabilities to completely destroy the collected products and convert them into materials to be used in production. From a biological perspective, a substance is available for recycling after the natural processes of biochemical degradation or modification to regain material for human activities.

The recycling principle has gained popularity all over the world, since governments have imposed important restrictions through legislation for sustainable and circular economy strategies as well as for the treatments involved in the various recycling steps. For example, the EU Directive 2000/53/EC [14] set the recycling rates to be reached for passenger vehicles. Since 2015, for all end-of-life vehicles, the reuse and recycling must increase by 85% according to the average weight per vehicle and year. Similarly, in the textile industry, the EU Directive 2008/98/EC [15] regulates recycling activities, since textile waste is considered to be special waste and therefore needs special treatment. This restriction impacts firms' plans and strategies, as they are directed to use a specific disposal system depending on the level of disassembly of the recovered materials. According to Sandin

secondhand clothing on sharing economy platforms: The influence of sustainability, distance from the consumption system, and economic motivations. *Psychology & Marketing*, *37*(5), 724-739.

[14] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32000L0053.

[15] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098.

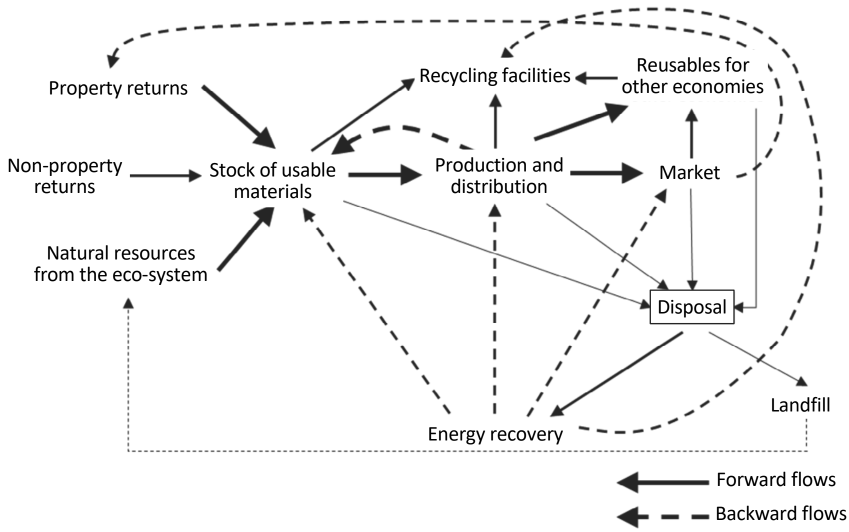
and Peters (2018), if the fabric of a textile product is recovered and reused in new products, it is classified as *fabric recycling*[16]. If the fabric is dissembled, but the original fibers are preserved, then the textile is classified as *fibre recycling*. If the fibers are dissembled but the polymers or oligomers are preserved, it is *polymer/oligomer recycling*. If the polymers/oligomers are dissembled but the monomers are preserved, this is *monomer recycling*. Indeed, the recycling costs associated with this classification can vary substantially, since the recycling process requires a combination of various mechanical, chemical, and thermal processes.

While it is out of the scope of this work to review all EU Directives in the theme of recycling restrictions, it is important to consider the difference between the recycling potential and the recycling rate. The former refers to the amount of material that can be potentially subject to recycling and that provides opportunities to be evaluated in such directions. The latter measures the quantity of recyclable material that can be recycled, with considerations for technological advancements, economic convenience, and possible environmental impacts. According to van Schaik and Reuter (2004), passenger vehicles are subject to a high recycling rate[17]. For example, the metal content of cars can be fully recovered, providing a potential recycling of 100%; however, the recycling rate is much lower than that, since the quality of the recycled material results from a mechanical separation process that depends on thermodynamics and kinetics processes. Furthermore, the increased complexity of recycling pyrometallurgy and the current composition of vehicles containing a combination of metals considerably decreases the recycling rate.

[16] Sandin, G., & Peters, G.M. (2018). Environmental impact of textile reuse and recycling. A review. *Journal of Cleaner Production*, *184*, 353-365.

[17] Van Schaik, A., & Reuter, M.A. (2004). The time-varying factors influencing the recycling rate of products. *Resources, Conservation and Recycling*, *40*(4), 301-328.

Figure 2. Forward and backward flow analysis.



To consider the complexity of recycling, Haas et al. (2015) assessed the circular economy potential by analyzing the material flows, waste production, and recycling rates within one unique framework [18], which is reproposed in Figure 2 according to the waste cascade. The theoretical framework proposed in the figure illustrates how the material flow is considered at a global level and how the processes used to properly treat them can be quantified within a circular economy setting. The latter is based on a model applied to an economy-wide material flow accounting proposed by Eurostat [19], which defines the flow of materials from extraction and import, by processing, immediate consumption, or temporary accumulation in material stocks to recycling or final treatment before all materials leave the system as waste and emissions. To assess the circularity of an economy based on the material flows, Haas et al. (2015) proposed the following set of key indicators [20]:

- Material size of the processed materials (PMs): PMs (gigatons, Gt) and tons per capita (t/cap);
- Stock growth: Net addition to stocks as share of PMs (%);

[18] Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M. (2015). How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. *Journal of Industrial Ecology*, *19*(5), 765-777.

[19] Eurostat. 2012. Economy-wide material flow accounts (EW-MFA). Compilation guide 2012. Luxembourg: Eurostat.

[20] Haas et al. (2015). *Ibidem*.

- Degree of circularity within the economy: Recycling as share of PMs (%);
- Biodegradable flows: Biomass as share of PMs (%);
- Throughput: DPO as share of PMs (%);
- Flows either biodegradable or recycled in economy as share of PM;
- Fossil energy carriers as share of PM;
- Material for energetic use as share of PM;
- Material for material use as share of PM;
- Waste rock as share of PM;
- Short-lived products as share of PM;
- EOL waste as share of PM;
- Recycling as share of EOL waste (overall recycling rate).

As Figure 2 shows, the recycling principle can be activated only when there is a circular economy system that supports its implementation. Such a system is composed of three steps, which create a continuous loop and ensure circularity:

- ***Step 1: Collection and Processing.*** Firms and governments must identify the best collection option for the involved society, choosing from among such options as curbside collection, drop-off centers, and deposits. The collection is followed by sustainable operations activities through which recyclables are sent to a specialized recovery facility to be sorted, cleaned, and processed into materials.
- ***Step 2: Manufacturing.*** Once the material is obtained, the collectors must identify the products and, more generally, the potential output that can be manufactured by using recycling materials. As previously mentioned, the EU Directives impose a certain percentage of recycling materials and recycled content. Collectors and authorities must then build a map of possible buyers for the recycled materials as a prerequisite to initiate any circular economy project. This need has led to stringent legislation and constraints, which have made recycling common to many applications like newspapers and paper towels, aluminium, plastic, and glass soft drink containers, steel cans, plastic laundry detergent bottles and more.
- ***Step 3: Purchasing New Products Made from Recycled Materials.*** Circular economy systems can require – considering the various markets – important changes in the current markets as well as the identification of new and emerging markets. Both options depend on both the economics and the marketing levers (which will be discussed in Chapter 2) that firms need to evaluate and activate to make circular economy systems sources of value rather than causes of business deterioration.

According to the Environmental Protection Agency (EPA), recycling content can be presented to the market in three forms, namely: *Recycled content product, recyclable product,* and *post-consumer content*[21]. The *recycled content product* are products made by using recycled materials that is either collected from an ad hoc recycling program or recovered from waste during traditional business processes like manufacturing and procurement. The firms are supposed to display on the label the percentage of recycled content to give full visibility and transparency to consumers. The *recyclable product* represents an important source for circular economy systems to accumulate the required feedstock. Those are products that can be collected, processed, and manufactured into new products after they have been used. Depending on the type of products, these items can be made either by virgin material only or by a certain percentage of recycled material. Therefore, the recycling activities and the value of returns highly depend on the product composition and the related level of recyclability. Finally, *post-consumer content* are the same types of items as recyclable content, with the main difference being the targets of the circular economy program. In fact, post-consumer content means items for which circular systems have a certain degree of interest and implies the adoption of specific take-back and recycling programs.

As explained by EP&C[22], recycling is defined as any recovery operation by which end-of-life waste is reprocessed into products, materials, or substances that can serve the original or comparable purposes. However, several details should be given regarding this definition with a particular lens on the difference between downcycling and upcycling.

Downcycling plays an important role that can be defined as the reprocessing of end-of-life (EOL) waste into products of inferior quality compared to the virgin material[23]. Therefore, downcycling implies a lower value and quality than the original product. There are sectors in which downcycling is heavily present, and it is even used as a synonym of recycling. The textile industry is one of those[24], and its flows and cycling opportunities are displayed in Figure 3.

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[21] Environmental Protection Agency (EPA). https://www.epa.gov/recycle/recycling-basics.

[22] EP&C (European Parliament and Council). 2008. Waste directive 2008/98. http://europa.eu/legislation_summaries/environment/waste_management/ev0010_en.htm. Accessed November 2021.

[23] Haas et al. (2018). *Ibidem*.

[24] Sandin, G., & Peters, G.M. (2018). Environmental impact of textile reuse and recycling – A review. *Journal of Cleaner Production*, *184*, 353-365.