Ekonomski signali, 2023, 18 (2): 049-068
UDK: 330.132.014.2
658.5:655.3.066.51
DOI: 10.5937/ekonsig2302049D

SYNERGY BETWEEN THE CIRCULAR ECONOMY AND 3D PRINTING

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Received: 02.10.2023; Accepted: 22.11.2023
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Abstract: The circular economy is the antithesis of the linear economy. Circular products are designed so that they can be easily reused, disassembled, repaired, or recycled. In the 3D printing sector, there are numerous initiatives to develop manufacturing processes where waste is reused and repurposed, thus reducing the environmental impact of additive manufacturing. It is necessary that all actors participating in the design and production process respect the principles of the sustainable production model and the maximization of the efficiency of processes and materials. 3D printing can facilitate circularity at various stages: production, maintenance, reuse, remanufacturing, and recycling. The aim of the paper is to point out the synergy between the circular economy and 3D printing, with a focus on the contributions of 3D printing to the circular economy.

Keywords: circular economy, 3D printing, additive manufacturing, sustainable development

1. Introduction

The circular economy is the antithesis of the linear economy. The main paradigm in the linear economy is take – make/use – dispose. In this way, natural resources are consumed uncontrollably, but huge amounts of hazardous waste are produced. The circular economy model emphasizes the importance of thinking about products, instead of waste, bearing in mind that waste from one industry/enterprise can be considered a valuable raw material for another industry/enterprise. Circular products are designed so that they can be easily reused, disassembled, repaired, or recycled. 3D printing is known as additive manufacturing which involves applying a certain material layer by layer to form a 3D shape or structure. In the first two decades of the 2000s, 3D printing experienced its full bloom, and the growth of the global additive manufacturing market is expected. 3D printing offers great potential for 3D objects production of in various sectors, such as: medicine and dentistry, aerospace, automotive, architecture, art, fashion, etc. 3D printing processes allow customization and personalization of products according to individual customer preferences. 3D printing can contribute to cost savings and reduce the inventory, but also minimize waste. The aim of the paper is to point out the synergy between the circular economy and 3D printing, with a focus on the contributions of 3D printing to the circular economy.

2. Transition from linear to circular economy

The linear model of production is based on the transformation of resources into products and their conversion into waste after use. The main paradigm in "linear economy" is take - make/use – dispose. This means that we don't only consume natural resources uncontrollably, but also, we produce huge amounts of hazardous waste, which nature cannot decompose and absorb (Kowszyk, Maher, 2018). The consequence of such action is the reduction of natural resources, large amounts of waste and environmental pollution. The situation is getting exponentially worse. This is why the linear economy must change (GIZ, 2016). The current policies of many countries, including the European Union, speak in favor of the fact that this model is ecologically, socially, and economically unsustainable in the long term. We are consuming more and much faster than the Earth can regenerate. According to estimates of the Global Footprint

Network, the current model of economic growth, based on the use of natural resources, has put humanity in a position to use as many resources in just seven months as all ecological systems on the planet can renew in a year. In other words, our generation uses the "Earth capital" of future generations. Linearity implies that by 2060 we will need at least two planets to meet all our needs (GIZ, 2016, World Bank, 2022, Stanković et al., 2023).

The circular economy is the antithesis of the previous linear model of the economy. The main goal of the circular economy (CE) is sustainable use of resources and elimination of waste (World Bank, 2022). The circular economy changes business models, habits, and way of thinking, both of producers and consumers, because the new eco-design of the product extends its life through repair, modification, and recycling. All processes take place with the use of renewable energy sources (Ministarstvo zaštite životne sredine Republike Srbije, 2020). The message that this model promotes is: Don't think about the waste, but about the product. The main source of economic growth is the greatest possible reuse of materials from products that have completed their "life cycle" and the least possible use of new resources. Products are designed so that they can be easily reused, disassembled, repaired, or recycled. In the concept of circular economy, waste does not exist, but only raw material that can be reused for the same or other production processes. In the circular economy, the waste of one industry is the raw material of another. According to the Circularity Gap Report, the world is only 9% circular, and that trend is negative (Kowszyk, Maher, 2018).

There is still no single definition of circular economy. According to the European Commission (2015), the circular economy is an economy in which the value of products, materials and resources is maintained in the economy as long as possible by returning them to the production cycle at the end of their use, thereby minimizing the generation of waste. The Ellen MacArthur Foundation 2018) defines the circular economy as a regenerative economy, which relies on systemic innovation and aims to redefine products and services while minimizing negative impacts. The circular economy is an alternative to the traditional linear economy (Figure 1.).

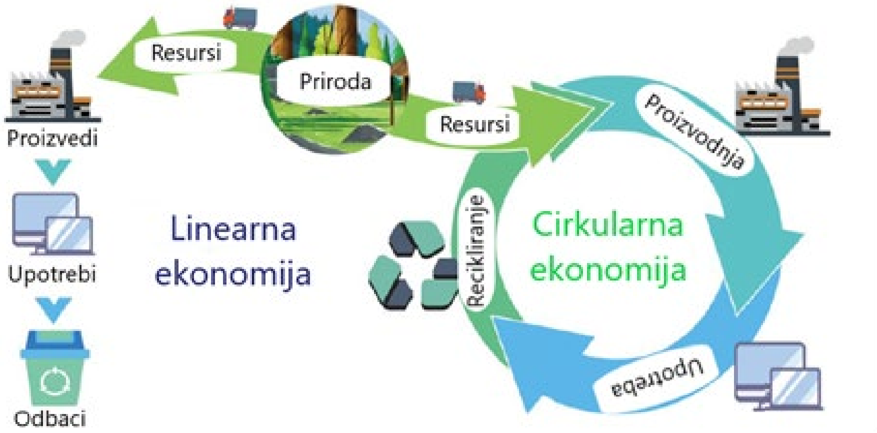

Figure 1: Linear economy and circular economy (Chen, 2022)

The circular economy mainly follows the 3R principle (Reduce, Reuse, Recycle), and its core is maintaining the permanent use of material resources and sustainable development (Dyer et al., 2021). "Reduce" is the first principle of the circular economy. It requires that the production process uses as little raw materials and energy as possible to meet predetermined production goals, reduce resource and energy consumption, and prevent the generation of waste and pollutants. "Reuse" is the second principle of the circular economy. Manufacturers are required to think about durable products during the design and production phase. Reuse can effectively extend product life and encourage the development of a recycling industry for disassembling, repairing, and assembling used and damaged products. "Recycle" is the third principle of the circular economy. It requires that products after disposal can be converted into usable resources and reenter the production process, to reduce the generation of waste and the consumption of natural resources (Luo and Gao, 2015, Chen, 2022, Garrido et al., 2020, Potting et al., 2017, Ekins et al., 2019). Kirchherr, Reike, and Hekkert (2017) extended 3R framework to more extensive frameworks such as the 9Rs hierarchy adopted by the Ellen MacArthur's Foundation: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanifacture, Repurpose, Recycle and Recovery.

In 2015, the United Nations adopted Agenda for Sustainable Development (Agenda 2030) as a universal call to action to end poverty, increase well-being and preserve the planet, ensure peace and prosperity, and solve the problem of climate change in the world by 2030. In 2019, the European Commission presented the "European Green Deal" as the most ambitious package of measures to make Europe the first climate-neutral continent in the world and a world leader in circular economy and clean technologies by 2050. With the Green Agreement, the EU committed itself to meet the goals of the 2030 Agenda and the Paris Agreement from 2015. For Europe by 2030, the potential economic gain from the transition to a circular economy is estimated at 1.8 billion euros (Ministarstvo zaštite životne sredine Republike Srbije, 2020).

There are three major trends which together are the drivers of the circular economy (PWC, 2018):

1. Changing consumer needs

According to Nielsen's 2016 global survey, 39% of respondents were prepared to pay more for products made from environmentally friendly or sustainable materials. Unilever's survey of 2017 reached a similar conclusion: one third of consumers take the brand's environmental and social impact into consideration when making purchasing decisions. Sustainability is especially important for generations Y (20-35 years old) and Z (15-20 years old). They pay closer attention to the environmental performance of companies, both when purchasing products and when choosing an employer.

2. Limited resources

The Earth's resources are only available in limited quantities, and because of the current linear economic model, most of them are used only once. In 2030, according to some forecasts, we will require 35% more food, 40% more water and 50% more energy than we do now. According to the World Economic Forum's survey, more than 20% of companies worry about the shortage of raw materials.

3. Technological drivers

We are currently witnessing the fourth industrial revolution, which is being driven by digitalisation. The fourth industrial revolution supports the circular business models that use renewable energy, in which there is no waste, and where the products of today are also the raw materials of tomorrow.

3. 3D printing tehnology

3D technologies have experienced a great expansion in recent years. The term "3D printing" refers to a wide range of processes and tools that provide opportunities to create components and products from various materials. Fundamentally, the commonality among all these processes and technologies is the way manufacturing takes place in an additive process, layer by layer, as opposed to conventional manufacturing methods, which include material removal methods or molding/casting processes. 3D printing can be defined as structuring of a three-dimensional object in its physical configuration from its digital form, which turns the virtual model into a physical object by successively applying layers of material (The Engineering Projects, 2021, Firtkiadis, 2022, Shahrubudin, 2019, EU, 2021). 3D printing is also known as additive manufacturing which involves applying a specific material layer by layer to form a 3D shape or structure. 3D printing starts with the process of designing the product in digital form using CAD software (Autodex Inventor, SolidWorks, CAtia...) or scanning with a 3D scanner. After approval of the 3D design, the file is translated into STL format. After translating the digital file into STL file format, 3D Slicer starts to configure the whole process, layer by layer and thus forms the G-code that represents the movement of the 3d printer tool. That file is fed into the printer and then printing can begin. Each layer is applied to the other according to 3D printing technology. The process then continues until all layers are formed and the three-dimensional object is complete (Figure 2) (The Engineering Projects, 2021).

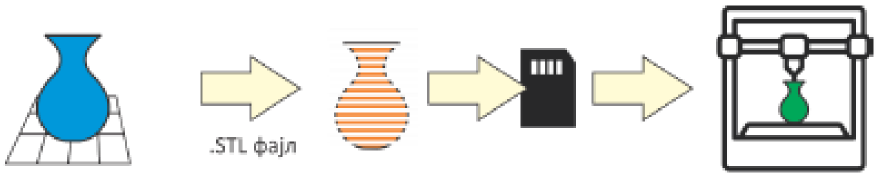

Figure 2.: 3D printing process (The Engineering Projects, 2021)

In the first two decades of the 2000s, 3D printing experienced its full boom and evolution, the process became cost-effective and efficient all thanks to the innovations and materials introduced in the 3D printing industry (The Engineering Projects, 2021). The global additive manufacturing market could reach $34.8 billion by 2026 (Markets and Markets, 2023). According to the EU Digital Education Action Plan (DEAP) 2021-2027, rapid digitization over the past decade has transformed many aspects of work and everyday life. Driven by innovation and technological evolution, digital transformation is reshaping society, the labor market, and the future of work. The use of digital technologies is also key for achieving the goals of the European Green Deal and achieving climate neutrality by 2050. Digital technologies are powerful drivers of the green economic transition, including the transition to a circular economy (EU, 2021).

In the past, 3D printing was used exclusively by large multinational corporations, but now, due to affordability, 3D printers can also be purchased by small and medium-sized businesses. There is a wide range of 3D printers available on the market, with wide variations in price; The Quintessential Universal Building Device is available for less than $200, while MakerBot's Replicator Z18 costs $6,500 (EU, 2021). In this way, 3D printing has become available to many small and medium-sized businesses and individuals. 3D printing has the potential to bring manufacturing closer to the end user/consumer, thereby reducing current supply chain constraints. The flexibility of 3D printing and the possibility of producing small production series at the request of the consumer is a sure way to reduce the accumulation of stocks and produce the number of products that are needed to satisfy the needs of the consumer (3D printing industry, 2023).

3D printing has a lot of advantages over traditional manufacturing methods. Comparing production time, cost and quantity, conventional manufacturing requires longer time in prototyping, but is much faster in producing final products compared to additive manufacturing. Conventional manufacturing requires high initial tool and die costs, but the average cost per product decreases as production volume increases, while additive manufacturing requires low initial setup costs, but the average cost per item remains the same regardless of quantity. As a result, conventional manufacturing is suitable for the mass production of homogeneous products, while additive manufacturing is more suitable for unique, complex, low-volume designs. Moreover, additive manufacturing can produce different components individually and repair small components in a very short time, without having to remake the entire item from scratch. This enables the reduction of material and energy consumption, reducing production time and costs (Wu et al., 2022).

3D printing is very often used for prototyping in the earliest stages of product development to quickly and efficiently reach an optimal solution for production. This saves time and money at the beginning of the whole product development process. 3D printing processes allow customization, personalization of products according to individual needs and requirements. In addition, complex parts and products are easily available through 3D printing technology, while traditional manufacturing methods had many limitations in case of complex and complex designs. A small modification or a major change in the design can be easily done, without disturbing the whole design. Assembly parts produced with the help of 3D printing are lightweight and durable because 3D printing can work with different materials that are more suitable for the manufacturer (The Engineering Projects, 2021). The 3D printing process is extremely cost-effective, cost savings can be achieved by purchasing less material. There is no need to hold large inventories, as as many products as needed can easily be printed according to supply and demand. 3D manufacturing is an additive process, and therefore less waste is produced, as material is added layer by layer successively (3D printing industry, 2023).

3D printers have found their application in many sectors, from building human hearts to building houses. Even NASA has a 3D printer on the International Space Station (EU, 2021). Apart from prototyping, 3D printers offer great potential to produce various 3D objects in different sectors, such as (Shahrubudin, 2019, The Engineering Projects, 2021, 3D printing industry, 2023, EU, 2021, Wu et al., 2022): medicine and dentistry, aviation industry, automotive industry, architecture, art, fashion, etc.

- Medicine. In medicine, 3D printing was adopted relatively early. Medicine represents a sector with enormous potential for growth in the use of 3D technology, due to the ability to customize and personalize technologies and the ability to improve people's lives as processes and materials are improved. In medicine, 3D printing can be used to create prototypes and to support the development of new products. Also, 3D printing finds its application in the production of dental crowns, hip and knee implants, hearing aids, orthotic insoles for shoes, personalized prosthetics and disposable implants for patients suffering from diseases such as osteoarthritis, osteoporosis, and cancer. 3D printed anatomical models allow surgeons to properly understand the internal structure of organs. In addition, 3D anatomical models allow better visualization and help surgeons plan detailed surgical procedures. As a result, clinical efficiency is increased, the risk of surgical errors is reduced, and patient outcomes are improved.

- Aerospace industry. Like the medical sector, the aerospace industry is an early adopter of 3D printing technologies for product development and prototyping. One of the key advantages of 3D printing in the aerospace industry is the production and repair of spare parts. The ability to design and manufacture components directly using CAD greatly benefits the aerospace industry. The possibility of using recycled material as raw material additionally solves the issue of material supply and waste.
- Automotive industry. Many automotive companies are using 3D technologies for prototyping, but they also see the potential of 3D printing to produce spare/replacement parts, on demand, instead of holding huge inventories. For example, the Urbee (Urban Electric with Ethanol) is the first car in the world that was made using 3D printing.
- Architecture. In architecture, 3D printing has been used for a long time as a relatively fast, easy and economically viable method of producing demonstration models of an architect's vision. More recently, some visionary architects are using 3D printing as a direct construction method. In architecture, 3D models of buildings and bridges are also printed for assessment and construction approval.
- Art. There are numerous artists who have now made a name for themselves working specifically with 3D modeling, 3D scanning and 3D printing technologies: Joshua Harker, Jessica Rosenkrantz, Pia Hinze, Nick Ervink, Lionel Dean, and many others. 3D scanning combined with 3D printing brings a new dimension to the art world, considering that

artists now have a proven methodology to reproduce the works of great artists of the past.

- Fashion. Fashion accessories created with 3D printing, including footwear, clothing, and accessories, have hit global catwalks. Some even more visionary fashion designers have demonstrated the possibilities of 3D technology in high fashion. Iris van Herpen deserves a special mention as a leading pioneer in this field, as she has produced a lot of collections that include 3D printed fashion items. Many have followed, and continue to follow, in her footsteps, often with completely original results.

4. Intersection of Circular Economy and 3D Printing

3D printing, also known as additive manufacturing, has become the primary cost-effective method of mass production, rewarding businesses with shortened product development times, reduced start-up costs and profitable returns on investment. Additive manufacturing eliminates material waste by "printing" parts in successive layers, achieving high levels of design complexity that are difficult - and in some cases impossible - with traditional manufacturing processes. The costs of transportation and storage of raw materials and energy consumption have been drastically reduced. The integration of 3D printing with the circular economy, therefore, further contributes to the elimination of the material waste problems that it can cause and reintegrates used products into use. Biomaterials would allow manufactured products to be safely broken down into natural elements and remanufactured without much reduction in physical properties or quality (Rayside et al., 2020).

In the 3D printing sector, various initiatives are currently underway to develop closed manufacturing processes that reuse and repurpose waste materials. Although the development of new environmentally friendly materials and the initiation of various projects that aim to reduce the impact of additive manufacturing on the environment are positive steps, there is still a long way to go before 3D printing becomes a fully circular manufacturing technology. For this to become a reality, it will be necessary for all parties active in the design and manufacturing process and the supply chain to play their part in achieving a model of sustainable production that goes beyond simply maximizing the efficiency of processes and materials (Everett, 2021). Despeisse et al. (2017) points out that the characteristics of 3D printing are well aligned with the principles of sustainability and circularity and hold significant promise for moving society in a more sustainable direction. 3D printing can facilitate circularity at various stages: production, maintenance, reuse, remanufacturing, and recycling. Each stage provides a unique but essential opportunity to reduce waste in terms of materials, energy, and costs. Various approaches are used to maximize the utility of materials, including reuse, repair, renovation, capacity sharing (Kunz et al., 2018).

The choice of materials is the key to achieving circular products. The possibilities for new materials in 3D printing are great and it should be remembered that through the recycling of materials used in 3D printing and reuse, many complex materials can be put back into use (Circular 3D, 2020). Manufacturing errors also occur with additive technologies. All the material that is discarded as scrap can be reused by being crushed, melted, and reshaped into the shape required for the operation of a particular 3D printer. A comparison between the original filament material and the recycled material showed that both filaments are very similar in mechanical properties of the 3D printed samples. This fact promotes further progress in the recycling of 3D printed filament (Mikula et al., 2021; Lanzotti et al., 2019), mainly by obtaining recycled filament from waste and using it to make samples and prototypes. By using recycled materials for 3D printing, material costs, CO2 emissions and energy consumption are reduced (Firtkiadis, 2022).

Additive manufacturing enables the reduction of waste, energy consumption and CO_2 emissions, and the time and costs of product production. In addition, additive manufacturing empowers individual start-up companies and contributes to the creation of new jobs, reducing the unemployment rate. 3D printing machines typically cost around $300 to $1,000, and some websites such as "Repetier.com" provide free CAD software. Considering that additive manufacturing requires a minimum level of skills and capital for production, anyone can start a home business and become a manufacturer. Additive manufacturing can create complex geometric patterns, empowering designers to improvise with unique creations (Wu, 2022). By enabling every user to become a potential manufacturer, 3D technology creates a close link between design, production, and marketing. Goods can reach local customers directly, without sophisticated logistics and transport. Additive manufacturing bypasses the limitations of the traditional supply chain by printing small quantities of products tailored to customers. Its flexibility and agile adaptation to demands creates many advantages that the traditional supply chain does not see, such as customized production, localized production and distribution, short delivery time, low transportation costs and low carbon footprint (Wu, 2022).

3D printing can fit well into the concept of circular economy. The 3D printing production process itself can lead to significant material savings. But 3D printing can also contribute to the maintenance, reuse, remanufacturing, and recycling of products. The aim of the paper is to point out the connection between 3D printing and the circular economy and the significant contributions that 3D printing has to the realization of the principles of the circular economy. A detailed analysis of the available literature was conducted to determine the connection between 3D printing and the circular economy and to identify opportunities for further integration. (Rayside et al., 2020). In Table 1, we indicated how 3D printing could contribute to these elements in the circular economy (van Wijk. & van Wijk., 2015).

Table 1. Contribution of 3D Printing to Circular Economy

Manufacturing	No or less waste in manufacturing processes. Less material used in products designed for 3D printing. Production on customers' demand. Production is local, requiring less transport and logistics. Personalized products that fit your size, preference, or style. Flexible production processes with reduced packaging material and costs. Manufacture of customized and multifunctional products. Bettered response to customer needs. Improved customer-manufacturer relationship through co-creation. Reliance on local materials and bettered control of its quantity and quality. Use of environmental-friendly biomaterials. Reduce material use and improved efficiency of printed products.
Maintenance	Print broken parts on demand, no spare parts necessary. Print broken parts in situ, problem is solved immediately. Print broken parts of any (old) product, lifetime of products is extended. The repair can be done by yourself, any time you want, faster and cheaper. Flexible production processes with reduced packaging material and costs. Reduced packaging costs and value chain autonomous production processes.
Reuse and remanifacture	Products can have a second, third, etc. life by upgrading parts, replacement of old parts and/or re-design or re-styling. Clothes can be adjusted to personal changes like size, shapes, preferences. Furniture can be adjusted to personal circumstances, shapes, preferences. Special elements could be added to the product afterwards. Repurposing of printed parts to extend the use of the product.
Recycle	Recycled materials can be easily used as a resource for 3D printing. Recycling can be done locally and be used locally, with less transport and logistics. Plastics can be remelted at home and directly used again in a 3D printer, without transport and logistics. Re-extrusion of new filament from plastic waste or 3D printing waste.

Source: Van Wijk, Van Wijk., 2015, Dinka, Nyika, 2023, Rayside et al., 2020

For manufacturing companies to remain competitive and profitable, they must demonstrate a commitment to environmental responsibility and sustainability as part of their operations. Products should be designed to last, to be repairable, and at the end of their life cycle, each of their parts can find another use (García-Muiña et al., 2019). This process must start in the product design phase. Rapid prototyping using 3D printing is a design practice that accelerates the design process while reducing product launch times. Additive manufacturing therefore allows designers to carry out rapid design iterations to reduce the waste that occurs in traditional manufacturing. Manufacturing strategies must also be developed to implement the technical features of modularity, disassembly, and repair into products (Despeisse, 2016). To comprehensively mitigate waste problems, circular economy strategies must be applied in all economic sectors, including the manufacturing sector, to extend the life cycle of used raw materials and their waste from production processes. 3D printing technology enables localized and decentralized production and reduces costs associated with inventory. Additive manufacturing can lead to savings in time and money through the production of spare parts by 3D printing (Dinka, Nyika, 2023).

The concept of circular economy pushes the boundaries of ecological sustainability. However, there are challenges in integrating 3D printing and the circular economy. The challenges can be classified into six main categories: technical, organizational, economic, social, legislative, and academic challenges. There is a high level of inter-dependence between these categories, which affects the complexity of the challenges themselves and the complexity of the responses to them. Technical challenges in-clude designing products that can be used for a long period of time, where it is important to ensure that the technologies used in the present are not obsolete soon, and that the importance of recycling is not neglected, that void considers the functional quality of raw materials for 3D printing and by-product toxicities (Hopkinson et al., 2018). Organizational issues such as supply chain restructuring and trade secrets and confidentiality are multisectoral, and it is possible for conflicts to arise due to poorly defined roles and responsibilities and the perception that 3D printing is only for small-batch production rather than mass production (Rayside et al., 2020). The identified economic challenges are closely related to organizational issues, as they were focused on the analysis of production costs, initial invest-ments and maintaining a consistent recycling system. Regarding the social impact of integration, numerous articles have confirmed that it is the most neglected aspect. Legislative challenges vary by country, but those identified relate to the need for laws and standardization in the circular economy, as well as well-defined policies and procedures. Academic challenges include a lack of studies examining the extent to which circular economy implementation strategies are feasible and the contribution that 3D printing has to the circular economy (Nascimento et al., 2018). Lack of education and awareness are also key factors that prevent the improvement of sustainability in production, and therefore it is important to initiate future research on the contribution of 3D printing to the circular economy, at the individual level, at the company level and at the macroeconomic level. It would be beneficial to continue further research on this topic as the world's economies are slowly shifting towards more sustainable practices. To achieve the global goal of environmental sustainability, it is important to integrate the circular economy into individual sectors, including the additive manufacturing industry (Rayside et al., 2020).

5. Conclusion

The integration of 3D printing and the circular economy contributes to the elimination of excessive waste and influences the reuse of recycled materials. Due to its specificity that excess material that is not used during printing can be recycled or reused, 3D printing is a technology that is often associated with the circular economy. In the 3D printing sector, there are numerous initiatives to develop closed manufacturing processes where waste is reused and repurposed, thus reducing the environmental impact of additive manufacturing. For the synergy of 3D printing and the circular economy to be complete, it is necessary that all actors participating in the design and production process respect the principles of the sustainable production model and the maximization of the efficiency of processes and materials. 3D printing can facilitate circularity at various stages: production, maintenance, reuse, remanufacturing, and recycling. In this paper, we pointed out the connection between

3D printing and the circular economy and the significant contributions that 3D printing has to the realization of the principles of the circular economy. For manufacturing companies to remain competitive and profitable, they must demonstrate a commitment to environmental responsibility and sustainability and must think about their products already at the product design stage. Additive manufacturing enables the creation of product prototypes, to think about the implementation of the technical features of modularity, disassembly, and repair in time. Additive manufacturing technology contri-butes to the principles of the circular economy and offers numerous opportunities; enables the use of locally sourced materials, supports on-site recycling through material recovery, remanufactu-ring, and redesign, thereby reducing the amount of waste generated and their resulting impact on the en-vironment. It is extremely impor-tant to further explore the topic of synergy of 3D printing and the circular economy and continue research, bearing in mind the aspi-ration towards the global goal of environmental sustainability.

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SINERGIJA CIRKULARNE EKONOMIJE I 3D ŠTAMPE

Sažetak: Cirkularna ekonomija je antiteza linearnoj ekonomiji. Cirkularni roizvodi su dizajnirani tako da se mogu lako ponovo koristiti, rastavljati, popravljati ili reciklirati. U sektoru 3D štampanja, postoje brojne inicijative za razvoj proizvodnih procesa u kojima se otpad ponovo koristi i prenamenjuje, čime se smanjuje uticaj aditivne proizvodnje na životnu sredinu. Da bi sinergija 3D štampe i cirkularne ekonomije bila potpuna neophodno je da svi akteri koji učestvuju u procesu projektovanja i proizvodnje poštuju principe modela održive proizvodnje i maksimizacije efikasnosti procesa i materijala. 3D štampa može olakšati cirkularnost u različitim fazama; proizvodnja, održavanje, ponovna upotreba, ponovna proizvodnja i recikliranje. Cilj rada je da ukaže na sinergiju između cirkularne ekonomije i 3D štampe, sa fokusom na doprinose 3D štampe cirkularnoj ekonomiji.

Ključne reči: cirkularna ekonomija, 3D štampa, aditivna proizvodnja, održivi razvoj