Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

Article

Core Elements Affecting the Circularity of Materials

Aurelija Burinskienė *[1], Olga Lingaitienė [1] and Artūras Jakubavičius [1]

[1] The Faculty of Business Management, Vilnius Gediminas Technical University, LT-10223 Vilnius, Lithuania; olga.lingaitiene@vilniustech.lt (O.L.); arturas.jakubavicius@vilniustech.lt (A.J.)
*Correspondence: aurelija.burinskiene@vilniustech.lt (A.B.)

Abstract: The authors have revised the circularity of materials, which is important to stimulate circular activity processes. The theoretical part starts with describing the characteristics of the circular activity and the comparison of circular and linear systems in terms of recycling. Later on, the authors examined key elements important for the circularity and the results of an examination of various sectors. The authors formed a correlation matrix and used a dynamic regression model to identify the circular material use rate. The authors suggested a three-level methodology, using it provided a dynamic regression model which could be applied for forecasting the size of circular material use rate in European Union countries. The results show that private investments into recycling and the recycling of electronic waste and the recycling of other municipal waste categories are important in seeking to increase the usage rate of circular materials.

Keywords: circularity of materials; circular activity; recycling; regression model; key elements

1. Introduction

Global consumption of fossil fuels, metals, minerals and biomass is projected to increase over the next few decades, and by 2050. the annual waste generation will increase by as much as 70%. The extraction and processing of resources account for half of all greenhouse gas emissions, the loss of more than 90% of biodiversity and severe water scarcity. To tackle harmful natural processes, the European Green Initiative has announced a coordinated strategy for a climate-friendly, resource-efficient and competitive economy. The strengthening of the role of the circular activity as a key economic player will ensure the long-term competitiveness of the EU until 2050. the aim will be to decouple climate neutrality and decouple economic growth from resource use.

The circularity of resources is important for sustainable development as it helps to save resources and reduce the negative impact on the environment. The literature review shows that the circularity loop is the main key element talking about the recycling of material. The other important element impacting the circularity of materials is the design of the product allowing re-use the material in the construction of other product later on or the extension of lifetime of the product.

Not all materials are recyclable, many cannot be recycled. Many of the materials recycled today are being reduced, and the recycling of some materials requires more energy than new production (Allwood, 2014).

Increased economic activity and consumption of raw materials have led to the dependence of many countries in the world, including the European Union (EU), on imports of materials and energy (Wijkman & Skånberg, 2015). Another consequence of the increased importance of human consumption is the significant increase in the amount of waste generated, which is also an opportunity to alleviate the problems of material (and partly energy) shortages (Jurgilevich et al., 2016; Schröder et al., 2020).

The paper consists of literature review where key elements important for circularity are revised, the concept of circularity is presented and the recycling as the option for the circularity is overviewed. Later on, empirical part is provided which consists from the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

three level methodology highlighting the circularity and the correlation matrix of variables allowing to identify ones that could be used for the construction of regression equation used to forecast the circular material use rate. Finally, discussions and conclusions are presented.

2. From Linear to Circular activity

According to a report washed by the United Nations, the current world population of close to 8 billion is expected to rise by 2030 will reach 8.6 billion by 2050 - 9.8 billion, and by 2100 - 11.2 billion. With an annual contribution of around 83 million people to the world's population, the population growth trend is expected to continue, even if the birth rate continues to fall (Ayres, 2008).

The essence of a linear model is summarized as "take - make – dispose of" (Sariatli, 2017; Velenturf & Purnell, 2021; Rodríguez et al., 2020; McDonough & Braungart, 2003): take the necessary resources, sell goods and make a profit and dispose of everything you don't need - including a product that is nearing the end of its life. The model of a traditional linear economy is not sustainable, it is based on product development, consumption, and disposal. This further reduces limited resources and generates large amounts of waste and emissions (Mentink, 2014). Rodríguez et al. (2020) emphasize that the linear model of production and consumption depletes natural resources and generates waste, but the environment does not have unlimited capacity to absorb waste and pollution. According to Di Maio & Rem (2015), it is necessary to rethink how materials are used in the current linear take-it-or-throw economy, because according to modern technology, not all stocks of basic materials seem to be sufficient to maintain the modern quality of life in the "developed world".

Authors (Sørensen, 2018; Michelini et al., 2017; Bocken et al., 2016; Mostaghel & Chirumalla, 2021) notes the need to build a sustainable society transforming the current linear "take-make-dispose" economy into a waste-free society. It is, therefore, necessary to move to a circular activity (CE) a model that will decouple economic growth from material costs.

Elisha (2020) has carried out a study on increasing the sustainability of the market by moving away from over-consumption and resource use in traditional take-do-throw practice (linear economy) to use (circular activity).

According to the authors Mostaghel & Chirumalla (2021), Zucchella & Previtali (2019), Bocken et al. (2016), Moreno et al. (2016) move from a linear to a circular activity, product development practices should conform to the definition of circular business modelling and traditional business modelling processes on the spot should anticipate current product design practices in determining necessary changes.

According to Oghazi & Mostaghel (2018), the development of circular business models is associated with product design activities that must meet longer or multiple-use cycles. Zucchella & Previtali (2019), Lieder & Rashid (2016); Bocken et al. (2016) note that the new products are stronger, more adaptable, and have a wider range of properties and are specially designed to be extendable, recyclable and remanufacture.

It is estimated that the potential for material savings from the European industry's shift to a more resource-efficient model would be € 500 billion a year (Europe INNOVA, 2012). The strategic benefits (Velenturf & Purnell, 2021; Korhonen, 2018) of the CE approach are reduced by the risk of price volatility and supply disruptions, the potential of new technologies (to increase resource productivity, material substitution, waste management and recycling), direct and reverse supply chain and logistics optimization cycles and business models. The reverse operations are quite important for recycling activity which supports the circularity of materials.

In her work, the author Bocken et al. (2016); Stahel (1994); Stahel (2010) distinguishes and describes three resource cycles: closing the resource loop, slowing the resource loop and narrowing the resource loop. A 'closed-loop system' distinguishes between two fundamentally different types of cycle: (1) re-use of goods and (2) recycling of materials

(Bocken et al., 2016; Stahel, 1994; Stahel, 2010). Re-use of goods means recovery of the extension of the goods period through the design of durable goods. To expand the existing one the lifetime of the product, including the re-use of the product itself, repair, renewal and technical upgrading, and service loops are introduced. The reuse of goods and the extension of the life of a product have a different relationship with time, the result is slowed the flow of materials from production to recycling.

According to Morseletto (2020), recycling is the treatment of materials to a different quality of materials: high quality, which is the same as were before processing, or lower quality. Worrell and Reuter (2014) note that the recycling of discarded materials/products results in materials that are called secondary materials. Recycled materials can also be recycled, a process in which materials are transformed into materials of higher quality and uniform / increased functionality, or vice versa when the quality of a product is reduced. Recycling should be the most appropriate solution to prolong product life, and increase value and quality, but not all products can be recycled and recycling is not possible in all cases (Migliore, 2019).

The second cycle involves the recycling of materials, which means loops between waste after recovery and closure of production. According to Merli et al. (2018), McDonough & Braungart (2010); Triguero et al. (2022); Moreno et al. (2016) these two key strategies focus on three resource cycles:

1) Closing of resource loops: A circular flow of resources occurs when processing closes the loop between use and production.

2) Slowing stock loops: t. y. service loops that adapt the design of services and products and extend the life of products when goods are repaired or recycled, thus slowing down resource flow. These two approaches differ from the third approach to reducing resource flows

3) Resource efficiency or narrowing of resource flows per product aims to use fewer materials.

To increase the use of end-of-life products, products are recycled and secondary materials are used, and the re-use, repair, refurbishment and production of products ensure several life cycles, thus closing material loops (Prendeville et al., 2014; Haupt et al., 2017; Brydges, 2021). To increase the longevity of the product, prolong its service life, and exploit the possibilities of re-use and repair, thus extending the material cycle. Narrowing the loops of materials involves a variety of efforts to achieve resource efficiency by increasing the productivity of materials throughout the product value chain and expanding the sharing and service economy (Geissdoerfer et al., 2018; Jørgensen & Remmen, 2018). These characteristics are summarized in Table 1.

Table 1. Main circular activity characteristics.

	Closing the resource loop	Slowing the resource loop	Narrowing the resource loop
Features	Recycling; Product repairing and remanufacturing	Product life extension; Product reuse and repair	Increased material productivity; Improved asset utilisation; Individual behaviour changes
Main effects	Decreased demand for primary materials; Increased use of secondary materials	Decreased demand for primary materials; Better quality and durability of goods with higher prices	Decreased demand for primary materials; Expanded sharing and services economy
Solutions examples	Subsidies to secondary materials; Subsidies to the recycling sector	Extended producer responsibility; Product design standards	Resource efficiency standards

In Table 1, the authors have introduced the terminology of slowing, closing, and narrowing resource loops in the circular activity, in each, distinguishing features and main effects, and providing solutions examples.

3. Circularity in 'Closed-loop' and 'open-loop' concepts

By applying the principles of the circular activity (Suárez-Eiroa et al., 2019; Velenturf & Purnell, 2021; Akhimien et al., 2021), it is expected that by 2030 0.5% of EU-wide GDP could increase EU GDP and create around 700,000 new jobs. Closed-loop models can increase the profitability of EU producers and protect them from fluctuations in resource prices, as on average about 40% of their materials are spent in the EU (Shekarian, 2020; Xu, & Wang, 2018).

The circular activity package (European Commission, 2015) currently being implemented and made the next step in that direction by introducing a 'closing the loop' concept of material/product lifecycle and measures that cover the whole life cycle of materials, from production and usage through waste management and ultimate disposal, to the market for recovered resources and recovery (Tomić & Schneider, 2018; Slowak & Regenfelder, 2017; Shevchenko & Kronenberg, 2020). 'Closing the loop' between the end of the life of the product and its production enables the circulation of resources, materials and products, and keeps its material and/or energy and economic value within the economy for as long as possible (Tonelliet al., 2013; Niero & Hauschild, 2017).

The circular activity and the concepts of closed-loop production have some features in common. It is widely accepted that both concepts cover reverse material flows through return systems, recycling, repair, reclamation, recycling and reuse (Triguero, 2022; Bocken et al., 2016). The circular activity, meanwhile, is defined through economic growth, the promotion of renewable energy, and the concepts of 'recovery' and replenishment. It should be noted that the concept of a closed-loop can also be understood through the definition of a circular activity. As a broader concept of loop closure, the circular activity is compatible with the review of eco-design (Prendeville et al., 2014; Hazen et al., 2020).

Closed-loop recycling is when a secondary material is recycled back into the same product, and open-loop recycling is when a secondary material is used to make something different from the previous product (Haupt et al., 2017).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

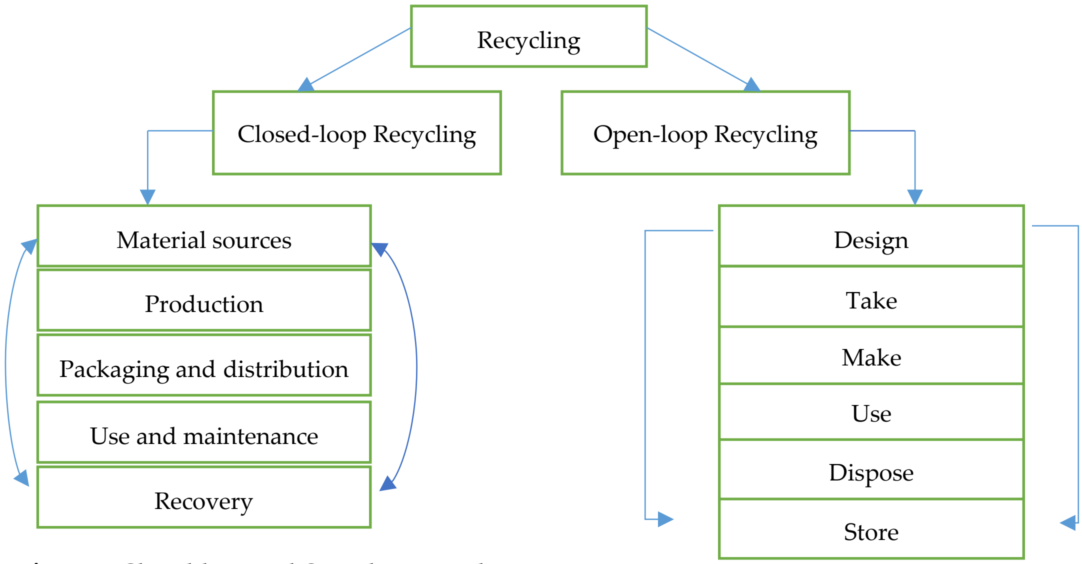

Figure 1. Closed-loop and Open-loop recycling.

When recycling takes place in the same, closed or other, open product system, we are talking about closed-loop or open-cycle recycling, different aspects need to be taken into account (Huysman et al., 2015; Nakatani, 2014). Closed-loop recycling is the process by which a secondary product is returned to a previous process in the same system, where it directly replaces the primary production costs of the same material (Souza, 2013; Amin & Zhang, 2012). Open cycle recycling occurs when at least some of the secondary goods are used in different systems (Souza, 2013; Amin & Zhang, 2012). According to the above mentioned statements, to achieve the objectives, priority should be given to closed-loop solutions over open-loop solutions, as transport and collection in third countries are avoided and the production process can process recycled raw materials without additional energy or additives. However, Geyer et al (2016) and Haupt et al. (2017) note that recycling depends on many factors such as use, prices, material types/properties, and losses/impurities associated with recycling. The authors also mentioned proving that not necessarily closed-loop recycling is better than open-loop recycling (Geyer et al., 2016; Camilleri, 2019; Niero & Hauschild, 2017; Niero & Olsen, 2016). The possibility of reducing environmental impact is a better principle for setting recycling targets (Geyer et al., 2016, Camilleri, 2019). According to this principle, goals are defined specifically for different products/materials/industries.

4. Recycling as a preferred option for waste recovery

A system based on 10 common circular activity strategies (i.e. recover, recycling, repurpose, remanufacture, refurbish, repair, re-use, reduce, rethink, refuse) is applied to verify the selected targets. According to Lingaitienė & Burinskienė (2021), three blocks of general circular activity strategies are distinguished. R0 refuse, R1 rethink and R2 reduce are included in the smarter use and production of products. Product life extensions include R3 re-use, R4 repair, R5 refurbish, R6 remanufacture and R7 repurpose. Useful materials include R8 recycle and R9 recover (Okorie et al., 2018; Ang et al., 2018; Foster, 2020). In this paper, we are going to examine the beneficial circular use and reuse of materials.

The problem of dependence on material imports can be alleviated to some extent by the recovery of materials from waste (Li et al., 2009, Chandrasekaran et al., 2018). EU waste policy focuses on reducing the health and environmental impact of waste management and improving resource efficiency. The waste hierarchy, which defines recycling as the preferred recovery option for waste, aims to extract more materials.

The recyclability and quantification of the various types of waste are highly dependent on the recyclability of technical goods and an understanding of how the result, which we will call 'recycled', is to be defined (Menikpura et al., 2013; Moraga et al., 2019). In some

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

cases, the amount of separately collected recyclable materials is considered 'recycled', in others, only the output of sorting plants is counted, and the contribution of an efficient recycling process to 'recycled' is taken into account. These different methods make the comparison of recycling rates difficult and even meaningless, as any step in the waste / recyclable recycling chain from collection to the efficient substitution of raw materials causes quantitative losses and thus reduces the practically achievable recycling rate (Fellner & Lederer, 2020). For example, due to the same recycling situation for a particular waste stream, the recycling rate can range from 40% to 80%, depending on different reporting rules for recycling rates. It is, therefore, necessary to clearly define recycling standards and agree on definitions when setting quantitative recycling targets.

When waste is recycled, secondary resources - materials that may be similar to waste - cease to be waste (end of waste – abbreviation EoW) and enter the product scope (Ragossnig & Schneider, 2019; Turunen, 2020). The transition from waste to product can take place in a process in which the secondary material enters as waste. Another possibility is that the EoW state is reached before a certain process using the appropriate secondary resources. In this case, the secondary substance must meet not only certain criteria of the EoW quality specifications but also the marketing criteria for chemicals and any other criteria applicable to any other primary substance (Lucchetti et al., 2019).

Facilitating and promoting recycling through the reduction of natural resources, the reduction of waste going to disposal and ensuring a high level of environmental protection are objectives of defining EoW criteria and obtaining materials from specific waste streams that can be traded freely on the open market scope (Ragossnig & Schneider, 2019; Hjelmar et al., 2013). Many of the factors that can be overcome when determining when waste ceases to be a waste and becomes a by-product make it difficult to recycle certain wastes. Certain specified wastes cease to be waste after recovery (including recycling) and meet specific criteria under the following conditions: 1. the substance or object is normally used for specific purposes; 2. there is a market or demand for a particular substance or object; 3. the material or object complies with the technical requirements for specific purposes and the legislation and standards applicable to the products, and 4. the use of the substance or object will not have an overall negative impact on the environment or human health. EoW status is classified as waste when it meets all four of the above criteria (Zorpas, 2016; Villanueva & Eder, 2014).

5. Elements affecting circularity

The take-it-or-throw-out linear model does not provide enough incentives for manufacturers to make their products more circular, even though up to 80% of a product's environmental impact is determined at the design stage. Many products break down quickly, are for single use only, and are not easy to reuse, repair, or recycle. At the same time, the single market sets product sustainability standards and influences product design and value chain management worldwide.

The authors (den Hollander et al., 2017; Lieder & Rashid, 2016; Zucchella & Previtali, 2019; Bocken et al., 2016; Mostaghel & Chirumalla, 2021; Oghazi & Mostaghel, 2018; Geissdoerfer et al., 2018) point out that companies which adopt to ring economy (CE) at the strategic company level should focus on both product design (PD) and business model (BM).

The circular activity seeks sustainable leadership that will gradually become the norm to use resources efficiently, reduce waste and make products climate-neutral. Principles of sustainability for leadership in the circular activity (Velenturf & Purnell, 2021; Suárez-Eiroa et al., 2019 Akhimien et al., 2021; Jawahir & Bradley, 2016):

- product sustainability, reuse, improvement and repair, removal of hazardous chemicals from products, energy and resource efficiency;
- increasing the number of processed products, ensuring their operation and safety;
- creating conditions for re-production and quality processing;
- reducing carbon and environmental footprints;

• restriction of single-use and prevention of premature ageing;

• introduction of a ban on the destruction of unsold durable goods;

• maintaining the ownership or responsibility of manufacturers for the operation of the product throughout its life cycle;

• product digitization, including solutions such as digital passports, marking and watermarks.

According to Velenturf & Purnell (2021) in a circular activity resource use is improved by minimising the extraction of natural resources, maximising waste prevention, and optimising the environmental, social, material and economic values throughout the lifecycles of materials, components and products.

The circular activity relied heavily on 3R Principles: Reduce, Reuse and Recycle (Lingaitienė & Burinskienė, 2021; Jawahir & Bradley, 2016; Dong et al., 2021). Using 3R principles, we aim to optimize production to use less natural resources, and production to minimize pollution, emissions and waste.

According to Ciulli et al. (2020) and Eriksenet et al. (2019), the recovery of waste depends on the establishment of links in the supply chain so that operators with goods at risk of becoming waste can pass it on to those who could use it as raw material or for their consumption. However, this use of waste is often hampered by what we call "circularity holes", i.e. y. there is a lack of communication between waste generators and potential recipients (Wijewickrama et al., 2021).

In Table 2, the authors singled out the effects of different types of waste on the circular activity. The indicator defining circularity in the municipal solid waste category is energy recovery from municipal solid waste (MSW). This recycling process has several important aspects, such as a positive impact on the environment, as it saves primary energy from fossil fuels, as well as the benefits of the energy itself from recycled municipal solid waste.

Waste electrical and electronic equipment (WEEE or e-waste) requires strategic planning based on the principles of a circular activity to return e-waste to new production cycles. This method implies measures that allow the anthropogenic system to re-import waste into new natural or technological cycles, creating environmental, social and economic benefits (McDonough & Braungart, 2003).

Zero Waste aims to eliminate all waste by recovering the material and biological cycles. In the Zero Waste methodology, all levels of production are required to identify the origin of the waste and innovative ways to reduce it and reuse or recycle what cannot be prevented.

Inorganic wastes such as plastics, metals, glass, rubber, and textiles cannot decompose and be reused in nature. Most household and commercial waste is collected by garbage trucks and taken to a landfill or to a waste recycling plant, where all collected waste is sorted, treated, and processed into a semi-finished or finished product.

Organic waste is organic and biodegradable, that is, that can be decomposed, it is food waste collected from households and catering establishments, vegetable market waste, yard waste, grass, plant and animal waste. Such waste can be composted, that is, naturally converted into a stable product, compost-rich in essential nutrients. Compost is a popular organic fertilizer that is a much cheaper alternative to conventional but expensive inorganic fertilizers.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

2. Waste affecting on circularity.

		Authors
Type of waste	Municipal waste	Giugliano et al., 2008; Lin at all, 2006; Mian et al., 2017; Hysa et al., 2020; Belaud et al., 2019; Trica et al., 2019; Smol et al., 2017; Khatiwada et al., 2021; Zhang, 2020; Cobo et al., 2018; Aceleanu et al., 2019; Fletcher et al., 2021; Manfredi et al., 2015; Colasante et al., 2022; Ottoni et al., 2020; Jai Singh Rathore, 2020; Angelis-Dimakis et al., 2022; Cano et al., 2022; Lange, 2021
	E-waste or WEEE (waste electrical and electronic equipment)	Xavier et al., 2021; Kazancoglu et al., 2020; Singh et al., 2020; Awasthi et al., 2018; Al-Thani& Al-Ansari, 2021; Baldé et al., 2017; Colasante et al., 2022; Ottoni et al., 2020; Jai Singh Rathore, 2020
	Inorganic waste (paper/cardboard, plastic, metal, glass rubber, leather, textil)	Velenturf & Purnell, 2021; Elisha, 2020; Cobo et al., 2018; Sayadi-Gmada et al., 2019; Kusch et al., 2021; Lange, 2021
	Organic waste (food, wood, agricultural)	Velenturf & Purnell , 2021; Rodríguez et al., 2020; Morseletto, 2020; Elisha, 2020; Mendoza et al., 2017; Khatiwada et al., 2021; Zhang, 2020; Cobo et al., 2018; Aceleanu et al., 2019; Manfredi et al., 2015; Xaviet et al., 2021; Sayadi-Gmada et al., 2019; Jai Singh Rathore, 2020; Angelis-Dimakis, et al., 2022; Cano et al., 2022; Lange, 2021;

In Table 2, the authors examined the type of waste dedicated to the circular activity are used by other authors for their research, emphasizing that reuse and recycling are two of the most important strategies for the practical implementation of the circular activity (CE) and for assessing the efficiency of waste management in different types of waste.

In Table 3, the authors have identified three dominant groups that influence the circular activity in terms of product design, environmental friendliness, and commercial. In each group, characteristic subgroups are identified, which are mentioned in the scientific literature by different authors.

 doi:10.20944/preprints202205.0391.v1

Table 3. Groups of circular elements affecting circularity.

Group	Elements affecting circularity	Authors
Design	Eco-design	den Hollander et al., 2017; Sassanelli et al., 2020; Mian et al., 2017; Mendoza et al., 2017; Babbitt et al., 2021; Belaud et al., 2019; de Koeijer et al., 2017; Thakker & Bakshi, 2021; Liu et al., 2018; Bag et al., 2022
	Product design	Whicher et al., 2018, den Hollander et al., 2017; Wastling et al., 2018; Sumter et al., 2020; Sassanelli et al., 2020; Jawahir & Bradley, 2016; van Schalkwyk et al., 2018; Mian et al., 2017; Sauerwein et al., 2019; Mugge, 2018; Burke et al., 2021; Mendoza et al., 2017; Babbitt et al., 2021; Cascini et al., 2020; Al-Thani& Al-Ansari, 2021; Walmsley et al., 2019
	Design for environment	Sassanelli et al., 2020; Steenis et al., 2017; de Koeijer et al., 2017; Bag et al., 2022
	Green product design	Li et al., 2019; Steenis et al., 2017; de Koeijer et al., 2017
	Design for product integrity	den Hollander et al., 2017; Wastling et al., 2018
	Design for sustainability	Sumter et al., 2020; Sassanelli et al., 2020; Mian et al., 2017; Sauerwein et al., 2019; Mendoza et al., 2017; Steenis et al., 2017; Al-Thani& Al-Ansari, 2021; Walmsley et al., 2019; de Koeijer et al., 2017; Thakker & Bakshi, 2021
	Closed-loop sustainable product design	Jawahir & Bradley, 2016; Burke et al., 2021; Mendoza et al., 2017
	Design for multiple use cycle	Sumter et al., 2020
	Design for CE/ circular design	Whicher et al., 2018; den Hollander et al., 2017; Wastling et al., 2018; Sumter et al., 2020; da Costa Fernandes et al., 2020; Sassanelli et al., 2020; Jawahir & Bradley, 2016; Sauerwein et al., 2019; Mugge, 2018; Burke et al., 2021; Babbitt et al., 2021
	Design-Driven Innovation	Whicher et al., 2018; Burke et al., 2021; Mendoza et al., 2017
	Future proof design	Wastling et al., 2018
	Design for disassembly	Wastling et al., 2018; Burke et al., 2021
	Design for maintenance	Wastling et al., 2018; Sauerwein et al., 2019; Mendoza et al., 2017; Babbitt et al., 2021
	Design for durability	Wastling et al., 2018; Sauerwein et al., 2019; Mugge, 2018; Mendoza et al., 2017; Babbitt et al., 2021
	Packaging design	Burke et al., 2021; Steenis et al., 2017; Cascini et al., 2020; de Koeijer et al., 2017
	Product-Service System Design (PSS)	Wastling et al., 2018; da Costa Fernandes et al., 2020; Sassanelli et al., 2020
	Design for recovery	Sumter et al., 2020; Sauerwein et al., 2019; Babbitt et al., 2021

	Design for remake and recycling	Wastling et al., 2018; van Schalkwyk et al., 2018; Sauerwein et al., 2019; Mendoza et al., 2017; Babbitt et al., 2021; Baldassarre et al., 2019
Environmental friendly	Eco-industrial approach	Baldassarre et al., 2019; Walker et al. 2021; Belaud et al., 2019; Al-Thani& Al-Ansari, 2021; Walmsley et al., 2019; Smol et al., 2017; Suchek et al., 2021; Hysa et al., 2020
	Industrial and territorial ecology approach	Petit-Boix & Leipold, 2018; Baldassarre et al., 2019; Walker et al. 2021; Belaud et al., 2019; Al-Thani& Al-Ansari, 2021; Walmsley et al., 2019; de Jesus et al., 2018; Liu et al., 2018
	Sustainable circular activity	Petit-Boix & Leipold, 2018; Baldassarre et al., 2019; Walker et al. 2021; Walmsley et al., 2019; Thakker & Bakshi, 2021; Smol et al., 2017; Maldonado-Guzmán et al., 2020; Suchek et al., 2021; Trica et al., 2019; Hysa et al., 2020
	Zero waste orientation	Whicher et al., 2018; Murray, 2002; Babbitt et al., 2021; Liu et al., 2018; Al-Thani& Al-Ansari, 2021; Xavier et al., 2021; Sayadi-Gmada et al., 2019; Kurniawan et al., 2021; Kerdlap et al., 2019
	Green (circular) economy focus	Al-Thani& Al-Ansari, 2021; Cainelli et al., 2020
	Green supply chain management	Walker et al. 2021; de Jesus et al., 2018; Maldonado-Guzm á n et al., 2020; Liu et al., 2018; Bag et al., 2022; Li et al., 2020; Suchek et al., 2021
	Eco-innovation approach	Petit-Boix & Leipold, 2018; de Koeijer et al., 2017; de Jesus et al., 2018; Smol et al., 2017; G Maldonado-Guzm á n et al., 2020; Cainelli et al., 2020; Liu et al., 2018; Bag et al., 2022; Suchek et al., 2021
	Environmental innovation implementation	de Jesus et al., 2018; Suchek et al., 2021; Trica et al., 2019; Hysa et al., 2020
	Sustainable innovation implementation	de Jesus et al., 2018; Bag et al., 2022; Suchek et al., 2021; Pieroni et al., 2019
	Green innovation implementation	Petit-Boix & Leipold, 2018; de Jesus et al., 2018; Maldonado-Guzm á n et al., 2020; Liu et al., 2018; Bag et al., 2022; Li et al., 2020
Ecological economic	Circular activity system / model application	den Hollander et al., 2017; van Schalkwyk et al., 2018; Wastling et al., 2018; Mian et al., 2017; Babbitt et al., 2021; Burke et al., 2021; Thakker & Bakshi, 2021; Walker et al. 2021; de Koeijer et al., 2017; Hysa et al., 2020; Belaud et al., 2019; Trica et al., 2019; Smol et al., 2017
	Private investment	Malinauskaite et al., 2017; Wellesley, et al., 2019; Hysa et al., 2020; Vega-Quezada et al., 2017; Domenech et al., 2019; Wasserbaur et al., 2022; Kaya et al., 2021;
	Circular business model	Sassanelli et al., 2020; Sumter et al., 2020; da Costa Fernandes et al., 2020; Wastling et al., 2018; Babbitt et al., 2021; Mendoza et al., 2017; Sauerwein et al., 2019;

	de Jesus et al., 2018;Walker et al. 2021; Baldassarre et al., 2019; Suchek et al., 2021; Pieroni et al., 2019
Resource /responsible consumption	Mendoza et al., 2017; Li et al., 2019; de Jesus et al., 2018; Walker et al. 2021; Hysa et al., 2020; Cainelli et al., 2020; Liu et al., 2018; Belaud et al., 2019; Suchek et al., 2021; Trica et al., 2019; Smol et al., 2017; Al-Thani& Al-Ansari, 2021; Bag et al., 2022; Walmsley et al., 2019; D.; Pieroni et al., 2019
Extending the duration of use/prolonging product life cycle	Sassanelli et al., 2020; den Hollander et al., 2017; Wastling et al., 2018; Babbitt et al., 2021; Mendoza et al., 2017; Sauerwein et al., 2019; de Jesus et al., 2018; Cainelli et al., 2020
Processing industry	van Schalkwyk et al., 2018; Persis et al., 2021; Cisternas et al., 2021; Narasimmalu & Ramasamy, 2020
Recycling	den Hollander et al., 2017; van Schalkwyk et al., 2018; Wastling et al., 2018; Mian et al., 2017; Babbitt et al., 2021; Burke et al., 2021; Mendoza et al., 2017; Mugge, 2018; de Jesus et al., 2018; de Koeijer et al., 2017; Baldassarre et al., 2019; Hysa et al., 2020; Cainelli et al., 2020; Maldonado-Guzm á n et al., 2020; Liu et al., 2018; Belaud et al., 2019; Trica et al., 2019; Smol et al., 2017; Al-Thani& Al-Ansari, 2021; Cisternas et al., 2021
Renewable energy/resources/ materials	den Hollander et al., 2017; van Schalkwyk et al., 2018; Mian et al., 2017; Babbitt et al., 2021; Burke et al., 2021; Mendoza et al., 2017; Sauerwein et al., 2019; Li et al., 2019; de Jesus et al., 2018; Hysa et al., 2020; Maldonado-Guzmán et al., 2020; Belaud et al., 2019; Trica et al., 2019; Smol et al., 2017; Al-Thani& Al-Ansari, 2021; Bag et al., 2022; Cisternas et al., 2021; Narasimmalu & Ramasamy, 2020

In Table 3, the main groups are divided into subgroups. It is noteworthy that more and more research is proving that the field of design is one of the most important in the transition to a circular activity. The design offers useful systems, tools, and strategies to enable the implementation of circular design principles. For example, a design that looks to the future slows down the flow of products and ensures that products are used for longer. According to den Hollander et al. (2017); the basic concepts of circular product design include two basic principles of product integrity and design recycling means that the product will not become obsolete and will be able to recover the highest value. He also describes a lot of design strategies when creating longevity are designed maintenance and refurbishment and planned refurbishment and repair.

In the interests of sustainable environmental and economic development, the circular activity is proposed as a way of economic growth. In Table 3, the authors have classified the literature according to the focus topics. The concept of an environmentally friendly one is loosely based on a set of fragmented ideas derived from some disciplines, including new fields and semi-scientific concepts. These sources include, for example, eco-industrial approach, industrial and territorial ecology approach, sustainable circular activity, green (circular) economy focus, green supply chain management, implementation of eco-innovation, environmental innovation, and green innovation, and other directions.

In Table 3, the authors have identified three components that embed the circular activity: design, ecology, and economics. Economics in the context of the circular activity has to be talked about from an ecological point of view, so the authors also presented subgroups of the ecological economy in the table. The ecological economy is a new field that has been separated from the field of the environmental economy and is treated as a new field. The authors note the importance of private companies investing in reuse projects and the importance of reusable management of ownership and business models. The unique role of private investment in the development and management of the waste system, which has a positive impact on climate change, is emphasized.

To achieve climate-neutral effects and long-term competitiveness, it should be noted that turnover is an essential part of a wider industrial transformation. It significantly saves materials in value chains and production processes, creating added value and opening up economic opportunities. The challenge of sustainability posed by key value chains calls for urgent, comprehensive and coordinated action to respond to climate emergencies.

The authors analysed the effect of key products consumption on waste, namely: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water and nutrients. Table 4 briefly described the environmental impact and consumption amount of these products.

Table 4. The effect of products consumption on waste.

Product	Essential description	Authors
Electronics and ICT	The current annual growth rate of electrical and electronic equipment is the fastest growing waste stream in the EU, at 2%, and less than 40% of electronic waste is recycled in the EU. If fully or partially functional products are discarded because they cannot be repaired, the value is lost.	Bressanelli et al., 2021; Gåvertsson et al., 2020; Bressanelli et al., 2020; Sarc et al., 2019; Lotz et al., 2022; Kim et al., 2022; Osmani et al., 2021; Ofori & Mensah, 2021; Glöser-Chahoud et al., 2021; Camilleri, 2019; Ahuja et al., 2020;
Batteries and vehicle	Sustainability in the transport sector is the key to future mobility, with progress being made in increasing the sustainability of the value chain and battery circulation potential of electric car batteries.	Sarc et al., 2019; Lotz et al., 2022; Alamerew & Brissaud, 2020; Glöser-Chahoud et al., 2021; Camilleri, 2019; Ahuja et al., 2020;
Packaging	Packaging waste in 2017 In Europe, it reached a record 173 kg per capita. To reap the economic benefits of packaging, by 2030 the aim is for all packaging on the EU market to be reused or recycled.	Sarc et al., 2019; Lotz et al., 2022; Kim et al., 2022; Camilleri, 2019;
Plastics	Trends show that plastic consumption will double over the next 20 years, leading to a global response to plastic pollution, through the initiatives set out in the circular activity strategy.	Sarc et al., 2019; Lotz et al., 2022; Ofori & Mensah, 2021; Camilleri, 2019; Kazancoglu et al., 2020;
Textiles	Only less than 1% of all textiles worldwide are recycled into new textiles. The EU textile sector is dominated by SMEs, but 60% of clothing is made outside the EU.	Lotz et al., 2022; Camilleri, 2019; Boiten et al., 2017; Kazancoglu et al., 2020; Sandvik & Stubbs, 2019; Mishra et al., 2020; Hou et al., 2022;

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

	Given the complexity of the textile value chain, the aim is to strengthen industrial competitiveness and innovation, promote the EU market for sustainable and circular textiles, the market for textile reuse, and develop new business models.	Karell & Niinimäki, K. 2019;
Construction and buildings	More than 35% of all waste in the EU is generated in the construction sector. 5-12% of total EU GHG emissions come from extraction, construction products, building construction and renovation materials. Higher material efficiencies can save 80% of these emissions.	Sarc et al., 2019; Lotz et al., 2022; Alamerew & Brissaud, 2020; Camilleri, 2019;
Food, water and nutrients	The circular activity has the potential to significantly reduce the negative environmental impact of extraction and exploitation of resources and to contribute to the key contribution of the EU economy to the recovery of biodiversity and natural capital in Europe.	Lotz et al., 2022; Ofori & Mensah, 2021; Camilleri, 2019; Hou et al., 2022;

Despite efforts, waste is not declining, generating € 2.5 billion a year from all economic activity in the EU. tons or 5 tons per capita per year, and each citizen produces on average almost half a ton of municipal waste. A lot of effort will be needed to decouple waste generation from economic growth throughout the value chain and in every home.

6. Materials and Methods

The circularity of materials involves production and recycling operations. In pursuit of sustainable development, this study aims to identify effective actions that are important in decision-making.

Various stakeholders make decisions:

- Manufacturers who decide which materials to use in products and to what extent, what production methods should be used;
- Consumers, who use sorting and product reuse practices;
- Waste collection service providers, sort the waste and identify circular materials.

The authors divided the methodology into three layers which highlight the circularity of materials (see Table 5).

Table 5. Three-level methodology highlighting the circularity of materials.

Level of Analysis	Relationship to the circularity of materials	Description of the circularity of materials	Application of Methods	Link with Sustainability
1st level Use of circular materials	The physical system supports the production and the increase of the circularity of materials.	Choice of methods to prolong the shelf life of substances.	Review of literature; Investigations.	Such a solution helps to reduce the negative impact on the environment.
2nd level Effect of private investments	The private investments are used to support the circularity.	Involvement of private investments to support the development of circularity.	Panel data analysis; Regression analysis.	Investments supporting sustainability.
3rd level Evidence in waste	The physical system supports circularity via waste collection.	Sorting during the collection of waste.	Panel data analysis; Regression analysis; Comparison.	Allows to return for reuse and to save natural resources

Table 5 presents a summary focusing on the increase of the circularity of materials with the support of a three levels methodology, providing descriptions, relationships and methods specific to each level.

For the research, the authors used indicators, such as

(1) Trade in recyclable raw materials;

(2) Patents related to recycling and secondary raw materials;

(3) Private investments, jobs and gross value added related to circular activity sectors;

(4) The recycling rate of e-waste;

(5) The recycling rate of municipal waste;

(6) Other recycling and waste generation indicators.

Eurostat (2021) data for the years 2000-2019 were obtained from 32 European countries (27 countries of the European Union, islands, Norway, the United Kingdom, Serbia and Turkey). There were a total of 6642 datasets with values.

The authors refined the data, constructed a correlation matrix, and selected only those elements with a probability of less than 0.1 for the regression model (Table 6). The novelty of the study is that the authors developed a dynamic regression model by analyzing the effects in year t and year t-n. The authors of this work use the dynamic regression model first applied by Petris et al. (2009). The first step in the modelling procedure was the transformation of the time series to help determine the dependent variable and its relationships to the regressors. The developed model meets the requirements important for the construction of a simple regression model but provides dynamic interrelationships.

Table 6. Correlation matrix for the variables which are transformed into dlog.

Indicators	Abbrevation	Statistical indicators	Circular material use rate
Patents related to recycling and secondary raw materials	DLOG(PATNTS)	Corr. Coefficient	-0,174
		Probability	0,282
	DLOG(PATNTS(-1))	Corr. Coefficient	-0,085
		Probability	0,601
Private investments, jobs and gross value added related to circular economy sectors	DLOG(PRINV_CIRC)	Corr. Coefficient	-0,057
		Probability	0,725
	DLOG(PRINV_CIRC(-1))	Corr. Coefficient	-0,279
		Probability	0,081
Recycling of biowaste	DLOG(REC_BIOW)	Corr. Coefficient	-0,072
		Probability	0,659
Recycling rate of e-waste	DLOG(REC_EW(-1))	Corr. Coefficient	-0,474
		Probability	0,002
Recycling rate of municipal waste	DLOG(REC_MU)	Corr. Coefficient	0,021
		Probability	0,897
	DLOG(REC_MU(-1))	Corr. Coefficient	-0,034
		Probability	0,834
	DLOG(REC_MU(-2))	Corr. Coefficient	-0,371
		Probability	0,019
Recycling rate of packaging waste by type of packaging	DLOG(REC_PCW)	Corr. Coefficient	0,130
		Probability	0,424
	DLOG(REC_PCW(-1))	Corr. Coefficient	-0,110
		Probability	0,500
Recovery rate of construction and demolition waste	DLOG(RECOV_CNSTR)	Corr. Coefficient	-0,213
		Probability	0,186
	DLOG(RECOV_CNSTR(-2))	Corr. Coefficient	0,042
		Probability	0,799
Trade in recyclable raw materials	DLOG(TRD_REC(-1))	Corr. Coefficient	-0,039
		Probability	0,809
Generation of municipal waste per capita	DLOG(MUNW)	Corr. Coefficient	0,024
		Probability	0,884
	DLOG(MUNW(-1))	Corr. Coefficient	-0,094
		Probability	0,565

Table 11 presents the results of the correlation analysis performed for this study, noting the level of correlation between the elements listed in the table. The constructed table demonstrates the relationship between the circular material use rate and other elements. Table 11 shows that the circular material use rate has links with two recycling rate indicators (specifying municipal waste in the second year and electrical and electronic waste in the third year) and private investments indicated in the previous year.

The authors formed a dynamic regression model used to estimate the size of circular material use rate.

The authors identified the regressors in constructing mathematical equation. The mentioned equation is placed below (1):

$$circ_t = \beta_0 + \beta_1\, prinv\_circ_{(t-n)} + \beta_2\, rec\_ew_{(t-n)} + \beta_3\, rec\_mu_{(t-n)} + u_t \quad (1)$$

where:
$circ_t$—dlog of circular material use rate in year t, measures in percentage the share of material recycled and fed back into reuse;
β_0—intercept in the equation;
$prinv\_circ_{(t-n)}$—dlog of private investments, jobs and gross value added related to economic sectors;
$rec\_ew_{(t-n)}$—dlog of recycling rate of electrical and electronic waste, in year t − n;
$rec\_mu_{(t-n)}$—dlog of recycling rate of the municipal waste, in year t − n, the tonnage recycled from municipal waste divided by the total municipal waste arising;
u_t—random error of regression model;
$\beta_{1,2,3}$—the influence of regressors on the circularity of materials processing reflected the coefficients of elasticity.

7. Results

The results demonstrate that the residuals of the formed equation spread by following normal distribution (Figure 2).

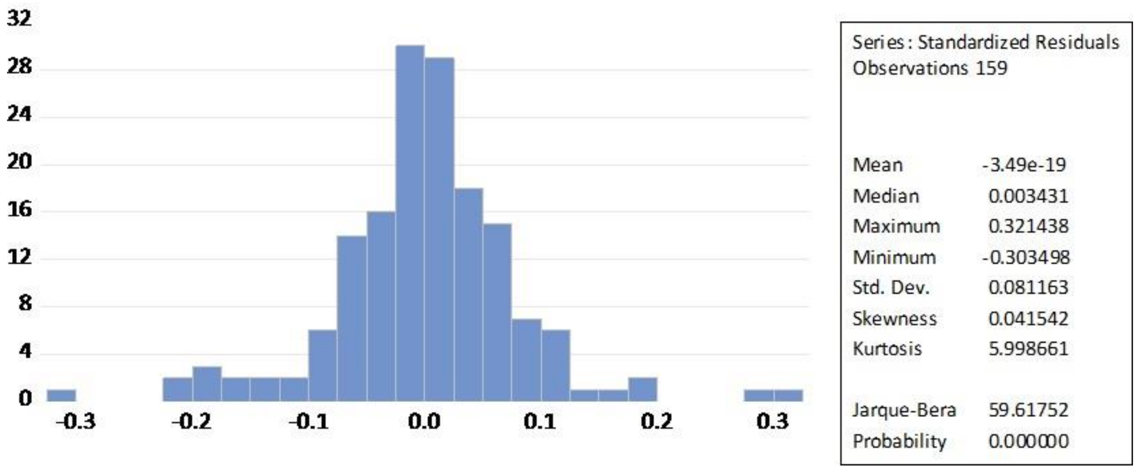

Figure 2. Equation residuals spread.

Figure 2 presents that the average of residuals approximates zero. The forecasting of volumes generated due to the circularity of materials is shown in Figure 3.

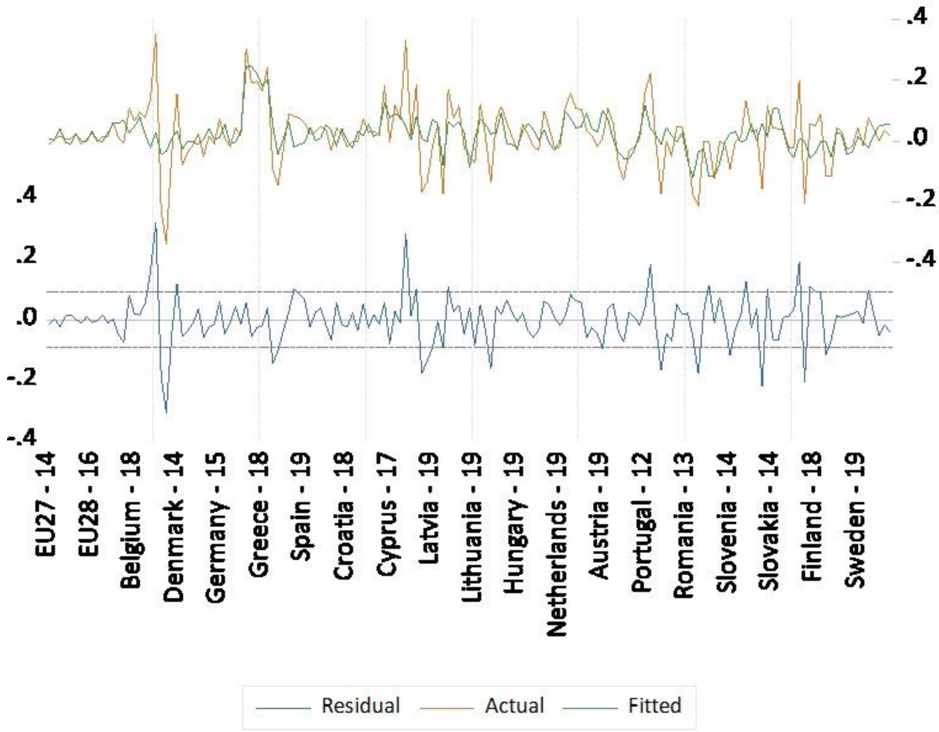

Figure 3. Forecasting the recycled biowaste level by the European Union countries.

The equation of the dynamic regression model is placed below (2). The authors identified coefficients of the equation and standard error:

$$circ_t = \underset{(0.009)}{0.03} - \underset{(0.107)}{0.261}\, prinv\_circ_{(t-1)} + \underset{(0.05)}{0.105}\, rec\_ew_{(t-3)} - \underset{(0.048)}{0.115}\, rec\_mu_{(t-2)} \quad (2)$$

Seeking to summarize concrete values for the dynamic regression model (2), the authors used the Panel least squares method and reached results that are demonstrated in Figure 4 where Durbin-Watson statistics is 1.76.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0,030	0,009	3,202	0,002
DLOG(PRINV_CIRC(-1))	-0,261	0,107	-2,435	0,016
DLOG(REC_EW(-3))	0,105	0,050	2,114	0,037
DLOG(REC_MU(-2))	-0,115	0,048	-2,367	0,020

Root MSE	0,081	R-squared	0,332
Mean dependent var	0,022	Adjusted R-squared	0,149
S.D. dependent var	0,099	S.E. of regression	0,092
Akaike info criterion	-1,751	Sum squared resid	1,041
Schwarz criterion	-1,075	Log likelihood	174,187
Hannan-Quinn criter.	-1,476	F-statistic	1,815
Durbin-Watson stat	1,759	Prob(F-statistic)	0,010

Figure 4. Formation of equation (2): panel least squares revision method.

The application of the method identifies that the R squared is 0.33. The statistical validity is tested by applying the Lagrange multiplier tests. The tests present the correct statistical validity.

Also, the authors performed Redundant Fixed Effects tests and tested cross-section and period fixed effects.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 May 2022 doi:10.20944/preprints202205.0391.v1

Effects Test	Statistic	d.f.	Prob.
Cross-section F	1,565	-24 124	0,060
Cross-section Chi-square	42,081	24	0,013
Period F	0,885	-7 124	0,520
Period Chi-square	7,754	7	0,355
Cross-Section/Period F	1,457	-31 124	0,077
Cross-Section/Period Chi-square	49,395	31	0,019

Figure 5. Formation of equation (2): panel least squares revision method.

The probability of the Chow test is lower than 0.05 and shows the fixed evaluation method is chosen properly. The constructed equation could be used to forecast the circular material use rate.

8. Discussion

The circularity of material management involves various aspects. These activities must be focusing on product design, product consumption, waste management. In the article, the authors present key elements that helps to improve the circularity of materials.

For sustainable development, the authors point to the need to create and expand activities, apply approaches, implement innovations in production, supply chain management and consumption areas. In addition, sustainable development in particular seeks to address the integrated approach to environmental, and ecologic aspects that lead to long-term effect.

The development of sustainable activities is crucial for environmental protection. By reducing the overall negative environmental impact of production, consumption, helps to reach results in all types of waste streams, especially municipal waste. Therefore, the article discusses sustainable practices such as the improvement of material circularity.

The study has some limitations: the authors do not revise the survival of materials; they identify opportunities to increase material circularity use rates and provide a dynamic regression model to forecast this.

9. Conclusions

The links and interdependencies between the circularity of materials and waste recycling are a new topic that other authors have not addressed so far. The article also discusses the essential elements of material circularity. The authors compiled the literature review to investigate aspects of material circularity, and found that many key elements could be included into research.

The authors identified aspects of the materials and their recycling possibilities. This article reveals that municipal waste is strongly and directly related with the circular material use rates. Emphasis is also placed on design of material, which plays the role in achieving sustainable development. The authors provided a methodology that identifies the points of connection between key elements and material circularity. The second level of the methodology was investigated mathematically to determine the links between private investments and improvement of material circularity. The third level of the methodology is dedicated to waste. To recycle the waste, reverse supply chain and logistics seems to support circularity of material and its collection from consumers. The authors identified three levels of analysis. The authors found that the relationship between the components identified above is important.

Further research could assess the impact of specific materials and production methods on improving circular material use rates. The study could also be extended to other countries and include the review of their practices. The authors were also able to compare the elements and define which of them could give better results on material circularity.

Supplementary Materials: Not applicable

Author Contributions: Conceptualization, O.L. and A.B.; methodology, A.B.; validation, A.J.; formal analysis, A.J.; investigation, A.J.; writing—review and editing, O.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding

Data Availability Statement: Not applicable

Acknowledgements: The authors acknowledge the Lithuania Innovation centre.

Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflict of interest."

References

Ayres, R.U. (2008) Sustainability Economics: Where Do We Stand? Ecological Economics, 67, 281-310. http://dx.doi.org/10.1016/j.ecolecon.2007.12.009

Sariatli, F. (2017). Linear economy versus circular economy: A comparative and analyzer study for optimization of economy for sustainability. *Visegrad Journal on Bioeconomy and Sustainable Development*, *6*(1), 31-34.

Velenturf, A. P., & Purnell, P. (2021). Principles for a sustainable circular economy. *Sustainable Production and Consumption*, *27*, 1437-1457.

Rodríguez, C., Florido, C., & Jacob, M. (2020). Circular economy contributions to the tourism sector: A critical literature review. *Sustainability*, *12*(11), 4338.

McDonough, W., & Braungart, M. (2003). Towards a sustaining architecture for the 21st century: the promise of cradle-to-cradle design. *Industry and environment*, *26*(2), 13-16.

Mentink, B. (2014). Circular business Model Innovation. Dutch: Technical University Delft.

Di Maio, F., & Rem, P. C. (2015). A robust indicator for promoting circular economy through recycling. *Journal of Environmental Protection*, *6*(10), 1095.

Sørensen, P. B. (2018). From the linear economy to the circular economy: A basic model. *Finanz-Archiv: Zeitschrift für das Gesamte Finanzwesen*, *74*(1), 71-87.

Michelini, G., Moraes, R. N., Cunha, R. N., Costa, J. M., & Ometto, A. R. (2017). From linear to circular economy: PSS conducting the transition. *Procedia CIRP*, *64*, 2-6.

Bocken, N.M.P., de Pauw, I., Bakker, C. and van der Grinten, B. (2016), "Product design and business model strategies for a circular economy", Journal of Industrial and Production Engineering, Vol. 33 No. 5, pp. 308– 320. https://doi.org/10.1080/21681015.2016.1172124

Mostaghel, R., & Chirumalla, K. (2021). Role of customers in circular business models. *Journal of Business Research*, *127*, 35-44.

Elisha, O. D. (2020). Moving beyond take-make-dispose to take-make-use for sustainable economy. *Int. J. Sci. Res. Educ*, *13*, 497-516.

Zucchella, A., & Previtali, P. (2019). Circular business models for sustainable development: A "waste is food" restorative ecosystem. *Business Strategy and the Environment*, *28*(2), 274-285.

Moreno, M., De los Rios, C., Rowe, Z. and Charnley, F. (2016), "A Conceptual Framework for Circular Design", Sustainability, Vol. 8 No. 9, pp. 937. https://doi.org/10.3390/su8090937

Oghazi, P., & Mostaghel, R. (2018). Circular business model challenges and lessons learned—An industrial perspective. *Sustainability*, *10*(3), 739.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of cleaner production*, *115*, 36-51.

Jouni Korhonen, Antero Honkasalo, Jyri Seppälä. Circular Economy: The Concept and its Limitations, Ecological Economics (143), 2018, 37-46, ISSN 0921-8009, https://doi.org/10.1016/j.ecolecon.2017.06.041.

Bocken, N. M., Ritala, P., & Huotari, P. (2017). The Circular Economy: Exploring the Introduction of the Concept Among S&P 500 Firms. Journal of Industrial Ecology, 21, 487–490.

[49] Stahel, W. R., "The utilization focused service economy: Resource efficiency," in B. R. Allenby and D. J. Richards (eds), The Greening of Industrial Ecosystems, National Academy Press, Washington, DC, 178–190 (1994).

[50] Stahel, W. R., The Performance Economy, Palgrave Macmillan Hampshire, Hampshire UK, (2010).

Morseletto, P. (2020). Targets for a circular economy. *Resources, Conservation and Recycling*, *153*, 104553.

Worrell, E., & Reuter, M. A. (Eds.). (2014). *Handbook of Recycling: State-of-the-art for Practitioners, Analysts, and Scientists*. Newnes.

Migliore, M. (2019). Circular economy and upcycling of waste and pre-consumer scraps in construction sector. The role of information to facilitate the exchange of resources through a virtual marketplace. *Environmental Engineering and Management Journal*, *18*(10), 2297-2303.

Roberto Merli, Michele Preziosi, Alessia Acampora. How do scholars approach the circular economy? A systematic literature review. Journal of Cleaner Production (178), 2018, 703-722, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2017.12.112

[38] McDonough, W. and M. Braungart, Cradle to Cradle: Remaking the Way We Make Things, North Point Press, New York, NY (2002)

Triguero, Á., Cuerva, M. C., & Sáez-Martínez, F. J. (2022). Closing the loop through eco-innovation by European firms: Circular economy for sustainable development. *Business Strategy and the Environment*.
Moreno, M., De los Rios, C., Rowe, Z., & Charnley, F. (2016). A conceptual framework for circular design. *Sustainability*, *8*(9), 937.
Prendeville, S., Sanders, C., Sherry, J., & Costa, F. (2014). Circular economy: is it enough. *EcoDesign Centre, Wales, available from: http://www. edcw. org/en/resources/circulareconomy-it-enough, Accessed on July*, *21*, 2014.
Haupt, M., Vadenbo, C., & Hellweg, S. (2017). Do we have the right performance indicators for the circular economy?: insight into the Swiss waste management system. *Journal of Industrial Ecology*, *21*(3), 615-627.
Brydges, T. (2021). Closing the loop on take, make, waste: Investigating circular economy practices in the Swedish fashion industry. *Journal of Cleaner Production*, *293*, 126245.
Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. *Journal of cleaner production*, *190*, 712-721.
Jørgensen, M. S., & Remmen, A. (2018). A methodological approach to development of circular economy options in businesses. *Procedia CIRP*, *69*, 816-821.

[15] Gordon, R.B., Bertram, M. and Graedel, T.E. (2005) Metal Stock and Sustainability. Proceedings of the National Academy of Sciences of the United States of America, 103, 1209-1214.
[17] Europe INNOVA (2012) Guide to Resource Efficiency in Manufacturing.
[1] Ellen Mac Arthur Foundation (2014) Toward the Circular Economy—Accelerating the Scale-Up across Global Supply Chains

Suárez-Eiroa, B., Fernández, E., Méndez-Martínez, G., & Soto-Oñate, D. (2019). Operational principles of circular economy for sustainable development: Linking theory and practice. *Journal of cleaner production*, *214*, 952-961.
Akhimien, N. G., Latif, E., & Hou, S. S. (2021). Application of circular economy principles in buildings: A systematic review. *Journal of Building Engineering*, *38*, 102041.
Shekarian, E. (2020). A review of factors affecting closed-loop supply chain models. *Journal of Cleaner Production*, *253*, 119823.
Xu, L., & Wang, C. (2018). Sustainable manufacturing in a closed-loop supply chain considering emission reduction and remanufacturing. *Resources, Conservation and Recycling*, *131*, 297-304.
Tomić, T., & Schneider, D. R. (2018). The role of energy from waste in circular economy and closing the loop concept–Energy analysis approach. *Renewable and Sustainable Energy Reviews*, *98*, 268-287.
Slowak, A. P., & Regenfelder, M. (2017). Creating value, not wasting resources: sustainable innovation strategies. *Innovation: The European Journal of Social Science Research*, *30*(4), 455-475.
Shevchenko, T., & Kronenberg, J. (2020). Management of material and product circularity potential as an approach to operationalise circular economy. *Progress in Industrial Ecology, An International Journal*, *14*(1), 30-57.
Tonelli, F., Evans, S., & Taticchi, P. (2013). Industrial sustainability: challenges, perspectives, actions. *International Journal of Business Innovation and Research*, *7*(2), 143-163.
Niero, M., & Hauschild, M. Z. (2017). Closing the loop for packaging: finding a framework to operationalize Circular Economy strategies. *Procedia Cirp*, *61*, 685-690.
Hazen, B. T., Russo, I., Confente, I., & Pellathy, D. (2020). Supply chain management for circular economy: conceptual framework and research agenda. *The International Journal of Logistics Management*.
Huysman, S., Debaveye, S., Schaubroeck, T., De Meester, S., Ardente, F., Mathieux, F., & Dewulf, J. (2015). The recyclability benefit rate of closed-loop and open-loop systems: A case study on plastic recycling in Flanders. *Resources, Conservation and Recycling*, *101*, 53-60.
Nakatani, J. (2014). Life cycle inventory analysis of recycling: mathematical and graphical frameworks. *Sustainability*, *6*(9), 6158-6169.
Souza, G. C. (2013). Closed-loop supply chains: a critical review, and future research. *Decision Sciences*, *44*(1), 7-38.
Amin, S. H., & Zhang, G. (2012). A proposed mathematical model for closed-loop network configuration based on product life cycle. *The International Journal of Advanced Manufacturing Technology*, *58*(5), 791-801.
Geyer, R., Kuczenski, B., Zink, T., & Henderson, A. (2016). Common misconceptions about recycling. *Journal of Industrial Ecology*, *20*(5), 1010-1017.
Camilleri, M. A. (2019). The circular economy's closed loop and product service systems for sustainable development: A review and appraisal. *Sustainable Development*, *27*(3), 530-536.
Niero, M., & Olsen, S. I. (2016). Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. *Resources, Conservation and Recycling*, *114*, 18-31.
Lingaitienė, O., & Burinskienė, A. (2021). Core elements towards circularity: evidence from the European countries. *Sustainability*, *13*(16), 8742.
Okorie, O., Salonitis, K., Charnley, F., Moreno, M., Turner, C., & Tiwari, A. (2018). Digitisation and the circular economy: A review of current research and future trends. *Energies*, *11*(11), 3009.
Ang, K. L., Saw, E. T., He, W., Dong, X., & Ramakrishna, S. (2021). Sustainability framework for pharmaceutical manufacturing (PM): A review of research landscape and implementation barriers for circular economy transition. *Journal of Cleaner Production*, *280*, 124264.

Foster, G. (2020). Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environm Allwood, J. M. (2014). Squaring the circular economy: the role of recycling within a hierarchy of material management strategies. In *Handbook of recycling* (pp. 445-477). Elsevier.
ental impacts. *Resources, Conservation and Recycling*, *152*, 104507.
Wijkman, A., & Skånberg, K. (2015). The circular economy and benefits for society. *Club of Rome*.
Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards circular economy in the food system. *Sustainability*, *8*(1), 69.
Schröder, P., Lemille, A., & Desmond, P. (2020). Making the circular economy work for human development. *Resources, Conservation and Recycling*, *156*, 104686.
Li, J., Gao, S., Duan, H., & Liu, L. (2009). Recovery of valuable materials from waste liquid crystal display panel. *Waste Management*, *29*(7), 2033-2039.
Chandrasekaran, S. R., Avasarala, S., Murali, D., Rajagopalan, N., & Sharma, B. K. (2018). Materials and energy recovery from e-waste plastics. *ACS Sustainable Chemistry & Engineering*, *6*(4), 4594-4602.
Menikpura, S. N. M., Gheewala, S. H., Bonnet, S., & Chiemchaisri, C. (2013). Evaluation of the effect of recycling on sustainability of municipal solid waste management in Thailand. *Waste and Biomass Valorization*, *4*(2), 237-257.
Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., ... & Dewulf, J. (2019). Circular economy indicators: what do they measure?. *Resources, Conservation and Recycling*, *146*, 452-461.
Fellner, J., & Lederer, J. (2020). Recycling rate–The only practical metric for a circular economy?. *Waste Management*, *113*, 319-320.
Ragossnig, A. M., & Schneider, D. R. (2019). Circular economy, recycling and end-of-waste. *Waste Management & Research*, *37*(2), 109-111.
Turunen, T. (2020). The missing link: regulating waste-based materials in the circular economy. In *Handbook of the Circular Economy*. Edward Elgar Publishing.
Lucchetti, M. G., Paolotti, L., Rocchi, L., & Boggia, A. (2019). The role of environmental evaluation within circular economy: an application of life cycle assessment (LCA) method in the detergents sector. *Rigas Tehniskas Universitates Zinatniskie Raksti*, *23*(2), 238-257.
Hjelmar, O., van der Sloot, H. A., Comans, R. N., & Wahlström, M. (2013). EoW criteria for waste-derived aggregates. *Waste and Biomass Valorization*, *4*(4), 809-819.
Zorpas, A. A. (2016). Sustainable waste management through end-of-waste criteria development. *Environmental Science and Pollution Research*, *23*(8), 7376-7389.
Villanueva, A., & Eder, P. (2014). End-of-waste criteria for waste plastic for conversion. *Institute for Prospective Technological Studies*.
Den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product design in a circular economy: Development of a typology of key concepts and terms. *Journal of Industrial Ecology*, *21*(3), 517-525.
Jawahir, I. S., & Bradley, R. (2016). Technological elements of circular economy and the principles of 6R-based closed-loop material flow in sustainable manufacturing. *Procedia Cirp*, *40*, 103-108.
Dong, L., Liu, Z., & Bian, Y. (2021). Match circular economy and urban sustainability: Re-investigating circular economy under sustainable development goals (SDGs). *Circular Economy and Sustainability*, *1*(1), 243-256.
Ciulli, F., Kolk, A., & Boe-Lillegraven, S. (2020). Circularity brokers: Digital platform organizations and waste recovery in food supply chains. *Journal of Business Ethics*, *167*(2), 299-331.
Eriksen, M. K., Damgaard, A., Boldrin, A., & Astrup, T. F. (2019). Quality assessment and circularity potential of recovery systems for household plastic waste. *Journal of Industrial Ecology*, *23*(1), 156-168.
Wijewickrama, M. K. C. S., Rameezdeen, R., & Chileshe, N. (2021). Information brokerage for circular economy in the construction industry: A systematic literature review. *Journal of Cleaner Production*, *313*, 127938.
Giugliano, M., Grosso, M., & Rigamonti, L. (2008). Energy recovery from municipal waste: A case study for a middle-sized Italian district. *Waste management*, *28*(1), 39-50.
Lin, C. F., Wu, C. H., & Ho, H. M. (2006). Recovery of municipal waste incineration bottom ash and water treatment sludge to water permeable pavement materials. *Waste Management*, *26*(9), 970-978.
Mian, M. M., Zeng, X., Nasry, A. A. N. B., & Al-Hamadani, S. M. (2017). Municipal solid waste management in China: a comparative analysis. *Journal of material cycles and waste management*, *19*(3), 1127-1135.
Hysa, E., Kruja, A., Rehman, N. U., & Laurenti, R. (2020). Circular economy innovation and environmental sustainability impact on economic growth: An integrated model for sustainable development. *Sustainability*, *12*(12), 4831.
Belaud, J. P., Adoue, C., Vialle, C., Chorro, A., & Sablayrolles, C. (2019). A circular economy and industrial ecology toolbox for developing an eco-industrial park: perspectives from French policy. *Clean Technologies and Environmental Policy*, *21*(5), 967-985.
Trica, C. L., Banacu, C. S., & Busu, M. (2019). Environmental factors and sustainability of the circular economy model at the European Union level. *Sustainability*, *11*(4), 1114.
Smol, M., Kulczycka, J., & Avdiushchenko, A. (2017). Circular economy indicators in relation to eco-innovation in European regions. *Clean Technologies and Environmental Policy*, *19*(3), 669-678.
Khatiwada, D., Golzar, F., Mainali, B., & Devendran, A. A. (2021). Circularity in the Management of Municipal Solid Waste–A Systematic Review. *Environmental and Climate Technologies*, *25*(1), 491-507.
Zhang, A. (2020). Circularity and enclosures: metabolizing waste with the black soldier fly. *Cultural Anthropology*, *35*(1), 74-103.

Cobo, S., Dominguez-Ramos, A., & Irabien, A. (2018). Minimization of resource consumption and carbon footprint of a circular organic waste valorization system. *ACS Sustainable Chemistry & Engineering*, *6*(3), 3493-3501.
Aceleanu, M. I., Şerban, A. C., Suciu, M. C., & Biţoiu, T. I. (2019). The management of municipal waste through circular economy in the context of smart cities development. *IEEE Access*, *7*, 133602-133614.
Fletcher, C. A., Clair, R. S., & Sharmina, M. (2021). A framework for assessing the circularity and technological maturity of plastic waste management strategies in hospitals. *Journal of Cleaner Production*, *306*, 127169.
Manfredi, S., Cristobal, J., de Matos, C. T., Giavini, M., Vasta, A., Sala, S., & Tuomisto, H. (2015). Improving sustainability and circularity of European food waste management with a life cycle approach. *Publications Office of the European Union*.
Colasante, A., D'Adamo, I., Morone, P., & Rosa, P. (2022). Assessing the circularity performance in a European cross-country comparison. *Environmental Impact Assessment Review*, *93*, 106730.
Ottoni, M., Dias, P., & Xavier, L. H. (2020). A circular approach to the e-waste valorization through urban mining in Rio de Janeiro, Brazil. *Journal of Cleaner Production*, *261*, 120990.
Jai Singh Rathore, G. (2020). Formality and informality in e-waste economies: exploring caste-class in urban land and labor practices. *Urban Geography*, *41*(6), 902-906.
Angelis-Dimakis, A., Arampatzis, G., Alexopoulos, A., Pantazopoulos, A., Vyrides, I., Chourdakis, N., & Angelis, V. (2022). Waste Management and the Circular Economy in Cyprus—The Case of the SWAN Project. *Environments*, *9*(2), 16.
Cano, N. S. D. S. L., Iacovidou, E., & Rutkowski, E. W. (2022). Typology of municipal solid waste recycling value chains: A global perspective. *Journal of Cleaner Production*, 130386.
Lange, J. P. (2021). Managing Plastic Waste─ Sorting, Recycling, Disposal, and Product Redesign. *ACS Sustainable Chemistry & Engineering*, *9*(47), 15722-15738.
Xavier, L. H., Ottoni, M., & Lepawsky, J. (2021). Circular economy and e-waste management in the Americas: Brazilian and Canadian frameworks. *Journal of Cleaner Production*, *297*, 126570.
Kazancoglu, Y., Ozkan-Ozen, Y. D., Mangla, S. K., & Ram, M. (2020). Risk assessment for sustainability in e-waste recycling in circular economy. *Clean Technologies and Environmental Policy*, 1-13.
Singh, A., Panchal, R., & Naik, M. (2020). Circular economy potential of e-waste collectors, dismantlers, and recyclers of Maharashtra: a case study. *Environmental Science and Pollution Research*, *27*(17), 22081-22099.
Awasthi, A. K., Cucchiella, F., D'Adamo, I., Li, J., Rosa, P., Terzi, S., ... & Zeng, X. (2018). Modelling the correlations of e-waste quantity with economic increase. *Science of the Total Environment*, *613*, 46-53.
Al-Thani, N. A., & Al-Ansari, T. (2021). Comparing the convergence and divergence within industrial ecology, circular economy, and the energy-water-food nexus based on resource management objectives. *Sustainable Production and Consumption*, *27*, 1743-1761.
Baldé, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). *The global e-waste monitor 2017: Quantities, flows and resources*. United Nations University, International Telecommunication Union, and International Solid Waste Association.
Whicher, A., Harris, C., Beverley, K., & Swiatek, P. (2018). Design for circular economy: Developing an action plan for Scotland. *Journal of Cleaner Production*, *172*, 3237-3248.
Murray, R. (2002). *Zero waste*. London: Greenpeace Environmental Trust.
Babbitt, C. W., Althaf, S., Rios, F. C., Bilec, M. M., & Graedel, T. E. (2021). The role of design in circular economy solutions for critical materials. *One Earth*, *4*(3), 353-362.
Liu, J., Feng, Y., Zhu, Q., & Sarkis, J. (2018). Green supply chain management and the circular economy: Reviewing theory for advancement of both fields. *International Journal of Physical Distribution & Logistics Management*.
Sayadi-Gmada, S., Rodríguez-Pleguezuelo, C. R., Rojas-Serrano, F., Parra-López, C., Parra-Gómez, S., García-García, M. D. C., ... & Manrique-Gordillo, T. (2019). Inorganic waste management in greenhouse agriculture in Almeria (SE Spain): Towards a circular system in intensive horticultural production. *Sustainability*, *11*(14), 3782.
Kurniawan, T. A., Avtar, R., Singh, D., Xue, W., Othman, M. H. D., Hwang, G. H., ... & Kern, A. O. (2021). Reforming MSWM in Sukunan (Yogjakarta, Indonesia): A case-study of applying a zero-waste approach based on circular economy paradigm. *Journal of cleaner production*, *284*, 124775.
Kerdlap, P., Low, J. S. C., & Ramakrishna, S. (2019). Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. *Resources, conservation and recycling*, *151*, 104438.
Kusch, A., Gasde, J., Deregowski, C., Woidasky, J., Lang-Koetz, C., & Viere, T. (2021). Sorting and recycling of lightweight packaging in Germany—climate impacts and options for increasing circularity using tracer-based-sorting. *Materials Circular Economy*, *3*(1), 1-15.
Rodríguez, C., Florido, C., & Jacob, M. (2020). Circular economy contributions to the tourism sector: A critical literature review. *Sustainability*, *12*(11), 4338.
Mendoza, J. M. F., Sharmina, M., Gallego-Schmid, A., Heyes, G., & Azapagic, A. (2017). Integrating backcasting and eco-design for the circular economy: The BECE framework. *Journal of Industrial Ecology*, *21*(3), 526-544.
Cano, N. S. D. S. L., Iacovidou, E., & Rutkowski, E. W. (2022). Typology of municipal solid waste recycling value chains: A global perspective. *Journal of Cleaner Production*, 130386.
Sassanelli, C., Urbinati, A., Rosa, P., Chiaroni, D., & Terzi, S. (2020). Addressing circular economy through design for X approaches: A systematic literature review. *Computers in industry*, *120*, 103245.

de Koeijer, B., Wever, R., & Henseler, J. (2017). Realizing product-packaging combinations in circular systems: Shaping the research agenda. *Packaging Technology and Science*, *30*(8), 443-460.
Thakker, V., & Bakshi, B. R. (2021). Toward sustainable circular economies: A computational framework for assessment and design. *Journal of Cleaner Production*, *295*, 126353.
Wastling, T., Charnley, F., & Moreno, M. (2018). Design for circular behaviour: Considering users in a circular economy. *Sustainability*, *10*(6), 1743.
Sumter, D., De Koning, J., Bakker, C., & Balkenende, R. (2020). Circular economy competencies for design. *Sustainability*, *12*(4), 1561.
Bag, S., Dhamija, P., Bryde, D. J., & Singh, R. K. (2022). Effect of eco-innovation on green supply chain management, circular economy capability, and performance of small and medium enterprises. *Journal of Business Research*, *141*, 60-72.
Van Schalkwyk, R. F., Reuter, M. A., Gutzmer, J., & Stelter, M. (2018). Challenges of digitalizing the circular economy: Assessment of the state-of-the-art of metallurgical carrier metal platform for lead and its associated technology elements. *Journal of Cleaner Production*, *186*, 585-601.
Sauerwein, M., Doubrovski, E., Balkenende, R., & Bakker, C. (2019). Exploring the potential of additive manufacturing for product design in a circular economy. *Journal of Cleaner Production*, *226*, 1138-1149.
Mugge, R. (2018). Product design and consumer behaviour in a circular economy. *Sustainability*, *10*(10), 3704.
Burke, H., Zhang, A., & Wang, J. X. (2021). Integrating product design and supply chain management for a circular economy. *Production Planning & Control*, 1-17.
Cascini, G., O'Hare, J., Dekoninck, E., Becattini, N., Boujut, J. F., Guefrache, F. B., ... & Morosi, F. (2020). Exploring the use of AR technology for co-creative product and packaging design. *Computers in Industry*, *123*, 103308.
Walmsley, T. G., Ong, B. H., Klemeš, J. J., Tan, R. R., & Varbanov, P. S. (2019). Circular Integration of processes, industries, and economies. *Renewable and sustainable energy reviews*, *107*, 507-515.
Steenis, N. D., van Herpen, E., van der Lans, I. A., Ligthart, T. N., & van Trijp, H. C. (2017). Consumer response to packaging design: The role of packaging materials and graphics in sustainability perceptions and product evaluations. *Journal of Cleaner Production*, *162*, 286-298.
Li, Q., Guan, X., Shi, T., & Jiao, W. (2020). Green product design with competition and fairness concerns in the circular economy era. *International Journal of Production Research*, *58*(1), 165-179.
da Costa Fernandes, S., Pigosso, D. C., McAloone, T. C., & Rozenfeld, H. (2020). Towards product-service system oriented to circular economy: A systematic review of value proposition design approaches. *Journal of Cleaner Production*, *257*, 120507.
Baldassarre, B., Schepers, M., Bocken, N., Cuppen, E., Korevaar, G., & Calabretta, G. (2019). Industrial Symbiosis: towards a design process for eco-industrial clusters by integrating Circular Economy and Industrial Ecology perspectives. *Journal of cleaner production*, *216*, 446-460.
Walker, A. M., Vermeulen, W. J., Simboli, A., & Raggi, A. (2021). Sustainability assessment in circular inter-firm networks: an integrated framework of industrial ecology and circular supply chain management approaches. *Journal of Cleaner Production*, *286*, 125457.
Suchek, N., Fernandes, C. I., Kraus, S., Filser, M., & Sjögrén, H. (2021). Innovation and the circular economy: A systematic literature review. *Business Strategy and the Environment*, *30*(8), 3686-3702.
Petit-Boix, A., & Leipold, S. (2018). Circular economy in cities: Reviewing how environmental research aligns with local practices. *Journal of Cleaner Production*, *195*, 1270-1281.
De Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of Cleaner Production*, *172*, 2999-3018.
Maldonado-Guzmán, G., Garza-Reyes, J. A., & Pinzón-Castro, Y. (2020). Eco-innovation and the circular economy in the automotive industry. *Benchmarking: An International Journal*.
Cainelli, G., D'Amato, A., & Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, *49*(1), 103827.
Pieroni, M. P., McAloone, T. C., & Pigosso, D. C. (2019). Business model innovation for circular economy and sustainability: A review of approaches. *Journal of cleaner production*, *215*, 198-216.
Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., ... & Spencer, N. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *Energy*, *141*, 2013-2044.
Wellesley, L., Preston, F., & Lehne, J. (2019). An Inclusive Circular Economy.
Vega-Quezada, C., Blanco, M., & Romero, H. (2017). Synergies between agriculture and bioenergy in Latin American countries: A circular economy strategy for bioenergy production in Ecuador. *New biotechnology*, *39*, 81-89.
Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. *Resources, conservation and recycling*, *141*, 76-98.
Wasserbaur, R., Sakao, T., & Milios, L. (2022). Interactions of governmental policies and business models for a circular economy: A systematic literature review. *Journal of Cleaner Production*, *337*, 130329.
Kaya, D. I., Dane, G., Pintossi, N., & Koot, C. A. (2021). Subjective circularity performance analysis of adaptive heritage reuse practices in the Netherlands. *Sustainable Cities and Society*, *70*, 102869.

Persis, D. J., Venkatesh, V. G., Sreedharan, V. R., Shi, Y., & Sankaranarayanan, B. (2021). Modelling and analysing the impact of Circular Economy; Internet of Things and ethical business practices in the VUCA world: Evidence from the food processing industry. *Journal of Cleaner Production*, *301*, 126871.
Cisternas, L. A., Ordóñez, J. I., Jeldres, R. I., & Serna-Guerrero, R. (2021). Toward the Implementation of Circular Economy Strategies: An Overview of the Current Situation in Mineral Processing. *Mineral Processing and Extractive Metallurgy Review*, 1-23.
Narasimmalu, A., & Ramasamy, R. (2020, November). Food Processing Industry Waste and Circular Economy. In *IOP Conference Series: Materials Science and Engineering* (Vol. 955, No. 1, p. 012089). IOP Publishing.
Bressanelli, G., Pigosso, D. C., Saccani, N., & Perona, M. (2021). Enablers, levers and benefits of Circular Economy in the Electrical and Electronic Equipment supply chain: A literature review. *Journal of Cleaner Production*, *298*, 126819.
Gåvertsson, I., Milios, L., & Dalhammar, C. (2020). Quality labelling for re-used ICT equipment to support consumer choice in the circular economy. *Journal of Consumer Policy*, *43*(2), 353-377.
Bressanelli, G., Saccani, N., Perona, M., & Baccanelli, I. (2020). Towards circular economy in the household appliance industry: An overview of cases. *Resources*, *9*(11), 128.
Sarc, R., Curtis, A., Kandlbauer, L., Khodier, K., Lorber, K. E., & Pomberger, R. (2019). Digitalisation and intelligent robotics in value chain of circular economy oriented waste management–A review. *Waste Management*, *95*, 476-492.
Lotz, M. T., Barkhausen, R., Herbst, A., Pfaff, M., Durand, A., & Rehfeldt, M. (2022). Potentials and Prerequisites on the Way to a Circular Economy: A Value Chain Perspective on Batteries and Buildings. *Sustainability*, *14*(2), 956.
Kim, C. H., Kuah, A. T., & Thirumaran, K. (2022). Morphology for Circular Economy Business Models in the Electrical and Electronic Equipment Sector of Singapore and South Korea: Findings, Implications, and Future Agenda. *Sustainable Production and Consumption*.
Osmani, M., Pollard, J., Forde, J., Cole, C., Grubnic, S., Horne, J., & Leroy, P. (2021). Circular economy business model opportunities, challenges, and enablers in the electrical and electronic equipment sector: stakeholders' perspectives.
Ofori, D., & Mensah, A. O. (2021). Sustainable electronic waste management among households: a circular economy perspective from a developing economy. *Management of Environmental Quality: An International Journal*.
Glöser-Chahoud, S., Huster, S., Rosenberg, S., Baazouzi, S., Kiemel, S., Singh, S., ... & Schultmann, F. (2021). Industrial disassembling as a key enabler of circular economy solutions for obsolete electric vehicle battery systems. *Resources, Conservation and Recycling*, *174*, 105735.
Ahuja, J., Dawson, L., & Lee, R. (2020). A circular economy for electric vehicle batteries: driving the change. *Journal of Property, Planning and Environmental Law*.
Alamerew, Y. A., & Brissaud, D. (2020). Modelling reverse supply chain through system dynamics for realizing the transition towards the circular economy: A case study on electric vehicle batteries. *Journal of Cleaner Production*, *254*, 120025.
Boiten, V. J., Han, S. L. C., & Tyler, D. (2017). Circular economy stakeholder perspectives: Textile collection strategies to support material circularity. *European Union's: Brussels, Belgium*.
Mishra, S., Jain, S., & Malhotra, G. (2020). The anatomy of circular economy transition in the fashion industry. *Social Responsibility Journal*.
Hou, E. J., Huang, C. S., Lee, Y. C., & Chu, H. T. (2022). Upcycled aquaculture waste as textile ingredient for promoting circular economy. *Sustainable Materials and Technologies*, *31*, e00336.
Karell, E., & Niinimäki, K. (2019). Addressing the dialogue between design, sorting and recycling in a circular economy. *The Design Journal*, *22*(sup1), 997-1013.
Eurostat (2021). Accesees from the internet on 8th of August https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics#Municipal_waste_treatment
Petris, G.; Petrone, S.; and Campagnoli, P. Dynamic linear models. In Dynamic Linear Models with R. Springer. 2009, New York, NY, 31-84.