Review of Management and Economic Engineering
Vol. 22, No. 2(88), June 2023, p. 104 - 109, ISSN (print): 1583-624X, ISSN (online): 2360-2155

CIRCULARITY PRACTICES RELATED TO THE RECYCLING OF WOOD WASTE FROM INDUSTRIAL PROCESSES: A SYSTEMATIC REVIEW OF THE LITERATURE

Geanina-Maria DAVID[1], Roxana-Maria DRUȚĂ[1], Ligia-Maria NAN[1], Laura BACALI [2]

1 *Institute for Research in Circular Economy and Environment "Ernest Lupan", geanina.david@ircem.ro; roxana.druta@ircem.ro; ligia.nan@ircem.ro;*
2 *Engineering and Management Department, Faculty of Industrial Engineering, Robotics and Production Management, Technical University of Cluj-Napoca, laura.bacali@mis.utcluj.ro;*
* *Correspondence: geanina.david@ircem.ro*

Abstract: Globally, a major shift is taking place to ensure sustainable development in the reuse and reduction of wood waste. The aim of this paper is to present a series of circularity practices on the recycling stage of wood waste from industrial processes. The environmental impact due to improper storage of wood waste mainly from the construction and related industries, demolition and renovation is global warming; due to greenhouse gas emissions from deforestation for the production of processed wood for this industry. Thus, the focus is on the low recovery rate of wood from the disposal phase. This review was drawn from a total of 94 articles that we analyzed from a database of selected keywords "circular economy", "recycling", "wood".

Keywords: circular economy, recycling, wood, sustainability.

1 INTRODUCTION

A key contribution to the EU's efforts to develop a sustainable and resource-efficient economy is the transition to a more circular economy, where the value of products, materials and resources is kept in the economy for as long as possible and waste is being reduced to at least the lower limit. This change is an opportunity to transform our economy and generate new sustainable interests in Europe (COM (2015) 614).

The definition of the circular economy in the vision of the Ellen MacArthur Foundation (EMF) describes "An industrial economy that is restorative and renewable by intention and design" (MacArthur, E., 2013). "The use of the word 'restoration' is important because the circular economy is not only a preventive approach, reducing pollution, but also aims to repair previous damage by designing better systems within the industry entity itself" (Murray, Skene and Haynes, 2017).

Due to urban population growth, which has been a major factor influencing economic growth, there have been significant developments in the construction industry. Thus, due to the rapid development of the construction sector, considerable amounts of waste have been generated as a result of construction or demolition, often making waste management systems inefficient. In order to achieve a sustainable future, it is necessary to assess the quantities of waste generated and establish strategies for reuse and recycling.

This article outlines the idea of circularity as the basis for sustainable resource management, with the aim of minimizing the generation of wood waste. The idea of a more sustainable future for the construction industry, as it is the main source of the largest fraction of wood waste, must be founded from the design stage, thinking about strategies to use sustainable materials or materials that over time have the ability to be reused and recycled.

2 THE CURRENT STATE OF THE LITERATURE

2.1 Basic concepts of wood waste recycling

Waste management refers to training in the collection, transportation, treatment, recycling and disposal of waste. The term refers to materials created by human activity that reduce their impact on the environment, human health, or the appearance of a habitat. Waste management also emphasizes the conservation of natural resources by reusing recyclable parts. Waste can be solid, liquid or gaseous and can have certain properties (such as radioactivity), each property having a specific disposal method.

A circular economy must promote the cascading use of resources that are renewable, so that reuse and recycling are done as often as needed. Biomaterials such as wood can be used in different ways, with the reuse and recycling process occurring several times. This technique involves applying a waste hierarchy to achieve the best overall environmental result. National measures such as increased producer responsibility for wooden furniture, wooden packaging as well as separate collection of wood can have a positive impact. Efforts are being made to continue to find and share best practice in this area. The revised waste legislative proposal also includes a mandatory EU (European Union)-wide target for the recycling of wood packaging waste [COM(2015) 614].

2.2 Peculiarities of wood waste recycling

Wood recycling has many advantages and, in addition, it is one of the simplest recycling processes, as it is a physical process that does not require the introduction of chemicals that would involve environmental contamination. Wood waste can be represented by wooden panels, crates, wooden boxes, pallets, even sawdust or other such items. Given the fact that they are not as common as those from other materials, such as glass or aluminum waste, this type of recycling is not talked about as much. However, there are many companies that produce such waste. A large amount of wood waste is generated from construction and demolition, mostly stored, contributing to serious effects on the environment. Managing this type of waste is a big challenge because is a hazardous contaminated waste. Thus a hazardous contaminated waste. There is much research on end-of-life management in the literature, but research on CE (Circular economy) implementation considering each stage of life cycle is still short. Therefore, we do our best to include CE (Circular economy) to find out waste management techniques in life cycle levels (Maria, G.M., et al., 2021). As such, it encourages waste management to promote CE and sustainability by promoting the use of recycled wood for more valuable products. (Jahan, I., et al., 2022). The first thing that is done when wooden objects arrive at a recycling station is to separate

them properly. Remove screws, hinges, melamine sheets or any other non-wooden element. Then, when the wood is separated, it is crushed to produce sawdust or wood chips, the raw material for other wood products. Later, this sawdust or shavings are mixed with glues or resins (natural or synthetic) and the wood is shaped. Finally, wood chips are made into chipboard that can be used for a multitude of functions, from industrial products to furniture making, among many others.

2.3 National and European legislation on wood waste recycling

Correlated with the amount of waste generated, the waste from the wood processing industry and from the chemical, metallurgical and steel sector has the largest share of the total recovered waste. In the case of the wood processing industry, the amount of waste recovered in 2014 is over 40% higher than the amount generated. The biggest difference between the amount recovered and the amount generated is recorded in the case of the primary processing of wood (amount collected is at least 2.8 times the amount generated). The amount of recycled waste much higher than the amount generated in the case of wood processing waste is recorded throughout the analysis period (2010-2014). (National Waste Management Plan (PNG, 2017).

The European Framework for a Circular Economy an ambitious circular economy action plan has been adopted at EU (European Union) level since 2015. It aims to facilitate the transition to a competitive circular economy to accelerate sustainable economic growth and job creation at work. This approach is known as the Circular Economy Package (II) and consists of a series of legislative proposals and detailed action plans adopted in 2019. The proposed concept of circularity is closely related to the efficient use of natural resources at system level on entire lifetime. of the product. An important aspect in promoting circularity and adding value to new waste disposal products on the domestic market. In addition, COM (2015) included for the first time a definition of the circular economy as an economy where "the value of products, materials and resources is kept in the economy for as long as possible and the generation of waste is minimized". (Directives 2008/98/EC; Gálvez-Martos at al., 2018).

3 METHODOLOGY

The objective of this study is to analyze the most important papers in the WOS (Web of Science) database, looking for indicators and categories that can help understand the current state of the academic world. From 2009 to 2022, the database was searched and analyzed using Web of Science database. Following the search, 94 articles were selected and then the life cycle stages were analyzed. This analysis shows us that CE is needed for wood waste with great growth potential.

The first step was to search for keywords to select only relevant research papers for this study. The following keywords were used in the search: circular economy, recycling, wood, sustainability. After selecting the works that have fulfilled criteria imposed by us, we created a database and organized them according to the topic addressed. Of course, the classification it was done according to the year in which it was published (2009-2021), journal name, subject (main research objective), and results to have a more complete picture of it being easier for them to identify the information.

4 RESULTS

The main features of the literature studies are annotated with keywords, which help to reveal the evolution of research trends over time. Chronologically similar keywords used were found from 2009 to 2022. Therefore, the hot topics in the research of CIRCULARITY

PRACTICES RELATED TO RECYCLING WOOD WASTE FROM INDUSTRIAL PROCESSES are: circular economy, environmental impact and wood waste.

Between 2009 and 2022, wood research begins to transform waste into energy through the production of biofuels and bioenergy, thus the transition from a linear economy to a circular one as a research trend in recycling, and the reuse of wood has been emphasized in recent years (Corona, B ., et al, 2019; Risse, M., et al, 2019), thus chemical analysis of wood treated for decontamination (Janin, A. et al.) and life cycle analysis to reduce environmental impact have become the focus of research (Hossain, M.U. et al., 2017; Hossain, M.U. et al., 2018); Hussein, MU; Wang, L.).

Recent literature focuses on the production of activated carbon from wood waste (Heidari, A., et al, 2019). Investigations into recycling, reuse, processing and activated carbon production of wood products from recycled plywood, glue-laminated wood and activated carbon production were observed and documented. (Kim, M.H., et al., 2018; Kim, M.H., et al., 2014; Heidari, A., et al., 2019; Silva, D.A.L., et al., 2018). LCA (Life cycle analysis) methodology was used to determine energy demand and ecological footprint.

A methodology was used by LCA to compare the potential environmental impacts of the production of bio-oil and activated carbon from eucalyptus wood waste, in terms of energy demand and ecological footprint. LCA's study found that producing activated carbon from 1 ton of wood waste could reduce GWP (Global Warming Potential) by 163 kg CO^2 equivalent, compared to the same amount being stored. In the specialized literature, chipboard manufacturing is the most popular practice for wood waste recycling. They used 26 articles to analyze the environmental benefits of producing activated carbon from wood waste compared to landfill disposal. Numerous LCA studies have been conducted on the environmental perspective of PAL production (Rosa Azambuja, R., et al, 2018; Merrild, H., et al., 2009; Rivela, B., et al., 2006).

Rivela et al., 2006 (Rivela, B., et al, 2006) indicated that in the production of PAL the recycling of wooden structures is beneficial for the environment, energy generation being in total opposition. Another study shows that medium density chipboard can be produced from wood waste from demolitions, this study was conducted by (Azambuja, R.D.R., et al, 2018).

Other similar conclusions were reached by Merrild and Christensen (2009) and Kim and Song (2014) for the use of recycled wood. Another study was conducted by Faraca, Astrup and Tonini in 2019 (Faraca, G., et al, 2019), using post-consumer wood waste to produce wood chips that can be used in panels based on wood, so they demonstrated that this waste can be used 100%, contributing to the practice of the circular economy with the help of the manufacture of agglomerated boards so that they are no longer thrown into landfills by Hossain et al., 2018 (Hossain, M.U., et al., 2018; Ulubeyli et al., 2017).

5 CONCLUSIONS

Circular economy methods for reducing, reusing and recycling wood waste are described in the literature. Reducing waste during the design and planning stages is critical to minimizing the waste that is generated. Material recycling is estimated for the cascading use of wood waste. There is an urgent need to develop a secondary market for wood waste from recycled construction and demolition materials, as economics play an important role in improving the market for secondary materials in the construction industry.

A significant proportion of the wood waste stream results from construction and demolition, which is pre-treated to remove impurities (Farsi, M., 2010). After that, a suitable recycling process is selected to develop new

materials. For wood left over from construction and demolition, recycling methods are ineffective, leading to the illegal disposal of huge amounts of wood waste in landfills without environmental protection (Esa, M.R., et al., 2017). Due to the few studies that propose cost-effective decontamination of treated wood waste to be implemented on an industrial scale, engineered wood products are a major contributor to the amount of waste in the construction and demolition wood waste stream (Ximenes, F.A., et al 2018) .

Thus the most considerable environmental effect is global warming, and to reduce the burden on the environment, it is important to manage the wood waste left over from construction and demolition and to improve the recycling rate. Circular economy is an appropriate solution that includes environmental benefits and socio-economic opportunities in an integrated manner. There are various types of literature on the treatment of wood-containing waste, but the implementation of a circular economy at each stage of the life cycle is limited. Finally, there are six stages of the wood waste life cycle; extraction, preparation, exploitation and construction, demolition, end of life.

The circular economy for wood waste is developing, this fact emerges from this literature review, thus noting that the recycling of wood waste brings environmental benefits, social benefits and economic benefits. However, new materials from wood waste need more practical implications. To minimize the generation of wood waste it is essential to follow waste management practices at all stages of the life cycle to implement the circular economy. the main recommendation being: demolition projects generate large amounts of wood waste, so prior audits for waste reuse, selective demolition and source separation of treated or untreated wood waste emphasize waste recovery and utilization processes.

Further research is essential to integrate aspects of construction and demolition wood waste management (collection, sorting, separation) and disposal scenarios. To implement a circular economy, the construction industry must take action and value the reuse, recycling and wood waste.

BIBLIOGRAPHY

Azambuja, D.R.R.; de Castro, V.G.; Trianoski, R.; Iwakiri, S. Utilization of construction and demolition waste for particleboard production. J. Build. Eng. 2018, 20, 488–492. [CrossRef]

Corona, B.; Shen, L.; Sommersacher, P.; Junginger, M. Consequential Life Cycle Assessment of energy generation from waste wood and forest residues: The effect of resource-efficient additives. J. Clean. Prod. 2020, 259, 120948. [CrossRef]

Esa, M.R.; Halog, A.; Rigamonti, L. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. J. Mater. Cycles Waste Manag. 2017, 19, 1144–1154. [CrossRef]

Farsi, M. composites, Wood-plastic composites: Influence of wood flour chemical modification on the mechanical performance. J. Reinf. plastic Composed. 2010, 29, 3587–3592. [CrossRef]

Gálvez-Martos, J.-L.; Styles, D.; Schoenberger, H.; Zeschmar-Lahl, B. Construction and demolition waste best management practice in Europe. Resour. preserved Recycle 2018, 136, 166–178

Heidari, A.; Khaki, E.; Younesi, H.; Lu, H.R. Evaluation of fast and slow pyrolysis methods for bio-oil and activated carbon production from eucalyptus wastes using a life cycle assessment approach. J. Clean. Prod. 2019, 241, 118394. [CrossRef]

Hossain, M.U.; Poon, C.S.; Lo, I.M.; Cheng, J.C. Comparative LCA on using waste materials in the cement industry: A Hong Kong case study. Resour. preserved Recycle 2017, 120, 199–208. [CrossRef]

Hossain, M.U.; Wang, L.; Iris, K.M.; Tsang, D.C.; Poon, C.S. Environmental and technical feasibility

study of upcycling wood waste into cement-bonded particleboard. Construction Build. Mater. 2018, 173, 474–480. [CrossRef]

Huang, B.; Wang, X.; Kua, H.; Geng, Y.; Bleischwitz, R.; Ren, J. Construction and demolition waste management in China through the 3R principle. Resour. preserved Recycle 2018, 129, 36–44.

Ihnat, V., Lübke, H., Balbercak, J., & Kuna, V. (2020). Size reduction downcycling of waste wood. Review. Wood Res, 65, 205-220.

Jahan, I., Zhang, G., Bhuiyan, M., & Navaratnam, S. (2022). Circular Economy of Construction and Demolition Wood Waste—A Theoretical Framework Approach. Sustainability, 14(17), 10478.

Janin, A.; Blais, J.-F.; Mercier, G.; Drogui, P. Optimization of a chemical leaching process for decontamination of CCA-treated wood. J. Hazard. Mater. 2009, 169, 136–145. [CrossRef]

Kim, M.H.; Jeong, I.T.; Park, S.B.; Kim, J.W. Analysis of environmental impact of activated carbon production from wood waste. Environment. Eng. Res. 2018, 24, 117–126. [CrossRef]

Kim, M.H.; Song, H.B. Analysis of the global warming potential for wood waste recycling systems. J. Clean. Prod. 2014, 69, 199–207. [CrossRef]

MacArthur, E. (2013). Towards the Circular Economy: Opportunities for the consumer goods sector. Ellen MacArthur Foundation.

Maria, G. M., DRUTA, R. M., BIRGOVAN, A. L., BACALI, L., & LUNGU, F. (2021). INDUSTRY 4.0 AND THE CIRCULAR ECONOMY: A SYSTEMATIC REVIEW OF THE LITERATURE. *ACTA TECHNICA NAPOCENSIS-Series: APPLIED MATHEMATICS, MECHANICS, and ENGINEERING*, *64*(4s).

Merrild, H.; Christensen, T.H. Recycling of wood for particle board production: Accounting of greenhouse gases and global warming contributions. Waste Manag. Res. 2009, 27, 781–788. [CrossRef]

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. Journal of Business Ethics, 140(3), 369-380.

Risse, M.; Weber-Blaschke, G.; Richter, K. Richter, Eco-efficiency analysis of recycling recovered solid wood from construction into laminated timber products. Sci. Total Environ. 2019, 661, 107–119. [CrossRef]

Rivela, B.; Moreira, M.T.; Muñoz, I.; Rieradevall, J.; Feijoo, G. Life cycle assessment of wood wastes: A case study of ephemeral architecture. Sci. Total Environ. 2006, 357, 1–11. [CrossRef]

Rosa Azambuja, R.; de Castro, V.G.; Trianoski, R.; Iwakiri, S. Recycling wood waste from construction and demolition to produce particleboards. Maderas. Cienc. Tech. 2018, 20, 681–690. [CrossRef]

Silva, D. A. L., de Oliveira, J. A., Filleti, R. A. P., de Oliveira, J. F. G., da Silva, E. J., & Ometto, A. R. (2018). Life Cycle Assessment in automotive sector: A case study for engine valves towards cleaner production. *Journal of Cleaner Production*, *184*, 286-300.

Ulubeyli, S.; Kazaz, A.; Arslan, V. Construction and Demolition Waste Recycling Plants Revisited: Management Issues. Proceeding Eng. 2017, 172, 1190–1197. [CrossRef]

Ximenes, F.A.; Cowie, A.L.; Barlaz, M.A. The decay of engineered wood products and paper excavated from landfills in Australia. Waste Manag. 2018, 74, 312–322. [CrossRef]

Zheng, L.; Wu, H.; Zhang, H.; Duan, H.; Wang, J.; Jiang, W.; Dong, B.; Liu, G.; Zuo, J.; Song, Q. Characterizing the generation and flows of construction and demolition waste in China. Construction Build. Mater. 2017, 136, 405–413. [CrossRef]

*** DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

*** (PNG, 2017) National Waste Management Plan Quantity (tons/year) PNGD_vers5.pdf (mmediu.ro)