Applying the Circular Economy Principles in the Wood Construction Industry

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Abstract

The purpose of this paper is to investigate the possibilities of implementing the principles of circular economy in the wood construction industry. The general context of the research is characterized by the new and more demanding challenges regarding the environmental protection issues arising from the current rhythm of development of modern society. One way of responding to these challenges is to transform our consumption society into a more sustainable one. The circular economy has recently become a focal point of European Union policy for transforming production and consumption toward a more sustainable and environmentally friendly direction. The circular economy is mainly related to the use of materials after their life cycle and must be implemented at the design stage of a product or system. However, the meaning and implementation of the concept often remain vague and ambiguous. The construction industry is one of the sectors that use a lot of natural resources, put a lot of pressure on the environment, and generates large amounts of waste. The focus of this research is on wood construction and the possibilities of better use of the potential of wood. Through the implementation of the circular economy principles, wood waste can be used furthermore in the product industry and if further research will be carried out it will bring great benefits to businesses, including economic gains in addition to the environmental ones.

Keywords

Circular economy; construction industry; buildings materials; wood constructions; wood waste; sustainability

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Introduction

In recent years people are more aware of the environmental challenges that limit the continuous process of development in all areas of society. Environmental protection and the issues regarding climate change are one of the challenges that are becoming more and more present in our everyday life. The construction industry is one of the human activities that put a lot of pressure on the environment as it needs to deliver more and better spaces for a growing population. The process of construction also generates pollution and waste all over the world.

The current level of growth for the modern society and the pressure exerted on the environment led to the consideration more and more of the "circular economy" idea and solutions to implement the 3R's (Reduce-Reuse-Recycle) are beginning to take shape. The principles of the circular economy are based on reducing the use of natural resources through efforts to increase efficiency through reuse, reduction, recovery, redesign, and remanufacturing. In this context, the scientific community aims to reach a consensus on the significance of this concept and on the approaches that will allow its successful implementation. The construction industry is adhering to this idea (López Ruiz, Roca Ramón and Gassó Domingo, 2020) and is focusing on developing various solutions to better use the construction and demolition waste. The waste resulting from the construction activity is very diverse and not all the waste can be used for energy production so the focus of this research is on wood waste.

Forests are a huge treasure, as sought after and necessary as other sources of raw materials. Tree trunks and crowns are true accumulators of solar energy and stores of precious organic matter. Wood has been used since the earliest times of human existence, sharing with stone and clay the glory of being born of the first tools, the first homes, and the first means of human defense. Wood is a natural, renewable building material, having inhomogeneous (anisotropic) characteristics, made up of a large number of plant cells organized into specialized tissues, also called anatomical elements, which are very diverse. They differ in their lifetime and tree functions, shape and size, position in the tree, and quantity or number. Many of the cells die during the life of the tree, retaining only the role of ensuring the mechanical strength of the tissues in its composition. How the anatomical elements observable to the naked eye are grouped is called the macroscopic structure. It is important to know it because, depending on its appearance, the various species of wood can be identified, and also the most convenient areas of technological use of wood can be established (Maier, 2021). At this point, it is necessary to point out that all the discussions implying the use of wood are referring to the wood resulting from sustainably managed forests, wood harvested responsibly from the forest where there is continuous replanting, and that the harvest of the wood did not damage the surrounding environment, or to native flora and fauna.

Even if the wood is the most abundant biodegradable and renewable material there is a need to optimize its use. Garcia and Hora (2017) highlight economic, social and environmental issues, such as greenhouse gas emissions and forest threats, which may be effectively combated by increasing the use of wood waste. Wood waste is a mass of wood that cannot be used in a production stage, it can be distinguished according to the location of the waste, the waste from wood harvesting in the forest, and the wood processing waste that is located in the industry. Worldwide, large quantities of wood waste are produced, most of which are not used, and their disposal in landfills creates major environmental problems. The further use of the wood waste besides eliminating the ecological problems has the advantage of dealing with a very low-cost raw material.

The general research question that arises from the described context can be formulated as: *What are the possibilities of implementing the principles of circular economy in the wood construction industry?* To answer this research question, the existing literature was investigated in search of reported practices and the presentation of alternative practices for those less developed areas. The structure of this study is specific to a scientific article. The first part is dedicated to the presentation of the initial considerations around the approached topic. The next part is dedicated to the presentation of a short theoretical context on the circular economy and sustainable development. The next section will present the current context of wood waste research and then present a suggestion for the use of wood waste in the context of the circular economy. The final part of the paper is reserved for conclusions and bibliographic titles used.

1. The research methodology

The research objectives pursued in this paper involve the use of a descriptive analysis of some principal papers published in the field. The literature was interrogated to understand and present the main concepts related the circular economy and sustainable development. For the description of the wood waste context one of the main scientific databases, the Clarivate Web of Science, was interrogated. To better understand the main topics covered in the field of "wood waste" the most important articles that resulted in the interrogation of the Clarivate ISI WoS database was exported and further processed. The analysis of the raw data was performed by exporting the journal articles identified in the scientific database in a plain text file format. The format of the export data file was chosen based on the files supported by the software used. For data processing, the software Bibliometrix was used. This software was developed by Massimo Aria and Corrado Cuccurullo, from the Department of Economics and Statistics, University of Naples Federico II, Italy(Aria and Cuccurullo, 2017).

2. The concepts of circular economy and sustainable development

The sustainable development of modern society implies changes in the way humans relate to the planet. The consumption society where the natural resources are used irresponsible to produce more than we need has negative effects on the environment and solutions to reduce these effects must be developed. In this sense, the concept of circular economy is becoming more and more important.

According to the European Parliament, the circular economy is a model of production and consumption that involves sharing, reusing, repairing, renovating, and recycling existing materials and products as much as possible. The notion of circular economy is based on ideas from scientific and semi-scientific concepts that include industrial symbiosis, cleaner production, and the concept of zero emissions (Korhonen, Honkasalo and Seppala, 2018). According to the Ellen MacArthur Foundation (Macarthur, 2017), the circular economy is based on three principles (Figure no. 1): design out waste and pollution; keep products and materials in use; regenerate natural systems.

Figure no. 1. The circular economy principles
Source: Fernandes, 2020

Although there is no single concept of circular economy, it can broadly be defined as a model in which the value of materials, products, and components remain in the production cycle for as long as possible. Thus, at the end of the life of a product, it can be used repeatedly as a secondary resource, while avoiding and reducing the input of raw materials, materials, energy and minimizing waste generation (Maier et al., 2018). The circular economy has many benefits for both the environment and society. On the one hand, it contributes to reducing waste, increasing resource productivity, and ensuring a more competitive economy, and on the other hand, by significantly reducing waste, it helps to reduce the impact on the environment, production, and consumption, allowing resources to be regenerated. Eco-design and reuse can bring significant savings not only to organizations but also to society, with consumers benefiting from more sustainable and innovative products that will enhance their quality of life and help them save money in the long run.

The term sustainable development designates a way of using resources that allows human needs to be met while protecting the environment so that these needs can be met not only now but also in the future. Thus, in this defined context, it can be stated that the circular economy is an integral part of sustainable development; both policies pursue a common goal, which is to protect the environment.

3. The current context of wood waste research

Lately, there is an increased interest in the research field for developing solutions to protect the environment. In this direction, the subject of using waste generated in the construction industry is becoming more and more important. A search in the primary scientific database Clarivate ISI Web of Science using "wood waste" as search criteria reveals a growing number of papers dealing with this subject in the last years (Figure no. 2). The graph is formed by the number of articles published in journals indexed in the ISI WoS, from the period of 1975 up to 2021.

The graph reveals that in 1975 were published five articles addressed the subject of "wood waste" and since then the number of articles published each year was quite small, a maximum of 10 articles were published in 1979, 13 articles in 1998, and 17 articles in 2004. The interest in this topic increased in 2008 when 26 articles were published. Since then the number of articles continued to grow, reaching 44 articles in 2011, followed by a decrease in the published articles in 2012 and 2013, and starting from 2017 the trend continued to grow, 69 articles in 2018 and reached 109 articles in 2021. Considering the growing interest in subjects related to environmental protection, the number of articles published annually on this topic is expected to continue to grow in the coming years.

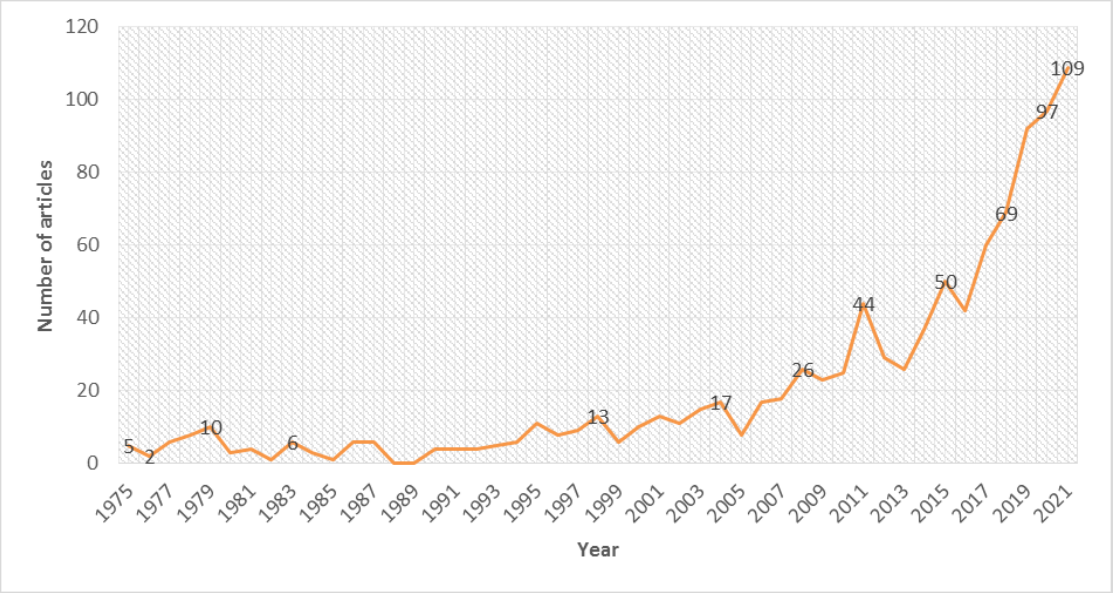

Figure no 2. Evolution of the number of articles published on "wood waste"

With the help of the Bibliometrix software a trend topic plot was generated (Figure no. 3). In the generation of the trend topics were introduced only papers published from 2008 up to 2021. Other graphical parameters refer to the use of the author's keywords field, a minimum word frequency of 5 and the number of words to be considered per year was set to 5. Under these conditions, the main keywords used each year can be seen. The lines represent the years when that word was used, and the time when that word was used most frequently in a year was highlighted by a bubble. The size of the bubbles is the frequency of use for each term, the larger the bubble, the higher the frequency of use.

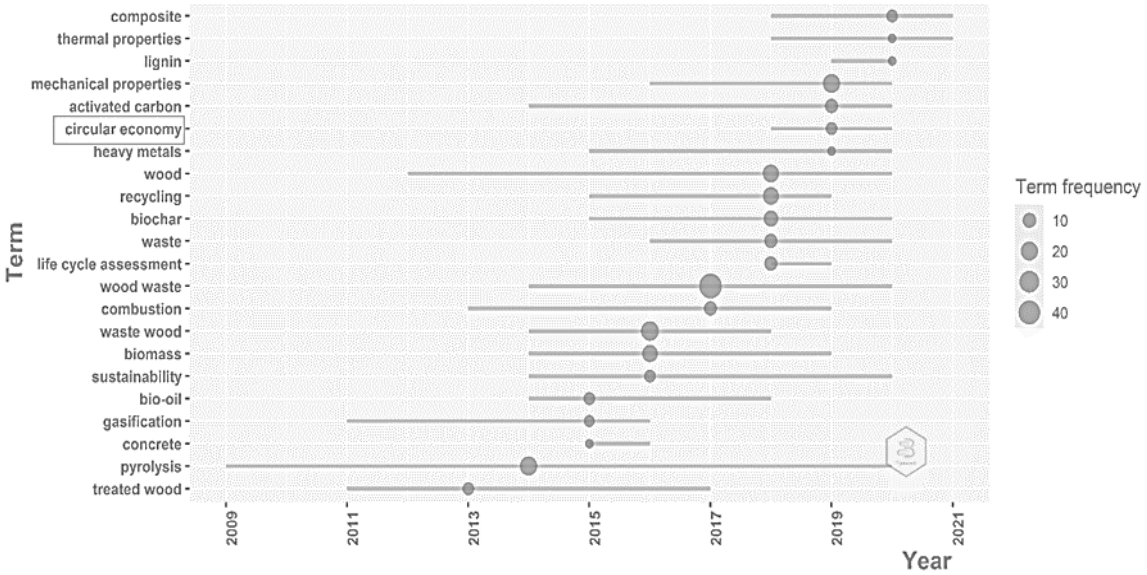

Figure no 3. The trend topic plot for articles dealing with wood waste subject

Analyzing the graph can be observed that in 2013 the most frequent word was "treated wood", then the research evolved and in 2014 "pyrolysis" was explored more, followed by words like "bio-oil", "biomass", "sustainability" or "wood waste". In the last years, words like "recycling", "circular economy", "mechanical proprieties" or "composite" appear. Just by reading these keywords, it can be seen that in the early 2010s the wood waste was analyzed mainly from the combustible point of view, from solutions to generate energy, in the last period, last five years, in the context of rising the challenge of environmental protection, the researchers try to look at the wood waste as solutions to be used in the construction industry as building materials.

The topics covered in the field of wood waste research are focused in several directions and most of them have a general context based on the rapid growth of the population and the need to provide more diverse

living spaces, to ensure more energy to maintain a constant temperature, especially during the cold periods of the year and all of this should be made with proper waste management. From the wood construction point of view, most of the wood waste is disposed of in landfills which creates other problems because the disposal of wood could lead to methane emissions and/or leakage of hazardous constituents that pollute water or soil. Wood waste is a low-cost source of wood biomass (Joshi, Grebner and Khanal, 2015), making it suitable for use in a variety of ways, to reduce environmental impact or to reduce the cost of building elements.

There are multiple possibilities for using waste wood in the composition of several building materials. The most used way is in the composition of wood particle boards. Particleboards can be obtained by using waste wood formwork, as shown in (Hossain et al., 2018) or in (He et al., 2019), and can be transformed into cement-bonded particleboards using MOC (magnesium oxide cement) as a green cement-based binder (Maier and Manea, 2022), so it presents a practical and environmentally friendly option for the management of construction wood waste. Other materials, such as tire fibers or biomass ash, can be added to the mixture of chipboard in addition to wood waste(Amiandamhen et al., 2021).

Another use of wood waste is in the mixture of building materials, such as concrete or mortar. The study of (del Río-Merino et al., 2021) addresses the use of residual aggregates in gypsum mortars. Another way to use wood waste is in the form of ash and then it can be added to the mortar or concrete mixture (Grabowski and Smoliński, 2021). Researchers (Ramos, Matos and Sousa-Coutinho, 2013) state that "wood waste ash appears promising to be used as a partial replacement material for ordinary cement, without loss of strength and leading to increased durability and thus contributing to sustainable construction. In (Ince, Tayançlı and Derogar, 2021) it is demonstrated that "the use of residual wood materials both in the form of wood powder and in the form of wood fibers offers a more environmentally friendly alternative for the recycling of industrial waste compared to existing waste, options management, as well as the saving of natural resources and CO2 emissions necessary for the production of raw materials for the manufacture of cement mortars ". The use of bio-coal as a component in the concrete mix can be another solution and (Sirico et al., 2021) it has been shown that, if used in an optimal percentage, its addition can have a positive effect on concrete and thus help to develop construction material of the circular economy.

The main limitation of this approach is the incompatibility between the cement and the wood. The cement needs a certain humidity to activate and to increase its strength while the wood is acting as absorbance of humidity thus the concrete obtained from this combination can significantly decrease mechanical strength and also a large number of cracks appear on the surface of the elements. A lot of studies show that there is a need for a proper mix of ingredients and finding that ratios still need further investigations. The incompatibility between wood and cement is analyzed and it has been shown that "alkaline hydrolysis is the most effective treatment for the suppression of inhibitory substances and the greatest decrease in the mechanical properties of the resulting composites". There is an obvious need to find an appropriate balance in the composition of wood and cement, which is quite difficult to determine (Quiroga, Marzocchi and Rintoul, 2016). A solution to this problem is proposed by(Caprai et al., 2018) by developing a model for calculating the water absorption of natural fibers (wood wool) and cement from wood-cement composites.

The thermal insulation properties of wood products are another topic addressed in the literature (Cintura et al., 2021) or (Huang and Sun, 2021). In (Chikhi et al., 2013) it is shown that the use in the gypsum mixture of 5% of palm fibers can lead to a composite material with good mechanical and thermal properties. The possibility of using wood waste as a renewable energy resource is another topic addressed in the literature. In (Derčan et al., 2012) and in (Dodić et al., 2012) the importance of a better use of wood biomass both as a renewable energy source and the involvement of the development of the modern way of production and use of wood is studied.

4. Suggestions for the use of wood waste in the context of the circular economy

Nowadays, due to the growing population, the need for shelter is increasing and among the materials that can be used in construction, wood is becoming more and more popular. Because wood resources are depleted and wooden houses can have a long shelf life, there is a multitude of possibilities for using wood waste other than that of a heat generator. Wood waste can be returned to the production process to add value to the composite material, such as becoming wood panels at the end of its life cycle, which aims to bring economic and environmental benefits to the industry instead of being disposed of improperly (Figure no. 4).

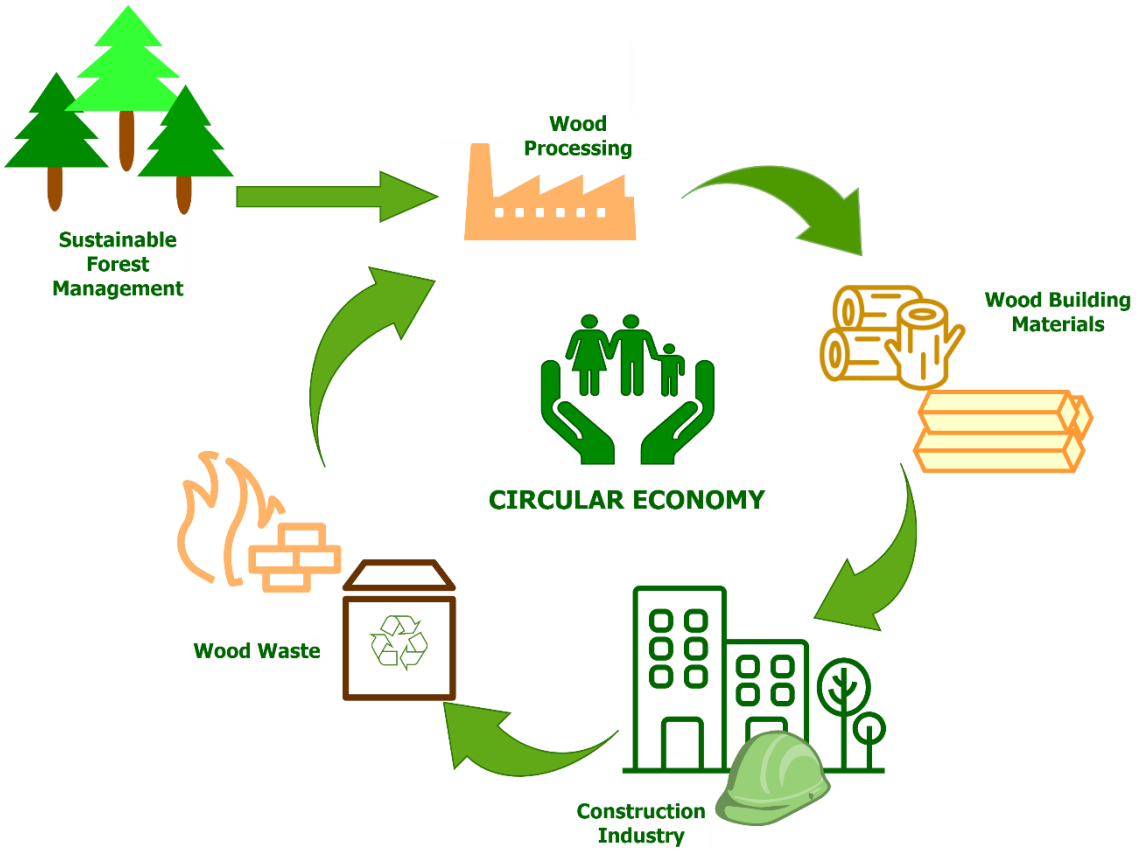

Figure no 4. The circular economy in the field of wooden construction

Large quantities of wood waste are produced throughout the entire cycle of using wood, starting from the harvesting of the wood through sustainable forest management, its cutting in the lumber factories, and later to be used in the production of semi-finished products or the construction of wooden houses. According to the source of waste, the following categories can be observed: from forestry (bark, sawdust, fine wood), from the wood processing industry - from cutting, carpentry, furniture factories, parquet (chips, sawdust, scrap), and scrap (construction wood, railway sleepers, pallets, formwork wood, etc.). The condition of the wood waste can be: natural wood (bark, sawdust), wood residues (resulting from carpentry, construction, planning chips), used wood (beams, windows, pallets), and treated wood railway sleepers.

According to the principles of the linear economy, all this waste is used either as fuel and incinerated or stored in a landfill. According to the new vision, the implementation of the principles of the circular economy involves intervention in the last phase, before incinerating or storing the waste and reusing some of it for repair, reconditioning or recycling, and automatically being reintroduced into the circuit of using wood products or in the production of semi-finished wood products, in the construction of wooden constructions or directly in their use to the final consumer.

From the point of view of construction materials, the best results can be obtained by using wood waste in the production of particleboards. Particleboards can be obtained by using wooden formwork and can be turned into cement-bonded particleboards using MOC (magnesium oxide cement) as a green cement-based binder (Maier and Manea, 2022).

Conclusions

The rapid growth of urbanization and construction increases the demand for cement and aggregates, especially for concrete production. However, the production of cement and concrete increases the emission of carbon dioxide and the source of natural aggregates is depleted. Wood is becoming more and more popular as it is the only sustainable building material and it can decrease the negative impact of the construction activities on the environment. A big challenge in the construction industry is represented by the management of waste generated in various stages of execution. Recycling wood waste can bring multiple benefits to the environment, by decreasing the pressure of cutting trees and reducing the consumption of materials such as water and energy used in manufacturing processes.

Through the implementation of the circular economy principles, wood waste can be used furthermore in the product industry. There are several possible applications of the circular economy in the wood industry, as a result of reuse and recycling of what could be considered waste, by reusing it in the process or even as a raw material for a by-product. The knowledge level in this field is yet in its initial phase as the number of articles dealing with the subject of wood waste has increased only in the last five years. If further research will be carried out, involving the circular economy mainly in the end-of-life phase, as if applied in this industrial field, it will bring great benefits to businesses, including economic gains in addition to the environmental ones. The forest and implicitly the wood is an immense natural treasure and finding ways to better use it, developing solutions for the integral use of the wood from trees, including the remains, surely can lead, not only to the fulfillment of the sustainable development goals but also to better great welfare for all humankind.

Bibliography

Amiandamhen, S.O., Adamopoulos, S., Adl-Zarrabi, B., Yin, H. and Norén, J., 2021. Recycling sawmilling wood chips, biomass combustion residues, and tyre fibres into cement-bonded composites: Properties of composites and life cycle analysis. *Construction and Building Materials*, 297, p.123781. https://doi.org/10.1016/j.conbuildmat.2021.123781.

Aria, M. and Cuccurullo, C., 2017. bibliometrix : An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), pp.959–975. https://doi.org/10.1016/j.joi.2017.08.007.

Caprai, V., Gauvin, F., Schollbach, K. and Brouwers, H.J.H., 2018. Influence of the spruce strands hygroscopic behaviour on the performances of wood-cement composites. *Construction and Building Materials*, 166, pp.522–530. https://doi.org/10.1016/j.conbuildmat.2018.01.162.

Chikhi, M., Agoudjil, B., Boudenne, A. and Gherabli, A., 2013. Experimental investigation of new biocomposite with low cost for thermal insulation. *Energy and Buildings*, 66, pp.267–273. https://doi.org/10.1016/j.enbuild.2013.07.019.

Cintura, E., Nunes, L., Esteves, B. and Faria, P., 2021. Agro-industrial wastes as building insulation materials: A review and challenges for Euro-Mediterranean countries. *Industrial Crops and Products*, 171, p.113833. https://doi.org/10.1016/j.indcrop.2021.113833.

Đerčan, B., Lukić, T., Bubalo-Živković, M., Đurđev, B., Stojsavljević, R. and Pantelić, M., 2012. Possibility of efficient utilization of wood waste as a renewable energy resource in Serbia. *Renewable and Sustainable Energy Reviews*, 16(3), pp.1516–1527. https://doi.org/10.1016/j.rser.2011.10.017.

Dodić, S.N., Vasiljević, T.Z., Marić, R.M., Kosanović, A.J.R., Dodić, J.M. and Popov, S.D., 2012. Possibilities of application of waste wood biomass as an energy source in Vojvodina. *Renewable and Sustainable Energy Reviews*, 16(5), pp.2355–2360. https://doi.org/10.1016/j.rser.2012.01.079.

Fernandes, P., 2020. *Circular Economy As A Way Of Increasing Efficiency In Organizations - The Porto Protocol*. [online] Available at: <https://www.portoprotocol.com/circular-economy-as-a-way-of-increasing-efficiency-in-organizations/> [Accessed 20 April 2022].

Garcia, C.A. and Hora, G., 2017. State-of-the-art of waste wood supply chain in Germany and selected European countries. *Waste Management*, 70, pp.189–197. doi: 10.1016/j.wasman.2017.09.025.

Grabowski, J. and Smoliński, A., 2021. The application of hierarchical clustering to analyzing ashes from the combustion of wood pellets mixed with waste materials. *Environmental Pollution*, 276, p.116766. https://doi.org/10.1016/j.envpol.2021.116766.

He, P., Hossain, Md.U., Poon, C.S. and Tsang, D.C.W., 2019. Mechanical, durability and environmental aspects of magnesium oxychloride cement boards incorporating waste wood. *Journal of Cleaner Production*, 207, pp.391–399. https://doi.org/10.1016/j.jclepro.2018.10.015.

Hossain, M.U., Wang, L., Yu, I.K.M., Tsang, D.C.W. and Poon, C.-S., 2018. Environmental and technical feasibility study of upcycling wood waste into cement-bonded particleboard. *Construction and Building Materials*, 173, pp.474–480. https://doi.org/10.1016/j.conbuildmat.2018.04.066.

Huang, Z. and Sun, Y., 2021. Hygrothermal performance comparison study on bamboo and timber construction in Asia-Pacific bamboo areas. *Construction and Building Materials*, 271, p.121602. doi: 10.1016/j.conbuildmat.2020.121602.

Ince, C., Tayançlı, S. and Derogar, S., 2021. Recycling waste wood in cement mortars towards the regeneration of sustainable environment. *Construction and Building Materials*, 299, p.123891. doi: 10.1016/j.conbuildmat.2021.123891.

Joshi, O., Grebner, D.L. and Khanal, P.N., 2015. Status of urban wood-waste and their potential use for sustainable bioenergy use in Mississippi. *Resources, Conservation and Recycling*, 102, pp.20–26. doi: 10.1016/j.resconrec.2015.06.010.

Korhonen, J., Honkasalo, A. and Seppala, J., 2018. Circular Economy: The Concept and its Limitations. *Ecological Economics*, 143, pp.37–46. doi: 10.1016/j.ecolecon.2017.06.041.

López Ruiz, L.A., Roca Ramón, X. and Gassó Domingo, S., 2020. The circular economy in the construction and demolition waste sector – A review and an integrative model approach. *Journal of Cleaner Production*, 248, p.119238. doi: 10.1016/j.jclepro.2019.119238.

Macarthur, E., 2017. What is a Circular Economy? | Ellen MacArthur Foundation. *Ellen Macarthur Foundation*, [online] Available at: <https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview> [Accessed 19 April 2022].

Maier, A. and Manea, D.L., 2022. Perspective of Using Magnesium Oxychloride Cement (MOC) and Wood as a Composite Building Material: A Bibliometric Literature Review. *Materials*, 15(5), p.1772. doi: 10.3390/MA15051772.

Maier, D., Surugiu, I, Bumbac, R., and Maier, A., 2018. *Means of economic growth through innovation*, In: R. Pamfilie, V. Dinu, C. Vasiliu, D. Pleșea, L. Tăchiciu eds. 2018. 8th BASIQ International Conference on New Trends in Sustainable Business and Consumption. Heidelberg, Germany, 11-13 June 2018. Bucharest: ASE, pp. 793-799.

Maier, D., 2021. Building Materials Made of Wood Waste a Solution to Achieve the Sustainable Development Goals. *Materials*, 14(24), p.7638. doi: 10.3390/ma14247638.

Quiroga, A., Marzocchi, V. and Rintoul, I., 2016. Influence of wood treatments on mechanical properties of wood-cement composites and of Populus Euroamericana wood fibers. *Composites Part B: Engineering*, 84, pp.25–32. doi: 10.1016/j.compositesb.2015.08.069.

Ramos, T., Matos, A.M. and Sousa-Coutinho, J., 2013. Mortar with wood waste ash: Mechanical strength carbonation resistance and ASR expansion. *Construction and Building Materials*, 49, pp.343–351. doi: 10.1016/j.conbuildmat.2013.08.026.

Del Río-Merino, M., Vidales-Barriguete, A., Piña-Ramírez, C., Vitiello, V., Santa Cruz-Astorqui, J. and Castelluccio, R., 2022. A review of the research about gypsum mortars with waste aggregates. *Journal of Building Engineering*, 45, p.103338. https://doi.org/10.1016/j.jobe.2021.103338.

Sirico, A., Bernardi, P., Sciancalepore, C., Vecchi, F., Malcevschi, A., Belletti, B. and Milanese, D., 2021. Biochar from wood waste as additive for structural concrete. *Construction and Building Materials*, 303, p.124500. https://doi.org/10.1016/j.conbuildmat.2021.124500.

You Matter, 2020. *Circular Economy: Definition, Principles, Benefits and Barriers*, *You Matter*, [online] Available at: <https://youmatter.world/en/definition/definitions-circular-economy-meaning-definition-benefits-barriers/> [Accessed 19 April 2022].