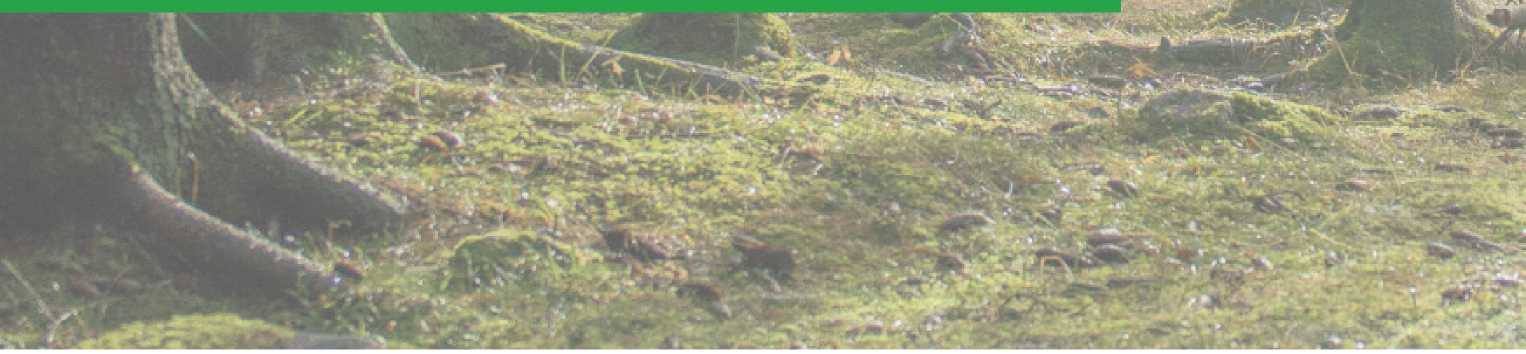
PROCEEDINGS OF SCIENTIFIC PAPERS

CURRENT TRENDS AND CHALLENGES FOR FOREST-BASED SECTOR:

CARBON NEUTRALITY AND BIOECONOMY

Prague, Czech Republic,
June 14th-16th, 2023



Faculty of Forestry
and Wood Sciences

WoodEMA, i.a. – International
Association for Economics
and Management in Wood Processing
and Furniture Manufacturing

FOREST
BIOECONOMY
TEAM

WoodEMA i.a. – International Association for Economics, Management, Marketing, Quality and Human Resources in Forestry and Forest Based Industry

Faculty of Forestry and Wood Sciences

Czech University of Life Sciences Prague
Faculty of Forestry and Wood Sciences

FOREST BIOECONOMY TEAM

CURRENT TRENDS AND CHALLENGES FOR FOREST-BASED SECTOR: CARBON NEUTRALITY AND BIOECONOMY

Proceedings of Scientific Papers

Prague, Czech Republic

June 14th-16th, 2023

CURRENT TRENDS AND CHALLENGES FOR FOREST-BASED SECTOR:
CARBON NEUTRALITY AND BIOECONOMY

Proceedings of Scientific Papers

Publisher: **WoodEMA, i.a. – International Association for Economics, Management, Marketing, Quality and Human Resources in Forestry and Forest Based Industry**
Savska cesta 50, Zagreb, Croatia

Czech University of Life Sciences Prague
Kamýcká 129, 165 00 Praha 6 – Suchdol, Czech Republic

Editor-in-chief: **Assoc. prof. Roman Dudík, Ph.D.**

Print: **powerprint s.r.o.**

Edition: **150 copies**

ISBN: **978-953-8446-01-6**

Preface

The Czech University of Life Sciences in Prague, the Faculty of Forestry and Wood Sciences is honoured to organise the 16th annual international scientific conference held in Prague, June 14th-16th, 2023, under the auspices of WoodEMA, i.a. The aim of the conference is to transfer knowledge and experience from the field of economics and management of the forest-based sector in the spirit of the conference title: Current Trends and Challenges for Forest-Based Sector: Carbon Neutrality and Bioeconomy.

The conference proceedings fully support the above mentioned aim. Moreover, it includes 55 quality articles containing the results of the applications of the newest methods and approaches. Authors come from 11 different countries, including South America, which highlights the international dimension of cooperation of researchers under WoodEMA, i.a.

We believe that the outcomes of this conference including the proceedings will help to support and evolve the interest of published topics in the future.

Editors

List of authors:

Alan ANTONOVIĆ (HRV)
Diyana BANKOVA (BGR)
Martina BASARAC SERTIĆ (HRV)
Karlo BELJAN (HRV)
Ružica BELJO LUČIĆ (HRV)
Dimitar BLAGOEV (BGR)
Dominika BÚRYOVÁ (SVK)
Ibrahim BUSULADZIC (BIH)
Rastislav ČEREŠŇA (SVK)
Tatiana ČOREJOVÁ (SVK)
Petar ĆURIĆ (HRV)
Yana DONEVA (BGR)
Roman DUDÍK (CZE)
Michal DZIAN (SVK)
Miloš GEJDOŠ (SVK)
Pavol GEJDOŠ (SVK)
Daniela Ventsislavova GEORGIEVA (BGR)
Tanya GEORGIEVA (BGR)
Branko GLAVONJIĆ (SRB)
Luka GOROPEČNIK (SVN)
Emilia GRZEGORZEWSKA (POL)
Seid HAJDAREVIC (BIH)
Miroslav HÁJEK (CZE)
Eva HAVIAROVA (SVK)
Antonijo HERCEG (HRV)
Diana Carolina HUERTAS-BERNAL (COL)
Daniela HUPKOVÁ (SVK)
Alen IBRISEVIC (BIH)
Josip IŠTVANIĆ (HRV)
Pavlina IVANOVA (BGR)
Denis JELAČIĆ (HRV)
Matej JOŠT (SVN)
Miljan KALEM (SRB)
Martina KÁNOVÁ (SVK)
Vladislav KAPUTA (SVK)
Mirko KARIŽ (SVN)
Damyan KIRECHEV (BGR)
Manja KITEK KUZMAN (SVN)
Kristina KLARIĆ (HRV)
Ljudmila KOPRIVEC (SVN)
Jože KROPIVŠEK (SVN)
Tajana KRUHAK (HRV)
Władysław KUSIAK (POL)
Aleksandra LAZAREVIĆ (SRB)
Petra LESNÍKOVÁ (SVK)
Erika LOUČANOVÁ (SVK)
Petar MARINOV (BGR)
Velichka MARINOVA (BGR)
Živka MELOSKA (MKD)
Goran MIHULJA (HRV)
Katarína MICHAJLOVÁ (SVK)
Maja MORO (HRV)
Darko MOTIK (HRV)
Renata NOVÁKOVÁ (SVK)
Martina NOSÁĽOVÁ (SVK)
Leon OBLAK (SVN)
Jelena OBRANKOVIĆ (HRV)
Murčo OBUĆINA (BIH)
Miriam OLŠIAKOVÁ (SVK)
Mária OSVALDOVÁ (SVK)
Petra PALÁTOVÁ (CZE)
Hubert PALUŠ (SVK)

Antonijo PAPAK (HRV)
Ján PAROBEK (SVK)
Alena PAULIKOVÁ (SVK)
Petra PEJIĆ (HRV)
Ivana PERIĆ (HRV)
Slavica PETROVIĆ (SRB)
Benjamín PETRŽELA (CZE)
Andreja PIRC BARČIĆ (HRV)
Radostina POPOVA-TERZIYSKA (BGR)
Stjepan POSAVEC (HRV)
Marek POTKÁNY (SVK)
Natalia PRYADILINA (RUS)
Katarína REPKOVÁ-ŠTOFKOVÁ (SVK)
Katarina REMIC (SVN)
Alena ROKONALOVÁ (SVK)
Ante RUPIĆ (HRV)
Łukasz SARNIAK (POL)
Pavol SEDLÁK (SVK)
Mariana SEDLIAČIKOVÁ (SVK)
Renata SKÝPALOVÁ (CZE)
Gergana SLAVOVA (BGR)
Selver SMAJIC (HRV)
Mariya STANIMIROVA (BGR)
Renata STASIAK-BETLEJEWSKA (POL)
Antoaneta STOYANOVA (BGR)
Jaroslav SVOBODA (CZE)
Anna ŠATANOVÁ (SVK)
Jana ŠTOFKOVÁ (SVK)
Mikuláš ŠUPÍN (SVK)
Mária ŠUPÍNOVÁ (SVK)
Jiří TAUBER (CZE)
Krunoslav TESLAK (HRV)
Teodorina TURLAKOVA (BGR)
Róbert UHRÍN (SVK)
Rozália VAŇOVÁ (SVK)
Mislav VEDRIŠ (HRV)
Luis VILLARREAL (COL)
Karla VUKMAN (HRV)
Leszek WANAT (POL)
Marek WIERUSZEWSKI (POL)
Martin ZACH (CZE)
Martina ZBAŠNIK-SENEGAČNIK (SVN)

CONTENTS

Introductory paper

CIRCULARITY AND FOREST BIOECONOMY IN THE CZECH REPUBLIC

Palátová, P., Dudík, R.

Abstract: From an economic point of view, Czech forestry and related wood-processing industry play a rather insignificant role in the national economy of the Czech Republic. The long-term problem is the high export of raw wood, the low share of products with a higher added value, the small share of wood structures and, in recent years, also the impacts of the bark beetle calamity. The negative effects caused by the bark beetle calamity were on the predominant spruce monoculture stands, the degradation of which has caused the domestic market to be oversaturated with spruce wood. Subsequently, this led to problems in the wood-processing chain due, among other things, to the lack of a long-term standard structure of raw wood assortments introduced to the market before the onset of the calamity. The paper focuses on the potential and perspectives of the use of wood in the bioeconomy regarding the cascading principle of wood use. Cascading principles are in line with the bioeconomy and circular economy concepts, and, at the same time, circular economy helps in fulfilling the goals related to climate neutrality. The contribution considers the trends of the cascade use of wood at the European level and places them in the context of national conditions in the Czech Republic. The contribution evaluates the content side of the measures that are listed in the related strategic materials of the Czech Republic. The importance of the issue is enhanced by its interdisciplinarity and the fact that the circularity and bioeconomy in the Czech Republic belongs under the responsibility of several ministries.
Keywords: circular economy, bioeconomy, cascades, wood, strategies

1. INTRODUCTION

The forestry-wood sector in the Czech Republic has faced many challenges in the last few years. Many of them are caused or, on the contrary, are causing mainly negative phenomena (high export of raw timber, high proportions of salvage logging due to the bark beetle outbreak, negative public image of forestry). The increasing proportion of damaged monoculture spruce stands also raises the question of how well the Czech Republic is prepared to adapt to climate change and how quickly and effectively it is possible to adapt to these changes not only in the forestry sector but also in the downstream economic sectors (especially the wood-processing industry). The paper deals with current topics that resonate at national and European level, namely bioeconomy and circularity. In the field of use of wood, the cascading principle is then addressed.

2. FORESTRY AND WOOD-PROCESSING INDUSTRY IN THE BIOECONOMY

2.1. Bioeconomy and forestry

The share of forestry in GDP in 2021 was only 0.228% (CZ NACE 02 - Forestry and logging). Including sawmilling (CZ NACE 16), paper industry (CZ NACE 17) and furniture manufacturing (CZ NACE 31), the total share of these sectors is more than 1.5% of GDP (MoA, 2022). Forestry and wood-processing are among the areas supported by the bioeconomy strategy, even though the Czech Republic has not yet adopted its own bioeconomy strategy (MoA, 2019). The Bioeconomy Concept from the perspective of the Ministry of Agriculture (2019-2024) defines the bioeconomy as follows: "*bioeconomy is a tool for reinsurance of the sustainable use of natural resources, respectively sustainable agriculture, forestry and aquaculture, food and feed production and amplification role of primary producers and their integration into the value chain of bioeconomy, as well on the side of forestry to involve whole value chain of following industry.*" This definition is in line with the European definition (EC, 2012). However, the bioeconomy is also defined by some authors only in direct relation to forestry. According to Ronzon et al. (2015), the bioeconomy is "*the production of biomass and the conversion of biomass into value added products, such as food, feed, bio-based products and bioenergy. It includes the sectors of agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries.*" Hetemäki (2017) defines the bioeconomy as "*the use of renewable biomass of forests or forest (biome) for materials, products and services*".

2.2. Bioeconomy and circular economy

With regard to the topic of the paper, it is necessary to mention the relationship between bioeconomy and circular economy - bioeconomy can be understood as a superstructure of circular economy, which aims mainly at replacing linear chains with circular ones, i.e. ensuring the circulation of already used materials and eliminating waste production (Nova Institute, 2016; Kislingerová et al., 2021). In the Czech Republic, one of the key documents in this context is the Waste Management Plan of the Czech Republic for 2015-2024 (MoEnv, 2022). The EU target is to achieve a recycling rate of 70% for packaging waste (in 2030) and 30% for wood (Hrtúsová, Novák, 2020). Circular economy follows the European objectives, because it is one of the key priorities of the EU. Currently, selected CZ NACE sectors with a direct link to forestry and downstream manufacturing industries contribute to waste generation as follows:

Table 1. Waste in selected CZ NACE sections

Sector	CZ NACE	Waste production	Waste production in total: 37 031 438 tons
Forestry and wood logging	02	388 783	10
Wood-processing	16	84 987	5
Paper production	17	260 787	4.5
Furniture manufacturing	31	46 132	19.5
		In total: 780 689	Share on the overall waste production: 2.11%

Source: own processing based on data from CZSO, 2021

Circularity is defined by the life cycle of products in the long term, the durability and reparability of materials used (or availability of spare parts), recycling and consumer involvement (Maitre-Ekern, 2017). A key principle of the circular economy is the introduction of circular production chains and ensuring the circulation of already used materials with an emphasis on the principles of efficient use. The circular economy is also one of the transformational policies of the European Green Deal, as the circular economy is intended to help meet carbon neutrality goals. The EU has committed to carbon neutrality in line with the Paris Agreement and specifically in the European Green Deal. The study by Verkerk et al. (2022) states that forests and forestry play a crucial role in achieving climate neutrality targets.

Different demands are currently placed on forests and, with regard to alternative uses of wood, it should be used with sustainability principles, respecting cascade principles and circular economy. In particular, wood should be used in long-life products (carbon storage), such as furniture and wood buildings. Building materials are promoted in the *New European Bauhaus* initiative, and wood for heating is also to help meet renewable energy commitments - here this relates to biomass (EC, 2021). The *New EU Forest Strategy for 2030* is linked to the *European Green Deal* and the *Biodiversity Strategy to 2030* and the 2013 *European Forest Strategy*.

At the European level, cascading biomass has been addressed in the past by three studies - *European Wood* in 2010, *Indufor* from 2014 on biomass availability and competitiveness of forest-based industries and *Cascades* in 2016. Any resource efficient and circular use of biomass is considered as cascade biomass utilization (EU, 2019), principles include:

- Sustainability (in relation to the SDGs)
- Resource efficiency
- Circularity, new products and new markets
- Subsidiarity (respecting availability and processing capacity).

Biomass cascading is the use of biomass in sectors that depend on forestry, specifically wood-processing, pulp and paper production and biorefineries. Although cascading principles are now coming to the fore, they have been discussed in the context of mitigating negative environmental impacts since the 1970s. The principles of cascading are promoted in the Czech Republic, for example by the Cyrkl initiative. Cyrkl (https://cyrkl.com/cs) is a marketplace for waste and residues, helping companies turn waste into resources. Users can choose in twelve categories, including wood (pallets, woodpackaging, solid wood, chipboard, wood fibre, hoblins, sawdust, plywood). The use of wood through cascades is seen not only in the concept of "reuse, recycle" (emission reduction, carbon removal) but also downcycling (emission reduction, carbon removal) and energy recovery from discarded wood - emission reduction (Verkerk et al., 2022). The publication on cascading (EU, 2019) mentions direct links to agriculture, forestry, environment, climate change, research and energy. The publication also directly discusses examples of specific cascades; best practices include biochar from woody biomass, wood bark extract for pharmaceutical products, upcycling of old recycled paper, new cellulose-based fibres, tall oil, new models of cooperation, clustering, regional cooperation.

2.3. Strategy for Bioeconomy and Circular Economy in the Czech Republic

The Czech Republic has not yet adopted a national bioeconomy strategy (May 2023). Terminological inconsistency is also typical, with official documents using both the terms "bioekonomika" and "biohospodářství". Both terms are translated identically into English as "bioeconomy", but in the Czech public space the fragmented nomenclature causes complications. The basis for the future strategy for the bioeconomy is considered to be the *Concept of Bioeconomy from the perspective of the Ministry of Agriculture* (2019-2024), while for the circular economy it is an official document called the *Circular Czech Republic 2040 Strategic Framework* (Circular Czech Republic 2040).

2.3.1. Bioeconomy concept in the Czech Republic from the perspective of the Ministry of Agriculture (2019-2024)

The Concept reflects the Sustainable Development Goals and the European Bioeconomy Policy 2012 and 2018. There are three key activities:

1) Reinsurance of steering and realization of the Bioeconomy concept on the national level
2) Development support of bioeconomy in the Czech Republic with the use of international cooperation
3) Reinforcement of the technological development and innovations

The concept includes several areas, namely *Food industry*, *Innovation and research*, *Ecoystems and ecosystem services*, *Rural-social area* and *Economic area*. These areas explicitly mention forest ecosystems (their stability and vitality; optimising the provision of forest ecosystem services), sustainable value chains based on biotechnology and bioenergy, sustainable development of the bioeconomy in rural areas, use of renewable resources, use of innovative technologies in traditional sectors including wood production, use of biomass). Circularity is also directly mentioned (MoA, 2019).

2.3.2. Strategic framework for the circular economy of the Czech Republic 2040

Circular Czech Republic 2040 is a document that was approved by the Czech government in December 2021. The implementation of the strategy is to strengthen the resilience of the Czech Republic to future environmental threats and focus on increasing competitiveness, technological maturity, creating new jobs and developing a sustainable social system. The strategy itself is divided into 10 areas (MoEnv, 2021):

1) Products and design
2) Industry, raw materials, construction, manufacturing
3) Bioeconomy and Food
4) Consumption and consumers
5) Waste management
6) Water
7) Research, development and innovation
8) Education and Knowledge
9) Economic instruments
10) Circular cities and infrastructure

Although the above-mentioned strategies fall directly under the responsibility of the Ministry of Agriculture and the Ministry of the Environment of the Czech Republic, circularity and bioeconomy are interdisciplinary strategies. The principles of bioeconomy and circularity can be found in a number of national strategies that fall under the responsibility of other institutions or ministries. The linkage of sub-national strategies with forest bioeconomy issues has been addressed, for example, by Palátová et al., 2022; Rinn et al., 2023; Purwestri et al., 2021. It can be summarised that both circularity and bioeconomy strategies have their place at both national and European level and that cascading principle of wood use is fully consistent with them.

3. DISCUSSION

The cascading use of wood is in line with the concepts of circular economy and bioeconomy. The search for new ways to use wood raw material, including the recovery of wood waste, seems to be an appropriate approach in meeting the sub-objectives of national and European strategies. In recent years, several studies on wood cascade utilization have been conducted (e.g., WWF, 2016; EC, 2016), and the issue is also covered in scientific articles (e.g., Navare et al., 2022; Bais-Moleman et al., 2018; Sadegh Taskhiri et al., 2019; Mair and Stern, 2017; in the case of the Czech Republic, for example, Babuka et al., 2020). When looking at the key words in these articles, there is a huge overlap with "forestry", "wood", "bioeconomy", "bioenergy", "LCA", "circular economy", "waste", etc. In terms of examples of good practice from the Czech Republic, we can mention the company Konospan, which uses recycled wood (construction and demolition wood, packaging material, furniture and bulk wood waste) for the production of panels (Kronospan, 2019). And although a completely circular system cannot exist due to energy losses and material degradation (Kislingerová et al., 2021), promoting innovative and alternative ways of using wood as a raw material and keeping it in a cascading life cycle for as long as possible is fully in line with modern national and European trends. A strategy containing specific measures should be developed in a coherent manner so that the objectives can be achieved in a synergistic way.

4. CONCLUSION

This paper assessed the role of wood cascades in the frame of bioeconomy and circular economy concepts. Considering the current challenges that Czech and European forest-based sector face, innovative utilization of wood would help fulfilling national and European goals related to sustainability, circularity and carbon neutrality.

REFERENCES

1. Babuka, R.; Sujová, A.; Kupčák, V. Cascade Use of Wood in the Czech Republic. *Forests* 2020, 11, 681. DOI:10.3390/f11060681.
2. Bais-Moleman, A. L., Sikkema, R., Vis, M., Reumerman, P., Theurl, M. C., Erb, K.-H., 2018. Assessing wood use efficiency and greenhouse gas emissions of wood product cascading in the European Union, *Journal of Cleaner Production*, Vol. 72, pp. 3942-3954, DOI: 10.1016/j.jclepro.2017.04.153.
3. CZSO, 2021. Produkce, využití a odstranění odpadů – 2019. Available at: https://www.czso.cz/csu/czso/produkce-vyuziti-a-odstraneni-odpadu-2019. [In Czech].
4. EC, 2012. European Commission. Innovating for sustainable growth: a bioeconomy for Europe. Available at: http://ec.europa.eu/research/bioeconomy/policy/strategy_en.htm.
5. EC, 2016. European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Reichenbach, J., Mantau, U., Vis, M.et al., CASCADES – Study on the optimised cascading use of wood, Mantau, U.(editor), Vis, M.(editor), Allen, B.(editor), Publications Office, 2016, Available at: https://data.europa.eu/doi/10.2873/827106.
6. EC, 2021. Nová Lesní strategie EU do roku 2030. Available at: https://commission.europa.eu/document/cf3294e1-8358-4c93-8de4-3e1503b95201_cs.
7. EU, 2019. Evropská unie. Pokyny pro kaskádové využití biomasy s vybranými příklady osvědčených postupů v souvislosti s dřevní biomasou. ISBN 978-92-79-93136-9, 66 s.
8. Hetemäki, L., 2017. Future of forest industry in bioeconomy. Lecture at the Managerial economics and business strategy in forest industry course, University of Helsinki, 16 February 2017. DOI: 10.13140/RG.2.2.25828.78727.

9. Hrtúsová, T., Novák, R., 2020. Cirkulární ekonomika v ČR: Třídit neznamená recyklovat. Ekonomické a strategické analýzy. Česká spořitelna. [In Czech].
10. Kislingerová, E., 2021. Cirkulární ekonomie a ekonomika. Praha: Grada Publishing, Expert, 264 s. ISBN 978-80-271-3230-0.
11. Kronospan, 2019. Udržitelnost pro další generace. Available at: https://www.mojekrono.cz/o-nas/udrzitelnost-pro-dalsi-generace/. [In Czech].
12. Mair, C., Stern, T. Cascading Utilization of Wood: a Matter of Circular Economy? *Curr Forestry Rep* 3, 281–295 (2017). DOI: 10.1007/s40725-017-0067-y.
13. Maitre-Ekern, E., 2017. The Choice of Regulatory Instruments for a Circular Economy. In: Mathis, K., Huber, B. (eds) Environmental Law and Economics. Economic Analysis of Law in European Legal Scholarship, vol 4. Springer, Cham. DOI: 10.1007/978-3-319-50932-7_12.
14. MoA. 2019. Koncepce biohospodářství v ČR z pohledu Ministerstva zemědělství (2019–2024) [Bioeconomy concept in the Czech Republic from the perspective of the Ministry of Agriculture (2019–2024)]. Available at: http://eagri.cz/public/web/mze/poradenstvia-vyzkum/vyzkum-a-vyvoj/koncepce-a-strategie/koncepcebiohospodarstvi-v-ceske.html [In Czech].
15. MoA, 2022. Report on forests, 2021. Zpráva o stavu lesa a lesního hospodářství České republiky. [Report on the state of forests and forestry in the Czech Republic]. Praha: Ministerstvo zemědělství, 2022. ISBN 978-80-7434-571-5.
16. MoEnv, 2021. Strategický rámec Cirkulární Česko 2040. [Strategic framework Circular Czech Republic 2040]. Available at: https://www.mzp.cz/cz/cirkularni_cesko [In Czech].
17. MoEnv, 2022. Odpady. Available at: https://www.mzp.cz/cz/odpady_podrubrika [In Czech].
18. Navare, K., Arts, W., Faraca, G., Van den Bossche, G., Sels, B., Van Acker, K., 2022. Environmental impact Assessment of cascading use of wood in bio-fuels and bio-chemicals, *Resources, Conservation and Recycling*, Vol. 186, 106588, DOI: 10.1016/j.resconrec.2022.106588.
19. Nova institut, 2016. Bioeconomy – more than Circular Economy. Available at: https://www.bioeconomy.fi/bioeconomy-more-than-circular-economy/
20. Palátová, P., Purwestri, R.C., Marcineková, L., 2022. Forest bioeconomy in three European countries: Finland, the Czech Republic and the Slovak Republic. *International Forestry Review*, 24(4), pp. 594-606. DOI:10.1505/146554822836282518
21. Rinn, R.; Palátová, P.; Kalábová, M.; Jarský, V., 2023. Forest Bioeconomy from the Perspectives of Different EU Countries and Its Potential for Measuring Sustainability. *Forests*, 14, 33. DOI:10.3390/f14010033.
22. Sadegh Taskhiri, M., Jeswani, H., Geldermann, J., Azapagic, J., 2019. Optimising cascaded utilisation of wood resources considering economic and environmental aspects, *Computers & Chemical Engineering*, Vol. 124, pp. 302-316, DOI: 10.1016/j.compchemeng.2019.01.004.
23. Vis, Martijn & Mantau, Udo & Allen, Ben & Essel, Roland & Reichenbach, Jan. (2016). CASCADES, Study on the optimised cascading use of wood. DOI: 10.2873/827106.
24. Purwestri, R.C., Hájek, M., Hochmalová, M., Palátová, P., Huertas-Bernal, D.C., García-Jácome, S.P., Jarský, V., Kašpar, J., and Marušák, R. 2021. The role of Bioeconomy in the Czech national forest strategy: a comparison with Sweden. *International Forestry Review* 23(4): 492–510.
25. Ronzon, T., Santini, F., and M'Barek, R. 2015. The bioeconomy in the European Union in numbers. Facts and figures on biomass, turnover and employment. Brussels: European Commission. Joint Research Centre. [Online]. Available at: https://ec.europa.eu/jrc/sites/jrcsh/files/JRC97789%20Factsheet_Bioeconomy_final.pdf
26. Verkerk, P.J., Delacote, P., Hurmekoski, E., Kunttu, J., Matthews, R., Mäkipää, R., Mosley, F., Perugini, L., Reyer, C. P. O., Roe, S., Trømborg, E. 2022. Forest-based climate change mitigation and adaptation in Europe. From Science to Policy 14. European Forest Institute DOI:10.36333/fs14.
27. WWF, 2016. Mapping Study on Cascading Use of Wood Products. WWF, Mondi. Technical report. Lara Dammer, Catherine Bowyer, Elke Breitmayer, Asta Eder, Silvia Nanni, Ben Allen, Michael Carus, Roland Essel.

Authors address:

Palátová, P.[1*]; Dudík, R.[1]
[1] Department of Forestry and Wood Economics, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Czech Republic
[*]Corresponding author: petpalatova@gmail.com; palatovap@fld.czu.cz

Invited papers

WOOD-BASED WASTE MANAGEMENT - IMPORTANT RESOURCES FOR CIRCULAR ECONOMY

Parobek, J., Paluš, H., Dzian, M., Rokonalová, A., Čerešňa, R.

Abstract: Wood as a renewable resource represent one of the most important advantage of the forest based industry and all related industries. The circular economy focuses on the utilisation of resources and the reutilisation of these resources and waste streams into value added products. The principles of the circular economy apply equally to all sectors of the national economy, while each sector has certain specificities that need to be focused on. Analysis of wood flows take into account not only the uses of wood as a material, but also by-products and waste generated by the production to be used as inputs for further uses in construction, wood processing or energy sectors. Better use and knowledge of wood material flows may ensure production of higher added value products as well as to lead to cost reduction. This paper deals with the analysis of raw wood flows in Slovakia with a focus on wood-based waste management, utilisation of wood waste. The concept of cascading aim to optimise the use of wood in the whole chain of its processing and utilisation. In Slovakia, among the forest based industries, the most important producers of wood-based by-products are the sawmill industry (with approximately 40% of the total volume of processed wood). In particular the results show some particular examples of wood flows focused on possibilities of utilisation of wood waste from the wood processing industry (WPI) and recycled wood.
Keywords: construction, environment, wood-based waste

1. INTRODUCTION

The way humanity manages natural resources is reflected in climate change by the constant increase in air pollution, weather fluctuations, the weakening of the earth's protective gaseous envelope and the extinction of organisms across the planet. One way to put humanity back on track and reverse this catastrophic course is through the green economy.

The wood processing industry generates a significant amount of waste, including sawdust, shavings, bark, and trimmings. Antov et al. (2020) found that various forms of wood-based waste are often discarded and can potentially lead to environmental harm if not managed properly. However, innovative approaches such as converting the waste into biofuel or using it for animal bedding can help reduce environmental impact and create economic opportunities.

1.1. The current status of wood-based waste management in the circular economy

The circular economy is currently seen as a viable alternative to traditional linear economic systems, and a growing number of industries are investigating ways to incorporate it into their operations. The wood-based industry is one such area, and while the commodity has integrated some circular principles to its production processes, it still primarily approaches waste management from a linear perspective. The Nordics, for instance, are experiencing increased demand for wood-based products, necessitating a more sustainable approach to manufacturing. However, there remain gaps in knowledge regarding the relationships between actors in wood-based waste management in the circular economy and bioeconomy. Therefore, empirical investigations are required to address these research gaps. It is suggested that inter-organizational collaboration (IOC) could be key to enabling effective circular solutions in the wood-based waste management sector. By establishing partnerships between businesses, policymakers, and other stakeholders, IOC can facilitate knowledge sharing and resource optimization, leading to more efficient and sustainable waste management practices (Iannitelli & Pangerl, 2022).

1.2 The potential benefits of using wood-based waste in the circular economy

The concept of biorefinery is an important development in the field of sustainable processing of biomass into marketable products and energy. Among biorefineries, lignocellulosic biorefinery has the highest market potential. Wood-based waste can be used as a feedstock for biorefinery which contributes to both the circular economy and bioeconomy. In particular, wood-based innovations have potential benefits for the circular economy and bioeconomy. Nanocellulose products, composites, and building materials are new bio-based products and technologies that have potential benefits for the circular economy and bioeconomy. Wood-based waste can be used as a resource in the circular economy and bioeconomy, leading to reduced waste and more efficient resource use in manufacturing processes. Furthermore, biorefineries have the potential to revitalize the pulp and paper industry. However, market failures can impede the potential benefits of using wood-based waste in the circular economy and bioeconomy, highlighting the importance of effective governance and policy making to ensure successful implementation of circular and bio-based solutions.

The application of wood for industry represents ideal results from an economic, as well as, an environmental point of view. A altered way of potential wood waste and wood residues consumption in the value chain is identified in the concept of cascading use of wood and wood base products. The ultimate and ideal use of wood, both from the point of view of binding carbon dioxide (CO2) and from an economic point of view is exactly in the wood processing industry. A cascade concept can be defined as multiple utilisation of the wood from forests and wood processing industry by using residues, recovered (collected after consumption) or resources recycling (utilization in production) resources (Hekkert et al., 2000; Odegard et al., 2012). The higher the cascade factor gets when more frequently by products and recycling products are used. Cascade concept represent utilisation of wood in an effort to increase added value of wood raw material from primary resources as forests. It also means that wood should be primary used in the added value products as furniture, construction or other products with a long life cycle. On the other side, an energy should primarily be produced from wood waste (which is not able utilise for industry purpose) or recycled products. In this sense we consider energy uses of wood as the least preferred way of utilization. The theory of cascading use of biomass can be describe as cascading in function. It is actually coproduction, which can be achieved by using bio-refinery. Coproduction is the production of different functional streams (e.g. protein, oil and energy) from one biomass stream, maximizing total functional use. Naturally, after cascading in function, cascading in value or time follows. The cascading in time can be explain as meaning that the life span of biomass utilisation is increased (e.g. paper recycling). Additional, different approach can also be defined as 'cascading in value' meaning that the maximum value of the whole life cycle of biomass is gained through optimizing the use of biomass for multiple services (Piškur & Krajnc, 2007).

The main objective of the study is the identification of raw wood flows in Slovakia with a focus on utilisation of wood waste for long term wood products in the built environment. To follow above mention aim the re-search applied the concept of cascading to optimise the use of wood in the chain of its processing. The approach was applied to identify relations between the re-sources and primary uses of wood focused on possibilities of utilisation of wood waste from the WPI and recycled wood in the construction sector.

1.3 Circularity concepts in forest-based industries

A circular economy refers to a wide range of materials and processes, both in the technical and biological cycle of the economy. As an example, wood may enter the technical cycle when it is combined with technical materials in the construction of buildings.

The term "value chain" entails a series of manufacturing steps that link raw materials to final products through different sub-sectors of an industrial or economic sector. A value chain can vary in scale from being local to global and the range of activities along the value chain may be implemented by different actors, such as resource extractors, processors, traders, retailers and service providers. Each sub-sector (e.g., furniture manufacturing or construction) could be described as a distinct value chain, however, processing steps in different product groups downstream often have common sources upstream (UNECE, 2022).

1.4 Analysis of wood flows – theoretical approach

Material flow analysis was used to reveal and quantify relations between the resources and the primary uses of wood. EUROSTAT (2001) distinguishes and explains the three basic dimensions of material flows: territorial dimension, product chain or life cycle dimension and the product dimension. Different approaches to material flow analysis and modelling have been used by e.g. (Binder et al., 2004; Bringezu, 2003; Fischer-Kowalski, 1998; Zhou & Sun, 2008). The analysis of material flows can be also used as an analytical and modelling tool for different areas and sectors e.g., material balances of corporations and urban regions in industrialised countries (Baccini & Bader, 1996), regional wood management (Műller, 1996), and the generation of waste in regional systems (Schwarzenbach et al., 1999). The analysis of wood flows enables one to determine a balance between the production and the use of wood in the country. The analysis results reveal relationships between the production, quality, and availability of data, the balance of foreign trade, and the importance of wood in domestic consumption. Wood flow analysis is focused on all uses of wood and takes into account by-products and waste generated by processing the material input for further use. Both sides of the balance, the resources and the use side, are specific, as they incorporate different markets and products; therefore, it is necessary to examine each side individually. The overall structure of the balance is not constant and may vary depending on the uses of wood and wood products. In most cases, the balance includes such uses of wood for which there are no official statistics available, and the total consumption therefore cannot be simply calculated. Consequently, the consumption of wood may be much higher than indicated by official statistics.

1.5 Concept of Cascading Use of Wood Products

The utilization of wood for building industry represent optimal solution from an economic, as well as, an environmental point of view. A different way of potential wood and wood residues utilization in the value chain is described in the concept of cascading use of wood products. The final and optimal use of wood, both from an economic point of view and from the point of view of binding CO2, is precisely in the construction industry. A cascade use can be defined as multiple use of the wood from trees by using residues, recycling (utilization in production) resources or recovered (collected after consumption) resources (Hekkert et al., 2000; Odegard et al., 2012). The more often by products and recycling products are used the higher the cascade factor gets. Cascade principle means to use wood in an effort to increase added value of wood raw material from forests. It also means that wood should be primary used in the construction, furniture or other products with a long life cycle and energy should primarily be generated from waste or recycled products. In this sense we consider energy uses of wood as the least preferred way of utilization. The concept of cascading use of biomass can be defined as cascading in function. It is actually co-production, which can be achieved by using bio-refinery. Co-production is the production of different functional streams (e.g. protein, oil and energy) from one biomass stream, maximizing total functional use. Of course, after cascading in function, cascading in value or time follows. The cascading in time meaning that the life span of biomass use is increased (e.g. paper recycling). Another approach can also be defined as 'cascading in value' meaning that the maximum value of the whole life cycle of biomass is gained through optimizing the use of biomass for multiple services (Piškur & Krajnc, 2007).

2. WOOD-BASED WASTE MANAGEMENT - METHODICAL APPROACH TO THE IDENTIFICATION OF WOOD RESOURCES

Two main approaches have been applied for identification of wood and wood waste resources utilisation. Firstly, a single wood balance represents a total assessment on the resources and primary uses of roundwood without an opportunity to identify internal flows ow wood waste or particular assortments of roundwood. The main groups of wood resources are characterised by the domestic production and wood imports, and the uses by the domestic wood consumption and exports. The sources are completed by the wood waste and recycled wood and stocks changes, the side of utilisation by the increase of stocks from the previous years. The accessibility and consistency of data could be consider as a limiting issue for the realisation of wood balance study. Presented data from the FAOSTAT database (FAOSTAT, 2021) and the Reports on forestry in Slovakia (National Forest Centre, 2022) were applied. To achieve the state of wood balance the side of resources should equal the side of uses. Moreover, there are not available data on domestic consumption. Therefore, they are calculated from the statistic of foreign trade and roundwood production.

The wood balance of resources represents a detail analysis of wood products and wood wastes, as well as, roundwood flows. Unlike the wood balance, which takes into account only uses of wood as a material, the wood resource balance is focused on different uses within the internal environment of the sector. First of all, it takes into consideration by-products and waste generated by the production to be used as inputs for further uses in wood processing or in energy sector (Parobek et al., 2014). The Table 1 shows measured categories of wood resources and uses for wood resource balance.

The quality of final analyses of wood resource balance depends directly on the quality and availability of data on wood production and use in individual sectors. Generally, availability of data on consumption is usually poor or detail data do not exist. An empirical research and expert estimations based on the available production data are commonly used to gain the missing data. Under present circumstances, wood resources balance must be compiled as a mix of officially published and empirically obtained data. Statistics are easily accessible for extremely concentrated sectors such as wood base panels industry and pulp and paper industry. Though, particular sectors of sawmill industry, are not at all concentrated, that is why the access to data is based on empirical study. Therefore, to obtain data on the major material flows to different wood processing sector as well as various flows of kinds of wood waste, are accounted from data gained by empirical survey. In particular, a questionnaire survey was carried out to gain additional data, which are not included in the official statistics (production of other logging residues, use of sawmill and other production co-products and waste, use of energy wood for internal use within the industry, stocks changes). A survey containing questionnaires adapted to specific sectors. It was useful to quantify the missing data. Available business databases and trade register were applied to identify the main wood processing companies in each sector (sawmilling, panel industry). In total more than 400 questionnaires were distributed to the different owners of primary wood processors in sawmilling and panel production sector.

Table 1. Categories of Wood Resources and Uses

<table>
<tr><td>Woody biomass</td><td colspan="3">Wood products and waste</td></tr>
<tr><td colspan="2">Sources</td><td colspan="2">Uses</td></tr>
<tr><td rowspan="5">Forest woody biomass</td><td>Coniferous roundwood (logs, pulp wood, other industrial wood, wood fuel)</td><td>Sawmill industry</td><td rowspan="6">Wood processing industry</td></tr>
<tr><td>Non-coniferous roundwood (logs, pulp wood, other industrial wood, wood fuel)</td><td>Veneer and plywood industry</td></tr>
<tr><td rowspan="2">Forest chips</td><td>Particleboard and fibre board industry</td></tr>
<tr><td rowspan="2">Wood fuel industry</td></tr>
<tr><td>Other logging residues</td></tr>
<tr><td>Used material (paper and other)</td><td>Post-consumer fibres</td><td>Pulp and paper industry</td></tr>
<tr><td>Other woody biomass</td><td>Woody biomass outside forests</td><td>Power and heat</td><td rowspan="4">Energy users</td></tr>
<tr><td rowspan="2">Wood processing residues</td><td>Sawmill residues (sawdust, chips, particles)</td><td rowspan="2">Industrial internal</td></tr>
<tr><td>Pulp production co-products</td></tr>
<tr><td>Processed wood fuel</td><td>Processed wood fuel</td><td>Private households</td></tr>
<tr><td>Total</td><td></td><td></td><td>Total</td></tr>
</table>

During the couple of rounds of survey, finally we received 128 answers. Some of them, which were not filled correctly were again recommunicated with the respondents. Knowing the aggregated data of main wood products production from the official statistics we used the answers to identify the particular rates of residues and waste production by each sector. However, there were significant differences among sectors. In case of sawmilling industry the returned questionnaires covered approximately 32% of the total coniferous sawnwood and 20% of non-coniferous sawnwood production. In the wood panels industry all main producers have responded. Pulp and paper sector was analysed according to official data from sectorial statistics as well as the sector using wood fuel for energy purposes. All data were aggregated in order to quantify the respective wood flows. In order to quantify flows and balances in a single measurement unit (M3), the UNECE/FAO (2021) official input/output ratios were used.

As wood is a universal material which could be ideal for circular economy, because wood after its life cycle in one production process can be utilise in other production processes. It was main approach, in order to calculate volumes of individual wood flows, to identify on both sides of the balance whether the products were final or intermediate products entering the opposite site of the balance to be used again. When considering this multiple use of wood material we were able to calculate the cascade coefficient pointing out the volumes entering repeatedly the resource side of the balance. However, such a cascade approach neither overvalued nor undervalued the final balance; it only broadened the scope of products or product groups included in the analysis. Thus the final balance included the flows of intermediate products, i.e. it comprised also indirect wood flows.

3. RESULTS – CASE STUDY OF WOOD BASED WASTE MANAGEMENT IN SLOVAKIA

The volume of domestic consumption (9.59 mil. M3) was deducted from the volumes of roundwood production and foreign trade. Wood balance presents a global view on the resources and primary uses of roundwood in Slovakia and is illustrated in following Table 2. Due to unavailability of data it does not consider the stock changes.

Table 2. Domestic wood resources in Slovakia (in M3).

Wood Reources		Use of Wood	
Roundwood Production	7 448 000		
Roundwood Import	2 000 000	Roundwood Export	2 290 000
Recycled Paper	141 113		
		Domestic Consumption	7 299 113
Total sources	**9 589 113**	**Total uses**	**9 589 113**

Wood balance of is primarily focused on to analyse domestic consumption regardless the additional use of wood and, unlike wood resource balance, it considers foreign trade in wood products. Logs are processed by sawmills and only a minor proportion is consumed by plywood or veneer producers. As a paradox, in spite of a higher composition of broadleaved forests in Slovakia coniferous logs are the main raw material used by sawmills. Non-coniferous pulp wood and other industrial roundwood is mainly used by pulp and paper industry.

3.1. Wood Resource Analysis and Cascade factor

Results of the wood resource analysis show that the total resources were 9.59 mil. M3 round wood equivalents (Table 3.).

Excluding of roundwood the resource side is supplemented by wood waste, namely processing residues consisting mainly of wood waste from sawmills and black liquor from pulp and paper industry. The majority of waste was produced by the pulp and paper industry (black liquer 1.01 mil. M3) followed the waste produced by sawmill industry (1.0 mil. M3).

Indirect wood flows can be expressed by a cascade factor, which considers the repeated use of wood originating on the use side and returning back to the resource side and vice versa. Considering the actual total consumption of wood and wood based inputs 9.59 mil. M3 and the volume of wood supply from forest wood biomass 7.2 mil. M3 (domestic wood resources) the value of cascade factor was 1.32.

Table 3. Utilization of by-products derived from industrial wood processing.

Wood Based Resources		***M3***	***Use***	***Use M3***	***Production***	
Forest woody biomass	Coniferous Logs	**2 722 420**	Coniferous Sawnwood	2 289 096	1 067 517 M3	Wood processing Industry
			Non Coniferous Sawnwood	947 839	266 879 M3	
	Non Coniferous Logs	**951 839**	Veneer, Plywood and other Large Boards Production	437 325	437 325 M3	
	Pulp Wood and Other Industrial Wood	**2 923 388**	Particleboard and Fibre Board Production	1 138 644	882 487 M3	
	Wood Fuel	**560 352**			3 299 T	
	Energy Wood and Logging Residues	**47 125**				
Recycled material	Post-Consumer Paper	**141 113**	Pulp and paper industry	2 310 188	1 238 430 T	
Industrial residues	Sawdust	**254 585**	Other Energy Wood	2 382 392	722 TJ	Energy Users
	Chips	**472 543**				
	Particles	**166 950**	Energy Use of Wood in Industry		12 536 TJ	
	Black liquor	**988 467**				
Processed wood fuel	Pellets, briquettes and others	**276 702**	Private Households		24 359 TJ	
Total		**9 505 484**			**9 505 484**	

* M3 cubic meters, T tons, TJ Terajoule

4. CONCLUSION

Wood residues and by-products are produced during industrial processing of wood. The waste stream is represented by different types of waste generated during the logging operations (e.g., logging residues) as well as the waste generated during primary mechanical and chemical processing of wood (sawdust, chips, black liquor), which can be used either industrially or for the production of energy. The primary source of wood residues used for production of agglomerated wood-based panels, processed fuel wood, and energy generation is the sawmilling industry. Wood balance is primarily used to estimate domestic consumption, regardless of the further use of wood; unlike the wood resource balance, it considers foreign trade in wood products. Taking into account roundwood classification, the wood resource balance distinguishes wood flows for individual sectors according to the intended use of assortments. Logs are primarily processed by sawmills, and only a small portion is consumed by plywood or veneer producers.

As a paradox, in spite of the large proportion of broadleaved forests in Slovakia, coniferous logs are the primary raw material used by sawmills. Non-coniferous pulp wood and other industrial roundwood is used by the pulp and paper industry for the production of pulp, or alternatively for the production of particleboard and fibre board.

The importance of wood for energy production has been increasing recently. Wood fuel is used for energy production in either internal or external facilities. At the same time, it represents a significant source for heat energy in households. Wood, which was traditionally utilised as material for the production of wood products, is presently in demand for energy production. The increasing direct or derived demand for energy wood causes an increase in energy wood prices.

Wood cascading considers complete wood using cycle and recognizing the differences in wood flows. The concept of cascading can help to optimize the use of wood in the whole chain of its processing and utilization in Slovakia. Results of the analysis can help in many innovations to increase the efficiency of the cascade of wood processing for construction industry.

The utilisation of wood is continually changing, and the demand for roundwood is changing depending on the technologies and on the demand of final wood products. On one side, wood and wood products production is subject to available resources and has been recently influenced by the high proportion of accidental felling. On the other side, wood production tries to adapt to rapidly changing on the market. The applied concept of cascading can describe the actual consumption of wood in various forms. The outcome of the analysis of wood material flows and cascading concept in Slovakia go out the balance between the resources and the primary uses of wood and wood residues. The analysis describes in detail the relationships between resources (wood and waste), basic production indicators, foreign trade relations, and the use of raw wood material and waste in the domestic conditions. Main conclusions can be considered as follow:

- The wood market in Slovakia is permanently developing and the demand for roundwood is changing depending on the possibilities of its use. There are many specifics influencing production and consumption patterns at the domestic market. On one hand, timber production is subject to available resources, which are the result of long-term forest management and long-term planning.
- Timber production has recently been influenced by the high proportion of accidental felling. However, it tries to adapt to rapidly changing market conditions and requirements of wood processing sector that vary over a relatively short period of time.
- The applied material flow analysis can transparently reveal the actual consumption of wood in its various forms. Such an approach also allowed pointing out the vulnerability of revealed relationships occurring due to the limited wood resources and exiting regulative as well as supporting measures.

Acknowledgements:

The author would like to thank for the support of the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic Grant No. 1/0494/22 Comparative Advantages of the Wood Based Sector under the Growing Influence of the Green Economy Principles and Grant No. 1/0495/22 Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors and the Slovak Research and Development Agency, grant number APVV-20-0294 Assessment of Economic, Social and Environmental Impacts of Forest Management in Protected Areas in SR on Forestry and Related Industries.

REFERENCES

1. Antov, P., Jivkov, V., Savov, V., Simeonova, R., & Yavorov, N. (2020). Structural application of eco-friendly composites from recycled wood fibres bonded with magnesium lignosulfonate. Applied Sciences (Switzerland), 10(21), 1–12. https://doi.org/10.3390/app10217526
2. Baccini, P., & Bader, H. P. (1996). Regionaler Stoffhaushalt. Erfassung, Bewertung und Steuerung, Spektrum.

3. Binder, C. R., Hofer, C., Wiek, A., & Scholz, R. W. (2004). Transition towards improved regional wood flows by integrating material flux analysis and agent analysis: The case of Appenzell Ausserrhoden, Switzerland. Ecological Economics, 49(1), 1–17. https://doi.org/10.1016/j.ecolecon.2003.10.021
4. Bringezu, S. (2003). Industrial ecology and material flow analysis. Basic concepts, policy relevance and some case studies. In Perspectives on Industrial Ecology (pp. 24–30). Greenleaf Publishing.
5. Eurostat. (2001). Economy-wide material flow accounts and derived indicators. In Fuel. https://ec.europa.eu/eurostat/documents/3859598/5855193/KS-34-00-536-EN.PDF.pdf/411cd453-6d11-40a0-b65a-a33805327616?t=1414780409000
6. FAOSTAT. (2021). Food and Agriculture Organization of the United Nations, Statistics Division. Forestry Production and Trade. Retrieved April 4, 2021, from http://www.fao.org/faostat/en/#data/FO
7. Fischer-Kowalski, M. (1998). Society's Metabolism: The Intellectual History of Materials Flow Analysis, Part I, 1860-1970. Journal of Industrial Ecology, 2(1), 61–78. https://doi.org/10.1162/jiec.1998.2.1.61
8. Hekkert, M. P., Joosten, L. A. J., & Worrell, E. (2000). Analysis of the paper and wood flow in The Netherlands. Resources, Conservation and Recycling, 30(1), 29–48. https://doi.org/10.1016/S0921-3449(00)00044-6
9. Iannitelli, A. M., & Pangerl, M. (2022). Circular Branches Inter-organisational collaboration for circular economy in wood-based manufacturing in the Nordics. http://urn.kb.se/resolve?urn=urn:nbn:se:mau:diva-52078
10. Műller, D. (1996). Szenarien zur nachhaltigen regionalen Holzbewirtschaftung. Schweizerische Zeitschrift Für Forstwesen, 147(11), 873–885.
11. National Forest Centre. (2022). Report on the Forest Sector of the Slovak Republic 2021 - GREEN REPORT. Ministry of Agriculture of the Slovak Republic, National Forest Centre.
12. Odegard, I., Croezen, H., & Bergsma, G. (2012). Cascading of Biomass 13 Solutions for a Sustainable Bio-based Economy. https://www.cedelft.eu/publicatie/cascading_of_biomass%3Cbr%3E13_solutions_for_a_sustainable_bio-based_economy/1277
13. Parobek, J., Paluš, H., Kaputa, V., & Šupín, M. (2014). Analysis of wood flows in Slovakia. BioResources.
14. Piškur, M., & Krajnc, N. (2007). Roundwood flow analysis in Slovenia. Croatian Journal of Forest Engineering, 28(1), 39–46.
15. Schwarzenbach, R. C., Scholz, R. W., Heitzer, A., Stäubli, B., & Grossmann, B. (1999). A regional perspective on contaminated site remediation - Fate of materials and pollutants. Environmental Science and Technology, 33(14), 2305–2310. https://doi.org/10.1021/es990642q
16. UNECE/FAO: Forest Product Conversion Factors for the UNECE Region, ECE/TIM/DP/49, UN, Geneva (2010).
17. UNECE. (2022). Circularity concepts in forest-based industries. https://unece.org/forests/publications/circularity-concepts-forest-based-industries
18. Zhou, Z., & Sun, L. (2008). Analysis on Characteristics of Regional Material Metabolism Based on MFA: A Case Study of Chengyang District in Qingdao. 2nd International Conference on Bioinformatics and Biomedical Engineering, ICBBE 2008. https://doi.org/10.1109/ICBBE.2008.688

Authors address:

Parobek, J.[1*]; Paluš, H.[1]; Dzian, M.[1]; Rokonalová, A.[1]; Čerešňa R.[1]
[1] Department of Marketing, Trade and World Forestry, Faculty of Wood Sciences and Technology, Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovakia
[*]Corresponding author: parobek@tuzvo.sk

CONTRIBUTION AND IMPORTANCE OF WOOD-BASED SECTOR TOWARDS CARBON NEUTRALITY AND BIOECONOMY

Pirc Barčić, A.

Abstract: Wood based sector together with forest and forest-based sectors plays a central role in a bioeconomy, because it provides material, bioenergy and a wealth. Following objecting from society and pressure form policymakers' issues about energy crisis, climate change, and pollution problems, the modern industry actors are working towards a low-carbon circular bioeconomy. The wood-based industry is in many ways the perfect fundament of the bioeconomy. Forests and harvested wood products have been acting as net carbon sinks in the EU, removing up to 400 Mt CO2e per year. Wood is a renewable natural material with various uses, and it has always satisfied people's frequently changing needs. The aim of this paper is to present contribution and importance of wood-based sector towards carbon neutrality and bieconomy.
Keywords: wood-based sectror; wood products; carbon neutrality; bioeconomy

1. INTRODUCTION

The importance of protecting our living space is one of the most important problems in modern times. The European Union, in numerous documents, presented the concept of sustainable development, which introduces a systematic solution to the issue of environmental protection as a key political paradigm by promoting sustainable consumption and production, environmental management in an environmentally friendly way and the process of informing the public about negative impacts and the production of environmentally friendly products (Nekić and Krajnović, 2015). Wood processing and furniture production, along with their connection to forestry in the chain of added value creation, are a true example of the circular economy as a new concept of the European Union economy, because the economic growth of these activities is primarily based on forest maintenance, that is, on the use of raw resources, in accordance with permanent sustainable development.

Sustainable development, carbon neutrality and bioeconomy are concepts which complement each other. Furthermore, wood-based sector together with forest and forest-based sectors plays a central role in achieving sustainability, because it provides material, bioenergy and a wealth. It is especially important regarding the fact that, beside seas and oceans, wood represents the most important atmosphere carbon storage. Opposite to expectations of individuals that cutting the forests creates imbalance in ecosystem, it is important to observed the problem in total to present the carbon balance correctly for certain products, regarding its specific qualities, using of additional material, local energy resources and technology, possibilities of recycling and, of course, principles of sustainable forestry. Cascade use of wood is the smart way to use a natural resource – putting it to good use before it is reused, recycled and finally burnt for energy. It strongly overlaps with circular economy and sustainability concepts. A circular bioeconomy – which turns renewable biological resources and waste streams into new products – is at the heart of the EU's efforts to slash its carbon emissions while also maintaining economic growth. The aim of this paper is to present contribution and importance of wood-based sector towards carbon neutrality and bieconomy.

2. SUSTAINABLE DEVELOPMENT, CARBON NEUTRALITY AND BIOECONOMY

Sustainable development is a framework for shaping policies and strategies for continuous economic and social progress, without harming the environment and natural resources essential for human activities in the future. It relies on an ambitious idea according to which development must not endanger the future of future generations by consuming non-renewable resources and by long-term destruction and pollution of the environment. The main goal is to ensure the sustainable use of natural resources at the national and international level. It is a model of sustainability that places emphasis on conducting development policy with the maximum application of scientific achievements and new technologies in order to protect nature and preserve the environment. In other words, sustainable development is a way of production and consumption that considers the natural resources of the ecosystem within which these processes take place. It is a matter of social responsibility that production and consumption processes do not threaten the ability to renew natural resources

Furthermore, the goal of sustainable development is threefold - it strives for economic efficiency (economic development), social responsibility (social progress) and environmental protection. We call the above three items the pillars of sustainable development. One of the main goals of sustainable development is the reduction of CO2 emissions into the atmosphere, and this process is called decarbonization (Duić, 2010).

The European Union's commitment to climate change mitigation is demonstrated in e.g.
the Paris Agreement. Carbon neutrality is a term that has been used to describe a system that has no climate change impacts. However, carbon neutrality is a vague term, and therefore not often used in legislation. It may refer to very significant emission reductions or a situation where the sources and sinks of atmospheric carbon are equal within a production system, country, or the whole globe and within a given time period. EU level documents usually either state quite specific numbers such as emission reduction percentages, or they refer to the climate or need to reduce carbon emissions on a general level. Furthermore, the concept of the circular bioeconomy has risen in importance in recent years Hetemäki,2017; Palahí, 2020.) According to Birner (2017) and D'Amato et al. (2020) the understanding of the bioeconomy focused on resource substitution and biotechnology and the concept has been broadened to encompass sustainability, services, and circularity aspects (Global Bioeconomy Summit, 2018). More recently, the bioeconomy has been defined as "the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy" (Global Bioeconomy Summit, 2020).

3. WOOD BASED SECTOR AND CARBON NEUTRALITY

Neither manufacturers of wood products (industry) nor end users are aware of their own role and the possibility of influencing the reduction of adverse effects of products on the environment.

Wood processing and furniture production are of strategic importance for the EU economy, and the most significant parameter of their importance is reflected in their spatial distribution throughout its territory, thus occupying a significant place in the concept of rural development. In addition to the economic, they also have great local or regional and social significance, employing and retaining the population in small communities where they are often the only source of employment. They also have a special significance for the development of the green and circular economy, so on this basis they are also essential for ensuring the energy sustainability of the country, with an extremely low ecological footprint. However, wood processing and furniture production have not yet used all their potential, nor achieved possible results through their optimal use. The availability and quality of the raw material base, on whose potential they base their production, provides them with the first and basic market advantage, but it is not enough. All other elements of development and growth should be ensured, from optimal technical capacities, own design and innovation, publicity, pricing policy to business skills and strong management capacities, expertise and skills of all human resources. It is necessary to increase the productivity and efficiency of the use of all own resources and, in accordance with the potential of the available wood resource, to the optimum possible increase the share of products with a higher added value in the total production.

When it comes to a sustainable built environment, material choices matter. Wood is a natural, renewable, and sustainable material for building. Maximizing wood use in both residential and commercial construction could remove an estimated 21 million tons of C02 from the atmosphere annually—equal to taking 4.4 million cars off the road (Think Wood, 2023). When we talk about the reduction of CO2 emissions in the wood industry and the use of wood, it is an important factor in the fight against climate change caused by CO2 emissions in the atmosphere. Wood reduces CO2 emissions in two ways. The first way is "incorporated energy", that is, the amount of energy that needs to be invested in the production and transportation of materials for the production of the finished product. Wood has a low "embodied energy" compared to other materials, that is, in the industry and processing of wood, much less CO2 is emitted than in the production of, for example, steel, which has a high "embodied energy". Each m3 of wood is 1.1 tons less CO2 in the atmosphere (Turkulin and Živković, 2018). Another way is by stored CO2 in the wood, that is, the wood "captures" 0.9 tons of CO2 from the atmosphere during growth. This amount would be released from the wood by burning it, but with the use of wood in various products, CO2 remains trapped in the wood (Turkulin and Živković, 2018).

Socially responsible business refers to the company's responsibility to continuously contribute to sustainable development with its production and business activities. Due to the lack of knowledge about the concept of

sustainable development, many participants in the product value creation chain identify the principles of environmental sustainability with activities
to reduce the impact of the production process on the environment. However, according to the principles of environmental sustainability, the goal of the so-called of green processes is to strive to reduce the impact of all activities in all phases of the life cycle of a product and/or service (raw material-production-use-recovery/recycling) on the environment, through: reducing emissions, giving priority to renewable materials and reducing the total costs of the product's life cycle and/or service (Shrivastava and Hart, 1995).

According to Vilja Varho et al. (2018) the bio economy can offer solutions to the carbon issue in three ways. − First, the biomass-producing sectors can upkeep and increase carbon sinks. The new CAP and regulations supporting climate-smart forestry may emphasise this function. − Second, production of bio-based products having a long lifetime, such as furniture or wooden buildings, may constitute carbon sinks. The cascade principle, waste prevention and sector specific regulations are relevant. Various policy instruments such as economic incentives may be used to encourage increased and prolonged carbon storage in products. − Third, the bio-based products may substitute non-renewable and fossil-based products, e.g., in chemical industry, packaging, textiles, and energy. Public procurement, various product standards and sectoral policies may be harnessed to increase the markets of these products. It is vital, however, to make sure that the bio-based products really have (significantly) lower GHG emissions over their life-cycle. Sustainability criteria should be drafted for all biomass uses, or carbon impacts could be optimised through comprehensive carbon pricing. It is also vital that the use of bio-based products implements substitution rather than additional production and consumption. A key problem is that increased use of biomass for production means reduced sinks. There are tradeoffs between the three ways in which the bioeconomy can contribute to the climate challenge. According to global agreements, we need to equalise the sinks and emissions of GHGs, but the richer countries need to be in the forefront of the development. Therefore, it can be argued that the EU should remove more carbon from the atmosphere than it emits. As the EU also imports a great deal of its energy and raw materials, the overall carbon footprint of the Union is larger than that of its own production.

4. SUSTAINABLE DESIGN AND USAGE OF WOOD-BASED PRODUCTS

Nowadays, producing sustainable wood-based products and materials is challenging. Trends toward increasing consumer involvement in design decisions, and increasing interest in the sustainability of product design. According to Saval (2019) design has become too aesthetic and commercial in its aim and that the concept of good design should be extended to the sustainable and practical functioning of products. Olkowicz and Grzegorzewska (2014) argued that furniture designers should be aware of the consequences of their work and consider environmental impacts, and this in turn could help the competitiveness of small family-owned Polish furniture manufacturers. On the other hand, Vicente et al. (2018) found that wood furniture manufacturers used design more as a product development tool rather than for reduction of environmental impacts. On example that highlight sustainability principles and sustainable design in the field of wood furniture is IKEA. IKEA has been piloting various initiatives across its European stores to see how they can build circularity into their offer to customers with aim to support customers to care and repair, rent, share, bring back and resell their IKEA products to prolong product life.

Green purchasing often called as well environmentally preferable purchasing is a way of buying with which public and private institutions purchase goods and services with the least possible negative impact on the environment to replace goods and services that would normally

be purchased for execution same function but with a lower environmental impact (Rizza, 2008). Additionally, green purchasing increases the demand for green goods, promotes green production, and helps environmentally sound technologies to succeed in the market. On the other hand, green procurement policies and programs can reduce expenditure and waste; increase resource efficiency; and influence production, markets, prices, available services and organisational behaviour (Paluš and Slašťanová, 2019).

Savitri, Safitri, and Rachmat (2021) showed how waste pine wood has potential to be sold as new product which first required a new design. In that way businesses can learn about the optimal use of the characteristics and potential of waste material. This provides business opportnities for interior and furniture contractor to develop new entrepreneurial from material that would have become waste. Processing waste into new product is an effort to increase the welfare of small business and their employees in the form of new entrepreneurs without requiring additional investment. On the other hand, Mamić and Domljan (2022) analysed the production processes and observed what is left as residue, how it is produced and how to turn residue back into valuable raw material from which a new eco-friendly product could be created. The research findings noted that waste raw material can be turned into a more usable raw material, as well as into a final product with a higher added value and thus contributes to improving the market competitiveness of the company. When it comes to wood residue revision, they pointed out the vast majority of oak cut veneer waste is selected on an aesthetic basis, due to which the raw material is eliminated. Wood does not have the same characteristic as a plastic, for example, so the visual defects in wood are a natural occurrence. Today's trends encourage the use of wood that emphasizes the natural appearance and irregularities, in contrast to the recent desirable perfectly flat, uniform grain and wooden strips. The results from Burnard and Kutnar (2020) indicated that, under certain conditions, using wood in the built indoor environment may lead to improved stress responses. For example, stress responses indicated by salivary cortisol levels were lower in the test environment with oak furniture than in the corresponding control environment. They discussed that the reduced reaction to stress has a small effect for any single stressful situation, but, over time, even small reductions to stress responses can contribute to improved mental and physical health outcomes.

Solid wood and wood-based products used in buildings are also a carbon absorber. The use of wood-based products instead of other construction materials will both reduce the use of high CO2-containing materials and carbon dioxide emissions thanks to their carbon retention feature. The easiest way to reduce carbon emission from materials is to increase the use of wood materials in buildings. The use of wood in buildings is a very economical method of reducing CO2 emission. In addition, the use of wood in buildings is a very economical method of reducing CO2 emission in terms of cost. The carbon absorbing effect of forests and carbon sink of wood-based product make wood a very advantageous material today where the amount of carbon emission is constantly increasing. Especially, LCA of wood-based composites used in buildings will be important in terms of increasing the use of wood materials (Aras and Kalaycıoğlu, 2020).

5. CONCLUSION

Sustainability, carbon neutrality and bioeconomy are increasingly becoming a key consideration of all stakeholders within wood-based sector and its products, since the world is moving towards zero-energy construction. A more rational use of raw materials is also very important, particularly when this material has a significant impact on reducing CO2 emissions compared to other materials. The higher promotion of wood in construction and interior design and encouragement of the use of wood raw materials in production is needed because they contribute to environmental protection. By increasing the quality of individual and overall life of the population, the increase in well-being is measured. In order to achieve sustainable development on a global scale level, it is necessary to implement systemic changes from the market and politics all the way to institutions and behaviours that support innovations and feel the need to introduce them. Wood and wood products can be used in any form and that it can be a good substitute for other products and that they can compete materials that people think are stronger, stronger and better quality. Wood industry with its product, process and business innovations it contributes to the achievement of goals sustainable development and keeping forests and ecosystems healthy. Therefore, the market is important inform, educate and direct in sustainable development about the importance of using wood, innovations wood products, as well as by recycling and reusing them. Rational by using wood and innovations, we can greatly contribute to the reduction of harmful emissions into the atmosphere and in achieving greater energy efficiency and reduced climate change.

REFERENCES

1. Aras, U. Ğ. U. R., and Kalaycıoğlu, H. Ü. L. Y. A. (2020). EVALUATION OF CARBON FOOTPRINT AND ENVIRONMENTAL IMPACT IN WOOD BASED PRODUCT. Wood Industry and Engineering, 2(2).
2. Birner, R. *Bioeconomy Concepts*; Lewandowski, I., Ed.; Springer International Publishing: Cham, Switzerland, 2018; ISBN 978-3-319-68152-8.
3. D'Amato, D.; Droste, N.; Allen, B.; Kettunen, M.; Lähtinen, K.; Korhonen, J.; Leskinen, P.; Matthies, B.D.; Toppinen, A. Green, Circular, Bio Economy: A Comparative Analysis of Sustainability Avenues. *J. Clean. Prod.* 2017, *168*, 716–734.
4. Duić, N. (2010). Održivi razvoj energije, voda i okoliša. Strojarstvo, 52 (4), 404-404.

5. Global Bioeconomy Summit Innovation in the Global Bioeconomy for Sustainable and Inclusive Transformation and Wellbeing. In Proceedings of the Global Bioeconomy Summit 2018, Berlin, Germany, 19–20 April 2018.
6. Global Bioeconomy Summit Expanding the Sustainable Bioeconomy—Vision and Way Forward. In Proceedings of the Global Bioeconomy Summit 2020, Berlin, Germany, 16–20 November 2020.
7. Hetemäki, L.; Hanewinkel, M.; Muys, B.; Ollikainen, M.; Palahí, M.; Trasobares, A. *Leading the Way to a European Circular Bioeconomy Strategy*; European Forest Institute: Joensuu, Finland, 2017; Volume 5.
8. Mamić, D., & Domljan, D. (2023). Design of Decorative Wooden Wall Panels from Sliced Pedunculate Slavonian Oak (Quercus robur L.) from Veneer Production Residue. Forests, 14(2), 414.
9. Michael David Burnard & Andreja Kutnar (2020) Human stress responses in office-like environments with wood furniture, Building Research & Information, 48:3, 316-330, DOI: 10.1080/09613218.2019.1660609
10. Nekić, B., Krajnović, A., 2015: Politika zaštite okoliša u RH nakon pristupanja Europskoj uniji, Zadar, str. 3-5.
11. Palahí, M.; Pantsar, M.; Costanza, R.; Kubiszewski, I.; Potočnik, J.; Stuchtey, M.; Nasi, R.; Lovins, H.; Giovannini, E.; Fioramonti, L.; et al. Investing in Nature to Transform the Post COVID-19 Economy: A 10-Point Action Plan to Create a Circular Bioeconomy Devoted to Sustainable Wellbeing. Solutions 2020, 11.
12. Olkowicz, M.; Grzegorzewska, E. Eco-design as a strategic way to competitiveness in global markets for furniture family-owned MSMEs. J. Intercult. Manag. 2014, 6, 203–214.
13. Paluš, H., & Slašťanová, N. (2019). REQUIREMENTS FOR GREEN PUBLIC PROCUREMENT OF WOOD-BASED PRODUCTS IN THE EU. *DIGITALISATION AND CIRCULAR ECONOMY*, 309.
14. Rizza, I. (2008). Lean And Clean With Green Purchasing. www.environmentalleader.com/2008/04/27/lean-and-clean-with-green-purchasing//
15. Shrivastava P. i Hart S. (1995): Creating sustainable corporations. Business Strategy and the Environment, vol 4, issue 3.
16. Saval, N. How good design failed us. The New Yorker. 2019.
17. Turkulin, H., V.Živković (2018.); Ekološki, estetski i funkcijski aspekti uporabe drva na podovima.
18. Think Wood - https://www.thinkwood.com/sustainable-architecture-design
19. Varho, V., Rautiainen, A., Peltonen, M., Niemi, J., & Ovaska, U. (2018). Biopaths to carbon neutrality.
20. Vicente, J.; Frazao, R.; da Silva, F.M. Sustainable product design and the wood furniture sector. In Advances in Ergonomics in Design, Advances in Intelligent Systems and Computing; Rebelo, F., Soares, M., Eds.; Springer: Cham, Switzerland, 2018; Volume 588, pp. 762–772.
21. Savitri, S., Safitri, R., & Rachmat, G. (2021). PINE WOOD PRODUCTS AND SUSTAINABILITY. *Prosiding ISBI Bandung*, *1*(1).

Authors address:
Pirc Barčić, Andreja
[1] Department of Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
*Corresponding author: apric@sumfak.hr

ENERGY ANALYSIS OF DIFFERENT SCENARIOS FOR THE MANAGEMENT OF WOOD BIOMASS AS BY-PRODUCTS IN LCA

Remic, K., Goropečnik, L., Kropivšek, J., Oblak, L., Jošt, M.

Abstract: Forest products and by-products are generally considered ecologically sustainable, especially due to carbon storage and continuous material growth. However, if not strategically managed, both wood products and by-products can be a burden on the environment. Lignocellulosic biomass can play an important role in economic and sustainable development if the right choices are made. Especially in countries with large forest stands, woody biomass represents an optimal contribution to the circular economy. The aim of this study was to present three possible scenarios for the management of wood by-products, which often appear in LCA analyses, and to analyse the energy balances for the energy mass flow for each of these scenarios. The energy assessment was carried out in the form of an input-output system analysis. The scenarios serve as a starting point for further LCA analyses, which should include closing the material-energy cycles and taking into account the main principles of the bioeconomy.
Keywords: energy analysis, wood by-products, biomass, LCA, bioeconomy

1. INTRODUCTION

Woody biomass and biomass in general is considered an alternative source of energy that could (partially) replace fossil fuels and reduce dependence on them (Reyes et al., 2021). The sustainable circular bioeconomy takes into account different aspects of biomass processing and can be the answer to new socio-economic challenges. This concept allows synergies between the economic, social and environmental components of development. When evaluating strategies for economic development, the sustainable circular economy proposes the inclusion of added value, innovation, knowledge, competition, economic growth, new job creation, rural development, conscious consumption, health, climate change mitigation, natural resource conservation and waste reduction (Juvančič et al., 2023). Accordingly, various strategies such as the EU Biodiversity Strategy 2030 and the 2030 Agenda for Sustainable Development have been adopted in the European Union to address socio-economic challenges, including sound solutions for sustainable energy production and consumption. An important part of the sustainable development agenda are the 17 Sustainable Development Goals (SDGs), which are directly aimed at solving societal problems. SDG 7 - Affordable and Clean Energy - specifically addresses the need to ensure access to affordable, reliable, sustainable and modern energy for all. In addition to enabling infrastructure and international cooperation to facilitate access for energy systems development, this goal aims to significantly increase the share of renewable energy in the global energy mix (United Nations, 2015). Currently, the energy mix in the European Union is composed of different sources: 34% petroleum, 23% natural gas, 17% renewable energy, 13% nuclear energy and 12% solid fossil fuels. For Slovenia, the energy mix is composed of 34% petroleum, 12% natural gas, 19% renewable energy, 20% nuclear energy and 15% solid fossil fuels (Eurostat, 2021). As about 53% of energy in the EU is imported, it is important to understand that both primary (from forests) and secondary (from industry) woody biomass used for energy production is almost entirely from domestic sources, which is a key advantage (European Commission, 2015). Especially in countries with large forest areas (in Slovenia the forest area is 58%), wood is the most promising feedstock for the bioeconomy (Juvančič et al., 2023). Biomass, as promising as it is, is a relatively limited source whose use and distribution must be as efficient as possible. (Reyes et al. 2021, European Commission, 2015). In line with SDG 12 - Responsible Consumption and Production - it is important to ensure sustainable consumption and production patterns and efficient use of natural resources, which is also reflected in bioenergy scenarios where there is a risk of poor forest management, which is also highlighted in SDG 15 - Life on Land (United Nations, 2015).

Crucial to the success of the bioeconomy is the constant availability of raw materials (Juvančič et al., 2023), and in this context it is important to understand that wood supply is partly dependent on natural disturbances. It is reported that there has been a continuous increase in salvage logging in Slovenia since 2014. In the period from 2004 to 2019, 44% of the logging was caused by wind, 49% by insects and 7% by other causes (European

Commission, 2015). Although industrial and energy uses of wood are in constant competition, waste wood remains a valued feedstock for biorefineries and offers untapped opportunities not only for energy production but also for new biological materials (Juvančič et al., 2023). Besides the competition for the primary source (wood), material and energy use are in synergy. In the context of SDG 9 - Industry, innovation and infrastructure, which is focuses on building resilient infrastructures, promoting inclusive and sustainable industrialization and fostering innovation, the wood industry is often mentioned as a promising sector (United nations, 2015). In regards to biorefineries, the wood industry, especially the sawmill industry, is very important as it provides by-products that are used for pulp (paper and textile fibers) and energy production. Furthermore, the by-products of chemical pulping can additionally be used for the chemical industry or energy production. It is therefore clear that although roundwood is mainly used in the material sector, the by-products that are produced in addition to the main products play an important role in providing raw materials for biorefineries (European Commission, 2015).

The transition from a fossil-based to a bio-based economy may come with some trade-offs and hidden dangers related to the environmental impacts, which is why an effective assessment system is crucial (Sinkko et al., 2023). LCA has proven to be an excellent solution for assessing various environmental impacts throughout the life cycle. It can also be combined with net energy yield (energy input-output analysis) to measure energy efficiency and estimate the amounts of energy consumed. It is worth noting that energy consumption has a significant impact on the LCA analysis. Energy used in processes can be further divided into direct, indirect, renewable and non-renewable sources for a more correct interpretation. Direct energy sources include labour, fossil fuels and electricity, while indirect energy sources include chemicals and machinery (Taghavifar et al., 2015).

2. ENERGY ANALYSIS

For this study, a theoretical scenario (Figure 1) for the production of spruce chairs was designed to understand the proportions of the different wood residues generated. The scenario included processes from debarking, sawing, turning, milling to sanding of the finished chair parts. When analysing the mass flows of wood products in LCA, they are usually considered as by-products, which are often not considered relevant for the original analysis. In our study we decided to focus specifically on by-products. We divided the residues into bark, coarse residues and fine residues. The share of bark in spruce logs is about 10% (Music et al., 2019; Čabalová et al., 2021), coarse residues, which are mainly generated during sawing and trimming, account for 47,5% and fine residues, which are generated during turning, milling and sanding, account for 27,5% (Zamar et al., 2016; Yang et al., 2008).

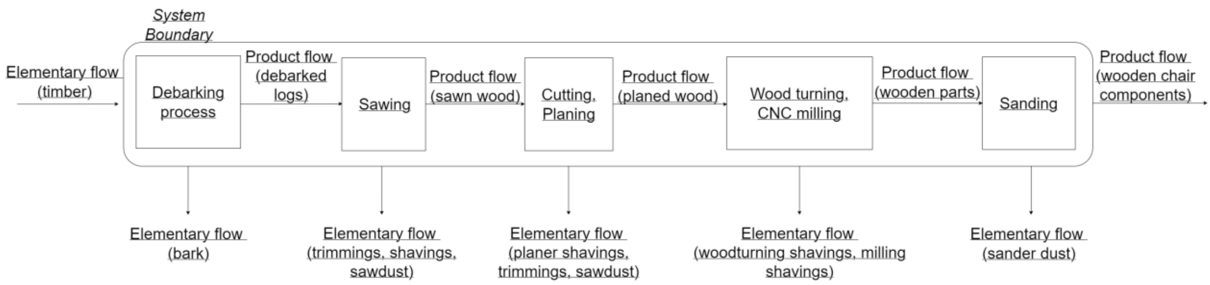


Figure 1. The elementary flow of wooden by-products in spruce wood chairs production.

If we consider the residues in our scenario as a total mass input, the ratios are as follows: 12% bark, 56% coarse residues and 32% fine residues. Due to the general differences in moisture content, density and chemical composition of woody biomass, we wanted to define a functional unit that would allow us to additionally perform a detailed LCA analysis. Therefore, we entered 1 tonne of lignin in the form of coarse and fine residues into the system. We defined the approximate value of 28 % lignin in spruce wood (coarse and fine residues with an average EMC of 25 %) (Čabalová et al., 2021), so the input of collected residues was about 4933 kg (Table 1).

Table 1. Shares of wooden residues for system input data.

Type of wooden waste	Percentage [%]	System input mass – dry wood [kg]	System input mass [kg]
Bark	12	487,2	592
Coarse waste	56	2273,6	2762
Fine waste	32	1199,2	1579

The first modelled scenario was used as the reference scenario. The mass allocation for this scenario divides the residuals into a bark stream, a coarse residual stream and a fine residual stream. The bark is burned in the debarking plant and transported only by an agricultural forklift. The coarse residual is processed and shredded on site (e.g. at the sawmill) and then transported to a regional incineration plant where the wood chips are fed to the combustion chamber as required. The fine residual is stored on site and loaded for transport to the regional pellet production plant. After pellet production, the pellets can either be burned or packaged for household use, but this was not considered in our study.

In the second scenario, the flows of coarse and fine residual wood are merged, while the bark flow remains the same as in the reference scenario. The woody biomass is fed to pulp production, with the black liquor leaving the system as a side stream. In this scenario, all the black liquor is evaporated and then burnt by gasification. The kraft process requires a high water input, so the black liquor contains a significant amount of water. Marson et al., 2023 have described a water content of approx. 30% in the black liquor.

Finally, the third scenario is also based on the kraft process to produce cellulose from coarse and fine residues, and the bark stream is the same as in the reference scenario. In addition, we decided to separate 25% of the lignin (Vakkilainen and Vaelimaeki, 2009) from the black liquor in the recovery boiler. The remaining black liquor is gasified and burnt.

2.1. Wood biomass

The Ecoinvent database, 2022 (version 3.9) provided us with information on estimated energy demand for biomass processing and other biomass information. For bark, a net calorific value of 3,07 MJ per kilogramme of wet bark used was estimated. Spruce wood in the form of coarse and fine residues changes its shape, moisture content and density throughout the process. For wood chips, the energy requirement for shredding is 0,07 MJ per kilogramme of biomass used and the net heating value (LHV) is estimated at 6,38 MJ/kg. For the production of wood pellets, the energy demand is estimated at 0,47 MJ per kilogramme of biomass used and the net heating value at 12,16 MJ/kg. For all heating values, the moisture content typical for the industry was taken into account. For all production processes, the energy demand can vary, but especially for pulp production, the energy demand is difficult to assess due to the different end products, chemicals used in the process, technology, biomass used, etc. The estimated energy demand for an exemplary pulp production process is 4,77 MJ per kilogramme of biomass used. From one kilogramme of biomass used, about 0,7 kilogramme of pulp is obtained with a LHV of 13,23 MJ per kilogramme of pulp. The waste (black liquor) has a water content of 30%, so the total mass of solid particles and wastewater produced from 1 kg of biomass is 0,4 kg. Marson et al. 2023 reports that the energy requirement for the evaporation and combustion of one kilogramme of black liquor by gasification is 7,2 MJ. The LHV of black liquor is 14,15 MH /kg (Vakkilainen and Vaelimaeki, 2009). With additional extraction of lignin in the recovery boiler, the energy demand is 15,2 MJ per kilogramme of black liquor. When part of the lignin is extracted, the LHV of the black liquor decreases; at 25% extraction, the LHV is 13,22 MJ/kg (Vakkilainen and Vaelimaeki, 2009), while the LHV of the extracted lignin is 21,68 MJ/kg (Marson et al., 2023).

2.2 Transport, fuel consumption and human labour

An agricultural forklift was used to handle and transport biomass on site for biomass storage, loading into the kiln or loading onto the lorry for return transport. It was assumed that each forklift operation takes 2 minutes for 1 tonne of biomass. For the purposes of this study, it was assumed that one forklift use was required for bark flow, while two uses were required for chip and pellet production. For the entire kraft process one forklift operation was presumed. It is assumed that there is one larger kraft process plant in Slovenia, so that the biomass would have to be transported on average 80 km by lorry (90 min driving time). The average lorry transport of the fine residues to the pellet production plant and the transport of the wood chips to the incineration plant is 30 km (45 min driving time), as these plants are located regionally. The lorry used in this study (EURO 6) has a transport capacity of 21 tonnes. The consumption of lubricants and other oils was not considered. It was assumed that both the forklift and the lorry run on diesel fuel. We have taken the fuel consumption data from the Ecoinvent database, 2022 (version 3.9). The forklift consumes 1,6 kg of diesel fuel per operating hour and the lorry consumes 0,02 kg of diesel fuel per tkm (tonne-kilometre). It is taken into account that 1 kg of burnt diesel is equivalent to 45 MJ.

The operating times for forklift operation and the driving times for biomass transport by lorry are also the times for human labour, which is categorised as energy expenditure for a one-hour activity involving some form of muscle activation and is estimated at 30 MJ (Zhang et al., 2007), which is the recommended value for LCA calculations.

2.3 Chemicals

Because of the variety of possible chemicals selected for the kraft process, it's difficult to estimate the exact energy required for chemical production. However, some laboratory studies (Kargupta et al., 2021) have been carried out to determine the quantities of chemicals required for pulp processing and to determine the energy consumption in the production of chemicals. The Ecoinvent database, 2022 (version 3.9) contains some data on chemicals used in pulp production, divided into three groups: consumption of inorganic chemicals, consumption of EDTA and consumption of sulphur-containing chemicals. For 1 kg of pulp, the following chemicals are consumed: 0,001 kg of inorganic chemicals, 0,002 kg of EDTA and 0,025 kg of sulphur-containing chemicals. For the production of inorganic chemicals and sulphur-containing chemicals, the energy demand is 1,5 MJ/kg, while the energy demand for the production of 1 kg EDTA is 3,6 MJ/kg. Marson et al., 2023 have discussed chemical recovery in the black liquor recovery boiler, which enables the recovery of sulphur-containing chemicals that can be reused for further processing.

3. RESULTS WITH DISCUSSION

The results of the energy analysis for different scenarios of wood by-product management are presented in Tables 2 to 4. The analysis shows the energy demand and energy equivalence results for each scenario. The first (reference) scenario shows a positive energy balance of 37514,7 MJ for our functional unit. The required energy input consists of 83% non-renewable energy and only 17% renewable energy.

Table 2. The energy equivalents for the first modelled scenario.

S1 (ref.)	Energy equivalent inputs [MJ]		Energy equivalent outputs [MJ]		
Human labour	50		-		
Diesel burned by forklift	22,26		-		
Diesel burned by lorry	117,21		-		
Chips shredding process	193,34		-		
Pellet production process	742,13		-		
Net combustion of bark	-		1817,44		
LHV chips	-		17621,56		
LHV pellets	-		19200,64		
	Renewable energy	Non-renewable energy	Renewable energy	Non-renewable energy	
	157,09	789,34	38639,64	-	Total scenario balance
Total	946,43		38639,64		37514,71

For the pellet production process and the power plant process in scenarios two and three, where electricity is required, we calculated the share of renewable and non-renewable energy sources for the specific energy demand based on the Slovenian energy mix. In an overall concept, part of the energy demand could also be replaced by the renewable energy produced in the bark stream. The energy output in the first scenario comes entirely from renewable sources.

The second scenario has a positive energy balance of 33187,3 MJ. The energy input is 19% renewable and 81% non-renewable. The energy equivalent of the baseline scenario also consists of some non-renewable energy - the energy from recovered sulphur-containing chemicals. The pulp production and black liquor evaporation process is almost completely self-sufficient, as the energy recovered from the black liquor covers 74% of the energy demand.

The third scenario has a positive energy balance of 26339,6 MJ. Similar to the second scenario, the energy demand for cellulose production, black liquor evaporation and lignin extraction is mostly (58%) covered by the energy recovered from the black liquor. Of the energy used, 19% comes from renewable sources and 81% from non-renewable sources. Lignin recovery is an optimal solution for the development of the bioeconomy, for which special awareness is required. The proportion of lignin recovered must be controlled so that the LHV of the black liquor does not become too low. When the extraction rate is 80-90% of the lignin, the LHV of the black liquor drops below 10 MJ/kg and the whole process is no longer considered economic (Vakkilainen and Vaelimaeki, 2009). The extracted lignin can be used as raw material for value-added products such as chemicals, and lignin can also be used as fuel to produce heat and bioelectricity. With the cogeneration of 1 kg of recovered lignin, we can produce 10,62 MJ of heat and 1,53 kWh of bioelectricity (Marson et al., 2023). The energy balances of the more complex processes (scenarios two and three) don't differ significantly from the reference scenario. Even more: Products with added value and stored biogenic carbon are created. For the functional unit chosen in this study the stored biogenic carbon for cellulose is 1337,03 kg and in third scenario 48,13 kg of carbon is stored in the extracted lignin (Siddiqa et al., 2023).

Table 3. The energy equivalents for the second modelled scenario.

<table>
<tr><td>S2</td><td colspan="2">Energy equivalent inputs [MJ]</td><td colspan="2">Energy equivalent outputs [MJ]</td><td></td></tr>
<tr><td>Human labour</td><td colspan="2">47</td><td colspan="2">-</td><td></td></tr>
<tr><td>Diesel burned by forklift</td><td colspan="2">11,91</td><td colspan="2">-</td><td></td></tr>
<tr><td>Diesel burned by lorry</td><td colspan="2">314,71</td><td colspan="2">-</td><td></td></tr>
<tr><td>Cellulose production</td><td colspan="2">20849,67</td><td colspan="2">-</td><td></td></tr>
<tr><td>Black liquor evaporation</td><td colspan="2">12588,48</td><td colspan="2">-</td><td></td></tr>
<tr><td>Production of chemicals</td><td colspan="2">201,94</td><td colspan="2">-</td><td></td></tr>
<tr><td>Net combustion of bark</td><td colspan="2">-</td><td colspan="2">1817,44</td><td></td></tr>
<tr><td>LHV pulp</td><td colspan="2">-</td><td colspan="2">40479,83</td><td></td></tr>
<tr><td>LHV black liquor</td><td colspan="2">-</td><td colspan="2">24739,86</td><td></td></tr>
<tr><td>Chemicals recovery</td><td colspan="2">-</td><td colspan="2">163,91</td><td></td></tr>
<tr><td rowspan="2"></td><td>Renewable energy</td><td>Non-renewable energy</td><td>Renewable energy</td><td>Non-renewable energy</td><td></td></tr>
<tr><td>6400,25</td><td>27613,46</td><td>67037,13</td><td>163,91</td><td>Total scenario balance</td></tr>
<tr><td>Total</td><td colspan="2">34013,71</td><td colspan="2">67201,04</td><td>33187,33</td></tr>
</table>

Table 4. The energy equivalents for the third modelled scenario.

S3	Energy equivalent inputs [MJ]		Energy equivalent outputs [MJ]		
Human labour	47		-		
Diesel burned by forklift	11,84		-		
Diesel burned by lorry	312,55		-		
Cellulose production	20706,57		-		
Black liquor evaporation	12502,08		-		
Production of chemicals	200,55		-		
Lignin extraction	6598,32		-		
Net combustion of bark	-		1817,44		
LHV pulp	-		40202		
LHV black liquor	-		22955,21		
LHV extracted lignin	-		1581,09		
Chemicals recovery	-		162,79		
	Renewable energy	Non-renewable energy	Renewable energy	Non-renewable energy	
	3248,83	26166,77	66555,75	162,79	Total scenario balance
Total	40378,92		66718,53		26339,62

Apart from the fact that biomass is extremely diverse, has different moisture content and density, and usually contains a high density of inert substances, it is also challenging because of its particular distribution at the national level. The biggest challenges still lie in the logistical processes such as collection, transport and storage of the biomass. To enable a functioning wood-based bioeconomy at the national level, collection and transport from local wood processors and mills to biomass facilities need to be organised and cost-efficient supply chain management needs to be established.

4. CONCLUSION

This study presents the energy consumption analysis of three different gate-to-gate scenarios of wood by-product management as a preliminary study to further LCA analysis. The aim of this study is to quantitatively understand the impact of the chosen management strategy for wooden by-products on the energy balance in the mass-energy system equation and to assess the sustainability of advanced scenarios with value-added products as opposed to energy-only production. As the European Union aims for a sustainable circular bioeconomy, it is important to create a sustainable bioenergy system that can generate both heat and electricity without compromising other environmental impacts. Energy consumption analysis is the first step in assessing the feasibility of a scenario. The next step would be a comprehensive LCA analysis that would help decision-makers understand all possible environmental impacts to avoid new, unexpected societal problems. Energy needs to be affordable, reliable, sustainable and modern, which means there is an open window of opportunity for biorefineries. Energy production, as well as the entire bioeconomy, is usually best located in a geographical area that shares a common type of biomass. This usually means that strategies are located at the national or regional level, and rarely are there common strategies for the whole EU, as some countries are rich in marine biomass (blue-green bioeconomy), for example, and others are rich in woody biomass. One of the countries rich in woody biomass is Slovenia, where (as in many other countries) the main problem is managing the supply chain - collection, transport and storage. Nevertheless, the circular bioeconomy based on woody biomass is a promising solution for Slovenia, as the spatial distribution does not represent uneconomic distances, even if the material is widely scattered. A possible solution would be to organise smaller biomass plants at regional level and a larger one at national level.

All the scenarios we have analysed have a positive energy balance, with the second and third scenarios being highly energy self-sufficient. Depending on the current needs of the national economy, each scenario has its own advantages and weaknesses. Therefore, it is important to consider each scenario in this context and analyse it further using the LCA method. In terms of energy consumption, the scenario has an almost equal share of renewable (19%) and non-renewable (81%) energy sources. Scenarios number two and three are overall superior to the reference scenario, both from an environmental and economic point of view, as a significant part of the biogenic carbon is stored in high value-added products.

Acknowledgements: We would like to acknowledge the Slovenian Research Agency for financial support within the program "Wood and lignocellulosic composites" (P4-0015).

REFERENCES

1. Čabalová, I.; Bélik, M.; Kučerová, V.; Jurczyková, T. (2021): Chemical and Morphological Composition of Norway Spruce Wood (Picea abies, L.) in the Dependence of Its Storage. Polymers 13 (10): 1619.
2. Juvančič, L.; Gasan Osojnik Črnivec, I.; Berne, S.; Oven, P.; Mihelič, R., 2023: Povzetek strokovnih izhodišč za strategijo razvoja biogospodarstva v Sloveniji. BIOEASTsUP (Obzorje 2020).
3. Kargupta, W.; Seifert, R.; Martinez, M.; Olson, J.; Tanner, J.; Batchelor, W. (2021): Sustainable production process of mechanically prepared nanocellulose from hardwood and softwood: A comparative investigation of refining energy consumption at laboratory and pilot scale. Industrial Crops and Products 171: 113868.
4. Marson, A.; Samec, J. S.M.; Manzardo, A. (2023): Consequential life cycle assessment of kraft lignin recovery with chemical recycling. Science of The Total Environment 882: 163660.
5. Musić, J.; Lojo, A.; Balić, B.; Ibrahimspahić, A.; Avdagić, A.; Knežević, J.; Halilović, V. (2019): Modelling Bark Thickness of Norway Spruce (Picea abies Karst). SEEFOR 10 (2): pp. 125-135.
6. Reyes, L.; Abdelouahed, L.; Mohabeer, C.; Buvat, J.; Taouk, B. (2021): Energetic and exergetic study of the pyrolysis of lignocellulosic biomasses, cellulose, hemicellulose and lignin. Energy Conversion and Management 24: 114459.
7. Siddiqa, A.; Yhobu, Z.; Nagaraju, D. H.; Padaki, M.; Budagumpi, S.; Pasupuleti, V. R.; Lim, J. W., 2023: Review and Perspectives of Sustainable Lignin, Cellulose, and Lignocellulosic Carbon Special Structures for Energy Storage. Energy & Fuels 37 (4): pp. 2498-2519.
8. Sinkko, T.; Sanyé-Mengual, E.; Corrado, S.; Giuntoli,J.; Sala, S., 2023: The EU Bioeconomy Footprint: Using life cycle assessment to monitor environmental impacts of the EU Bioeconomy. Sustainable Production and Consumption, 37: pp. 169-179.
9. Taghavifar, H.; Mardani, A. (2015): Energy consumption analysis of wheat production in West Azarbayjan utilizing life cycle assessment (LCA). Renewable Energy 74: pp. 208-213.
10. Vakkilainen, E. K.; Välimäki, E. (2009): Effect of Lignin Separation to Black Liquor and Recovery Boiler Operation. In: Procedings for "TAPPI Engineering, Pulping, Environmental Conference".
11. Yang, P.; Jenkins, B.M. (2008): Wood residues from sawmills in California. Biomass and Bioenergy 32 (2): pp. 101-108.
12. Zamar, D. S.; Gopaluni, B.; Sokhansanj, S.; Ebadian, M. (2016): Economic Optimization of Sawmill Residues Collection for Bioenergy Conversion. IFAC-PapersOnLine 49 (7): pp. 857-862.
13. Zhang, T. W.; Dornfeld, D. A. (2007): Energy Use per Worker-Hour: Evaluating the Contribution of Labor to Manufacturing Energy Use. In: Procedings for "CIRP Conference on Life Cycle Engineering".
14. ***: Ecoinvent v3.9 database, 2022.
URL: https://ecoinvent.org/the-ecoinvent-database/
15. ***: Eurostat, 2021.
URL: https://ec.europa.eu/eurostat/web/main/home

16. ***: European commission, 2015: The JRC-EU-TIMES model. Bioenergy potentials for EU and neighbouring countries.
URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC98626
17. ***: United Nations, 2015: 2030 Agenda for Sustainable Development.
URL:
https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

Authors address:

Remic, K[1]*; Goropečnik, L[1]; Kropivšek, J[1]; Oblak, L[1]; Jošt, M[1]
[1] Chair of Management and Economics of Wood Companies, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
*Corresponding author: katarina.remic@bf.uni-lj.si

Other papers

CORK AS A RENEWABLE AND RECYCLABLE MATERIAL AND THE POSSIBILITY TO USE A CIRCULAR PRODUCTION MODEL FOR VARIOUS CORK PRODUCTS

Slavova, G., Doneva,Y.

Abstract: Cork is a one-of-a-kind material that derives from the bark of cork trees. The trees that are used for commercial use can be found throughout southwestern Europe and northwestern Africa, covering quite a few countries. Harvesting is happening between nine and twelve years when the bark is peeled from the trees. They can live for more than 200 years, which means that each tree can usually be harvested as many as 15 times. In addition to their versatility, cork oaks have another remarkable feature: they serve as carbon sinks. After the tree's bark is harvested, the cork oak's carbon consumption is boosted by three to five times, making it an important ally in the fight against climate change. The tree absorbs more CO2 to fuel the energy required to grow back its lost bark. The cork material has a wide range of applications in various industries, including construction, agriculture, fashion, and transportation. Moreover, it has also made its way into cutting-edge fields like aerospace technology and even vaccine production. It is even used in NASA's space capsules for thermal protection. What sets cork apart is not only its periodic extraction from the same trees over a nine to twelve-year span, the fact that it acts as a carbon sink, but also that the residues after the production of cork products can be repurposed and given a new life, thanks to the application of circular economy principles. Cork is a natural, renewable, and recyclable material, which is highly versatile and also one of the most widely utilized forest resources on the planet that can help us fight climate change.

The purpose of this report is to provide a comprehensive overview of the unique features and diverse applications of cork as a material, with a focus on its sustainable properties. The report aims to explore the technology of extraction, processing, and application of cork in various industries and highlight the benefits of using cork as a circular material. The report also seeks to raise awareness of cork oak trees' role as carbon sinks and their potential to help combat climate change. The methods used are deduction, induction, synthesis, analysis, and extrapolation. The conclusions drawn are based on the present analysis and are useful for everyone involved in the forest sector of cork extraction and processing, as well as for the general public of people who use cork products.
Keywords: Cork oak tree (Quercus suber), Cork, Cork industry, Circular economy, Sustainability, Forestry, Agriculture, Ecosystem conservation

1. INTRODUCTION

Professor Joaquim Vieira Natividade defines the cork oak as one of the most useful tree species in the world. (Guerreiro, M., 1993). This tree is evergreen, has a limited distribution range and is extremely well adapted to the hot summers of the southern regions of Europe. It is best known in the world for its unique outer bark. After the bark is harvested the cork oak is capable of naturally regenerating it. While there are other tree species that can also regenerate their bark to some extent, the cork oak's ability to do so is particularly remarkable and widely acknowledged as one of the most significant examples of bark regeneration in the plant kingdom. Additionally, the cork that is leftover from making other cork products can be used as raw material. These unique features make cork oak an excellent choice for circular production models, where resources are conserved and used efficiently. By embracing this innovative approach, we can address the pressing challenges of resource scarcity and maximize resource utilization through subsequent processing. (Chobanova, 2021)

The cork oak, scientifically known as Quercus suber, is a species of oak tree belonging to the Fagaceae family. It grows in specialized cork forests and typically the extracted cork material is certified. (Díaz-Maroto, Ignacio J., 2022) These forests are mainly located in the western Mediterranean region and cover approximately 2.2 million hectares in Portugal, where they are known as “montado”, and in Spain, where they are called “dehesa”. A “dehesa” or “montado” is a multifunctional, agrosilvopastoral system and cultural landscape of southern and central Spain and southern Portugal, where the cork oak is one of the main tree components alongside holm oaks (Quercus rotundifolia). “Dehesas” can be private or communal property, and are primarily used for grazing, producing a variety of products, including non-timber forest products such as mushrooms, honey, cork, and others. The “dehesa” offers not only a diverse range of foods but also serves as a crucial wildlife habitat and is also used to raise the Spanish fighting bull and the Iberian pig.

2. RESULTS

The cultivation of cork oak presents a remarkable prospect for achieving a symbiotic partnership between the forestry and agricultural sectors, as it holds enormous potential for both industries. While the cork processing industry benefits greatly from the production of raw cork materials, utilizing forested cork terrains for animal pastures provides an ideal opportunity to combine the two sectors and optimize land use. By doing so, sustainable production and ecosystem conservation can be achieved.(Slavova, Doneva, 2022)

In order to safeguard the vital ecological role of cork forests, specific measures are implemented to ensure their conservation. These measures are crucial as cork trees are an instrument in combating soil desertification and have a potential to help combat climate change. The Sobreiro Monumental, also known as The Whistler Tree (Sobreiro Assobiador), is a true testament to the magnificence of the cork oak species, with an impressive age of 236 years. Located in Águas de Moura, Palmela, Portugal, this majestic tree has been cultivated for over two centuries, yielding over 1000 kg of cork from its 4.15-meter trunk. It has become a popular tourist destination, with its cork waste products utilized as mulch in various ecotourism trails, thereby demonstrating an excellent symbiosis between the forestry and tourism sectors. (Slavova, Ivanova, 2019)

Cork production is primarily used for cork stoppers, which accounts for about 60% of its global production. Another significant application of cork is its use in construction boards. Portugal is the largest producer of cork, accounting for approximately 50% of the world's production. Cork forests span across roughly 2.5 million hectares worldwide and are primarily found in Portugal, Algeria, Spain, Morocco, France, Italy, and Tunisia. The average lifespan of a cork tree is about 250-300 years, making them a long-term investment for both the environment and the economy. (World Wildlife Fund, 2023)

Portugal stands at the forefront of the cork industry, producing over 100,000 tons of cork annually and leading countries such as Spain, France, Italy, Morocco, Algeria, and Tunisia. The export value of raw cork material from Portugal exceeds an impressive 1 billion euros, with wine producers being the primary buyers responsible for over 70% of exports. As a result, 7 out of every 10 wine bottles on the global market are sealed with cork. (Record year for the Portuguese cork industry, 2023) The Portuguese Cork Association (Associação Portuguesa da Cortiça) strives for zero waste and aims to use every particle of wood, including the smallest particles, which are subsequently burned for energy or turned into lightweight cork objects. (Coppelli and others, 2022) In the fight against single-use plastics, cork is a valuable substitute and can be used for various products in different sectors, from clothing to cars. With over 40 million corks produced daily, it is highly likely that when opening a bottle of wine, the cork was made in Portugal, says João Rui Ferreira, the president of the Portuguese Cork Association.

It takes approximately 25 years for the cork oak to grow before it can be harvested for the first time. The cork material extracted during the first harvest, called "desbola," is unsuitable for cork stoppers due to its structure but can be used for many applications after grinding, such as producing bags, backpacks, shoes, souvenirs, and flooring.

In the intricate process of cork harvesting, the second cork extraction, occurring around 9 to 10 years after the first one, yields a more uniform structure, allowing it to be conveniently handled. Although not yet suitable for the production of cork stoppers, this secondary cork can be processed into small fragments, from which an array of products can be crafted, ranging from building construction elements to shoes, cork backpacks, floorboards, and even surfboards (Pereira, H.207). After the third cork harvesting, which occurs around 43 to 45 years after planting, the bark of the cork oak tree develops a smooth and even surface, making it an ideal material for crafting natural and high-quality cork stoppers. These stoppers are held to rigorous standards due to their direct contact with wine, and of course they must preserve the wine's unique characteristics and taste. Besides, at this stage, cork materials can have various applications that involve skin contact, food, and medical devices, among others (Ferreira, 2023) The most harmless is the production of cork souvenirs as long as they are not intended for children.

It takes approximately 9 to 10 years from the first cork harvest to the second harvest, completing one cycle. The circles on the cork oak's trunk and marked numbers often indicate the year of the last harvest. These evergreen trees, belonging to the order Fagales and the family Fagacea, are highly prized and protected. Most cork oaks grow spontaneously from a single acorn, and it takes around 25 years for them to mature for the first harvest. Cork oak is a versatile and valuable species that provides many raw materials. Its ability to withstand adverse conditions makes it an ecological wonder. Cork is the most well-known natural resource obtained from the cork oak, and it can be used to produce a wide variety of materials and goods. (Cork Encyclopedia, 2023)

The acorns, on the other hand, are the fruit of the cork oak and are the main food of wild pigs, while its leaves make for excellent fodder and natural fertilizer. The wood obtained from pruning is also valuable as firewood. But undoubtedly, the cork oak's most well-known asset is the cork material itself.

In Portugal, cork oaks are meticulously cataloged and monitored, with each tree being identified by species and number to ensure the long-term sustainability of cork oak forests. These forests cannot be considered a completely natural system as some of them are manmade and represent multifaceted cultural landscapes that combine forest, agriculture, and livestock. By providing a habitat for diverse flora and fauna, cork oak forests play a critical role in maintaining a harmonious environment and promoting biodiversity.

As global temperatures continue to rise, the Mediterranean region is particularly vulnerable, experiencing an average increase of 0.8°C. However, cork oak plants and forests are helping to combat this trend by sequestering carbon dioxide. In southern Europe, where temperatures have already risen by 0.5°C above the global average, cork oak forests are especially vital for mitigating climate change (Tártaro, 2017; Spampinato et al., 2018). Every year, cork oak trees absorb an astonishing 14 million tons of carbon dioxide, and this ability to sequester carbon is passed on to cork products (Spampinato et al., 2018). What's more, harvested cork actually helps to increase carbon absorption: cork oaks that have been harvested absorb three to five times more carbon dioxide than those that haven't (Leithead, 2022). For each ton of cork harvested, cork forests absorb 70 tons of CO2 from the atmosphere, making cork a carbon-negative material that can help offset emissions (Power of Cork, 2023).

Cork trees also play a vital role in soil conservation by promoting rainwater infiltration and preventing soil erosion. Additionally, they regulate hydrological cycles, mitigating the risk of drought. As cork is a slow-burning material, cork forests act as a natural barrier against fires and desertification. The historical use of cork in shipbuilding dates back to the 15th and 16th centuries, when navigators utilized it to construct their boats and ships, enabling the exploration of the so-called new world. Currently, cork is still utilized to create floats for fishing nets. Moreover, the microscopic structure of cork, discovered by Sir Robert Hooke in 1665, consists of thousands of small, empty cells with a honeycomb-like structure that resembles a refuge for small insects. Cork has been recognized as a valuable material for centuries, as seen in the case of the Franciscan monks who lined their dwellings entirely with cork boards in Portugal's Convento dos Capuchos around 100 years earlier in 1565. (National Geographic Society, 2022)

The largest cork tree in the world is located in Portugal and stands at an impressive height of around 16.2 meters. Each harvest from this tree can yield around 1,000 kg of cork, which can be used to produce more than 100,000 corks. When it comes to cork stoppers, the most suitable cork is harvested from the third or subsequent harvests, known as "amadia". This type of cork has a flat face and back with a regular structure, making it ideal for the production of high-quality corks that are about 45 mm in length.

In 1678, Dom Pierre Pérignon discovered the solution to creating bottle caps, but it was the English who made its global distribution possible during the 17th and 18th centuries. The wine bottle's popularity in the 19th and 20th centuries contributed significantly to the worldwide boom of the cork industry. While manual labor was once the norm, today the cork industry utilizes high levels of technology, with cork boards graded by thickness and porosity. The highest quality cork stoppers are made from a single piece of high-quality cork with fewer imperfections. Cork boards with more imperfections are milled to make other cork materials. This circular economy model provides a great opportunity to apply zero-waste technology and utilize residual products from the material.

The production of cork involves several essential stages that transform it from raw bark into a valuable resource for a final product. These stages are carefully orchestrated and require a high degree of expertise and attention to detail.

The first and most critical stage is the boiling process. This process involves immersing cork boards in large stainless steel tanks and boiling them to remove any organics embedded in the pores and reach an ideal moisture level for processing. A high-tech tank is used to boil each batch for an hour, causing the inner cork cells to expand by about 10%, making them more pliable.

After boiling, the boards undergo a drying process where they are arranged and stabilized in a well-ventilated area for at least two days. This process helps to remove moisture and harden the boards, making them more resilient.

The next step involves stabilizing the cork boards by leaving them in the yard for at least six months. Each lot is labeled and registered to trace its origin, a crucial step inobtaining a certificate of authenticity. The boards are stacked at an angle on stainless steel structures in large concrete areas, preventing re-contamination and promoting water drainage and air circulation.

In the sorting process, skilled workers in the logging and forestry sector sort the boards by hand. Premium-quality cork boards are carefully chosen for the production of cork stoppers, while thinner boards can find their application in the creation of various household items or in industrial settings. Alternatively, they may undergo a grinding process to be transformed into cork granules, which are utilized in diverse manufacturing processes.

The finest cork boards with fewer pores are selected for the stamping process, where they are cut into strips and pierced by machines to extract cylindrical plugs from natural cork. This modern, highly precise, semi-automatic or automatic process ensures that only the highest-quality natural cork stoppers are produced. The remaining cork material is then granulated and used for a variety of other products, including agglomerated cork products used for insulation in construction, decoration and design materials, and household items.

After the cork boards have been processed and obtained, the remaining rough edges are prepared and trimmed, and all cork boards are carefully re-assessed according to strict parameters based on key characteristics such as appearance, thickness, and ripple. Only the good-quality boards are selected for the production of cork stoppers, while the small and insignificant defects are sent for grinding and turned into cork products. The next stage involves quality control, which includes visual classification, computerized photography, gas chromatographic analyses, and other highly sophisticated assessment methods to ensure that only the best materials are used for production.

The modding or easing process involves molding the body of the cork to create thicker stoppers used for sparkling wine. The diameter of this cork is around 30 mm and is compressed for easy insertion into the neck of the bottle. Agglomerated cork and ground cork are used to produce a wide range of products, including wine stoppers that are made with agglomerated cork and two clean circles of cork at the end that come into contact with the wine.

In the late 19th century, the advent of soft drinks revolutionized the beverage industry. However, the metallic caps used at the time often left a metallic taste in the drink, greatly diminishing the taste experience. William Paintery, who ingeniously developed an affordable metal and cork cap that was lined with a slim cork disc, providing an effective and disposable seal that preserved the flavor of the beverage. This game-changing invention, known as the crown cork product, was so named due to the 21 teeth that securely gripped the bottle's neck, resembling a royal crown.

The entire cork processing cycle is closely linked with biotechnology, a cutting-edge approach that holds tremendous potential for generating employment opportunities in rural regions (Turlakova, 2021). Additionally, this methodology offers a unique opportunity to integrate local communities into the creation of a circular economy model, thereby bolstering the social dimension of the process (Antikainen, Valkokari, 2016). Unfortunately, in the 1960s, plastic replaced cork in wine stoppers, causing widespread environmental degradation. However, today, manufacturers employ advanced techniques to sort sparkling wine corks, branding them with unique markers and treating their surfaces with thin layers of paraffin prior to packaging and shipment.

The versatile application of cork is unparalleled. From fashion to furniture, from shoes to stadiums, from bridges to dams, cork finds itself in an extensive range of uses. It is the epitome of a natural material that has stood the test of time and is as relevant today as it was centuries ago. The circular model applied in cork production is a testament to its sustainability, where its natural extraction occurs every 9 to 10 years, and the surplus of production is ground and repurposed for other cork products, extending the natural resistance of cork in every new creation.

Innovation in technology has unlocked endless possibilities in creating new products, goods, and materials from cork, making it a 100% natural, recyclable, and renewable resource. With its unique combination of properties it has found its way into advanced sectors such as aerospace, automotive, and transportation industries. Even NASA has utilized cork for protecting the heat shields of spacecraft, shuttles, and rockets. It is also widely used for energy efficiency and cost reduction in modern transportation.

Despite being biodegradable, the term of cork's degradation remains unknown, with ancient glass vessels at the bottom of the ocean found with cork stoppers that are almost untouched by time and water. This valuable resource continues to be one of the most surprising and modern materials on earth, with sustainability and human creativity being a powerful combination for creating new and successful products.

In the realm of health and wellness, cork proves to be a versatile and valuable material. Notably, cork insoles and flooring offer ergonomic benefits by promoting better posture and lessening the effort required for walking.

Furthermore, cork stoppers play a vital role in the health benefits of wine consumption, as the complex antioxidants and anti-carcinogenic reactions resulting from corked wine reduce the risk of heart and degenerative diseases. It is remarkable to consider that the highest quality cork stoppers can be obtained for approximately one euro.

Cork's impressive properties extend far beyond the realm of health and into the domains of technology and architecture. For instance, Siemens has developed an above-ground subway featuring innovative cork flooring, making it the lightest subway in the world. Moreover, architectural mastermind Antoni Gaudi incorporated cork into the Basilica "Sagrada Familia" in Barcelona, using cork plates to improve acoustics and thermal insulation. Indeed, cork proves to be a material that helps highlight the beauty of nature and showcases its riches, as it is an indispensable component in insulation.

3. CONCLUSION

In summary, cork stands out as one of nature's finest materials with numerous impressive attributes. It serves as an excellent sound and heat insulator, is impermeable to water, and is highly fire-resistant, while remaining lightweight and long-lasting. The circular economy model is implemented in cork production by recovering the bark and utilizing the waste mass in the manufacturing of cork products and stoppers. Cork has found utility in many sectors and its residue is used to enhance vaccine acceptance by the immune system due to its hypoallergenic qualities. Cork proves to be an invaluable resource in different sectors. The cork oak forests are utilized to feed animals, and processed cork residues are also used for mulching in both agricultural and tourism applications, highlighting its versatility and importance as a sustainable material. Moreover, harvested cork oak trees play a crucial role as carbon sinks, absorbing more carbon dioxide than many other types of trees. This is highlighting their potential to aid in the fight against climate change. It is clear that cork is an incredibly valuable and irreplaceable resource that merits utmost protection and appreciation by humanity. To underestimate the enormous potential of cork is to overlook the possibilities that it holds for the future.

REFERENCES

1. Andreola, F., Plastic and screw top alternatives to natural cork stoppers could lead to the disappearance of Mediterranean cork oak forests — and the rural communities and wildlife that depend on them, WWF – World Wide Fund For Nature, 2023
2. Antikainen M, Valkokari K (2016) A framework for sustainable circular business model innovation. Technol Innov Manag Rev 6(7):5–12. https://doi.org/
3. Chobanova, R. (2021). Circular economy concept as a response to contemporary global challenges., 2021, 19.
4. Coppelli P, Pedrazzi S, Puglia M, Morselli N, Allesina G, Andreola F, Lancellotti I, Barbieri L. Pyrolysis Process for the Recycling of Cork Dust Waste from the Processing of Cork Agglomerate Caps in Lightweight Materials. Applied Sciences. 2022; 12(11):5663. https://doi.org/10.3390/app12115663
5. Díaz-Maroto, Ignacio J. (2022). Certification System for Sustainable Forest Management of Cork Tree (Quercus suber L.) Forests, 22.
6. Ferreira, J. (2019). Cork. It's more than a detail, Portugal makes over 40 million cork wine stoppers a day-witness their journey, from bark to bottle.
7. Guerreiro, M., Natividade, J. V. (1993). O último monge-agrónomo de Sta Maria de Alcobaça. Universidade do Algarve
8. Leithead, A. (2022). Prized for the lightweight, elastic bark, cork oaks can also store large amounts of carbon during their long lifetimes. Now there are moves to find new uses for this material. BBC Future. https://www.bbc.com/future/article/2022
9. National Geographic Society. (2022). Cell Theory. National Geographic. https://education.nationalgeographic.org/resource/history-cell-discovering-cell/
10. Slavova, G., Ivanova, M. (2019). "Someone's garbage is someone else's treasure"–cross-sectoral integration in circular economy. Digitalisation and Circular Economy, 61.
11. Slavova, G., Doneva, Y. (2022). Application of the model of circular economy between the forestry and agricultural sector. Crisis Management and Safety Foresight in Forest-Based Sector and SMEs Operating in the Global Environment, 383.
12. Spampinato, G., De Pasquale, M., Musarella, C. M., De Paola, P., Malerba, A., Musolino, M. (2018).

Carbon sequestration by cork oak forests and raw material to build up a post-carbon city.
13. Tártaro, A. S., Mata, T. M., Martins, A. A., & Esteves da Silva, J. C. G. (2017). Carbon footprint of the insulation cork board, 925-932.
14. Turlakova, T. (2021). Bioeconomy as an innovative approach to rural development in the context of Common Agricultural Policy in the EU. In Sixth International Scientific Conference: Business and Regional Development (pp. 1-7). EDP Sciences. (SHS Web of Conferences; 120)

Authors address:
Slavova, G; Doneva, Y;
Department of Agricultural Economics, Faculty of Economics, University of Economics, Varna, Bulgaria
*Corresponding author: ggss@abv.bg

POTENTIAL OF THE CROATIAN WOOD INDUSTRY IN ACHIEVING CARBON NEUTRALITY – PRODUCTION TRENDS ANALYSIS FROM 1900 TO 2020

Ćurić, P., Pirc Barčić, A., Motik, D., Moro, M., Basarac Sertić, M., Meloska, Ž.

Abstract The total area of forests and forest lands in Croatia is 2,76 million ha, which is 49.3% of the land area of the country. Of this, 2,1 million ha are public owned forests, while 661,721 ha are owned by private forest owners. The majority of forests owned by the state are managed by the public forest owner company. According to available data a total amount of wood stock is 418.6 million m3. Croatian wood-based industry has been developed on high quality forest raw material and as such, it represents an important economic segment of the country. On the other hand, beside seas and oceans, wood represents the most important atmosphere carbon storage, but no wood products manufacturers nor final customers, are aware of their role and possibilities of influence on decreasing of products negative influence on environment. The objective of this paper is to present production trends of selected wood products from 1900 to 2020 in Croatia aiming to motivate all relevant stakeholders within wood-based sector to pay more attention about its potential and emphasize its importance in achieving carbon neutrality goals.
Keywords: wood products; market; production trends;

1. INTRODUCTION

The total area of forests and forest lands in Croatia is 2,76 million ha, which is 49.3% of the land area of the country. Of this, 2,1 million ha are public owned forests, while 661,721 ha are owned by private forest owners. The majority of forests owned by the state are managed by the public forest owner company. According to available data a total amount of wood stock is 418.6 million m3. Croatian wood-based industry has been developed on high quality forest raw material and as such, it represents an important economic segment of the country.

From a global point of view, the use of wood and wood products and the production of energy and heat from wood, which depend on sustainable and proper forest management, leads to a long-term permanent and sustainable reduction of CO2 emissions (Lundmark et al., 2014). The International Union of Forest Research Organizations (IUFRO) emphasizes the very significant potential of the forestry sector to mitigate climate change, where it is very important to understand the importance of sustainable forest management and the necessity of developing strategies on the use of wood and wood products in mitigating climate change (Candell and Raupach, 2008). Sustainable forest management can greatly contribute to reducing the emission of carbon dioxide (CO2) into the atmosphere, and one of the ways is the storage of carbon in wood products and the use of wood in the production of heat and electricity, as a substitute for fossil fuels (Nabuurs et al., 2007). Forests, wood and wood products play a very important role, on the one hand, in the process of reducing emissions of harmful gases into the atmosphere, and on the other hand, in increasing the creation of reservoirs (places) for the atmosphere of harmful gases (Schalamadinger and Murland, 1996).

Investigating the potential of forestry and wood processing in Sweden, Lundmark et al. (2014) conclude that in order to optimize the domestic CO2 balance, it is necessary to increase the use of wood products, such as sawn timber, wood panels, etc. Using the Swedish and Finnish examples, Gustavsson et al. (2006) determined that the process of producing wooden building materials requires less energy consumption and emits less CO2 into the atmosphere, compared to the process of producing materials for concrete structures. The increased use of wooden construction materials represents an opportunity to reduce CO2 emissions due to the relatively low energy required for the production of wood products compared to other construction materials (metal, aluminum, concrete, etc.), furthermore, wood products and wood materials represent carbon reservoirs and increase production, and thus the availability and use of bio fuel from wood residues, which are created as a result of the use of wooden building materials and products (Gustavsson et al., 2006). The emission and storage of greenhouse gases resulting from activities within the LULUCF sector - The Land use, land-use change and forestry (LULUCF) are not included in the calculation of the 20% reduction in greenhouse gas emissions of gases at the EU level for the period up to 2020.

Beside seas and oceans, wood represents the most important atmosphere carbon storage, but no wood products manufacturers nor final customers, are aware of their role and possibilities of influence on decreasing of products negative influence on environment. The objective of this paper is to present production trends of selected wood products from 1900 to 2020 in Croatia aiming to motivate all relevant stakeholders within wood-based sector to pay more attention about its potential and emphasize its importance in achieving carbon neutrality goals**.**

2. THE IMPORTANCE OF CARBON NEUTRALITY IN THE CONTEXT OF THE EUROPEAN UNION

The idea and pursuit of carbon neutrality has been around for a long time, but the achievement of broader global consensus and action on the issue became evident two decades ago. At the UN Conference on Sustainable Development in 2012 (known as Rio+20), the concept of "green growth" and the need to transition to a low-carbon economy to address climate change were increasingly emphasized. However, a key moment in the quest for carbon neutrality was the 2015 climate conference UN (COP21) in Paris. This conference adopted the Paris Agreement (EC, 2016), which established a global consensus on how to combat climate change. The goal of the agreement is to limit global warming to less than 2 °C compared to pre-industrial levels, with an aspiration to limit it to 1.5 °C. In this way, almost all countries in the world, including the largest emitters of greenhouse gases, have committed to reducing their emissions and achieving climate neutrality in the second half of this century.With this goal in mind, in 2019 the European Union adopted the European Green Deal – a new growth strategy – whose central element is to achieve carbon neutrality by 2050 (EC; 2019). In addition, the Green Deal is an integral part of the Commission's strategy to implement the United Nations 2030 Agenda and the Sustainable Development Goals, and focuses on reducing greenhouse gas emissions in all sectors of the economy, including energy, industry, transport, agriculture and buildings. In this context, the wood industry also plays an important role in achieving carbon neutrality in the European Union. The sectors of the wood industry, such as forestry, wood processing and furniture manufacturing, can contribute to the reduction of greenhouse gas emissions and the sustainable use of resources, for example, by investing in sustainable forestry, using wood as a renewable material, reducing emissions from wood processing, the production and use of biomass, and the management of wood products and waste. In addition, the EU is taking various measures to support a sustainable and carbon-neutral timber industry. These include legislation to promote sustainable forest management, the promotion of sustainability certification, financial incentives for innovation in the wood industry, and support for research and technology development. An important step on the road to carbon neutrality is the adoption of the European Climate Act (EC; 2021a), which made the EU's climate neutrality by 2050 legally binding. Finally, the EU presented Fit for 55 in 2021 - a package of legislative proposals to reduce greenhouse gas emissions by at least 55% from 1990 levels by 2030 (EC, 2021b). The proposals cover energy, transport, industry, and other sectors and include revising the EU Emissions Trading Systeme, establishing a carbon cap management mechanism, promoting electromobility, and other measures.

3. WOOD-BASED SECTOR AND CARBON NEUTRALITY

According to the Decision of the European Parliament and the Council no. 529/2013. of May 21, 2013 on the rules for calculating emissions and outflows of greenhouse gases resulting from the activities of land use, changes in land use and forestry and on information related to these activities (Decision No. 529/2013/EU of the European parliament and the Council of 21st May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities) sector Land use, changes in land use and forestry (The Land use, land-use change and forestry) (LULUCF) in the European Union, of which the Republic of Croatia is a member, represents greenhouse gas storage facilities in an amount equivalent to a significant share of the total greenhouse gas emissions of the European Union.

Furthermore, the decision emphasizes how increased sustainable use of wood and wood products (Harvested wood products) can significantly limit greenhouse gas emissions into the atmosphere and, on the other hand, create space for storage.

4. MATERIAL AND METHODS

For the purposes of analysis of changes in carbon reserves in wood products, based on available materials: a) Statistical annual reports of the State Bureau of Statistics AND b) Statistical annual reports on wood products of UNEC/FAO (United Nations Economic Commission of Europe/Food and Agriculture Organization of the United Nations for the period from 1900 to 2020, data was collected on the following categories of wood products, which were classified and coded according to the JQ form (Joint FAO/UNECE/EUROSTAT Forest Sector Questionnaire): sawn wood; wood-based panels (veneer sheets, plywood and particle board) and paper and paper board. Additionally, a production of industrial round wood – wood in the rough was collected). For the purposes of systematizing data on defined categories of wood products, an MS Excel database was created, in such a way that a 'row' of the worksheet represents one wood product, and a 'column' of the worksheet represents the year for which the data is collected, which refers to the period from 1900. ending with 2020.

4.1. Data collection protocol and database of wood products

For the period from 1991 to 2020, the data was taken from the UNECE/FAO database, which the Republic of Croatia submits to the UNECE/FAO Forestry Department once a year, based on the data of the National Bureau of Statistics on the production, export and import of wood products (Harvested Wood Products – HWP).For the period from 1960 to 1991, data on wood products in the Republic of Croatia were taken from numerous statistical yearbooks, statistical reports, statistical bulletins, and statistical yearbooks, which are stored/available at the National Bureau of Statistics. For the period from 1900 to 1960, for certain years, data were found and taken from some of the previously mentioned statistical reports of the National Bureau of Statistics, while for other years, according to the recommendations of the IPCC Gudlines for HWP, they were prepared 'backward predictions'. According to the recommendations and instructions of the IPCC guide, the following formula (Equitation 12.6) was used to estimate the value of wood product data for the period from 1900 to 1960, which is presented in the IPCC guide in chapter 12 on page 12.18:

$$V_t = V_{1961} * e^{[U*(t-1961)]}$$

whereas:

V_t represents the annual production, import or export of wood products or paper products for a certain year *t*, (Gg C yr^{-1});
t represents the year for which the value prediction is carried out
V_{1961} represents the annual production, import or export of wood products or paper products for the year 1961, Gg C yr^{-1};
U represents the estimated continuous rate of change in industrial roundwood consumption of the region to which the reporting country belongs for the period 1900 to 1961, yr^{-1}.

According to Table 12.3 in Chapter 12 - Harvested wood products (Chapter 12 - Harvested wood products), page 12.18 of the IPCC guide, the estimated annual rate of change in log consumption for the Republic of Croatia in the period from 1900 to 1961 was 0.0151, considering that of the offered world areas, the Republic Croatia belongs to the territory of Europe.

After collecting all the data on defined wood products for the period from 1961 to 2013 and performing a 'backward forecast' of the data on defined wood products for the period from 1900 to 1961, the share of domestically produced logs (domestic harvest) in the Republic of Croatia in to the total log production of the Republic of Croatia for each individual year using the following expression:

$$SRC_t = \frac{(IRW_{production} - IRW_{export})}{(IRW_{prodiction} + IRW_{import} - IRW_{export})}$$

whereas:

SRC_t represents the share of domestically produced logs in the Republic of Croatia in the total production of logs for a certain year *t*, (m^3);
$IRW_{production}$ represents the amount of log production in a certain year, (m^3);
IRW_{export} represents the amount of logs exported in a certain year, (m^3);
IRW_{import} represents the amount of logs imported in a certain year, (m^3).

The calculated shares of domestically produced logs in the Republic of Croatia in the total production for a certain year (SRCt) were multiplied by the production values of each of the defined product categories (sawn wood; wood based panels and paper and paperboards), which defined the production values of defined product categories based on domestic production (domestic harvest) of the Republic of Croatia for each observed year in the period from 1900 to 2020 (FAO – Data/converted to production on the basis of domestic harvest for the county). The 'backward forecast' method was applied for all years of the mentioned product categories for the period from 1900 to 1960, based on the reference year 1961, so that the 'real' values were omitted from the database.Based on part of the existing data for paper and paper boards, the linear trend equation for the period from 1962 to 1981 was calculated:

$$y = 21582 \cdot t - 42231736$$

where ***t*** presents a year, a ***y*** value of variable paper and paper boards in tons.

The correlation coefficient r=0.99202183, as well as the coefficient of determination R2=0.98410732 are extremely high, which indicates that the trend equation perfectly describes the movement of the value of the variable in the analyzed period.

5. RESULTS

Given that wood products are carbon stores, the retention time of carbon in wood products is different because it depends on the type of wood product and its purpose, for example, firewood can be burned in the same year in which it was 'produced'; The lifespan of paper and paper products is usually less than 5 years (it may also include the recycling process), while sawn timber or wooden panels in wooden building elements can have a lifespan of more than 100 years). Likewise, 'used' wood products can be deposited in landfills where they can remain for a very long period of time (IPCC Guide, Chapter 12: HWP; p. 12.5). Despite the storage in wood products in use and wood products deposited in landfills, the carbon oxidation of these products in a given year may be less or potentially greater in relation to the total amount of wood products produced in that particular year. Globally, according to studies by Winjum et al. (1998) and according to UNFCCC reports (2003), it is to be expected that the amounts of carbon stored in wood products will increase (IPCC guide; chapter 12; p. 12.5 and 12.6).

5.1. Production trends of wood products from 1900 to 2020

As seen in Figure 1, in 1900 domestic production of sawn wood was 230.000m^3, in 1950 was 460.000m^3, followed by 630.000m^3 in 2000. In 2020 domestic production of sawn wood was 1.265.000 m^3. In 1900 domestic production of wood panels was 17.500 m^{3,} in 1950 was 37.200 m^3, followed by 77.000 m^3 in 2000. In 1900 domestic production of paper and paperboard was 36.000 m^3, in 1950 was 76.000 m^3, followed by 400.000 m^3 in 2000.

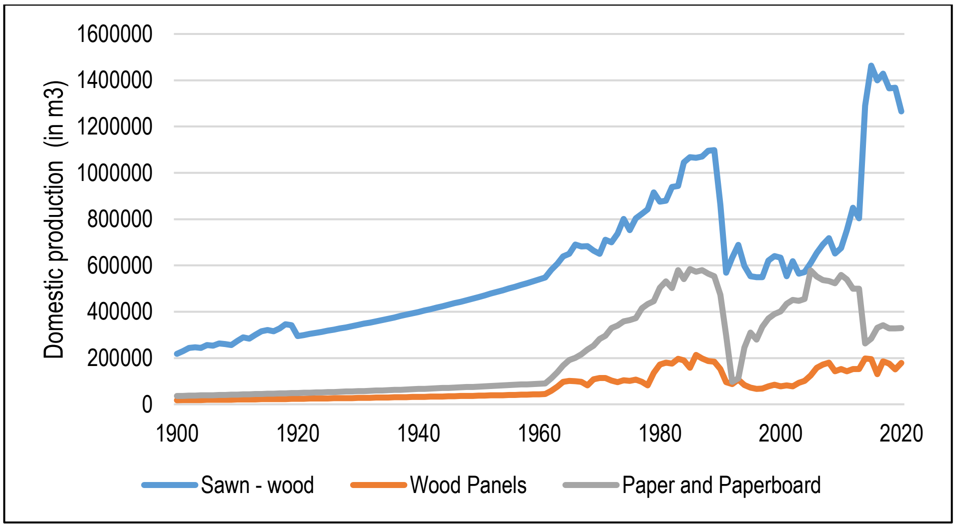


Figure 1. Domestic production trends of selected wood-products from 1900 to 2020

5.2. Projection trends of wood products production to 2050

Correlation analysis to determine the degree of correlation between the values of domestic production of sawn wood, wood panels and paper & paperboard as dependent variables and time (*t*) as independent variable were used. We found that the direction and strength of the correlation relationship was positive and relatively high in both cases (r_1=0,89 for sawn wood; r_2=0,90 for wood panels; and r_3=0,89 for paper &paperboard), so we developed linear trend models for prediction of future values of sawn wood, wood panel and paper & paperboard domestic production.

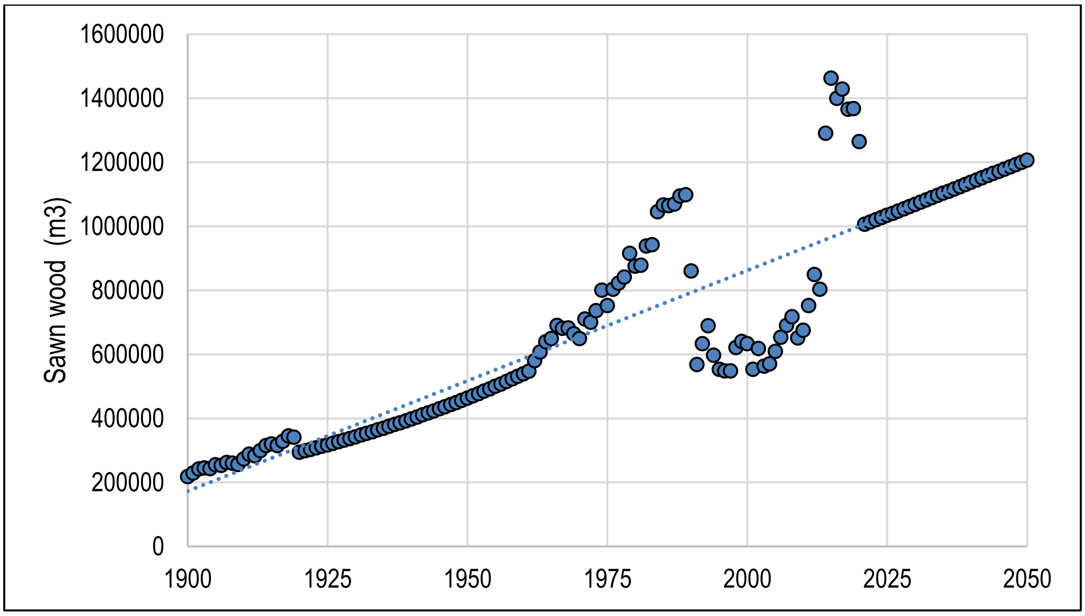


Figure 2. Existing and projected Sawn Wood domestic production values (in m^3)

In all models, *t* is mark for the *time*, where *t* = 0 compared to year 1900, *t* = 1 for year 1901; ... , *t* = 91 to year 1961, etc. Unit for predict values of sawn wood, wood panel and paper & paperboard is in m^3. Constructed models for predicting the future values of sawn wood, wood panel and paper & paperboard domestic production were as follows: y_1 = 6893,4x – 1E + 07; y_2 = 1394,4x – 3E+ 06; and y_3 = 4490,1x-9E+ 06

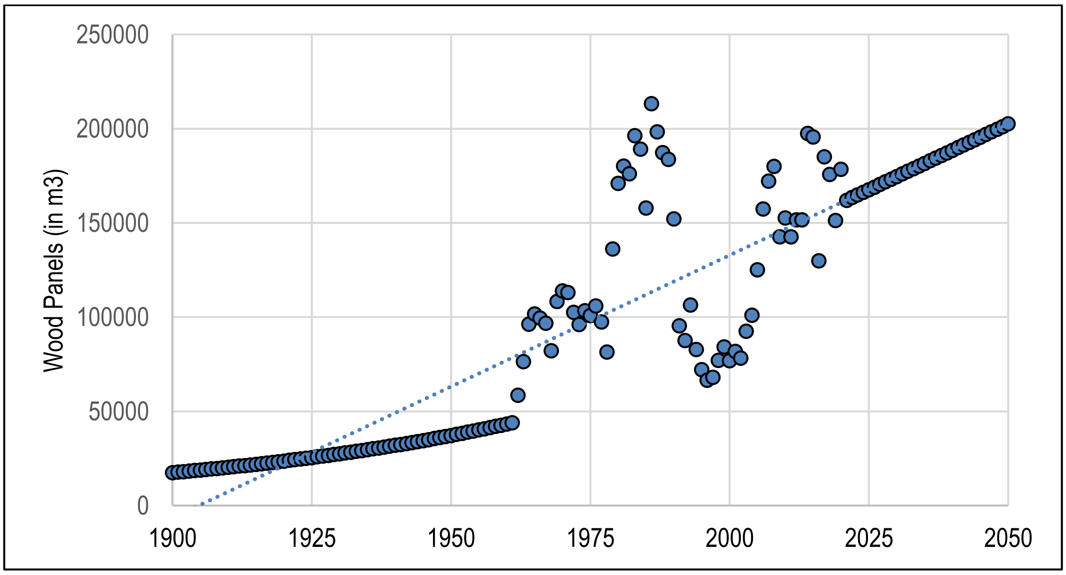


Figure 3. Existing and projected Wood Panels domestic production values (in m³)

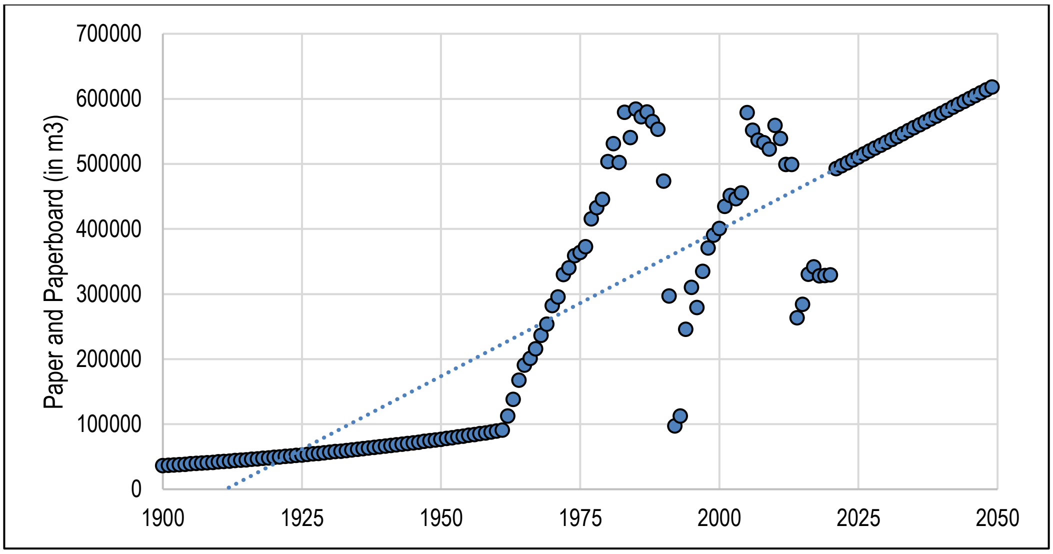


Figure 4. Existing and projected Paper & Paperboard domestic production values (in m³)

Comparison of existing and calculated predicted values by models for sawn wood, wood panels and paper & paperboard domestic production in m3 are shown in Figure 2 to Figure 4.

According to the linear trend model (Figure 2) the expected linear increase in the annual sawn wood domestic production values is 6.893 m3. The expected production of sawn wood domestic production according to the linear trend model in 2050 would amount to about 1.200.000 m3. According to the linear trend model (Figure 3) the expected linear increase in the annual wood panel domestic production values is 1.394 m3. The expected production of wooden panels according to the linear trend model in 2050 would amount to about 200.000 m3. According to the linear trend model (Figure 4) the expected linear increase in the annual paper & paperboard domestic production values is 4.490 m3. The expected production of paper and paper boards according to the linear trend model in 2050 would amount to about 600.000 m3.

6. CONCLUSIONS

According to this research, it is possible to conclude that there are high-quality statistical reports on the wood industry for a large number of years. The collected data of the requested product categories within the wood industry are uniform, which indicates the relative accuracy of the data. According to the projections (linear trend models), it is to be expected that in future periods the production of wood products, both sawn timber and wood panels, as well as paper and paperboard, will increase. It is very important to continue activities of collecting all relevant data of all categories of products from the field of wood processing and production of wood products in such a way that they are stored in a database created for this purpose and that they are updated in the shortest possible period of time, so the analysis of carbon storage parameters in wood products would be as accurate as possible.

REFERENCES

1. Candell, J.G.; Raupach, M.R. 2008: Managing forests for climate change mitigation. Science , 320:1456–1457.
2. European Commission (2019) The European Green Deal, Brussels, 11.12.2019 COM(2019) 640 final.
3. European Commission (2021b) „Fit for 55“: delivering the EU's 2030 Climate Target on the way to climate neutrality, Brussels, 14.7.2021 COM(2021) 550 final.

4. FAO/UNECE Forestry Department: FAO Yearbooks of Forest Products 2020 (2016 - 2020). FAO/UNECE Forestry Department. Food and Agriculture Organization of the United Nations, Rim, 2021.
5. Gustavsson, L.; K. Pingovd; R. Sathre, 2006: Carbon dioxide balance of wood substitution: Comparing concrete and wood framed buildings. Mitigation and Adoption Strategies for Global Change, 11: 667 – 691.
6. Lundmark, T.; J. Bergh; P. Hofer; A.Lundström; A. Nordin; B. C. Poudel; R. Sathre; R. Taverna; F. Werner. 2014. Potential Roles of Swedish Forestry in the Context of Climate Change Mitigation. Forests, vol.5: 557-578.
7. Nabuurs, G.J.; Masera, O.; Andrasko, K.; Benitez-Ponce, P.; Boer, R.; Dutschke, M.; Elsiddig, E.; Ford-Robertson, J.; Frumhoff, P.; Karjalainen, T.; et al. Forestry. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A., Eds.; Cambridge University Press: Cambridge, UK, 2007.
8. Official Journal of the European Union (2016) Paris Agreement, 19.10.2016, L 282/4.
9. Official Journal of the European Union (2021a) Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law'), 9.7.2021., L 243/1.
10. Winjum, J. K., Brown, S., & Schlamadinger, B. (1998). Forest harvests and wood products: sources and sinks of atmospheric carbon dioxide. *Forest Science*, *44*(2), 272-284.

Authors address:

Ćurić, Petar, Pirc Barčić, Andreja; Motik, Darko; Moro, Majal[1]; Basarac Sertić, Martina[2]; Meloska, Živka[3]
[1] Department for production management; Faculty of Forestry and Wood Technology, Zagreb, Croatia
[2] Croatian Academy of Sciences and Arts Act; Institute of Historical and Social Sciences; Zagreb; Croatia
[3] Faculty of Design and Technology of Furniture and Interior, Ss. Cyril and Methodius University, City, Skopje; Republic of North Macedonia
*Corresponding author: petar.curic@gmail.com; apirc@sumfak.unizg.hr

PSYCHOLOGICAL FACTORS INFLUENCING THE PERCEPTION OF FINANCIAL AND NON-FINANCIAL BENEFITS AND BARRIERS OF CONTROLLING IN THE COMPANY

Šatanová, A., Sedliačiková, M.

Abstract: In the presented paper, we have tried to approach the issues related to controlling, benefits of controlling and its barriers, as well as the psychological factors affecting the employees of the company. The main goal of this paper was to propose a model of implementation of controlling respecting the psychological aspects influencing the perception of controlling in the company. In order to fulfill the main goal of the article, it was necessary to study the first part of the issue of controlling, psychological aspects and internal interest groups, where more emphasis was put on employees. In the next part, we focused on the graphical and statistical evaluation of the results of the empirical survey, based on which it was possible to create a model of implementation. The conclusion was devoted to the evaluation of the achieved results and recommendations for the monitored wood processing enterprises.
Keywords: controlling, psychological aspects, employees, model of implementatio

PSYCHOLOGICAL FACTORS INFLUENCING IMPLEMENTATION OF CONTROLLING IN THE COMPANY

Controlling as a term entered the European terminology from the USA. In theory and in practice, we encounter different definitions of controlling. For this reason, we present only some of them. Controlling is also a tool that allows you to maintain the right direction and not lose sight of your goals (Foltínová, 2007; Šatanová, Potkany, 2004). Sometimes it is also understood as management support (Chodasová, 2012; Edelman, Van Knippenberg, 2018.). Controlling is characterized by a specific form of working with information. (Foltínová, 2007; Šatanová a kol., 2015). Gradually, new approaches and tools began to be developed, which can be used even today. We are talking about process-oriented managerial accounting and controlling (Kutáč, Janovská, 2012; Cuéllar, García-Gabrera, Déniz-Déniz, 2019). In the current practice of companies, we can see the intermingling of the Anglo-American and German concepts of controlling. (Bashir, 2017). The advantage of the controlling system lies in obtaining accurate, efficient and timely information for management purposes, which requires the development of internal accounting that will function independently (Sedliačiková, 2011, Sedliačiková a kol. 2015).

The use of psychology in economic practice means that we try to see in every economic situation the human factor, which is the most important and affects all activities (Mikulaštík, 2007, Becker, Ulrich, Staffel, 2011). There are 6 psychological rules that are suitable to apply for effective controlling (Waniczek, 2002). Among these 6 psychological rules we can include: motivation, communication, "feed-back", enforcement, creating trust and change (Eschenbach, 2000). Controlling finds its place in the field of human resource management, where we talk about personnel controlling (www.casopysy.euke.sk). Internal interest groups include: company owners, managers and employees (www.sjf.tuke.sk).

The goal of our article is to propose a controlling implementation model that will respect the psychological aspects affecting the perception of controlling by company employees. After processing the basic theoretical assumptions about controlling and psychological aspects, we conducted an empirical survey (questionnaire), where we found out how individual psychological factors influence the perception of the benefits and barriers of controlling. Based on the graphic and statistical display of the results, we proposed a model for the implementation of controlling to the company.

On the territory of the Slovak Republic, wood processing company (further on WPC/ still has the highest representation of micro, small and medium enterprises. The objective of the conducted empirical research was to find out what impact financial and non-financial benefits and barriers of controlling have on employees, taking into account individual psychological factors. The questionnaire is divided into four parts and consists of 18 questions. The first part of the questionnaire is focused on the company itself, its size, type (production, non-production), industry, length of operation, legal form and job position of the person filling out the questionnaire. In the second part of the questionnaire, we sought information about controlling in the company, whether controlling is implemented in the company, what activities precede its implementation, in what way is it most suitable for them to introduce controlling in the company, which of the mentioned psychological aspects have the greatest impact on the implementation of controlling in the company and which conditions influence its effective introduction.

In the third part, we focused on the benefits and barriers of controlling. With the questions in this section, we wanted to find out whether controlling is a necessity for the respondents, a good solution, a need caused by the environment or it is unnecessary. Next we studied what are the most significant financial and non-financial benefits and barriers to the implementation of controlling in the company for the respondent. The fourth part of the questionnaire is devoted to psychological aspects.

When defining the results of the questionnaire survey, it was necessary to determine a representative sample. The size of the research sample was determined based on the following mathematical relationship designed to calculate the minimum number of respondents included in the research:

$$n \geq \frac{(z^2 * p * q)}{\Delta^2} \qquad (1)$$

The minimum number of interviewed respondents in the formula is represented by *n*; the reliability coefficient represents the quantity *z*; the quantities *p* and *q* show the number of respondents expressed as a percentage. The value represented by the quantity Δ means the maximum permissible significant error (Kozel et al. 2006). For higher reliability of the research, namely up to 95.4%, we decided to set the value of the quantity z=2. We set the value of the maximum error for determining a representative sample to 5%. By inserting the individual values into the formula, we determined the minimum number of respondents for the reliability of the research (Kozel et al. 2006).

$$n = \frac{2^2 * 0{,}5 * 0{,}5}{0{,}05^2} = 400 \qquad (2)$$

After inserting the values into the formula, we found that the monitored set should consist of at least 400 respondents in order for the research to be reliable. Out of a total of 1,620 respondents, 471 took part in our survey, which is 29.07% of all respondents.

After summarizing and subsequent evaluation of the questionnaire survey, it is possible to state that 49% of employees work in companies where controlling has not yet been implemented. The trend of introducing controlling into the company is not yet as popular in the territory of the Slovak Republic as in Western Europe. However, the positive is the fact that more and more companies are planning to implement this complex management system and thus gain more control over their business activities. With the introduction of controlling, many changes come to the company, which can also cause certain concerns about this system. For that reason, we tried to find out what benefits or barriers are seen by employees in controlling. Our effort was also to find out their feelings about the introduction or also how individual psychological factors affect their perception of this system.

After summarizing the results, we found that the employees do not see any financial benefit in controlling, on the contrary, for them, controlling represents the streamlining of activities with the aim of minimizing costs.

According to employees, the most significant barrier to this system is excessive control. Looking at it from their perspective, this concern was somewhat predictable. Employees may feel less freedom, which may also result in conflicts at the workplace. Employees are also afraid of losing their current job position due to their possible lack of skills or knowledge. All of this can be prevented by properly informing employees about the changes that are to occur in the company.

We see the positive side of the results of the questionnaire survey in the fact that employees feel motivated by controlling. Since the implementation of controlling, employees expect a change in the motivational system, which will ensure a fairer assessment of their performance. However, the implementation of the system is also associated with feelings of fear, which we consider justified. Many employees do not know the concept of controlling and do not know its impact on business activity, and it evokes a kind of respect in them. However, any misunderstandings can be avoided with proper communication. After summarizing the results of the empirical survey, it was possible to move on to the design of the controlling implementation model, which should respect the needs of employees.

PROPOSAL OF THE CONTROLLING IMPLEMENTATION MODEL INTO THE COMPANY WITH RESPECT TO THE EMPLOYEES

After a thorough analysis of the results of the empirical survey, we proposed a model for the implementation of controlling in the company, which takes into account the psychology and requirements of the company's employees.

The implementation model itself consists of three basic phases: pre-implementation phase, implementation and final phase.

Pre-implementation phase

This phase consists of seven steps that must be fulfilled in order for the enterprise to be ready for the actual implementation of controlling.
Step no. 1- Determining the main objectives of controlling
Step no. 2- Overall analysis of the company
Step no. 3- Choosing the most suitable method of implementation
Through a questionnaire survey, we found that the introduction of controlling gradually by department represents the most suitable way of implementation for employees. The introduction of controlling from top management downwards or gradually by individual operations is also a consideration.
Step no. 4- Selection of controller
Step no. 5- Choice of suitable controlling software
The company has a choice of professional controlling software or software support through the Microsoft Excel program, which represents lower costs and is sufficient for the needs of such companies.
Step no. 6- Changing the employee evaluation system (motivational system)
Step no. 7- Informing employees about changes
In our case, **the phase of implementing controlling** into the company consists of six steps. A smooth transition between the individual steps will be ensured by the controller who, at the end of this phase, together with the management, will launch a trial version of controlling.
Step no. 8- Defining the main tasks of individual departments
Step no. 9- Defining the competencies and responsibilities of individual employees
Step no. 10- Preparing employees for changes in company management through additional education and training
Step no. 11- Implementation of controlling software in the company
After choosing the controlling software, it is important to adjust it by the supplier to meet the needs of the company. The software modification contractor uses the information obtained from the performed analyzes and the information provided by the management and the controller in the form of a consultation.
Step no. 12- Ensuring the correct flow of information between individual departments and also from top management down and vice versa
Step no. 13- Implementation of controlling in the company in the trial version
After the implementation of controlling in the company in the trial version, the last, **final phase** occurs, associated with the elimination of deviations and errors.
Step no. 14- Carrying out an in-depth inspection of the company by the controller and removing any errors that occurred in the trial version of the implementation
Step no. 15- Informing management and other employees about the course of controlling
Step no. 16- Extending the scope of controlling to the enterprise
Step no. 17- Introduction of controlling throughout the company
Controlling can be considered established only when it has its own position in the company and thus forms a comprehensive management system.
Step no. 18- Use of controlling
The final step of the entire implementation model is the active use of controlling in the company. After following all the previous steps along with taking into account psychological aspects, the use of controlling in the company should be problem-free and especially respected by its employees.

Evaluation of the achieved results

Among the most important benefits of the controlling implementation model with respect for the psychological aspects of the perception of this system by employees, we consider:

- division of the implementation process into three phases to ensure fluency,

- detailed description of individual steps to make activities more transparent and eliminate possible misunderstandings,
- a new created model that respects the needs of employees based on the results of an empirical survey and a scheme of psychological
- sufficient information and preparation of employees for the changes that are to occur in the company,
- the presence of a controller, whose main task is the constant supervision of the transition between the individual steps of the model,
- the possibility of adapting the model to the specific needs of any company, regardless of its size,
- the results of empirical research, which were presented through descriptive, graphic and statistical evaluation,
- a summary of the results of the questions regarding the benefits and barriers of controlling, its influence, the feelings it evokes into a diagram showing the psychological aspects,
- the final draft of the implementation model focusing on respecting the results of the questionnaire survey and the scheme of psychological aspects, thanks to which this model will have a positive effect on the company's employees.

REFERENCES

Al Samman, A., Ahmed, G. I., Aldeeb, H. M. A. 2018. *How Employees' Attitudes are Influenced by Organizational Change*: Evidence from a Non- Profit Organization in Bahrain. In International Journal of Economics and Management Studies, 2018, 5(12): 31-37.

Bashir, A. N. 2017. *Leadership connection to emotional intelligence and stress at workplace.* In Journal of Management Research, 2017, 9(1): 43-51.

Becker, W., Ulrich, P., Staffel, M. 2011. *Management accounting and controlling in German SMEs – do company size and family influence matter?* In International Journal of entrepreneurial venturing, 2011, 3(3): 281-300.

Cuéllar, M., García-Gabrera, A., Déniz-Déniz, A. M. 2019. *Emotional intelligence of the HR decision-maker and high-performance HR practices in SMEs*. In European Journal of Management and Business Sciences, 2019, 28(1): 52-89.

Dobroszek, J. 2015. *Analysis of factors affecting the implementation of controlling in logistics enterprises and the resulting effects – the case of Poland*. In Procedia – Social and Behavioral Sciences, 2015, 213: 248-253.

Dolinayová, A., Ľoch, M. 2015. *Controlling Instruments Used for Monitoring and Evaluation Processes in the Rail Freight Companies*. In Procedia Economics and Finance, 2015, 34: 113-120.

Edelman, P., Van Knippenberg, D. 2018. *Emotional intelligence, management of subordinate´s emotions, and leadership effectiveness.* In Leadership and Organization Development Journal, 2018, 39(5): 592-607.

Eschenbach, R. *Controlling*. Praha: ASPI publisching, 2000. ISBN 80-85963-86-8.

Foltínová, A. *Nákladový controlling*. Bratislava: Elita, 2007. ISBN 978-80-89085-70-5

Holá, J. *Interní komunikace ve firmě*. Brno: Computer Press, 2006. ISBN 80-251-1250-0

Horváth a Partners. *Nová koncepce controllingu*. 1. Praha: Profess Consulting, 2004. ISBN 80-7259-002-2.

Chodasová, Z. *Podnikový controlling*. Bratislava: STATIS, 2012. ISBN 978-80-85659-70-2.

Kubáni, V. *Psychológia práce*. Prešov: PU v Prešove, 2005. ISBN 80-8068-331-X

Kutáč, J. a JANOVSKÁ, K. *Podnikový controlling*. Ostrava: Technická univerzita Ostrava, 2012. ISBN 978-80-248-2593-9.

Letovancová, E. *Psychológia v manažmente*. Bratislava: Vydavateľstvo UK, 2010. ISBN 978-80-223-2783-1

Mikulaštík, M. *Manažerská psychologie*. Praha: Grada Pubishing, 2007. ISBN 978-80-247-1349-6.

Sedliačiková, M. 2011. Implementation of controlling in the selected company, *Journal of Economics and Social Research* 12(1): 45-53.

Sedliačiková, M.; Vaček, V.; & Sopková, E. 2015. How Slovak Small and Medium Enterprises Perceive Financial Controlling. *The 4th World Conference on "Business, Economics and Management":* Procedia Economics and Finance, Vol. 26, April 30 – May 2, Ephesus, Turkey. 82-85.

Srpová, J., ŘEHOŘ, V. a kol. *Základy podnikání*. Praha: Grada Publishing, 2010. ISBN 978-80-247-3339-5.

Steinocker, R. *Strategický controlling*. Praha: BABTEXT, 1989. ISBN 80-90017-82-5

Szarková, M. *Psychológia pre manažérov a podnikateľov*. Bratislava: Elita, 2009. ISBN 978-80-89393-00-8

Šatanová, A., Potkány, M. 2004. *Controlling – modern tool of company control*. In Ekonomický časopis, 2004, 52(2): 148-165.

Šatanová, A.; Závadský, J.; Sedliačiková, M.; Potkány, M.; Závadská, Z.; & Holíková, M. 2015. How Slovak small and medium manufacturing enterprises maintain quality costs: an empirical study and proposal for a suitable model, *Total Quality Management and Business Excellence* 26(11-12): 1146-1160. https://doi.org/10.1080/14783363.2014.916477

Verešová, M. *Sociálna psychológia: Človek vo vzťahoch*. Nitra: Enigma, 2007. ISBN 978-80-89132-47-8ň

Vybíral, Z. *Psychologie komunikace*. Praha: Portál, 2005. ISBN 80-7178-998-4

Výrost, J a I Slaměník, I. *Sociální psychologie 2*. Praha: Grada Publisching, 2008. ISBN 978-80-247-1428-8

https://www.sjf.tuke.sk/transferinovacii/pages/archiv/transfer/18-2010/pdf/110-119.pdf

http://casopisy.euke.sk/mtp/clanky/3-2005/hitka.pdf

http://www.ibispartner.sk/sk/manazment-a-podnikanie/404-manazeri-si-potrebuju-uvedomit-vyznam-dovery

http://www.libellius.com/blog/doveruju-vam-vasi-zamestnanci

http://www.sbagency.sk/sites/default/files/pictures/sprava_o_stave_msp_v_sr_v_roku_2016.pdf

https://www.etrend.sk/podnikanie/zamestnanec-klucovy-nositel-uspechu-firmy.html

Acknowledgements

This research was supported by Slovak Research and Development Agency, project number APVV-18-0378, APVV-18-0520, APVV-20-0004 and APVV-21-0051.

Authors address:

prof. Ing. Anna Šatanová, CSc.
College of International Business ISM Slovakia in Prešov
Duchnovičovo námestie 1, 080 01 Prešov, Slovakia,
e-mail: satanova@ismpo.sk
mobil: +421 905299828

prof. Ing. Mariana Sedliačiková, PhD.
Department of Economics, Management and Business
Faculty of Wood Sciences and Technology
Technical University in Zvolen
T.G. Masaryka 24, 960 01 Zvolen, Slovak Republic
tel: +421 45 5206 420
mob: +421 907 354 603

FOREST-BASED RESOURCE MANAGEMENT IN THE TRANSITION TO CARBON NEUTRALITY IN BULGARIA

Kirechev, D., Stanimirova, M., Ivanova, P.

Abstract: The report focuses on the role of forests as carbon sinks. The potential of the Bulgarian forestry sector to mitigate carbon emissions through the implementation of land use practices and land-use change is explored. The introduction of agroforestry practices can contribute significantly to solving the problems in this plan. Carbon management in forest ecosystems focuses on the amount of carbon stored as well as the rate at which new carbon is sequestered. Determining the impact of carbon cycle management will focus on forest areas across the country. It is theorised that sustainable management of forest systems has sustainable climate change benefits and long-term carbon neutrality.
Keywords: forests, LULUCF, decarbonisation, forest management, forest-based policy

1. INTRODUCTION

Ecosystems and protected areas are under pressure from climate change and other stressors. Observed impacts of climate change threaten biodiversity, affecting forestry, fisheries, agriculture and human health (European court of audition, 2019). The forest-based sector can contribute significantly to global climate change mitigation efforts. "The 'triple role' of forests – absorbing, storing and replacing carbon dioxide – contributes to reducing greenhouse gases in the atmosphere, while ensuring that forests continue to grow and provide a host of other services (European Parliament, 2021). The sector's contribution will depend largely on the sector's ambitions in this direction, the potential costs of these actions and the level of public support available. This implies a deeper look at achieving lasting reductions in GHG emissions and increasing the sink and retention capacity of forest ecosystems. By implementing effective forest-based management, the forest sector can adopt practices aimed at achieving carbon neutrality, with coherence between environmental and economic objectives. In the context of global climate change, the forest-based sector should take actions aimed at increasing its contribution to reducing GHG emissions and balancing anthropogenic GHG emissions from sources and removals by sinks (UNFCCC, 2015). This can be done by increasing carbon stocks in forest areas and wood products and by substituting fossil fuels in economic sectors with renewable energy sources from the forest sector. In this sense, in the context of international agreements and policies, the aim of this study is to explore the possibilities and assess the management of the Bulgarian forest sector to carbon neutrality.

1.1. International commitments and European Union policy in the forest-based sector to achieve carbon neutrality

The Republic of Bulgaria is an active party in complying with its obligations under a number of international agreements aimed at the sustainable and multifunctional management of its forest potential. Bulgaria has accepted the 1992 United Nations Framework Convention on Climate Change (UNFCCC) and the additional measures adopted by the Kyoto Protocol, which introduced measures and binding targets to reduce greenhouse gas emissions and set policies aimed at sustainability in socio-economic terms.

In December 2007, the UN General Assembly adopted a non-legally binding instrument on all types of forests (United Nations, 2007), which seeks to 1) strengthen political commitment and action at all levels in implementing sustainable management of all types of forests; 2) increase the contribution of forests to the achievement of internationally agreed targets included in the Millennium Development Goals; 3) provide a framework for national action and international cooperation. Countries, including Bulgaria, have agreed to implement the principles of sustainable forest management at national level and to cooperate at international level for their implementation.

In December 2015 at the 21st UN Climate Conference in Paris (Paris Agreement is a legally binding international treaty on climate change), a legally binding commitment was adopted to contain temperature increases and reduce carbon emissions, which Bulgaria signed in 2016. The need to enhance the ability of all countries to adapt to the adverse effects of climate change by preparing for and promoting climate resilience and reducing greenhouse gas emissions was also recognised.

In 2018, the 13th session of the United Nations Forum on Forests (UNFF13) adopted an Omnibus Resolution on Forests (Omnibus Resolution). It recommends increasing global efforts to address forest issues, including by supporting the development of sustainable supply chains in the agriculture and forestry sectors, as well as "greening" the financial sector by prioritizing support for investments in this direction.

The 2018 update of the EU Bioeconomy Strategy (European Commission, 2018) had to respond to changed policies related to the transition towards sustainability, circularity and carbon neutrality, which also changed the scope of the strategy. It includes and interconnects: ecosystems and the services they provide; all primary production sectors (including forestry); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy and services. The main objectives of the bioeconomy set out in the strategy are: ensuring food security; sustainable management of natural resources; reducing dependence on non-renewable resources; mitigating and adapting to climate change; creating jobs and maintaining European competitiveness.

The EU Biodiversity Strategy 2030 (European commission, 2020) is an ambitious and long-term plan to conserve nature and reverse ecosystem degradation. Member States have made commitments to contribute to what has been agreed in the international negotiations on the post-2020 global framework for biodiversity. The strategy is a core element of the European Green Pact, with a particular focus on supporting an environmentally sound recovery from the COVID-19 pandemic.

In 2021, the European Commission adopted the EU Forest Strategy 2030 as one of the guiding elements of the European Green Pact, which builds on the EU Biodiversity Strategy 2030. The measures and actions proposed in the document rely on increasing carbon sequestration through improved sinks and stocks, thus expected to contribute to climate change mitigation. The Strategy commits Member States, including Bulgaria, to rigorously protect primary and ancient forests, restore damaged forests and ensure their sustainable management in a way that preserves the vital ecosystem services that forests provide and on which society depends. The strategy promoted the implementation of the most climate- and biodiversity-friendly forest management practices, stressed the need to keep the use of woody biomass within the limits of sustainability and promoted the resource-efficient use of wood. Greenhouse gas emissions and removals from forests and forest products will play a significant role in achieving the Union's ambitious net removals target of 310 million tonnes of carbon dioxide equivalents, as set out in the proposal to amend the Land Use, Land-Use Change and Forestry (LULUCF) Regulation The paper also sets out the policy framework for ensuring growing, healthy, diverse and sustainable forests in the EU, which contribute significantly to our biodiversity ambition, provide rural and non-rural livelihoods and support a sustainable forest bioeconomy that relies on the most sustainable forest management practices. The strategy is accompanied by a roadmap for planting three billion additional trees across Europe by 2030 in full respect of environmental principles.

1.2. Role of the forest-based sector in achieving carbon neutrality

It is recognised that greenhouse gas emissions contribute to almost all anthropogenic climate warming. Carbon dioxide is the most significant greenhouse gas trapping solar heat and warming the global climate. Forests have a great capacity to recover and adapt to damage, disturbance and weather impacts. However, climate change is intensifying these pressures, causing more frequent insect outbreaks and more frequent droughts and storms. Land-use change and fragmentation are hampering the connectivity of European forests, which is also hampering the natural processes of forest adaptation. This has huge economic implications, but also affects air quality, water quality, biodiversity and ecosystem services.

Forests act as a carbon sink as more carbon is absorbed than is released. How large a sink forests can be expected to be depends on the use and management of the forests, on climate impacts and on the intensity and frequency of other disturbances. The LULUCF (Land Use, Land Use Change and Forestry) sector includes emissions and removals from forest carbon pools – above and below ground biomass, dead wood, litter, mineral and organic soils. Carbon stored in wood products (standing timber, slabs and paper) is accounted for in the harvested wood products pool and is estimated separately. The LULUCF sector includes the land use categories: forest land, cropland, grassland, wetlands, human settlements and other land. Forest areas are the main net sink of the LULUCF sector. Harvested wood products are also a sink, while croplands, grasslands, wetlands and urban areas are net emitters.

The current EU LULUCF Regulation was adopted in 2018 as part of the energy and climate policy framework for the period 2021-2030 and contributes to the EU's target of reducing emissions by at least -40% by 2030, including in the land use sector. In July 2021, the European Commission adopted a set of proposals to make the

EU's climate, energy, transport and taxation policies fit to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. (European Council). EU Member States must ensure that reported greenhouse gas emissions from land use, land-use change or forestry are balanced by at least an equivalent reported removal of CO_2 from the atmosphere in the period 2021-2030 (Forest and climate): *EU LULUCF Greenhouse gas (GHG) Emissions (+) / Removals (-)*. Harvested wood products also store carbon. GHG inventories distinguish between three types of wood products: timber, panels and paper. Carbon is stored in the wood product over a period of time related to its use. At the end of the life cycle of the product and when released to the atmosphere, the carbon that was previously stored in the wood product is considered as an emission in the greenhouse gas inventory (Forest and climate). When more carbon enters the wood product pool than has reached the end of the life cycle, then carbon accumulation occurs in the products and this is reported as a net sink in the GHG inventory. Wood products can be accounted for as additional carbon sequestration in the GHG inventory, as the loss of biomass due to harvesting is already accounted for in the biomass of forest land. In the years from 1990 to 2021, net forest carbon sequestration in the EU ranges from -457 Mt to -289 Mt and in Bulgaria between -15,4 Mt and 8,7 Mt. (Figure 1). The overall contribution to carbon sequestration from the years amounts to about 7-8% of EU emissions and about 14-17% of Bulgaria's emissions. This indicates a fairly stable carbon sink capacity of forests.

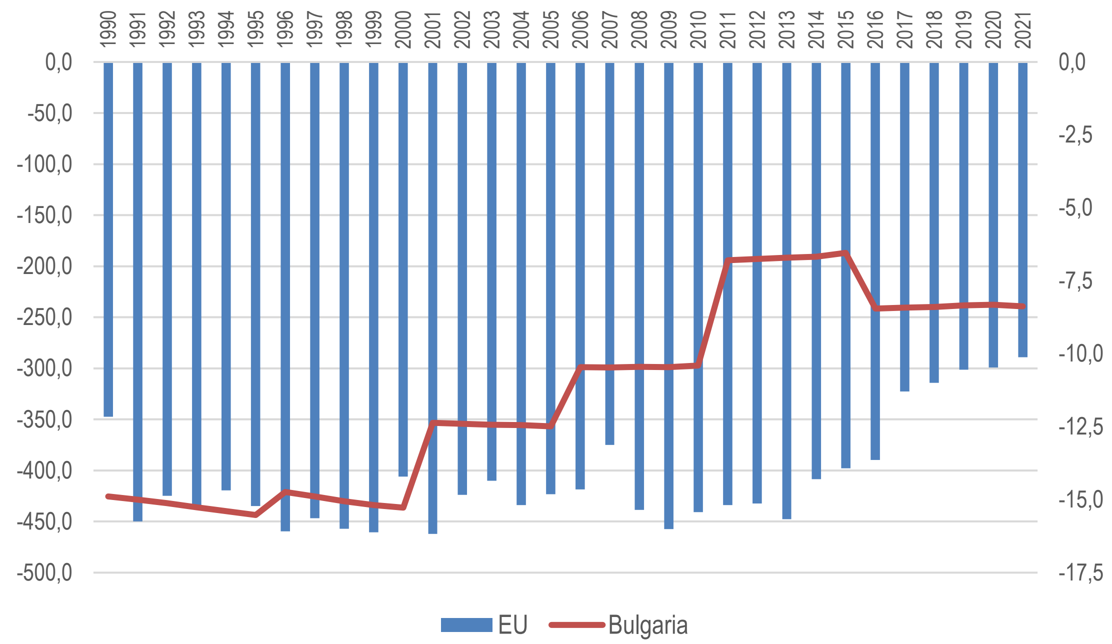


Figure 1. Net forest carbon sinks in the EU and Bulgaria 1990-2021 (Mt)

Source: European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer)

The downward trend in net carbon sequestration in the EU and Bulgaria is a consequence of the increase in wood harvesting. Since 2000, there has been a steady increase in logging in Bulgaria. In spite of the increase in wood removals, harvesting in these years is still below the planned harvest. In 2019, timber harvest is 20% higher than in 2010, as it has reached planned levels since 2012. The increase in harvest since 2011 is a response to market demand and also to the fact that since the adoption of the new Forestry Law in 2011 there has been an organisational change in the management of forestry activities and in most cases the planned harvest according to the plans has been implemented. Even with such an absolute increase in harvesting, the stock of plantations in Bulgaria has been increasing over the years and is expected to increase over the next 20-30 years. Despite the observed reduction, the share of removals in total greenhouse gas emissions (in CO_2eq) is still remarkable. The reason for this is that emissions in other sectors have decreased dramatically.

Achieving climate neutrality by 2050 will require drastic decarbonisation of sectors such as energy, transport, industry, agriculture, etc. As assessed by the European Commission (European Commission's Knowledge Centre for Bioeconomy, 2021), for the EU to become climate neutral by 2050, net removals from LULUCF would need to reach around -425 $MtCO_2e$/year. The European Commission estimates that for the EU to become climate neutral by 2050, the net uptake from LULUCF will need to reach around -425 $MtCO_2e$/year (EC, 2020b) in order to offset other GHG emissions, for example from agriculture and some industrial sectors. For forest areas, this scenario implies an increase in net removals from the current level to -450 $MtCO_2e$/year by 2050. The mitigation potential, combined with other aspects of sustainability, of using wood to replace GHG-intensive materials and of using wood for energy are attracting increasing attention in scientific and policy discussions.

In addition to their role as carbon sinks, forests provide other ecosystem services other than wood supply and carbon sequestration (e.g. regulating the water cycle, protecting against erosion, maintaining and conserving biodiversity, providing cultural and social benefits). Therefore, modern forest management must balance the different services, so that society can make the most of all the benefits.

2. THE FOREST SECTOR IN BULGARIA IN THE TRANSITION TO CARBON NEUTRALITY

2.1. Forest-based sector potential for carbon neutrality

According to the data of the Executive Forest Agency in Bulgaria, the forests and forest areas in 2021 are 4 270 thousand hectares and the trend is to increase. The forested area is 3 921 ha and the unforested area - 348 ha. The forest areas are 3 949 thousand ha. Almost 77,8% of the forests are state owned. The total stock of wood in forests is 680,5 million m^3 in 2015 and 718,4 million m^3 in 2020. The average stock per ha increased from 178 to 184 m^3/ha. The total increment is 13,5 million m^3 and the average is 3,48 m^3/ha. The average age of forests in the country is increasing to 60 years, which explains the decrease in increment from 14,3 million m^3 in 2010 to 13,5 million m^3 in 2020. Forest density in the territory increases to 35,3% by 2020. The stock by forest group is as follows: 44% are coniferous, 31% are deciduous; 23% are suckers and 2% are low stands. The total forested area for the period increased in all forest types, except coniferous forests, due to the drying of crops and their transformation into broadleaves. Total stock and stock per hectare increased in all forest types except low-status forests. The average age increases in all forest types, reaching 80 years in broadleaved forests and 60 years in coniferous forests (Executive Forest Agency).

The total stock of forests in Bulgaria by 2020 is set at 718 410 thousand m^3 (compared to 644 840 thousand m^3 in 2010), of which 62,2% are concentrated in forests with special functions, 8,5% are included in protective forests and 29,4% in commercial forests. Of the total stock, 5% is the stock of forests on agricultural land. The total stock of forests with tree-producing and environment-forming (economic) functions is 210 919 thousand m^3, which compared to 2010 (372 229 thousand m^3) is a decrease of 44% on account of the increase of forests with special functions, which include forests in Natura 2000 areas. The average stock of wood per 1 ha is 184 m^3. The average wood stock per hectare in coniferous and broad-leaved (tall-stem and conversion-shoot) forests in 2020 was 222 m^3/ha and 117 m/ha, respectively. A clear trend of increasing stock per hectare is outlined for all forests, except for low-stemmed ones. The sustainable growth of the stock is at the expense of coniferous and broad-leaved tall-stemmed forests. The basis of this trend is the annual growth of forest plantations, the forestry activities carried out for their cultivation and regeneration and the significant increase in the forested area. Reduces the growth and stock of young forests as a result of the uneven transition of individual stands from one age class to another. For forests aged 1-20 years, the wood stock as of 2020 has decreased by 12 501 thousand m^3 compared to 2010, for forests aged 21-40 years, the decrease for the same period is 45,874 thousand m^3, and for 81-100 the decrease was 6,771 thousand m^3. For all other age classes, there was an increase in the wood stock compared to the data from 2010, and the total stock was increased by 73,849 thousand m^3. There is an increasingly permanent transformation of forests with economic functions into forests with protective and special ones.

Carbon stocks in woody biomass and soils in forest and other wooded areas is an indicator related to society's efforts to mitigate climate change by reducing net greenhouse gas emissions to the atmosphere. As trees grow and physiologically function, carbon accumulates in biomass. As a result, forests contain large stocks of carbon. There are also carbon stocks in dead organic matter and soils. These carbon stocks can either increase or decrease, depending on what type of forest management practices are adopted. Changes in carbon stock levels in the three main carbon pools - biomass, dead organic matter and soils - form the basis for calculating the uptake or release of CO_2 from forests. This estimate makes it possible to determine the extent to which forests offset GHG emissions and help mitigate the impacts of climate change.

The estimated carbon stock in the biomass of deciduous forests in 2020 is 50 Gg, while for coniferous forests it is 90 Gg. Data for the period 1995 to 2020 show an increasing trend (Figure 2).

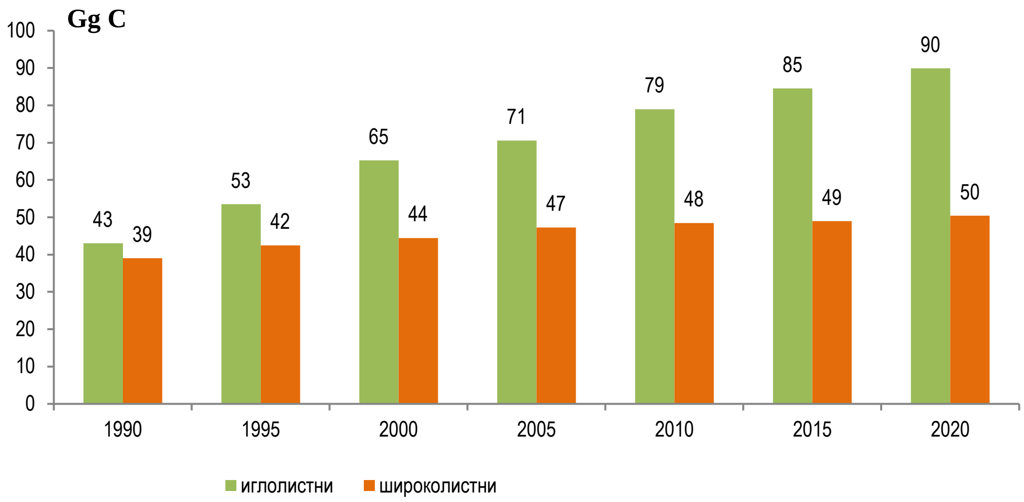


Figure 2. Carbon stock in biomass of coniferous and deciduous forests (Gg), 1995-2020.

Source: (National Report on the State and Protection of the Environment, 2020, 2022)

Data from the National Greenhouse Gas Inventory Report (Executive Environment Agency, 2023) for Bulgaria for 2020 show that the LULUCF sector is a net sink of CO_2. This is mainly due to the "Forests" category, which is responsible for absorbing 90% of the total emissions for the sector or about 8 600-8 800 Gg CO_2 eq per year for the last 5 years. The GHG uptake of the Forestry category has decreased by 47% compared to the base year of 1988. This is due, on the one hand, to the increase in the average age of the forest in Bulgaria and, on the other hand, to the gradual increase in wood harvesting over the last two decades. At the same time, the sector's carbon sequestration has stabilised at the same level in recent years, with a positive upward trend over the last four years, due to the increase in forest area.

2.2. Managing the forest-based sector in the context of carbon neutrality

Determining the most effective mitigation strategies in the forest sector requires a systems perspective (IPCC, 2019), (Kurz, Smyth, & Lemprière, 2016) which implies an analysis of the effects of forest conversion, the flows between forest carbon pools (including living biomass, dead organic matter, and soils) and the harvested wood products pool, and the interactions between the forest sector and other sectors (European Commission's Knowledge Centre for Bioeconomy, 2021).

The choice between different forest management practices has a crucial step in forestry decision-making and in establishing measures to support regional or national forest policy (Duncker, et al., 2012).

Changes in forest carbon stocks are influenced by wood extraction and processing. Increasing harvest increases the level of carbon sequestered in wood, but decreases the carbon sink capacity of forests (European Commission's Knowledge Centre for Bioeconomy, 2021). Longer use of processed wood products retain carbon for longer. Therefore, one way to store carbon in processed wood products is to increase the yield, but only if the duration of processed wood used is long enough to reduce the amount of unabsorbed carbon. This is an untapped potential for transition that will increase the sustainability of the forest-based sector. The balance between total average annual growth and average annual wood use is one of the most important indicators for assessing sustainable forest management. For the period 2005-2010 to 2020, the average annual increment increases from 14,1 million m^3 to 14,4 million m^3 of wood in 2010 and starts to decrease to 13,6 million m^3 by the end of 2021. Logging is the main silvicultural tool used to manage forests and guide the processes in forest ecosystems to balance the ecological, economic and social functions of forests. During the period under review, industrial timber harvesting accounted for an average of 53% of reported annual timber production. The remainder, 40%, represents the volume of wood harvested and used as standing timber at the root. For the period 2013 to 2021, there is an increase in the share of standing timber harvested from 42 % in 2013 to 52 % in 2021. The amount of roundwood harvested during the period under consideration varies between 5 830 thousand m^3 and 7 046 thousand m^3.

Maintaining the health and vitality of forest ecosystems is done on the basis of the ecological approach to forest protection and by carrying out timely silvicultural and forest protection activities and applying harmless biological forest protection agents. During the period 2013-2020, forest health is good. The damage detected ranged from 1.3% to 3.8% of the total forest area in the country, and plant protection measures were carried out in more than 30 thousand ha.

With a forested area for the country of 3 896 thousand ha, the amount of annual use from all logging represents 1,79 m^3/ha or 51,4% of the average annual increment per hectare. This indicates good sustainability of the management of Bulgarian forests and a significant potential for increasing their use and carbon sequestration capacity. The volume of afforestation activities carried out and the total annual amount of forested areas in the period 2013-2021 is uneven by year: 2013 – 1 255,8 ha, 2015 – 2 638,2 ha, 2021 – 1 793,4 ha.

At the end of 2021, the total number of protected areas in Bulgaria is 1 025 with a total area of 583 625,9 ha or approximately 5,3% of the country's territory, divided into the following categories. The total area of protective, recreational and other protective forests and forests in protected areas (respectively forest areas with protective and special functions) increased from 1 583 533 ha (38,3% of the total area of forest areas) to 2 872 278 ha (67,2%). The total area of forest areas with harvesting and environment-forming functions (respectively forests with economic functions) during the same period decreased from 2 554 564 ha (61,7%) to 1 398 717 ha (32,7%), mainly on account of the included protected areas for the conservation of natural habitats of wild flora and fauna. By 2020, forest areas included in the European Natura 2000 ecological network account for more than 57% of the total forest area. The increase in protected forests has important implications for improving the ability of forests to sequester carbon.

3. CONCLUSION

Forests and forestry are more closely linked to climate than any other sector in the economy. Forest conservation, sustainable forest management and the even and long-term use of wood have a positive effect on the uptake of CO_2, a greenhouse gas linked to rising air temperatures. On the other hand, climate change can have a negative impact on the health of national forests. The release of CO_2 into the air from pollutants can be reduced as a result of carbon sequestration and fixation in forests, the substitution of fossil fuels, and the storage of CO_2 in long-lived wood products. The state of Bulgaria's forests allows this potential to grow and its importance in achieving carbon neutrality to increase.

Acknowledgements: The author thanks the Scientific Research Fund for the support in carrying out the work on the POZESIN project "Land Relations and European Policy: Synergy and Prospects for Bulgarian Agriculture", contract № КП-06-Н35/2-18.12.2019, funded by the National Research Fund at the Ministry of Education and Science of Bulgaria.

REFERENCES

1. Duncker, P. S., Barreiro, S. M., Hengeveld, G. M., Lind, T., Mason, W. L., Ambrozy, C., & H, S. (2012). Classification of forest management approaches: a new conceptual framework and its applicability to European forestry. *Ecology and Society, 17*((4)).
2. European Commission (2018). A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. *Updated Bioeconomy Strategy*. Luxembourg: Publications Office of the European Union.
3. European Commission (2018b). A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment. *COM(2018) 673 Final*. Brussel: European Commission.
4. European commission (2020). EU Biodiversity Strategy for 2030. Bringing nature back into our lives. *COM (2020) 380 final*. Brussels: European Commision.
5. European Commission. (2021). New EU Forest Strategy for 2030. *COM(2021) 572 final*. European Commission.

6. European Commission's Knowledge Centre for Bioeconomy (2021). *Brief on the role of the forest-based bioeconomy in mitigating climate change through carbon storage and material substitution.* European Union.
7. European Council Fot for 55. https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/.
8. European court of audition (2019). *EU greenhouse gas emissions: Well reported, but better insight needed into future reductions.* Special Report.
9. European Parliament (2021). Regulation (EU) 2021/1119 of the European Parliament and of the Council. *establishing the framework for achieving climate neutrality*. Official Journal of the European Union.
10. Executive Environment Agency (2023). *National Inventory Report 2023. Greenhouse gas emissions in Bulgaria.* Ministry of Environment and water of Republic of Bulgaria.
11. *Executive Forest Agency*. Retrieved 5 14, 2023, from http://www.iag.bg/
12. *Forest and climate*. from Forest Information System for Europe: https://forest.eea.europa.eu/topics/forest-and-climate/introduction
13. IPCC (2019). *Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [Shukla et al. Eds.].* Intergovernmental Panel on Climate Change.
14. Kurz, W., Smyth, C., & Lemprière, T. (2016). Climate change mitigation through forest sector activities: principles, potential and priorities. *Unasylva 246, 67*(1), 61-67.
15. *National Report on the State and Protection of the Environment, 2020* (2022). Retrieved 5 14, 2023, from Executive Environmental Agency: https://eea.government.bg/en/output/index.html
16. *Paris Agreement is a legally binding international treaty on climate change*. Retrieved from United Nations Climate Change: https://unfccc.int/process-and-meetings/the-paris-agreement
17. UNFCCC (2015). *Adoption of the Paris Agreement. Report No. FCCC/CP/2015/L.9/Rev.1.* United Nation.
18. United Nation (2007). Resolution adopted by the General Assembly . *Non-legally binding instrument on all types of forests, A/RES/62/98*. United Nations.

Authors address:

Kirechev, D.,[1 *]; Stanimirova, M.[1]; Ivanova, P.[1]
[1] Department of agricultural economics, University of economics - Varna, Varna, Bulgaria
[*]Corresponding author: dkirechev@ue-varna.bg

POTENTIAL OF THE FOREST-BASED SECTOR FOR THE DEVELOPMENT OF BULGARIA'S BIOECONOMY

Kirechev, D., Stoyanova, A., Marinova, V.

Abstract: Bulgaria's forests have untapped potential for bioeconomy development. Based on the forest sector, the bioeconomy provides jobs, wood products for industry and renewable energy. The forest bioeconomy covers the whole value chain. Bulgaria's forest sector can play an important role in the country's climate change mitigation policy by providing sustainable materials for construction, insulation materials, packaging, biofuels, etc. Forests are crucial for maintaining biodiversity and provide regulating and cultural ecosystem services. The forest sector in Bulgaria faces a number of challenges due to changes in the quality of forest potential, illegal logging, climate change, etc.
Keywords: bioeconomy, forests, forest-based sector, sustainability

1. INTRODUCTION

1.1. Bioeconomy and forestry

Although the term "bioeconomy" was introduced more than a hundred years ago, the understanding of bioeconomy has undergone significant changes over time (Beluhova-Uzunova, Shishkova, & Ivanova, 2019). The bioeconomy is a modern concept involving a range of policies that has found popularity in recent decades. It refers to the production and use of biological resources to provide products, processes and services in a range of economic sectors, with the aim of achieving a sustainable economic system. The bioeconomy as a concept has been formulated by the OECD as a world through which biotechnology contributes a significant share of economic output and involves the exchange of knowledge derived from the natural sciences towards new, clean, eco-efficient and competitive products (OECD, 2009). With the adoption of the Europe 2020 strategy (European Commission, 2010), the European Union has accepted that it must radically change its approach to the production, consumption, processing, storage, recycling and disposal of biological resources. The Europe 2020 strategy calls for a bioeconomy as a key element for smart and green growth in Europe, allowing for improved management of Europe's renewable biological resources and opening up new markets for bio-based products.

According to the European Commission (European Commission, 2012), (European Commission, 2018b), the bioeconomy encompasses all sectors and systems that rely on biological resources, their functions and principles. The 2018 update of the Bioeconomy Strategy optimises the contribution of the bioeconomy to key European policy priorities by enhancing its sustainability (European Commission, 2018b). The sustainable bioeconomy is the renewable segment of the circular economy (European Commission, 2018a). The scope of the strategy includes: policies targeting biomass providing sectors (agriculture, forest-based sector), fisheries, aquaculture and seaweed, waste); policies targeting biomass using sectors (food and food security, energy, bio-based industries); cross-cutting policies related to the bioeconomy (environmental protection and climate change, regional policies - smart specialisation, research and innovation, industrial policy) (European Commission, 2018a).

In the new realities defined by the bioeconomy concept, forests and the forest-based sector have the opportunity to take the lead in the sustainable development of a circular bioeconomy. A forest-based bioeconomy provides jobs for the population, wood and non-wood materials harvested sustainably and is the bio basis for renewable energy production. At the same time, it supports livelihoods and multiple regulatory and cultural ecosystem services, ultimately contributing to climate change mitigation and a sustainable future. The bioeconomy should pave the way for an unprecedented expansion of the forest-based sector by opening up new markets and perspectives on how forest resources will be managed (Duchesne & Wetzel, 2003). Demand for forest resources can be expected to increase when the forest-based sector becomes a preferred source of energy, building materials, pharmaceuticals, food and food additives, consumer products, etc. The forest-based bioeconomy can contribute to climate change mitigation through the use of sustainably sourced, innovative and bio-based products that sequester carbon from the atmosphere and replace non-renewable materials and energy. Examples include building materials, chemicals, plastics, textiles, insulation materials and packaging. Forests can be critical for biodiversity and provide many other regulating and cultural ecosystem services, including many non-wood forest-based products (Forest and bioeconomy). In the context of the adoption in 2021. The EU Forestry Strategy 2030 (European Commission, 2021), adopted in 2021, relies on forests and the forest-based sector to provide socio-economic functions and benefits, including additional jobs, rural growth opportunities, recreational functions contributing to the physical and mental health of citizens. The EU Forest Strategy promotes and aims to stimulate a whole sustainable forest-based bioeconomy that works in synergy with the EU's enhanced climate and biodiversity ambition, including: promoting a sustainable forest-based bioeconomy for durable wood products; ensuring the sustainable use of wood-based resources for bioenergy; promoting a wood-free forest-based bioeconomy, including ecotourism; developing skills and empowering people for a sustainable forest-based bioeconomy.

The forest-based bioeconomy is defined by several categories following the supply chain logic - forests, forest biomass and raw materials, primary wood processing and secondary wood processing (Lovrić, Lovrić, & Mavsar, 2017). The scope of this study is the forestry sector and wood processing industry in Bulgaria. Bulgaria's forests are a key ecosystem and the forestry and wood processing sector has an important place in the country's economy and in providing employment. Over the last decade, the forestry sector in Bulgaria has faced challenges due to increasing management demands, climate change, achieving balance and sustainability in forest resource consumption, etc. In this sense is the aim of this study - to examine and assess the state of the forest-based sector, the place of the forest-based sector in the bioeconomy of the country and to look for opportunities to increase the potential of the forest-based sector in the bioeconomy of Bulgaria. The range of bioeconomy sectors covered in this study is based on data and a framework defined by the Joint Research Centre (JRC) of the European Commission (Joint Research Centre), studies in the literature focused on the scope and mapping of the bioeconomy (Lovrić, Lovrić, & Mavsar, 2017), (Grossauer & Stoeglehner, 2020), (Beluhova-Uzunova, Shishkova, & Ivanova, 2019), (Branzova, 2019), (Toteva, Popov, & Marinov, 2020) and evaluating the bioeconomy (Wolfslehner, et al., 2016), (Parobek, Rokonalová, & Slašťanová, 2022), (Di Cori, Robert, Franceschinis, Pettenella, & Thiene, 2022).

1.2. Status and assessment of Bulgaria's forest sector

Forests and forest areas in the Republic of Bulgaria cover approximately 4 270 million hectares, which represents 38,5% of the national territory. They are valuable ecosystems, carbon sinks, protected and recreational areas, and important suppliers of raw materials. In addition to protecting forests, their sustainable management and use must be ensured.

The Europe’s forest-based industries have an important role in strengthening the European low-carbon circular bioeconomy (Kruhak, et al., 2022). There were almost 400 thousand enterprises that carried out their activities. Table 1 presents data on employment, value added and turnover in the EU and Bulgarian bioeconomy and data for the forestry and forest-based sectors.

As of 31.12.2021 the total area of forest areas in Bulgaria is 3 949 526 ha. State ownership of the forest territories prevails – 77,8% of their total area. Municipal forest territories account for 11,1% of the total area of forest territories. Forest areas owned by individuals and legal entities occupy 11,1% respectively. According to the data of the Executive Forest Agency, (Executive Forest Agency), the total stock of forests in Bulgaria as of 31.12.2020 is 718 410 637 cubic meters (vs. 644 840 247 cubic meters in 2010), of which 62,1% are concentrated in forests with special functions, 8,5% - in forests with protective functions and 29,4% - in forests with economic functions. The stock of forests on agricultural land is 37 014 thousand cubic meters, which represents 5% of the total. The total stock of forests with economic functions is 210 919 thousand cubic meters, which compared to 2010 (372 229 thousand cubic meters) is a decrease of 29,4% due to the increase in the stock of forests with special functions, including forests in Natura 2000 areas and forests with protective functions. The average wood stock per hectare is 184 cubic metres as of 31.12.2020. The average wood stock per hectare in coniferous and deciduous (high-stemmed and coppice conversion) forests in 2020 is 222 cubic metres and 117 cubic metres, respectively. There is a clear trend of increasing stock of wood per hectare, except in the hemlock forests. Bulgarian forests are steadily increasing their stock. Between 2010 and 2020, the average age of forests increased from 53 to 60 years. The coniferous forests with the largest area contribution are those aged 41 to 60 years - 35,4%, followed by 21 to 40 years - 25,4% of the area of this group of forests. Coniferous plantations over 80 years old occupy 25,5% of the coniferous forest area.

Table 1. Number of people employed in biomass production, value added of biomass production and turnover of biomass production and converting sectors of bioeconomy

Country,	Year	Employed,	Value added		Turnover	
sector		number, 000	million €	per person employed, 000 €	million €	per person employed, 000 €
European Union	2008	20 270	513 000	25,3	1 938 000	95,6
	2020	17 160	665 000	38,8	2 333 000	136,0
Bulgaria	2008	970,3	3 582	3,7	12 568	13,0
	2020	764,6	4 605	6,0	14 843	19,4
Forestry	2008	18,53	156,8	8,5	352,5	19,0
	2020	21,87	229,9	10,5	392,5	17,9
Wood product	2008	18,81	90,86	4,8	428,42	22,8
	2020	14,04	129,64	9,2	525,85	37,5
Wood furniture	2008	15,44	70,05	4,5	262,46	17,0
	2020	10,42	99,4	9,5	306,4	29,4

Source: (Joint Research Centre)

The volume of afforestation activities carried out and the total annual amount of afforested forest areas in the period 2013 - 2021 is uneven by year: 2013 - 1255,8 ha, 2015 - 2638,2 ha, 2021 - 1793,4 ha. The total area of protective, recreational and other protective forests and forests in protected areas (respectively forest areas with protective and special functions) increased from 1 583 533 ha (38,3% of the total area of forest areas) to 2 872 278 ha (67,2%). By 2020, forest areas included in the European Natura 2000 ecological network will represent more than 57% of the total forest area. At the end of 2021, the total number of protected areas in Bulgaria is 1025 - with a total area of 583 625,9 ha or approximately 5,3% of the country's territory.The total area of forest areas with economic functions decreases from 2 554 564 ha in 2013 (61,7%) to 1 398 717 ha in 2021 (32,7%), mainly due to the inclusion of protected areas for the conservation of natural habitats of wild flora and fauna.

2. THE FORESTRY AND WOODEN-BASED SECTOR IN BULGARIA'S BIOECONOMY

The forestry sector has a limited but important place in Bulgaria's bioeconomy. The employment share is just over 6% in 2020. The value added of forest industries increases from € 310 million (9%) in 2008 to € 450 million in 2020 (10%). The turnover of forest industries grows from €1,04 billion (8,3%) in 2008 to €1,22 billion (8,2%) in 2020. The data for the bioeconomy sectors presented in Table 2 show that agriculture has the largest share, followed by food, beverage and tobacco production. In fact, forest industries occupy the third place in the structure of the country's bioeconomy. The changes in the level of employment, value added and turnover in 2020 compared to 2008 are presented in Figure 1.

Table 2. Sectors of the bioeconomy of Bulgaria and the place of the forest and forest-based sectors in the period 2008-2020

Year	2008						2020					
Sector	Employed		Value added		Turnover		Employed		Value added		Turnover	
	number	%	millon €	%	millon €	%	number	%	millon €	%	millon €	%
Agriculture	716 970,	73,89%	2 019,4	56,37%	4 914,6	39,1%	572 230,	74,84%	1 899,2	41,23%	4 202,9	28,31%
Forestry	18 530,	1,91%	156,8	4,38%	352,7	2,81%	21 870,	2,86%	229,9	4,99%	392,5	2,64%
Fishing and Aquaculture	1 080,	0,11%	10,	0,28%	25,9	0,21%	1 600,	0,21%	21,2	0,46%	68,2	0,46%
Food, beverage and tobacco	110 696,	11,41%	862,3	24,07%	5 208,5	41,44%	90 686,	11,86%	1 426,9	30,98%	6 894,4	46,45%
Bio-based textiles	72 187,03	7,44%	247,27	6,9%	732,14	5,83%	33 833,82	4,43%	284,91	6,19%	739,45	4,98%
Wood products and furniture	34 253,4	3,53%	160,9	4,49%	690,88	5,5%	24 459,21	3,2%	229,04	4,97%	831,27	5,6%
Paper	10 974,94	1,13%	69,65	1,94%	387,43	3,08%	9 418,95	1,23%	169,86	3,69%	684,82	4,61%
Bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels)	5 310,37	0,55%	54,87	1,53%	235,67	1,88%	8 524,51	1,11%	256,39	5,57%	747,36	5,03%
Liquid biofuels	278,08	0,03%	1,06	0,03%	19,92	0,16%	1 365,22	0,18%	37,7	0,82%	183,57	1,24%
Bio-based electricity	4,91	0,%	0,16	0,%	0,5	0,%	582,72	0,08%	50,8	1,1%	99,16	0,67%
Total bioeconomy:	970 284,72	100%	3 582,43	100%	12 568,23	100%	764 570,42	100%	4 605,91	100%	14 843,63	100%

Source: (Joint Research Centre)

Figure 1. Change in the level of employment, value added and turnover for the country's bioeconomy, including the forestry and manufacturing sectors, 2008-2020

2.1. Ecosystem services and products provided by the forest sector

Ecosystem functions and services of forests provide important contributions to a sustainable bioeconomy and society, such as protective functions, climate regulation (e.g. carbon sequestration), air purification, fresh water supply, soil protection, biodiversity (habitat and gene pool protection), recreation and tourism, socially and culturally important services and many others.

Wood is a raw material that provides a wide range of human needs, including building materials, textiles and fibres, paper, chemicals and energy (heat, electricity and fuel). Demand for wood-based products and other forest ecosystem services is increasing. This is partly due to changes in policy agendas with interest in the bioeconomy and the use of biomass to meet renewable energy targets. Meeting these needs sustainably requires action in areas ranging from sustainable management of forests and balancing the services they provide to more efficient use of wood in society (Pauliková & Chovancová, 2022). Wood can play a vital role in the development of the circular economy and bioeconomy (Slavova & Doneva, 2022), (Šupín, Loučanová, Šupínová, & Olšiaková, 2022).

The balance between total average annual growth and average annual wood use is one of the most important indicators for assessing sustainable forest management. For the period 2005-2010 to 2020, average annual growth increases from 14,1 million cubic metres to 14,4 million cubic metres of wood in 2010 and starts to decrease to 13,6 million cubic metres by the end of 2020. The amount of roundwood harvested during the period under consideration varies between 5 830 thousand cubic metres and 7 046 thousand cubic metres. The lowest value of the volume of wood harvested was recorded in 2020. The average annual timber harvest during the period was 7 994 thousand cubic metres standing timber (6 693 thousand cubic metres standing timber). The lowest value of total wood harvested was recorded in 2020.

Forests provide a wide variety of non-wood forest products, such as berries, mushrooms, aromatic and ornamental plants, juices and resins, nuts, honey and wild meat. Although the economic importance of these products is not great, the social importance of non-wood forest products is significant. Available data on non-wood forest products are incomplete and difficult to compare. It is very difficult to make a more accurate assessment of these products given that they are largely consumed on their own and do not reach the market. A study by the European Forest Information System (Forest and bioeconomy) is estimated that 86% by weight of non-wood forest products are consumed, with around 90% of households in the EU-28 consuming non-wood forest products and more than a quarter of households (26%) actively collecting them.The total amount of non-timber forest products harvested in Bulgaria over the last eight years has been declining, as have revenues from non-timber forest products, services and uses in state forest areas - from €1 million in 2013 to €0,65 million in 2021. In the case of traditional sources of revenue in the past, such as wild mushrooms, berries and herbs and others, the total amount of fees from non-timber forest products is on a downward trend.

During the period 2013 - 2021, the potential of forest areas for the development of various forms of tourism and diversified activities in forest areas is increasing (Ivanova & Slavova, 2022). According to the Executive Forest Agency, activities are taking place in nature parks that integrate tourism services based on forest resources.

2.2. Funding and certification

The financial resources needed for the forestry sector are significant. It can be assumed that the forestry sector is underfunded. The main sources of funding are the state budget and the financial resources of state enterprises and private organisations operating in the sector. Within the framework of European support, the most important is the Rural Development Programme and, to a lesser extent, other programmes such as LIFE, etc. Funding could also be available from the National Recovery and Sustainability Plan.

The adoption in 2018 of the international standard PEFC ST 1003:2018 puts into practice requirements aimed at managing activities by applying a systematic approach, encompassing management and production processes aimed at achieving sustainable forest management objectives. The validated version of the international standard PEFC ST 1003:2018 has been adopted as a national scheme in the Republic of Bulgaria, having gone through an assessment and validation process ensuring compliance with the established international requirements. In Bulgaria, this standard has been presented as PEFC BG ST 1002:2019 "Standard for Sustainable Forest Management in Bulgaria" since September 2019. The standards are to be applied to any type of organizations; independent to the size of the organizations or the kind of products manufactured or services provided, in private and public organizations, including government services (Nováková, Pauliková, & Čekanová, 2017). According to the official data of FSC, the area of certified forest areas as of 14.02.2022 is 2 339 102,4 ha, which represents 59% of the total forest area in the country, and there are 32 certified units. The FSC Chain of Custody certificate has 443 units. The area of the certified state forest areas managed by the state enterprises is 2 317 993,8 ha or 80% of the total area managed by them in the country, and the certified units are 29. According to the PEFC (Programme for the Endorsement of Forest Certification) electronic information portal, the PEFC Chain of Custody certificate as of December 2021 has 4 certified units.

3. CONCLUSION

The main problems related to increasing the economic viability and competitiveness of the forestry sector are: 1) low labour productivity; 2) difficult access to finance; 3) lack of opportunities to use financial resources from EU structural funds to invest in the renewal of equipment in logging, machinery, production lines and transport of forest products; 4) insufficient participation (support) of banks in investment projects. All this limits the access of forest products to external markets. The development of the forestry sector during the period was hampered by the incomplete realisation of the potential of the measures of the Rural Development Programme 2014-2020 intended to support the forestry sector.

Efficient and sustainable forest management, wise use of available resources, regional production of raw materials close to processing sites are of great importance not only in terms of environmental impact. They are an important basis for a highly productive and competitive wood, pulp and paper and furniture industry. Security of supply from domestic and global markets is also a prerequisite for safeguarding jobs and added value. In addition, forests perform essential functions for people and the environment. They regulate the climate, provide habitat for animals and plants, protective cover on steep slopes, filter drinking water, purify the air, create conditions for recreation and restoration. The functions of forests and the measures taken to protect them sustainably are at the heart of forest, protected area and biodiversity conservation laws.

REFERENCES

1. Beluhova-Uzunova, R., Shishkova, M., & Ivanova, B. (2019). *Concepts and key sectors of the bioeconomy*. Trakia Journal of Sciences, 17, pp. 227-233.
2. Branzova, P. (2019). *Terminological apparatus in the field of bioeconomy*. Trakia Journal of Sciences, 17(Suppl. 1), pp. 395-399.
3. Di Cori, V., Robert, N., Franceschinis, C., Pettenella, D., & Thiene, M. (2022). *Framework Proposal to Quantify the Contribution of Non-Wood Forest Products to the European Union Forest-Based Bioeconomy*. Forests, 13.
4. Duchesne, L. C., & Wetzel, S. (2003). *The bioeconomy and the forestry sector: Changing markets and new opportunities*. The forestry chronicle, 79(5), pp. 860-864.
5. European Commission. (2010). *EUROPE 2020. A strategy for smart, sustainable and inclusive growth*. COM (2010) 2020. Brussels: European Commission.
6. European Commission. (2012). *Innovating for Sustainable Growth: A Bioeconomy for Europe*. COM (2012) 60 final. Brussels: European Commission.
7. European Commission. (2018a). *A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy*. Luxembourg: Publications Office of the European Union.
8. European Commission. (2018b). *A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment*. COM (2018) 673 Final. Brussel: European Commission.
9. European Commission. (2021). *New EU Forest Strategy for 2030*. COM (2021) 572 final. European Commission.
10. Executive Forest Agency. Retrieved 5 14, 2023, from http://www.iag.bg/
11. Forest and bioeconomy. Retrieved 5 14, 2023, from Forest Information System for Europe: https://forest.eea.europa.eu/topics/forest-bioeconomy
12. Grossauer, F., & Stoeglehner, G. (2020). *Bioeconomy—Spatial Requirements for Sustainable Development*. Sustainability, 12(5).
13. Ivanova, M., & Slavova, G. (2022). *Resilience through diversification: the case of agriculture and forest-based sector in Bulgaria*. Crisis management and safety foresight in forest-based sectot and SMS's operating in the global environment (p. 131). Trnava, Slovak Republic: WoodEMA.
14. Joint Research Centre. *Jobs and Wealth in the European Union Bioeconomy (Biomass producing and converting sectors)*. Retrieved 5 14, 2023, from European commission: https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html
15. Kruhak, T., Barčić, A., Klarić, K., Perić, I., Motik, D., & Ostoić, I. (2022). *Contribution of forest-based industry in low carbon circular bioeconomy: life cycle assessment of selected wood-based products using SIMAPRO software*. Crisis management and safety foresight in forest-based sector and SMS's operating in the global environment (p. 205). Trnava, Slavak Republic: WoodEMA.
16. Lovrić, M., Lovrić, N., & Mavsar, R. (2017). *Syntesis on forest bioeconomy research and innovation in Europe*. Common agricultural and wider bioeconomy research agenda.
17. Nováková, R., Pauliková, A., & Čekanová, K. (2017). *Risk management as a part of a quality management system in woodworking companies*. More wood, better management, increasing effectiveness: stating points and perspective, (p. 171). Prague, Czech Republic.
18. OECD. (2009). *The Bioeconomy to 2030: designing a policy agenda*. Paris: OECD Publishing.
19. Parobek, J., Rokonalová, A., & Slašťanová, K. (2022). *Evaluetion of forest-based sector for the national economy in the bioeconomy context*. Crisis management and safety foresight in forest-based sector and SMS's operating in the global envoronment (pp. 313-317). Trnava, Slovakia: WoodEMA.

20. Pauliková, A., & Chovancová, J. (2022). *Improving energy efficiency through management systems implementation - a cluster analysis of ISO 50001*. Crisis management and safety foresight in forest-based sector and SMS's operation in the global environment (p. 319). Trnava, Slovak Republic: WoodEMA.
21. Slavova, G., & Doneva, Y. (2022). *Application of the model of circular economy between the forestry and agricultural sector*. Crisis management safety foresight inforest-based sector and SMS's operation in the global environment (pp. 383-387). Trnava, Slovak Republic: WoodEMA.
22. Šupín, M., Loučanová, E., Šupínová, & Olšiaková, M. (2022). *Biomass potential in the bioeconomy strategy*. Crisis management and safety foresight in forest-based sector and SMS's operating in the global environment. (p. 417). Trnava, Slovak Republic: WoodEMA.
23. Toteva, D., Popov, R., & Marinov, P. (2020). *Establishment of a system of indicator for transforming the regional farm of Bulgaria towards the bioeconomy in the context of biomass*. Trakia Journal of Sciences, 18(Suppl. 1), pp. 480-484.
24. Wolfslehner, B., Linser, S., Pülzl, H., Bastrup-Birk, A., Camia A., & Marchetti, M. (2016). *Forest bioeconomy – a new scope for sustainability indicators. From Science to Policy 4*. European Forest Institute.

Authors address:

Kirechev, D.[1 *]; Stoyanova, A.[2]; Marinova, V.[3]
[1] Department of Agricultural economics, University of economics - Varna, Varna, Bulgaria
[2, 3] Department of Commodity science, University of economics - Varna, Varna, Bulgaria
[*]Corresponding author: dkirechev@ue-varna.bg

THE ROLE OF THE FINANCIAL AUDITOR FOR THE PARTICIPATION OF FORESTRY ENTERPRISES IN GLOBAL VALUE CHAINS

Ventsislavova Georgieva, D., Bankova, D.

Abstract: The independent external financial audit is of fundamental importance in the management of any sector, including forestry. Economic theories argue that evidence from external sources is considered more reliable. In addition, external financial auditors have an important role in terms of the strategic development of the entity, the disclosure of data in the financial statements, and managerial decisions. However, the forestry sector in Bulgaria is very conservative and closed to effective collaboration with foreign partners. In this respect, the financial auditors can have an important role as a factor for forestry enterprises' participation in global value chains (GVC). The paper‘s main goal is to outline the role of external financial auditors in the participation of Bulgarian forestry enterprises in GVCs. For this purpose, the authors present summarized data from interviews conducted with representatives of the financial audit sector in the Republic of Bulgaria. In conclusion, it can be stated that auditors do not have the right to influence management decisions and processes related to GVCs, but at the same time, part of the analysis of risk factors such as foreign suppliers and customers are taken into account by the management who directly or indirectly relays on auditors' opinions and even seeks consultations and advice from them. In addition, based on the procedures the financial auditors perform, they analyze and evaluate the business as a whole, with which they consciously or unconsciously evaluate the influence of global chains on the activities of their clients.
Keywords: external auditor, forestry, global value chains

1. INTRODUCTION

World trade and production are increasingly structured around global value chains (GVCs). GVCs are a systematic process, representing a series of stages, including all the main activities related to the production, distribution and after-sales service of a product or service, where each stage is adding value. Value chains become 'global' when at least two of the stages take place in different countries (World Bank, 2020). GVCs include functionally and geographically fragmented productions, which are usually coordinated and controlled by leading firms (Mayer et al., 2017). Micro-level benefits are related to the transfer of activities to other countries and cost reduction, importation of foreign products of lower cost or better quality, creation of competitive effects in domestic markets, and the diffusion of knowledge by multinational companies (Criscuolo & Timmis, 2017).

Scholars (Constantinescu et al., 2017); Constantinescu et al., 2019) argue that the participation of enterprises in GVCs increases labor productivity. Kummritz, Taglioni, and Winkler (2017) argues that it even leads to an increase in sectoral added value, especially in the phases of development and design, marketing and customer service. The main advantages that can be pointed out from the participation of enterprises in GVCs are (Strange, 2020):

- Cost reduction based on the use of cheaper raw materials and cheaper labor in the country where a given stage of the process is outsourced;
- Improvement of the production capacity in the quantities desired or required quality by the management;
- Reducing the company's risks from unforeseen circumstances, such as epidemics, strikes, hurricanes, floods, terrorist threats, etc.

The participation of enterprises in such chains is a complex process, tied to a lot of preliminary research and analysis. Studies on Bulgaria, however, report little or even no participation of enterprises in GVCs (Georgieva et al., 2022; Georgieva, 2023). In the wood processing value chain, forest certification as a voluntary verification tool has been gaining importance worldwide (Paluš et al., 2018). However, less importance is given to financial auditing and its relation to the problem.

In the knowledge-based economy, the creation of value through intensive knowledge or professional services is subject to extensive analysis (Nguyen et al, 2014). The independent external financial auditors are helping the management by increasing the quality control of the company. Financial auditors' main functions are related to the review, assessment and monitoring of the adequacy, effectiveness and efficiency of the control and accuracy of the financial statements. Research by Paul Verbruggen (2022) emphasizes the role of the auditor in GVCs. The importance of auditors' professional judgment in assessing the risk that is related to key customers and suppliers, reviewing strategic plans and decisions made by companies as well as the audit function itself are also discussed. However, it is necessary to distinguish between different types of audits to better understand the impact of the audit's function on the GVCs. For example, the audit of financial statements is based on IFRS and concerns the information in the financial statements and the correctness of the application of accounting policies by the audited company. When it comes to assessing the risk of key customers or suppliers, financial auditors are not entitled to express opinions. The reason is that this is a consultation that would affect the financial result of the report and is in breach of International Auditing Standards. Therefore, the audit function is expanded based on the systematic methodology of the Compliance Audit. It is an additional audit dedicated to how specific standards are applied.

Even though the independent financial auditor has no right to influence managerial decisions, the auditor is a "role model" in the decision-making process and is often consulted by managers. In this respect, we agree with the statement of Nguyen et all (2014), that in audit services, the client's stakeholders are an important aspect to be considered in value creation processes. The financial audit should express an opinion on the reliability of the information in the financial statements to the external data users that are making informed economic decisions, whose attitude and interest in the audit service may affect the creation of asymmetric information and the indirect impact on managerial decisions. Hence, the auditor may have a direct or indirect role in the participation of enterprises in the GVCs, based on the expressed opinion on matters regarding specific customers or suppliers.

The main goal of the paper is to outline the role of the external financial auditor in the decision-making process by enterprises in the forest sector whether to participate or not in the GVCs. The object of analysis is independent external financial auditors that are auditing forestry enterprises. The used scientific methodology is based on the methods of analysis and synthesis, induction and deduction. To collect primary data, the in-depth interview method with the target group was used.

2. RESEARCH METHODOLOGY AND RESULTS

In-depth interviews were carried out to identify the role of the external financial auditors in the forestry GVC participation. The goal is to identify the attitude of the interviewees to:

- the benefits and added value for forest industry enterprises from their participation in GVCs;
- the added value from the performed audit procedures about the assessment of risk areas in the financial statements of companies and assessment of external impacts (COVID-19, the war with Ukraine);
- the added value from the performed audit procedures about the assessment of dependence on customers and suppliers, as well as the sustainability of the company, more specifically, the Bulgarian market is experiencing currency risk related to the accession of the country to the Eurozone and acceptance of the euro as the official currency.

A total of 7 in-depth interviews were held in the period April-May 2023. The target group are independent financial auditors with experience in auditing furniture manufacturing enterprises. The interviews were conducted by telephone or via online call with an average duration of 25 minutes. The interviewees were mostly female (86%) with experience in the field over 10 years (71.43%).

Nearly 29% of the interviewees share the opinion that the financial auditor should not participate in any form or influence anyway of their clients to participate in global value chains, as it conflicts with the auditor's activities and duties. For 43%, however, the auditor performs procedures for assessing the impact of environmental risks on the company's activity. This information can even indirectly influence the management staff and the decision-making process. The entire financial audit process, starting with the examination of the enterprise processes, corrections, and communication with management, contributes both to the improvement of financial reporting and to the understanding of management to build and eliminate weaknesses in the internal control environment and business management. The financial auditor's added value can be related to the fact that they point out weaknesses in the internal control environment, correct errors and increase the level of disclosure in the financial statement, hence focusing on compliance with regulatory requirements, including non-financial information.

The literature supports the idea that if a company is international or dependent on external investment, more disclosure pressure is applied to that entity (Oliveira et al., 2006; Gerpott et al., 2008). However, nearly 29% of the interviewed auditors believe that the disclosure of non-financial information should be in line with regulatory requirements and should not influence managerial decisions to participate in global value chains. On the opposite aspect, the rest of the auditors indicate that the identification of weaknesses in the internal control environment (including environmental risk, credit risk, etc.) is a reason for management to change one or more processes in the enterprise. The formation of an understanding of sustainable business development is a process that should gradually cover a large part of business and society. Financial auditors gain knowledge of the many aspects of reporting and the impact of sustainable development on business. Discussion between the financial auditor and its client of the individual manifestations both at the level of financial statement and at the level of reporting of non-financial information helps speed up the process of understanding and applying the needed standard's requirements. In this respect, regardless of the requirement not to provide consultations to their clients, the majority of interviewees admit that they do so and that this directly or indirectly affects managerial decisions. It often happens that managers ignore the opinion of their accountants in favour of the auditor, therefore auditors are often "consultants" in cases and questions that arise.

3. CONCLUSIONS

GVCs are a channel for the dissemination of technological knowledge, entrepreneurial culture and innovation capacity. In this way, they change the profile of the related economic sectors and regions in which the activity of the companies is concentrated. In cases where an independent financial auditor also offers consulting services, the auditor's dependence on the client may increase, but vice versa as well. This can significantly affect the quality of the auditor's work and his independent opinion. It could lead to the expression of an incorrect opinion by the auditor which can mislead the users of the reports. Regardless of this fact, financial auditors are often treated as consultants on issues and cases that arise.

Based on the in-depth individual interviews of financial auditors of forestry enterprises, the following conclusions can be drawn:

- auditors who are hired to carry out an independent financial audit of the financial statements of enterprises should not participate in clients' consultations, as the standards do not allow such a circumstance due to the risk of auditors checking their own work;
- auditors do not have the right to influence management decisions and processes related to GVCs, but at the same time part of the analysis of risk factors such as foreign suppliers and customers are taken into account by the management;
- the auditors do not realize that, based on the procedures they perform, they analyze and evaluate the business as a whole, with which they consciously or unconsciously evaluate the influence of global chains on the activities of their clients.

Management's attitude and vision for the audit work require that the audit function expands to meet the needs of users. New types of audit are emerging - CSR audit (Application of the International Federation of Accountants Standards of Assurance on Corporate Social Responsibility) (Peycheva et all, 2016) and ESG (an audit that is fully specialized in environmental, social and governance issues, key areas – Climate Change and Sustainability, Diversity, Equity, and Inclusion, Supply Chain Issues, International Conflict). In this respect, the management of a forest industry enterprise can arrange an audit based on a special area, such as an audit of key customers and suppliers in GVCs. However, it is necessary to carefully describe the goals and responsibilities of both parties in a contract. Accordingly, the professional competence of the financial auditors can be affected – the risk profile of the audited objects, dependence on the client, study of the legislative framework, and reflection of specifics when trading with third parties. Because of that, there is a need to be developed specific standards for auditing global value chains.

Acknowledgements: The paper presents primary data from Project „Development and implementation of a model for assessing the innovation potential of global value chains as a basis for increasing regional competitiveness" financed by the National Science Fund, contract No КП-06-Н55/8 from 16.11.2021.

REFERENCES

1. Criscuolo, C.; Timmis, J. (2017): *The relationship between global value chains and productivity*. International Productivity Monitor, (32): pp. 61–83.
2. Constantinescu, C.; Mattoo, A.; Ruta, M. (2019): *Does vertical specialisation increase productivity?* The World Economy, (42): pp. 2385–2402.
3. Kummritz, V.; Taglioni, D.; Winkler, D. (2017): *Economic upgrading through global value chain participation: Which policies increase the value-added gains?* World Bank Policy Research Working Paper 8007. Washington, DC: The World Bank.
4. Strange, R. (2020): *The 2020 Covid-19 pandemic and global value chains*, Journal of Industrial and Business Economics, (47): pp. 455–465, https://doi.org/10.1007/s40812-020-00162-x.
5. Georgieva, D.; Mitkova, M.; Georgieva, T. (2022): *Globalnite verigi na stoynostta v selskoto stopanstvo po primera na Balgarskite zemedelski proizvoditeli*, KNOWLEDGE – International Journal, 55(1): pp. 51-56.
6. Georgieva, D. (2023): *Predizvikatelstva pred uchastieto na inovativni balgarski predpriyatia v globalnite verigi na stoynostta*. Tendentsii i strategii za vazstanovyavane na ikonomicheskata i obshtestvenata sistema sled pandemiyata ot Covid-19, UNSS.
7. Paluš H.; Parobek J.; Vlosky R.P.; Motik D.; Oblak L.; Jošt, M.; Glavonjić, B.; Dudík, R.; Wanat, L. (2018): *The status of chain-of-custody certification in the countries of Central and South Europe*. European Journal of Wood and Wood Products 76(2): pp. 699-710, https://doi.org/10.1007/s00107-017-1261-0.
8. Nguyen, L.; Kohda, Y.; Umemoto, K.; Nguyen, H. (2014): *A Framework for the Analyzing of Value Creation Processes in Auditing Service*, Conference: Asian Conference on Information Systems 2014 (ACIS 2014) At Nha Trang, Vietnam, pp. 506-513.
9. Verbruggen, P. (2022): *Tort Liability of Private Safety Auditors in Global Value Chains"*. European Journal of Risk Regulation (13): pp. 584–602. https://doi.org/10.1017/err.2022.29 602
10. Oliveira, L.; Rodrigues, L.; Craig, R. (2006): *Firm-specific determinants of intangibles reporting: evidence from the Portuguese stock market*. Journal of human resource costing & Accounting, 10(1), pp. 11–33.
11. Gerpott, T. J.; Thomas, S.; Hoffmann, A. (2008): *Intangible asset disclosure in the telecommunications industry*. Journal of intellectual capital, 9(1), pp. 37–61.
12. Peycheva, M.; Veysel, A.; Dineva, V. (2016): *Korporativna sotsialna otgovornost – teoria, otchetnost i odit*, Sofia, ATL-50 OOD, pp. 392-438.
13. ***:Villanueva, E. (2022): *ESG Audit Checklist and Best Practices for 2022*. https://www.auditboard.com/blog/esg-audit-checklist/

Authors address:

Daniela Ventsislavova Georgieva (with a share of 50% of the paper's text)[1]; Diyana Bankova (with a share of 50% of the paper's text)[2]
[1] International Business School, Botevgrad, Bulgaria
[2] Department of Accounting and Audit, Higher School of Insurance and Finance, Sofia, Bulgaria
*Corresponding authors: danielagr999@gmail.com, diyanabankova@gmail.com

MODERN MARKETING COMMUNICATIONS IN THE FOREST SECTOR AS A FACTOR TO INCREASE THE ADDED VALUE IN TERMS OF COVID-19

Ventsislavova Georgieva, D., Popova-Terziyska, R.

Abstract: The closure of international borders due to COVID-19 has made it difficult to plan the timing of orders along the entire global value chain. This negatively affected the ability to timely produce the desired and ordered customers' furniture. As a result, when communicating with customers and suppliers, a shorter period of validity of the price offer was introduced. It required a review and update of the price offer and additional delay in the negotiations. A study of the main marketing strategies of the Bulgarian companies in the furniture industry is needed to outline to what extent they have been able to meet customer expectations. This research presents the role and significance of modern marketing tools for furniture manufacturers and clients in crisis conditions. Hence, the trends in the furniture market compared to consumer desires in the context of the new working and living conditions. The research methodology includes a study of 85 Bulgarian furniture manufacturers. The data were collected using a large-scale questionnaire distributed on the spot during the months March-April 2022. In addition, 80 furniture consumers were questioned regarding the used and preferred marketing communications by furniture manufacturers. The questionnaires were distributed in the period of September-October 2022. The results of the survey show that furniture manufacturers in Bulgaria have not yet met consumer expectations, using mainly traditional marketing methods of communication.
Keywords: marketing communications, global value chain, forest sector, questionaries

1. INTRODUCTION

In the last 2-3 years, the furniture industry has faced several global and national challenges. First, the COVID-19 crisis began, followed by a global shortage of raw materials, problems with transportation, an increase in the price of energy resources, and finally the war in Ukraine. Because of the digital revolution, traditional business models have changed and digital business models have emerged (Atanasov, 2022, p.19). This led to several difficulties and challenges for furniture companies, but it also opened up new opportunities. This leads companies to focus on the processes of optimization, automation, and robotization of production, search for new raw materials, new energy sources, and improvement of energy efficiency in the manufacturing process. More and more furniture companies are realizing the importance of technological innovation and digital marketing tools to attract and keep their customers.

The furniture market in Bulgaria has been developing very dynamically in recent years. Consumer preferences are growing, which leads furniture production to be increased by over 25% in 2021, furniture exports - by over 30%, and imports - by over 38%. Over 4000 are enterprises in the furniture industry which calculates 3% of the GDP of the country (Economics, 2022, p. 44). A large part of purchases goes through the five largest furniture chains in Bulgaria - JYSK, Videnov, Aiko, IKEA, and INTERIOR-I, which provide more than half of furniture sales in the country. Over 85% of the furniture is destined for export, the demand for upholstered and kitchen furniture increase, meanwhile purchasing of office furniture and commercial furniture decreases. Industry experts explain this with the ongoing trend of home-office ways of working, which encourages consumers to make their homes more comfortable and functional for living and working (Jivkov, 2022). As a result, leading furniture companies operating in the Bulgarian market report an increase in online sales by 20% in 2022, compared to 2016 (Capital, 2023). Consumers rely heavily on prior online research regarding product offerings and prices to find the most suitable choice for themselves, and then carefully choose which retailer they will physically visit to make the purchase. In general, online furniture sales are increasing, but a visit to a physical store, where the customer has the opportunity to receive professional advice, is still a preferred option.

The primary goal of all marketing activities is to create value for the consumer by choosing online instruments to maintain lasting relationships with customers. According to Drayse (2008), furniture manufacturers use the capabilities of information technology to manage their production process, logistics, and supply, which in turn helps to accelerate the process of globalization. Essential in this process is the effective use of social media as well as virtual reality pictures, timely updating of websites, effective use of content marketing, innovative banners, and easy payment methods (Popova-Terziyska, 2021). According to NSI data, in 2021, 51.9% of all Bulgarian companies have a website, but only 11.8% of them sell their goods and services online. Although social media is one of the most frequently used tools for advertising and communication with customers in 2021, only 38.9% of all Bulgarian companies use this tool effectively for their digital marketing purposes. Research in the field of the furniture industry shows that even Bulgarian furniture manufacturers have not reached the necessary level of digitalization that corresponds to the environment in which they operate (Georgieva, 2022). Very little progress has been made in terms of connectivity, especially in the implementation of online stores and 3D applications. Even though the COVID-19 pandemic has forced the introduction of innovative forms of communication with buyers and suppliers, based on digital tools and instruments, Bulgarian furniture manufacturers have not yet taken advantage of all the functionalities of the digital environment to create competitive advantages.

The main goal of the paper is to outline customer expectations about the digital marketing strategies and tools provided by furniture manufacturers. More specifically, the object of analysis is the type of advertising and the functionalities of the company's websites. The used scientific methods and approaches are the logical, inductive, and deductive approaches, as well as the survey method. The object of research is on the one hand furniture enterprises in Bulgaria, and on the other hand - end customers. The main conclusion of the study is that furniture manufacturers are neglecting customer preferences when advertising their products as they use mainly traditional digital instruments. In addition, they do not see the use of social media, 3D interactive images, and functionality of the company's website as factors improving the popularity of the brand and the image of the enterprise.

2. SURVEY METHODOLOGY AND RESULTS

To study the used online advertising practices of furniture companies in Bulgaria, 85 medium and large enterprises, were surveyed. The survey was conducted in March-April 2022 by the use of questionaries. The questionnaire includes 33 closed and open questions and was distributed on the spot (in the territory of Bulgaria) by the use of interviewers. The response rate of the selected entities is 23%, and the respondents are representatives of the management staff of the enterprises. The study of statistical relationships and dependencies is based on the Chi-square test, and the measure of association is done by the use of Cramer (V) with the program IBM - SPSS Statistics.

For consumer opinion research, a questionnaire with 7 open and closed questions was distributed on the spot in front of Videnov, IKEA, and Aikov shops in Sofia. The study was carried out during the period of September-October 2022 by students from the University of Forestry in Sofia. The response rate was 15%. From a socio-demographic point of view, the respondents are in the 25-50 age group, and around 80% of them are at the age gap between 25-35 years old. Primary customers of the shop were families where both partners (male and female) were visiting the shop. The majority (85%) of the respondents visit the shop after making research in the online catalogue of the manufacturer.

The results of the study of the furniture companies are indicative that 41.2% of them have developed and implement new changes in sales and distribution methods in the last 12 months. However, only 30.6% of them use social media (mainly Facebook), and 36.5% - electronic media as a tool for sharing marketing news and offers for upcoming discounts. Enterprises are mainly presenting their products during fairs and exhibitions (40%) and hence distributing company paper catalogues (56.5%).

89% of the respondents point out that they have an internet page, and for 80% of them, their page is the main channel for advertising. However, only 56.5% of businesses claim that the information on their website is up-to-date, while 40% report that their website is static and provides general information about the company. Of the respondents who have a website, 41.2% indicate that their customers can make online orders, and 25.9% - that customers can also pay for the goods online. 20% of companies offer the possibility for customers to generate 3D interactive images before ordering, and 5.9% have an augmented reality option. It is noteworthy that, even though a relatively large percentage of the companies under study are using paper catalogues, 31.8% of the respondents have electronic catalogues with complete specifications of their products, which they use to attract customers. Only 11.8% have developed mobile applications and use a similar channel for communication with their customers and advertising purposes.

Consumer survey data indicates that 70% of respondents trust humorous furniture ads with little text in them and more visuals. Although they would pick up a paper catalogue from the store, the priority is online catalogues and advertisements, which are the real reason customers come and physically look at the products at the store. In this respect, nearly 80% prefer to buy furniture primarily from furniture stores that have functional and detailed websites, electronic catalogues, and online payment options.

When choosing to buy furniture, 70% would trust recommendations from acquaintances and friends, while 30% rely on social networks, reviews, and comments of other users. Consumer preferences are to live in a smart home, so they want the furniture manufacturer to understand this need and to integrate different options for easy access to the remote controls of the smart home in the furniture. The respondents are more willing to buy furniture in light colours, natural textures, and natural elements. The majority of the respondents like a golden accent in the furniture, however, the furniture must fit in rooms with different wall colours preferably in brown and grey, and white for the bathrooms. However, before making the relevant purchase, they prefer to have the option to see how the selected furniture will relate to the rest of the decor through the use of 3D interactive images.

3. DISCUSSION

Based on the collected and analyzed data from the surveyed customers, we can state that they rely on entertaining advertisements in the Internet space. However, such a tool is neglected by the analyzed furniture enterprises. The majority of surveyed customers are young people in the age group up to 50 years, who constantly use mobile devices and smart applications in their daily lives. The changes caused by COVID-19 and the new way of working, mainly the home office, is the reason why customers rely even more on online orders, the possibilities for an interactively presented product, and more functionalities on the companies' websites, incl. the use of 3D interactive images. However, based on the data from the surveyed furniture enterprises, no statistically significant relationships were reported between the use of 3D interactive images and the image of the enterprise (Cramer's V: 0.094, $p > 0.05$). There were no statistical relationships and dependencies between the popularity of the brand and the possibility of generating 3D interactive images from the company's website (Cramer's V: 0.150, $p > 0.05$). A weak statistical relationship was calculated between the popularity of the brand and the presence of electronic catalogues with full product specifications on the company's website (Cramer's V: 0.215, $p < 0.05$), which, however, is a marketing tool used by a significantly small proportion (about 32%) of the respondents.

Although social media is part of the marketing tools of the surveyed businesses, they mostly post data on Facebook. With the development of other social media such as LinkedIn, Twitter, and Tiktok, the use of Facebook is mostly by users in the age group above 40 years. This requires furniture companies to use other social media to target representatives from other age groups. Advertisements in these media should, however, be focused on customer preferences and based on in-depth marketing analysis, which the surveyed furniture enterprises do not make. No statistically significant relationships were calculated between the use of social media and the popularity of the analyzed furniture companies (Cramer's V: 0.093, $p<0.05$). On the contrary, an average statistical relationship was calculated between the use of print media for advertising purposes and brand popularity (Cramer's V: 0.375, $p > 0.05$). It should be noted that the development of one's brand and the creation of a marketing strategy for this should be a priority for the enterprises of the Bulgarian furniture industry, which currently works on the principle of "toll manufacturing".

The low level of digital tools used for communication with customers corresponds to the overall development of enterprises in Bulgaria in this area. Although the paper does not present factor analysis as a prerequisite for this negative trend, such can be sought firstly in the overall managerial vision for the main advantages of the company and the factors for achieving competitiveness. In this context, the surveyed companies do not consider their marketing strategy among the main factors of competitive advantage. Priority is given to product quality, value for money, and design. The above is not surprising taking into consideration the current inflationary situation in the country and the decrease in demand for low-budget furniture, where the price, not so much advertising, has a leading role. Essential to the use of digital tools is the availability of qualified personnel for this purpose. However, 45.9% of the surveyed enterprises indicate that they did not conduct training for their staff in the last 12 months. However, the preservation of the current staff and their professional development should be among the priorities of the enterprises in our country.

4. CONCLUSIONS

The analyzed furniture companies mainly rely on traditional methods of advertising such as visiting fairs and exhibitions, paper catalogues, advertisements in print media, etc. Even though the COVID-19 pandemic has forced the introduction of innovative online instruments for communication with customers, Bulgarian furniture companies have not yet taken advantage of all the functionalities of the digital environment to create competitive advantages. However, the current marketing strategies adopted by them do not meet customer expectations. The broadcasted negative news on television and radio, customer psychology is increasingly looking for fun and light forms of advertisements. At the same time, however, Bulgarian furniture companies are unprepared and have a typical "traditional" marketing attitude toward customers. As a reason it can be stated that furniture companies still do not consider modern digital marketing instruments as a way of attracting customers, improving the company's reputation and brand popularity.

As a result of the current geopolitical situation in the world, the countries of Western Europe are starting a massive search for suppliers of raw materials, not from China, but from Eastern Europe. Bulgaria must take advantage of this and actively participate in the Global Chains for the creation of added value by attracting new partners and investors looking for alternatives to move their production from Asia to Europe.

Acknowledgements: The paper presents primary data from Project „Development and implementation of a model for assessing the innovation potential of global value chains as a basis for increasing regional competitiveness" financed by the National Science Fund, contract No КП-06-Н55/8 from 16.11.2021.

REFERENCES

1. Atanasov, A. (2022): *Digitalization of the corporate reporting in Europe - evidence from Bulgarian wood-based industry*, 15th International Scientific Conference WoodEMA 2022 Crisis management and safety foresight in the forest-based sector and SMEs operating in the global environment, International Association for Economics, Management, Marketing, Quality and Huma Resources in Forestry and Forest Based Industry – WoodEMA, i.a., Slovak Association for Quality, n.o, pp. 19-24.
2. Drayse, M. (2008): *Globalization and Regional Change in the U.S. Furniture Industry*, Growth and Change, 39(2): pp. 252–282.
3. Economics (2022): *The rise and the brakes of the furniture industry*, 2022(111), pp. 44-47.
4. Georgieva, D. V. (2022): *Digitization of Bulgarian furniture manufacturers during the COVID-19*, New Knowledge, Journal of Science, Academic Publishing House „Talent", University of Agribusiness and Rural Development Bulgaria, Volume XI (2): pp. 22- 30.
5. Jivkov, V. (2022): Challenges and opportunities for the furniture industry in Bulgaria after the covid crisis, war, and raw material shortages, 2022: XI-th International Scientific and Technical Conference Innovations in the forest industry and engineering design, INNO-2022, 3-5 October 2022, Hotel Rila, Borovets, Bulgaria.
6. Popova-Terziyska R. (2021): *Digital marketing instruments at the furniture enterprises in Bulgaria*, The response of the forest-based sector to changes in the global economy. 14th International Scientific Conference WoodEMA 2021 proceedings of papers, Koper, Slovenia 2021, International Association for Economics and Management in Wood Processing and Furniture Manufacturing - WoodEMA, i.a., University of Ljubljana, Biotechnical Faculty, Department of wood science and Technology. pp. 259-265.
7. ***: Capital (2023): Top 5 Furniture Chains: Over Half a Billion in Sales and Increasingly Online.
8. URL: https://www.capital.bg/biznes/stoki_i_prodajbi/2023/01/16/4430288_top_5_na_verigite_za_mebeli_prodajbi_za_nad_polovin/ [accessed on 03.05.2023].

Authors address:

Daniela Ventsislavova Georgieva (with a share of 80% of the paper's text)[1]; Radostina Popova-Terzyiska (with a share of 20% of the paper's text)[2]
[1] International business school, Bulgaria
[2] University of Forestry – Sofia, Bulgaria
*Corresponding author: danielagr999@gmail.com

WOOD ENERGY CONSUMPTION AND GHG EMISSIONS FROM WOOD FUELS USED FOR HEATING PURPOSES IN EASTERN SERBIA

Glavonjić, B., Lazarević, A., Kalem, M.

Abstract: This paper contains the research results on wood energy consumption in the region of Eastern Serbia during the heating season 2020/2021. The aim of the research was to collect data on the types, amounts, and values of wood fuels being consumed in this region in Serbia, as well as GHG emissions from their combustion. Based on the conducted research, the following results were obtained: total consumption of wood fuels for energy purposes in Eastern Serbia in heating season 2020/2021 was the following: firewood 1.07 million m^3; wood pellets 34,419 tonnes, wood chips 2,205 tonnes, wood briquettes 127 tonnes and sawdust 13,203 tonnes. The average consumption of wood energy per $1m^2$ of heating surface in households in Eastern Serbia amounts to 232.6 kWh/m^2 (a) in urban households and 242.9 kWh/m^2 (a) in other households. Such high values of the wood energy consumption are unsatisfactory because they are beyond the values of the last class of the energy passport for residential buildings [G class > 188 kWh/m^2 (a)].Total CO_2 emissions from the wood fuels combustion in Eastern Serbia during the heating season 2020/2021 are estimated to be 1.3 million tonnes.
Keywords: wood, fuels, heating, emissioms, GHG.

1. INTRODUCTION

The research on the consumption of wood energy in Serbia is the subject of a continuous process carried out for various purposes, most commonly for the needs of ministries, agencies, official statistics, international organizations, scientific institutions, and companies. Two surveys have been conducted since 2020, one intended for the Energy Community of Southeast Europe, and the other as part of the national forest inventory in 2022. This paper presents the results of the research on wood energy consumption in the Eastern Serbia region, obtained through the implementation of a project within the national forest inventory and with the support of the FAO organization.

Due to the high participation of wood energy in the total energy consumption in Serbia, especially in households, wood energy represents the most significant form of energy obtained from renewable sources and as such is the subject of special attention by decision-makers. According to the results of surveys conducted by the Statistical Office of Serbia, the total consumption of wood energy in households in Serbia amounted to 15.77 million MWh in 2020. Electricity came in second with 12.45 million MWh, while the consumption of energy from other fuels was far below that of wood energy and electricity [1].

Taking into account the level of its consumption as well as its position in relation to other forms of energy, the role of wood energy in achieving Serbia's projected goal of a 41% share of energy from renewable sources in total gross final energy consumption by 2030, is of great importance [2].

The first comprehensive survey of wood energy consumption in Serbia was conducted in 2010, and the results of that survey showed that the production and consumption of wood fuels were 5.2 times higher than the statistically recorded figures [Glavonjić 2011]. For the purposes of that survey, a special methodology was developed which was further improved in later years and currently represents one of the most respectable methodologies used for researching wood energy consumption in Southeast Europe.

2. MATERIALS AND METHODS

The aim of the research was to collect the data on types, amounts, and values of wood fuels being consumed in the region of Eastern Serbia, as well as GHG emissions from their combustion. In addition, through this research, data on sources of wood fuel supply were collected, as well as the data on appliances used for their combustion.

The research included t*he most important categories of wood energy consumers: (i) households (urban and other), (ii) public buildings (schools, health-care centres, ambulances, kinder gardens, local government facilities, etc.), (iii) commercial buildings (restaurants, meat roasters, bakeries, car repair services, shops, business facilities,* *etc.), (iv) district heating systems, (v) CHP plant, and (vi) wood fuels producers (producers of pellets, briquettes, wood chips).*

Based on the results the corresponding balance of GHG emissions was developed. The inventory included a calculation of the emissions of carbon dioxide and nitrogen oxides.

The methodological concept that was used within the WISDOM projects in Serbia, Montenegro, Bosnia and Herzegovina, North Macedonia and Albania was adopted in this research as well.This concept was developed in a way that it can comprehend all significant consumer categories. It takes into consideration the consumers' size and number. Furthermore, the presence of households in the total (statistical) population was very well reflected in the sample. The data about other consumers' categories were gathered through direct interviewing and covers either all of them, like district heating systems and wood fuels producers, or the vast majority of them (like public, commercial and industrial facilities) in the chosen region. All of that guarantees a high level of data confidence and relevance for assessing the objective representation of the wood energy consumption in this region.

The second important element of the selected methodological approach referred to the need to conduct the stated research on a county level because of differences among counties in Serbia mostly regarding climate characteristics, household size, the tradition in using certain fuels for heating, availability and convenience of using certain fuels (wood, coal, agricultural biomass and others) and socioeconomic factors (income level, level of equipping with various combustion devices, etc.).

Out of the stated number of households, those households using either district heating systems, electricity, gas or fuel oil for heating were deducted in order to obtain the number of households that use solid fuels such as wood, coal, briquettes, pellets or combined fuels. For this research, the sample was 309 households in Eastern Serbia as well as 75 commercial buildings, 2 district heating systems, 16 administrative buildings, 17 health institutions, 59 kindergarten and school institutions, and 60 wood industry enterprises.

The calculation of the GHG emissions from the wood fuels combustion process in the chosen region was based on the IPCC 2006 methodology and additions from the corresponding European standards, relevant scientific papers and publications measurements from practice.

3. RESEARCH RESULTS AND DISCUSSION

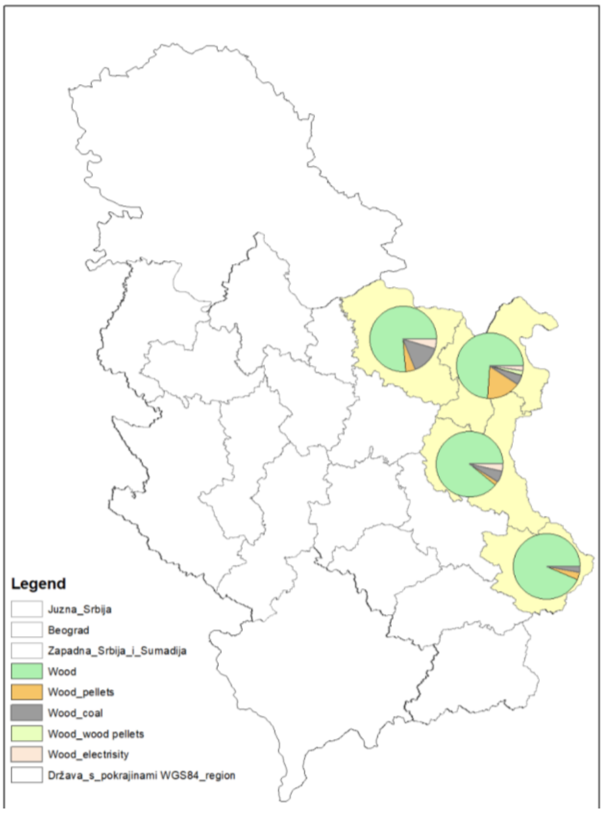


Figure 1. Overview of certain fuel types consumed for heating households in Eastern Serbia (Glavonjić, 2022)

The main characteristic of wood fuel consumption in the region of Eastern Serbia is the dominant participation of firewood (Fig.1). The total consumption of wood fuels in households in this region was: firewood 1,014,294 m^3, wood pellets: 33,850 tonnes, and wood briquettes 127 tonnes. Another important characteristic of the consumption is the small number of solid fuel combinations. Fig. 1 shows that over 2/3 of households use firewood. Observed by counties, it looks like this: in Bor county 73.8%, in Zaječar county 89.1%, in Braničevo county 76.1%, and in Pirot county 93.4%.

The second most commonly used fuel in households is a combination of wood and coal, followed by wood pellets in third place. The use of agrobiomass fuels is very low.

In addition to quantities, an important result of the research is the efficiency of wood fuels consumption. It is measured by the consumption of wood energy per 1 m^2 of heating surface. The ontained results show an unsatisfactory state in terms of this indicator. In urban households, the average consumption of wood energy was 239.6 kWh/m^2, while in rural households it was 242.9 kWh/m^2.

Boths values are beyond the values of the last class of the energy passport for residential buildings [G class > 188 kWh/m^2 (a)].

An important characteristic of wood consumption is also the timing of firewood purchase relative to the beginning of the heating season, because firewood contains different amounts of water depending on how many months have passed since it was cut. The results of this indicator are presented in Figure 2.

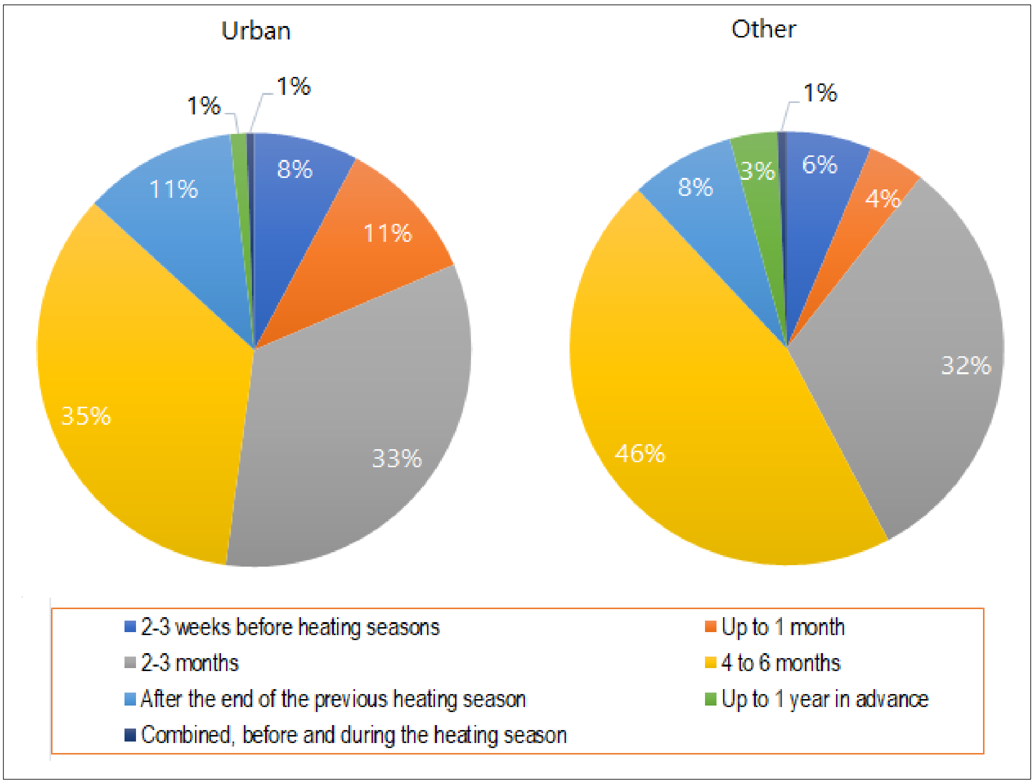


Figure 2. Timing of purchase of firewood by households relative to the beginning of the heating season in Eastern Serbia

In Eastern Serbia, the largest number of households purchased firewood 4 to 6 months before the heating season (35% in urban, and 46% in other households), then follow households that purchased it 2 to 3 months before the heating season and those that purchased firewood right after the end of the previous heating season.

The heating systems are one of the most important elements on which the efficiency of consumption, as well as the consumption of wood fuels itself, depend in every household. The research results showed that 57% of households in Eastern Serbia use individual heating appliances. It is known that individual heating appliances are less efficient compared to heating appliances from central heating systems.

Besides the heating system, the important firewood consumption and efficiency factor is the age of a heating appliance. According to the survey, 41% of households in Eastern Serbia possess heating appliances over 10 years old. The share of households with up to 5 years old heating appliances amounts to only 27% (Fig. 3).

Based on the obtained results, it can be concluded that the age of the appliances in households in Eastern Serbia is unsatisfactory because the share of appliances over 10 years old is one of the key factors contributing to wood energy inefficiency and big consumption.

Regular chimney servicing is also one of the activities which are tightly connected to the efficiency of wood fuels combustion in the heating/combusting appliances, as well as to the wood fuels consumption. In Eastern Serbia, the situation is satisfactory because 86% of the interviewed households regularly service their chimneys every year.

Apart from households, firewood is an important fuel for heating numerous public and commercial buildings, in district heating systems, and is also used in industry for the production of wood pellets. The total consumption of firewood in public and commercial buildings in 2020/2021 was 2,620 m^3. Wood pellets followed with 569 tonnes. District heating systems in Eastern Serbia consumed 7,944 m^3 of firewood for heating purposes.

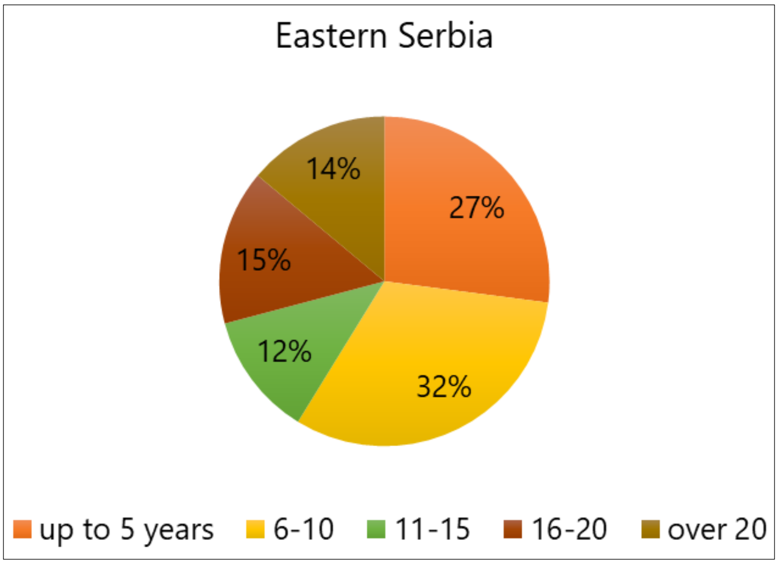


Figure 3. Overview of certain age ranges of heating appliances in households in Eastern Serbia

However, the highest consumption of firewood in this region, after households, was recorded in the wood industry. The reason is that the largest wood pellet production factory in Serbia is located in this region, as well as one CHP plant that produces electricity from woody biomass. The total wood fuel consumption in the wood industry was: firewood 43,106 m^3, wood chips 2,205 tonnes, and sawdust 13,203 tonnes.

When it comes to GHG emissions that arise from burning wood fuels, the results of conducted research have shown the following:

- Total CO_2 emissions stemming from the wood fuels combustion in Eastern Serbia during the heating season 2020/2021 are estimated to 1.3 million tonnes. Some 1.21 million tonnes or 93.1% of total emissions stemmed from households, whereas the remaining 6.9% stemmed from all other consumers categories.
- The emissions of nitrous oxide (N_2O) were not that high: 44.4 tonnes.
- The emission of sulfur oxides is symbolically low from wood fuels.

The following example very well shows the impact of moisture content on the GHG emissions: wood purchased a half month before the beginning of the heating season with the moisture content of approximately 50% emits in the process of combustion 43.2% more GHG compared to the wood purchased 6 months before the beginning of the heating season.

4. CONCLUSION

Based on the results of conducted research, it can be concluded that firewood is one of the most important fuels for heating households in the Eastern Serbia region. Besides households, this wood fuel is also important for numerous commercial and public buildings. Even one heating plant in this region uses firewood for heating the population.

Despite the high importance of firewood for heating households and various public and commercial buildings in the Eastern Serbia, the efficiency of its use is unsatisfactory. The consumption of wood energy per 1m^2 of heating surface is extremely high, which requires appropriate measures to be taken to improve the situation.The education campaign for households and other consumers on the efficient usage of firewood should be conducted because that is very important both for the increase in the efficiency of the firewood usage and for the reduction of GHG emissions and air pollution. The air pollution in most urban areas in Eastern Serbia during the heating season has reached warning levels.

When it comes to replacing old heating appliances, the Government of Serbia grants significant financial resources to local communities every year to improve the situation in this area. However, the process is clearly slow in this region, as there are still a large number of households that have old heating appliances. In this sense, a more active role of local authorities with appropriate grants for households that do not have the necessary income level to be able to replace old appliances with new, more efficient ones is necessary.

Acknowledgements: This article was published as a part of the project "**Inventory of wood energy consumption and GHG emissions from wood fuels in Serbia** – TCP/SRB/3801/C1 suported by FAO.

REFERENCES

1. Energy consumption in households in Republic of Serbia, Statistical office of the Republic of Serbia, Belgrade, 2021
2. https://www.mre.gov.rs/dokumenta/strateska-dokumenta/integrisani-nacionalni-energetski-i-klimatski-plan-republike-srbije-za-period-2021-do-2030-sa-vizijom-do-2050-godine
3. Glavonjić, B. (2011): Consumption of wood fuels in households in Serbia - present state and possible contribution to the climate change mitigation, Thermal Science, Vol. 15, No. 3, Vinča Institute of Nuclear Sciences, Belgrade, ISSN: 0354-9836, p. 571-585, DOI: 10.2289/TSCI1103571G.
4. Rule book on conditions, content and manner of issue certificate of energy properties building, Official Gazette of the Republic of Serbia No. 69/2012; available at: https://www.mgsi.gov.rs/sites/default/files/PRAVILNIK%20O%20USLOVIMA%20SADR%C5%BDINI%20I%20NA%C4%8CINU%20IZDAVANJA%20SERTIFIKATA%20O%20ENERGETSKIM%20SVOJSTVIMA%20ZGRADA.pdf
5. WISDOM SERBIA: Spatial wood fuels production and consumption analysis, FAO, Rome 2015, available at: http://www.fao.org/3/i4394e/i4394e.pdf

Authors address:
Glavonjić Branko, Lazarević Aleksandra, Kalem Miljan
Department of Wood Science and Technology, University of Belgrade - Faculty of Forestry, Belgrade,Serbia
*Corresponding author: branko.glavonjic@sfb.bg.ac.rs

MODELS AND FORMS OF INTERNATIONALIZATION OF MEDIUM AND LARGE POLISH FURNITURE COMPANIES - SELECTED ASPECTS IN THE LIGHT OF THE EMPIRICAL RESEARCH FINDINGS

Grzegorzewska, E., Stasiak-Betlejewska, R.

Abstract: The Polish furniture industry is one of the most important producers and exporters of furniture both in the European Union and internationally. The main economic potential of the furniture industry in Poland are medium and large enterprises. The internationalization of this group of business entities is very important path for the development of the national economy. Hence, it is important to analyse the aspects of the internationalization processes of Polish furniture manufacturers.
The main purpose of the research was to analyze the most important models and forms of internationalization used by furniture companies. The research was conducted in 100 medium and large enterprises operating on the foreign market. The analysis showed differences in the implementation of internationalization processes between groups of companies that take into account the size of the company measured by the number of employees.
Keywords: furniture industry, internationalization, medium and large companies, Poland

1. INTRODUCTION

The Polish furniture industry is one of the most important on the European market. For years, Poland has had a leading position in the ranking of furniture manufacturers and exporters. The furniture industry is also of great importance to the Polish economy. It shows a positive trade balance, which has been steadily increasing for years. Even in the face of the difficulties that have arisen because of the COVID 19 pandemic, the Polish furniture industry has achieved relatively good financial results. However, Polish furniture manufacturers did not avoid problems related to the drop in demand for their products. Nevertheless, the Polish furniture industry still plays an important role on the European market, exporting in particular to its neighbors, especially to Germany, the Czech Republic, Great Britain, and France. Internationalization remains one of the most important development paths for Polish furniture manufacturers. About 90% of the sold production value goes to the foreign market, of which as much as 80% to European countries. The development of activities on the external market is very important from the point of view of the development of the entire national economy. This applies in particular to the furniture industry. Hence, it is important to examine the aspects of the internationalization processes of Polish furniture manufacturers.

The main purpose of the research was to analyze the most important models and forms of internationalization used by furniture companies. The research was conducted in 100 medium and large enterprises operating on the foreign market.

2. MODELS AND FORMS OF INTERNATIONALIZATION - LITERATURE REVIEW

One of the best-known theories explaining the processes of internationalization of companies is the model of the Uppsala developed in the 20th century by J. Johansson and F. Wiedersheim-Paul. This model assumes a sequential, staged and gradual nature of the internationalization process [Gorynia 2000]. According to this concept, companies initially enter nearby markets and then make decisions to expand their operations to geographically distant markets. Typically, company starts its internationalization in countries relatively similar to it and gradually extends it to other countries [Pogrebnyakov, Maitland 2011]. In response to arguments pointing to the significant limitations of the phased approach, other models of internationalization have been developed. The choice of the form of foreign expansion is adapted to the nature of the industry, market and resources of a given company. This concept emphasized the phenomenon of leapfrogging, i.e. skipping certain stages of the internationalization process. The simultaneous nature of activities, consisting in simultaneous operation on many markets, increases the pace and scope of the company's internationalization. An important element in the concepts are global companies from the beginning - born global. These are organizations that from the beginning operate in many markets, often founded by entrepreneurs with extensive international experience, and the choice of new markets is determined by economic factors [Madsen, Servais 1997; Rasmussen, Madsen 2002]. According to Cavusgil et al. [2008] born globals companies provide unique, high-quality products and use advanced communication and information technologies.

Activities on foreign markets may also take various forms. The choice of instruments and forms of internationalization results from factors related to the potential of the enterprise, as well as factors resulting from the characteristics of a given target market or industry in which the company operates [Daszkiewicz, Wach 2013]. In the internationalization process, companies usually go through several phases, often starting with irregular export activity, through the sale of licenses, joint ventures, opening a branch, to the final stage involving the opening of production plants abroad [Oczkowska 2007]. In the Polish literature, it is emphasized that the most frequently used instrument of internationalization is export [Rembiasz 2011; Duliniec 2009]. Moreover, Leonidou et al. [2010] and Majacchi et al. [2005] emphasized that export is the cheapest, easiest, and fastest way to enter foreign markets.

3. RESULTS OF EMPIRICAL RESEARCH ON INTERNATIONALIZATION OF POLISH FURNITURE COMPANIES

One of the important elements affecting the internationalization processes of the Polish furniture industry is the choice of the internationalization model. As emphasized, traditional models of internationalization indicate that it is a phased transition from less to more developed forms of activity. In such a situation, the company initially operates in a market or markets close to its home market and usually starts with exports. In the surveyed medium and large furniture companies, the traditional model was most often used. In total, 71% of respondents confirmed undertaking expansion in accordance with the assumptions of the traditional model. On the other hand, the simultaneous internationalization model was implemented in 11% of companies. This concept is about entering distant markets in the early stages of expansion without the need to engage in stages. On the other hand, the born global model was used in almost every 5th enterprise. The structure of answers of respondents representing medium-sized companies, i.e. those employing from 50 to 249 people, was similar. 3/4 of these entities implemented the staged model, 8% the simultaneous model, and 17% chose the path of early foreign expansion. On the other hand, in the case of large enterprises employing more than 249 people, 65% engaged in the foreign market in stages and every fifth company chose the born global approach. Therefore, the research shows that the early internationalization model is most often implemented in companies with the highest level of employment. However, the differences compared to medium-sized companies are not significant.

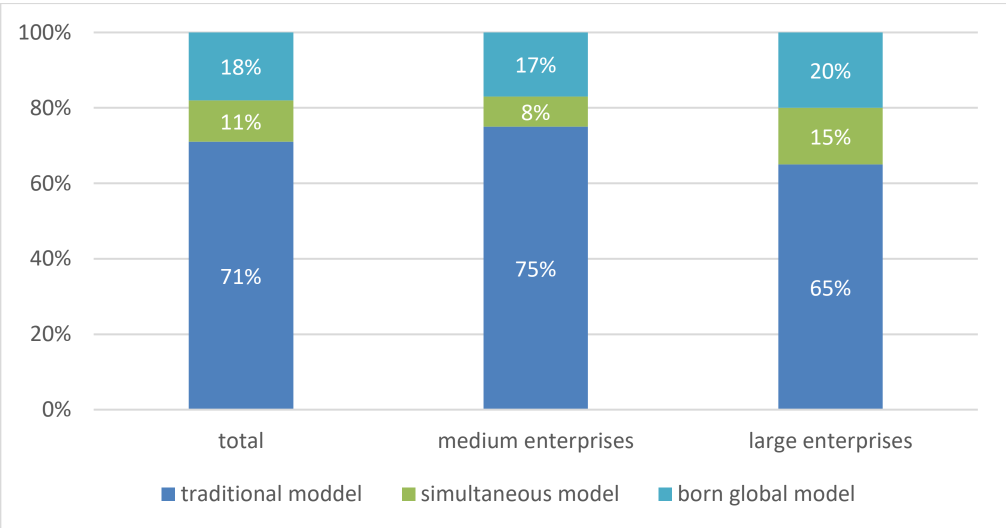


Figure 1. Internationalization models used in the furniture enterprises
Source: own elaboration.

The results of the research confirm the greater use of less advanced forms of internationalization by furniture companies. Direct and indirect exports were indicated by 84% and 94% of respondents, respectively. These forms of internationalization were the most common regardless of the size of the company. Direct export was used by

93% of medium-sized enterprises and 95% of large enterprises. The surveyed enterprises imported furniture products to a lesser extent. Among the more advanced instruments of internationalization, activities commissioned by large retail chains were indicated. In total, this form of activity on the foreign market was used by 57% of the surveyed companies, and for large enterprises this rate was even 70%, while for companies with an average employment level it was 48%. Every second enterprise carried out a joint venture with a foreign partner on the external market. Again, this form of activity was chosen more often by large companies employing more than 249 people. These enterprises more often used more advanced forms of involvement in the foreign market. A greater number of enterprises set up their own subsidiaries on the foreign market. Franchise agreements were also concluded more often. Polish furniture companies relatively rarely sold or purchased licenses from a foreign partner. In total, the sale of licenses to foreign partners was confirmed by 5% of respondents, and the purchase of such a license from a foreign partner was indicate by only 13% of respondents. This means that one of the most important instruments of internationalization in the furniture industry is still export, especially through independent representatives.

Table 1. Forms of internationalization in furniture enterprises [%]

Itemisation	Total	Medium enterprises	Large enterprises
Indirect export	84	75	98
Direct export	94	93	95
Indirect import	58	53	65
Direct import	66	62	73
Sales of licenses to foreign partners	5	5	5
Purchase of a license from a foreign partner	13	17	8
Franchise agreement with a foreign partner as the principal	20	18	23
Franchise agreement with a foreign partner as a contractor	19	15	25
Activity on behalf of large retail chains	57	48	70
Own sales branch on the foreign market	28	18	43
Own production branch on the foreign market	22	15	33
Joint venture with a foreign partner on the domestic market	33	28	40
Joint venture with a foreign partner on the external market	52	40	70

Source: own elaboration.

It is worth emphasizing that the traditional character of internationalization consisting in entering foreign markets in stages and the choice of indirect or direct export as the basic instrument of internationalization has also been confirmed in other studies. This also applies to companies that do not operate in the furniture industry. This means that Polish companies usually enter the markets of countries that are geographically and culturally similar. In this case, export is also most often used. In addition, advanced forms of internationalization are used in the case of large enterprises employing more than 249 people. These companies usually operate on the market longer, operate on a larger number of markets and have more experience in internationalization processes. Therefore, they take the risk more often, which is related to the company's greater involvement in the external market.

4. CONCLUSIONS

Internationalization has been an important development path for Polish furniture manufacturers for years. Poland is at the forefront of producers and exporters of furniture industry products, both on the EU and global markets. The conducted research shows that the traditional model of internationalization, which consists in initially entering the geographically closest and culturally similar markets, is still most often used by furniture companies in Poland. In addition, export to other countries is the most frequently used instrument of internationalization. Among the more advanced instruments of internationalization, activities commissioned by large retail chains were indicated. However, it should be emphasized that large enterprises employing more than 249 people use more advanced internationalization instruments to a greater extent than companies with an average employment level. Large producers more often take the risk associated with the company's greater involvement in the foreign market.

Acknowledgements: Research was carried out under project "Internationalization of Polish furniture companies - conditions and strategies for building competitive advantage" (No. DEC- 2019/03/X/HS4/01342), financed by National Science Centre Poland.

REFERENCES

1. Cavusgil, S.T.; Knight, G.; Riesenberg, J.R. (2008): *International Business: Strategy, Management and the New Realities*. Pearson Prentice Hall. New Jersey.
2. Daszkiewicz, N.; Wach, K. (2013): *Małe i średnie przedsiębiorstwa na rynkach międzynarodowych*. Wydawnictwo Uniwersytetu Ekonomicznego w Krakowie. Kraków.
3. Duliniec, E. (2009): *Marketing międzynarodowy*. PWE. Warszawa.
4. Gorynia, M. (2000): *Podstawy strategii przedsiębiorstwa w biznesie międzynarodowym*. In: Strategie przedsiębiorstw w biznesie międzynarodowym, M. Gorynia (ed.), Wydawnictwo Akademii Ekonomicznej w Poznaniu, Poznań.
5. Leonidou, L.C.; Katsikeas, C.S.; Coudounaris, D.N. (2010): *Five decades of business research into exporting: a bibliographic analysis*. Journal of International Management 16(1): pp. 78-91.
6. Madsen, T.K.; Servais P. (1997): *The internationalization of born globals: an evolutionary process?* International Business Review 6(6): pp. 561-583.
7. Majocchi, A.; Mayhofer, U.; Bacchiocchi, E. (2005): *Firm size, business experience and export intensity in SMEs: a longitudinal approach to a complex relationship*. International Business Review 14(6): pp. 719-738.
8. Oczkowska, R. (2007): *Przedsiębiorstwo na rynku międzynarodowym. Uwarunkowania strategii internacjonalizacji i globalizacji*. Krakowskie Towarzystwo Edukacyjne sp. z o.o. – Oficyna Wydawnicza AFM. Kraków.
9. Pogrebnyakov, N.; Maitland, C.F. (2011): *Institutional distance and the internationalization process: The case of mobile operators*. Journal of International Management 17: 68-82.
10. Rasmussen, E.; Madsen, T.K. (2002): *The born global concept*, University of Southern Denmark, Paper for the EIBA Conference on SME Internationalization and Born Globals – Different European Views and Evidence, December.
11. Rembiasz, M. (2011): *Zachowania strategiczne małych i średnich przedsiębiorstw sektora meblarskiego w procesie internacjonalizacji*. Wydawnictwo Politechniki Poznańskiej. Poznań.

Authors address:

Grzegorzewska, E.[1]; Stasiak-Betlejewska R.[2]
[1] Department of Technology and Entrepreneurship in Wood Industry, Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences (SGGW), Poland
[2] Department of Production Engineering and Safety, Faculty of Management, Czestochowa University of Technology, Poland
*Corresponding author: emilia_grzegorzewska@sggw.edu.pl

FROM INNOVATION TO SUSTAINABLE PRODUCTION AND CONSUMPTION: CHALLENGE FOR ECO-INNOVATION IN THE ENVIRONMENT OF WOOD PROCESSING INDUSTRY

Lesníková, P., Kánová, M.

Abstract: The paper points to the field of innovation in connection with Sustainable Development Goals. Innovation is directly addressed by goal 9 Industry, innovation, and infrastructure. However, many topics can be found by looking at the goal 12 Sustainable production and consumption. In many aspects, sustainable production and consumption overlap with the circular economy. In this direction, the aim of the paper was to provide an insight into selected indicators of sustainable production and consumption of wood processing industry within V4 group. It also highlighted the possible challenges in the form of eco-innovations in this field. Objects of analysis were countries of V4 group and the Sweden as the top innovation leader of EU. Data was obtained from Global innovation index and UNEP. For analyses, descriptive statistic was used. At the end of the paper, possible directions of development are highlighted.
Keywords: innovation, sustainable production and consumption, indicators, wood processing industry

1. INNOVATION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT GOALS

Innovation moves the world. It concerns all areas of people's lives or businesses, or the whole society. In a business uncertain and changing environment, it is expected that companies' ability to innovate promotes to improve business performance. Moreover, it leads to sustain their competitive advantage (de Paris Caldas et al., 2019). Innovative and integrated approaches are necessary also in the field of sustainable development. The 2030 Agenda and its 17 Sustainable Development Goals (SDGs) represents a global reference point for the transition to sustainable development at all. These goals call for the transformation of existing institutional structures in every country in the world and require a concerted effort of not only governments but business sphere and individuals too (Weiland et al., 2021). The importance of innovation for achieving the SDGs has long been recognized and there are many examples of innovative solutions. Innovation is specifically addressed by goal 9 *Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*. We addressed this goal in our previous paper (Kánová and Lesníková, 2022). The connection with innovations is also evident within the goal 12 *Ensure sustainable consumption and production patterns*.

Sustainable consumption and production (SCP) was defined at the 1994 Oslo Symposium as "*the use of services and related products, which respond to basic needs and bring a better quality of life while minimizing the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardize the needs of future generations"* (IISD, 1995). Some of the subgoals are following (UN, 2015):

- By 2030, achieve the sustainable management and efficient use of natural resources.
- By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse.
- Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production.

SCP is directly related to the field of circular economy. This represents an economic system used to transform the traditional linear economy and it has been considered as a potential driver of sustainable development (Urbinati et al., 2017). For manufacturing industries which facing challenges of resource scarcity and environmental impact, it is important to reduce, reuse and recover resources in production and consumption patterns (Kirchherr et al., 2017). Eco-innovation generally positively influences the environmental, economic, and social growth of companies that gradually adopt sustainable development (Loučanová and Nosáľová, 2020). From the definition point of view the eco-innovation is *"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives"* (Kemp and Pearson, 2007 p. 7). The aim of the paper is to provide an insight into selected indicators of SCP of wood processing industry within V4 group. It also highlights possible challenges in the form of eco-innovations in this field.

2. METHODOLOGY AND DATA

The objects of the analysis are the countries of V4 group and Sweden as a leader in innovation within EU countries. The data are reported at the macro level, but mainly for a sector of the wood processing industry. Data from Global Innovation index (period 2014-2022) which ranks world economies according to their innovation capabilities, and Sustainable Consumption and Production Hotspots Analysis Tool (SCP-HAT) (available data 2014-2018) are used. SCP-HAT is a tool to analyze a range of environmental pressures and impacts caused by domestic production. It also shows the environmental consequences of a country´s consumption occurring abroad. It contains of indicators for over 164 countries and regions. SCP-HAT has a wide range of indicators, covering environmental pressures, environmental impacts and key socio-economic indicators like population, gross domestic production (GDP) and human development index (HDI) (SCP Hotspot Analysis, 2021). In the paper we analyzed two types of indicators SCP which are shown in Table 1.

Table 1. Indicators SCP of selected countries (Source: own, data UNEP, 2022)

Environmental impacts (Domestic production)	**Environmental impacts (Consumption footprint)**
Raw material use	Material footprint
GHG emissions	Carbon footprint
Air pollution	Air pollution footprint
Blue water consumption	Blue water consumption footprint
Water scarcity	Energy footprint

The domestic production ('territorial approach') allocates environmental pressures and impacts to the country where they physically occur, irrespective of where goods and services are finally consumed. The consumption footprint ('footprint approach') allocates environmental pressures and impacts to the country where final consumers reside, irrespective of where those pressures and impacts physically occur (SCP Hotspot Analysis, 2021).

3. DISSCUSION AND RESULTS

From the macro perspective, the development of innovation index between 2014-2022 (by score) of V4 group and Sweden as a leader among EU countries is shown in Figure 1. Except for the Czech Republic, the V4 countries are below the EU average in terms of achieved values. There is a clear distance from the innovative leader, whereas all countries showing a decline from 2021 (in V4 countries occurs more distinctive) which is also attributed to the circumstances in the macro environment.

Level of R&D investment which is considered as a base for innovation, is in wood processing industry very low. It has a several causes (Kánová and Lesníková, 2022). In 2018, the average business process and product innovation intensity in the wood processing industry is around 32%, which is relatively low compared to other sectors. The average innovation intensity in this sector is about 42% (OECD, 2022).

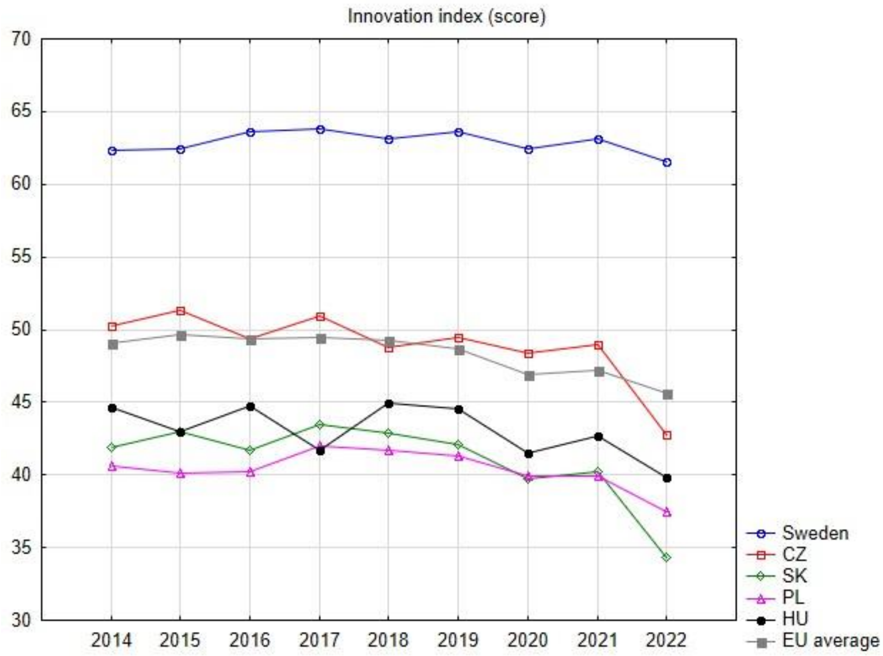


Figure 1. Innovation index of analysed countries (Source: own, data Global innovation index)

3.1. A brief view on SPC indicators in wood processing industry

From the perspective of SCP performance of wood processing industry, Table 2 and Table 3 contain of selected environmental categories; the domestic production perspective and consumption footprint perspective.

Table 2. SCP indicators of environmental impacts in 2018 (Source: own, data UNEP, 2022)

Environmental impacts (%)	CZ	HU	PL	SK	Sweden
Raw material use*	2.1	0.3	0.8	0.8	8.2
GHG emission*	0.4	0.5	0.3	0.6	0.3
Air pollution*	0.8	0.6	0.7	1.3	9.4
Blue water consumption*	6.3	1.6	0.7	4.4	13.8
Water scarcity*	6.1	1.5	0.7	4.4	15.2
Material footprint**	0.4	0.4	0.6	0.7	1.2
Carbon footprint**	0.4	0.5	0.5	0.7	0.6
Air pollution footprint**	0.3	0.4	0.4	0.6	0.8
Energy footprint**	0.9	0.8	0.8	1.3	1.8

Note: * domestic production perspective; ** consumption footprint perspective

Domestic blue water consumption encompasses water withdrawn from surface water sources or groundwater bodies within a specific country that is either incorporated into products or evaporated during the growth period of a crop or the production process of a good. The water scarcity is the relative available water remaining per area in a watershed, after the demand of humans and aquatic ecosystems has been met (UNEP, 2022).

Wood processing industry is known for the utilization of a wide range of raw materials. Despite the fact that in 2018 the sector which contributed the most to material use in Slovakia was Construction (67.5%) and Transport (16,6%), Agriculture (47%) and Food (from 25-36%) in other indicators (UNEP, 2022), the Wood processing sector it also has its weight. In 2018 this sector had not completely slight share in the overall domestic environmental pressures and impacts. The situation within domestic production perspective is similar within V4 countries. However, in several indicators, Slovakia showed the least favorable values (0.6% of GHG emission; 1.3% of air pollution).

From the consumption footprint perspective, the wood processing industry of the Slovak Republic reaches the highest values among V4 countries. This sector is contributing to the material footprint of the each analyzed country. The contribution of this industry to the material footprint in Slovakia accounted the highes value (0.7%) among V4 countries. Biomass had the largest share of raw material use (most in Poland, compared to the other V4 countries), which is followed by fossil fuels and non-metallic minerals. Sweden achieves better values in the indicators: GHG emission, carbon footprint. The others are at roughly the same level, with the exception of raw material use, air pollution, blue water consumption.

Table 3 describes the selected data of environmental indicators of industry during period 2014-2018. The Slovak Republic shows raw material use with average 0.11 tonnes/capita. The highest average consumption among V4 countries reached the Czech Republic (0.26 tonnes) and Poland (0.13 tonnes). In relation to biomass, the situation is slightly different. Except Sweden, the Poland shows the highest value on average (4.87 mill. tonnes). On contrary, the lowest average value of biomass uses shows Hungary (0.44 mill. tonnes) followed by Slovakia (0.60 mill. tonnes). The climate change indicator expressed by mill. tonnes CO^2 – the highest average value show Poland (0.95) and the Czech Republic (0.44).

Table 3. Selected indicators of environmental impacts (Source: own, data UNEP, 2022)

Indicator/Country	Valid N	Mean	Median	Minimum	Maximum	St. dev.
Raw material use (tonnes/per capita)						
CZ	5	0.26	0.25	0.22	0.35	0.05
HU	5	0.04	0.05	0.04	0.05	0.00
PL	5	0.13	0.13	0.12	0.13	0.01
SK	5	0.11	0.09	0.08	0.18	0.04
Sweden	5	1.97	1.98	1.95	1.99	0.02
Raw material use (biomass in mill. tonnes)						
CZ	5	2.77	2.60	2.30	3.69	0.56
HU	5	0.44	0.44	0.42	0.45	0.01
PL	5	4.87	4.77	4.61	5.25	0.28
SK	5	0.60	0.47	0.41	0.96	0.23
Sweden	5	19.60	19.60	19.33	19.86	0.20
Climate change (mill. tonnes CO^2)						
CZ	5	0.44	0.44	0.44	0.45	0.00
HU	5	0.26	0.26	0.23	0.27	0.02
PL	5	0.95	0.96	0.91	0.99	0.03
SK	5	0.23	0.22	0.21	0.24	0.01
Sweden	5	0.22	0.22	0.21	0.23	0.01

4. CONCLUSION

Global innovation index of analyzed countries showing a decline from 2021 (in V4 countries occurs more distinctive). This decline is among other things also attributed to the circumstances in the macro environment and it also be reflected in individual sectors of the economy. Presented data about SCP in this sector points out on the fields for improvement where action is needed. Not only in the wood processing industry is need to consider the manufacturing process with emphasizes on the raw material consumed. The SCP perspective offers many opportunities for innovation. All business or manufacture processes are facing issues regarding product quality, process efficiency, energy and water consumption, and cost and environment. There is a need for further upgrading the technologies and promote eco-innovation, applying life cycle assessment. On the other hand, technological obsolesce and cost of implementing new technologies are crucial. The challenge for wood processing industry is among others also the ability to take a naturally low-carbon material; equipping machines and plants with smart sensor systems to promote energy efficiency; use wood-plastic composites which continue to be innovated, developed and proliferated to ensure construction process cheaper, faster and cleaner. Eco-innovation is not a new business approach but nowadays it is important part of businesses and society approach towards sustainability future.

Acknowledgements: We wish to thank project VEGA: Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic; (Project No.1/0093/23 Research on the circular economy potential in the Slovak business environment in the production of innovative products based on recycled materials wood – rubber – plastic).

REFERENCES

1. de Paris Caldas, L.F.; de Oliveira Paula, F.; de Macedo-Soares, T.D.L.A. (2019): *Industry innovation spending and openness to collaboration as levers for firm performance.* European Journal of Innovation Management 22 (4): pp. 617-638.
2. IISD (1995): *Oslo roundtable on sustainable production and consumption*. New York: The International Institute for Sustainable Development (IISD).
3. Global innovation index (2014-2022). WIPO. URL: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf
4. Kánová, M.; Lesníková, P. (2022): *Investment and innovation activity in wood-processing industry of Slovakia*. In: 15th International Scientific Conference WoodEMA 2022 "Crisis management and safety foresight in forest-based sector and SMEs operating in the global environment". Slovakia. June 2022. 155-162.
5. Kemp, R.; Pearson, P. (2007): *Final Report MEI Project About Measuring Eco-Innovation (Call FPG-2005-SSP-5A)*, European Commission, Brussels, Belgium.
6. Kirchherr, J.; Reike, D.; Hekkert, M. (2017): *Conceptualizing the circular economy: An analysis of 114 definitions.* Resource, Conservation and Recycling 127: pp. 221-232.
7. Loučanová, E.; Nosáľová, M. (2020): *Eco-innovation Performance in Slovakia: Assessment Based on ABC Analysis of Eco-innovation Indicators*. Bioresources 15 (3): pp. 5355-5635.
8. OECD (2022): OECD Business Innovation Indicators: Highlights. OECD Directorate for Science, Technology and Innovation. URL: https://www.oecd.org/innovation/inno /innovation-indicators-2021-highlights.pdf
9. SCP Hotspot Analysis (2021): *Sustainable Consumption and Production Hotspots Analysis Tool (SCP-HAT). A brief guide for users*: URL: http://scp-hat.lifecycleinitiative.org/wp-content/uploads/2021/11/Sustainable-Consumption-and-Production-Hotspots-Analysis-Tool-_SCP-HAT_-A-brief-guide-for-users_final-Nov.21.pdf
10. UN (2015): *Transforming our world. The 2030 Agenda for sustainable development.* A/RES/70/1. URL: https://sustainabledevelopment.un.org/content/documents/2125 2030%20Agenda%20for%20Sustainable%20Development%20web.pdf

11. UNEP (2022): *SCP-HAT database v2.0. UN Life Cycle Initiative.* UN One Planet Network, UN International Resource Panel. Paris. URL: http://scp-hat.lifecycleinitiative.org/methods
12. Urbinati, A.; Chiaroni, D.; Chiesa, V. (2017): *Towards a new taxonomy of circular economy business models*. Journal of Cleaner Production 168: pp. 487-498.
13. Weiland, S.; Hickmann, T.; Lederer, M.; Marquardt, J.; Schwindenhammer, S. (2021): *The 2030 Agenda for Sustainable Development: Transformative Change through the Sustainable Development Goals?* Politics and Governance 9 (1): pp. 90-95.

Authors address:

Lesníková, P.[1]; Kánová, M.[1]
[1] Department of Economics, Management and Business, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovakia
[*]Corresponding author: lesnikova@tuzvo.sk

CURRENT TREND OF EVALUATION OF THE INNOVATION ACTIVITY IN THE WOOD PROCESSING INDUSTRY

Loučanová, E., Šupín, M., Čorejová, T., Štofková, J., Olšiaková, M., Šupínová, M., Repková-Štofková, K., Nosáľová, M., Kaputa, V. and Hupková, D.

Abstract: The paper is aimed at the evaluation of the innovation activity of the wood processing industry in Slovakia. The situation is assessed from the point of view of innovation activity concentrating on three areas: Wood processing, Furniture production and Wood, pulp, paper and paper products production. We analyse the comparative development of the innovative activity of the woodworking industry in Slovakia in the period from 2014 to 2020. The paper identifies the innovation activity and performance of the wood-processing industry of Slovakia and its favorable and critical areas through the analysis. The results of the analysis point to the state of innovation activity of the wood processing industry in Slovakia compared to other industries.
Key words: innovation, innovation activity, wood processing industry.

1. INTRODUCTION

The concept of sustainability in the forest-wood sector has developed from a limited concentration on sustainable wood production to a much wider evaluation of environmental, social, and economic sustainability for all value chains. Forest-Wood-Chains are understood as chains of production processes (e.g. harvesting–transport–industrial processing), which are associated with wood products. Sustainability is determined by analysing environmental, economic, and social sustainability indicators for all production processes. Lindner et al. (2010) states that the forest-wood-chains sustainability is presented as the less intensive management system with natural regeneration and motor–manual harvesting shows higher carbon storage and slightly less energy use. It creates more employment and higher labour costs, but the average rate of accidents is also higher.

Sustainability has been the main idea in forestry for many years. The forest management is aimed to organise timber harvesting schedule with regard to the forest growth potential to maintain a continuous flow of timber production. In the twentieth century we recorded a change, specifically the multiple use of forest resources was replaced by the narrow focus on timber production that used to be a management objective. Consequently, there were included multi-dimensional aspects of sustainability in forest management. After entering into the 21st century, the idea sustainability has been spread and economic sectors of Forest-Wood Chains have become its part (Päivinen, Lindner, 2006).

Innovation activities are one of the elementary preconditions for the company´s success based on the sustainable development within the market economy. These activities are a significant dynamic factor of each company. They also create an important link between the present and future of each company. Schumpeter (1939) defines innovation as creating a new production function representing application of new ideas into the production process. Some authors (OECD and Kotsemir, Abroskin, 2017, Olšiaková et al. 2017) characterise innovations as one of the factors influencing economic changes. Radical innovations create significant changes in the world; sequential innovations present the change process.

Innovations can take many forms, such as introduction of a new product, process innovations, opening of a new market, development of new sources of inputs supply and changes in industrial organization.

If an enterprise considers increasing its investments, implementing new innovations and competitiveness, it should search all available sources and mainly use all factors that support innovation processes.

Innovation process is strongly associated with predictions in innovative process. The statement or prophecy about future state of investigated object is systematically derived by the prognosis. It means that innovation in innovative process will be applied under specific conditions in a specific period. The prognosis is primarily aimed at estimates of market changes, customers' requirements and needs, competition development, market capacity development, changes in disposable incomes and macroeconomic parameters (Loučanová, 2016; Straka, 2013; Štofková, 2013; Havierniková, 2012).

From the point of view of the National program for the utilization of wood potential in the Slovak Republic (Ministry of Agriculture of the SR, 2016) wood processing industry reports insufficient competitiveness on domestic and mainly on foreign markets. The reason rests in the lack of own financial resources for innovations. It mainly concerns small and medium-sized wood processing companies. This economic unstable situation causes problems in preparation of innovation and their implementation that leads to lowered competitiveness. It is consequently reflected in many difficulties.

Most of domestic wood processing companies attempt to use the direct entry to foreign markets. Their products are often sold as semi-finished or low value production to subsequently processing companies.

Indicates that the comparative advantages are changing with the stage of wood products processing. In particular, they decline with the increasing value added products. The stage of wood processing also influences the trade specialisation. Slovakia is inter-industry country specialised on the raw material stage and the stage of semi-finished mechanical wood products with low added value (e. g. sawnwood). Slovak trade changes in specialisation with the industry with the increasing added value of the products (Loučanová et al. 2017; Šupín 2009).

There were not recorded any important changes in customers´ behaviour towards wood as a material. Therefore it is recommended to keep the existing position and implement innovative strategic business models that emphasize wood as a material and its quality compared to substitute materials (Olšiaková et al., 2016; Loučanová et al., 2014).

The purpose of these models rests in defining expectations and needs of customers taking into account their environmental as well as other reflections (Paluš et al., 2014; Paluš et al. 2011). Thus they identify the specific product characteristics taking into account the customers´ requirements.

The elements specification is an important impulse to identify trends and to determine consecutive procedures, improvements and innovations for selected products (Loučanová et al., 2014) when applying the quality management systems with the objective to ensure a higher efficiency in the whole sector (Gejdoš, 2016).

The study results by Kaputa et al. (2016) validate that foreign competition is considered to be the most substantial obstacle for the Slovak exporters of wood products. To succeed in foreign surroundings they have to invest in promotional activities. They also have to deal with limited access to capital. Another problem rests in an absence of the strategic development of the whole forest sector that would provide more effective problems solutions resulting from the industry structure transformation as well as problems connected with business relations within the supply chain which is influenced by a number of above mentioned factors and cyclical changes in wood prices.

As it is stated by Klenk and Wyatt (2015) and Šterbová et al. (2016) the strategy in the forest sector should fixate on mobilisation of knowledge. It leads to innovation that means a level of engagement with partners. It is rather creative and transformative than informative and cooperative. In the long term, it should establish new ways for innovation for all types of wood in this sector.

The aim of the paper is the assessment of the innovation activity of the wood processing industry in the Slovakia.

2. METHODOLOGY

The analytical-synthetic method presents an elementary approach to process the innovation activity issue of the wood processing industry valuation. In the paper we analyse the issue within the individual parts of the wood processing industry through the researched features and processes analysis. The situation is assessed from the point of view of innovation activity concentrating on three areas: Wood processing, Furniture production and wood, pulp, paper, paper products. We are analysis of the comparative development of the innovative activity of the woodworking industry in Slovakia in the period from 2014 to 2020. The results that we have obtained describe the innovation activity of wood processing enterprises in several respects, identifying the basic causalities and coherences. The results of the research are partial findings and conclusions, which are combined through a synthesis into a unified whole of the examined issue.

3. RESULT AND DISCUSSION

In the years 2018-2020, there were 34% of innovatively active enterprises in the Slovak Republic, which represents an increase of 6 percentage points (hereinafter only p.p.) compared to the previous survey (for the years 2016-2018). In industry and services together (without construction) they were 36.6%. Enterprises in the industrial sector (41.6%) had a higher innovative capacity than in the service sector (31.4%). Compared to the previous survey, the share of innovatively active enterprises in industry increased by 7 p.p., in service sectors by 4.9 p.p. and in the construction industry by 5.6 p.p. It follows from the above that the industry sector contributed the most to the overall increase in innovative activities.

Companies with innovation activities are those that have launched new or radically improved products or introduced new or significantly improved processes in the company or introduced organizational or marketing innovations. We can also include here those companies that have unfinished or suspended innovation activities.

On average, up to 41% of industrial and service enterprises that performed innovative activities in 2018-2020 were part of a group of enterprises, while 29.7% of them had headquarters abroad.

In the individual branches of economic activity within industry and the service sector, the share of enterprises with innovative activity was different and ranged from 17% to 80.6%. On average, it reached 41.6% in industry and 31.4% in services. It is important to note that while all industries were included in the survey, the services sector only included selected industries, thus the coverage of this sector is not complete.

While the share of the number of enterprises with innovative activity in industry and services together represented 36.6%, their share in total sales reached 67% and in the total number of employed persons 61.7%. This indicates that the economic weight of enterprises with innovative activity is higher than their number.

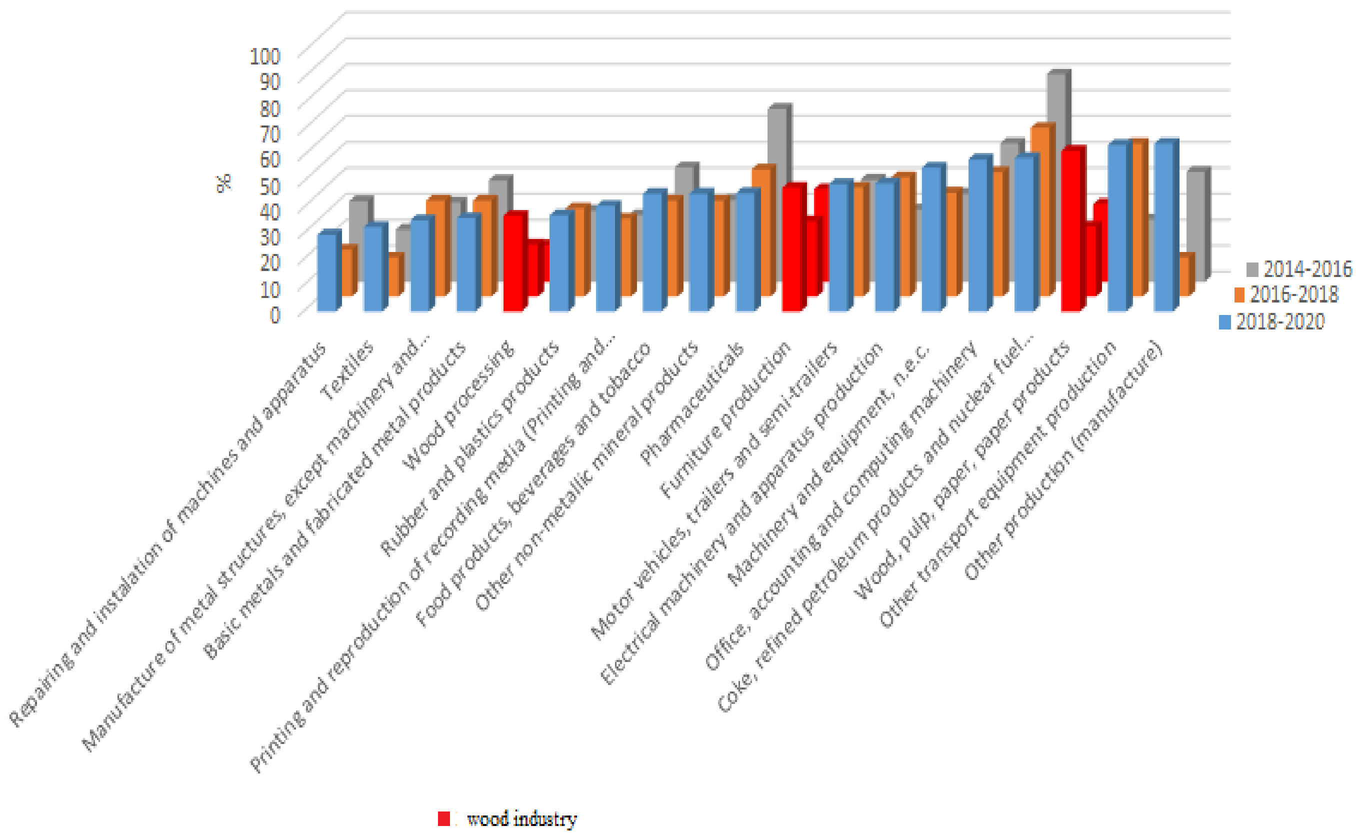


Figure 1 The share of enterprises with innovation activity from the total number of enterprises in industry

Source: Statistical Office of the Slovak Republic (2018); Statistical Office of the Slovak Republic (2020); Statistical Office of the Slovak Republic (2022)

28.7 % of enterprises were active in innovations in the Slovak Republic in the monitored period review. 30.7 % comes from industry and selected services (except construction). Enterprises from the industrial sector had higher innovation ability (32.7 %) than in the service sector (28.4 %).

The wood processing industry's innovation activity in terms of furniture production is 47.62 %, paper and paper products 61.88 % and wood processing 36.82 %. The average value of innovation activity in the wood processing industry is 48.77 % in complex. This value does not reach the average of the innovation activity of enterprises in Slovakia, so we can state that it is below average. Compared to the previous monitored period, it has increased by 18.62 % in furniture production, by 34.88 % in wood, pulp, paper and paper products, but it has increased by 16.82 % in wood processing (seen Figure 1).

The highest component of innovation expenditure was the procurement of machinery, equipment, software and buildings (40.3%).

This component of spending in industry reached 47%, in services 23.6% and in construction 25.6% of total innovation spending (Statistical Office of the Slovak Republic*, 2018; 2020, 2022)*.

CONCLUSION

Innovation activities create a significant component strongly influencing the success of the enterprise on the market regardless of which sector the enterprise belongs to. The paper is aimed at the current trend evaluation of the innovation activity in the Slovak wood processing industry. Results from our study point to below innovation activity in the wood processing industry. It should be noted that wood processing has improved in the all area of innovation activity compared. The greatest innovation activity was recorded in the area wood, pulp, paper and paper products. The lowest progress in innovative activity is recorded in the area of Wood processing.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 “Environmental Consumer and Environmental Citizen”, grant number 1/0495/22, “Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors" and grant number 1/0494/22 “Comparative Advantages of the Par Sector under the Growing Influence of the Green Economy Principles”.

REFERENCES

1. Gejdoš, P. (2016): *Analysis of performance improvement of wood processing companies in Slovakia and the Czech Republic through the implementation of quality management systems*. In: Acta Facultatis Xylologiae 2016, 58 (1), pp. 113-124.
2. Havierniková, K. (2012): *Selected aspects of clusters initiatives in the field of industry in the Slovak Republic*. In Proceedings of 21st International Conference on Metallurgy and Materials (METAL 2012), pp. 1838-1845.
3. Kalamárová, M., Parobek, J., Loučanová, E., Trebuňa, P. (2014): *Competitiveness evaluation of the slovak forest industry.* In: Proc. 7th Int. Scientific Conf. of Int. Assoc. for Economics and Management in Wood Processing and Furniture Manufacturing (WoodEMA), Zvolen, pp. 58-62.
4. Kaputa, v., Paluš, h. (2014):. *Architects and wood as a construction material: a case of Slovakia.* In: Position and role of the forest based sector in the green economy : proceedings of scientific papers. Zagreb - WoodEMA, 2014, pp. 63-68.
5. Kaputa, v., Šupín, M. (2010): *Consumer preferences for furniture.* In: Wood processing and furniture manufacturing : present conditions, opportunities and new challenges. - Zvolen : Technical University in Zvolen, 2010. pp. 81-90.
6. Kaputa, V.; Paluš, H.; Vlosky, R. P. (2016): Barriers for wood processing companies to enter foreign markets: a case study in Slovakia. European journal of wood and wood products, 2016, 74 (1), pp. 109-122.
7. Klenk, N.L.; Wyatt, S. (2015): *The design and management of multi-stakeholder research networks to maximize knowledge mobilization and innovation opportunities in the forest sector.* In: Forest Policy and Economics, 61, pp. 77–86.

8. Lindner, M.; Suominen, T.; Palosuo, T.; Garcia-Gonzalo, J.; Verweij, P.; Zudin, S.; Päivinen, R. (2010): *ToSIA—A tool for sustainability impact assessment of forest-wood-chains.* In: Ecological modelling 221(18), pp. 2197-2205.
9. Loučanová, E. (2016): *Inovačné analýzy a stratégie*. Technical University in Zvolen, Zvolen, Slovakia, 2016; p. 149.
10. Loučanová, E., Paluš, H., Dzian, M. (2017): *A course of innovations in wood processing industry within the forestry-wood chain in Slovakia: A Q methodology study to identify future orientation in the sector*. In: Forests, 8(6).
11. Loucanova, E., Parobek, J., Kalamarova, M., Palus, H., Lenoch, J. (2015): *Eco-innovation performance of Slovakia*. In: Procedia Economics and Finance, 26, pp. 920-924.
12. Loučanová, E.; Kalamárová, M.; Parobek, J. (2014): *The competitiveness of wood products from the perspective of used material.* In: Acta Facultatis Xylologiae 2014, 57 (2), pp. 155-163.
13. Loučanová, E.; Parobek, J. Paluš, H. (2014): *Identification of Slovak customers' requirements for storage furniture based on the KANO mode*l. In: Acta Facultatis Xylologiae 2014, 56 (1), pp. 109-117.
14. Loučanová, E., Nosáľová, M. (2020): *Eco-innovation performance in Slovakia: Assessment based on ABC analysis of eco-innovation indicators*. BioResources, 15(3), 5355-5365.
15. Olsiakova, M. et al. (2017): *Application of new trends of marketing communication as a competitiveness tool in furniture industry.* In: More wood, better management, increasing effectiveness: starting points and perspective, pp. 5-10 .
16. Loučanová, E., Olšiaková, M. (2020): Identification of customers'drivers for the wood building as an ecological innovation in building construction in Slovakia. *Acta Facultatis Xylologiae Zvolen res Publica Slovaca*, 62(1), 177-188.
17. Olšiaková, M.; Loučanová, E.; Paluš, H. (2016): *Monitoring changes in consumer requirements for wood products in terms of consumer behavior*. In: Acta Facultatis Xylologiae 2016, 58 (1), pp. 137-149.
18. Päivinen, R.; Lindner, M. (2006): *Assessment of sustainability of forest-wood chains*. European Forest Institute.
19. Paluš, H. et al. (2011): *End users´ preferences for joinery products and furniture*. In: Intercathedra 27/2, pp. 58-61.
20. Palus, H. et al. (2015): Contracts and risk management of innovation process of forestry services contractors in Slovakia. In: Reports of forestry research - Zpravy lesnickeho vyzkumu 60(1), pp. 8-13.
21. Paluš, H., Kaputa, V. (2009). *Survey of attitudes towards forest and chain of custody certification in the Slovak Republic.* In. Drewno: prace naukowe, doniesienia, komunikaty, 52, pp. 65-81.
22. Paluš, H.; Mat'ová, H.; Križanová, A.; Parobek, J. (2014): *A survey of awareness of forest certification schemes labels on wood and paper products.* In: Acta Facultatis Xylologiae, 56 (1), pp. 129-138.
23. Shumpeter, J. A. (1939): Business Cycle: A *Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, McGraw-Hill, New Youk, USA,1939; p. 1095.
24. Statistical Office of the Slovak Republic (2018): *Inovačná aktivita podnikov v Slovenskej republike 2012 – 2014*. Ústredie ŠÚ SR, 2020.
25. Statistical Office of the Slovak Republic (2020): *Inovačná aktivita podnikov v Slovenskej republike 2014 – 2016*. Ústredie ŠÚ SR, 2020.
26. Statistical Office of the Slovak Republic (2022): *Inovačná aktivita podnikov v Slovenskej republike 2018 – 2020*. Ústredie ŠÚ SR, 2020.
27. Štěrbová, M., Loučanová, E., Paluš, H., Ivan, Ľ., Šálka, J. (2016): *Innovation strategy in Slovak forest contractor firms—A SWOT analysis*. In: Forests, 7(6).
28. Štofková, J. et al. (2017): *Possibilities of using E-learning system of education at universities*. In: Proceedings of the 11th International Technology, Education and Development Conference, Valencia, Spain, pp. 5-8.
29. Štofková, K. (2013): *Sieťové podnikanie*. In: Manažment a sieťové podnikanie vo vedomostnej ekonomike. Žilina: Žilinská univerzita, p. 25-60.
30. Straka M. (2013): *Logistika distribúcie, Ako efektívne dostať výrobok na trh*, Bratislava, EPOS 2013, 400 p.
31. Šupín, M. (2009): *Megatrendy vo vývoji svetového hospodárstva a možnosti Slovenskej republiky zmäkčiť dôsledky hospodárskej krízy*. In: Marketing a obchod 2009 : vplyv hospodárkej krízy na marketing a obchod, pp. 5-8.
32. Šupín, M. (2014): *The impact of the global recession on wood processing industry and wood products trade and the road to recovery.* In: Position and role of the forest based sector in the green economy, 159.

33. Šupín, M. et al. (2019): Sustainable bioenergy policy for the period after 2020. In: Digitalisation and circular economy, 315.
34. *** Kotsemir, M.; Abroskin , A. (2017): *Innovation concepts and typology – an evolutionary discussion*. URL: https://www.hse.ru/pubs/share/direct/document/76780100.
35. *** Ministry of Agriculture of the SR (2016): *Proposal of the national program for the utilization of wood potential in the Slovak Republic 2016.* URL: ww.mpsr.sk/download.php?fID=7417
36. *** OECD (2017): *Oslo Manuals. The measurement of scientific and technological activities*. URL: https://www.oecd.org/sti/inno/2367580.pdf
37. *** OECD. (2019): *Oslo Manuals. Guidelines for Collecting and Interpreting Innovation Data, 3rd edition*. URL: https://www.oecd-ilibrary.org/docserver/9789264013100-en.pdf?expires=1559824060&id=id&accname=guest&checksum=9528F043A991195ED5A02E07DDD439EA

Authors address:

Erika Loučanová[1*], Mikuláš Šupín[1], Tatiana Čorejová[3], Jana Štofková[3], Miriam Olšiaková[1], Mária Šupínová[2], Katarína Repková-Štofková[3], Martina Nosáľová[1], Vladislav Kaputa[1], Daniela Hupková[5]

[1] Department of Marketing, Trade and World Forestry, Technical University in Zvolen, Masaryka 24, 960 53 Zvolen, Slovakia

[2]Slovak Medical University in Bratislava, Faculty of Health, Sládkovičova 21, 974 05 Banská Bystrica, Slovakia

[3]Department of Communication, University of Zilina, Univerzitná 8215/1, 010 26 Zilina, Slovakia

[4]Slovak University of Agricultur in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia

[*]Corresponding author: loucanova@tuzvo.sk

PAPER-BASED COSMETIC PACKAGING

Nosáľová, M., Loučanová, E., Parobek, J., Olšiaková, M.

Abstract: The trend's growth indicates that sustainability is becoming important issue also for beauty and cosmetics sector. In the pursuit of sustainability, in addition to the natural and eco-friendly cosmetic products, the companies are moving forward to use more ecological, recyclable and reusable packaging. Many beauty brands have found the answer in paper-based packaging for their products: as a recyclable, sustainable and plastic-free resource, ideal to complement their eco-friendly products. The paper reflects these actual trends and innovation in cosmetics packaging to enhance customers' awareness about sustainability applied to cosmetics by using ecofriendly packaging materials. It focuses on the perception and opportunities of paper-based packaging use in beauty and cosmetics products packaging.
Keywords: cosmetic packaging, sustainability, paper-based packaging, customer's attitudes

1. INTRODUCTION

The paper is aimed at actual trends and innovation in cosmetics packaging reflecting the rising sustainability awareness and ecofriendly packaging materials use. The paper also introduces attitudes and preferences of Slovak consumers associated with the cosmetics about cosmetics packaging material and motivation for recycle and reuse. The literature review and studies focusing on cosmetic packaging is the base of the paper. Especially, studies on attitudes and preferences of consumers for cosmetics packaging material, recycling and reusing are investigated. To enrich the introduced topic, the article also brings selected findings from the questionnaire survey of a sample of Slovak respondents. The final sample consisted of 120 respondents. It focuses on preferences when byuing cosmetics and future behavior with cosmetic packaging. Consumer demand continue to drive the movement toward sustainable packaging. Bio-based packaging materials such as paper are ideally positioned to capture some of this market growth. Following the above, in the conclusion the article provides specific examples of innovative paper-based cosmetic packaging pointing to the future trends to improve the use of paper-based packaging in cosmetic more.

2. THE COSMETIC PACKAGING MARKET – GROWTH AND TRENDS TOWARDS SUSTAINABILITY

As stated in the 2022 Market Research Report (2022) the cosmetics sector is quickly expanding sector, where the consumers' preferences are shifting toward premium beauty and cosmetics products, with increasing interest in green, organic and natural cosmetics. There is an evident, strong trend towards the use of sustainably produced raw materials in the cosmetics field, mainly as active ingredients in formulations. Sustainably produced raw materials are being introduced into the cosmetics field not only as ingredients for cosmetics but also as components of the packaging materials. Indeed, cosmetics marketing stresses that the use of green, possibly compostable or biodegradable packaging is an added value to the cosmetics product, since it witnesses customers' and producers' environmental attitude (Cinelli et al, 2019). While cosmetics companies are innovating and improving their products towards the natural, they are also effectively branding their products through innovative packaging in order to attract more customers emphasizing their ecological requirements.

The cosmetic industry has a very heavy impact on packaging (Gatt and Refalo, 2022). In fact, more than 120 billion units of cosmetics packaging were recorded to be produced globally in 2018 (Moore Kaleigh, 2019, In Gatt and Refalo, 2022). The cosmetic packaging market was valued at USD 49.4 billion in 2020 and it is estimated to growth and reach USD 60.9 billion by 2025 (Market research report, 2023).

Based on material type, the market is segmented as glass, paper, plastic, metal, and others. In fulfilling its sustainability mission, the cosmetic industry strategy is moving towards using more renewable and bio-based packaging materials. The attention is primarily focused on biodegradable materials, made from a renewable resource and easily recyclable materials, such as tree-based products, as wood, paper and cardboard (Environmental Sustainability Report, 2019). Therefore, with the regard of material, the paper-based segment is projected to be the fastest developing section in the cosmetic packaging market. For example in the year 2020 paper segment held the largest market share. Factors as recyclability and utilization of eco-friendly material make it very desirable material for cosmetic packaging. The paper material type segment is expected to grow at a CAGR of 6% from 2022 to 2030 (Market research report, 2023). This is also supported by a positive perception from the consumer perspective, because paper as a packaging material is experiencing a revival, as consumers perceive it as a high-value and environmentally friendly material (e.g. Lindh et al, 2016; Loučanová et al., 2017).

3. CONSUMERS' PERCEPTION AND ATTITUDES TOWARD COSMETIC PACKAGING

People's health awareness has extended from the food industry to the personal beauty industry and it caused that consumers have increased their interest in natural ingredients, sustainable packaging, and other green elements of cosmetic (Lin et al., 2018). As Annual Research Report (Plant Based Products Council, 2021) notes consumer demand for sustainable products is driving innovation in the beauty industry.

A comparison of the motivation to plastic packaging reduction across product categories showed that a considerable proportion of the respondents (40.1%) are favourable to reduce plastic packaging for cosmetic and beauty products. Which is, however, to a much lesser extent than the interest in reducing food packaging (75.3%) (Siddiqui et al., 2023). The ecological awareness and interest in nature, health and sustainability evidently manifests itself also in the interest to pay more, what confirmed, for example, a study (Amberg and Fogarassy, 2019): 68% of respondents are similarly willing to pay extra for a cosmetic in packaging made of natural material.

According to the UK consumers research (Corbin, 2021) plastic waste was identified as the biggest sustainability challenge facing the cosmetic industry, around half of the respondents (46%) see it this way. The consumers see the solution in less packaging in their beauty and personal care products (19%), more products with natural ingredients (17%), in-store refill stations so they can re-use existing containers (15%), sustainable packaging (12%) and in-store recycling bins (11%). The study also highlighted the importance of recycling and confirmed the interest to recycle among consumers: 45% of consumers look for symbols to show their health and beauty products use recycled materials, 67% have recycled old packaging from those products themselves (Corbin, 2021).

From the point of view of customer perception, the used packaging material predominantly signals the environmental friendliness (Resimovič et al., 2022). This study demonstrated that the material influences the perception of the product's naturalness and environmental friendliness mostly, followed only after that by the visual elements, such as the illustrations, labels, color and typeface (Resimovič et al., 2022). The research from the Plant Based Products Council (2021) shows growing interest in and demand for products made from renewable materials (for example familiarity with corn use at 47%, bamboo use at 35%), what can be positively used in packaging innovations also in cosmetic sector.

4. SLOVAK CONSUMERS' PERCEPTION AND ATTITUDES TOWARD COSMETIC PACKAGING

To enrich the analysed topic we surveyed cosmetic consumers in Slovakia about their packaging choices in cosmetic, their attitudes toward recycling, reusing, refilling the cosmetic packaging and their preferences. In terms of eco friendliness, most of the surveyed Slovak respondents only occasionally (45 %) even rarely (30%) are consciously making eco-friendly purchases when shopping for cosmetics. Regarding preferred materials, our survey confirmed that the glass is still number one with consumers, who rate it the most appealing packaging for cosmetics (46 %), followed by plastic (32 %) and by paper/cardboard in third place (18 %), what is consistent with the study of Herich (2022).

In the market for cosmetic products, consumers look for in packaging a few sustainability attributes. The number one preference is reusable/refillable and recyclable packaging (85 %), followed by the requirement that the package has minimal/ fewer materials (15 %). If they have the choice to reuse/refill or recycle the cosmetic package, they prefer to reuse/refill the given packaging (60 %). According to the data, consumers are willing to use refillables to varying degrees, depending on the cosmetic product category. Refillable packaging is preferred above all by skin care cosmetics (38 %), followed by body care cosmetics (31 %) and hair care cosmetics (25 %). Minimally refillable packaging, as far as the type of cosmetics is concerned, is decorative cosmetics (6 %), intimate cosmetics not even at all.

Along with recyclable packaging, refillable packaging is growing in importance with consumers, though as pointed out the survey Consumers' Sustainable Beauty Attitudes (Herich, 2022), it still takes some persuasion to entice them to choose refillable packaging. According to our survey the most powerful motivators for consumers to refill cosmetics are: future shopping discounts (56 %), attractive design of the cosmetic packaging for refill/reuse (16 %), as well as rewarding consumers with free goodies such as samples (13 %).

5. PAPER BASED COSMETIC PACKAGING ON THE RISE

As Cinelli (2019) notes cosmetic packaging is harder collected and recycled, thus the use of sustainable compostable or environmentally biodegradable materials for cosmetic packaging is an important challenge. Some innovative bio-based and compostable materials are already developed while others are prospectively under development. Consumer and policy awareness is important to support the development of sustainable cosmetic packaging, which represent an important step versus the saving of our environment (Cinelli, 2019).

As response to sustainable challenges, many cosmetic brands are looking for innovative eco-friendly approaches to products as well packaging. The interest is mainly concentrated in two directions, namely developing innovative materials as well as minimalism as a significant part of the next generation cosmetics packaging. As plastic alternatives are now gaining popularity innovative materials, beside bamboo – seaweed, cornstarch, mushroom fibers, avocado nuts. Bioplastics are highly durable and made from corn that can be used to make bottles, films and other containers. New eco cellophane "NatureFlex" in made out of wood pulp, while biodegradable plastic similar to polystyrene is made out of milk (Drobac et al., 2020).

In this context of material sustainability, companies are starting to introduce paper products instead of plastic in order to meet the health and green needs of consumers, in the sense of the call for "paper instead of plastic" (Mao, 2021). Here, we present in our opinion some examples of the revolutionary innovations in terms of paper-based cosmetics packaging (Figure 1).

Figure 1. Examples of paper-based cosmetic packaging in practice
Source: www.loreal.com; www.albea-group.com; www.toppan.co

We can consider the paper cosmetic tube packaging launched by cosmetic giant L'Oreal in collaboration with Albéa, a world leader in cosmetic packaging, as a breakthrough innovation regarding the paper used on the packaging of cosmetics. They are responsible for the development of the very first cosmetic tube integrating certified paper-based material to gradually replace plastic (L'Oreal, 2022). In addition, some cosmetic brands have also started to adopt a "paper instead of plastic" packaging strategy. After the launch of the first paper-based tube in 2019 in partnership with L'Oréal, Albéa Tubes extended its paper-based solutions by introducing the first paper-based bottle. The bottle contains a minimum of 50% FSC-certified paper content (without the cap or the pump), the Albéa Tubes unique paper-based web structure contributes to reducing plastic content, lowering the carbon footprint of its packaging for a better environmental impact (Sustainable packaging news, 2022). Toppan Printing, a global leader in communication, security, packaging, décor materials has improved user-friendliness while reducing resource use to achieve enhanced environmental performance by developing the paper tube-pouch. It is an innovation of an existing tube-pouch into new paper-based version easy to squeeze like a pouch, ideal for use in the cosmetics, as well as food or pharmaceutical sectors (Toppan, 2020).

4. CONCLUSION

The paper implies that the issue of sustainability is very much linked to packaging.Sustainable packaging emphasizes on using eco-friendly packaging, as well as supporting green behavior - reuse, recycle or refill to the greatest extent possible. One way is using natural materials such as paper and paper-based materials. This is also a challenge for cosmetic sector taking into account all the specifics of cosmetic products. A positive finding of our survey is, consumers' interest in packaging sustainability attributes, their willingness to recycle and to an even greater extent to reuse or refill what should the companies in cosmetic sector apply to their communication campaign. It is also obvious that the packaging material is also taken into account during consumers decision making and the paper and paper-based material is positively perceived by the consumers as well as the cosmetic companies with varying degrees of use and growth perspective.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 "Environmental Consumer and Environmental Citizen", grant number 1/0495/22, "Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors" and grant number 1/0494/22 "Comparative Advantages of the Wood Based Sector under the Growing Influence of the Green Economy Principles".

REFERENCES

1. Amberg, N.; Fogarassy, C. (2019): *Green Consumer Behavior in the Cosmetics Market*. In: Resources 8(3).
2. Cinelli, P.; Coltelli, M.B.; Signori, F.; Morganti, P.; Lazzeri, A. (2019): *Cosmetic Packaging to Save the Environment: Future Perspectives*. Cosmetics *6 (*26). URL: https://doi.org/10.3390/cosmetics6020026
3. Corbin, T. (2021): *Survey: shoppers call for more sustainable beauty products/packs*. URL: https://www.packagingnews.co.uk/luxury/news-business/survey-shoppers-call-sustainable-beauty-products-packs-03-03-2021
4. Drobac, J.; Alivojvodić, V.; Maksić, P.; Stamenovic, M. (2020). *Green Face of Packaging – Sustainability Issues of the Cosmetic Industry Packaging*. In: MATEC Web of Conferences 318.
5. Gatt, I. J.; Refalo, P. (2022): *Reusability and recyclability of plastic cosmetic packaging: A life cycle assessment.* In: Resources, Conservation & Recycling Advances 15.
6. Herich, D. (2022): *Consumers' sustainable beauty attitudes*. In: Global Cosmetic Industry Magazine. URL: https://www.gcimagazine.com/consumers-markets/article/22249829/consumers-sustainable-beauty-attitudes
7. Lin, Y.; Yang, S.; Hanifah, H.; Iqbal, Q. (2018): *An Exploratory Study of Consumer Attitudes toward Green Cosmetics in the UK Market*. In: Administrative Sciences 8(4).
8. Lindh, H.; Olsson, A.; Williams, H. (2016): *Consumer Perceptions of Food Packaging: Contributing to or Counteracting Environmentally Sustainable Development?* In: Packaging, Technology and Science 29: pp. 3–23.
9. Loučanová, E.; Kalamárová, M.; Parobek, J. (2017): *Innovative approach to product packaging.* In: Innovations in forestry, wood processing and furniture manufacturing, Zagreb, 2017.
10. Mao, A. (2021): *Paper-based cosmetic packaging on the rise*. URL: https://www.linkedin.com/pulse/paper-based-cosmetic-packaging-rise-aaron-mao
11. Resimović, L.; Brozović, M.;Kovačević, D. (2022): *Design of Sustainable Packaging for Natural Cosmetics*. In: Journal of Applied Packaging Research 14(1).

12. Siddiqui, S.A.; Profeta, A.; Decker, T.; Smetana, S.; Menrad, K. (2023): *Influencing Factors for Consumers' Intention to Reduce Plastic Packaging in Different Groups of Fast-Moving Consumer Goods in Germany.* In: Sustainability *15*.
13. ***:Environmental Sustainability Report. 2019. *Environmental sustainability the European cosmetics industry's contribution 2017-2019*. URL: https://www.cosmeticseurope.eu/files/3715/6023/8402/Environmental_Sustainability_Report_2019.pdf
14. ***: L'Oréal. 2022. *L'Oréal and Albéa launch the first paper-based cosmetic tube*. URL: 20https://www.loreal.com/en/news/commitments/loreal-and-albea-launch-the-first-paper-based-cosmetic-tube/
15. ***:Market research report. 2022. *Europe Cosmetic Packaging Market Size, Share & Industry Trends Analysis Report By Material Type (Plastic, Glass, Metal, and Paper Based), By Application (Skin Care, Hair Care, Perfume, Oral Care), By Packaging Type, By Country and Growth Forecast, 2022 – 2028*. URL: https://www.kbvresearch.com/europe-cosmetic-packaging-market/
16. ***:Market research report. 2023. *Cosmetic Packaging Market by Type, Material (Glass, Metal, Rigid Plastic, Paper Based, Flexible packaging), Application (Skin Care, Hair Care, Oral Care, Sun Care, Color Cosmetic, Fragrance & perfume) and Region – Global Forecast to 2025*. URL: https://www.marketsandmarkets.com/Market-Reports/cosmetic-packaging-market-1307.html
17. ***:Plant Based Products Council. 2021. *Annual Research Report*. URL: https://pbpc.com/plant-based-products-consumer-research-2021/
18. ***: Sustainable packaging news. 2022. *Albéa Tubes expands its paper-based range with the first squ*. URL: https://spnews.com/alb%C3%A9a-tubes-expands-its-paper-based-range-with-the-first-squ/
19. ***:Toppan. 2020. *Toppan Develops Paper-Based Tube-Pouch to Reduce Plastic Use*. URL: https://www.toppan.com/en/news/2020/04/newsrelease200428e.html
20. ***:Two Sides North America 2021 Trend Tracker Survey. 2021. URL: www.twosidesna.org

Authors address:

Nosáľová, M.[1*], Loučanová, E.[1], Parobek, J.[1], Olšiaková, M.[1]
[1] Department of Marketing, Trade and World Forestry, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Slovakia
[*]Corresponding author: nosalova@tuzvo.sk

CONCEPTS OF CREATING ADDED VALUE OF WOODEN PRODUCTS IN ACHIEVING INTERNATIONAL MARKETING ACTIVITIES AS CONTRIBUTION TO CARBON NEUTRALITY AND BIOECONOMY

Obranković, J., Pirc Barčić, A., Motik, D.

Abstract: Wood-based products present the most important material for furnishing and interior decoration for rental property owners, which present an important segment regarding the carbon neutrality goals. The aim of this paper is to investigate the concepts of creating added value of wooden products on the example of interior furnishing, for the purpose of achieving marketing activities in the international market. The results indicated that the most important factor for the users of luxury vacation accommodation, which influences their choice of vacation accommodation, is the interior design and interesting architecture of the luxury vacation home. In Croatia, based on research results, furnishing the interior and exterior with carefully selected products made of wood and wooden materials is a truly high-quality tool for creating added value of the real estate itself, and by raising the quality level of the products, extraordinary products are created that exceed the expectations of users and have a positive effect on achieving marketing activities on the international tourism market. By encouraging the use of wood products in interior furnishing, we contribute to the realization of the concept of sustainable development.
Keywords: wooden product, marketing, added-value, carbon neutrality; bioeconomy

1. INTRODUCTION

Wood-based products present the most important material for furnishing and interior decoration for rental property owners, which present an important segment regarding the carbon neutrality goals. Nowadays, to run a successful company, it is not enough to produce quality products, but it is important to create added product value that will differentiate the company from the competition. The added value of the product is considered to be the positive difference between what the customer will pay by purchasing a product or service and what will satisfy his need and contribute to the solution of his current problem. To define the added value of a product, it is necessary to know the customer well and to be aware of the fact that added value is not a permanent value, but must be constantly redefined because the competition and the market are constantly changing and adapting. Something that was added value today may be standard tomorrow. When making a purchase, consumers do not actually buy the product itself, but rather the perceived value of that product, which depends on the expected benefit that the product will bring to them. The higher the perceived value of the product, the higher the price the consumer is willing to pay for that product. While researching the international market of wood and wood products, we were intrigued by the question of whether the wood industry also has a potential for creating value-added products and how to achieve it.

Necessary conditions for successful business and production is finding potential customers, satisfying their needs and desires, and achieving a comparative advantage. Therefore, it is very important to build a relationship with customers in order to obtain information that is the key to success in recognizing added value. Luxury tourism is one of the fastest growing branches of tourism and therefore requires special attention. The use of modern solutions in terms of attracting guests is one of the main tasks in achieving excellence in the hospitality and tourism sector. Creating the added value of a luxury holiday home by using unique and representative products made of wood is certainly one of the tools for raising the quality of the offer, which directly affects the attraction of guests, and at the same time contributes to the creation of added value of the wood products used in furnishing the space.

A substantial amount of carbon is stored in wood products. Differences in the type of wood product, its production, its use, and its disposal have substantial influences on the amount and duration of carbon storage (Grainger, 2021). Depending on end-use and service life conditions, wood products can store carbon for many decades or longer, providing long-term climate benefits for people worldwide. As one example, carbon emissions can be lowered by as much as 20 times by simply installing wood flooring instead of vinyl. The green building movement has created a renewed interest in maximizing the use of wood products (Salazar and Meil, 2009.

The aim of this paper is to investigate the concepts of creating added value of wooden products on the example of interior furnishing, for the purpose of achieving marketing activities in the international market.

2. THEORETICAL BACKGROUND

Since there is no business without customers, companies are aware that their success depends on acquiring and retaining customers, as well as increasing their number. When purchasing a certain product, customers usually consider several offers and evaluate which one will bring them the greatest perceived value. Kotler (2014) defines marketing as “the science and art of exploring, creating and delivering value to satisfy the needs of a target market at a profit. Marketing identifies unfulfilled needs and desires. It defines, measures and quantifies the size of the identified market and the profit potential. It pinpoints which segments the company is capable of serving best and it designs and promotes the appropriate products and services.”

2.1. Creating added value

The concept of added value, which is created through the entire value chain, is analyzed not only at the national level, but also at the global level and at the company level. Concept is a term that denotes an abstract or generic idea generalized from specific cases. Therefore, the concept of creating added value of a product represents the creation of an idea about a potential way of achieving the greatest possible value for the customer and achieving a competitive advantage (Bruce, 2007). In luxury tourism, the added value does not only refer to services, but also to the atmosphere, aesthetics of the space and design.

2.2. The use of wood products in furnishing of holiday homes

Tourism is temporary travel to destinations outside the usual place of permanent residence and work and includes activities during the stay in the destination and services that meet the needs of tourists (Cooper et al., 2008). The tourist resource base is part of the entire economic resource base of a certain area, which, in addition to the tourist attraction base as a fundamental tourist resource, also contains other direct tourist resources and indirect tourist resources. Direct tourism resources include hospitality and catering facilities, which form a group of contents related to accommodation services and food and beverage services, such as hotels, motels, rooms, holiday homes, apartments, tourist resorts, campsites, marinas, restaurants, bars, pubs and inns. Since we emphasized the importance of luxury tourism, the area of interest in this paper is the furnishing of luxury holiday homes with wooden products. Holiday home can be defined as an object in which the renter provides accommodation and use of the garden, and which is equipped so that the guest can independently prepare and consume food (Ćorluka, 2020). Lately, luxury holiday homes occupy an increasingly large segment of the tourist market, and their daily rent reaches up to several thousand euros. The fact that the Republic of Croatia is excellently positioned and has an extremely well traffic connection with the outbond markets in the area has a very positive impact on tourism and the demand for tourist accommodation. Also, the demand is equal among foreign and domestic guests. New business conditions and new market requirements determined luxury tourism as an important potential for destination development. Nowadays, luxury tourism refers to safety, environment, accommodation facilities, high gastronomy, but also sustainability and responsible development of a tourist destination (Sarčević, 2021). Luxury holiday homes represent an important part of luxury tourism and the biggest advantage of this type of accommodation is the privacy guaranteed by villas, unlike hotels, and spaciousness, unlike apartments. While staying in luxury holiday homes guests usually enjoy exclusive amenities such as gym, sauna, cinema room, billiard table, table tennis, children's playground and many more. The advantages of these types of properties for rent are also their high-quality construction which includes a combination of premium natural materials, high-tech equipment, security and surveillance systems and excellent communication between the interior and the exterior. Also, the interior of a luxury holiday home must be equipped with authentic and impressive furniture that creates a sense of glamour and prestige, and it is desirable that it includes designer items. Wood products can fit into any interior. No architectural style, no design school is capable of rejecting this material (Bakhodirovna and Erkinovna, 2022.). In order to create elegant impression of the house, it is important to use top quality furniture because it is a guarantee of true enjoyment for exclusive guests who can very easily recognize what are the qualities of certain materials (Sobrinho, 2021.)

3. MATERIALS AND METHODS

3.1. Survey research

sample for data collection consisted of 209 business entities classified by activity based on the National Classification of Products by Economic Activity - NKD 2007, Official Gazette no. 58/07. According to the NKD 2007, the examined business entities belong to area L - Real estate business, section 68 - Real estate business with associated classes 68.31 - Real estate agencies and 68.32 - Real estate management for a fee or on a contract basis. The sample for data collection was taken from the internet database bisnode.hr. The following information was taken from all available data within the database about each business entity: 1. official name of the business entity, 2. address of the business entity and 3. e-mail address of the business entity. Certain variables were defined by multiple statements, since it was determined that a certain variable/element would be better described by applying multiple statements, rather than just one. Furthermore, certain variables were measured using a five-point Likert scale, so that the ranges from 1 to 5 were indicated along with individual statements, where 1 indicated "strongly disagree" or "unimportant", and 5 indicated "strongly agree" or "very important" (Churchill, 1976). This way respondents determined the degree of satisfaction or significance they attach to certain statements. The survey consisted of three parts: 1. general information about the respondents/business entities, 2. user expectations of holiday home, 3. use of wood products in furnishing the interior and exterior of holiday home. Five questions were defined in the first part, three questions in the second, and 12 questions in the third. The survey contained a total of 20 questions. The total number of properly completed surveys returned, the data of which was used in further analysis, was 30, which means the final response rate was 14.35%. Data collection was carried out between May and August 2022. In this paper, only some of the questions were analyzed - Categories of wood products that are most often used when furnishing the interior and exterior of luxury houses for rent/sale and Selection of materials when furnishing the interior and exterior of luxury houses for rent/sale.

3.2. Research site

A luxury holiday home in Rovinjsko Selo in Istria served as a research site for the purposes of this research. According to the project, the area of the facility is 460 square meters and consists of three floors, the first of which is underground and has a wellness area, a gym, a room for playing video games, a wine room and a laundry room. On the second, ground floor, there is a garage, an entrance hall, a living room, a kitchen, a dining room with a terrace, a bathroom and one bedroom. The third floor is reserved for three bedrooms with separate bathrooms.

Figure 1. Exterior design, made by: Arscom Studio

4.RESULTS

4.1. Respondents profile

As mentioned earlier, 30 real estate agencies established between 1995 and 2021 based in Croatia sent their responses to the survey. The largest number of agencies with the number of employees from 11 to 15 participated in the survey, 36.7% of them, followed by agencies with 6 to 10 employees (26.7%). Third place is shared by agencies with 1-5 employees (13.3%) and those with more than 20 employees (13.3%), while the lowest number of responses was recorded from agencies employing 16-20 people (10%). Of the 30 agencies engaged in renting luxury holiday homes in the Republic of Croatia, 12 of them achieved a total income of between 650 000 and 1 200 000 EUR in 2021.

4.2. Reflections of real estate rental agencies regarding consumers' needs

When they were asked to indicate the categories of wood products that, in their opinion, are most often used when furnishing the interior and exterior of luxury houses for rent or sale, respondents most often indicated exterior joinery (73.3%), floor coverings (66.7%) and wardrobes, dressers and sideboards (63.3%). In addition to marking the answers offered, two agencies added their product categories, unique decorative items and wooden decorations (Figure 2). Figure 3 shows us the average ratings by which the surveyed agencies assessed the importance of certain materials in the decoration and furnishing of the interior of luxury holiday homes. According to the graph, the most important materials for rental property owners are solid wood and chipboard and fiberboard panels, while they value plastic the least.

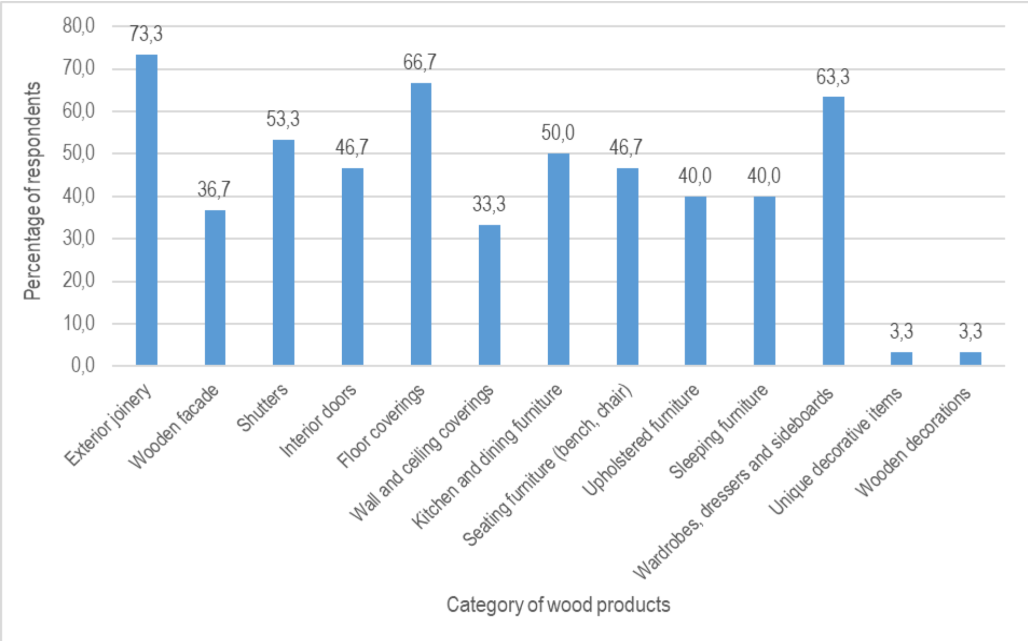


Figure 2. Categories of wood products that are most often used when furnishing interiors and exteriors of luxury houses for rent/sale

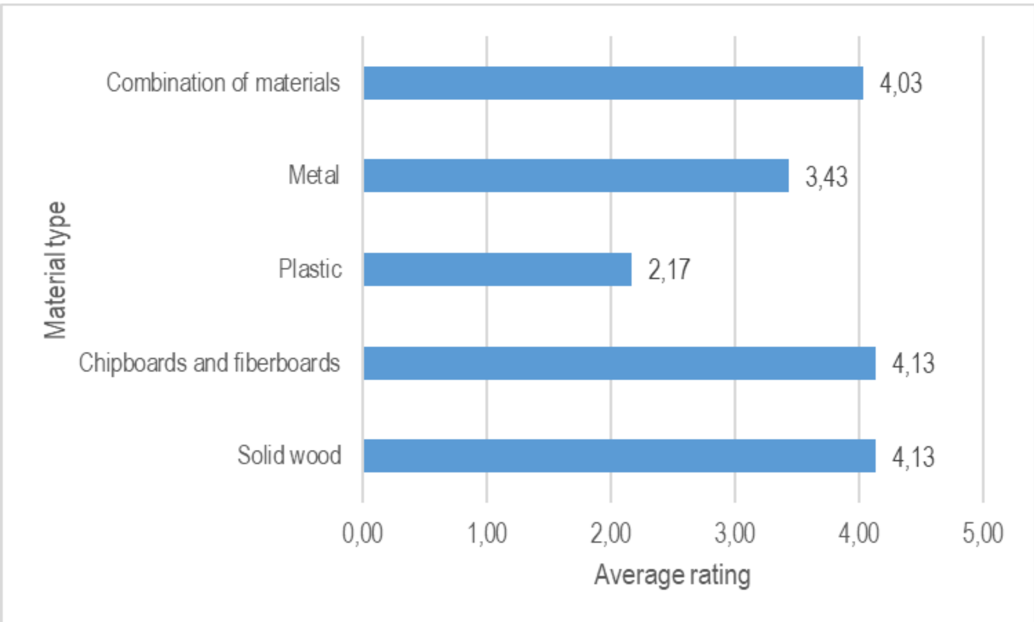


Figure 3. Average ratings of certain types of materials in the interior

According to Figure 4, which shows the average ratings by which the surveyed agencies assessed the importance of certain materials in the decoration and furnishing of the exterior of luxury holiday homes, we can see that the combination of materials achieved the highest average rating, while rental property owners are the least inclined to use chipboard and fiberboard panels in the exterior. Croatia has top-quality wood raw materials and talented designers, but when it comes to furniture production, the potential of the domestic wood industry is still underutilized. However, the fact that the furniture produced by Croatian manufacturers is increasingly valued in the world is also proven by world fairs where it is becoming in demand and domestic woodworking companies show that they have something to surprise and amaze the European and world market (Gelenčer, 2014). A great competitive advantage of Croatian furniture manufacturers is the high-quality raw material base.

With such a raw material base, it is necessary to reposition producers of semi-finished products and products with low added value into suppliers of superbly designed final products with high added value (Vlahinić-Dizdarević and Uršić, 2014).

For this reason, when furnishing a luxury holiday home in Rovinjsko Selo, emphasis was placed on the maximum use of Slavonian oak wood, which represents a world-class quality brand.

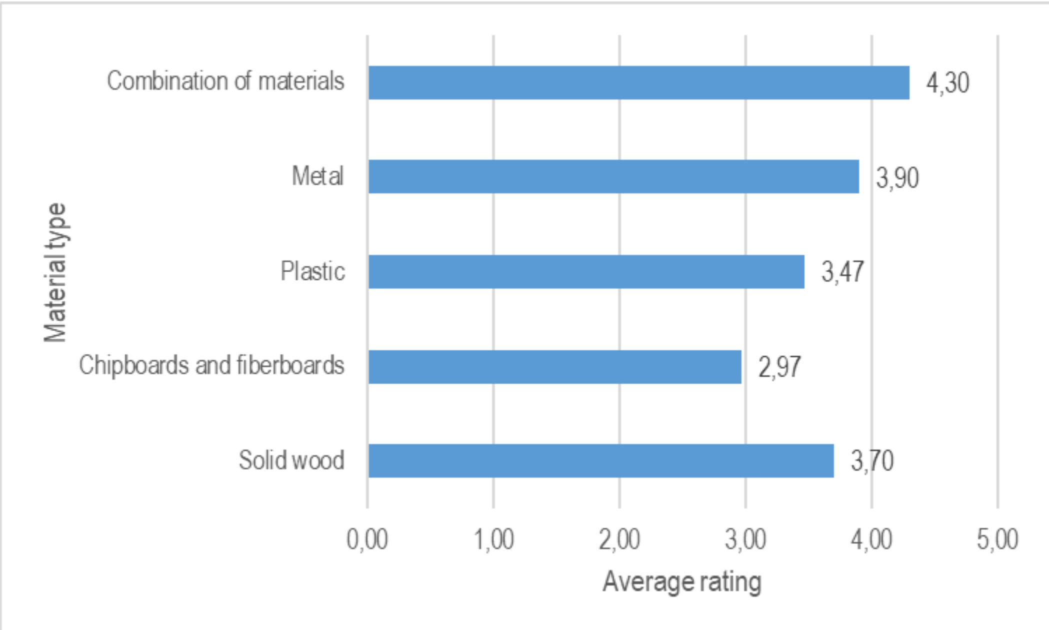


Figure 4. Average ratings of certain types of materials in the exterior

4.3. The results of interior and exterior furnishing of the luxury holiday home

Slavonian oak wood was used to make window frames and window sashes, massive floor coverings, stair treads, tables and complete furniture in the wine room with a wine cellar. Solid oak wood flooring boards were used as floor covering in the interior of the house. Window frames and window sashes for 25 windows and two big balcony doors were made of glued laminated timber coated on the outside with a clear matte varnish, while on the inside with a pigmented varnish in white color in order to harmonize with interior. Also, the interior and entrance doors were made of a combination of massive oak wood and wood-based panels and Slavonian oak was also used to make numerous furniture details. The exclusivity of the door leaves was achieved by making decorative panels, while the door jambs were decorated with profiled mouldings.

Two doors in the wellness room were made by combining door frames made of glued laminated oak wood covered with varnished MDF panels and door leaves made of tempered glass. The table in the wine room is particularly interesting, for the production of which old oak timber was used, while the knots and checks were filled with epoxy resin. The most important material used to make the furniture in the wine room is the old oak wood that adorned the traditional Slavonian house in the last century. The reuse of old oak timber in the new building symbolizes the need to preserve, revitalize and give new, added value to the inherited heritage and it authentically promotes traditional knowledge and skills in woodworking.

Figure 5. Interior doors

Figure 6. Wine room cabinet

In addition to solid wood, panel materials were also used in the furnishing of the luxury holiday home. The bodies of the kitchen cabinets were made of refined chipboard, while the fronts were made of varnished fiberboards. For the production of bathroom furniture, kerrock boards were also used, as well as veneered MDF surface-treated with varnish, and MDF refined with acrylic coating in white and gray colors. Bodies of the wardrobe cabinets in the bedrooms and storage rooms, as well as the TV cabinet in the living room, were made of chipboards refined with decorative paper pre-impregnated with melamine resins and MDF refined with acrylic coating. Upholstered modular furniture designed in Croatia played a major role in furnishing the living room of the luxury holiday home.

The wellness room is equipped with a custom-made sauna, which enables the choice of materials and equipment, designing the interior and exterior of the sauna according to the existing space and making the sauna on an aluminium substructure. Abachi wood was used to make the interior of the sauna, while the outer cladding is made of heat-treated ash wood.

Figure 7. Wardrobe

4.4. Creating added value of wooden products

In 2016, authors Eric Almquist, John Senior and Nicolas Bloch published an article in Harvard Business Review in which they identified 30 “elements of value”. These elements fall into four categories: functional, emotional, life changing, and social impact. Based on the researched example of furnishing and decorating a luxury holiday home in Istria, the basic elements, i.e. ways to achieve added value, which are part of the mentioned pyramidal hierarchy can be defined as concepts of creating added product value. On a functional level, we can say that a luxury holiday home, with its interior and exterior decoration, has a favorable effect on the element of sensory appeal. Since the highest quality materials were used during the construction and furnishing of the house, an element of quality was also achieved. Numerous additional facilities, such as a pool table, gym, wellness, game room and availability of bicycles and electric scooters, increase the value of the house by fulfilling the element of diversity. A very important functional element of adding value is the integration, which was achieved by using Istrian stone and Slavonian oak in the furnishing of the house. In this way, the most important building material and one of the recognizable symbols of Istria, the Kanfanar stone, and the golden emblem of Slavonia, the Slavonian oak, were connected. Such a combination of materials represents the presentation of architectural heritage and highlights the attractiveness of using wood and stone in furnishing modern interiors and exteriors. This way the element of belonging to a certain culture was also satisfied. Also, by alternating classic and modern design, an authentic spirit has been created and the element of staying in an aesthetically appealing space with attractive design and architecture is satisfied.

5. CONCLUSION

Analyzing the above examples of creating added value, we conclude that the luxury holiday home, which served as a research site in this study, provides its guests with numerous elements of added value, which are ensured by careful interior and exterior design. Many of the mentioned concepts of creating added value refer to wood products that, in addition to their basic function, provide users with an authentic experience enriched with numerous additional values, forming an augmented product. The use of materials such as Slavonian oak wood, whose quality is recognized worldwide, when furnishing the interior and exterior of a luxury holiday home, raises the quality level of the products themselves, but also of the entire space. The traditional use of solid oak wood is brought closer to younger generations of guests by combining it with new and modern materials when creating unique custom-made furniture. In this way, an aesthetically attractive space was created, with a contemporary design, but proven quality that promotes Croatian heritage. Wood products will play an essential role in the future of circular economy therefore, it is necessary to make as much use of wood as possible when furnishing, especially using high-value added wooden products. All this can help to carbon neutrality achievement and contribute to circular economy assessment.

6. REFERENCES

1. Almquist, E., Senior, J., & Bloch, N. (2016). The elements of value. *Harvard business review*, *94*(9), 47-53.
2. Bajramović, S., 2018: Luksuzni turizam i turoperatorske inicijative. Završni rad. Pula: Sveučilište Jurja Dobrile u Puli, Fakultet ekonomije i turizma "Dr. Mijo Mirković".
3. Bakhodirovna, Y. K., & Erkinovna, K. D. (2022). Interior styles of a wooden house. Vital Annex: International Journal of Novel Research in Advanced Sciences, 1(1), 13-19.
4. Bruce, M., & Daly, L. (2007). Design and marketing connections: creating added value. Journal of marketing management, 23(9-10), 929-953.
5. Churchill, Jr. G. A., 1979: A paradigm for developing better measures of marketing constructs. Journal of Marketing Research, 16(1):64-73
6. Cooper, C.; Fletcher, J.; Fyall, A.; Gilbert, D.; Wanhill, S. (2017): *Tourism: Principles and Practice*, Pearson Education UK
7. Ćorluka, G. (2020): Menadžment turizma – zbirka poslovnih slučajeva. Sveučilište u Splitu.1-261.
8. Grainger, A., & Smith, G. (2021). The role of low carbon and high carbon materials in carbon neutrality science and carbon economics. *Current Opinion in Environmental Sustainability*, *49*, 164-189.
9. Gelenčer, G. (2014): Što su hrvatski proizvođači namještaja pokazali na sajmu u Koelnu?. https://lidermedia.hr/aktualno/biznis-i-politika/hrvatska/sto-su-hrvatski-proizvodaci-namjestaja-pokazali-na-sajmu-u-koelnu-86384 (Accesed 30.04.2023.)
10. Kotler, P., Keller, K., Martinović, M., 2014: Upravljanje marketingom, MATE d.o.o., Zagreb
11. Salazar, J., & Meil, J. (2009). Prospects for carbon-neutral housing: the influence of greater wood use on the carbon footprint of a single-family residence. *Journal of Cleaner Production*, *17*(17), 1563-1571.
12. Sobrinho, A. C. F. (2021). How can luxury interior design brands grow through digital?-the case of covet group and the launch of home´ society platform: engaging final consumers and professionals to home´ society (Doctoral dissertation).

13. Šarčević, A. (2021). *Zastupljenost i važnost učenja talijanskog jezika u turizmu* (Doctoral dissertation, Polytechnic of Sibenik. Management).
14. Vlahinić-Dizdarević, N., & Uršić, V. (2010). Drvno-prerađivački kompleks u Republici Hrvatskoj: SWOT matrica i projekcije rasta. *Poslovna izvrsnost*, *4*(1), 63-82.

Authors address:

Obranković, J[1]; Pirc Barčić, Motik, D[1]
[1] Department of Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia
*Corresponding author: apric@sumfak.hr; jelena.obrankovic@gmail.com

TRENDS IN CONSUMERS´ REQUIREMENTS IN THE FURNITURE INDUSTRY

Olšiaková, M., Loučanová, E., Nosáľová, M.

Abstract: The furniture industry has to face different trends that accompany constant changes in the market. Recently, the furniture industry had to deal with unexpected challenges brought by the Covid-19 pandemic, which significantly affected demand for furniture products and nowadays there are novelties in consumers requirements that are related to trends that result from the social, cultural, economic, or environmental needs. The paper deals with the most significant wants and needs of the consumers in the furniture industry that businesses must consider if they want to achieve success in a strongly competitive marketplace.
Keywords: furniture industry, consumers, furniture requirements

1. INTRODUCTION

The covid pandemic brought a lot of complications that also affected the furniture industry. The furniture industry was dealing with a large-scale shutdown of domestic and global production, and similar steps were also noted in other sectors. Retailers cancelled orders, closed their operations, and thus significantly reduced their production due to the uncertain future that accompanied the pandemic. In the spring of 2020, both production and distribution of any kind was severely curtailed, and it wasn't until June 2020 that several regions began experimenting with soft reopening, which led to an immediate increase in online sales for home goods, including upholstered products and case goods, floor coverings and accessory pieces (Brown and Brian Resutek, 2021)

In view of the above, we decided to conduct a survey on the extent to which the pandemic has changed consumer preferences manifested in the area of furniture selection.

2. METHODOLOGY OF THE SURVEY

In the article, we focus on the results of the survey conducted through a questionnaire that was distributed to respondents electronically. The aim of the survey was to find out preferences of consumers related to selected tools of marketing mix applied on the market with furniture and consumers preferences associated with furniture. The survey took place from 30.01.2023 to 16.3.2023 and a total of 393 respondents took part in it.

The questionnaire consisted of 9 closed questions; respondents chose from pre-formulated answers. The results from the survey were evaluated by the means of one-dimensional and two-dimensional analysis- cluster analysis was one of the used methods.

Cluster analysis belongs to the statistical methods that deal with the similarity of multidimensional objects, i.e. objects characterized by a larger number of variables. The basis of cluster analysis is the formation of clusters in such a way that the objects within one cluster are as similar as possible and, at the same time, that the similarity of the clusters is as small as possible. Similarity, or the dissimilarity of objects is determined using similarity measures, which are classified into distance measures, correlation measures, and association measures. Only after the construction of the object similarity matrix is followed by the process of object clustering, for which hierarchical or non-hierarchical methods of cluster analysis are used. These cluster analysis algorithms are related to the construction of the tree structure of clusters – dendrogram (Trebuňa et al., 2023).

When evaluating the data through cluster analysis, we monitored the importance of selected factors influencing the purchase decision of consumers when considering the furniture purchase. A very important factor that influences the choice of specific furniture is its price. The design of the furniture, the quality of the furniture and the material from which it is made create a group of factors that influence the customer in accordance with the price. The availability of a furniture store and the sales staff themselves are not among the decisive factors influencing the consumer's purchase decisions, which is also caused by the possibility of purchasing furniture in e-shops, and thus the customers do not come into direct contact with the sales staff, therefore we consider these results to be logical.

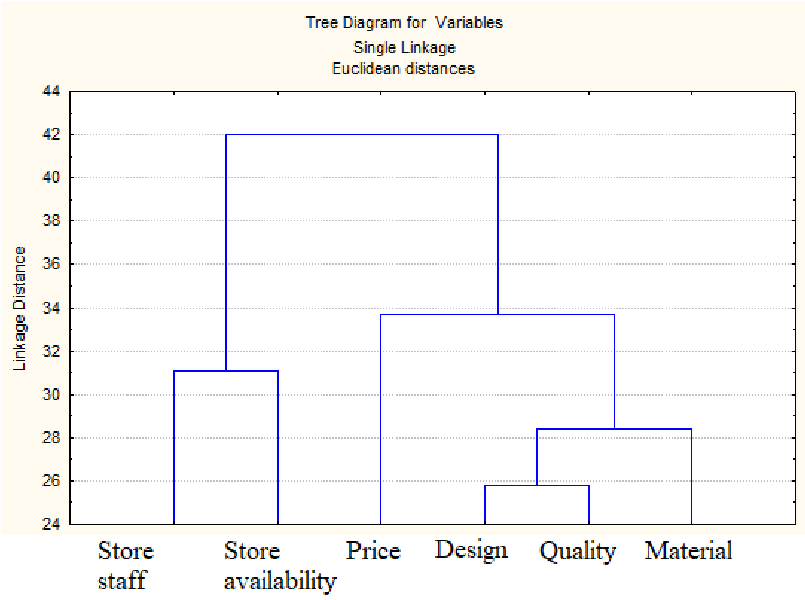


Figure 1. Cluster analysis – Factors influencing purchasing decision making

Customers primarily make decisions related to the furniture with respect to the design of the furniture, its quality, the material from which it is made and of course the price which is also a very important factor taken into account when buying some furniture.

Figure 2 shows the evaluation of the respondents' answers to the questions where they get inspiration for the furniture for their home, as well as which other factors significantly influence the choice of a specific type of furniture.

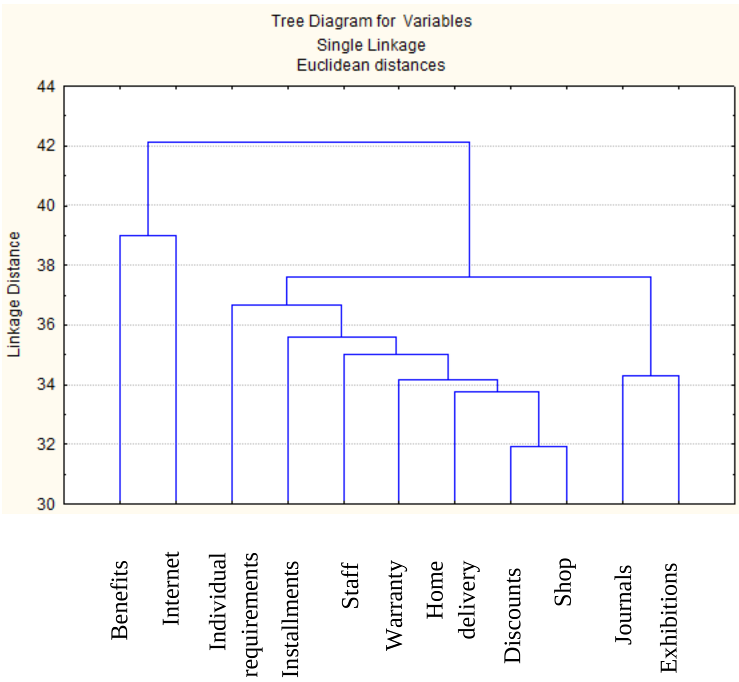


Figure 2. Cluster analysis – Preferences associated with furniture purchase

As it is presented in the dendogram, important sources of inspiration include exhibitions, where visitors have opportunities to order furniture and get it at a better price. Although the organization of exhibitions was significantly limited by the pandemic, the situation is returning to its original state, and furniture exhibitions enjoy the same popularity as they did in the period before the pandemic. Specialized magazines focused exclusively on furniture and housing are another source of inspiration for furnishing spaces in the household.

The Internet can clearly be considered as another alternative for searching for options how to furnish home, but the sample of respondents who took part in our survey shows rather conservative behavior and the Internet represents only such a supplement to traditional forms of marketing communication.

Potential customers often visit furniture stores with a certain idea of an ideal type of furniture, where they are confronted by the final price of the furniture which could exceed the financial capabilities of the customer, and therefore the possibility of buying the furniture in installments can be perceived as an important factor that affects the final purchase decision. Furniture sellers should also take into account the perception of discounts as a factor that is perceived positively by consumers interested in furniture, as it has already emerged from the previous cluster analysis that the price is often the significant factor that influences the choice of a specific type of furniture.

An important role is associated with the sales staff, their willingness, and professional skills. Other factors are also important (mainly home delivery) that can positively influence customers' decision to purchase.

CONCLUSION

In the furniture sector, as well as in other industrial sectors, we notice changes that are not only reflected in the technologies used in the production of furniture, but significant changes are also noted in consumer preferences. Many marketing factors influence the purchasing behavior of consumers and besides them there are many trends that consumers consider when they choose a product (these can be manifested in the requirements for the material from which the furniture is made).

At the same time, the price is a very important factor, which often significantly exceeds other considered factors. In the area of marketing communication, we recommend creating a suitable communication mix consisting of traditional but also innovative communication forms that can effectively influence consumers to realize the purchase. As for distribution, consumers prefer traditional brick-and-mortar stores where they can see the furniture in its real form.

Changing environment can even be reflected in consumers preferences so it is inevitable to monitor and adapt new challenges to achieve the success and to make customers as satisfied as possible to stay competitive in the industry with a saturated market.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 “Environmental Consumer and Environmental Citizen”, grant number 1/0495/22, “Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors" and grant number 1/0494/22 “ Comparative Advantages of the Wood Based Sector under the Growing Influence of the Green Economy Principles”.

REFERENCES

1. Brown, K. ; Resutek, B. (2021). Furniture in Flux: The State of the Furniture Industry and the Impact on Factors. Available at: https://magazine.factoring.org/magazine-articles/furniture-in-flux-the-state-of-the-furniture-industry-and-the-impact-on-factors
2. Trebuňa, P.; Halčinová, J.; Fiľo, M. Jadro aglomeratívnych metód zhlukovej analýz. Available at: https://www.engineering.sk/strojarstvo-extra/1802-jadro-aglomerativnych-metod-zhlukovej-analyzy

Authors address:
Miriam Olšiaková, Erika Loučanová, Martina Nosáľová
Department of Marketing. Trade and World Forestry, Faculty of Wood Sciences, Technical University in Zvolen, Slovakia
Corresponding author: olsiakova@tuzvo.sk

Comparison of Calculation Procedures for the Production of Recycled Wood-Plastic Products in the Context of Circular Economy Principles

Osvaldová, M., Potkány, M.

Abstract: The circular economy, as a strategy for separating growing prosperity and intelligent resource management within global boundaries, is currently an important concept concerning environmental protection. It is focused on the aspects of environmentally friendly production processes, and lower and more economical financial volume, which can be reflected through calculations in the profit indicator. The increasing share of both plastic and wood waste creates the potential for business plans for the production of innovative products combining these waste components into a wood-plastic board. The aim of this paper is to present a comparison of proposed calculation methodologies for the production of the wood-plastic board using traditional Calculation of Overhead Cost and innovative Machine Hour Calculation.
Keywords: cost, calculation methods, circular economy, wood plastic composites

1. INTRODUCTION

The rapid growth of the economy and the emergence of a consumer society have resulted in accelerated production processes and shortened product life cycles (Lowitt et al., 2009). Since the Industrial Revolution, the linear production model has essentially dominated the global industrial system (Sakthivelmurugan et al., 2022). The linear economy, as stated by Ghisellini and Ulgiati (2020), prevents the implementation of sustainable development. Increasing environmental pressure and resource limitations create the conditions for circular economy. The CE model emphasizes growth and development, considering the limited resources of consumption systems (Fogarassy, 2017; Webster, 2015). Studies conducted by Parobek et al. (2019) and Palu et al. (2020), who compared different scenarios of industrial wood utilization in Slovakia and resulting effects on the national carbon footprint, demonstrate this phenomenon. Wood can be turned into a wide range of products and at the end of their life these products can be recycled or reused as an energy source. It is also becoming more apparent that plastic waste (especially from the automotive industry) can be used as a component of innovative products such as wood plastic composites (WPCs Several previous studies have indicated that WPC production has an environmental impact. There are currently studies investigating the environmental impact of composite pallets made from construction and demolition waste in Finland (Khan et al., 2021) or study Turku et. al (2017). Among domestic authors, professor Sedliačik (Lyuty et al., 2019) or Čabalová et al. (2021) dealt with this issue. Recently, the WPC manufacturing sector has experienced rapid growth. According to Coherent Market Insights (2022), the WPC market is expected to generate $5.84 billion in revenue in 2021 and $12.99 billion by 2028. In this research is presented for modification to the traditional methodology of cost calculation, followed by comparisons of the results of an innovative method of calculation based on a business plan for the development of a product using recycled wood and plastic. The area of interest has been identified as having a potential research gap.

2. MATERIAL AND METHODS

Paper is a partial contribution to the UNIVNET project, in which selected Slovak universities and the Automotive Industry Association seek solutions to make innovative products from end-of-life vehicles. As part of the research, a product based on recycled wood-plastic raw material, named Wood Plastic Composite, with large dimensions of 2,500 mm - 1,250 mm - 20 mm (width, height, thickness) and a weight of 48.5 kg will be investigated. The technological line incorporates a pulveriser, homogenizing silo, drum dryer, cladding machine, and auger conveyor (amount 1,032,000 €). A predicted output of the extrusion line mixture is 1,600 kg per hour, which means that during an 8-hour shift, with capacity utilization at 87.5%, it would be possible to produce 11,200 kg (an annual production capacity of 2,800 tons). Following is a typical calculation formula for traditional Overhead Cost Calculation based on recommendations from a variety of theoretical sources (Král et al., 2018; Coenenberg et al., 2016; Potkány, Krajčírová, 2015; Popesko, 2009; Däumler, Grabe, 2002), as well as practical examples:

Direct Material Cost (sawdust + plastic waste + additives)
+ Direct Labour Cost
+ Overhead Production Cost (OPC) (Production Overhead Cost/ Direct Material × 100)
= Total Production Cost
+ Administrative and Sales Overhead Cost (ASOC) (Other Overhead Cost of Company/ Total Production Cost ×100)
= Total Own Cost of Product
+ Profit Margin
= Price without VAT

To allocate overhead costs, it is necessary to start with the financial forecast of the business plan of the identified group and the value of overhead costs. Due to this, it is possible to set rates for production, administrative, and sales overhead based upon allocation bases. A disadvantage of their approach is the application of overhead cost averaging. Materials cost refers to the cost of the input components (wood and plastic waste, binders, and UV stabilizers). This research examines WPCs based on HDPE (high density polyethylene). For calculating the rough estimate of the final product cost, the ratio of input raw materials to 1 ton mixture weight is 40:60. Wood sawdust constitutes 40% of the product, and HDPE plastic granules constitute 60% of the product (along with an unspecified amount of a classified formula of UV stabilizers and colourants, whose financial complexity is included in the item). The direct labour cost represents the additional cost resulting from the investment in the need to operate the proposed technology which consists of six super-gross salary employees. In the following comparison of both calculation procedures, the same profit margin level (20% as the industry's average level of Return on Cost) was used. The surcharge also includes a margin to cover unexpected overhead costs and a margin to adjust for the reduced utilization of production capacity during the beginning phase of production.

3. RESULTS

The Production Overhead Cost surcharge was 18.68%. Surcharges for Administrative and Sales Overhead Costs were 5.73%. It was followed the methodical process of traditional overhead cost calculation when respecting the established limits of production capacity and the resulting values of direct and overhead costs (tab. 1).

Table 1. Final Calculation of Overhead Cost Calculation

Calculation item	Calculation Unit (€/1 ton of mixture WPC)
Material Cost - sawdust	22.00
+ Material Cost - HDPE and additives	372.00
+ Labour Cost	53.54
+ Overhead Production Cost (18.67%)	73.59
= Total Production Cost	521.13
+ Administrative and Sales Overhead Cost (5.73%)	29.86
= Total Own Cost of Product	550.99
+ Profit Margin (20%)	110.20
= Price without VAT	661.19

Source: Own processing

The offer selling price of WPC with set dimensions, as determined by a preliminary gross conversion surcharge calculation, is €661.19 per ton, excluding VAT. While standard calculation methods offer a wide range of applications, they are limited by the changing conditions in the cost structure and production automation. The factor of the average principle contributes to this (Král et al., 2018; Popesko, Papadaki, 2016). While the share of production wages as a direct cost decrease over time, the overhead costs associated with machines used in the creation of outputs steadily increase. Due to the use of Overhead Cost Calculations, the question arises as to whether production wages and material can continue to represent an appropriate allocation base for redistributing production overhead costs. Moreover, this fact is also underscored by the constantly increasing level of technology and the change in the cost structure that results from it. This problem was highlighted in their studies Wöltje (2016); Mumm (2015). The changed conditions therefore require solving the problem of how to preserve the principle of causation as far as possible and how to increase the accuracy of the calculation, when overhead costs calculation is still needed. Calculation of Machine Hour Rates is one of the solutions. It is a method of calculating overhead costs that aims to achieve a more accurate allocation of overhead costs. It is a methodical procedure for allocating the production costs based on the technological nature of production. This is done with the dominant use of machinery compared to the declining share of manual work. Identifying the potential production capacity of machine technology is an essential step in determining allocations. With a real utilization rate of 87.5%, the total number of machine hours (MH) must be considered at 1,750 MH per year rather than the maximum level of 2,000 MH/year. An estimated 1,600 kilograms of product mixture were produced per machine hour. The final price of the product thus includes direct production costs, which involve the cost of input material (wood waste overhead valued at the in-house price) and additional components (HDPE plastic granulate + binder valued at the market price); wage costs including the cost of technology staff and sales managers recalculated by the relevant LCR/MH; energy costs represent the recalculation of overheads for the propulsion of machinery technologies converted to ECR/SH and calculation depreciation as overhead calculated by DCR/MH. Indirect costs are expressed as a percentage of common overhead costs. As a result of the calculations, it is necessary to include them in the sales price through the Other Overhead Cost surcharge (OOC). The innovative Calculation of Machine Hour Rate can be presented using the practical knowledge of the cost structure of the business plan (tab. 2).

Table 2. Final Calculation of Machine Hour Rate

Calculation item	Notes to calculation	Calculation Unit (€/1 ton of mixture WPC)
Material Cost - sawdust	- 22 €/ton	22.00
+ Material Cost (HDPE and additives)	- 620 €/ton	372.00
+ Labor Cost Rate/MH	LCR 85.66 €/MH *Labour Cost Rate / Machinery Hour*	53.54
+ Energy Cost Rate/MH	ECR 17.01 €/MH *Energy Cost Rate / Machinery Hour*	10.63
+ Depreciation Cost Rate/MH	DCR 98.29 €/MH *Depreciation Cost Rate / Machinery Hour*	61.43
= Total Production Cost		519.60
+ Other Overhead Cost	surcharge 55.8% *other overhead cost/direct labor cost) × 100*	29.87
= Total Own Cost of Product		549.47
+ Profit Margin	20%	109.89
= Price without VAT		659.36

Source: Own processing

Comparison of the results of both calculations reveals slight differences in how the selling price was calculated. By calculating overhead costs, the price was determined to be 661.19 € per ton of mixture. Using the innovative procedure Calculation of Machine Hour Rate, it was €659.36 for 1 ton of mixture. However, this seemingly insignificant difference is the result of a fundamental fact. As mentioned, the methodical calculation procedures used were based on the input database of data on individual cost items from the business plan proposal concept. The minimal differences in sales price calculations can be attributed to the fact that he considered the conditions of homogenous production. Nevertheless, this fact needs to be explained and expanded to include the possibility of diverse production, which is more widely prevalent in practice. It could be identified in our case with the possibility of modifying the size and volume of the WPC (especially its thickness), perhaps modifying the proportion of wood-plastic components, or changing the final surface treatment. Several essentially different products would be created, and the effect of recalculating machine hour rates more accurately would be demonstrated. As a result of the requirement to allocate costs, these groups of costs would have to be budgeted for several products with different amounts of allocation bases. Consequently, there would be a difference in the cost of goods and the price of sales. In other words, the difference in price calculated using the Machine Hour Rate Calculation application is not significant enough to affect the minimum profit markup on the product. Future research will be directed in this area. This study by Potkány and Škultétyová (2020) uses an innovative methodical procedure to calculate machine hourly rates, as well as a quantification of the price difference for the product solid wood table. A summary of the advantages of the massive wooden table that was developed is included in the study. It has also been demonstrated by Tenovici (2014) that the given method is applicable to industrial production.

4. CONCLUSION

According to the post, wood is a suitable material for CE principles and suitable for use in combination with plastic waste from the automotive industry. There is a significant amount of added value in a WPC product that has been innovated, as well as a contribution to protecting the environment. The basic premise of innovation and comparative calculation methods is the conception of a business plan, which the authors presented in the study Osvaldová, Potkány (2021). Even though the results of the comparison of the differences in the methodical procedures of price quantification have not yet revealed a fundamental change in the allocation of costs, it is possible that the difference will be increased by possible variations in the final product design as a result of these variations. Nevertheless, the greatest benefit from using the calculation of machinery cost rates is not only the elimination of inaccuracies in overhead cost calculations through the use of fixed rates of machine hours (Ostermann, 2010), but also the possibility of a quick response and flexible adjustment to changing conditions that can be provided by such a proposal. Therefore, this is once again a concept proposal with a rapidly applicable and flexible rate change for the technological component of energy consumption. The effect of depreciation and interest on business plan may also have inflationary implications on the change in material inputs. Finally, we believe the presented proposals will encourage future discussion and comparison of similar results.

Acknowledgements: This contribution is a part of the work on the project VEGA no. 1/0093/23 “Research of the potential of the circular economy in the Slovak business environment in the production of innovative products based on recycled materials wood - rubber – plastic “, and project UNIVNET “University Research Association for Waste Recovery, especially from the Automotive Industry”

REFERENCES

1. Coherent Market Insights. (2022): Wood Plastic Composite Market. URL: https://www.coherentmarketinsights.com/market-insight/wood-plastic-composite-market-4849
2. Čabalová, I.; Ház, A.; Krilek, J.; Bubeníková, T.; Melicherčík, J.; Kuvik, T. (2021): Recycling of Wastes Plastics and Tires from Automotive Industry. Polymers 13(13): pp. 2210.
3. Däumler, K.; D., Grabe, J. (2002): Kostenrechnung 2, Deckungsbeitragsrechnung. 7., neubearb. und erw. Auflage. Herne/Berlin.
4. FOGARASSY, C. (2017): The Theoretical Background of Circular Economy and the Importance of it's Application at Renewable Energy Systems. (Project). Reykjavík University. URL: https://www.researchgate.net/publication/319403544_The_Theoretical_Background_of_Circular_Economy_and_the_Importance_of_it's_Application_at_Renewable_Energy_Systems_The_Theoretical_Background_of_Circular_Economy_and_the_Importance_of_it's_Application_/citation/download
5. Ghisellini, P.; Ulgiati, S. (2019): Managing the transition to the circular economy. Handbook of the circular economy. Edward Elgar Publishing Ltd, Cheltenham.

6. Khan, M.; Deviatkin, I.; Havukainen, J.; Horttanainen, M. (2021): Environmental impacts of wooden, plastic, and wood-polymer composite pallet: A life cycle assessment approach. The International Journal of Life Cycle Assessment, 26(8): pp. 1607–1622.
7. Král, B. et al. (2018): Manažerské účetnictví. 4. rozšířené a aktualizované vydání, Management Press, Praha.
8. Lowitt, E.M.; Hoffman, A.J.; Walls. J.; Caffrey, A.M. (2009): Sustainability and its Impact on the Corporate Agenda. URL: https://webuser.bus.umich.edu/ajhoff/panels/2009%20Accenture_WBCSD.pdf
9. Lyutyy, P.; Bekhta, P.; Ortynska, J.G.; Sedliačik. J. (2019): The properties of reinforced lightweight flat pressed wood plastic composites. Acta Facultatis Xylologiae Zvolen: vedecký časopis Drevárskej fakulty 61(1): pp. 103–110.
10. Mumm, M. (201: Kosten- und Leistungsrechnung: Internes Rechnungs-wesen für Industrie- und Handelsbetriebe. Springer Gabler, Berlin.
11. Ostermann, R. (2010): Basiswissen Internes Rechnungswesen: Eine Einführung in die Kosten- und Leistungsrechnung. Witten: W3L., Herdecke.
12. Osvaldová, M.; Potkány, M. (2021): Koncept business plánu pre výrobu drevoplastových dosiek v kontexte princípu obehového hospodárstva. LH a DSP v podmienkach zelenej ekonomiky: zborník vedeckých prác. pp.113–123.
13. Paluš, H.; Parobek, J.; Moravčík, M.; Kovalčík, M.; Dzian, M.; Murgaš, V. (2020): Projecting Climate Change Potential of Harvested Wood Products under Different Scenarios of Wood Production and Utilization: Study of Slovakia. Sustainability (Basel, Switzerland), 12(6): pp. 2510.
14. Parobek, J.; Paluš, H.; Moravčík, M.; Kovalčík, M.; Dzian, M.; Murgaš, V.; Šimo-Svrček, S. (2019). Changes in Carbon Balance of Harvested Wood Products Resulting from Different Wood Utilization Scenarios. Forests, 10(7): pp. 590
15. Popesko, B. (2009): Moderní metody řízení nákladů: jak dosáhnout efektivního vynakládání nákladů a jejich snížení. 1. vyd. Praha: Grada.
16. Popesko, B.; Papadaki, Š. (2016): Moderní metody řízení nákladů: jak dosáhnout efektivního vynakládání nákladů a jejich snížení. 2., aktualizované a rozšířené vydání. Grada Publishing, Praha.
17. Potkány, M.; Krajčírová, L. (2015): Kalkulácie a rozpočty. Zvolen: Technická univerzita vo Zvolene.
18. Potkány,M.; Škultétyová, M. (2020): Tradičný verzus inovatívny prístup ku kalkulácii režijných nákladov (2. časť). Drevársky magazín. URL: https://drevmag.com/2020/10/05/tradicny-verzus-inovativny-pristup-ku-kalkulacii-rezijnych-nakladov-2-cast/
19. Sakthivelmurugan, E.; Senthilkumar, G.; Karthick, N.K. (2022): Analysis of the impact of circular economy over linear economy in the paper processing industry. Materials Today: Proceedings 66(3): pp. 1446–1452.
20. Tenovici, C-O. (2014): UTILITY OF THE METHOD T.H.M. (MACHINE - HOUR - RATE) PRODUCTION CENTURY PROCESS AUTOMATION. Management Strategies 7(4): pp. 262–270.
21. Tongsanmachine.com. 2023. URL: https://www.tongsanmachine.com/recycled-pp-pe-plastic-wpc-plank-exterior-wall-cladding-machine.html
22. Turku, I.; Keskisaari, A.; Kärki, T.; Puurtinen, A.; Marttila, P. (2017): Characterization of wood plastic composites manufactured from recycled plastic blends. Compos. Struct 161: pp. 469–476.
23. WEBSTER, K. (2015): The circular economy – a wealth of flows. 2. Ellen MacArthur Foundation Publishing, UK. 2015. 110.
24. Wöltje, J. (2016): Kosten- und Leistungsrechnung. Freiburg: Haufe Lexware,
25. Yearbook of Industry of the SR 2021.URL: https://slovak.statistics.sk/

Authors address:
Osvaldová, Mária[1*]; Potkány, Marek[2]
[1] Department of Economics, Management and Business, Faculty of Wood Sciences and Technology, Technical university, Zvolen, Slovak republic
[*]Corresponding author: xosvaldova@tuzvo.sk

THE IMPACT OF DOMESTIC CONSUMPTION ON NATURAL RUBBER FARMGATE PRICE IN COLOMBIA: AN ANALYSIS OF ITS ECONOMIC AND SOCIAL EFFECTS

Villarreal, L.

Abstract: This study analyzes the effect of domestic consumption on natural rubber farmgate prices in Colombia. collected the data for analysis from the Colombian National Administrative Department of Statistics (DANE) and the Colombian Federation of Rubber Growers (FEDECAUCHO) from 2000 to 2020. The study used an autoregressive distributed lag (ARDL) approach to estimate domestic consumption's long-run and short-run effects on natural rubber farmgate prices in Colombia. The study results indicate that domestic consumption significantly impacts natural rubber farmgate prices in the long run. In contrast, the effect is negative but insignificant in the short run. The study concludes that domestic consumption is an essential determinant of natural rubber farmgate prices in Colombia and recommends that policymakers focus on promoting domestic consumption to support the natural rubber industry.
Keywords: Natural rubber, farmgate price, domestic consumption, Colombia

1. INTRODUCTION

Natural rubber is an important agricultural product in various sectors, including automotive, construction, and healthcare. Natural rubber production is one of Colombia's most important agricultural industries, besides coffee, employing thousands of people and contributing considerably to the country's economy. The cost The price of natural rubber consumption we determine by many factors, including worldwide demand and supply, manufacturing costs, and domestic consumption. Natural rubber consumption is the quantity of natural rubber consumed inside a country for various uses such as tire manufacturing, footwear manufacturing, and industrial applications. Domestic consumption is an important predictor of natural rubber pricing because it influences domestic demand for natural rubber, influencing the farmgate price of rubber. Natural rubber literature prices suggest domestic consumption is an essential factor affecting rubber's farmgate price. According to Acharya et al. (2018), domestic consumption of natural rubber significantly positively affects the farmgate price of rubber in India. The study found that increased domestic consumption led to increased rubber prices due to higher demand in the domestic market. Similarly, Kurniawan et al. (2019) found that domestic consumption significantly determines natural rubber prices in Indonesia. The study found that increased domestic consumption led to increased rubber prices due to increased demand in the domestic market.

In Colombia, there needs to be more research on the effect of domestic consumption on natural rubber prices. However, a study by Ospina and Sánchez (2017) on the competitiveness of the rubber sector in Colombia found that domestic consumption is an essential driver of the rubber industry in the country. The study found that domestic consumption of natural rubber has been growing steadily in recent years, driven by the increasing demand for rubber-based products in the domestic market.

2. METHODOLOGY.

Data for the study were collected from the Colombian National Administrative Department of Statistics (DANE) and the Colombian Federation of Rubber Growers (FEDECAUCHO) from 2000 to 2020. The study used an autoregressive distributed lag (ARDL) approach to estimate domestic consumption's long-run and short-run effects on natural rubber farmgate prices in Colombia. The ARDL approach is suitable for analyzing the dynamic relationship between variables in the presence of non-stationarity ones.The model used in the study is as follows:

$$Yt = \beta 0 + \beta 1Xt + \beta 2Xt\text{-}1 + \beta 3Yt\text{-}1 + \beta 4Zt + \beta 5Zt\text{-}1 + \varepsilon t$$

Yt represents the natural rubber farmgate price, Xt represents domestic consumption, Yt-1 represents the lag of natural rubber farmgate price, Zt represents the exchange rate from COP to USD, and Zt-1 represents the exchange rate lag.

The ARDL approach estimates domestic consumption's long-run and short-run effects on natural rubber farmgate prices. The long-run impact represents the change in natural rubber farmgate price due to a one-unit increase in domestic consumption. In contrast, the short-run effect represents the immediate change in natural rubber farmgate price due to a one-unit increase in domestic consumption.

2.1. Results

This table presents the summary statistics of the variables used in the analysis, including natural rubber price, domestic consumption, exchange rate, and lag of natural rubber price. The mean, standard deviation, minimum, and maximum values are reported for each variable. This table provides a descriptive data summary and helps identify potential outliers or unusual patterns.The results of the study are presented in Table 1. The coefficients of the ARDL model indicate that domestic consumption has a significant positive effect on natural rubber farmgate prices in the long run (β1= 0.403, t= 2.205, p< 0.05). These results indicate that a one-unit increase in domestic consumption leads to a 0.403-unit rise in natural rubber farmgate prices in the long run. However, in the short run, the effect of domestic consumption on natural rubber farmgate prices is negative but insignificant (β1= -0.080, t= -0.462, p> 0.05).

Table 1. Summary Statistics of Variables Used in the Analysis

Variable	Mean	Std. Dev.	Minimum	Maximum
Natural rubber price (NR)	1206.94	305.55	750.08	1860.12
Domestic consumption (DC)	0.32	0.16	0.08	0.58
Exchange rate (ER)	2114.78	112.43	1975.67	2323.56
Lag of NR (LNR)	1196.27	303.57	741.09	1845.91

NR = Natural rubber, DC = Domestic consumption, ER = Exchange rate, LNR = Lag of natural rubber price.

2.1.1. Results of the ARDL Model

The model also indicates that the lag of the natural rubber farmgate price (Yt-1) has a significant positive effect on the current natural rubber farmgate price (β3= 0.713, t= 7.510, p< 0.05). This indicates that the natural rubber farmgate price in the previous period has a significant influence on the current natural rubber farmgate price. The exchange rate (Zt) has a significant negative effect on natural rubber farmgate price (β4= -2.867, t= -4.092, p< 0.05). This indicates that a depreciation of the exchange rate leads to an increase in natural rubber farmgate prices.

Table 2. Results of the ARDL Model

	Coefficient	Std. Error	t-Statistic	p-Value
Variable Constant	9.596	1.222	7.858	0.000
Xt	0.403	0.183	2.205	0.029
Xt-1	0.093	0.128	0.725	0.474
Yt-1	0.713	0.095	7.510	0.000
Zt-2	-2.867	0.701	-4.092	0.000
Zt-1	-0.479	0.308	-1.554	0.124
εt	0.094	0.401	0.234	0.815
R^2	0.956	Adjusted R^2	0.942	
F-static	67.935	p-value	0.000	

Yt = Natural rubber farmgate price, Xt = Domestic consumption, Yt-1 = Lag of natural rubber farmgate price, Zt = Exchange rate from COP to USD, and Zt-1 = Exchange rate lag.

2.1.2. Discussion

The study results indicate that domestic consumption significantly positively affects natural rubber farmgate prices in the long run. In contrast, the impact is negative but insignificant in the short run. This suggests domestic consumption is essential in determining Colombia's farmgate price of natural rubber. The positive long-run effect indicates that an increase in domestic consumption leads to an increase in natural rubber farmgate prices in the long term, as higher domestic demand stimulates production and increases the value of natural rubber. However, the negative short-run effect suggests that the market may take some time to adjust to changes in domestic consumption, and other factors may temporarily affect natural rubber farmgate prices in the short term. The study also found that the lag of natural rubber farmgate prices significantly positively affects the current price. This suggests that past prices play a role in determining current prices, possibly due to production and supply chain dynamics. Furthermore, the study found that the exchange rate significantly negatively affects natural rubber farmgate prices. This indicates that a depreciation of the exchange rate leads to an increase in natural rubber farmgate prices. This finding is consistent with previous studies that have found that changes in exchange rates can affect the prices of agricultural commodities in developing countries.

Overall, the results of this study suggest that domestic consumption and exchange rates are important factors to consider when analyzing natural rubber farmgate prices in Colombia. Policymakers and market actors can use this information better to understand the dynamics of the natural rubber market and make informed decisions regarding production, consumption, and trade.

3. CONCLUSION

This study has some limitations to consider when interpreting the results. First, the analysis is limited to the Colombian natural rubber market, and the results may need to be generalizable to other countries or regions. Second, the study must account for other factors affecting natural rubber farmgate prices, such as weather patterns, government policies, and market speculations. Future research could include these factors to provide a more comprehensive analysis of the natural rubber market. Using an ARDL approach to analyze the effect of domestic consumption on natural rubber farmgate prices in Colombia, we can appreciate that results indicate that domestic consumption significantly impacts natural rubber farmgate prices in the long run. In contrast, the effect is negative but insignificant in the short run. The study also found that the lag of natural rubber farmgate prices and exchange rates significantly affects farmgate rubber prices. These findings suggest that policymakers and market actors should consider domestic consumption and exchange rates when analyzing natural rubber farmgate prices in Colombia.

Table 3. Descriptive Statistics of Natural Rubber Production and Consumption in Colombia (2000-2020).

Variable	Total	Min	Max.	Mean	Std. Dev
Natural Rubber Production (metric tons)	50,124	31,425	86,068	52,593.20	16,881.75
Domestic Consumption (metric tons)	5,803	1,928	10,204	5,809.85	2,225.73
Export Volume (metric tons)	44,321	22,939	79,682	46,424.35	14,325.15
Farmgate Price (COP/kg)	1,332.05	796.28	1,860.45	1,245.33	287.16

Note: COP = Colombian Peso, Table 3: Provides descriptive statistics for natural rubber production, domestic consumption, export volume, and farmgate price in Colombia from 2000 to 2020. The table shows that the mean natural rubber production was 52,593 metric tons, with a minimum of 31,425 and a maximum of 86,068. The mean domestic consumption was 5,809 metric tons, with a minimum of 1,928 and a maximum of 10,204. The mean export volume was 46,424 metric tons, with a minimum of 22,939 and a maximum of 79,682. The mean farmgate price was COP 1,245.33 per kilogram, with a minimum of COP 796.28 and a maximum of COP 1,860.45.

Acknowledgments: I sincerely thank my supervisor for their invaluable guidance, support, and mentorship. His expertise and unwavering commitment have played a significant role in shaping the outcome of this project. Additionally, I extend our heartfelt appreciation to my loving wife, whose endless encouragement, understanding, and patience have been a constant source of inspiration. Lastly, I want to acknowledge the presence of Isabela, whose arrival brings immeasurable joy and reminds me of the beautiful blessings in my life.

REFERENCES

1. Acharya, A., Prasad, A., & Nair, S. (2018). An Analysis of Domestic Consumption and Export Demand of Natural Rubber in India. International Journal of Sustainable Economy, 10(3), 336-355.
2. Chen, J., & Guo, X. (2020). Impact of China's macroeconomic policies on natural rubber price: Evidence from ARDL approach. Journal of Cleaner Production, 276, 123311. https://doi.org/10.1016/j.jclepro.2020.123311
3. Colombian Ministry of Agriculture and Rural Development. (2021). Anuario Estadístico del Sector Agropecuario. http://www.minagricultura.gov.co/estadisticas/Paginas/anuarios.aspx
4. Guan, Z., Liu, B., & Xue, F. (2020). The impact of global economic policy uncertainty on natural rubber prices: Evidence from the ARDL model. Resources Policy, 68, 101765. https://doi.org/10.1016/j.resourpol.2020.101765
5. Ospina, D. A., & Sánchez, C. A. (2017). Análisis de la competitividad de la cadena de valor del caucho en Colombia. Revista Científica Agroecosistemas, 5(2), 19-30.
6. United Nations Conference on Trade and Development. (2017). The Colombian rubber industry: Analysis and recommendations for upgrading its competitiveness. https://unctad.org/system/files/official-document/tcsdtlb20172_en.pdf
7. World Bank. (2021). World Development Indicators. https://databank.worldbank.org/source/world-development-indicators

Authors address:
Villarreal, L[1];
[1] Department of Forestry and Wood Economics, FLD, Czech University of Life Sciences (CZU), Prague, Czech Republic
[*]Corresponding author: villarreal_patino@fld.czu.cz

MATHEMATICAL MODEL FOR THE FORMATION OF SETTLEMENTS BASED ON FOREST AND GREEN INFRASTRUCTURE

Marinov, P.

Abstract: The research will trace the historical-geographical formation of the first urbanized spaces (industrial areas), oriented towards a "new way" of life related to the natural environment. The application of the comparative analysis will affect the relationship between green spaces (forests, parks, leisure and recreation areas) and the urban environment. Stepping on the above-mentioned scientific review, the study examines the theoretical creation of urbanized spaces through a mathematical model, based on forest resources, green infrastructure, including all the attributes of a settlement environment. The mathematical model will be based on principles and factors combining the interaction between forest environment, green infrastructure and urban environment.
Keywords: forest resources, green infrastructure and urbanized areas

1. INTRODUCTION

The accelerated development of urbanization in a local and global plan, requires a change of the paradigm for Sustainable Development (Bruntland, 1987) and sets the task for the formation of forests, green spaces and green infrastructure in urban areas. The change of climate changes and society in a socio-economic plan leads to the transformation of the urbanized environment from being highly indifferent to green spaces to an increased enforcement of Green Policy. In order to clarify the concepts of "settlement forests", "green spaces", "green infrastructure" and "green cities", we will have to look for the roots and problematics, back in time space (until today, the creation of mathematical models of settlements based on " green philosophy") associated with the birth of the "Industrial Revolution" in England.

The creation of a new type of settlement is based on the idea of harmonizing the industrial way of life with an ecological one and dates back to the time of XIX century. This utopia was first conceived in 1817 by the industrialist Robert Owen (1771-1858), who built the settlement of New Lanark, near Glasgow, Scotland, for poor workers. Subsequently, other similar ideas were developed, such as that of Sir Titus Saul (1803-1876), the construction of an industrial city - Saltaire (the settlement is located near the waterway between Leeds and Liverpool, which served the textile industry) for 1500 workers in the city Shipley in West Yorkshire metropolitan. The settlement is distinguished by houses that have the large pretension of the living quarters, as well as the distances between the buildings (in the construction of modern settlements, this proportion is respected, as laid down in the mathematical model of the publication). In 1894, a similar village, Bournevill, was built in the south-west of Birmingham, England, founded by the Quaker Cadbury family for workers at the Cadbury factory, designed to be a "garden village". The concept of the New Town, which is based on the idea of improving the quality of life through sustainable development of the urban environment, has its roots in early 1898, with the formation of the Garden City Association in England. The idea for its creation was based on Ebenezer Howard's (1850-1928) book "To-morrow a "Peaceful Path to Real Reform" (1898). Four years later, the book was published under the title "Garden Cities of Tomorrow" (1902), this popularized the author himself and his ideas.

The tendency to create green spaces and parks in England began at the beginning of the XIX century and in the following decades gained more and more popularity and authority among industrialists and the political class, striving to create favorable conditions for life in the industrial part of the empire. In 1820, a part of the still private Regent's Park was opened for public use, in 1826, Hyde Park and in 1846, Victoria and Battery Parks. Also during the same period, architect John Nash had the idea of placing residential buildings "in the middle of a sea of greenery" on the territory of Regency Park, with all the facades facing the park space (Radovanova, 2021).

Why precisely in England, in particular London, in the industrial areas of the country (the beginning of the 19th century) did these ideas arise about - green space, rest areas, parks and the like? - The answer lies in the socio-economic way of life in England at that time - the use of huge amounts of coal (charcoal) and wood material for any kind of activity in the settlements, when they were burned, ash, soot, smoke and other gases were released, which polluted the environment of the settlements. Before and after the Industrial Revolution, Britain was the largest producer and consumer of charcoal in Europe.

The formation of an idea for a new type of settlement, "garden cities" or spaces with a larger green area, began in the early 1950s. The first town to be declared a "new town" was Cumbernauld in Scotland and opened on 9.12.1955, the second such settlement was Runcorn, Cheshire, North West England, declared a "new" type in September 1963. Here again we must mention that the innovative ideas came from Albion and in this direction during the period 1945 - 1960, 15 new towns were formed in England and another 17 were formed within ten years from 1961 to 1971. The cities of Milton Keynes from 1960 and Redditch from 10.04.1964 are cities where the "new city" philosophy is successfully applied. The city of Redditch largely conforms to the model proposed in the scientific publication, with an area of 2 914 ha and a population of 70 000. The most essential element for an urban forest or green spaces is that they can provide maximum conditions for the functioning of the socio-economic life of the population, Redditch being a 'green belt' settlement. It was first drawn up by Worcestershire County Council and the size of the borough in 2017 is 1 800 hectares or 18 km². From the practical and evidentiary part to the publication, in Redditch the sustainable use of forest plantations for leisure and recreation in the territory of the settlement constituted more than 15%, several decades ago. We believe that there is currently over 20% coverage of spaces with green spaces – urban forests and parks. It is estimated that there is currently 17% of land in Britain which is 'vacant' and could be occupied by green space. Theoretically, this model is applicable in the majority of countries in Europe (Dobrev, 2012).

Some authors have the opinion that the formation of new eco-villages can be based on already existing ones (Harvey, 2005), and not by creating new ones in separate areas. The study is based (as a philosophy) on the "New Urbanism" movement created in the USA at the beginning of the eighties of the XX century. Creation and operation of buildings with zero carbon emissions; providing 30% of housing in a city to be owned and formed on green areas (green infrastructure spaces), making up 40% of the urbanized territory. Many authors believe that the urban ecosystem is part of the biosphere and it is not subject to management and as such, it is completely controlled by natural factors. With the change of climate from local to global level, it has been established from a purely practical point of view that the urban ecosystem represented in all varieties is affected by the occurred and occurring climate changes, which in turn it can change and regulate by anthropogenic activity. This forces more and more people and especially those in power, to pay attention to the changing climate and create concepts for the formation of green spaces and other similar initiatives related to the construction of green philosophy in urbanized spaces. Such an initiative is the construction of "Green Infrastructure", its development and enforcement, as a concept in the settlements of planet Earth. In connection with the development of "Green Infrastructure" as a concept in the EU, the Council of Ministers of the Environment from March 2010, regarding biological diversity to Document No. 7536/10, accept as a definition: "Green infrastructure is an interconnected network of natural areas, including farmland, greenways, wetlands, parks, forest reserves, native plant communities, and marine areas that naturally regulate storm runoff, temperature, flood hazards, and water, air, and ecosystem quality." . The definition was agreed by a subsequent EC study in 2012: Science for Environment Policy – In-depth report on Green Infrastructure. When developing different types of strategies related to green infrastructure, the EC takes into account different definitions, which do not have a precise regulation, but are applicable to certain territories and correspond to theoretical-practical activities (Bachev, 2016).

There are approximately 7.888 billion people living on Earth today. There are built hypotheses that interpret the number of the population in different ways and whether the arable land of the planet can feed them. This is an important issue that we will not dwell on here, but it is directly related to urbanization, increasing the number of the population in large cities (Markov, 2019). Of course, all this leads to climate change and so on, for us it is more important to create a theoretical mathematical model based on various components and especially green spaces for a certain territory and whether it will help to build a settlement from a new kind, related to the Green philosophy of the moment.

2. MATERIALS AND METHODS

The presentation of the theoretical mathematical model in the scientific work aims to present the construction of a settlement according to the number of inhabitants, on the basis of forest and green infrastructure, which will meet the socio-economic needs of this population (Dokuzova, ets, 2014). The model presents different types of conditions, which are interconnected and form the entire theoretical settlement structure, assuming:

$$S = Sh + \frac{N\,x\,X}{10^6} + \frac{\mathrm{N\,x\,Y}}{10^6} \quad \leftrightarrow \quad \mathbf{S = Sh + 10^{-6}\ x\ N\ x\ X + 10^{-6}\ x\ N\ x\ Y}$$

Where:
Sh – residential and communication area for each inhabitant in km²
S - area of the entire settlement in km²
N – number of inhabitants in the city ≈ 50,000 / the figure can be changed /
X - green area per inhabitant in m²
Y – area for social activities per inhabitant in m²
X ≥ 20 m² of green space per inhabitant in the settlement

In the development of the theoretical mathematical model, mathematical methodology, historical overview, geographical approach and comparative analysis have been applied in the scientific research (Milusheva, 2012). Microsoft Word and Excel were used in the research and analysis of statistical information.

3. RESULTS AND DISCUSSION

In the theoretical mathematical model, we assume a one-floor building that represents a square with a side of 22 m², then its area will be 484 m² or it will have 4 apartments of 100 m² each, with a total area of 440 m². Conditionally, we can assume that each of them is inhabited by 4 people or a total of 16 people per floor. For the model, we will assume that 3 200 such single-storey buildings are needed, or:

Where: 3 200 x 16 = 51 200 inhabitants will be the settlement

Therefore, these buildings will be located in the shape of a rectangle with sides ABCD:
Where:

80 - residential buildings /one-story/	40 - rows of residential buildings
39 - streets length	79 - streets in width between buildings
22 m - side of the residential building	15 m - width of the streets

AB = 80 x 22 + 79 x 15 = 2,945 km
CB = 40 x 22 + 39 x 15 = 1,465 km **S ABCD = 2,945 + 1,465 = 4,410 km²**

Answer: The presented 3,200 buildings in the theoretical mathematical model are located in a rectangle with sides ABCD in a 40 x 80 row, assuming that:

X = 20 m² of green area per person from the settlement
Y = 40 m² of social area per person from the settlement

$$\mathrm{S} = 4{,}41 + \frac{51\ 200\ x\ 20}{1\ 000\ 000} + \frac{51\ 200\ \mathrm{x}\ 40}{1\ 000\ 000} \qquad \boldsymbol{S = 7{,}482\ km^2}$$

According to (Marinov, 2022), a formula is presented, in which a coefficient (K) is accepted, which gives a prerequisite for a good, better or bad settlement for living. This formula is derived from the condition that 40% of the areas of the given settlement are green (Radovanova, 2021). In the example we present and assume as a theoretical mathematical model, this green area is up to 40%. This gives us reason to assume that Sh can also allow a certain number of two-storey and multi-storey buildings, which will free up spaces for green areas and, if necessary, for social activities.

This gives reason that the values of (Y) and (X) may change, depending on the spatial urbanization of the settlement. The model we offer is mathematically theoretical and allows changing all the values in the condition. The creation of new types of settlements on the basis of a mathematical model (at this stage theoretical), forest environment and green infrastructure, according to the author, factors and principles must be observed to meet, form and develop the respective settlement as such. They can be supplemented and changed, changes are allowed, but they must always be purposeful and corresponding to the philosophy of the settlement. The presentation of various factors will support the development of the settlement, in a vertical and horizontal direction, namely: 1) Social - aimed at the construction of forests, parks, green spaces and social activities; 2) Economic - financing activities from the above-mentioned factors; 3) Ecological - a basic factor unifying all activities related to the creation of an ecological way of life, based on the philosophy of the settlement; 4) Climatic - the subconscious reason for the creation of a new type of settlement. The change in climate processes on a global scale is a basis for "new paradigms" related to Sustainable Development of settlements; 5) Infrastructural factors are key in the construction of forests, parks and green infrastructures in certain spaces. The application of *principles* (the model allows changes) for the respective settlement is an addition to the factors presented above, namely: 1) Geodemography, including - birth rate, death rate and mechanical movement of the population; 2) Independent administrative structure; 3) Meeting the conditions for a "Smart and Green City", the application of new technologies must be fully consistent with the philosophy of the settlement (Mutafov, 2021).

The use of Synergetics as an approach between the presented theoretical mathematical model in the scientific research, applicable in the formation of the new settlements, parks, green infrastructures, urban and forest resources is an essential connection between them. The socio-economic status of the population will depend on the created connections between principles and factors in a future time period in the new types of settlements based on green philosophy. Ecology will be leading in every action by society (Tsvyatkova, 2021).

4. CONCLUSIONS

Climate change is a fact that has and will have significant impact on the socio-economic life of society, in a global aspect in the coming decades. The imposition of a new paradigm for Sustainable Development of settlements is urgent from the point of view of the upcoming climate changes. The concept of building and operating a "new" type of settlement dates back to the beginning of 19th century, and this philosophy is constantly undergoing changes and development, encouraging the society towards a "new" way of life (Mihailova, 2019).

The construction of green villages and green infrastructure is a continuation of the industrial philosophy for a better lifestyle for the population. In the functioning of the new type of green settlements and infrastructures, the compliance with the factors and principles related to them is essential for society, every single change will result in a change in the territorial spaces. The model proposed in the scientific study can be applicable to any territory and settlement under construction. The values (parameters) associated with the settlement can be changed depending on what is being targeted (Yarkova and Mutafov, 2017). All this presented scientific presentation has signification for future projects related to the planning and construction of green spaces and settlements.

Acknowledgements: We express our gratitude for the financial support of the National Scientific Program “INTELLIGENT PLANT PRODUCING” to Component 4: Artificial Intelligence and Digital Technologies - Engine of Innovative Management Systems, Sectoral Dynamics and Change in Quality of Life. WP 4.3. Rural development and human capital driven by artificial intelligence and digital technologies.

REFERENCES

1. Bachev, H., (2016), Defining and Assessing the Governance of Agrarian Sustainability, Journal of Advanced in Law and Economics, Volume VII, Issue 4 (18), 797-816. Gary, D. (2012): *Nanocellulose: From Nature to High Performance Tailored Material*. Holzforschung 67 (3): pp. 353-353.

2. Brundtland, G., (1987), Our Common Future, Report of the United Nations World Commission on Environment and Developmen.
3. Dobrev, P., (2012), Importance of the green system for urban ecology, ed. UCE “L. Karavelov”, publishing house Avangard Prima - Sofia, pp. 5-25.
4. Dokuzova, I, Razpopov, D. and Dzhelepov, G., (2014), Three-dimensional Riemannian manifolds with circulant structures, Journal reference: Advances in Mathematics: Scientific Journal. vol. 7, no.1 pp. 9-16
5. Harvey, D., (2005), Contested cites: Social process and spatial form, from book Transforming cities, this edition published in the Taylor & Francis e-Library, pp 17-25.
6. Marinov P. (2022), Impact of the Forest - Resource Potential at Formation of the »New« Eco-Settlements, 15th international scientific conference Woodema 2022 Crisis management and safety foresight in forest-based sector and smes operating in the global environment - Trnava, Slovakia Juny 8th – 10th 2022, pp. 233-239
7. Markov N., (2019), Spatial analysis of trade activity using geographic information systems, Economic Thought Journal, p. 111.
8. Mihailova M. (2019), Urban forests: bioeconomy and added value, WoodEMA 2019, Conference proceedings, Union of Scientists of Bulgaria, WoodEMA, i.a. Manufacturing, Svetošimunska 25, Zagreb, Croatia pp. 117 -125.
9. Milusheva, V., (2012) Methodology for Assessment and Analysis of the Competitiveness of Industrial Companies, Economic and Social Alternatives, issue 4, p. 104.
10. Mutafov, E., (2021), “Regional Development and Cohesion Policy of EU 2021-2027”, Trakia Journal of Sciences, Vol. 17, Suppl. 1, p. 85.
11. Radovanova, P., (2021), Sustainable Urban Development, pp 29-47.
12. Tsvyatkova, D. (2021), Land relations: a condition and factor for socio-economic growth of rural households. pp. 85-95. In: Land Relations: Challenges and Opportunities for Development. Ed. Institute of Agrarian Economics. Sofia.
13. Yarkova, Y. and E. Mutafov (2017), Rural Areas in Bulgaria–Investigation on some Factors for Development, Eastern European Countryside 23(1): pp. 51–70.

Authors address:
Marinov Petar
[1] Institute of Agrarian Economics at the Agricultural Academy, Sofia
*Corresponding author: tea4er@mail.bg / ppm1886@gmail.com

IMPACT OF THE WOOD SECTOR ON CLIMATE CHANGES (FOLLOWING THE EXAMPLE OF BULGARIA)

Blagoev, D.

Abstract: In the last two decades, and especially in recent years, topics related to the climate change and the influence of industry on the climate have become increasingly relevant. On one hand, the geopolitical situation associated with series of crises (Covid-19, war, natural disasters and cataclysms, etc.) slows down the intention of the world community to deal with the causes of global warming. On the other hand, economic factors like inflation and supply uncertainty (including energy) lead to a partial reconsidering of the goals set in relation to the decarbonization of the world industry and economy. The purpose of the present study is to identify eventual presence of a relationship between indicators of the climate change and the activity of the wood industry in Bulgaria, based on statistical data for indicators change over a 20-year period. Such indicators are the concentration of carbon dioxide in the atmosphere, the average annual temperature, and the average annual volume of precipitation. The performed analysis reveals that there is insignificant influence of the wood industry in Bulgaria on both the total emissions of pollutant gases and the climate change. However, the wood industry may have important negative effect on the environment because of the expanding deforestation.
Keywords: Climate, GHG, Wood Industry, Global warming, Industrial production

1. THE CLIMATE CHANGE AND THE INDUSTRIAL PRODUCTIVITY

The climate change and the accompanying problems have been attracting special attention of both scientists and politicians in the last several decades. The scientific community has been struggling to elucidate the very nature and the true reasons for the climate change. In the present study, we attempt to clarify the possible influence of the logging and wood processing industry (wood industry) on some of the important indicators of the climate change. The major aim is to find eventual dependence (or absence of such) between the climate change and the wood industry expansion. This approach uses statistical information for a past period (20 years) and further processing of the data.

First, we regard shortly some problems, connected to the occurrence of the greenhouse gases (GHG) (Naudé, 2011). The basic materials sector is one of the main generators of GHG on a global scale (Fischedick at al., 2014). The scientists have proved that GHG emissions and the greenhouse effect may have both natural and artificial origin. Most of the human activities and especially the industrial productivity can catalyze the process of accumulation of GHG. This leads to substantial rise in the quantity of GHG, predominantly carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4). In order to make a relation between human activities and GHG emissions, we use the “Kaya identity” (Girod at al., 2009):

$$GHG\ emissions = population \times \frac{GDP}{Population} \times \frac{Energy\ Use}{GDP} \times \frac{GHG\ emissions}{Energy\ Use} \quad (1)$$

where GDP is the Gross Domestic Product.

The Kaya identity shows that GHG emissions (and the climate change) originate in human activities, measured by GDP, energy intensity and carbon emissions intensity, and all of them couples to the rise in the human population.

The climate change is often associated with the global warming. The global warming is expected to be with devastating consequences for the economic development and would lead to a greater poverty in the world (Ojha, 2008). The high level of industrial productivity and the explicit consumerism in the global society have the highest contribution to the GHG emissions, although this conception is still debatable. One thing can be sure though – the initiatives for decreasing GHG emissions and decarbonization of the economies will have greater (and negative) impact on poorer countries. The price will be paid via some reduction in GDP and in social spending.

The raw material in the wood industry is a natural absorbent for GHG emissions. If the wood industry continues to “flourish”, that would possible result in increase of the GHG emissions. The increasing emissions of CO_2 from the industry could be compensated to some extent by a progress in the industrial effectiveness (Martin, 2010).

2. METHODICAL FRAME OF THE STUDY

The analyzed data is strictly for Bulgaria. The most important indicators of the climate change, which we consider in the present study, are the following:

1) Pollutant gases. The most significant air pollutants, which are the primary reason for the climate change, are: CO, ozone (O_3), and dinitrogen monoxide (N_2O) (Kaldamukova, 2021). For the purposes of the investigation, GHG (e.g. N_2O, CH_4, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3)) are analyzed via aggregated data and CO_2 equivalents, which is in accordance with the Eurostat methodology.

2) Climate change indicators. We chose two climate change indicators: (1) *Average annual precipitation* – the data (ASP, 2022) from 26 national weather stations is averaged; (2) *Average annual temperature* – the data (ASP, 2022) from 17 weather stations is averaged.

3) Economic activity indicators. The indicators of economic activity are: turnover, production, gross value added, etc. Here, we use the ***production quantity indicator***.

These indicators may fall into two categories of variables – **independent** variables and **dependent** variables.

Table 1. Economy-related variables, used in the study

Dependent variables	Independent variable(s)
CO_2 equivalent	Production quantity of the wood industry (logging and wood processing), expressed as currency value and/or natural units
Average annual precipitation	
Average annual temperature	

Analyzing the data for a given period, we attempt to find some functional dependence between the quantities listed in Table 1.

3. ANALYSIS, RESULTS AND DISCUSSION

Results and discussion are based on the above-described methodical frame. **First**, the available data is presented in a retrospective manner in order to track the dynamics of the investigated variables. **Second**, we attempt to identify possible functional dependence between the mentioned economy-related variables.

3.1. Dynamics in the development of the logging and wood processing industry in Bulgaria.

The logging and wood processing industry in Bulgaria has been developing fast since 2000. (Fig. 1 and Fig. 2). The production quantity has increased roughly by 600% (in currency value) for a period of 20 years.

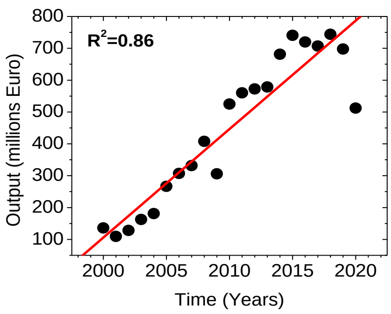


Figure 1. Output of the wood industry activities in Bulgaria

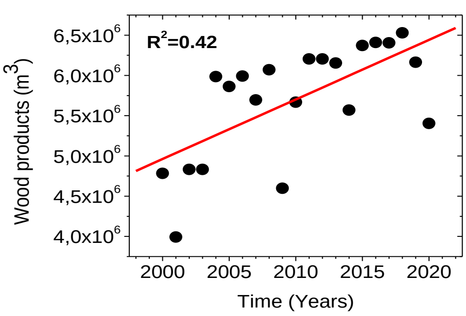


Figure 2. Wood products in Bulgaria for the period 2000-2020.

The increase in the output in currency value is strongly dependent on two factors: (i) the inflation processes in the Bulgarian economy and especially the increase in price of the production quantity, and (ii) improving the quality of life, which means more and more consumed production (see also eqn. (1)). Accordingly, expressed in natural units, the development of the wood industry is relatively less dynamical. There is an increase of less than 50% for the last 20 years (Fig. 2), and we can see clearly the years of crises). Naturally, there are other much smaller fluctuations in the dynamics of the wood industry.

3.2. Influence of the industrial production on GHG emissions in Bulgaria

Besides the dynamics in the development of the logging and wood processing industry, of substantial interest is also the dynamics in the level of GHG emissions that are the main reason for the global warming and the climate change (Fig. 3).

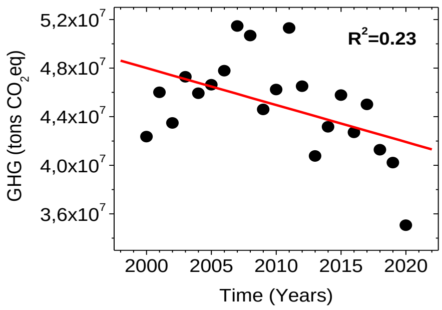


Figure 3. GHG emissions in Bulgaria for the period 2000-2020.

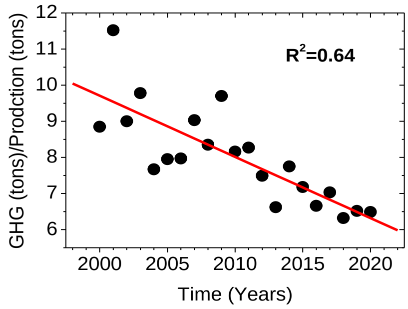


Figure 4. Dependence of the ratio GHG/production quantity.

The rate of the decrease in the ratio is stable and shows that the quantity of the pollutants becomes less and less if compared to a unit production quantity of the wood industry. Although the data appears somewhat scattered, the linear dependence is relatively good approximation and is instructive for the overall trend. The wood industry generates more and more production as GHG emissions shrink. Even though no direct connection is obvious here, the wood industry improves and innovates constantly, which would inevitably lead to less GHG emissions per unit production quantity. Still, we can directly compare the decrease in GHG emissions and the increase in wood products – the emissions decrease at a lower rate (Fig. 3) than the production increases (Fig. 4). This combined effect leads to steep change of the regarded ratio.

3.3. Influence of the industrial production on the average annual temperature and precipitation in Bulgaria.

Another essential indicator of the climate change is the increase in the average annual temperature, which induces the overall warming of the Earth's surface. This phenomenon is responsible for extended periods of precipitation deficiency and/or heavy rains that cause flooding, landslides or other natural disasters. The global trend of temperature increase is valid for Bulgaria as well, but at the same time, there is a slight decrease in the average annual precipitation over the last two decades (Fig 5).

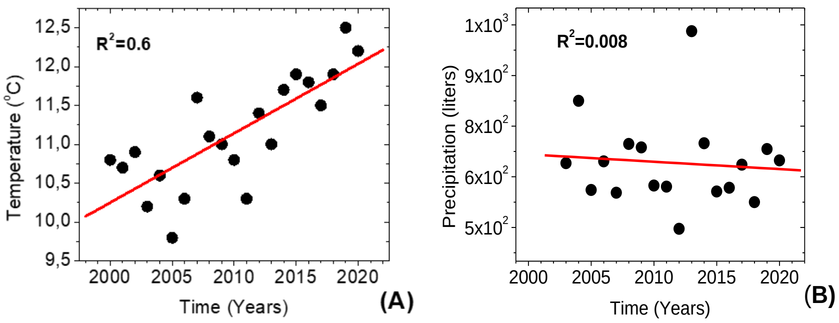


Figure 5. Average annual temperature (A) and average annual precipitation (B) in Bulgaria for the period 2000–2020

The investigated period is not too long. However, the trend of constant increasing of the average annual temperature is particularly disturbing, because this temperature in Bulgaria is higher than the average global value. For the last two decades, the average annual temperature in Bulgaria has increased with almost 2°C, but there is an average drop in the precipitation of about 10–12%. If this trend appears strong during the following several decades, we can expect a substantial risk for water shortage in the country. This shortage may lead to other risks – shortage of electric power, because the water is used as a resource in hydroelectric power plants and pumped hydro storage plants, and as a cooling medium in nuclear power plants and thermal power stations. The water deficiency may also block many industrial processes and could bring severe problems for the agriculture. Here we can track an eventual correlation between the increase in the average annual temperature (the decrease in the average annual precipitation) and the production quantity of the wood industry in Bulgaria (Fig. 6).

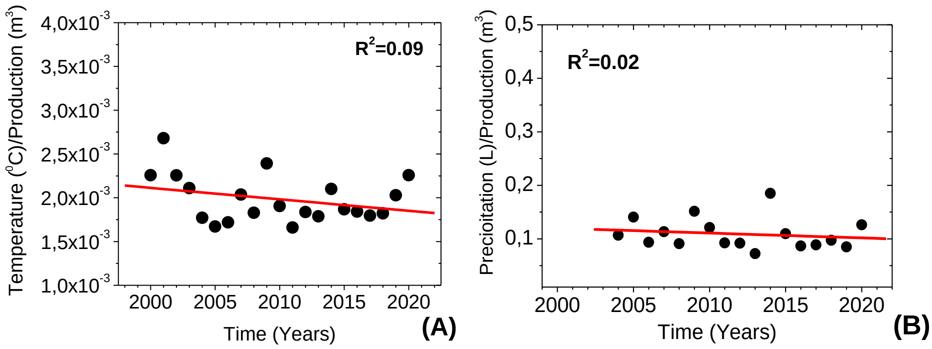


Figure 6. Dependence of the ratio average annual temperature/production quantity (A) and the ratio average annual precipitation/production quantity (B) on the year for the period 2000-2020

In the frame of the assumed linear dependence (Fig. 6), we can see that there is practically no change of the respective ratios through the years. This means that the wood industry barely have any effect on the environment, when considered separately from other industries or economic sectors, and in this particular correlation.

As mentioned above, the trees are the raw material in the wood industry, but they are also a very important natural absorbent for GHG emissions. This provide a possibility for comparing the removal of GHG emissions form the forestry to the production quantity of the wood industry in Bulgaria (Fig. 7).

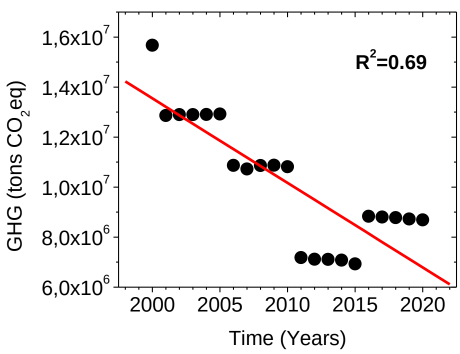


Figure 7. Removal of net emissions of GHG from forestry in Bulgaria for the period 2000-2020.

The observed negative trend through the years is an intuitive one – as the wood industry progresses, more and more deforestation occurs, which means that less and less GHG emissions could be effectively absorbed by the trees. Figure 7 also shows that the forestry activities are insufficient, although there is a sign for reversing the trend during the last decade. Still, the wood industry definitely has a negative impact on the nature and its capacity for GHG absorption.

4. CONCLUSIONS

The presented data analysis indicates that the logging and wood processing industry in Bulgaria has a negligible influence on the emissions of GHG, considered as CO_2eq, if we recognize the wood industry as representative for all industries or economic sectors. Still, the ratio of GHG to the production quantity of the wood industry is decreasing, and we may suggest it as a positive outcome. The wood industry also barely affects the climate, if we connect its production quantity to the average annual temperature and average annual precipitation. Both the temperature and the precipitation remain essentially flat through the years if expressed in a ratio with the wood industry production quantity. This is a negative effect, because the positive one would be when this ratio is decreasing either by temperature normalization or by higher industrial productivity. Highly negative, however, is the trend of substantial decrease in the Bulgarian forestry capacity to absorb GHG emissions. If this trend continues to dominate over the next decades, the logging and wood processing industry in Bulgaria would become unfavorable player in the issue of GHG emissions.

Acknowledgements: We acknowledge the financial support of the project "Research and Development of a Conceptual Model of an Academic Innovation-based Incubator", №NID NI-3/0222/A, R&D Fund, University of National and World Economy, Sofia, Bulgaria.

REFERENCES

1. *** National Inventory Report 2022 Greenhouse Gas Emission in Bulgaria 1988-2020, Executive Environmental Agency, Ministry of Environmental and Water, Republic of Bulgaria, April 2022, Sofia.
2. ***IEA. Electricity Information 2020; IEA Publications: Paris, France, 2020.
3. Annual summaries of precipitation (ASP) 2022
4. Annual summary of temperatures (AST) 2022
5. Fischedick, M.; et al. Industry. In Climate Change (2014): Mitigation of Climate Change. Cambridge University Press: New York, NY, USA, pp. 739–810.
6. Girod, B.; Wiek, A.; Mieg, H.; Hulme, M. The Evolution of the IPCCIIs emission scenarioIIs. Environ. Sci. Policy 2009, 12, 103-118.
7. Kaldamukova, R. (2021). Nitrous oxide – the greenhouse gas that no one talks about, Climatheca – climate science in your language (BG text),
8. Martin, P. (2010). Climate Change, Agricultural Development, and Migration. GMF Study Team on Climate-Induced Migration; German Marshall Fund of the United States: Washington, DC, USA.
9. Naudé, W. (2011). Climate Change and Industrial Policy. Sustainability, 3(7), 1003–1021. https://doi.org/10.3390/su3071003
10. Ojha, V.P. (2008). Carbon emissions reduction strategies and poverty alleviation in India. Environ. Dev. Econ. 14, 323-348.

Authors address:
Blagoev, D.
Department "Industrial Business", Business Faculty, University of National and World Economy, Sofia, Bulgaria
*Corresponding author: blagoev@unwe.bg

IMPLICATION OF ERP IMPLEMENTATION: CASE STUDY OF FURNITURE MANUFACTURING COMPANY

Perić, I., Klarić, K., Papak, A., Vukman, K.

Abstract: Efficient management of business systems, particularly valid for manufacturing companies, implied the production of necessary quantities and quality products at market-acceptable prices and desired delivery dates. Digitalising business processes via information systems like ERP software can bring a company the improvements required to achieve efficient production goals. This paper will present and discuss pre-implementation and implementation activities connected to the digitalisation of business processes in the caste of a furniture manufacturing company.
Keywords: ERP, ERP implementation activities, furniture manufacturing company.

1. INTRODUCTION

With the development of new technologies, every severe company tries to keep up with the demands of the modern business world. Today, information plays a crucial role in making knowledge. The information represents both a product and a commodity for the market, and most business flows are conducted through information systems. The procurement process and the sale of goods on the global market are unthinkable without the support of information systems. Therefore, every company that strives to realize its potential applies some form of information system. To ensure the normal functioning of all system functions and to efficiently manage system processes, a large amount of information about the state of the business system needs to be collected and processed, which exceeds human capabilities (Papak, 2022). Therefore, people use additional tools, among which computers play a central role as places to store data and as tools for processing and presenting information (Grladinović, 1999).

The term „information system" (IS) refers to these systems in the academic sphere. Practitioners often refer to them as business software, application software (application system, application package) or an application. The general definition of the term information system is as follows: an information system (IS) is a computer system that processes input information or data, stores information, searches for information and creates new information to solve its tasks automatically or to support people in work, control, and decision-making within an organization. The central component of the information system is information, along with the technology used to perform information processes (Kremenjaš et al., 2021; Kremenjaš et al., 2022; Pavlić, 2011; Perić et al., 2019; Perić et al., 2019). To facilitate more efficient monitoring of the entire process within an individual company, integrated information software systems called Enterprise Resource Planning (ERP) systems are used. The acronym ERP was first used in 1990 to refer to enterprise resource planning. The ERP market has been undergoing changes and improvements for over thirty years. Starting as simple client-server on-premises software, ERP systems evolved into web-based solutions stored on physical servers. Now that cloud computing rules the world, ERP systems have been mitigated to the cloud, with on-premises software becoming a legacy technology (Papak, 2022).

1.1. ERP systems

ERP systems comprise various modules, each addressing a specific company requirement, depending on the business and the niche in which the company operate. For example, products-based companies typically have modules for accounting, inventory and order management, customer relationship management (CRM), and manufacturing if they produce or assemble products. Services businesses may turn to modules for accounting, project management, professional services automation and CRM. Each module pulls information from and pushes information into the central database, a crucial ERP system component. This shared data repository provides visibility into all departments and thus allows leaders to evaluate and compare the business performance of different areas and understand the full impact of decisions. It also powers other ERP benefits, like process automation, improved internal controls and more innovative business intelligence (Oracle NetSuite, 2023).

The structure of the company's organizational system is the basis for modelling the ERP structure. There are two primary approaches to building out an ERP system. The first is to purchase software that can handle core business functions like accounting, sales, inventory and manufacturing from different vendors. These solutions are then integrated with a central database (the ERP). The second is to buy all the modules that the company need from the ERP vendor and avoid integrations since the applications are already designed to work together. Despite its advantages and disadvantages as a business application, an ERP system brings numerous benefits to the company, regardless of the number of modules it includes.

1.1.1. Benefits and obstacles of ERP systems in the implementation process

ERP systems can significantly improve company's internal process management, boost the team's performance and productivity, and provide numerous other benefits. There are numerous advantages, such as (Huang et al., 2019; Papak, 2022):

- Data numerical integration, faithful presentation of financial information.
- Centralized data control to prevent numerical falsification.
- Integration of business processes such as production, marketing and inventory management,
- Standardization of business operations.
- Real-time monitoring of corporate information and analysis of data.
- Implementation and evaluation of decision-making programs and many other examples, etc.

On the other hand, findings from literature and practice highlight several obstacles (Accenture ERP Report, 2020; Huang et al., 2019; Loch et al., 2004; Papak, 2022; Perić et al., 2019):

- High costs related to the procurement of ERP software and implementation activities.
- Implementing a system takes a long time, and projects can take 1 to 3 years (or more) to be completed and functional.
- User participation is crucial to successfully implementing an ERP project, so thorough user training and a simple user interface can be crucial. However, ERP systems are generally difficult to learn and use.
- It is difficult to determine when the investment in the ERP system will be returned.
- Transferring existing data to new ERP systems is difficult or impossible to achieve.
- Integrating an ERP system with other independent software systems can be complicated, etc.

1.1.2. ERP system implementation process

Implementing an ERP system is a complex process that requires systematic planning, professional consulting and a well-structured approach. It is recommended that the ERP system be implemented by consulting companies or ERP representatives, in which case the consultants are responsible for consulting, customization and support. A typical ERP implementation plan can be divided into six phases, each with specific objectives (Oracle NetSuite, 2023; Papak, 2022): 1. Discovery & Planning, 2. Design, 3. Development, 4. Testing, 5. Deployment, and 6. Support & Updates. Phases 1 to 4 represent pre-implementation activities, while phases 5 and 6 represent post-implementation activities.

A furniture manufacturing company was chosen for the research polygon to obtain insights into the implications of the ERP system or to understand the role of the ERP system in companies. The company is a user of the ERP GoSoft software solution.

The study aimed to achieve the following objectives through interviews with GoSoft software consultants, furniture manufacturing company employees, and an analysis of the company's business processes integrated by an information system:

- Gain insight into the implementation process of the ERP system
- Determine obstacles that companies encounter when implementing an ERP system.
- Evaluate ERP system's impact on company's processes.

2. COMPANY PROFILE AND ERP IMPLEMENTATION PROCESS

The research polygon represents a wooden industrial company located in the Republic of Croatia, with long experience producing exclusive furniture for business and sales premises. According to its size, it is a medium-sized company with 60 employees (NKD, 2007). The company's production process can be characterised as project-based, dominated by highly sophisticated technology and qualified and well-educated personnel. Given that the company exclusively focuses on producing furniture "for a well-known customer", it operates with a "just-in-time" production model without holding inventory. The need for business improvement arose to meet the market's demands and respond to every customer's request with quality, especially in the segment of luxury decoration, which ultimately enables the company to distance itself from the competition.

Improvements imply implementing GoSoft ERP to digitise the entire business, increase productivity and efficiency and facilitate production planning on a higher level. These steps involved reducing paper usage in production and standardizing document storage, such as reclamation and delivery notes. In addition, the intention was to introduce ERP and improve worker record-keeping, which refers to recording work on individual operations and the controlling the entire process within the production.

As the text above mentions, the ERP implementation process follows certain phases. The implementation activities in the observed research polygon are described below (Papak, 2022).

Phase 1: Choosing an appropriate ERP system for the company's digitalisation needs was necessary. The company's management and department representatives chose the ERP software solution GoSoft, which is specialised for manufacturing companies and offers a wide range of modules and specifications for system customisation. During this phase, the company also assessed its current systems and processes, identifying the requirements the ERP software will need to support with either built-in ERP modules or custom software development. This phase also involved thoroughly analysing the company's current business processes and engaging key stakeholders to understand their needs and expectations. One of the key activities during the planning phase is to conduct a gap analysis. The analysis involves comparing the organisation's current systems and requirements with the capabilities and features of the chosen ERP system. Further, the analysis aims to identify gaps or areas for improvement, develop a plan for addressing these gaps, and implement the necessary changes. The output of this phase was a detailed project plan that outlined the scope, timeline, and budget for the new ERP implementation.

Phase 2: During the design phase, a critical activity was to define the system's functional and technical requirements. The step involved working with the GoSoft team to determine what the system needs to do and how it needs to do it. Also crucial in the second phase was conducting a more detailed analysis of the organisation's legacy data and processes. It involved looking at how the organisation currently operates and figuring out how the ERP software can support the business better by designing new, more efficient workflows and other business processes that exploit the system. The outcome of this phase was a custom-made ERP system based on the following modules: Finance and accounting, Sales, Procurement, Cooperation, Preparation of Production (technical office), Production, and Warehouse operations.

Phase 3: The development implied work with the GoSoft team to construct and configure every component and feature defined in the design phase. During the development stage, a crucial task was configuring the ERP software's modules and functionality to fulfil the requirements determined in previous steps. It involved consulting with the GoSoft software consultants as they set up the system and implemented ERP functionality for future deployment.

Phase 4: It required system testing and validation of the ERP software through a series of tests to ensure the system ran smoothly.

Phase 5: During deployment, the migration, entry and creation of new data within the GoSoft ERP system and the education of company staff were done. Also, the entry of all necessary parameters within each module was carried out. After this, the system was tested in production to ensure it worked correctly. Any bugs or migrated data integrity issues found during this testing phase were addressed and fixed before the system was made available to the user.

Phase 6: This stage starts when the system has been successfully set up and used. This stage is ongoing and vital to ensure the company's software runs smoothly and effectively.

2.1. Assessment of the impact of the ERP system on company's operations

Implementing the ERP system brings the company many improvements but also difficulties. After two years of usage of GoSoft in the observed company, the following conclusions can be drawn:
The advantages of introducing an ERP system for a company are:

- Easier and more controlled monitoring of production.
- Reduced production costs.
- Better inventory control.
- Digitization of the production system using barcodes and scanners, which are utilized in warehouse operations and production work orders.
- Better evidence of monitoring worker norms
- Obtaining the actual cost prices of each segment within the company
- Reduced use of paperwork.
- The connection between the user and the web module of the GoSoft application.

The difficulties that occur using the ERP system are:

- Adjustment and resistance of workers.
- Posting of work by departments which sometimes leads to a collision between technical and construction departments.
- Delayed delivery by certain suppliers, regardless of the agreed delivery date.
- Additional software maintenance may require extra financial investments.

Overall, despite the difficulties encountered implementing the GoSoft ERP system has positively impacted on the company's operations. The system's benefits, including improved efficiency and cost reduction, outweigh the challenges encountered during the implementation process.

3. CONCLUSION

Along with the new software solutions currently available on the market, the GoSoft EPR system has proven to be one of the better options for small and medium-sized companies. In the example of a research training ground, a furniture manufacturing company, and the management of the GoSoft ERP system, a big step was taken for the digitization of their business. The following conclusions were drawn from an insight into the operations and implementation activities of GoSoft in the company.

Before the actual implementation, pre-implementation activities are necessary, which begin with the first phase of introducing the ERP system. It involves determining the company's goals and strategic plans and familiarizing all employees. Researching literature and the knowledge obtained from the practical part of the work, it can be established that the time required to implement and operate the ERP system depends on the company's activity. It is closely related to the complexity and requirements of production systems, especially for wood processing companies.

Moreover, employee education is a crucial factor in the actual implementation process. They must transition from an "analogue" way of thinking and acting to a "digital" one. Factors such as the employees' qualification structure and the company's organizational readiness to accept "new ideas and solutions" are also related to this problem. In conclusion, introducing an ERP system represents a significant financial investment for a company, with a return to be visible only after a few years (usually three or more) (Papak, 2022). One of the essential reasons of choosing a GoSoft software solution was the availability of consultants. In general, with the introduction of the ERP system in the company, many positive developments have been achieved in terms of the efficiency of the organization and management production. However, the "real effects" of the ERP system will be visible only after a few years.

In conclusion, future research should focus on exploring the potential of integrating AI technologies into ERP systems and their impact on organizational performance. As AI advances, ERP systems will likely become more intelligent and capable of providing greater benefits to organizations. Thus, researchers and practitioners need to stay up-to-date with the latest advancements and consider how they can leverage these technologies to drive business success.

REFERENCES

1. Grladinović, T. (1999). *Upravljanje proizvodnim sustavima u preradi drva i proizvodnji namještaja*. Zagreb: University of Zagreb, Faculty of Forestry and Wood Technology.
2. Huang, S.; Yan, A., A.; Chiu, Po, C., C.; Arniati A. (2019): *Critical Success Factors in Implementing Enterprise Resource Planning Systems for Sustainable Corporations*. In: Sustainability, 11 (23): pp. 6785. doi: https://doi.org/10.3390/su11236785.
3. Loch, T. C.; Koh, S. C. (2004): Critical elements for a successful enterprise resource planning implementation in small and medium-sized enterprises. In: International Journal of Production Research, 42 (17): pp. 3433-3455.
   doi.org/10.1080/00207540410001671679
4. Kremenjaš, K.; Klarić, K.; Perić, I. (2021): *The importance of integrated information systems in time of COVID-19 crisis.* In: Proceedings of the 14th International Scientific Conference WoodEMA "The Response of the Forest-Based Sector to Changes in the Global Economy". Koper, Slovenia. 221-227.
5. Kremenjaš, K.; Marković, L.; Klarić, K.; Pirc Barčić, A.; Perić, I. (2022): *Implementation of ERP Systems in Higher Education Context: Functionalities and Characteristics.* In: Proceedings of the 15th International Scientific Conference WoodEMA "Crisis management and Saefty Foresight in Forest based Sector and SMEs operating in Global Environment". Trnava, Slovakia. 197-204.
6. Papak, A. (2022): *Production management with the support of ERP systems*. Zagreb: University of Zagreb, Faculty of Forestry and Wood Technology, Diploma work.
7. Perić, I.; Kremenjaš, K; Pirc Barčić, A.; Klarić, K. (2019): *Role of Integrated Information Systems in Wood Processing Companies*. In: Proceedings of the 30th International Conference on Wood Science and Technology (ICWST 2019) "Implementation of wood science in woodworking sector". Zagreb, Croatia. 62-168.
8. Perić, I.; Kropivšek, J.; Grošelj, P.; Sujová, A.; Kalem, M.; Greger, G. (2019): *Analysis of Implementation of Integrated Information Systems in Croatian Wood Processing Industry*. In: Drvna industrija, 70 (2): pp. 129-139. doi:10.5552/drvind.2019.1911.
9. *** NKD 2007: Government of the Republic of Croatia.
   https://narodne-novine.nn.hr/clanci/sluzbeni/2007_06_58_1870.html
10. ***Oracle NetSuite. 2023. ORACLE NETSUITE.
   https://www.netsuite.com/portal/resource/articles/erp/what-is-erp.shtml.

Authors address:
Perić, I[1]; Klarić, K[1*]; Papak A[1]; Vukman K[1]
[1] Department for Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Republic of Croatia
[*]Corresponding author: kklaric@sumfak.unizg.hr

CARBON FOOTPRINT MONITORING: EU LEGISLATION AND IMPLEMENTATION

Petržela, B.

Abstract: The aim of this paper is to make a general review of the available literature and legislation connected with carbon footprint monitoring in the wood processing industry with a particular focus on EU legislation Corporate Sustainability Reporting Directive (CSRD). European legislation is generally very complex and comprehensive and sometimes it seems difficult to navigate throughout this wide combination of laws, directives, and regulations. Whilst the drafting of legislation is long and continuous process all subjects involved must be prepared to meet the necessary requirements, otherwise it could result in inconvenient consequences. CSRD will be phased in from 2024 (with reporting for the year 2023). The EU anticipates that the CSRD will affect approximately 50.000 companies doing business in the European area. Unfortunately, only few of Central European companies have already experience with such reporting. This study will be used for professional and academic purposes related to wood processing industry as this legislation links both spheres and even certification bureaus, banks and final customers. The information provided will help to keep up with dynamically evolving legislation and keep abreast of public opinion.
Keywords: carbon footprint, CSRD, directive, EU legislation, wood processing

1. INTRODUCTION

Environmental concerns play a crucial role in justifying industrial decisions due to the fact that global climate change is regarded as one of the most worrisome and intricate environmental issues of our time, as stated by various sources including Schramm (1998), Mirasgedis et al. (2008), Samarakoon and Gudmestad (2011), and Vrabcová (2018).

According to Stocker et al. (2013), the most significant contributor to global climate change is human activity, with a 95% certainty, a finding that has been supported by other studies, including Matondo et al. (2004). Therefore, it is crucial to monitor carbon footprint in all industries, with a particular emphasis on reducing it. Additionally, Hönisch et al. (2009) have demonstrated that the current concentration of CO_2 in the atmosphere is the highest it has been in the past 2.1 million years.

Anthropogenic greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ground-level ozone, chlorinated hydrocarbons, and fluorocarbons (Houghton 1998; Joos and Spahni 2008; Plummer et al. 2017; Vrabcová 2018).

The main objective of this study is to focus on legislation and monitoring of the carbon footprint in the Central Europe timber industry. Wood products have many environmental advantages over non-wood alternatives (Wegner et al. 2010; Eriksson et al. 2012; Bergman et al. 2014), however, like any other industry, they are an emitter of CO_2 and other greenhouse gases. The production of wood products requires fewer fossil fuels than non-wood alternative building materials such as concrete, metals or plastics (Bergman et al. 2014; Vrabcová 2018). Wood is inherently composed of carbon, which is captured from the atmosphere during tree growth (Santori 2018). Carbon is also stored in plant matter and soil, making forests a "carbon sink". Substitution and sequestration are two of the main effects why the carbon impact of wood products is beneficial (Bergman et al., 2014).

Results of peer-reviewed studies (Gustavsson and Sathre, 2011; Spinney et al., 2013; Bergman and Bowe 2010) show significant carbon savings when wood products are used in building construction instead of non-wood alternatives.

2. LEGISLATION

Non-financial reporting of carbon footprint is mandated by the new EU CSRD (Corporate Sustainability Reporting Directive) with effect from 16 December 2022, which replaces the existing NFRD (Non-Financial Reporting Directive) legislation from 2014 (Directive 2014/95/EU - NFRD), and up to 50,000 companies operating in the European area will have to comply with it by 2026, whereas in the case of the NFRD it was only 12,000 companies. This directive mandated non-financial reporting, especially for large companies. For example, as part of the annual report for 2023, companies with over 250 employees and a turnover of over EUR 50 million, will have to provide non-financial reporting on environmental impacts, including carbon footprint production (Pwc.cz, 2021). As of 8 August 2022, the provisional draft of the new CSRD has been open to public comment. These comments were discussed by the newly established European Commission EFRAG (European Financial Reporting Advisory Group). The Directive proposes a phased-in approach to the effectiveness of non-financial reporting for companies based on their size according to the following key (European Union, 2022):

- 1 January 2024 - introduction of validity for the largest corporations (which are already covered under the current NFRD legislation) and meeting 2 out of 3 criteria:
    - 250 or more employees
    - a net turnover of more than EUR 50 million,
    - a balance sheet total of more than EUR 43 million,
- 1 January 2025 - companies with 250 or more employees,
- 1 January 2026 - connection of all companies listed on the stock exchange with the possibility of a two-year exemption.

For other SMEs, reporting will be on a voluntary basis to which they should be motivated by its benefits. Reporting is also an important component in relation to project financing through financial institutions (TÜV NORD GROUP, 2022). Banks will approach the financing of individual projects considering non-financial reporting and may provide so-called "Green Loans".

Reporting should be consistent, measurable, and comparable, as well as officially audited, and easily accessible to investors, rating agencies, banks, insurers and business partners (especially for tender purposes). According to EY's global survey in 2020, 91% of investors said that information on non-financial performance was key to their investment decision-making (HAVEL & PARTNERS, 2022).

A subsidiary is exempted from non-financial reporting if the parent company produces a consolidated sustainability report that complies with the CSRD. This exemption for subsidiaries also applies to subsidiaries that are public interest entities if they do not reach the thresholds for large enterprises (Official Journal of the European Union, 2021).

3. CARBON FOOTPRINT MONITORING METHODOLOGIES

When assessing the carbon footprint, the term carbon dioxide equivalent (CO_2-eq) is commonly used. However, its determination at the macro level is very difficult (Lupač et al. 2012). Carbon footprint assessment can be based on different governing international standards and calculation methods (Pandey et al. 2011). Several studies have used different assessment methods, such as life cycle assessment (Filimonau et al. 2011; Vrabcová 2018; Kim et al. 2022).

When reporting carbon footprint, selecting an appropriate methodology is crucial to fulfil the requirements of the new CSRD, considering the availability of hundreds of methodologies to choose from (Sarto et al., 2019; ISO, 2018).

For non-financial reporting, the rule of technical and financial standardisation should apply, where one organisation sets the rules, the other produces the report (including calculations) and the third verifies (certifies). This will be introduced mainly to maintain the independence of the reporting, which will thus be verified by several entities. On 31 October 2023, the Commission will adopt delegated acts specifying (European Commission, 2021):

- the additional information to be disclosed by undertakings with regard to sustainability issues and the reporting areas referred to in Article 19a(2), if applicable;
- information to be disclosed by undertakings that is specific to the sector in which they operate.

For specific requirements on the modalities and scope of non-financial reporting, the planned publication date by the European Commission is 30 June 2023 (European Union, 2022) and will include:

- sectoral standards,
- appropriate standards for listed SMEs,
- standards for non-EU companies that exceed the defined EU giant values.

The methodology for non-financial reporting is expected to be defined more precisely by the new requirements. It is anticipated that this methodology will be based on the Environmental, Social, and Governance (ESG) principles that formed the foundation of the initial Non-Financial Reporting Directive (NFRD).

Carbon footprint monitoring involves various methodologies that help measure and track greenhouse gas emissions throughout an organization's activities. Some of the most used methodologies include Life Cycle Assessment (LCA), Environmental Product Declarations (EPDs), and the Greenhouse Gas Protocol (GHGP). LCA is a comprehensive approach that assesses the environmental impact of a product or service throughout its life cycle, from raw material ex-traction to disposal, while EPDs are standardized documents that provide information on the environmental impact of a product. The GHGP, on the other hand, is a widely accepted framework for measuring and reporting greenhouse gas emissions, used by organizations to track and manage their carbon footprint. These methodologies have been extensively discussed in the literature, including the works of Azapagic and Clift (2014), ISO (2018), and WRI/WBCSD (2004), among others.

Life cycle sustainability assessment consists of three methods: life cycle assessment, life cycle costing and social life cycle assessment (Neugebaurer et al. 2015). These three life cycle assessment methods correspond to the ESG (Environmental, Social, Governance) principles assessment, of which carbon footprint monitoring is a part.

Another internationally accepted methodology for determining the carbon footprint of a company is the GHG protocol (Ranganathan and Bhatia, 2004). It can also be based on the normative standards of ISO 14 000 series (note ISO 14064 - Carbon footprint of the company), which not only gives the calculation of the carbon footprint as a number for comparison, but also the whole protocol with a discussion of recommendations for decarbonisation and decarbonisation strategy. The GHG Protocol methodology divides the calculation of the carbon footprint into 3 main scopes of interest called Scope 1,2 and 3. Each section represents (Ranganathan and Bhatia, 2004; WRI/WBCSD, 2004; ISO, 2018):

- Scope 1 - This includes emissions that are directly produced by the company. This includes the amount of greenhouse gases from production, from company car journeys or from gas consumed for own heat production, etc.
- Scope 2 - This includes indirect emissions associated with the production of energy for the firm that are produced off-site for the firm's consumption. This includes electricity generation, district heat, or district cooling.
- Scope 3 - The most complex reporting of the impacts of a firm and its products or services is found in Scope 3, which includes all emissions associated with the entire production chain, with the firm's suppliers and customers etc.

4. CARBOT FOOTPRINT MONITORING IMPLEMENTATION

Although carbon footprint monitoring is common in many developed countries, few companies in the Czech Republic pay attention to this issue. Carbon footprint monitoring initiatives are mostly from abroad, particularly Germany, Austria, and the United States. CI2, o.p.s., BUREAU VERITAS CERTIFICATION CZ, s.r.o., TÜV NORD Czech, Enerfis s.r.o., and other Czech companies are involved in carbon footprint monitoring.

Most Czech wood processing companies are not yet actively working with carbon footprint measurement because they are not subject to the current non-financial reporting obligation under the NFRD. Companies that are subject to reporting and are also subsidiaries of foreign holdings (the majority of such PPAs in the Czech Republic) have parent company sustainability reporting. Biocel Paskov a.s. (Lenzing AG, 2022) or Mondi Štětí a.s. (Mondi Group, 2022) are such example.

Implementing those legal requirements is one thing; correctly reporting relevant data is quite another. Companies are to be ranked into different categories of sustainable management level based on their reported results, according to this directive. As a result, they should concentrate on reducing carbon emissions to improve their market competitiveness. This is possible by reducing carbon footprint directly by reducing energy and water consumption, reviewing logistics, switching to green energy, recycling, or reducing packaging. Offset programs, for example, are another indirect option.

Offset programmes

Offset programmes are linked to the principle of capturing and storing carbon from the atmosphere to prevent further climate change. According to Keles et al. (2019), possible ways of capturing CO_2 are:

- afforestation, reforestation, and reforestation with the aim of greater carbon sinks,
- biochar/terra preta or soil carbon storage,
- oceanic algal reforestation and ocean fertilisation,
- carbon-friendly construction,
- CCS and sequestration - technologies for direct capture of CO_2 from the air,
- indirect offsetting.

For additional reduction of own greenhouse gas emissions, beyond their reduction through active measures, it is possible to additionally use external emission compensation - the so-called offset, usually ensured by the implementation of a special offset project (CI2, o. p. s., 2022). Offset projects are initiatives that aim to reduce or avoid greenhouse gas emissions in one location or sector to compensate for emissions that are released in another location or sector. These projects are typically used as part of carbon offsetting programs, where companies or individuals seek to mitigate their carbon footprint by funding or investing in projects that reduce or avoid greenhouse gas emissions, such as renewable energy projects, energy efficiency improvements, or afforestation projects. The reduction in emissions achieved by these offset projects can be quantified and used to offset or balance out emissions produced by the organization or individual, thereby reducing their overall carbon footprint. Examples of specific offset programmes implemented in the Czech Republic include (Greenfilming.cz, 2022):

- planting projects (avenues, forests),
- creation of elements of the territorial system of ecological stability,
- implementation of photovoltaic panels for non-profit and state organizations,
- methane capture at landfills.

Another option of carbon offsetting are carbon emissions certificates, also known as carbon credits, which are a tradable commodity that represents the right to emit a certain amount of greenhouse gases, usually measured in tons of carbon dioxide equivalent (CO_2-eq). These certificates are used in carbon offsetting programs to enable businesses, organizations, and individuals to compensate for their carbon emissions by funding or investing in projects that reduce greenhouse gas emissions. Carbon emissions certificates are regulated by different standards and schemes, such as the Verified Carbon Standard (VCS), the Gold Standard, and the Clean Development Mechanism (CDM) under the United Nations Framework Convention on Climate Change (UNFCCC). These schemes ensure that carbon credits are verified and validated according to specific criteria, such as additionality, permanence, and verifiability, to ensure the credibility and integrity of the market.

5. CONCLUSION

In conclusion, the implementation of the Corporate Sustainability Reporting Directive (CSRD) is a complicated process that requires significant time and effort from companies to integrate it into their internal procedures. Nonetheless, companies should strive to reap the benefits of such reporting, as monitoring their carbon footprint has the potential to uncover inefficiencies in their production and other operations, resulting in both environmental and economic savings. Furthermore, Central European companies must stay up to date with market trends, as customers and other stakeholders are increasingly demanding sustainable production. The CSRD legislation provides a certification and comparative tool to meet these demands.

Acknowledgements: I would like to express my gratitude to Faculty of Forestry and Wood Sciences for affording me the opportunity to participate in the Young Scientific Assistant program and contribute to this project. In particular, I am grateful to Associate Professor Roman Dudík, Ph.D. for his invaluable counsel and direction in guiding me through the preparation of this paper.

REFERENCES

1. Azapagic, A., Clift, R. (2014). *Life cycle assessment and carbon footprinting*. In Sustainable Energy (pp. 125-146). Elsevier.
2. Bergman, R. D., Bowe, S. A. (2010). *Carbon consequences of using biomass in the built environment*. Journal of Industrial Ecology, 14(2), 298-311.
3. Bergman, R., A. Taylor, M. E. Puettmann, K. E. Skog. (2014). *The Carbon Impacts of Wood Products*. Forest Products Journal [online]. 64(7-8), 220-231 [cit. 2022-11-26]. ISSN 0015-7473. Available at: doi:10.13073/FPJ-D-14-00047
4. CI2, o.p.s. (2022). *Offsetting projects [Offsetové projekty].* [cit. 2023-1-17]. Available at: https://snizujemeco2.cz/cs/offsetove-projekty-0
5. European Commission. (2021). *Proposal for a Directive of the European Parliament and of the Council amending Directive 2013/34/EU, Directive 2004/109/EC, Directive 2006/43/EC and Regulation (EU) No 537/2014 as regards corporate sustainability reporting*. [online]. 21.4.2021 [cited 2022-12-29]. Available at: https://eur-lex.europa.eu/legal-content/CS/TXT/PDF/?uri=CELEX:52021PC0189&from=EN
6. European Union. (2022) *DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL [2022] OJ 2 322/15*
7. Eriksson, L. O., L. Gustavsson, R. Hänninen, M. Kallio, H. Lyhykäinen, K. Pingoud, J. Pohjola, R. Sathre, R. Solberg, J. Svanaes, and L. Valsta. (2012). *Climate change mitigation through increased wood use in the European construction sector—Towards an integrated modelling framework*. Eur. J. Forest Res. 131(1):131–144.
8. Filimonau, V., Dickinson, J., Robbins, D., and Huijbregts, M. A. J. (2011). *Reviewing the carbon footprint analysis of hotels: Life Cycle Energy Analysis (LCEA) as a holistic method for carbon impact appraisal of tourist accommodation*. J. Clean. Prod. 19(17-18), 1917-1930. DOI: 10.1016/j.jclepro.2011.07.002
9. Greenfilming.cz. (2022). *What are offsets, how to trade them and where to buy them [Co jsou offsety, jak se s nimi obchoduje a kde je koupit?]* [online]. Published 1.6.2022. [cit. 2023-1-17]. Available at: https://greenfilming.cz/clanek/463783-co-jsou-offsety-jak-se-s-nimi-obchoduje-a-kde-je-koupit
10. Gustavsson, L., Sathre, R. (2011). *Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels*. Forest Products Journal, 61(5), 355-365.
11. HAVEL & PARTNERS (2022). *Report o udržitelnosti - pro velké firmy povinnost, pro ostatní nutnost*. [online]. Ze dne 7.10.2022. [cit. 2023-1-30]. Available at: https://www.pravniprostor.cz/clanky/obchodni-pravo/report-o-udrzitelnosti-pro-velke-firmy-povinnost-pro-ostatni-nutnost
12. Houghton, J. T. (1998). *Global Warming [Globální Oteplování].* Academia, Prague, Czech Republic.
13. Hönisch, B., Hemming, N. G., Archer, D., Siddall, M., and McManus, J. F. (2009). *Atmospheric carbon dioxide concentration across the mid-Pleistocene transition*. Science 324(5934), 1551-1554. DOI: 10.1126/science.1171477
14. ISO. (2018). ISO 14067:2018, *Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification and communication (3rd ed.).*
15. Joos, F., and Spahni, R. (2008). *Rates of change in natural and anthropogenic radiative forcing over the past 20,000 years*. P. Natl. Acad. Sci. USA 105(5), 1425-1430. DOI: 10.1073/pnas.0707386105
16. Keles, E., Simsek, E. B., Sonmez, M. (2019). *Review on carbon capture technologies: current status and future prospects*. Journal of Cleaner Production, 240, 118209.
17. Lenzing AG. (2022). *Sustainability report 2021*. [online]. [cit. 2022-12-29]. Available at https://www.lenzing.com/?type=88245&tx_filedownloads_file%5bfileName%5d=fileadmin/content/PDF/04_Nachhaltigkeit/Nachhaltigkeitsberichte/EN/NHB_2021_EN.pdf
18. Lupač, M., Novák, J., and Třebický, V. (2012). *The Town of Chrudim - Case Study. Cities and Climate Change - Carbon Footprint of Towns as a Tool of Climate Protection Policy at the Local Level of the Czech Republic [Město Chrudim – Případová Studie. Města a Klimatická Změna – Uhlíková Stopa Měst Jako Nástroj Politiky Ochrany Klimatu na Místní Úrovni ČR]*, TIMUR, Prague, Czech Republic.
19. Matondo, J. I., Peter, G., and Msibi, K. M. (2004). *Evaluation of the impact of climate change on hydrology and water resources in Swaziland: Part I*. Phys. Chem. Earth, Parts A/B/C 29(15-18), 1181-1191. DOI: 10.1016/j.pce.2004.09.033
20. Mirasgedis, S., Hontou, V., Georgopolou, E., Sarafidis, Y., Gakis, N., Lalas, D. P., Loukatos, A., Gargoulas, N., Mentzis, A., Economidis, D., ET AL. (2008). Environmental damage costs from airborne pollution of

industrial activities in the greater Athens, Greece area and the resulting benefits from the introduction of BAT. Environ. Impact Asses. 28(1), 39-56. DOI: 10.1016/j.eiar.2007.03.006
21. Mondi Group. (2022). *Sustainable Development report 2021*. [online]. [cit. 2022-12-29]. Available at: https://www.mondigroup.com/media/15145/mondi-group-sustainable-development-report-2021.pdf
22. Neugebauer, S., Martinez-Blanco, J., Scheumann, R., Finkbeiner, M. (2015). *Enhancing the practical implementation of life cycle sustainability assessment – proposal of a Tiered approach*. Journal of Cleaner Production, Volume 102, Pages 165-176. ISSN 0959-6526. https://doi.org/10.1016/j.jclepro.2015.04.053
23. Official Journal of the European Union, 22 June 2021, L 197/1, *Corporate Sustainability Reporting Directive* (CSRD) 2021/0104/EU.
24. Pandey, D., Agrawal, M., Pandey, J. S. (2011). *Carbon footprint: Current methods of estimation*. Environ. Monit. Assess. 178(1-4), 135-160. DOI: 10.1007/s10661-010-1678-y
25. Plummer, S., Lecomte, P., Doherty, M. (2017). *The ESA Climate Change Initiative (CCI): A European contribution to the generation of the Global Climate Observing System*. Remote Sens. Environ. 203, 2-8. DOI: 10.1016/j.rse.2017.07.014
26. PwC. (2021). *Evropská komise: Povinný nefinanční reporting pro všechny větší firmy*. [online]. Published: 28.04.2021. [cit. 2022-11-26]. Available at: https://blog.pwc.cz/pwc_ceska_republika_news/2021/04/evropsk%C3%A1-komise-povinn%C3%BD-nefinan%C4%8Dn%C3%AD-reporting-pro-v%C5%A1echny-v%C4%9Bt%C5%A1%C3%AD-firmy.html
27. Ranganathan, J., Bhatia, P. (2004). *The Greenhouse Gas Protocol: a Corporate Accounting and Reporting Stan-dard, Revised Edition*. ISBN 1-56973-568-9.
28. Samarakoon, S. M. K., Gudmestad, O. T. (2011). *The IPPC directive and technique qualification at offshore oil and gas installations*. J. Clean. Prod. 19(1), 13-20. DOI: 10.1016/j.jclepro.2010.08.014
29. Santori, G., M. C. Ferrari, C. Charalambous, S. Brandani. (2018) *Adsorption artificial tree for atmospherical carbon dioxide capture, purification and compression*. Energy [online]. 162, 1158-1168 [cit. 2022-11-26]. ISSN 03605442. DOI: 10.1016/j.energy.2018.08.090
30. Sarto, L., Moretti, E., Petti, L., Vita, A. (2019). *Carbon footprint: A review of existing methodologies*. Journal of Cleaner Production, 219, 167-179.
31. Schramm, W. (1998). *Possibilities and limitations of a comparative assessment of process technologies from a cleaner production point of view*. J. Clean. Prod. 6(3-4), 227-235. DOI: 10.1016/S0959-6526(98)00017-1
32. Spinney, M., Karacabeyli, E., Mabee, W. (2013). *A review of the environmental implications of wood products in comparison to alternative products used in the production of furniture*. BioResources, 8(1), 1-14.
33. TÜV NORD GROUP. (2022). *Get ready for a new legislative obligation: carbon footprint reporting* [*Připravte se na novou legislativní povinnost: reporting uhlíkové stopy]*. [online]. [cit. 2022-11-26]. Available at: https://www.tuv-nord.com/cz/cs/novinky/news-detail/article/rozsirili-jsme-nase-sluzby-v-oblasti-certifikace-personalu-pro-ndt-o-dalsi-techniky-3-4-2-4-7-2-2-3-1/
34. Vrabcová, P., Hájek, M., Třebický V. (2018). *Carbon Footprint Measurement and Management: Case Study of the School Forest Enterprise*. BioResources. 13. 10.15376/biores.13.2.4521-4535.
35. Wegner, T., K. E. Skog, P. J. Ince, C. J. Michler. (2010). *Uses and desirable properties of wood in the 21st century*. J. Forestry 108(4):165–173
36. WRI/WBCSD. (2004). *The greenhouse gas protocol: a corporate accounting and reporting standard (revised edition)*. World Resources Institute and World Business Council for Sustainable Development.

Authors address:

Petržela, B.
Department of Forestry and Wood Economics, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences in Prague, Prague, Czech Republic
Corresponding author: xpetb016@studenti.czu.cz; ben.petrzela@seznam.cz

WOODEN HOUSING INDUSTRY MANAGEMENT – TRENDS AND PERSPECTIVES

Stasiak-Betlejewska, R., Grzegorzewska. E.

Abstract: The European prefabricated wooden houses industry continues its expansion. The future of the prefabricated housing market looks promising with opportunities in the residential and commercial construction industries. Paper presents research findings in the form of the market study concerning prefabricated wooden housing market in European Countries within market trends and drivers, market size and development and manufacturing process management.
Keywords: housing, wood, prefabrication, management, trends

1. INTRODUCTION

Wood is identified as one of the abundant construction raw materials because of its wide availability in nature and relative ease of handling [Pfeil and Pfeil 2003; Radkau 2011]. It is also environmentally friendly modern material [Fengel and Wegener 1983; Asif 2009]. The most important features of wood are following: renewable, recyclable, biodegradable and healthy for users.

Wooden housing is one of the most sustainable building alternatives. In many European and North American countries, wooden houses provide the most common, economical, and practical solution for construction. The timber buildings present adequate levels of durability, acoustics, and thermal comforts. Despite their popularity, wood houses do not have a standardized classification to define and organize their main aspects [De Araujo et al. 2016].

Trends in the construction industry lead to using natural renewable materials; that is why the interest in wood as a material in the construction field has greatly increased (globally) in the past decades. Aspect of climate changes and searching by building contractors and designers solutions that can be comfortable for the users have influence on current trends in the wood construction. In European countries, the wood is considered to be a strategic, while at the same time renewable, raw material, which is highly profitable for national economies [Moresová et al. 2019]. Development of numerous construction materials and technologies relates to the sustainability problem [Cooper 2006; Jansen 2014; Broto 2015]. Ecological characteristics of the wood and its systems and technologies have been considered as the growing importance in the construction industry with regard to sustainability trend. Preference of the construction materials depends on many factors. Besides environmental orientation of individuals, an important role is played by social, economic, climate or religious preferences [Potkány et al. 2018].

Growing ecological awareness means that consumers start to make decisions that will help minimize the negative impact of human activity on the environment. Houses made of wood are healthy for users, and at the same time allow to reduce carbon dioxide emissions. They retain it in their construction and store it throughout their life, so that it does not end up in the atmosphere. After the end of its life cycle, the building can be recycled and the material can be reused [Chen et al. 2022].

Due to the high degree of prefabrication, ready-module houses are the most cost effective alternative on the market for wooden single family houses. This attribute bears however the risk of being associated with low budget houses and less good quality [Waern 2008].

Prefabricated houses with a wooden structure are an advanced technology of frame houses. Their individual elements are not erected on the construction site, but in the production plant, on special assembly lines. C24 class structural timber is used for production. This class determines their bending strength equal to 24 MPa. Such wood is planned on four sides and kiln dried. Production is carried out in accordance with the harmonized European standard, which guarantees high quality and durability of the construction materials used. Prefabrication is regarded as improving the quality of the final product, since production settings are protected from weather impact and assembling is easier to control. Ready-module houses are mainly marked towards young families who have a tight budget but still want to buy a real estate. Higher income segments, on the other hand, potentially revert to wooden houses produced with more flexible, less standardized and thus more expensive prefabrication techniques than ready-modules, like e.g. partition wall elements [Smith 2009].

The main goal of the paper is a presentation and an analysis of the research findings on the prefabricated wooden housing market in European Countries that concern not only market trends and drivers, but also manufacturing process.

2. EUROPEAN WOODEN HOUSING MARKETS

Prefabricated housing demand is on the rise, as the building technique's advantages are increasingly being leveraged by new home buyers in an improving economic and demographically charged marketplace. By 2022, an estimated 70,100 units was sold across six Northern European countries, with German demand representing a sizeable level, particularly for turnkey solutions. The prefabricated housing market is picking up across Europe, as people increasingly focus on turnkey solutions that tick all the modern boxes. Acceptance of the manufacturing form, as well as ease of planning and consent processes, are expected to further boost demand. Meanwhile, the demand for better quality homes – from a sustainability standpoint – can be more easily met with well-developed prefabricated options.

Global modular construction market size was valued at USD 91.0 billion in 2022 and it is projected to reach USD 120.4 billion by 2027, growing at a cagr 5.7% from 2022 to 2027. The growth of this market is ascribed to an increase in concern for work-zone protection, the necessity for reduced environmental effects, and encouraging initiatives by the government. Growth in population and urban development offers prospects for the development of the market. In Italy, the prefabricated market for wood goods is expanding, as seen by the increased production of cross-laminated timber (CLT). CLT output in the "DACH" region (Germany, Austria, and Switzerland), the Czech Republic, and Italy totals over 750,000 m^3 and is increasing at a rate of more than 10% per year. Timber building is becoming increasingly popular in France. It has traditionally accounted for a smaller percentage of all apartment buildings and has been reserved mostly for structures up to four stories tall. There are already an increasing number of projects underway for buildings with 7 to 16 stories that use timber for the shell or structure of the building. According to the National House Building Council (NHBC), the number of new homes registered to be built in the United Kingdom fell by 23.2% in 2021, to 123,151, the lowest level since 2012 (104,922). The NHBC also stated that new home registrations fell in every UK region in 2021, with the largest drops occurring in the second quarter. According to data from the Office for National Statistics, in the second quarter of 2021, new housing construction orders in the private market explicitly – seasonally adjusted, volume – were up by 4.6% quarter-on-quarter and 154.8% Y-o-Y, indicating that the order book for property developers is on the mend following the lockdown [ReportLinker 2022].

Looking at the market for singe family houses in Scandinavia, it becomes obvious that wooden houses have least market share in Denmark. In Norway, Sweden and Finland, the market share of wooden houses accounts for more than 80%. These numbers show that the choice of building material in Norway, Sweden and Finland literally seen is a natural one, since the raw material wood is highly accessible in these countries, compared to Denmark. Ready availability of wood contributed to cost effective usages, which can explain the long tradition of high utilization of wood in the construction sector.

3. WOODEN HOUSING IN POLAND

Wooden construction has a great development potential in Poland. It can be based on one of the largest forest and wood resources in Europe, it can also use the potential of the wood sector, which is important for the Polish economy. However, this potential is still not fully exploited, while a wider use of wood in construction could bring significant benefits, not only in environmental, but also social and economic terms. Various conditions for the development of the wooden construction in Poland are pointed out - circumstances and conditions that should be met for this development to be possible. They are of the internal type (exogenous - resulting from the external environment of the wooden construction sector), internal (endogenous, originating in the sector itself) and are of a diverse nature, such as legal, organizational, economic or technological. To a large extent, they are a derivative of barriers that slow down the potential dynamics of development of this sector (and result from the need to overcome them).

It is estimated that there are about 800 companies/contractors of wooden houses in the country (according to the database of the Wooden House Association). Approximately 532 companies build wooden houses in the frame system (60-80 companies deal with full prefabrication), and 258 build log houses. Most are small companies, only 30-40 companies have a greater production potential. There are also companies on the market that produce only wooden seasonal and holiday houses (however, their number is difficult to determine). According to the Central Statistical Office in Poland, in 2019, 708 new residential buildings with a wooden structure with 730 apartments were commissioned in Poland. They accounted for only 0.8% of all residential buildings commissioned in the country and 0.4% of flats. Most of them, almost 91%, were built in the form of individual construction and the rest were built for sale or rent. Dwellings in timber-framed buildings had a larger average usable floor space (102 m^2), an average number of rooms per dwelling (4.7) and a shorter construction time (less than 38 months) than other types of buildings built using other technologies (89 m^2 respectively), 3.8 chambers and almost 39 months). In 2019, 1,361 summer and holiday houses as well as country residences were commissioned in the country, some of which, as it can be presumed, was also made of wood [Bidzińska et al. 2020].

The State Forests in Poland in 2017 announced a construction offensive and the creation of a portfolio of wooden properties for rent. Meanwhile, in Podlasie, two thriving companies have been selling wooden houses for years, generating revenues of hundreds of millions of zlotys. But it is not Poles who are the main clients of the companies. Danwood and Unihouse have their headquarters and factories located in Bielsk Podlaski. The location and raw material used for production, as well as a strong export orientation are basically the only issues common to both companies. They differ in the product and the markets. In 2016, Danwood had over PLN 665 million in revenue, which gave the company the 397th position in the ranking of the 500 largest companies of "Rzeczpospolita". The company sold 1.55 thousand houses and built nearly 1 thousand. Thanks to the launch of a new hall in November 2016, our capacity increased up to 1.4 thousand houses a year. The dominant sales market is Germany, to which 1,000 are to be delivered this year. houses. In Poland, the company expects to sell 70-100 homes, while in the relatively new market in the UK, 50. In 2016, Unihouse had PLN 156 million in revenue, which is over 16% more than a year ago. The company is part of the listed construction and development Group Unibep with annual revenues of PLN 1.2 billion. Unihouse produces wooden modules, of which even whole blocks are composed as if they were made of blocks. The advantage of modular construction is that it takes no more than half a year from design to implementation, while in the case of traditional construction it takes at least 18 months. In 2016, the company increased the production of modules by 23%, to 707 units. Virtually all sales are directed to the Scandinavian markets - since 2009 to Norway, and recently also to Sweden [Rogulski 2017].

In Poland, more than 1,000 wooden houses are put into operation annually [Puls Biznesu 2022]. The future of construction belongs to prefabrication. A trend common in many countries of Western Europe, the USA and Canada, it is also becoming popular in Poland, and access to high-quality prefabricated elements is much easier thanks to the modern STEICO factory with three production lines launched in Czarnków [Forum Holzbau Polska 2023]. The highly processed elements coming off the line are to supply mainly the domestic market, which has so far been overlooked by producers, mostly directing their offer to investors abroad. Prefabrication can not only improve the common belief about the quality and reliability of wooden buildings, but it is also competitive in relation to conventional construction, which is strongly affected by labour shortages and rising labour costs. Building with prefabricated elements requires fewer employees, and thanks to precisely made elements, it is more accurate and takes much less time, which shortens the entire investment process. Prefabricated elements are manufactured in a specialized plant under constant supervision, and we use high-quality raw materials for production, which is why they are much more accurate than structures made on site. The elements delivered from the factory only need to be assembled, and currently it takes only two days for the construction teams in accordance with the STEICO offer. Access to high-quality prefabricated elements and the growing experience of specialized contractors in their assembly is a milestone on the way to the modernization of the wooden construction sector, which has so far been associated with an economic system of investment implementation. The increasing number of completed buildings, not only residential but also public, proves that wooden prefabricated elements can be used to build permanently, safely and with the highest standards. Despite the natural properties of the raw material, not every building that will be made of it will meet the applicable legal regulations and energy efficiency standards. It should also be remembered that the regulations on energy performance will be more and more stringent, which results from the climate assumptions of the European Union. That is why it will be so important to make a conscious and reasonable choice of technologies and building materials that will allow to obtain the required parameters, without exposing the investor to costly and laborious modernization works soon after the construction is completed.

Wooden houses are a conscious choice to live in harmony with nature. More and more Poles want to live in healthy buildings, but at the same time they expect comfort and convenience. They are not meant to depend on handling complicated installations. Polish consumers also do not want to incur higher costs to maintain the optimal temperature inside the rooms. This is another reason why the wooden construction segment is undergoing a modernization process. The focus must be on technologies and materials that will be able to provide this comfort without a higher heating demand. This is only possible in buildings with high airtightness and excellent thermal insulation. This not only promotes the health and well-being of residents, but also acts as a heat buffer in winter and a heat barrier in summer.

4. CONCLUSION

Actions taken to prevent the effects of environmental degradation and climate change also affect the construction industry. Companies operating in this area have to take into account not only their own policies, but also environmental protection and social interests. The impact of buildings on the environment, both during the construction phase and throughout their lifetime, will become increasingly important. Therefore, sustainable construction must shift to natural renewable materials with a low carbon footprint and technologies that require significantly less energy than conventional methods and generate lower environmental costs. This is a good omen for wooden construction, which optimally meets these expectations. Co-responsibility for shaping the common space and taking care of the health and well-being of its inhabitants will influence rational investment decisions. At the same time, the time needed to complete construction processes is becoming more and more important, and only modern wooden construction in prefabricated frame technology can meet these requirements. In addition to the shortened operating cycle and economic benefits associated with lower operating costs of buildings, the ability to provide comfort to users and health aspects are also appreciated.

REFERENCES

1. Bidzińska, G., Leszczyszyn, E., Augustyniak, D. (2020): Budownictwo drewniane stymulatorem rozwoju mieszkalnictwa w Polsce, Łukasiewicz, Instytut Technologii Drewna, Poznań.
2. Chen, L., Msigwa, G., Yang, M., Osman, A.I., Fawzy, S., Rooney, W.D. & Yap, P.S. (2022): *Strategies to achieve a carbon neutral society: a review*. Environ Chem Lett 20, 2277–2310 (2022). https://doi.org/10.1007/s10311-022-01435-8
3. De Araujo, A.V., Cortez-Barbosa, J., Gava, M., Nivaldo Garcia, J., Jorge Duarte de Souza, A., Francisco Savi, A., Aparecida Martines Morales, E., Cesar Molina, J., Souza Vasconcelos, J., Luis Christoforo, A., Antonio Rocco Lahr, F. (2016): *Classification of Wooden Housing Building Systems*, BioResources, Vol 11, No 3, pp. 7889.
4. Asif, M. (2009): *Sustainability of timber, wood and bamboo in construction*. In: Khatib, J., Sustainability of Construction Materials, Woodhead Publishing, Cambridge, UK.
5. Broto, E. (2015): *Bamboo design guide & 59 case study*. Barcelona : Leading International Key Services Barcelona, 2015. pp. 300.
6. Cooper, I. (2006): *Cultural and Social Aspects of Sustainable Architectures*. In: Building Research & Information, 2006, vol. 34, pp. 82–86.
7. Jansen, S.J.T., (2014): *The Impact of the Have-Want Discrepancy on Residential Satisfaction*, In: Journal of Environmental Psychology, 2014, vol. 40, pp. 26–38.
8. Fengel and Wegener (1983): *Wood: Chemistry, Ultrastructure, Reactions,* Walter De Gruyter, New York, Ny.
9. Forum Holzbau Polska (2023): *Five trends that will change the timber construction market in* Poland, https://forum-holzbau.pl/pl/piec-trendow-ktore-odmienia-rynek-budownictwa-drewnianego-w-polsce/, version current as of 2023-05-14.
10. Moresová, M., Sedliačiková, M., Štefko, J., Benčiková, D. (2019): *Perception of wooden houses in the Slovak Republic,* Facultatis Xylolgiae Zvolen, 61(2): 121−135, Zvolen, Technická univerzita vo Zvolene, DOI: 10.17423/afx.2019.61.2.12
11. Pfeil, D.,Pfeil, G. (2003): *Wood: Chemistry, Ultrastructure, Reactions*, Walter De Gruyter, New York, NY.
12. Potkány, M. Gejdoš, M., Debnár, M. (2018): *Sustainable innovation approach for wood quality evaluation in green business*. In: Sustainability, vol. 10, pp. 1014.

13. Puls Biznesu (2022):*Udział drewnianych domów szybko rośnie*, https://www.pb.pl/udzial-drewnianych-domow-szybko-rosnie-1167974
14. Radkau, J. (2011): *Wood: A History,* Wiley, New York, NY.
15. ReportLinker (2022): *Europe Prefabricated Buildings Market - Growth, Trends, COVID-19 Impact, and Forecasts (2022 - 2027)*, https://www.globenewswire.com/news-release/2022/09/27/2523594/0/en/Europe-Prefabricated-Buildings-Market-Growth-Trends-COVID-19-Impact-and-Forecasts-2022-2027.html, version current as of 2023-05-14.
16. Rogulski, A. (2017): *Ekologiczne budynki cieszą się powodzeniem na Zachodzie*, https://www.rp.pl/nieruchomosci/art2439621-drewniane-domy-z-podlasia-na-europejskich-rynkach, 17.09.2017.
17. Smith, R.E. (2009). *History of Prefabrication: A Cultural Survey*. Proceedings of the Third International Congress on Construction History, Cottbus, May 2009. https://www-docs.tu-cottbus.de/bautechnikgeschichte/public/openaccess/smith_oa.pdf, version current as of 2010-09-20.
18. Waern, R. (2008). *Scandinavia: Prefabrication as a Model of Society*. In: Bergdoll & Christensen (edit.) (2008). Home Delivery, New York: The Museum of Modern Art, pp. 49-51.

Authors address:
Renata Stasiak - Betlejewska[1]; Emilia Grzegorzewska[2]
[1] Department of Production Engineering and Safety, Faculty of Management, Czestochowa University of Technology, Poland
[2] Department of Technology and Entrepreneurship in Wood Industry, Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences (SGGW), Poland
*Corresponding author: renata.stasiak-betlejewska@wz.pcz.pl

PRODUCTION AND QUALITY MANAGEMENT TRENDS IN THE FURNITURE INDUSTRY

Stasiak-Betlejewska, R.

Abstract: Furniture companies are looking for ways to shorten the time of order processing, improving production flexibility and faster response to market requirements. They also want to balance seasonal production loads and fully use the available material, personnel and infrastructure resources. Furniture manufacturers are increasingly investing in innovative solutions, although intelligent factories are still rare - this image emerges from the study of the degree of automation of companies. Meanwhile, the automation of production processes not only ensures optimization of the work of people and machines. The article concerns development directions in the field of production and quality management in the furniture industry on the example of Poland.
Keywords: furniture, production, quality, management

1. INTRODUCTION

The furniture industry in Poland is experiencing a boom. One of the main directions of development of the industry are solutions related to industry 4.0. Automation of production processes becomes not only an effective remedy for production problems, but above all contributes to an increase in profitability. Furniture companies are looking for ways to shorten order fulfilment times, improve production flexibility and respond faster to market demands. They also want to balance seasonal production loads and take full advantage of available material, human resources and infrastructural resources.

Furniture manufacturers are investing more and more in innovative solutions, although smart factories are still rare - this picture emerges from the study of the degree of automation of companies. Meanwhile, the automation of production processes ensures not only the optimization of the work of people and machines. Production automation brings many positive effects. It enables the optimization of the work of people and machines, more efficient material flow management, increased productivity, reduced media costs (mainly electricity), minimizing errors and preventing failures. All these elements significantly increase production efficiency. The main measures determining the competitiveness of a company operating in the furniture industry are efficiency and flexibility. The speed of action and the quality of the goods and services offered determine the success or failure in this business. The condition for maintaining them at a high level is the creation of a production system that will be able to manufacture and implement diversified products with the maximum use of existing resources. Smart factories in which machines communicate with each other and their work is monitored and analysed using specialized software are still rare in Poland. The study of Polish companies automation level shows that only 15% of domestic production plants are fully automated. Partial automation occurs in 76% of factories, while 9% of respondents indicated no automation. In addition, still only a small part of enterprises use IT systems for operational management and production control. Therefore, Polish industry still has a certain range of technologies related to the third wave of changes in the organization of production to master in order to be able to confidently go one step further, to Industry 4.0 [Astor 2016].

Furniture manufacturers are more and more often ready to invest in modern tools and systems, recognizing their potential and hoping that they will become a pass to strengthen their business position [Yang and Gu 2021]. However, these changes do not apply to all processes carried out in factories, but to their selected elements, e.g. ultralogistics, flow of raw materials, AGV systems or production of semi-finished products.

The main goal of the paper is a presentation and analysis of the innovative solutions implemented in today furniture industry in the context of production and quality management trends.

2. INDUSTRY 4.0 IN THE FURNITURE INDUSTRY

Industry 4.0 is a concept describing the complex process of technological and organizational transformation of enterprises, which includes the integration of the value chain, the introduction of new business models and the digitization of products and services. The implementation of these solutions is possible thanks to the use of new digital technologies, data resources and ensuring communication in the cooperation network of machines, devices and people. There are already numerous technologies, such as Internet of Things (IoT), Big Data, Cloud Computing (CC), digital twin, and Additive Manufacturing that help various industries to improve performance and achieve better productivity. These technologies are considered as a part of a wider concept which is called "Industry 4.0" or also known as "The Fourth Industrial Revolution" [Turkyilmaz et al. 2021].

The factor driving transformation towards the Industry 4.0 are the increasingly individualized needs of customers and the growing trend of personalizing products and services. The term industry 4.0 (German: industrie 4.0) comes from the German government's high technology strategy project and was first used during the international Hannover Messe fair in 2011. In turn, the beginning of the fourth industrial revolution is considered to be 2013, when the final report on the work of a working group operating in Germany, dealing with, among other things, preparation of recommendations in the field of smart industry. Among the guidelines, the authors mentioned the development of machines and devices capable of autonomously exchanging information, the design of intelligent factories and products, as well as the improvement of manufacturing processes [Issa et al. 2018]. The transformation towards Industry 4.0, according to the European Center for Advanced Manufacturing Support, includes 7 stages. The first concerns technological advancement, including flexible production systems that facilitate quick adaptation to changes in the number or category of products. The next step is to share information about the manufacturing process between people, machines and products. The third phase, on the other hand, concerns the inclusion of circular economy principles in order to fully use raw materials and reduce emissions. The process of comprehensively meeting customer expectations for products, i.e. End-to-End Customer Focused Engineering, is the fourth stage towards Industry 4.0. In the next one, it is crucial to focus on the human being, e.g. by using individual differences to strengthen the organization, and by building a meaningful work environment. The sixth stage, i.e. smart manufacturing, assumes the use of integrated systems that react to changing conditions in real time. In this context, the storage and sharing of large data sets (big data) is of great importance. The last step is an open factory that understands the needs of all participants in the value chain [Przemysł Przyszłości 2023].

Today, the furniture industry needs an innovative approach not only to the production process, but also to the entire flow of information in the company, to offering, designing, sustainable and economical use of material resources. This is the only effective way to increase the productivity and flexibility that today's market requires. On the one hand, customers expect tailor-made products, on the other hand, the costs of labor and materials are rising, which can be used more optimally thanks to automation. In order to successfully develop Industry 4.0 in a company, it is necessary not only to be open to the owners of the company and to be ready for changes, but above all to be able to carry out the necessary investments, which often means high costs.

The introduction of Industry 4.0 to the furniture industry is associated with very high investment expenditures. This applies to both machines and devices, as well as software in the preparation of technological documentation, directly connected with ERP systems, in the area of enterprise and production management. Treating such investments as an inseparable whole is the basis for the success of the automation process. As for the fact that Industry 4.0 in the case of the furniture industry is a necessary way of development, representatives of companies have no doubts. Especially those companies that are focused on the production of short, personalized series, addressed to demanding customers. Industry 4.0 solutions, which serve the purpose of effective information exchange, very clearly translate into work efficiency, and thus also cost efficiency. Industry 4.0 is a great opportunity to achieve the deadlines expected by the customer in terms of products already technologically developed or constructed on the basis of the variant configurator. A big challenge is the wide range of non-standard products, where in most cases the accuracy of technological data will be an obstacle that will have to be faced [Li Da et al. 2018; Lazi et al. 2014].

In factories in Poland, the time has come for companies from the furniture sector to implement industrial innovations of Industry 4.0. The inspiration comes from Western enterprises that use specific smart factory products in the production of furniture. The demand is because the society closed during lockdowns at home is more willing to invest in interior furnishings. At the beginning of 2020, the Polish furniture market was in third place among global furniture exporters, second only to China and Germany. 27,000 enterprises employ around 165,000 people. According to the report estimates of B+R Studio, developed in cooperation with the Polish Chamber of Commerce of Furniture Manufacturers, furniture exports from Poland in 2020 reached the amount of nearly PLN 50 billion. Despite the pandemic and the economic crisis, this sector recorded an increase of 3% compared to the previous year.

According to Eurostat data, the value of furniture exports produced in domestic factories located on the Vistula and Odra rivers has been growing steadily since 2016, when it fluctuated around EUR 9.6 billion, through 2017 - EUR 10 billion, 2018 - EUR 10.8 billion and 2019 - EUR 11.2 billion. For example, for Germany, this indicator has been estimated at EUR 12-14 billion in recent years. However, in the seating category, we are already second in the world behind China with a market share of as much as 43.5% [Eurostat].

3. AUTOMATION TRENDS IN FURNITURE PRODUCTION IN POLAND

The furniture factory Nowy Styl has been working on the global concept and technology for integrating systems and machines since 2013. Currently, each improvement or inclusion of a new element in the integration platform begins with conceptual work aimed at a specific goal, e.g. improvement of production processes. One of the possibilities is to improve the flow of information for existing machines and production cells, another - to buy a new machine. The factory also took steps to ensure that the machine received all the data needed for efficient operation, i.e. to automate the production process, and to generate information necessary for subsequent stages of work and monitoring. Thanks to the continuous expansion of system and machine integration and the improvement of the quality of data models, we can maintain a wide product portfolio. We also have the option of an individual approach to the client, without significant losses to efficiency. It's still an extra process, but it can be optimized.

Nowy Styl's production plant in Jasło, officially opened in 2015, is an investment which already in the name of the project had information about its high innovative potential. Technological lines have been designed here to enable full production flexibility and minimum changeover times. Production is carried out only on the basis of customer orders placed in the "just in time" system - only what has been ordered. The factory also enables the execution of "tailor-made" orders. The main production process is fully automated and operated only by machines - from storage and preparation of materials, to cutting, to the completion of ready furniture components in one place. In addition, automation supports the packaging and assembly processes. One of the most innovative technologies used in the new factory is the method of veneering curvilinear elements with a laser. This technology allows to obtain high quality and strength results in the field of joining the board with the rim. But in fact, in Nowy Styl, the concept of Industry 4.0 begins at the stage of offering. Thanks to this, for some products, the company is able to accept an order as individual as that which could be placed with a small carpenter's workshop. Currently, there are investments in information technology that will allow for even better management of information in real time [Michalik 2020].

The MDD Office Furniture Factory is a company that mainly produces products at the customer's request. For many years, it has specialized primarily in unit production, which requires appropriate adaptation of the production method. Until recently, similarly to most companies in the furniture industry, they supported themselves with optimization of production batches through various types of mechanisms for determining the optimal batch, and inventory design. In 2018 and 2019, MDD has completed two large investment projects worth over PLN 40 million. In the vast majority, it was the purchase of new machinery and equipment focused on unit production. Investments were made in three main production areas. The first one is the production of box furniture made of wood-based panels. Here, one of the key investments was the launch of a new cutting department with the world's fastest automatic panel warehouse. This investment was a response to the regularly falling production volume [Michalik 2020].

The company MDD managed to integrate not only the optimization of cutting, but also to receive feedback on the progress of the plan and real times of execution of operations on production orders. The times of loading machines with new types of decors have been significantly shortened and we effectively manage usable residues, which are also automatically used in subsequent orders from subsequent customers. In the field of veneering of narrow planes, veneering with waterproof PUR adhesives and work in the unit production system have been improved. The purchased solution allows, on the one hand, to obtain a waterproof adhesive joint, and on the other hand, the possibility of retooling in the gap between successive elements that can be covered with different veneers. The solution is integrated with the SAP ERP system, in which programs are created according to algorithms, and it also reports completed elements to the production system. In the field of drilling and milling of chipboard elements, the company has new feed-through drilling machines and machining centers that use the information contained in the ERP system and report the execution of orders. MDD has also invested in the automation of the production of metal furniture components. Two new tube lasers with a system for optimizing production orders and nesting on tubes, a sheet metal laser, wire bending machines up to 12 mm, a 5-axis center for mold preparation, welding robots, a powder paint shop operating in a continuous system with a quick change cabin have appeared colors and a mobile cabin adapted to the implementation of short production series. The production of soft furniture was significantly improved and optimized by two new fabric cutters, including a single-layer and multi-layer with a material optimization system and photodigitalization of new patterns. MDD is gradually integrating machine solutions with the ERP system, which is currently SAP, with the great involvement of high-class IT specialists. The vast majority of new devices are now prepared for two-way cooperation between production management systems and machine and device software.

There are more examples of companies that, despite the difficulties, successfully implement Industry 4.0. Step-by-step production automation is introduced by factories producing furniture for IKEA. For example, Mardom Pro, a company that produces pine wood furniture, is looking for ideas to optimize almost every aspect of its business. It has a team of experts designing e.g. the work of robots, which in the future will be able to replace employees. The automated sawmill and automatic painting lines require fewer and fewer people here. Optimizing production and introducing elements of digitization is the domain of not only large companies employing at least several hundred people. Small and medium-sized companies in the furniture industry also want to produce more, faster, more economically and exactly what customers expect. One of the medium-sized furniture companies introduced, for example, an automatic line for packing furniture. At its beginning there is a device for picking and cutting cartons, which, after cutting, are automatically transported to the packaging line and automatically folded. An important element is the robot placed at the end of the line, which places packages with elements on pallets. In another company, there is a socket for cutting boards into furniture formats. Automatic plate feeding and collection of formats, automatic waste collection, shredding and transport to the container, automatic collection of leftovers - the whole process is handled by two people, and the time of cutting a package of seven plates is about 3.5 minutes. There are also more and more small companies employing only a few people, which, for example, have CAD/CAM programs in the field of design and technological preparation of production. Combined with the controls of sawing machines or machining centers, they produce high-quality products in short lead times.

4. CONCLUSIONS

All innovative solutions related to the introduction of production 4.0 are very expensive and in order to earn money and bring appropriate financial results, they must be used to the maximum, which is not always possible. Modern machines and IT systems offer great opportunities in the planning and implementation of production from the organizational side, enabling a significant reduction in the time of order execution and reduction of production series, by significantly shortening the preparation and completion times. In well-organized furniture production plants, a series of 100 pieces of furniture should go through the production process within a few hours from its start. This is also difficult, but here it is a problem of the mentality of people planning and managing production. The modern furniture industry will be less and less determined by the price. The industry is shaped in the long term by precision, accuracy, and thus quality, supported by more flexible production processes, orders and deliveries of individual furniture. Changes resulting from the reduction of jobs in factories can be quickly offset by the skilful advance implementation of Industry 4.0 technology. Automation and robotization of machine parks and production lines, as part of a broader business strategy, is today the shortest way to competitiveness on global markets, also in the furniture sector.

REFERENCES

1. Astor (2017): Inżynierowie Przemysłu 4.0 (Nie)gotowi do zmian?, Kraków
2. *Biuletyn Informacyjny Ogólnopolskiej Izby Gospodarczej Producentów Mebli* (marzec 2017), http://www.oigpm.org.pl/art/files/209
3. Eurostat 2016 – 2019.
4. https://przemyslprzyszlosci.gov.pl/tag/przemysl-4-0/
5. Froidevaux, J.; Gril, J.; Navi, P. (2013): *Strengt Prediction of Mild Thermo-hydro treatments and extrapolation for natural aging*. In: Proceedings of the 3rd COST Action Annual Conference "Evaluation, processing and predicting of THM treated wood behaviour by experimental and numerical methods". Romania. April, 2013. pp. 33-34.
6. Issa, A., Hatiboglu, B., Bildstein, A., & Bauernhansl, T. (2018). Industrie 4.0 roadmap: Framework for digital transformation based on the concepts of capability maturity and alignment. Procedia CIRP, 72, pp. 973–978. Elsevier B.V.
7. Lasi, H., Fettke, P., Kemper, H-G, Feld, T., and Hoffmann, M. (2014): *Industry 4.0. Business & Information Systems Engineering*: The International Journal of WIRTSCHAFTSINFORMATIK, 6 (4), pp. 239-242.
8. Li Da Xu, Eric L. Xu & Ling Li, (2018): *Industry 4.0: state of the art and future trends*, International Journal of Production Research, 56:8, pp. 2941-2962.

9. Michalik, B. (2020): Przemysł 4.0 w fabrykach mebli – postęp jest widoczny, https://meblarstwo24.pl/kalejdoskop/przemysl-4-0-w-fabrykach-mebli-postep-jest-widoczny/
10. Turkyilmaz, A., Dikhanbayeva, D., Suleiman, Z., Shaikholla, S., & Shehab, E., (2021): *Industry 4.0 : Challenges and opportunities for Kazakhstan SMEs*. In: CIRPe 2020 – 8th CIRP Global Web Conference – Flexible Mass Customisation 14-16 October 2020 Online, 96C:214–2019. Elsevier.
11. Yang, F., Gu, S., (2021): *Industry 4.0, a revolution that requires technology and national strategies*. Complex Intell. Syst. 7, pp. 1311–1325.

Authors address:
Renata Stasiak - Betlejewska[1]
[1] Department of Production Engineering and Safety, Faculty of Management, Czestochowa University of Technology, Poland
*Corresponding author: renata.stasiak-betlejewska@wz.pcz.pl

CURRENT TREND IN THE DEMAND FOR INNOVATIONS IN THE WOODWORKING INDUSTRY IN SLOVAKIA

Šupín, M., Loučanová, E., Šupínová, M. and Olšiaková, M.

Abstract: The paper deals with innovations in the woodworking industry in Slovakia and its innovative trends based on the change in demand for these innovations in Slovakia. The primary method used in the paper is the calculation of the income elasticity of the demand, through which we calculated the income elasticity of the demand for innovations in the woodworking industry. Based on its values, we can state the necessity of using marketing communication to increase interest in ecological innovations, as the demand for this type of products does not grow sufficiently with the increasing incomes of Slovaks. Therefore, there is a lot of possibilities for the use of new forms of marketing communication based not only on outbound marketing but also on inbound marketing in the woodworking industry to promote wood products.
Key words: innovations, woodworking industry, demand, income elasticity.

1. INTRODUCTION

Currently, the market is paying special attention to innovative signals from an extremely influential group - customers. Consequently, the store often plays the role of an agent of innovation here, because thanks to its proximity to the target customers, it can find the weak points of the product offer and the latent need. Information about the behavior and attitudes of customers is very important for identifying the needs of innovations in consumer goods that are distributed through business networks. Marketers' information about the manufacturer's (product's) image is extremely important, because its image has a great influence on the success of product innovations that are distributed through the trade network (Trommsdorff, Steinhoff, 2009).

In the business environment, among global leaders in recent years, questions and challenges related to the so-called responsible business, which is based on the long-term sustainability of production. These challenges lead to a gradual change in the way of doing business. This is also contributed to by societal changes resulting in new demands from the market, customers and market regulations in the field of environmental protection, sustainable development and economic management of resources.

Therefore, the idea of ecological innovations is currently being presented in the world. These focus on reducing material requirements and energy requirements. They use alternative sources of energy, reduce health risks and environmental burden, etc.

Innovations create added value in increasing the company's profit, increasing the productivity and technical capacity of the company, but also access to attractive investments, as well as access to new emerging markets, increasing profitability within the value chain, gaining an edge over standards and regulations.

Constantly growing interest in innovations by consumers, changes the role of innovations from necessary to desired innovations, and thus they become a tool for the competitiveness of companies and at the same time present new challenges for companies (Loučanová, Nosáľová, 2020; Loučanová et al, 2022).

The need for innovation generated by target customers and business corresponds to the ideal case of Market Pull Innovations, which are associated with a relatively low risk of failure. In principle, this need for innovation can be derived from the difference between the structure of the problem and the existing offer. Product innovation should help to take advantage of opportunities and strengths and eliminate risks and weaknesses. The task of strategic situation analysis is to recognize the need for innovation and to develop it in the right direction according to the company's goals, which represent the assessment of business opportunities, where the company wants to be directed and at the same time to satisfy the needs of customers. The need for innovation is a dynamic variable during the innovation process, as are the needs of customers, which change from individual to individual. The starting point for the search for ideas for new products resulting from the discovery and discovery of business opportunities are the needs and wishes of customers, or consumers. Subjects from the external environment such as intermediaries and sales representatives are also a source of ideas, because they meet customers directly, know their needs, and have information about the competition. Therefore, it is appropriate to implement innovations of such a nature that satisfy the majority of the utility value of customers.

Value is only one criterion for choosing a certain innovation. Each innovation represents costs for the customer for its acquisition and use. Therefore, before deciding to buy a certain innovation, the customer will take into account its value and the costs associated with its acquisition (Loučanová, 2016; Stofkova et al., 2022; Gončárová et al. 2021; Šupín et al, 2021).

Therefore, the aim of this contribution is to analyse the income elasticity of the demand for innovations in the woodworking industry in Slovakia, characterizing the relationship between the share of innovation growth in the woodworking industry sector and the income of the population in Slovakia.

2. METHODOLOGY

One of the basic methods for processing this contribution is the analytical-synthetic method, combining analytical and synthetic approaches to the issue of innovation and demand. Through the analysis of the investigated phenomena and processes, we analyse the issue into individual parts and describe their mutual relations. The knowledge we have acquired speaks of past developments, but also of the current state in the researched area, and we describe them from various points of view and find out the basic relationships and connections between income elasticity of demand and innovations.

The income elasticity of demand is calculated as:

$$eID = \frac{\frac{\Delta Qx}{Qx}}{\frac{\Delta Ix}{Ix}} \qquad (1)$$

where:
q – quantity
I – income
eID > 0 – characterizes a normal farm
0 < eID < 1 – characterizes the required farm. With the growth of the consumer's income, the demand for this good increases to a lesser extent.
eID > 1 – characterizes a luxury estate. With the growth of the consumer's income, the demand for this good increases more than proportionally.
eID < 0 – characterizes an inferior farm. An increase in the consumer's income by 1% will cause an absolute decrease in the demand for this good (Majaro, 1996; Murín, 2011).

To calculate the income elasticity of demand for innovations, we used data on the share of innovative activities of the woodworking industry in Slovakia and the Statistical Office of the Slovak Republic on average wages in Slovakia, as well as data on the index on real wages in Slovakia for period from 2014 to 2020.

The result of the investigation is partial theoretical knowledge and conclusions, which are connected through synthesis into one whole of the issue of innovation and income of the population in Slovakia - income elasticity of demand.

3. RESULT AND DISCUSSION

Based on data from the Statistical Office of the Slovak Republic for the period from 2014 to 2020 on the innovative activity of the woodworking industry (hereinafter WI), the Global Innovation Index and the real wage index, as well as the average wage, we calculated the income elasticity of demand for innovations in Slovakia, see table 1.

Based on the calculated values of the income elasticity of the demand for innovations in the woodworking industry, we can conclude that the innovations of this sector in Slovakia represent a necessary good, which increases the demand for innovations in the sector by increasing the average wage.

Table 1 Income elasticity of demand for innovations in the woodworking industry

Period	The area to woodworking industry	Number of enterprises with innovative activity (Share of all enterprises %)	Average number of enterprises with innovative activity (Share of all enterprises %)	Average salary (Eur)	Real wage index	Income elasticity of demand for innovations to woodworking industry	Real income elasticity of demand for innovations to woodworking industry
2014	Wood processing	14,1	26,6	858,00	104,20	0,03	0,26
2015	Furniture production	35,7		883,00	103,20		
2016	Wood, pulp, paper, paper products	30		912,00	103,80		
2016	Wood processing	20	25,3	912,00	103,80	0,03	0,24
2017	Furniture production	29		954,00	103,30		
2018	Wood, pulp, paper, paper products	27		1013,00	103,60		
2018	Wood processing	36,82	48,8	1013,00	103,60	0,05	0,47
2019	Furniture production	47,62		1092,00	105,00		
2020	Wood, pulp, paper, paper products	61,88		1133,00	101,90		

Source: Statistical Office of the Slovak Republic (2018-2022) for the period 2014-2020

At the same time, however, the results also point to the fact that the demand for this type of innovation does not grow sufficiently with the increasing incomes of Slovaks. That is why there is a lot of room for new forms of marketing communication. Because, as stated by Kotler and Armstrong (2004), marketing, and its tools, which include marketing communication, is based on relationships with customers more than any other area in business and due to the fact that today's time is characterized by constant, increasingly rapid changes and thus also innovations, the market for them is specifically dynamic with intense competition. Therefore, according to Professor Majaro (1996), innovation and marketing must be an integral part of introducing innovations to the market as well as its system of shared values to increase the chances of succeeding in the market. The trend in communication in marketing is to redirect marketing activities from the field of classic outbound marketing to inbound marketing using innovative forms of marketing communication

In the future, it is assumed that up to 61% of marketers plan to increase spending on inbound marketing in the next year, which is also confirmed by the fact that the average company budget for blogs and social networks has doubled over the past two years. Likewise, the number of marketers who believe that Facebook has an irreplaceable place in their business has also doubled. In the global market, 67% of B2C (Business To Customer) companies and 41% of B2B (Business To Business) companies acquired a customer through Facebook, and 57% of all companies acquired a customer through a company blog. The answer to the question of why inbound marketing is on such a rapid rise is the fact that the price or the cost of contacting one potential customer is 62% lower compared to the traditional so-called by outbound marketing (Šupín et al, 2022).

To explain to him, within the framework of this marketing communication, the importance of innovations in the woodworking industry from the point of view not only of environmental impacts, but also from the point of view of increasing his comfort, safety and his health.

CONCLUSION

The paper is aimed at the current trend evaluation of the innovation activity in the Slovak wood processing industry and demand to innovation wood processing industry. Based on the calculated values of the income elasticity of the demand for innovations in the woodworking industry, we can conclude that the innovations of this sector in Slovakia represent a necessary good, which increases the demand for innovations in the sector by increasing the average wage.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 "Environmental Consumer and Environmental Citizen", grant number 1/0495/22, "Sustainability of Value Supply Chains and its Impact on the Competitiveness of Companies in the Forest and Forest-Based Sectors" and grant number 1/0494/22 "Comparative Advantages of the Wood Based Sector under the Growing Influence of the Green Economy Principles".

REFERENCES

1. Gončárová, Z., Piteková, J., Vrábliková, M. (2021): Ľudský faktor ako zdroj spokojnosti zákazníkov rodinných podnikov cestovného ruchu. REFLEXIE - Kompendium teórie a praxe podnikania, 3, 12-26.
2. Kotler, P., Armstrong, G. (2004): Marketing. Praha: Grada Publishing.
3. Loučanová, E. (2016). Inovačné analýzy a stratégie. Zvolen: Technická univerzita vo Zvolene, 2016. 149 p.
4. Loučanová, E., Nosáľová, M. (2020): *Eco-innovation performance in Slovakia: Assessment based on ABC analysis of eco-innovation indicators*. BioResources, 15(3), 5355-5365.
5. Loučanová, E., Olšiaková, M., Štofková, J. (2022): Ecological Innovation: Sustainable Development in Slovakia. *Sustainability*, *14*(19), 12620.
6. Stofkova, J., Poliakova, A., Stofkova, K. R., Malega, P., Krejnus, M., Binasova, V., Daneshjo, N. (2022): Digital Skills as a Significant Factor of Human Resources Development. Sustainability, 14(20), 13117.
7. Šupín et al. (2021): Dopyt po ekologických inováciách na Slovensku = The demand for ecological innovation in Slovakia / Mikuláš Šupín ... [et al.]. - VEGA 1/0674/19. In: Rozvoj Euroregiónu Beskydy XV [elektronický zdroj] : medzinárodná vedecká konferencia pod záštitou rektora Žilinskej univerzity v Žiline prof. Ing. Jozefa Jandačku, PhD. a rektora Wyższej Szkoły Finansów i Prawa w Bielsku-Białej dr hab. inž. Jacka Bindy, prof. WSFiP : zborník príspevkov : Žilina, 5. november 2021. Diagnostika spoločensko-ekonomických podmienok „súčasné zmeny spoločensko-ekonomickej situácie a výhľad do budúcnosti" / zost. Viktor Šoltés, Jozef Kubás, Matej Krejnus. - Žilina : Žilinská univerzita v Žiline, 2021. - ISBN 978-80-554-1835-3. - S. 319-325 [CD-ROM].
8. Trommsdorff, V.; Steinhoff, F. (2009): Marketing inovací. Nakladatelství CH Beck.
9. Majaro, S. (1996): Základy marketingu. Praha: Grada Publishing, a.s.
10. *** Murín, A. (2011): *Nové trendy marketingovej komunikácie*.
URL: <http://www.riant.sk/blog/nove-trendy-marketingovej-komunikacie#sthash.niu2bWzu.dpuf>.
11. ***: Statistical Office of the Slovak Republic. *Data 2014 to 2020.*
URL: https://slovak.statistics.sk;
http://datacube.statistics.sk/#!/view/sk/VBD_INTERN/pr0204qs/v_pr0204qs_00_00_00_sk
12. ***: *Priemerná mzda v SR, aktuálny stav 2022, história (2022*).
URL: https://www.kurzy-online.sk/makroekonomika/priemerna-mzda/

Authors address:
Šupín, M.[1], Loučanová, E.[1*], Šupínová, M.[2] and Olšiaková, M.[1]
[1] Department of Marketing, Trade and World Forestry, Faculty of Wood Sciences and Technology, Technical University, 960 01 Zvolen, Slovakia
[2]Slovak Medical University in Bratislava, Faculty of Health, Sládkovičova 21, 974 05 Banská Bystrica, Slovakia
*Corresponding author: loucanova@tuzvo.sk

APPLICATION OF REGIONAL CIRCULAR ECONOMY MODELS IN THE FORESTRY SECTOR

Turlakova, T., Slavova, G., Georgieva, T.

Abstract: The forestry sector is a resource sector that underpins many different business activities. Green investments can be beneficially and successfully combined with this line of business. The aim of this paper is to explore some possibilities for circular models, applicable in the regional economy of forest territories, which can contribute to a successful interaction between the forest sector and other sectors of the economy, leading to resource recovery and waste utilization. Models built on the basis of good collaboration between the forest sector and construction, industry, agrarian sector and tourism in different forest areas in Bulgaria have been analyzed. The research methods used are induction, deduction, comparative method, synthesis method and extrapolation. The carried out comparison between the various economic and social aspects of development of the various circular models, applicable to various business activities, provides an opportunity for both theoretical and practical application of the research results.
Keywords: circular economy, regional models, forest sector

The economic model that consists of extracting resources, using them to produce products that are then consumed and discarded is known as the linear economic model, but it is no longer viable. This is because it is highly wasteful, polluting and unsustainable in the long term. The circular economy is an approach that aims to contribute to reducing the application of the current linear method. It promotes the utilization of waste from various industries in different regions of the globe, and in particular in Bulgaria. The circular economy is based on specific, basic principles that include planning for the longer use of waste and resources, as well as reducing natural pollution, extending the life of products and materials, through re-purposing, re-using and regenerating natural systems. The circular economy has the potential to transform unsustainable production and improve existing regional production and recycling patterns.

Globally, many countries and businesses have initiated circular economy strategies that aim to transform production chains and consumption habits. Bulgaria, as part of the EU, is one of these countries. Concepts such as circular economy, bio economy and green economy are increasingly common in national and regional strategic development plans. The European Commission adopted the new circular economy action plan (CEAP) in March 2020. This plan is one of the main building blocks of the European Green Deal and is part of Europe's new sustainable growth agenda. The EU's transition to a circular economy is reducing pressure on natural resources and creating sustainable growth and new jobs in specific regions on a local basis. Promoting circular economy processes and sustainable consumption aims to ensure that waste and resources are reused and this gives the EU economy a chance to be more sustainable and reliable for longer (Lacy, P.,2015). The application of circular economy models is aimed at sectors that use the most resources, where the potential for circularity is much higher, such as: electronics, transport, packaging, plastics, textiles, tires, batteries, construction and buildings, food production, bottling and packaging of water and nutrients. One of the most authoritative definitions of circular economy is proposed by Ellen MacArthur Foundation: "(A circular economy is) an industrial system that is restorative or regenerative by intention and design... the concept of eco-effectiveness proposes the transformation of products and their associated material flows such that they form a supportive relationship with ecological systems and future economic growth. The goal is not to minimize the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle 'metabolisms' that enable materials to maintain their status as resources and accumulate intelligence over time (upcycling). This inherently generates a synergistic relationship between ecological and economic systems, a positive recoupling of the relationship between economy and ecology" (MacArthur, E.,2012).

The potential of the circular economy is recognized by a number of European countries and regions, as well as by the European institutions. In December 2015 The European Commission adopted an ambitious Circular Economy Package to stimulate Europe's transition towards a circular economy to boost global competitiveness, foster sustainable economic growth and generate new jobs. (European Parliamentary, 2023).

The United Nations Environment Programme and the Circularity Gap Report (2017) track the global development of the circular economy and highlight possible sectors, industries and areas where progress can be made in applying the model. In 2021, the Circularity Gap Report (Circularity Gap Report, 2021) outlines seven main areas in which the circularity model can be applied successfully. One of these directions is housing. The report advocates modernizing the existing housing stock in Europe and the world, and finding ways to extend the life of these homes. It explores alternative routes such as co-housing and modular design for new constructions that embrace flexibility and multi-functional use of the building materials used. This can be achieved by using the right recyclable materials, which provides less financial resources for materials, and a more flexible layout, which extends the useful life of the building as it adapts to the needs of its occupants. This, in turn, will revive the specific regional economy, since on the one hand the natural and material resources will be used, and on the other hand labor will be hired from the region. Moreover, the materials applied once in the production process will be recycled where possible and new raw materials and products will be obtained (Pearce, D., 1990).

In 2021, the Global Alliance for Circular Economy and Resource Efficiency (GACERE) was launched, and as early as 2015, the European Commission adopted the first circular economy action plan in its territory. In 2019, the European Green Deal is adopted, and in 2020, the European Commission adopts the new circular economy action plan. The circular economy is an economic and industrial model that keeps products, including their components and materials, in circulation for as long as possible to promote their sustainability as well as the sustainability of the economy. In this system, components of a product at the end of its life cycle are reused to recreate value, and industrial, agricultural and domestic residues are recovered to produce new products. Therefore, this system minimizes waste and uses resources as many times as possible.

In Bulgaria, the potential for producing briquettes from household waste is huge and they have better energy efficiency than traditional charcoal. Residues from the woodworking sector represent another major opportunity. One of the government's main development strategies in the forestry sector is to promote wood processing in the country as a source of income and job creation. However, there is no strategy to promote the use of residues for the production of other wood products. Over the past year, thanks to funding from the European Union and the help of various government institutions, the German Agency for International Cooperation (GIZ) and civil society organizations, CIFOR has been working to raise awareness of these issues related to wood processing companies in Europe, and including in Bulgaria. Manufacturers of wooden furniture, wood pellets and other wooden structures used in the agriculture, construction and industrial sectors rely on the private sector to include waste management in their corporate social responsibility strategies.

The regional principle of the circular economy model is based on the specific and characteristic features of each region. In mountainous areas, there is a very good opportunity for symbiosis between the agricultural and forestry sectors. In plain areas, the symbiosis between the agricultural and industrial sectors is greater, as well as between the forestry and industrial sectors. Thus, on the basis of the cascading cycle, regional models of a circular economy arise, since different regional factors predetermine the development of a different business direction, which, through the interrelationship between companies, builds a kind of business network. For example, in the North-Eastern region of Bulgaria, the symbiosis of "agriculture-industry-agriculture" is observed. It manifests itself in the use of waste from sunflower production to obtain so-called sunflower pellets, which in turn serve as raw material for heating greenhouse production (Turlakova, T.,2021). In the regions of the Rhodope, Rila and Pirin forest materials are mainly used in the field of furniture production, construction and industrial business, but when the wooden furniture, joinery boards, wooden boards in the construction and industrial sectors are used and worn out, they are successfully recycled and made into wood pellets. In the case described above, the models are "forest sector-industry-energy efficiency" or "forest sector-construction-energy efficiency".

As a closed business model, the circular economy represents an approach aimed at keeping components and materials at the highest level of applicability and value throughout the production cycle (Galuchi,T.,2018). The circular economy aims to change the meaning of waste as an unusable substance into a meaningful resource. From an economic and consumer point of view, it paves the way to improve the productivity and efficiency of raw materials through the creation of a circular system of development (Turlakova, T., 2019).

In the circular economy of the forest sector, the following regional patterns can be observed:

1. Creating a product from the forestry sector, i.e. from wood, applying it to a specific sector and a given region of the country, and then recycling it in an appropriate way so that the wood can be used again.
2. Follow-up sales – a business model by which the company can effectively restore its already used wood products and then re-market them to be able to profit from them a second time, why not a third time. An example of this is wooden desks, chairs, tables, pallets, wooden windows, wooden paneling, wooden tools, etc.
3. Transformation of products - not all products can be completely restored after use. However, in used products, there are often parts that are valuable or of high value, for example in manufactured upholstered furniture; the wood parts can be reused unlike the upholstery which has worn out.
4. Recycling - the new technology of recycling is highly suitable for products made of wood and from the forest sector. For example, the recycling of wooden desks, chairs, tables, pallets, wooden windows, wooden panels, wooden tools, etc. can be used to create new wooden objects for the home or industry.

The circular economy model is based on the supply of biological resources as well as forest and renewable resources. The application of the circular model favors the use of biological resources and above all the development of the bioeconomy (Turlakova, T., 2021). Reuse and recycling of biological "waste", as are all resources from the forest sector, leads to the creation of products from a natural source that avoids further environmental pollution. Recycling of biological waste does not compromise food production and keeps the ecosystem and biocenosis alive.

Many circular economy principles are already being applied in the forestry sector. Wood products used for construction purposes contribute to a lower carbon footprint of buildings. Wood, cellulose and its derivatives (such as lignin) are a viable substitute for non-renewable materials. The recycling of not only wood waste but also paper and cardboard is widespread. For example, in Belovo in the Rila region, recycling machines are also used in the paper factory. In the area of Svishtov, it is also common to use machines that recycle paper and cardboard in the production of paper. Both in the flat regions of Bulgaria and in the mountainous regions, the production and use of pellets is widespread. Furthermore, the residues from the forest processing sector are used with great success in the production of sawdust, which is used for bedding in animal husbandry and also for mulching (Slavova, G, Doneva, Y., 2022). In the field of tourism, recycled wooden boards are also used with great success, for example, to make sheds, fences, railings of fences, bridges and other facilities (Slavova, G, Ivanova, M., 2019). Such can be seen in a large part of Bulgaria's eco-trails. Good examples of this are: Eco-trail "Canyon of the Waterfalls" near Smolyan, Eco-trail "White river", as well as Eco-trail "Under the spray of Teteven waterfall", Eco-trail "Dangerous tooth" shelter above Teteven, Eco-trail "Tsarichina" and hundreds of others eco-trails in the country, located in highland and mid-altitude regions and sections of Bulgaria. Forest products can play a key role in the circular economy by providing a renewable source of raw materials. A more coordinated approach aimed at exploiting the full potential of the forestry sector can make this sector one of the key pillars of the circular economy. The construction sector is characterized by one of the highest carbon footprints: approximately 39 percent of all global carbon emissions originate from the construction sector. With the increase in the number and possibilities of engineered wood products, wood is increasingly used in the construction of residential and office buildings. The integration of circularity principles in this sector further contributes to the transition to a sustainable, low-carbon economy, reducing carbon emissions and waste on a massive scale. The ecological cost of forest materials and the conversion of wood into a resource that is then recycled and reused also leads to less risk in the use of forest resources and also to the possibility of applying crisis management in forest management (Gallucci, T.et al., 2019).

The transition to a circular economy is a crucial step for the development of humanity and the planet. For example, the recycling of traditional forest resources focuses on the mass production of wood, pulp and cardboard products by several large companies in Bulgaria, located mainly in the mountainous regions of Bulgaria (Table 1). This fact, in turn, creates an opportunity for the development of the forest, but also of the rural plain areas and provides employment, which is one of the main directions of the Common Agricultural Policy (CAP), as well as of the Operational Program for the Development of Rural Areas (Turlakova, T. 2019).

Table 1 Different types of wood production by region

Region type	Type of goods made of wood	Percentage of all domestically produced products of this type
Plain areas	Wood furniture	24%
	Wooden toys, souvenirs, accessories and ornaments	45%
	Wooden panels	11%
	Paper items	20%
Mountain areas	Wood furniture	76%
	Wooden toys, souvenirs, accessories and ornaments	55%
	Wooden panels	89%
	Paper items	80%

From the research carried out and the results presented in Table 1, it is clear that in the mountainous regions the production of wood products is represented to the greatest extent. The share of manufactured wooden boards is the highest, and the lowest is the share of wooden toys and souvenirs. All types of wooden products, including paper products, have a larger percentage share in mountainous regions compared to plains. This is mainly due to a traditional livelihood in the mountainous regions and their specialization in the processing and production of wooden products. A striking result is that small wooden products, such as souvenirs, accessories, toys, ornaments, are mostly produced in the flat areas, but there are also production bases for upholstered wooden furniture, such as chairs and sofas. It is of research interest whether in other countries of the European Union and the world, mainly in mountainous regions, the larger producers of wooden boards are concentrated, as is the case in Bulgaria, and whether small products have an almost equal share as production in the plains and mountainous regions.

In conclusion, we believe that the application of circular models at the regional level in the forest sector will create new tools and working models that will make qualitative new production and this will be a key feature in the future production of wood products. The wood that is currently discarded will in the future be reused in a sustainable way for the production of new products. In order to successfully realize such an expectation, the efforts of several producing groups of players must be combined. On the one hand, it is the forestry sector with the provision of wood resources, on the other hand, it is all wood enterprises and products produced from it, and then again there are designers and modelers, or perhaps there are wood traders and their goods. This socio-economic compilation is necessary in order to develop a new business model that is not only profitable but also regionally oriented. Before saying that different areas have different possibilities for applying this model, we must summarize that forest and mountain areas have a better base for the development of this type of business. Nevertheless, from the research we found that in plain areas there are also favorable conditions and companies that produce wood products.

REFERENCES

1. Gallucci,T. and others (2018) *Inovation models of circular economic*, UE-Varna, V.,p.19
2. Ellen MacArthur (2012) Foundation, *Towards the Circular Economy 1: Economic and business rationale for an accelerated transition;* January 2012
3. Gallucci, T., Lagioia, G., Amicarelli, V., Dimitrova, V., Kaneva, M. (2019) ICT and Environmental Indicators for Green Growth in Bulgaria. New Trends in Sustainable Business and Consumption: BASIQ: International Conference: Conference Proceedings, 30 May - 1 June 2019, Bari, Italy , Bucharest : Bucharest University of Economic Studies Publ. House, 730 - 738.

4. European Parliamentary Research Service, European Parliament. Understanding Waste Streams: Treatment of Specific Waste, 2015 (http ://www . europ ar1. europa. еи/RegD ata/etude sBR1E/2 015 /5 643 9 8/EPR S_ BRI(2015)564398-EN.pdf).
5. Lacy, P.; J. Rutqvist. (2015) *Waste to Wealth: The Circular Economy Advantages.* Accenture Strategy edition, 2015.
6. McArthur Foudation, 2015 (https: //www.ellenmacarthurfoundation.org/ case-studies).
7. Pearce, David W. R; Kerry Turner (1990) *Economics of Natural Resources and the Environment*, Johns Hopkins University Press,UK,1990
8. Slavova G.; Doneva Y. (2022) *Application of the Model of Circular Economy Between the Forestry and Agricultural Sector*, Crisis management and safety forestight in forest-based sector and smes operating in the global environment, WoodEMA 2022, p. 383
9. Slavova,G.; ,Ivanova, M. (2019) "*Someone's garbage is someone else's treasure"-Cross-sectoral integration in circular economy*. Digitalisation and circular economy, p.61
10. Turlakova, T. (2021) *Bioeconomy as an Innovative Approach to Rural Development in the Context of Common Agricultural Policy in EU:* Sixth International Scientific Conference: Business and Regional Development, EDP Sciences, 2021, 01008 - 1-7. - (SHS Web of Conferences; 120). / DOI 10.1051/shsconf/202112001008
11. Turlakova, T. (2019) *Business and Regional Models for the Application of the Circular Economy.* Trakia Journal of Sciences. Scientific Serial Published by Trakia University. Social Science , Stara Zagora : Trakia University, 17, 2019, Suppl. 1, 171 - 175.
12. Turlakova, T. (2019) *Business Localization Problems in Rural Areas*. Izvestia Journal of the Union of Scientists - Varna. Economic Sciences Series, Varna : Union of Scientists - Varna, 8, 1, p.202 - 209.

Authors address:
Turlakova, T[1]; Slavova, G; Georgieva, T
[1] Department of Agricultural Economics, Faculty of Economics, University of Economics, Varna, Bulgaria
[*]Corresponding author: tturlakova@ue-varna.bg

ASSESSMENT OF THE REPLACEABILITY OF DIFFERENT TYPES OF RAW MATERIALS AND PRODUCTS IN THE ENERGY MARKET

Pryadilina, N.

Abstract: In recent years, the problem of assessing the replaceability of various types of raw materials and products in the energy market, in the production of heat and electricity, has become increasingly relevant. Wood fuel in the form of pellets and wood chips has several substitutes with uncertain consumption prospects. This paper presents different approaches to assessing the efficiency of using wood materials as fuels due to high expectations from the development of a "green economy", designed to replace the use of non-renewable natural resources in energy production.
Keywords: energy market, substitutability of raw materials and products, pellets, bioeconomy, market price

1. INTRODUCTION

The primary issues facing humanity today include threats related to energy security, climate change, economic downturns, and pollution of the environment.

Energy consumption worldwide continues to increase, which leads to an increase in extraction and burning of fossil fuels. As a result, greenhouse gas emissions are also increasing, leading to global warming and catastrophes worldwide [1].

As of today, the issue of climate change is not only recognized by humanity, but measures are also being taken to address it. The Paris Agreement, which came into force in 2016, identifies the main directions for combating climate change and imposes restrictions on greenhouse gas emissions, with countries making commitments to reduce their greenhouse gas emissions [2].

In practice, this means reducing the consumption of traditional energy sources. However, the world economy's demand for energy continues to grow. To reduce the threat of climate change worldwide, it is necessary to use energy-saving technologies efficiently, to rationalize usage of energy resources, and develop renewable energy market. Alternative energy should be based on local renewable fuel resources [3].

The world is entering the era of the bioeconomy, an economy based on biotechnology that uses renewable raw materials to produce energy and materials [4].

2. MATERIALS AND METHODS

In recent years, the most relevant issue is the assessment of substitutability of different types of raw materials and products in the energy market for the production of thermal and electric energy.

The schematic representation of the energy market is shown in Figure 1.

From Figure 1, we can see that the position of each source of thermal and electric energy in the market is determined by its competitiveness, taking into account:

- Prices for each type of fuel at their extraction (production) sites;
- Costs of fuel delivery to points of thermal and electric energy production;
- Costs of energy production at the locations of consumption of fuel and energy resources;
- Investment needs in energy production;
- Costs of preventing environmental damage if energy production has a negative impact on the environment.

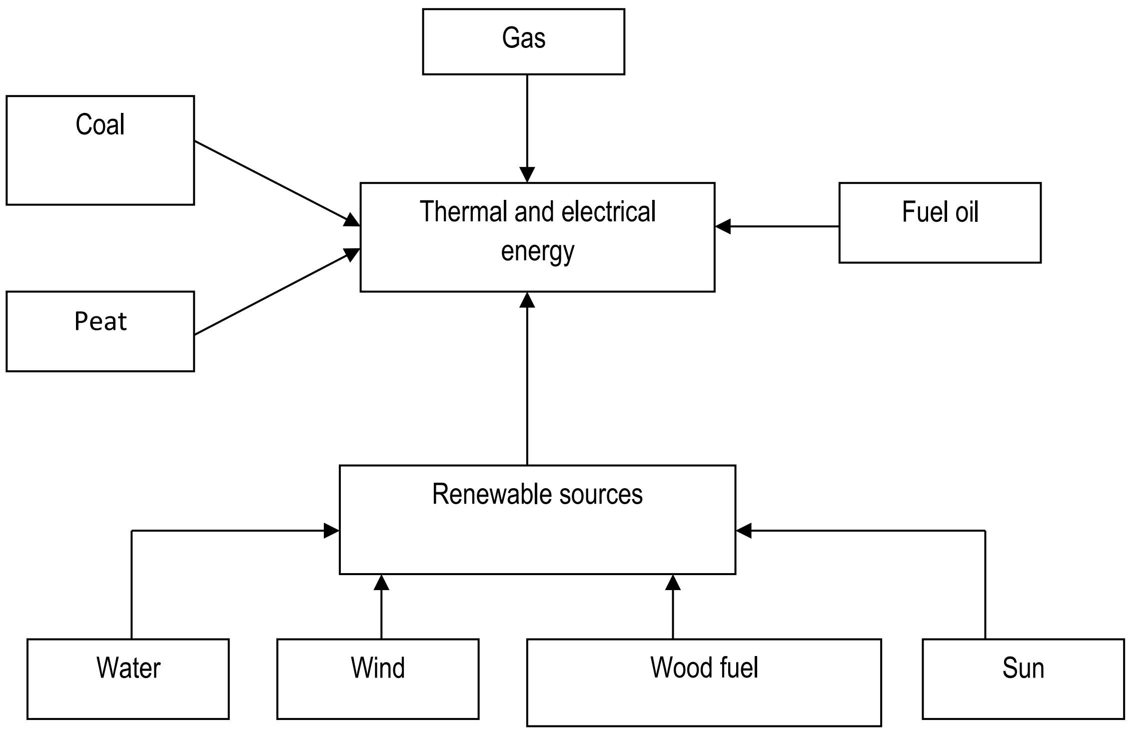


Figure 1. Schematic representation of the energy market

When establishing the market price for thermal and electric energy at a level that is the same for all fuel and energy suppliers, the conditions for their use should be determined by the inequality:

$$Z_{en} > (P_{en} + t_{en})m_{en} + q_{en} + r_{en} \quad (1)$$

Where:
Z_{en} is the market price of thermal or electric energy at the point of its production,
P_{en} is the price for a unit of fuel and energy resource at the place of its extraction (production),
t_{en} is the transport costs for delivering the fuel and energy resource to the point of consumption,
m_{en} is the fuel and energy resource consumption per unit of thermal or electric energy,
q_{en} is the cost of producing thermal or electric energy,
r_{en} is the normative profit that ensures the return on investment in energy production.

Using the formula above, we can find the conditions for the efficient consumption of wood fuel in energy production in competition with any of its substitutes.

For this, we assume:

$$Z_w = Z_m \quad (2)$$

Where:

Z_m is the market price per unit of thermal or electric energy at the point of its production based on the consumption of fuel "m" (for example, fuel oil),
Z_w is the market price per unit of thermal or electric energy at the point of its production based on the consumption of wood fuel "w" (for example, pellets).

The equality$Z_w = Z_m$ assumes that, for example, replacing fuel oil with pellets leaves the existing price of energy in the market.

Expanding equation (2) using formula (1), we get:

$$(P_{en} + t_{en})'m_{en}' + q_{en}' + r_{en}' = (P_{en} + t_{en})''m_{en}'' + q_{en}'' + r_{en}'' \quad (3)$$

Where the variables with a prime symbol (') characterize energy production based on wood fuel, and the variables with a double prime symbol (") correspondingly characterize energy production based on fuel oil.

To simplify the problem, assume that:

$$(P_{en} + t_{en})' = P_{oen}' \quad (4)$$

$$(P_{en} + t_{en})'' = P_{oen}'' \quad (5)$$

Where P_{oen}' and P_{oen}'' are the prices of fuel and energy resources (of pellets and fuel oil respectively) including cost of their transportation to the location of their use for energy production.

Solving the equation (3) for P_{oen}' (price of pellets) to get:

$$P_{oen}' = P_{oen}'' \frac{m_{en}''}{m_{en}'} + (q_{en}'' - q_{en}') + (r_{en}'' - r_{en}') \quad (6)$$

Denote

$$\Delta q_{en} = q_{en}'' - q_{en}' \quad (7)$$

$$\Delta r_{en} = r_{en}'' - r_{en}' \quad (8)$$

Where Δq_{en} is the difference in operating costs when processing fuel resources into energy,
Δr_{en} is the difference in the volume of attracted investment resources, which determine the size of the standard profit.

When the operation and investment costs are equal, the price of wood fuel is determined by the following equation:

$$P_{oen}' = P_{oen}'' \frac{m_{en}''}{m_{en}'} \quad (9)$$

From the given formula, it can be seen that the price of wood fuel is determined by:
- Existing prices for the types of fuel and energy resources that wood fuel can replace in consumption.
- Ratio in consumption per unit of thermal or electric energy for wood fuel and its substitute

Different types of fuel and energy resources have different transportability, and therefore transport costs will have a significant influence on their price. Taking this into account, the formula (9) transforms into formula (10):

$$P_{oen}' = P_{oen}'' \frac{m_{en}''}{m_{en}'} - t_{en} \quad (10)$$

Given these considerations, the demand price $P_{en}$for intermediate products, such as pellets or fuel chips, becomes the determinant of the conditions for efficient consumption of wood as a fuel.

When determining the price of wood fuel, significant adjustments should be made to account for the environmental consequences that occur during energy production based on the consumption of various fuel and energy resources.

It is well-known that burning coal and fuel oil in boilers can pollute the environment with gaseous waste. If we assess the damage caused to the natural environment by emissions of harmful substances into the atmosphere by the costs needed to prevent pollution, then the magnitude of these costs should be used to adjust the demand price for different types of fuel. This adjustment should favor wood fuel, usage of which in energy production does not have a negative impact on the environment.

Taking all of this into account, the demand price for intermediate wood products intended for energy production is determined by the formula:

$$P_{\text{w}} + P_{\text{en}} + \Delta P_{\text{env}} \quad (11)$$

Where:
P_{w} is the demand price for intermediate products (pellets, fuel chips),
ΔP_{env} is the prevented environmental damage per unit of intermediate product resulting from the use of replaceable traditional types of fuel and energy resources.

Table 1 shows a templatefor determining the conditions for effective consumption of wood based on its substitutability for other types of fuel.

Table 1. Template for determining the conditions for effective consumption of wood in energy production

№	Replaceable fuel types	Thermal energy		Electrical energy	
		Pellets	Fuel chips**	Pellets	Fuel chips
1.	Gas	*	**	*	**
2.	Fuel oil	*	**	*	**
3.	Coal	*	**	*	**
4.	Peat	*	**	*	**
5.	Other	*	**	*	**

* Demand price per ton
** Demand price per m^3

3. CONCLUSION AND RECOMMENDATIONS

Thus, competitors to wood in the production of thermal and electric energy include gas, fuel oil, coal, peat, and others.

The intersection of the vertical and horizontal columns of the table determines the demand price for pellets and fuel chips, at which wood fuel is an effective substitute for other fuel and energy resources.

The condition for the entry of wood fuel into energy resource markets should be its price, determined by comparing the above indicators for various types of fuel. In a market economy, approaches have been developed to establish prices for goods in conditions of their replaceability in consumption.

Under conditions of complete replaceability, the prices for materials are inversely proportional to their volume used in the production of one unit of product. Such an approach is applicable in solving specific economic problems (for example, converting a boiler to wood fuel and abandoning the use of fuel oil).

This detailed presentation of approaches to assessing the effectiveness of consuming wood as fuel is explained by the novelty of the problem and high expectations for development in countries with a "green economy" that aims to replace non-renewable natural resources in consumption.

For the development of bioenergy, it is important to account not only for the environmental aspect, but also for the energy security since biofuel is often produced within the country and is a renewable energy source.

In this situation, it is important to make strategic decisions on the development of biotechnologies based on economic and environmental priorities established with the use of reliable information sources.

REFERENCES

1. Karpachev S.P. Current state and prospects of bioenergy development based on processing of wood waste // Lesopromyshlennik. 2008. No. 3. Pp. 31-34. (in Russian)
2. URL: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
3. Danilov N.I. Energy conservation - the religion of the 21st century. Yekaterinburg: Voluntary group "Institute of Energy-Efficient Technologies", 2006. 63 p. (in Russian)
4. Usoltsev V.A. Russian forest as a guarantee of energy and environmental security of Russia // Eco-Potential (Yekaterinburg). 2014. No. 4(8). Pp. 7-15. (in Russian)

Authors address:
Pryadilina Natalia, PhD
Department of Economics and Economic Security, the Institute of Economics and Management, Ural State Forest Engineering University (USFEU), Ekaterinburg, Russia

CARBON STORAGE CAPACITY IN CROATIAN NARROW-LEAVED ASH FORESTS. THEORETICAL APPROACH

Beljan, K., Rupić, A., Pejić, P., Vedriš, M., Teslak, K., Posavec, S.

Abstract: The issue of carbon monitoring, reporting and management affects many industries and forestry is no exception. Since the carbon emission caused by industry, and other similar sources, needs a counterbalance, the best solutions can be found in forests. Forest trees by their growth absorb carbon and store it in wood. Carbon storage in the forest-based industry has two segments 1) storage in standing timber and 2) "outcome storage" in wood-based products. This paper aims to investigate both carbon storage possibilities and their monetary value in a theoretical narrow-leaved ash forest (*Fraxnius angustifolia* Vahl) example in Croatia by using the IPCC methodology (Intergovernmental Panel on Climate Change). Results indicated that in a 100-year rotation period (middle ranged rotation period between 80 and 120 years) the carbon storage varies from 159.63 to 157.44 tonnes per average forest hectare (varies before or after the annual harvest). From the annual harvest of 5,2 m^3 ha^{-1} (equals 1.4 tonnes of carbon) 51 % can be used for wood-based products. Furthermore, using different rotation period lengths (80-120 years) and site indexes (1 and 2) the storages and monetary values were calculated and compared accordingly. The economic importance is evident due to the fact that EU carbon permits (Emissions Trading System - ETS) in the last ten years have increased in price twenty times. Since longer rotation periods are resulting in higher volume stocks, containing large dimension trees suitable for wood-processing, the carbon storage and its monetary value result in the same logic. However, annual increment apropos harvest in the normal balanced narrow-leaved ash forest in shorter rotation periods (e.g. 80 years) results in larger amounts of outcome storages.
Keywords: forest management planning, carbon storage, economics of carbon, narrow-leaved ash, monitoring, wood products

1. INTRODUCTION

The issue of carbon importance and usage started back in 1997 at the UN's Kyoto conference on which industrialized countries (but not all, such as the USA) committed to reducing greenhouse gas emissions. Later, that commitment is known as Kyoto Protocol. The reduction in emissions, carbon in the first place, is defined for each state while the "base year" of reduction comparison is 1990 (United Nations, 1997).

Forests can be managed in order to sequester atmospheric carbon in addition to produce timber. A sequestration is possible if the vegetation, by increasing its volume, builds in carbon into itself and thus reduces its share in the atmosphere. So, the forest carbon represents a unique nature-based solution to climate change and global warming (Ussiri and Lal, 2017). This does not mean that forests should not be actively managed, e.g. harvested. By bigger consumption of wood for final products (e.g. flooring, roofing, etc.) carbon will stay stored in it. It should be emphasized what carbon returns to the atmosphere: forest fires, burning firewood for heating and dead-wood decomposition (Rattan et al., 2013).

Member states as parties to the Kyoto Protocol can participate in international emissions trading. In theory, it is assumed that countries that have a favorable ratio of stored and emitted carbon can sell excess carbon to other countries that do not. In other words, if a country stores more carbon than it emits, it can sell the difference to other countries that are in the opposite situation through a kind of exchange. In this way, a new commodity was created, which is tracked and traded like any other commodity. This is known as the "carbon market" on which the ETS units (Emission Trading System) are traded (World Bank, 2022).

The concept of ETS can be summed up in the term "Cap-And-Trade" system. First, the maximum is determined in Kyoto, i.e. the maximum allowed amount of emissions, "the Cap". On the other hand, "Trade" refers to the trading of ETSs emission units, that serves as a tool to achieve this goal. Nowadays 127 countries, 823 cities, 101 regions and 1,541 companies have committed to decarbonize their activities by 2050, thereby becoming, or about to become, participants in the international carbon trade (World Bank, 2022). Further, carbon can be traded on ICE (Intercontinental Exchange), Montreal Exchange (The Montreal Climate Exchange), CCFE (The Chicago Climate Futures Exchange), The New York Mercantile Exchange's Green Exchange, and on two European exchanges ECX (European Climate Exchange) and EEX (European Energy Exchange). It is important to say that, at least for now, carbon trading at the international level is not fully feasible because not all markets are compatible and connected.

The aim of this research is to investigate the carbon storage capacities in a selected forest type in the Republic of Croatia. The storage in the sense of this paper refers to two segments: storage in growing stock and the outcome storage in wood-based products. The paper aims to investigate both carbon storage possibilities and their monetary values. The topic is important because of the possibility that forests can serve as an offset for carbon emissions (World Bank, 2021). In other words, there is a possibility that forests can serve as a unique counterbalance for carbon emissions, which means that the forest owners would be able to sell their carbon on the market are that some factory (pollutant) by owning forests will be able to neutralize its carbon emissions.

2. MATERIAL AND METHODS

2.1. Narrow-leaved ash in Croatia

Narrow-leaved ash occurs in several forest types in the form of pure and mixed stands in the lowland parts of Croatia. The growing stock of 17.6 million cubic meters and an annual harvest of 245,000 cubic meters (one-half of the annual increment) represents an important forest and economic tree species. The total area cover of all seven Narrow-leaved ash forest types is about 750,000 hectares (Čavlović and Teslak, 2022). It is interesting to stress that only 11.4% of ash growing stock is concentrated in narrow-leaved ash forest types and the rest is found in the other (mixed)forest types. Due to the characteristics of its ecological niche (Ugarković et al., 2022) the majority of growing stock can be found in the pedunculate oak forests.

Health status of this tree species is in an unenviable position. The crown defoliation in the period 1998-2007 varied 10-20% but in recent years it reached 65% (Seletković et al., 2022). Due to multiple negative impacts (insects, fungi, abiotic factors, anthropogenic disturbances) the forests complexes are endangered and die backing. The dieback is present in all age classes and microrelief types ranging from 30 to 210 m^3 ha^{-1} of dead wood (Seletković et al., 2022).

2.3. Research method

The input data for this research has been taken from multiple sources. Data on growing stock, increment and annual harvest regarding to different rotation period lengths and site index for Narrow-leaved ash forests is previously published by Meštrović and Fabijanić (1995). Further, for quantifying the below- and above-ground forest biomass, dry matter, carbon in forest soil and carbon in wood the methodology by IPCC (2006) has been used.

Estimation is performed for three rotation period lengths (80, 100 and 120 years) and for two site indexes (I and II) which makes six cases in total. In order to make a comparison between case studies each of them is spatial equal (100 hectares). Since the theoretically balanced even-aged forest structure with a 20-year regeneration period is assumed, the certain case study had different characteristics of forest stands (consequently the number of forest stands varied from 70 to 120, while their size varied from 0.909 to 1.429 ha).

For each case (study) the carbon quantity in forest soil, above- and below-ground biomass, and in dead biomass (standing and lying dead trees) has been calculated and compared on the forest level. In addition, the comparison is performed on the annual harvest basics (i.e. before and after the harvest which implies an application of the so-called sustainable forest management regime where the annual harvest equals the annual increment).

Since carbon outcome storage in wood-based products is the second subject of this article the wood assortment structure of annual harvest is analyzed. In other words, the timber which has been annually harvested is quantified by Assortment Share Tables (Croatian Forests Ltd., 2000) in order to define the amount of timber suitable for a long-lasting wood-based product (e.g. flooring, roofing, etc.) in which the carbon can also be stored.

Monetary value of carbon in terms of EU carbon permits is calculated based on actual stock exchange prices (88.68 € per one carbon permit (Trading Economics, 2023)).

3. RESULTS

Carbon storage in narrow-leaved ash forests differs regarding the rotation period length and the side index. The storage is closely related to the growing stock and consequently to the above- and below-ground biomass. In a simplified comparison, it can be said that longer rotation periods, which implies greater growing stock, are resulting in greater carbon storage and vice-versa. The difference is about 0.6 t. C. ha^{-1} at site index I, and 1.6 t. C ha^{-1} at site index II for each additional year of rotation period starting from 80 years (Table *1* 1). However, the storage is identical in forest soil and dead biomass regardless to the rotation period length and site index.

Carbon storages and their monetary values are compared before and after the harvest on the forest level (Table *1* 1). The difference, which actually represents the harvest of the whole annual increment, revealed forest site potentials for carbon storage. It is evident that in a more productive forest site (index I) where higher increments are allowing higher intensities of harvesting (both thinning and final harvest) the carbon storage potentials are preferable. The reason why shorter rotation periods have greater values than longer ones is the fact that the best efficient rotations, in biomass production terms - not carbon terms, should not exceed 80 years.

Table 1. Carbon quantity in theoretical balanced even-aged narrow-leaved ash forests

Tonnes of carbon per average forest hectare (t. C. ha^{-1})		**Site index**					
		I			**II**		
		Rotation period length (years)					
		120	**100**	**80**	**120**	**100**	**80**
Before harvest	In forest soil *	80.92					
	In living biomass (above and belowground)	78.90	74.28	67.36	75.78	49.92	44.03
	In dead biomass (standing and lying) **	4.43					
	Total carbon value	164.25	159.63	152.71	161.13	135.27	129.38
	Total monetary value (€)	14,565	14,155	13,542	14,288	11,995	11,473
After harvest	In forest soil *	80.92					
	In living biomass (above and belowground)	77.01	72.09	64.87	74.02	48.22	42.18
	In dead biomass (standing and lying) **	4.43					
	Total carbon value	162.36	157.44	150.22	159.37	133.57	127.53
	Total monetary value (€)	14,398	13,962	13,321	14,133	11,845	11,310
Total differences in carbon		1.89	2.19	2.49	1.76	1.70	1.85

*value refers to forest soil no matter to aboveground biomass
**averaged value based on IPCC methodology

Table 2. Annual harvest characteristics per average forest hectare

Annual harvest presented in timber and carbon quantity		**Site index**					
		I			**II**		
		Rotation period (years)					
		120	**100**	**80**	**120**	**100**	**80**
Annual harvest	m^3 ha^{-1} $year^{-1}$	4.49	5.20	5.93	2.67	4.03	4.40
	t. d. m. ha^{-1} *	2.56	2.96	3.38	1.52	2.30	2.51
	t. C ha^{-1}**	1.28	1.48	1.69	0.76	1.15	1.25
Round wood suitable for long-lasting products	% of annual harvest	53.88	51.15	43.14	42.12	31.21	22.11
	m^3 ha^{-1} $year^{-1}$	2.42	2.66	2.56	1.12	1.26	0.97
	t. C ha^{-1}**	1.38	1.52	1.46	0.64	0.72	0.55
	€	61.18	67.22	64.64	28.42	31.81	24.59

*tonnes of dry matter per hectare
**tonnes of carbon per hectare

By observing the annual harvest results (Table 2) several attributes can be noticed. Annual harvests are greater if shorter rotations are applied. This makes an important link to the mass of dry matter and carbon values which vary according to the same principle. At first glance, one can get the wrong impression the shortest investigated rotation period (80 years) is the best for storing carbon in the form of outcome storage (i.e. carbon storage in wood-based products). However, not all timber is suitable for producing long-lasting wood-based products. The last rows in Table 2 show the shares and monetary values of harvested timber which can be used for further processing. By taking that into account the rotation of 100 years is the one which can outcome the greatest amount of carbon stored in final products (just observing the harvest component).

4. DISCUSSION AND CONCLUSION

Due to the input data characteristics and analytic tools used, possible deviations from presented results can occur. Data on narrow-leaved ash forests are theoretical/ideal, not measured in the field, and are intended to be used just in pure forests (10% or less of growing stock refers to other species). Considering that, we can say that results are have limited applicability – just to lowland pure narrow-leaved ash forests. However, the presented results are the basis for further data processing toward understanding the total carbon storage capacity of all forest types in which narrow-leaved ash is growing.

Possible variations in results are also expected by the day-to-day fluctuations in the monetary value of carbon permits (Trading Economics, 2023). When it all started in 2005 the initial price was around 15 € per permit and now is 88.68 € (a maximum of 105.00 € was in February 2023). It should be emphasized that biomass, apropos carbon storage values, are known, and that total monetary value can be easily obtained by applying the right permit monetary value in the given moment.

Although the rotation period in which the maximal annual harvest can be performed is 80 years, and one in which is possible to produce the maximum amount of timber suitable for long-lasting wood products equals 100 years, the best option when it comes to carbon storage (in growing stock, soil, dead wood and in harvest) is 120 years.

Narrow-leaved ash forests represent just one of many forest types in which carbon pull should be measured, accounted and certificated. By that, the total amount of stored carbon would be known and possibly used as a traded commodity (nowadays carbon is traded as an emission permit which can be characterized as a tax (Beljan et al., 2023)). Since carbon is an essential segment of the EU's Green Deal (European Commission, 2019) for regulation of carbon emissions and the list of economic entities, like aircraft operators and plants, is constantly expanding, an increase in the price of carbon, apropos carbon emission permits, is to be expected.

REFERENCES

Beljan, K.; Dolinar, D.; Pulitika, Đ.; Jurinić, D. (2023): *The importance of forests for carbon trading (in Croatian)*. Economic lab, pp. 10.

Čavlović, J.; Teslak, K. (2022): *Narrow-leaved ash - current state and perspectives of development and management*. In: Narrow-Leaved Ash in Croatia. Academy of Forestry Sciences, Zagreb, 507–532.

Meštrović, Š.; Fabijanić, G. (1995): *Handbook for forest management planning* (in Croatian). Ministry of Agriculture and Forestry, Croatia, Zagreb. pp. 416.

Lal, R.; Lorenz, K.; Huttl, R.F.; Schneider, B.U.; von Braun, J. (2013): *Ecosystem services and Carbon Sequestration in the Biosphere*. Springer, Dordrecht-Heidelberg-New York-London. pp. 464.

Seletković, I.; Potočić, N.; Ugarković, D.; Ognjenović, M. (2022): *Vitality and mortality of narrow-leaved ash in Croatia*. In: Narrow-Leaved Ash in Croatia. Academy of Forestry Sciences, Zagreb (Croatia), 315–336.

Ugarković, D.; Tikvić, I.; Seletković, Z.; (2022): *Climatic characteristics of the narrow-leaved ash distribution range in lowland Croatia*. In: Narrow-Leaved Ash in Croatia. Academy of Forestry Sciences, Zagreb, 145–174.

Ussiri, D.A.N.; Lal, R. (2017): *Carbon Sequestration for Climate Change Mitigation and Adaptation*. Springer, Cham, Switzerland. pp. 549.

World Bank, (2022): *Governance of Emissions Trading Systems, Governance of Emissions Trading Systems*. WB, Washington, DC. pp. 72.

World Bank, (2021): *Emissions Trading in Practice, Emissions Trading in Practice, Handbook on Design and Implementation*. pp. 252.

***: Croatian Forests Ltd. (2000): *Assortment Tables for Narrow-leaved ash (unpublished)*. Zagreb (Croatia).

***: European Commission (2019): *The European Green Deal*. URL. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN

***: IPCC (2006): *Agriculture, Forestry and Other Land Use (volume 4)*. URL: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

***: Trading Economics (2023): *Trading Economics.* URL: https://tradingeconomics.com/commodity/carbon

***: United Nations (1997): *Kyoto Protocol - United Nations Framework Convention on Climate Change*. URL :https://unfccc.int/resource/docs/convkp/kpeng.pdf

Authors address:

Beljan, K[1]; Rupić, A[2]; Pejić, P[3]; Vedriš, M[1]; Teslak, K[1]; Posavec, S[1]

[1] Department of Forest Inventory and Management, Faculty of Forestry and Wood Technology, University of Zagreb, Zagreb, Croatia

[2] home: Rakovo selo 125, 22000 Šibenik, Croatia

[3] home: Zagrebačka 33, Mali Lošinj, Croatia

[**]Corresponding author: kbeljan@sumfak.unizg.hr

NEW POSSIBILITIES FOR THE WOOD QUALITATIVE ASSESSMENT IN THE CIRCULAR ECONOMY

Gejdoš, M., Michajlová, K.

Abstract: Wood as a renewable raw material plays an important role in the challenges of the circular economy. Experience from operational practice shows that the initial qualitative sorting of wood in forest stands or immediately after felling does not take place optimally. The aim of the work is the practical verification of acoustic tomography for the evaluation of the quality of standing trees based on image analysis in the software and their subsequent classification into quality classes. A total of 130 standing trees were measured, where oak was dominant. A better overview of the qualitative distribution of assortments in the forest stand provides an informational basis for optimizing the management of the process of harvesting and assessment of raw-wood materials. The results proved the suitability of this method for optimization procedures within the current possibilities of managing the process of forest harvesting and the use of raw-wood material.
Keywords: wood assessment, quality of wood, circular economy, qualitative features of wood, sound tomography

1. INTRODUCTION

The current principles of the market economy and the global energy crisis, caused mainly by the geopolitical situation, have significantly increased the demand for both raw wood and timber products. With this, the importance of the precise structuring and management of the sale of cultivated wood, as well as the observance of the principles of the circular economy for the perfect utilization of wood, wood waste, and its recyclates, is growing. (Barcic et al. 2019; Aggestam, Giurca, 2022).

The precise assessment of the quality of produced wood during the growth of the forest stand is primarily based on a system of quantitative (height, thickness, volume) and qualitative characteristics (visible knots, fungal diseases, insect damage, mechanical damage, etc.). Currently, for the assessment of the quality of raw-wood material, we have established technical conditions in most cases, which are combined with national standards or other technical specifications. However, most of these technical standards are designed for harvested wood (Gejdoš, Suchomel, 2010).

We can qualitatively evaluate standing trees in forest stands only with the help of a visual assessment by qualified forestry staff or with the help of tree and stand assortment tables. However, their disadvantage is also the high degree of subjectivity of the assessor who, according to them, evaluates the given trees. It is also possible to evaluate trees only on the basis of qualitative characteristics that are visually accessible, while the qualitative characteristics inside the trunk are often decisive and can only be identified after it has been felled. For more sophisticated ways of evaluating the qualitative features that arose during the growth of trees, there are a number of methods that are based on destructive, semi-destructive and non-destructive ways of evaluating the trunks of standing trees (Ondrejka et al. 2021).

The aim of the work was to verify the non-destructive method of qualitative assessment of standing trees using an acoustic tomograph, to verify its accuracy and potential influence on the classification of ground parts of trunks into individual quality classes. At the same time, the goal was to determine the potential of using the detected quality classes in the field of wood processing and reuse from the point of view of circular economy principles.

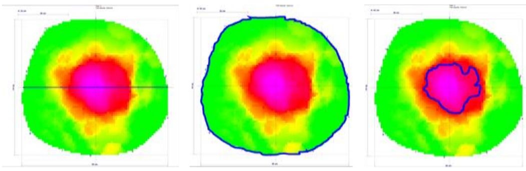
2. MATERIAL AND METHODOLOGY

An ARBOTOM acoustic tomograph with integrated software was used for the qualitative assessment of standing trees (Figure 1). The tomograph assesses the structure of the wood inside the tree based on an excited acoustic wave by tapping individual sensors that are distributed around the trunk. It then renders the image of the cross-section in its own software environment. The ImageJ software was used to evaluate and assess the proportion of negative qualitative features that are assessed based on the surface area. In the software, based on one reference dimension, which was the diameter of the tree trunk (Figure 2a), the cross-sectional area was determined, which was drawn by the tomograph software (Figure 2b). Subsequently, the area of potential damage was determined in the software based on the analysis of the tomograph (Figure 2c).

Based on the surface area and the detected potential occurrence of qualitative features as well as quantitative features, the individual analyzed ground parts of the trees was classified into qualitative classes under the standards STN 48 0055 and STN 48 0056 from 2007.

A total of 130 trees were analyzed, of which 63% were oak (82 pcs), and 32% linden (42 pcs). The remaining share was made up of pine (4%) and fir (1%). The wood composition of the selected sample was not chosen purposefully but was adapted to the field conditions of the measurement.

Figure 1. Acoustic tomograph ARBOTOM



a) b) c)

Figure 2. Assessment of the trunk quality from image developed by tomograph in software ImageJ (a – setting scale according to diameter; b – setting the area of cross-cut; c – setting the area of damaged wood)

3. RESULTS

The obtained results provide an overview of the qualitative structure in the ground part of the analyzed trunks, and at the same time, based on this structure and the achieved quantitative parameters, they determine the potential for classification into quality classes. Qualitative classes subsequently determine the possibilities of using these assortments for wood products and their further secondary use after recycling based on the principles of the circular economy.

3.1. Assessment of tree damage

The tomograph software detected four colored zones based on the speed of the acoustic signal. From the point of view of natural physiological development, the wood near the stem has a different structure and density than the wood at the edge of the trunk. Therefore, we can identify color changes near the stem in almost every strain. However, color changes in the red and purple spectrum of the image, which identify a slower propagation speed of the acoustic signal, are crucial for the identification of potential damage. It can be assumed that the wood of the trees in these software color spectra is damaged in some way, in the case of purple, almost certainly. Therefore, the area shares of these color spectra in individual strains were calculated in the ImageJ software, and a histogram of the extent of damage is shown in Figure 3.

From the frequency histogram, it is clear that almost half of the trees have obvious damage in the range of 0 to 11% of the cross-section area. In the red spectrum, from which it is not possible to clearly classify the damage, the largest number of trees was in the range of 20-40% damage. Extensive damage in the purple spectrum above the level of 85% of the cross-sectional area was identified in only one case. In the red spectrum of damage, it was in ten cases.

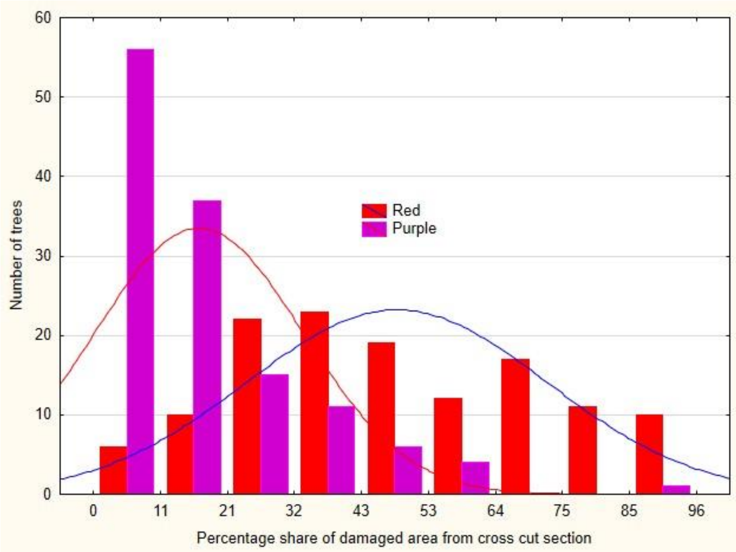


Figure 3. Percentage shares of damaged areas identified in trees by tomograph software and software ImageJ

Based on these shares, it is possible to analyze the potential classification into quality classes. For the avoidance of doubt, we considered real damage only with surfaces that were in the purple spectrum of the propagation of the acoustic signal in the cross-section. It should also be noted that the purple spectrum always represented a certain proportion of the area of the red spectrum, so if the damage zone were not purple, then the red spectrum would be present in this area. Thus, the identified purple spectrum in an individual tree always represented a certain proportion of the red spectrum on a circular cross-section.

3.2. Qualitative classification of ground parts of tree trunks and the potential of use in the circular economy

STN standards 48 0055 and 48 0056 from 2007 were used for qualitative classification. Since the qualitative feature of a false core is not considered on the analyzed trees, all zones with a purple color were assessed as rot in the given range of the cross-section. We considered the theoretical length of the assortments to be 4 meters. The first qualitative sorting was done based on visual assessment based on visible qualitative and quantitative features (middle thickness of the section, top diameter). The second qualitative sorting was performed based on the identified qualitative feature of rotting or wood damage inside the trunk by means of an acoustic tomograph. The results of these classifications and the assortment structure are shown in Figure 4.

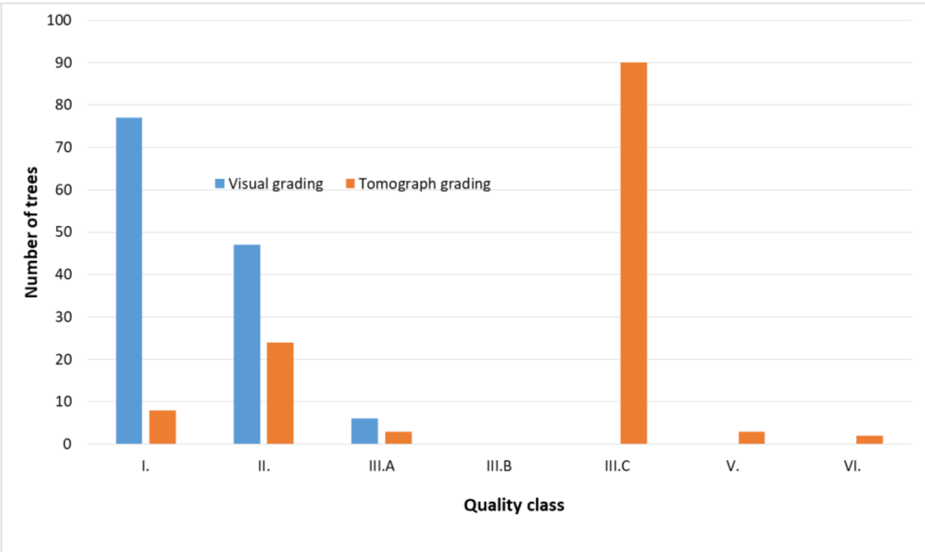


Figure 4. Number of trees in quality classes according to Slovakian standards based on visual assessment and assessment with an acoustic tomograph

The evaluation shows that in the qualitative classification of standing trees, only on the basis of their visible features and quantitative features, the classification into quality classes is considerably overestimated. More than 95% of all trunks are classified in the first two quality classes. This qualitative evaluation is imprecise mainly because of qualitative features that are not visible before the tree is felled and only the ground parts of the trunks of the growing trees are evaluated.

When detecting potential damage by rot using a tomograph, there is an obvious qualitative shift, where there are relatively strict restrictions on the occurrence of rot in oak wood. The occurrence of rot in the core part of oak is permitted to a certain extent from quality class III.C. When applying this classification, almost 70% of all trunks were classified in this class. Due to the large extent of damage, conifers were only classified in the classes of fuel wood and pulpwood. However, the reliability and accuracy of the classification are distorted by their low number in the evaluated forest stand.

From the point of view of reuse and recycling of wood products that can be made from the given assortments, the assortments classified in quality classes I. and II., or III.A, have the highest potential for reuse. To a certain extent, it is possible to consider recirculated use even for assortments from quality class III.C. However, it depends on the specific purpose of their processing. The potential of logs that can be circularly used in the reprocessing of wood from the products of its primary processing is shown in Table 1.

Table 1. Number and quality classes of assortments that are potentially reusable

Assortment	Number of trunks	
	First grading	Second grading (based on Acoustic tomograph
I.	77	8
II.	47	24
III.A	6	3

While during the visual assessment, it is possible to assume reuse for all evaluated trunks from the point of view of their qualitative classification, in the case of a more precise qualitative assessment based on the results provided by the acoustic tomograph, this can be assumed for only 27% of the evaluated trunks. It can therefore be concluded that the assessment of standing trees fundamentally refines the qualitative assessment of standing trees and the estimation of the quantitative and qualitative potential for reuse within the principles of the circular economy.

4. CONCLSUSION

The qualitative evaluation of standing trees in forest stands is still based on a system that is largely based on the subjective view of the evaluator. Non-destructive methods of assessing the qualitative state with a possible combination of laser ground scanning, with precisely determined algorithms of qualitative assessment, are a great promise for the objectification of this process in the future. In conjunction with the fact that the acoustic tomograph gives a relatively accurate picture of the internal structure of wood (± 5% compared to reality), it is possible to consider a more complex use of this technology in the qualitative assessment and selection of high-quality individuals in forest stands (Gejdoš et al. 2023). With a more accurate qualitative assessment already in standing stands, it is possible to more accurately plan the management of sales and possible wood processing. In perspective, it is also possible to calculate the volume of wood that will be available for reuse through recycling processes under the principles of the circular economy after the end of the life of the wood products. However, this process will require not only the improvement of computerization and the deployment of technologies in forestry operations but also the sharing of information and the planning of a common strategy within the forestry-timber complex with an orientation to bioeconomy and sustainable management of forest stands. Legislative changes, increasing the share of protected areas, and access to their management can also play a significant role in this process.

Acknowledgements: We wish to thank the Slovak Research and Development Agency (grant number APVV-19-0612 Modelling the detrimental natural hazards occurrence risk impact on the economic complex forestry - wood processing under conditions of the ongoing climate change); Scientific grant agency from Ministry of Education, Science, Research and Sport of the Slovak republic (grant number VEGA 1/0093/23 Research on the potential of the circular economy in the Slovak business environment in the production of innovative products based on recycled materials wood - rubber – plastic); and Cultural and Educational grant agency from Ministry of Education, Science, Research and Sport of the Slovak republic (grant number KEGA 004TU Z-4/2023 Innovative methods for assessing the quality potential of forest stands).

REFERENCES

1. Aggestam, F.; Giurca, A. (2022): *Implementing Circular-Bioeconomy Principles across Two Value Chains of the Wood-Based Sector: A Conceptual Approach*. Land 11(11): 2037.
2. Barcic, A.P.; Kuzman, M.K.; Haviarova, E.; Oblak, L. (2019): *Circular economy & sharing collaborative economy principles: A case study conducted in wood-based sector.* In: Digitalisation and Circular economy: Forestry and Forestry based Industry Implications. Bulgaria. September, 2019. 23-28.
3. Gejdoš, M.; Michajlová, K.; Gretsch, D. (2023). *The use of the acoustic tomograph and digital image analysis in the qualitative assessment of harvested timber – case study*. Central European Forestry Journal 69: 6 p.
4. Gejdoš, M.; Suchomel, J. (2010): *The Influence of Selected Factors on the occurrence of false heartwood in beech (Fagus sylvatica)*. Acta Facultatis Xylologiae 52: 5-13.
5. Ondrejka, V.; Gergeľ, T.; Bucha, T.; Pástor, M. (2021): I*nnovative methods of non-destructive evaluation of log quality*. Central European Forestry Journal 67: 3-13.
6. STN 48 0055 (2007): Qualitative classification of softwood round timber.
7. STN 48 0056 (2007): Qualitative classification of hardwood round timber.

Authors address:
Miloš Gejdoš, M.G.[1]; Katarína Michajlová, K.M.[1]
[1] Department of Forest Harvesting, Logistics and Ameliorations, Forestry Faculty, Technical University in Zvolen, Zvolen, Slovakia
*Corresponding author: gejdos@tuzvo.sk

THE WOOD PROCESSING INDUSTRY IN SLOVAKIA IN THE CONTEXT OF THE IMPLEMENTATION OF QUALITY MANAGEMENT SYSTEMS

Gejdoš, P.

Abstract: The article deals with the wood processing industry in Slovakia in the context of the implementation of methods, tools and principles of quality management systems. These systems enable organizations to achieve better economic results through an effective quality improvement process associated with the reduction of non-productive costs. The article presents the results of the research carried out in the period 2020-2022, the aim of which was to examine the impact of the implementation of quality management systems on the performance of enterprises in the woodworking sector.
Keywords: quality, quality management system, wood processing industry

1. INTRODUCTION

In order to maintain competitiveness on the domestic and foreign markets, it is essential that companies prefer approaches based on quality management. Quality includes not only product features, but also production processes, management and company image. By ensuring high quality in all these aspects, businesses can meet customer needs and achieve success. To ensure continuous growth in the quality of products and production processes, it is essential that enterprises use quality management systems and implement quality management methods and tools. These methodologies must be easily accessible and easy to implement. Therefore, the selection of appropriate quality management procedures is essential to solve problems associated with low product quality. Modern organizations will focus on the full use of principles, tools, techniques, methods that support the continuous development of society and continuous improvement. The aim of this paper is to analyse the current situation of implementation of quality management systems (QMS) in the conditions of the wood processing industry in Slovakia.

2. MATERIAL AND METHODS

Many organizations have searched and are still searching for the most suitable ways to transfer the principles of quality management into everyday practice. On a global scale, certain concepts of quality management have gradually crystallized, which are strategic for building and developing modern quality management systems. For several years now, we have been able to identify 3 basic concepts, which differ from each other in their complexity, resource requirements, including people's knowledge (Nenadal *et al.,* 2018). The ISO concept is the least demanding of them, but the most widespread in the world.According to (Sarb *et al.,* 2019) and (Knop, 2021), the implementation of the quality management system according to ISO 9001 is a strategic decision for an organization that can help to improve its overall performance and provide a sound basic for sustainable development. According to (Elwardi *et al.,* 2021) and (Ribeiro *et al.,* 2019), the ISO 9001 standard specifies the requirements for a quality management system in organizations that want and need to demonstrate their ability to consistently provide products in accordance with relevant regulations and customer requirements, and that strive to increase customer satisfaction.

The second concept is industry standards. A typical feature of these standards is that they are not generic. They are created to reflect the character and peculiarities of individual industries. Usually, these standards apply the basic requirements and structure of the ISO 9001 standard, but additionally define the specific requirements of individual industries.

The TQM concept is the most complex of all concepts. It is based on the fact that quality is everyone's business and must concern everything that happens in the organization. Total Quality Management (TQM) has been a universally applied management strategy to improve organizational performance and thereby to achieve competitiveness (Babu and Thomas, 2021). TQM cannot be considered a rigid set of requirements and rules. TQM is an open system that integrates the best of global practice and adapts it to the organization's own environment (Nenadal *et al.,* 2018).

Results of many studies (Nguyen *et al*. 2018; Alharbi *et al*. 2017; Rebelo *et al*. 2016;) indicate that implementation quality management system contribute positively to achieving sustainable development and higher performance.

3. RESULTS AND DISCUSION

To determine the minimum sample size, a formula for the finite population according to Yamane Taro (Lind, 2020) was applied. With a target population size of 2,504 units and the selected error e=0.05 was the minimum sample size derived as:

$$n = \frac{2\,504}{1 + 2\,504 \cdot 0.05^{2}} = 345 \tag{1}$$

The data were obtained through an on - line research questionnaire. The questionnaire survey was conducted during the years 2020-2022 through the platform docs.google.form. The questionnaire that have been researched, we can say that a survey sample of enterprises is relevant, has sufficient denunciation, which is also verified by selected mathematical and statistical methods.

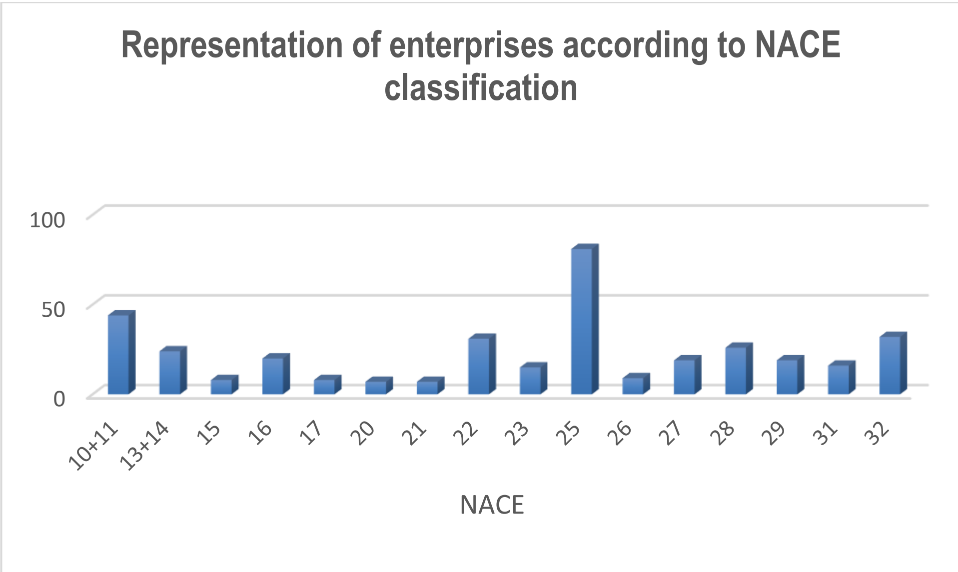


Figure 1. Representation of enterprises according to NACE classification

To illustrate the impact of the tools of the quality management system on the company's performance, we established the following hypothesis H1.

H1 Companies in the wood processing industry that use a wider range of quality management principles, techniques and approaches (QMPTA) also achieve a higher level of profit.

To test the fourth hypothesis, we divided the sample two-dimensionally in a contingency table (Table 1) according two variables - use of QMPTA and the profit achieved.

Table 1. Two-dimensional distribution of sample in contingency table - combinations of QMPTA using and profit categories.

Using of QMPTA	Profit in EUR thousands				Total by row
	< 0	0-100	100-500	> 500	
wider scale	6.25%	19.44%	16.67%	11.81%	54.17%
smaller scale	6.94%	29.17%	8.33%	1.39%	45.83%
Total by column	13.19%	48.61%	25.00%	13.19%	100.00%

The results of the contingency analysis are shown in Table 2. The null hypothesis of independence is rejected in favor of the alternative hypothesis (p=0.000) – the using of QMPTA and achieved profit of manufacturing enterprises are significantly dependent variables. Based on the value of the contingency coefficient 0.33, the strength of dependence is evaluated as moderate.

Table 2. Results of Pearson chi-square test of contingency – the use of QMPTA versus achieved profit of manufacturing enterprises.

Using of QMPTA vs. Profit	Chi-square test	Degree of freedom	p-level	Contingency coefficient
	17.82	3	0.000	0.33

From the values of the residual frequencies in Table 3, it can be concluded that wood processing manufacturing enterprises that use a wider scale of quality management principles, techniques and approaches also achieve a higher level of profit – more than 100 thousand euros.

Table 3. Contingency table of residual frequencies – the use of QMPTA versus achieved profit of manufacturing enterprises.

Using of QMPTA	Profit in EUR thousands			
	< 0	0-100	100-500	> 500
wider scale	-1.29	-9.92	**4.50**	**6.71**
smaller scale	1.29	**9.92**	-4.50	-6.71

4. CONCLUSION

The article deals with the implementation of the quality management system in enterprises of the wood processing industry in Slovakia. The main purpose of the article was to test the hypothesis, which assumed that enterprises of the wood processing industry that use a wider range of QMPTA will achieve higher profitability. Based on the research results, we can state that this hypothesis has been confirmed. The results confirm that companies that use QMPTA achieve higher profitability at the level of more than 100 thousand euros. Thus, the theoretical assumptions about the positive influence of the quality management system on the performance of companies and their economic results were confirmed. Nevertheless, we can state that there are still businesses where improvement is possible. These are mainly micro and small enterprises, where quality management systems are very little implemented. There are several reasons why this is so, especially the lack of qualified workforce, lack of confidence in the positive effects of quality management systems on the economy of companies, existential problems of companies and others. These reasons are common to several branches of the national economy of Slovakia, including the wood processing industry.

Acknowledgements: This contribution is a part of the work on the project VEGA no. 1/0093/23 "Research of the potential of the circular economy in the Slovak business environment in the production of innovative products based on recycled materials wood - rubber – plastic ".

REFERENCES

1. Alharbi, K., Yusoff, R. Y., and Al-Matari, E. M., 2017. "*The Moderating effect of organizational climate on the relationship between of total quality management (TQM) on organisational sustainability: The case of the hotel industry in Saudi Arabia*," *International Business Management* 11(2), 350-356. DOI: 10.3923/ibm.2017.350.356
2. Babu, F., Thomas, S., 2021. *Quality management practices as a driver of employee satisfaction: exploring the mediating role of organizational image. International Journal of Quality and Service Sciences,* 13(1), 157 – 174, https://doi.org/10.1108/IJQSS-10-2019-0124
3. Elwardi,B., Meddaoui, A., Mouchtachi, A., En-nhaili, A., 2021. *Towards a new maturity model of industrial performance improvement based on ISO 9001: version 2015 and VDA6.3: version 2016*. International Journal of Process Management and Benchmarking, 11(3), https://doi.org/10.1504/IJPMB.2021.115013
4. Knop, K., 2021. *The Use of Quality Tools to Reduce Surface Defects of Painted Steel Structures*. Manufacturing Technology, 21(6), 805–817, https://doi.org/10.21062/mft.2021.088
5. Lind, D. A., 2020. *Statistical Techniques in Business and Economics*. McGraw-Hill. 880.
6. Nenadál, J., Plura, J., Noskievičová, D., Vykydal, D., Hofbruckerová, Z., Tošenovský, F., Klaput, P., 2018. *Management kvality pro 21. století*. Management Press, 368, ISBN 978-89-7261-561-2.
7. Nguyen, M. H, Phan, A. Ch., and Matsui, Y., 2018. "*Contribution of quality management practices to sustainability performance of Vietnamese firms*," *Sustainability 10(2*), 375. DOI: 10.3390/su10020375
8. Rebelo, M. F., Santos, G., and Silva, R., 2016. "*Integration of management systems: towards a sustained success and development of organizations*," Journal of Cleaner Production 127, 96-111. DOI: 10.1016/j.clepro.2016.04.011Mirski, R.; Majka, J.; Dziurka, D. (2012): *The Effect of Residual Swelling after Drying on Internal Bond in OSB*. Drvna Industrija 63 (4): pp. 241-247
9. Ribeiro, L.H.M.D., Beijo, L.A., Salgado, E.G., & Nogueira, D.A., 2019. *Modelling of ISO 9001 certifications for the American countries: a Bayesian approach*. Total Quality Management & Business excelence, 32(11-12), p.1290-1315, https://doi.org/10.1080/14783363.2019.1696672,
10. Sarb, A., Glevitzky, I., Itul, L., Popa, M., 2019. *The improvement of quality management system in a porcelain factory*. *MATEC Web of Conferences* Vol. 290, Article number 05003, https://doi.org/10.1051/matecconf/201929005003

Authors address:

Gejdoš, P[1];
[1] Department of Economics, Management and Business, Faculty of Wood Science and Technology, Technical University in Zvolen, Zvolen, Slovakia
[*]Corresponding author: gejdosp@tuzvo.sk

Eco-Innovation Drivers in Wood Processing Industry in Slovakia

Rokonalová, A., Parobek, J.

Abstract: The implementation of innovations in companies is influenced by a number of factors that are crucial for understanding the innovative behaviour of companies. Different definitions of the concept of eco-innovation in the current literature underline the importance of recognizing different perspectives on the determinants that influence the development and implementation of eco-innovation. The discourse usually focuses on the driving forces (motivations) and barriers associated with the adoption of eco-innovations. This paper explores the drivers of eco-innovation in companies operating in the wood processing industry in Slovakia. Using a quantitative research approach, data was collected from a sample of companies in the industry to identify key factors that drive eco-innovation. The results examine differences in the importance of specific determinants between businesses that have adopted eco-innovations and those that have not. These findings contribute to the understanding of factors that influence eco-innovation in the wood processing industry and provide insights for policymakers and industry stakeholders on how to promote sustainable practices and innovation in the sector.
Keywords: eco-innovation, wood processing industry, determinants

1. INTRODUCTION

The term "ecological innovation" entered the public debate in the second half of the 1990s in the context of sustainable development after the Earth Summit in Rio in 1992 (Kemp et al., 2019). In general, ecological innovations represent those innovative activities whose goal or result is the reduction of the environmental burden related to the production of goods and services, and the strengthening of their ecological sustainability. Researchers are showing growing interest in ecological innovations, which are also referred to as green or environmental innovations, as they are considered to be a crucial element in attaining economic, social, and environmental goals.

Kemp and Pearson (2007) define ecological innovation as "the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives". Different authors and organizations have distinct viewpoints regarding eco-innovation. Nonetheless, all definitions of eco-innovation encompass two fundamental aims: decreasing adverse environmental effects and optimizing resource utilization. Based on the definitions, it is clear that eco-innovation covers a wide range of activities, including organizational changes and green technologies.

The implementation of innovations in businesses is influenced by various factors. Understanding these determinants is a significant prerequisite for comprehending the innovative behavior of companies. Similarly to how different definitions of the term eco-innovation are encountered in current professional literature, perspectives on individual determinants also differ. However, typically, the development and implementation of eco-innovations are discussed in terms of driving forces (motivations) and barriers. In the literature, determinants are often divided into internal and external (Kemp et al., 2019). Horbach (2008) adds technological opportunities (science-push), but these can be considered a specific class of external factors. In addition to traditional supply or demand-side factors, customer expectations, sensitivities and pressures for environmental sustainability must be considered, as well as impulses from employees and managers and sustainability-related requirements from customers. In this context, academics focus on identifying driving forces and barriers to the introduction of ecological innovations, which may differ from the determinants of traditional innovations.

Factors such as environmental awareness, knowledge, financial resources, environmental culture, collectively known as internal drivers, are crucial for firms to adopt sustainable business practices. These drivers shape a firm's culture and decision-making processes, and are integral to its long-term viability and competitiveness (Chen et al., 2012). The literature identifies human resources as a key factor in the success of innovations in a company. Human resources are responsible for developing, implementing, and managing eco-innovation strategies, as well as training employees and fostering a culture of sustainability within the organization. They also assist in discovering and utilizing external resources, such as suppliers and partners, while ensuring continuous improvement to sustain the company's competitiveness (Bornay-Barrachina et al., 2012; Lee et al., 2010)

External factors that potentially affect all sectors include government regulations, pollution taxes, access to financial resources, subsidies for implementing environmentally friendly product or process alternatives, as well as institutional and societal pressures. Ecological innovations also rely on environmental awareness among consumers and firms, which can be interpreted as a demand-driven, environmentally-oriented effect (Kemp et al., 2019).

2. METHODOLOGY

This paper aims to conduct a comparative analysis of the driving forces of eco-innovation within the woodworking industry, with a particular focus on the role of external and internal factors in promoting sustainable practices and innovations among companies. In addition, this study seeks to examine the differences in the relative importance of specific determinants between woodworking businesses that have already adopted eco-innovations and those that have not. Through this comparative investigation, the study aims to identify the key factors that facilitate the adoption of eco-innovations within the woodworking industry. Ultimately, this research aims to provide insights into how policymakers and firms can enhance their eco-innovation efforts to promote sustainable business practices.

Primary data were acquired through a questionnaire survey administered to businesses operating in the woodworking industry. The questionnaire-based research was executed electronically. The respondents were either business owners or senior employees (managers). They provided direct and personal knowledge on the topic. Consequently, the primary sources procured offer an up-to-date perspective on the issues addressed, derived directly from Slovak companies.

The factors influencing the adoption and implementation of eco-innovation were classified according to the literature into two categories: internal and external. Internal factors were further categorized into three main domains: the quality of human resources, the environmental culture of the organization, and financial resources. External factors are represented by legislation and government support, market factors and cooperation. Participants evaluated these factors in terms of their perceived impact on driving eco-innovation using a Likert scale, where 1 indicated total agreement and 5 indicated total disagreement.

To achieve the goal, it was necessary to perform an analysis of the reliability (consistency) of the research tool. Cronbach's alpha coefficient is most often used to determine the internal consistency of the questionnaire and assessment scales. In professional practice, a value above 0.7 is considered a level of internal consistency, which is acceptable in the context of most research studies (Stankovičová, 2021). Given that the responses were collected through the use of a Likert scale, descriptive statistics were employed, including measures of central tendency (such as arithmetic means $\bar{x}$) and measures of variability (such as standard deviations s). The standard deviation (s) was used as a statistical indicator to quantify the degree of variability within the data set, reflecting the extent to which values deviate from their average value. The analyzed data were subsequently displayed using graphical descriptive methods.

3. RESULTS

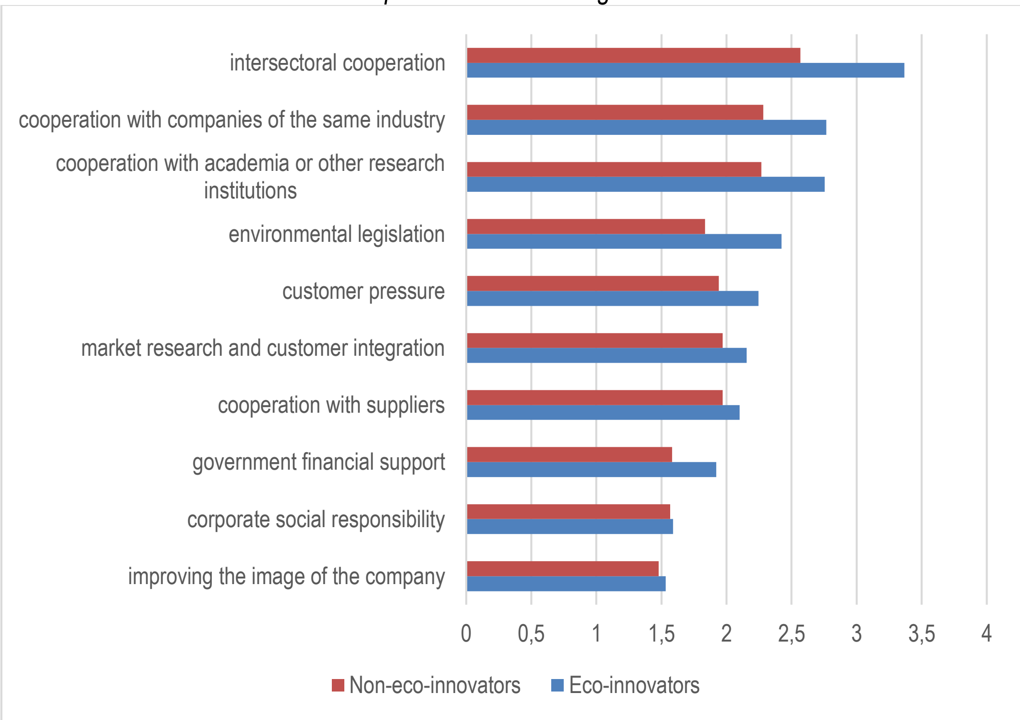
As part of the questionnaire survey, a filter question was applied, which made it possible to divide the respondents into two categories - the group that has already implemented an ecological innovation and the group that has not yet implemented such an innovation. Subsequently, the responses from the two groups were collected and their average values were compared for each factor within the questionnaire. The result was a comparison, specifically what are the differences in the opinions and priorities of companies in the field of ecological innovations.

Graph 1 and 2 show the differences in the average values of the responses to the determinants related to ecological innovations. These data show that there are minimal differences in the responses of those businesses that have already implemented eco-innovations and those that have not. From the graph 1, it follows that the most significant differences in the average responses are recorded in the case of determinants related to cross-sectoral cooperation ($\bar{x}$=3.37 for innovating companies and $\bar{x}$=2.57 for companies that did not innovate) and quick return on investment ($\bar{x}$= 2.92 for innovating companies and $\bar{x}$=2.37 for companies that did not innovate). Enterprises that have already implemented eco-innovations show a lower priority and importance of these factors compared to enterprises that have not yet implemented eco-innovations. On the contrary, the smallest differences in the average answers were recorded in the case of improving the image of the company ($\bar{x}$=1.53 for innovative companies and

$\bar{x}$=1.48 for companies that did not innovate) and corporate social responsibility ($\bar{x}$=1.59 for innovative companies and $\bar{x}$=1.57 for enterprises that did not innovate). Both groups rate these factors as significant drivers.

Within the group of enterprises that implemented eco-innovations, the factor of employee communication and interaction was evaluated as the only one with a higher degree of agreement ($\bar{x}$=2.18) compared to enterprises that did not implement eco-innovations ($\bar{x}$=2.28).

Graph 1. External driving forces



1-total agreement; 5-total disagreement

Graph 2. Internal driving forces

1-total agreement; 5-total disagreement

4. DISCUSSION AND COCLUSION

Most of the research studies that deal with the innovative activities reflect the fact that the forestry sector is facing extensive structural changes and sees the main driving forces of innovation in changing models of global competition and in changing structures of social demand with developing producers and markets. (Weiss et al., 2017).Knowing the internal and external factors that influence the implementation of ecological innovations is key to their successful introduction and support of the competitiveness of enterprises (Loučanová and Olšiaková, 2021).

In the study of the differences in the perception of the driving factors of eco-innovation, no significant differences were found between companies that have already implemented eco-innovation and those that have not. This result suggests that the perception of the factors that support eco-innovation may be relatively similar across companies, regardless of their experience with eco-innovation projects. External drivers confirm the important role of eco-innovation for improving the company image, as many consumers consider environmental sustainability a priority. The implementation of ecological innovations in a company can demonstrate its interest in environmental protection and efforts to minimize negative environmental impact, which can lead to a positive perception of the company by customers and provide it with a competitive advantage in the market (Zhou et al., 2021). According to empirical evidence, businesses tend to attribute greater importance to their corporate image as a driving force of eco-innovation than to external factors such as government legislation. Similarly, Clark and Charter (2007) found that drivers such as customer demands, reputation, and cost savings in terms of materials and energy are important drivers for the adoption of sustainability innovations. Yalabik and Fairchild (2011) found that competitive market pressure drives eco-innovation more than environmental legislation.

Financial resources, either own or in the form of subsidies, proved to be an important driver. In the countries of Central and Eastern Europe, however, a higher dependence on external factors in the field of research and development is observable, while technology transfer from Western countries to the East is taking place. In these countries, the state in particular plays a significant role in eco-innovations, which is why these countries are more dependent on government financial support (Horbach, 2014). On the other hand, research by Loučanová and Olšiaková (2021) identified a lack of financial resources, high bureaucracy, lack of relevant information for the creation of innovations as significant barriers to the development of ecological innovations in Slovakia. The paper emphasizes the need for increased financial support from government and public/private institutions, as well as raising awareness among firms about eco-innovation and green business practices. It also calls for less bureaucracy and better access to information, and highlights the necessity of implementing environmental business strategies and an effective system of environmental education and training.

Acknowledgements: The author would like to thank for the support of the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic Grant No. 1/0494/22 Comparative Advantages of the Wood Based Sector under the Growing Influence of the Green Economy Principles.

REFERENCES

1. Bornay-Barrachina, M., De la Rosa-Navarro, D., López-Cabrales, A., & Valle-Cabrera, R. (2012). Employment relationships and firm innovation: the double role of human capital. *British Journal of Management*, *23*(2), 223-240.
2. Chen, Y. S., & Chang, C. H. (2012). Enhance green purchase intentions: The roles of green perceived value, green perceived risk, and green trust. Management Decision, 50(3), 502-520.
3. Clark, T., & Charter, M. (2007). Sustainable innovation: Key conclusions from sustainable innovation conferences 2003–2006 organised by the centre for sustainable design.
4. Horbach, J. (2008). Determinants of environmental innovation—New evidence from German panel data sources. *Research policy*, *37*(1), 163-173.
5. Horbach, J. (2014). Determinants of Eco-innovation from a European-wide Perspective–an Analysis based on the Community Innovation Survey (CIS). *SEEDS Working Paper*, *7*, 2014.
6. Kemp, R. a kol. (2019). Measuring eco-innovation for a Green economy. *Wirtsch Blätter, Special Issue on Nachhaltigkeit/Sustainability*, *66*(4), 391-404.
7. Kemp, R., & Pearson, P. (2008). Final report MEI project about measuring eco-innovation: deliverable 15 of MEI project (D15). *Project Report.*

8. Lee, S. Y., Florida, R., & Gates, G. (2010). Innovation, human capital, and creativity. *International Review of Public Administration*, *14*(3), 13-24.
9. Loučanová, E., & Olšiaková, M. (2021). Proposal of a model for the eco-innovation integration into the innovation process of companies in Slovakia to increase their performance. *Acta Logistica*, *8*(3), 199-207.
10. Stankovičová, I. (2021). Analýza výskytu neetických praktík v slovenskom podnikateľskom prostredí pomocou faktorovej analýzy Analysis of the occurrence of unethical practices in the Slovak business environment using factor analysis. In *FORUM STATISTICUM* (No. 1, pp. 51-69).
11. Weiss, G., Pelli, P., Orazio, C., Tykka, S., Zivojinovic, I., & Ludvig, A. (2017). Forest industry clusters as innovation systems: analysing innovation support frameworks in five European regions. *Austrian Journal of Forest Science*, *134*(2), 119-147.
12. Yalabik, B., & Fairchild, R. J. (2011). Customer, regulatory, and competitive pressure as drivers of environmental innovation. *International Journal of Production Economics*, *131*(2), 519-527.
13. Zhou, M., Chen, F., & Chen, Z. (2021). Can CEO education promote environmental innovation: Evidence from Chinese enterprises. *Journal of Cleaner Production*, *297*, 126725.

Authors address:
Rokonalová, A. [1], Parobek, J. [1]
[1] Department of Marketing, Trade and World Forestry, Faculty of Wood Sciences and Technology, Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovakia
[*]Corresponding author: rokonalova.alena@gmail.com

THE EUROPEAN MARKET OF WOODEN TOYS

Petrović, S.

Abstract: Wooden toys, which have a very long history, are nowadays the subject of increased demand and relevance since ecological products are gaining ever more importance and value in society. This is the reason why wooden toys were chosen as the subject of this research, while special attention was paid to wooden puzzles. The aim of this research was to determine the trade volume in these products on the EU market in the period 2000-2021, the countries that are the most important for the supply of wooden toys, as well as the countries that are the biggest importers of these products. In addition to the above, another aim of this research was to identify the regulations governing the marketing of toys on the EU market. Toys, including wooden ones, that are placed on the EU market must be produced in accordance with the requirement of the toy safety Directive 2009/48/EC and standard EN 71. They have to have the CE mark and accompanying CE documentation. In addition, toys must be produced in accordance with the requirements of the REACH regulation that restricts the use of heavy metals in the product, i.e. its packaging. Wooden toys are not subject to the European Union Timber Regulation (EUTR).
Keywords: wooden toys, trade, quality, EN standard, regulations.

1. INTRODUCTION

Wooden toys, such as rattles, dolls, horses and toys with moving parts, can be said to have a history of use which is as long as human civilization [15]. The above mentioned toys belong to the first group, out of a total of three groups of toys, whereby toys are classified in the first group based on their functional and structural properties [2]. The second group of toys includes the ones that have educational and psychological characteristics, and are often called didactic toys [2]. The term 'didactic toy' was first mentioned in 1693 in the book “Some Thoughts Concerning Education” written by the philosopher John Locke [1]. Further, the German pedagogue Friedrich Froebel (1782-1852) significantly contributed to the development of didactic toys. In 1837, he designed Froebel Gifts, which are wooden sets consisting of constructive elements that are assembled in a certain way [16, 24, 25]. Subsequently, the Italian educator and doctor Maria Montessori (1870-1952) introduced a variety of colourful wooden objects of different finishes and geometrical shapes into childrens' game [17]. Didactic toys also include wooden jigsaws and puzzles. Jigsaws are believed to have been used as far back as at the time of Archimedes (c. 287 BC – c. 212 BC), while the first commercial wooden puzzle was made by the cartographer John Spilsbury in 1767 [3, 23]. In order to help children learn geography, he glued a map of Europe to a wooden board, and then cut the board along the borders of the countries [22]. The third group of toys includes those that have social anthropological characteristics, known as social games [2]. The above clearly indicates the importance of wood during the development of toys over the centuries. Today, in the first quarter of the 21st century, when the concern for the preservation of the environment is the most pronounced, and the measures to reduce the harmful effects of climate change are the most extensive, wooden toys have once again become very popular. The species that are most often used for the production of wooden toys are maple, birch, beech, oak, linden and spruce [16, 18, 19, 20, 21]. However, fibreboards (MDF) are not recommended for the production of toys, since the glue containing formaldehyde used in the production of these boards is carcinogenic.

2. MATERIALS AND METHODS

The analysis of trade flows of wooden toys in the EU27 in the period 2000-2021 was carried out based on data taken from the Eurostat database. In this database, the data used are recorded in chapter 95 entitled toys, games and sports requisites, parts and accessories thereof. The period during which the analysis was performed can be divided into two parts, i.e. 2000-2006 as the first period and 2007-2021 as the second one. During the first period, records were kept in the Eurostat database for three types of wooden toys, namely: wooden construction sets with customs tariff HS:95033010, wooden toys representing animals or non-human creatures (HS:95034910) and wooden puzzles (HS:95036010). Trade in other types of wooden toys was recorded together with the same toys made from other materials. In 2007, new customs tariffs were introduced for toys that are stil in use. According to the new nomenclature, the customs tariff for wooden puzzle is HS:95030061. Wooden construction sets, and wooden toys representing animals or non-human creatures, are registered under new nomenclature together with the same products made from other materials.[1] The customs tariff for wooden construction sets and sets made from other materials is HS:95030039, and for wooden toys representing animals or non-human creatures made from other materials HS:95030049. Due to the mentioned limitations, the analysis of the EU market supply with toys in the period 2007-2021 was conducted with common data for wooden toys and toys made from other materials, excluding plastic. The mentioned limitations are the reason why a more detailed analysis of the supply of the EU market was carried out only for wooden puzzles.

3. RESULTS AND DISCUSSION

This chapter presents the results of the analysis of wooden toys supply to the EU market from non-EU countries in the period 2000-2021. The analysis included types of wooden toys whose international trade is recorded in the Eurostat database. The most important non-EU countries for supplying the EU market with wooden toys were analysed, as well as the largest importers of these products in the EU. Also, an analysis of the most important legal acts regulating the marketing of them on the EU market was carried out.

3.1. Supply of the EU-27 market with wooden toys from non-EU countries

In the 2000-2006 period, the EU27 increased the import value of all types of wooden toys (sets, puzzles and animals) from non-EU countries from €27 million (2000) to €56.3 million (2006) (Figure 1) [14]. In the structure of the import value in 2006, wooden construction sets accounted for 48.1 % as the largest share, and they were followed by wooden puzzles with 33.4 % and wooden toys representing animals or non-human creatures with 18.5 % [14]. In the 2007-2021 period, the analysis was performed on the basis of common data for toys representing animals or non-human creatures made from wood and other materials, and construction sets made from wood and other materials. In 2021, the import value of toys representing animals or non-human creatures from wood and other materials reached €606.5 million, the import value of construction sets from wood and other materials reached €93.6 million, and the import value of wooden puzzles attained €70.4 million [14].

Figure 1. The value of wooden toys import to the EU from non-EU countries in the period 2000-2021 [14]

3.1.1. The import of wooden puzzles to the EU from non-EU countries

The import value of wooden puzzles to the EU from non-EU countries increased from €12.6 million in 2000 to €70.4 million in 2021 (Figure 2) [14]. At the same time, the intra EU27 import value increased from €8.6 million in 2000 to €40.6 million in 2021, which implies that non-EU countries are more important suppliers of the analyzed product to the EU market than its members [14]. In contrast to wooden puzzles, in 2021 the import of puzzles made from other materials to the EU from non-EU countries reached the value of €109.4 million, while the import among the EU27 members amounted to €350.1 million [14]. China is the major non-EU country for supplying the EU market with wooden puzzles [14]. In 2021, the import value of wooden puzzles from China to the EU amounted to €62.9 million,

[1] Other materials do not include plastic, because plastic toys are recorded under a specific customs tariff.

which is 7.6 times higher than in 2000 [14]. The share of the import of wooden puzzles from China in the total import value of the EU from non-EU countries ranged from 65.5 % (2000) to 89.5 % (2019) [14]. During the analysed period, except in 2021, Great Britain was the second largest supplier of wooden puzzles to the EU market [14]. The import value from this country ranged from €363.466 in 2004 to €3.4 million in 2020 [14]. Although during most of the analysed years the import from Russia was minor, it increased drastically in the 2020-2021 period. In 2021, the import value exceeded €2.0 million [14]. The Netherlands, Germany, Spain, France and Belgium mostly import wooden puzzles from China [14]. In 2021, their imports accounted for 71.4 % of the total EU import from China [14]. In 2021, Ireland, the Netherlands, France, Germany and Sweden imported the most from Great Britain, and from Russia Estonia, the Czech Republic and Germany [14]. In the group of non-EU SEE countries, the major foreign partner of the EU is Bosnia and Herzegovina [14]. The first EU import from this country took place in 2007, and in 2021, it reached its maximum of €302.000 [14]. Germany is the most important partner for Bosnia and Herzegovina, and in certain years of the analysed period, it was the only one [14]. The first import from Serbia to the EU was recorded in 2011, and the highest value of €56.500 was recorded in 2013 [14]. In addition to that, Bulgaria mostly imports wooden puzzles from Serbia [14]. It was also observed that during the analysed period, the import from Montenegro in the value of €25.3 thousand was registered only in 2020 [14].

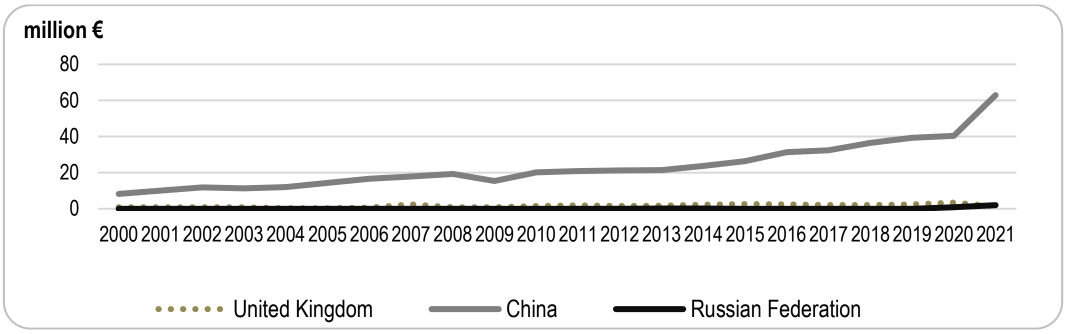


Figure 2. The largest suppliers of the EU market with wooden puzzles in the period 2000-2021 [14]

3.2. European toys regulations

The fundamental document for the marketing of toys, including the wooden ones, on the European market is Directive 2009/48/EC on the safety of toys. Article 2 of the Directive defines toys as “products designed or intended, whether or not exclusively, for use in play by children under 14 years of age” [4]. An analysis of the basic requirements prescribed by the Directive is given below. Toys marketed on the European market must have the CE mark in accordance with Regulation (EC) No 765/2008. Producers should indicate the type, batch, series or model number on the toys or their packaging. The Directive stipulates that Regulation (EC) No. 1907/2006 and Regulation (EC) No 1935/2004 apply to toys. The Regulation (EC) No. 1907/2006 (REACH) restricts the use of heavy metals such as lead, cadmium, mercury, iron and zinc in toys. However, Directive 2009/48/EC does not apply to puzzles that have more than 500 pieces, regardless of the material from which they are made. The annexes to Directive 2009/48/EC prescribe the content of the EC declaration of conformity and technical documentation, as well as the method of marking and warning if the toys are not intended for children under the age of 3. In 2023, the European Commission adopted Guidance document No. 11 on the application of Directive 2009/48/EC on the safety of toys - Toys intended for children under 36 months of age or of 36 months and over.[2] Standard ISO 8124-8: Safety of toys - Age determination guidelines was used to create the above Guidance document.[3] The criteria for 15 types of toys on the basis of which the classification is carried out are specified in the Guidance document [7]. The criteria for the classification of wooden toys are defined for seven types of toys [7].
The basic standard for toy quality on the European market is EN 71: Safety of toys, which consists of 14 parts. The standard complies with Directive 2009/48/EC, which means it does not apply to puzzles with more than 500 pieces. The most important parts of the standard for wooden toys are standards 1, 2, 3, 6, 7, 8, and 12 [13]. The specified

[2] https://www.tuvsud.com/en/e-ssentials-newsletter/consumer-products-and-retail-essentials/e-ssentials-2-2023/eu-european-commission-publishes-new-classification-guidance-for-toys-under-and-over-3-years-of-age
[3] https://www.tuvsud.com/en/e-ssentials-newsletter/consumer-products-and-retail-essentials/e-ssentials-2-2023/eu-european-commission-publishes-new-classification-guidance-for-toys-under-and-over-3-years-of-age

standard and two technical reports for toys safety CEN/TR 15071:2020 and CEN/TR 15371, were produced by the Technical Committee CEN/TC 52 "Safety of toys". Technical Report CEN/TR 15071:2020 provides a list of words in 27 European languages for the warning of children and parents when using toys, as well as the instructions for the use of certain parts of the EN71 standard [11]. In the Technical Report CEN/TR 15371, which consists of two parts, expert interpretations are given for certain clauses from the EN71 standard. In the first part of the Technical report, there is an interpretation of one clause from the EN71-1 standard that refers to glued wooden toys intended for up to 3-year-old children [12]. Wooden toys are not subject to the European Union Timber Regulation (EUTR) [5].

Toys, including wooden ones, are the subject of Nordic (SWAN), German (Blue Angel) and Austrian eco certifications, while the EU eco label award is under consideration [6, 8, 9, 10]. Toys that are eco certified must be produced in accordance with Directive 2009/48/EC and certain parts of the EN71 standard. The requirements for eco certification also apply to the packaging of toys and the materials used for their production [8, 9, 10].

4. CONCLUSION

Wooden puzzles are the only type of wooden toys, whose international trade flows for the 2000-2021 period could have been monitored in the Eurostat database. In 2021, the EU27 imported wooden puzzles worth €70.4 million from non-EU countries. China is the major supplier of the European market with this type of toys, and in the period 2020-2021, Russia also became a significant supplier. An analysis of the statistics conducted by Eurostat and European regulations for toys has shown certain inconsistencies. In the Eurostat database, wooden puzzles are recorded in the category of children`s toys, while according to Directive 2009/48/EC puzzles with more than 500 pieces are not considered toys. In the American market, it is believed that children aged from 10 to 12 are able to use puzzles with 2000 pieces, so the question arises whether it is necessary to revise the European regulations. This primarily refers to Directive 2009/48/EC as the fundamental document regulating the marketing of toys on the EU market, as well as all other documents dealing with this topic, such as the EN71 standard and the analysed eco certification which are harmonized with that Directive.

Acknowled gements: This paper represents part of an ongoing research project supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia – Agreement on financing the scientific research work in SRO 2023, registration number 451-03-47/2023-01/200169 dated 03.02.2023.

REFERENCES

1. Despinić M. (2021): Razvoj ekološkog dizajna i njegov uticaj na oblikovanje savremenih drvenih igračaka, Master rad, Univerzitet u Beogradu - Šumarski fakultet, Beograd
2. **Steenhold M. J.** (1999): Toys & Users, Billund Bogtrykkeri & Offset, Copenhagen Institute for Futures Studies, https://www.borneliv.dk/forskning-og-metoder/leget%C3%B8jsforskning/toys-and-users/toys-and-users-1-and-2/part-ii-toys/classification-systems, accessed: 19.05.2023
3. Williams D. A. (2004): The Jigsaw Puzzle: Piecing Together a History, Berkley Books, ISBN 0425198200, 9780425198209, https://www.puzzlewarehouse.com/history-of-puzzles/ (25.04.2023.)
4. ***: European Commission (2009): Directive 2009/48/ec of the European Parliament and of the Council of 18 June 2009 on the Safety of Toys, URL: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0048, accessed: 28.03.2023.
5. ***: European Commission (2010): Regulation (EU) No 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market Text with EEA relevance, https://eur-lex.europa.eu/eli/reg/2010/995/oj, accessed: 12.04.2023
6. ***:European Commission (2020): Strategic EU Ecolabel Work Plan 2020 – 2024, https://ec.europa.eu/environment/ecolabel/documents/EU%20Ecolabel%20Work%20plan%202020-2024%20Dec%202020.pdf, accessed: 13.04.2023
7. ***:European Commission (2023): Guidance Document No 11 on the Application of Directive 2009/48/ec on the Safety of Toys, URL: https://single-market-economy.ec.europa.eu/sectors/toys/toy-safety/guidance_en, accessed: 11.04.2023.

8. ***:Federal Ministry for the Environment: Blue Angel, The German Ecolabel, Toys, DE-UZ 207, Basic Aword Criteria, Version 4, URL: https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20207-201701-en%20Criteria-V4.pdf
9. ***: Federal Ministry Republic of Austria: The Austrian Ecolabel for products, https://www.umweltzeichen.at/en/products/start, accessed: 12.04.2023
10. ***: The Nordic Council of Ministers: Toys 095, https://www.nordic-swan-ecolabel.org/criteria/toys-095/, accessed: 12.04.2023
11. ***: CEN/TR 15071:2020: Safety of toys – National translations of warnings and instructions for use in EN71
12. ***: CEN/TR 15371: Safety of toys – Interpretation
13. ***: EN standard 71:2018: Safety of toys
14. ***: http://epp.eurostat.ec.europa.eu/newxtweb/setupdimselection.do, accessed: 12.04.2023
15. ***:http://woodentoys-shop.com/toy-history-toys-games.php3 (25.04.2023.)
16. ***:https://abafactory.com/about-abafactory/quality-and-safety/; (25.04.2023.)
17. ***:https://edxeducation.com/the-history-of-educational-toys/ (25.04.2023.)
18. ***:https://finland-wood.com/what-kind-of-wood-are-wooden-toys-made-from/; (25.04.2023.)
19. ***:https://lilykidstoys.com/what-are-wooden-toys-made-of/; (25.04.2023.)
20. ***:https://sina-spielzeug.de/know-how/?lang=en; (25.04.2023.)
21. ***:https://www.alexwoodentoys-bg.com/ (25.04.2023.)
22. ***:https://www.alljigsawpuzzles.ie/blogs/all-jigsaw-puzzles-blog/the-history-of-jigsaw-puzzles?shpxid=7e7120a8-3d76-4f4c-a0b2-ca3b304ce93a (25.04.2023.)
23. ***:https://www.cloudberries.co.uk/fun-stuff/the-history-of-the-jigsaw-puzzle/ (25.04.2023.)
24. ***:https://www.froebel.com.au/about-froebel/friedrich-froebel; (25.04.2023.)
25. ***:https://teiaeducation.ch/2022/05/24/who-was-froebel-and-what-are-froebels-gifts/

Authors address:
Petrović, S.
Department of Wood Technology and Science, Faculty of Forestry, University of Belgrade, Belgrade, Republic of Serbia;
Corresponding author: slavica.petrovic@sfb.bg.ac.rs

EU FUNDING FOR BIOECONOMY TRANSITION: PERCEPTION OF FOREST ACTORS

Huertas-Bernal, C.D., Hájek, M.

Abstract: The bioeconomy strategy has been established in several countries and regions; however, specific economic and legal instruments are required to encourage the production and consumption of products and services derived from the bioeconomy and thus stimulate the proposed economic transition. According to studies on bioeconomy, it was identified that investment in relevant sectors is currently the main bottleneck that hinders the shift toward a sustainable bioeconomy. In addition, bioeconomy projects face problems accessing private capital, especially in the transition stage between pilot and demonstration plants. This study aims to conduct a comprehensive review of the financing programs offered within the European Union (EU) and assess the perception of these programs among forest stakeholders. Specifically, the focus is placed on evaluating aspects such as program accessibility, resource monitoring, and utilization, as well as the overall effectiveness of funding in facilitating forest bioeconomy initiatives to enhance forest-based products. The results suggest that financing actions supported in the framework of EU policies such as the bioeconomy and the circular economy, will help achieve the EU's political objectives. However, implementing the financing mechanisms depends on each Member State's will according to the planned sectoral objectives. Additionally, changes in forest policy instruments may affect property rights. It will require adequate transition periods to encourage forest owners to adapt and generate conditions for sustainable forest use in the long term and synergies with various stakeholders to implement effective bioeconomy initiatives over time.
Keywords: Financing mechanism, forest actors' perception, stakeholders, in-depth interview, content analysis.

1. INTRODUCTION

The bioeconomy (BE) represents an opportunity to reshape the current economic model (Lewandowski, 2018; Patermann & Aguilar, 2021). Its objective is to achieve this transformation by promoting the creation, development and revitalization of economic systems based on the sustainable production, use and preservation of biological resources (Aguilar et al., 2019), encompassing many elements, including knowledge, science, technology, and innovation (Teitelbaum et al., 2020).The BE has aroused great acceptance within different sectors, policy makers, academia, and society, as it offers the potential to mitigate and adapt to climate change, reduce carbon emissions, promote job creation and replace fossil fuels for clean technologies characterized by neutral emissions (Bugge et al., 2016). The establishment of various bioeconomy strategies across the globe highlights the global efforts in this domain. Nevertheless, the effective stimulation of this transition demands the implementation of precise economic and legal instruments (Yakubiv et al., 2020).

Policy instruments play a crucial role in the implementation of environmental policy, providing policymakers with a range of mechanisms to enact effective change. These instruments can be classified into several main categories, including regulation, market-based instruments (MBIs), voluntary approaches, and education and information dissemination (Cocklin, 2009). Economic instruments, a type of MBI, possess considerable potential for addressing diverse environmental and natural resource challenges. By utilizing economic incentives, such instruments can incentivize desired behaviors and mitigate negative environmental impacts (Barde, 1994; EFTEC et al., 2010).

In the European context, legal instruments specifically pertain to the tools available to European institutions in fulfilling their functions. Regulations, characterized by their binding nature and direct applicability across all EU member states, encompass a comprehensive set of rules. Directives, on the other hand, establish specific results that EU countries must achieve, allowing flexibility in terms of their implementation methods within national legal frameworks. Decisions hold full binding force for their addressees, while recommendations and opinions serve as non-binding declarative instruments. By employing this array of instruments, European institutions are equipped to effectively address a wide range of policy objectives (Consolidated Version of the Treaty on the Functioning of the European Union, 2012).

The transition to a sustainable bioeconomy is impeded primarily by a prominent constraint—insufficient investment. In particular, bioeconomy projects encounter difficulties when seeking access to private capital, particularly during the critical transition phase between pilot and demonstration plants (Enriquez et al., 2021; Hinderer et al., 2021). Addressing this challenge, the European Union (EU) has taken measures to facilitate the financing of bioeconomy projects by introducing a mechanism encompassing grants, loans, and shares as financial instruments (European Commission, 2021a, 2021b).

This study examines the financial mechanisms proposed by the European Commission to facilitate the economic transition toward the circular bioeconomy. Through a comprehensive literature review, the document investigates the available financial mechanisms. Additionally, in-depth interviews were conducted with forestry experts across the EU to explore the perceptions of forestry stakeholders regarding these mechanisms. The findings of this research provide crucial insights into the stakeholders' perspectives and offer suggestions for enhancing the implementation and dissemination process of these mechanisms. This information is invaluable for policymakers aiming to ensure the effective utilization of the proposed mechanisms and their accessibility to the intended actors.

2. METHODOLOGY

The methodological framework employed to address the research questions regarding financing the transition to a circular bioeconomy in the forestry sector and the perceptions of forestry communities regarding the available financing mechanisms is outlined below.

2.1 Study Area

The study encompasses the member states of the European Union, with a specific focus on Austria, Belgium, the Czech Republic, Germany, Greece, Italy, Luxembourg, Poland, Slovakia, Slovenia, Spain, and Sweden. These countries were selected as they were the origin countries of the interested and responsive foresters who participated in our investigation and facilitated the conduct of in-depth interviews (see *Figure 1*).

The European Union represents a collaborative economic and political organization comprising 27 European countries. It operates through shared institutions that democratically make decisions concerning areas of common interest, including health, environment, climate, foreign relations, security, justice, and migration. The EU upholds some of the most stringent environmental standards globally, aiming to safeguard the environment, preserve biodiversity, mitigate risks to human health, and facilitate the shift toward a circular economy (European Commission & Directorate-General for Communication, 2020). Given the EU's commitment to these goals, it was chosen as the study area to investigate the application of financing mechanisms in facilitating the transition to a circular bioeconomy, specifically in the sustainable forest management and production of forest-based products.

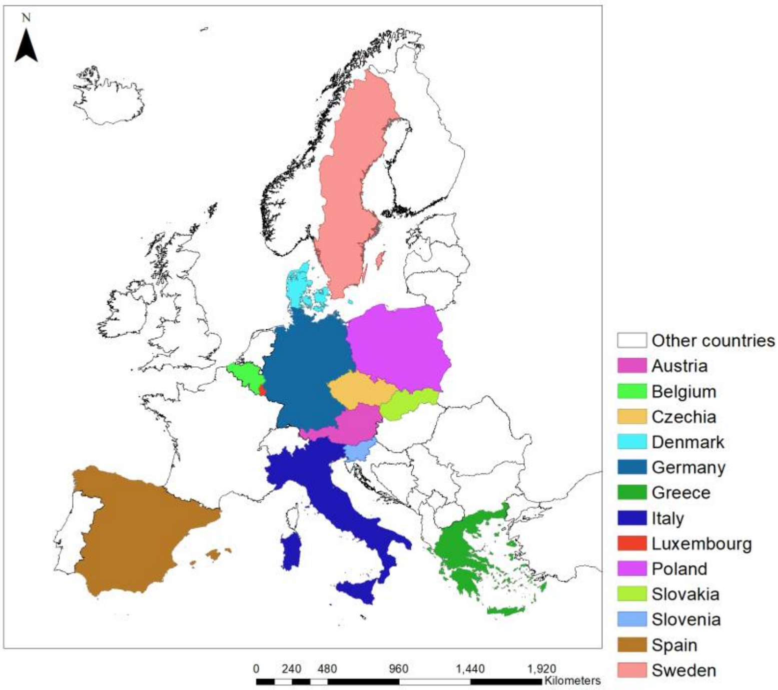


Figure 1. Location of the study area

2.2 In-depth interviews

The research methodology employed to address the research question entailed conducting in-depth qualitative interviews with experienced forestry professionals in the sector, focusing on exploring and delving into the financing mechanisms in facilitating the transition to a circular bioeconomy of the forestry sector and related topics of interest. A comprehensive interview guide consisting of 18 semi-structured open-ended questions, categorized into four types of knowledge (factual, conceptual, procedural, and metacognitive), was developed. The questionnaire served as a tool to elicit specific information from the study participants. The initial guide was modified and refined based on feedback received from three forestry doctoral students who pre-tested the questions for accuracy and relevance.

A database of forestry stakeholders was compiled, gathering information from FAO National Focal Points and other relevant forestry institutions, which facilitated access to individuals who met the research criteria in terms of years of experience in the forestry sector. Potential participants were invited via email, providing a concise overview of the study's background, objectives, and methodology. Upon receiving confirmation from interested individuals, 60-minute interview appointments were scheduled.

In total, 19 online interviews were conducted between August 1 and September 30, 2022, utilizing Microsoft Teams (Version 1.5.00.21668) as the communication platform. The interviews were recorded with participants' consent to ensure accurate capture of information. Subsequently, the interviews were transcribed using the oTranscribe open-source program, based on the transcript provided by the Teams application. While the majority of interviews were conducted in English, four interviews were conducted in Spanish, necessitating translation of the content into English during the transcription process. The Verbatim Intelligent method was employed to eliminate padding and repetitive comments, resulting in concise and readable transcriptions that maintained the intended meaning of the interviewees' remarks. To ensure confidentiality, participant responses were anonymized, preventing readers from associating specific responses with individual participants.

3. RESULTS AND DISCUSSION

The literature review revealed two primary financing categories the EU proposed to support the transition toward the bioeconomy: grants and financial instruments. Notably, these categories offer the possibility of combining multiple sources of financing (European Commission, 2021b). Specifically, the grants encompass five renowned programs and projects within the EU: Horizon Europe, LIFE, Common Agricultural Policy, European Structural and Investment Funds, and the Innovation Fund. On the other hand, the financial instruments encompass the European Investment Bank Group, along with a range of financial options tailored for high-risk sectors. These instruments play a crucial role in providing access to financing initiatives specifically designed for bioeconomy purposes, addressing the financing gaps that would otherwise hinder the progress of the forestry sector.

3.1 Stakeholder Perspectives on Financing Mechanisms

Based on stakeholder perceptions, we have identified critical considerations regarding utilizing and implementing financing mechanisms for the transition to the bioeconomy. Our analysis encompassed twelve European countries, revealing notable disparities in forest management practices and the efficacy of financing mechanisms.

- Notably, 65% of the interviewees were unfamiliar with the term "bioeconomy." However, upon explaining the concept of circular bioeconomy, they acknowledged practicing specific measures that align with its definition. This indicates a lack of widespread awareness among forest stakeholders regarding the principles of circular bioeconomy.
- Conversely, stakeholders acknowledge the overall utility of various financing options for forest management. However, certain instances demonstrate limited effectiveness due to cumbersome and costly procedures, deterring private forest owners from utilizing these mechanisms. As a result, private capital remains the preferred means of forest management for such owners.
- Previous research suggests that the general public lacks awareness of available economic instruments, hindering the efficacy of policy measures (Carattini et al., 2017). In contrast, the interviewed forestry stakeholders demonstrate awareness of the economic instruments offered by the EU to finance forestry initiatives. Consequently, we determined that forest owners and managers who seek financial resources

possess the necessary knowledge to identify suitable options through regional forestry institutes or the corresponding institute's website.

- The associations of forest owners and national institutes play a crucial role in transmitting information and acting as intermediaries between interested parties and the entities responsible for processing financing mechanisms. However, our findings reveal significant disparities in knowledge levels and information transmission among member countries. For instance, Sweden stands out as an example of active participation, with forest owners frequently seeking updates on available mechanisms for forest management and sustainable initiatives. In contrast, countries such as the Czech Republic, Slovakia, and Spain face challenges in this regard. Insufficient funding and difficulties in disseminating information hinder the sector's ability to convey the relevant material to users. These challenges arise from the need for translating informative materials into the respective languages of each country, along with agents' limited understanding of the application processes for available financial mechanisms. As a result, the preference remains with traditional mechanisms for which information is readily available, as they require less investment of time and resources for dissemination within the community.

4. CONCLUSIONS

The European Union offers various funding mechanisms to support the transition to the bioeconomy. However, adequate financing requires alignment with the goals and timeframes of bioeconomy strategies. Certain countries, such as Luxembourg, Belgium, Germany, Sweden, and Austria, have national forest plans and well-integrated bioeconomy strategies, aligning their forestry sector planning with EU policies. These countries have clearly defined funding mechanisms integrated into action plans, including robust monitoring measures and indicators to ensure sustainable forest management.

Other countries, including Spain, Italy, Greece, Poland, Slovakia, Slovenia, and the Czech Republic, have also developed forestry policies and some strategies related to the bioeconomy. However, their level of implementation is perceived to be lower. The financing mechanisms in their action plans are still in the early stages of utilization, presenting more significant limitations and restrictions for forest stakeholders.

Early-stage bioeconomy strategies can benefit from adopting proven financing mechanisms implemented in other countries or regions, serving as valuable models for successful implementation.

To enhance the dissemination and exchange of information between the state and the community, it is crucial to promote comprehensive training for state agents, facilitate their access to relevant information, and ensure their thorough understanding of the processes involved in accessing financing mechanisms. This will foster improved communication and awareness among forest stakeholders.

Acknowledgements: We wish to express gratitude to the Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague for the IGA funding 2021/2022, project No. A_21_30 that made possible this research.

REFERENCES

1. Aguilar, A., Twardowski, T., & Wohlgemuth, R. (2019). Bioeconomy for Sustainable Development. Biotechnology Journal, 14(8). https://doi.org/10.1002/biot.201800638
2. Barde, J.-P. (1994). Economic instruments in environmental policy: Lessons from the OECD experience and their relevance to developing economies. (Technical Paper No. 92).
3. Bugge, M. M., Hansen, T., & Klitkou, A. (2016). What is the bioeconomy? A review of the literature. Sustainability (Switzerland), 8(7). https://doi.org/10.3390/su8070691
4. Cocklin, C. (2009). Environmental Policy. In R. Kitchin & N. Thrift (Eds.), International Encyclopedia of Human Geography (pp. 540–545). Elsevier. https://doi.org/10.1016/B978-008044910-4.00569-1
5. EFTEC, IEEP, Dickie, I., Tucker, G., & Ozdemiroglu, E. (2010). The use of market-based instruments for biodiversity protection –The case of habitat banking – Technical Report. EFTEC, London.

6. Enriquez, S., Sánchez-Triana, E., & Guerra López, M. G. (2021). Economic Instruments and Financial Mechanisms for the Adoption of a Circular Economy. An Introduction to Circular Economy (pp. 455–482). Springer. https://doi.org/10.1007/978-981-15-8510-4_23
7. Consolidated version of the Treaty on the Functioning of the European Union, 326 OJ C (2012). http://data.europa.eu/eli/treaty/tfeu_2012/oj/eng
8. European Commission. (2021a). Horizon Europe—Investing to shape our future (p. 42).
9. European Commission. (2021b). Bioeconomy & EU financing instruments | Knowledge for policy. https://knowledge4policy.ec.europa.eu/bioeconomy/bioeconomy-eu-financing-instruments_en
10. European Commission, & Directorate-General for Communication. (2020). The European Union: What it is and what it does. Publications Office of the European Union. https://doi.org/doi/10.2775/41083
11. Hinderer, S., Brändle, L., & Kuckertz, A. (2021). Transition to a Sustainable Bioeconomy. Sustainability, 13(15), 8232.
12. Lewandowski, I. (Ed.). (2018). Bioeconomy: Shaping the Transition to a Sustainable, Biobased Economy. Springer International Publishing. https://doi.org/10.1007/978-3-319-68152-8
13. Patermann, C., & Aguilar, A. (2021). A bioeconomy for the next decade. EFB Bioeconomy Journal, 1, 100005. https://doi.org/10.1016/j.bioeco.2021.100005
14. Teitelbaum, L., Boldt, C., & Patermann, C. (2020). Global Bioeconomy Policy Report (IV): A decade of bioeconomy policy development around the world. Secretariat of the Global Bioeconomy Summit.
15. Yakubiv, V., Panukhnyk, O., Shults, S., Maksymiv, Y., Hryhoruk, I., Popadynets, N., Bilyk, R., Fedotova, Y., & Bilyk, I. (2020). Application of Economic and Legal Instruments at the Stage of Transition to Bioeconomy. Springer International Publishing. https://doi.org/10.1007/978-3-030-20454-9_64

Authors address:
Diana Carolina Huertas-Bernal[1*]; Miroslav Hájek[2]
[1] Department of Forestry and Wood Economics, Faculty Forestry and Wood Sciences, Czech University of Life Sciences Prague, Czech Republic.
[2] Department of Forestry Technologies and Construction, Faculty Forestry and Wood Sciences, Czech University of Life Sciences Prague, Czech Republic.
[*]Corresponding author: E-mail: huertas-bernal@fld.czu.cz

SIMPLIFIED LIFE CYCLE ASSESSMENT (LCA) STUDY FOR EARLY DESIGN STAGES OF WOODEN EXTERIOR DOOR

Kruhak, T., Pirc Barčić, A., Klarić. K., Motik, D.

Abstract: As industries are embracing circular economy, wood in manufacturing companies stands out as a representative example of renewable resource. Especially in the building sector, the wood is known as a highly durable material with versatile design possibilities. One of the well-known methods for better understanding the production process of a product is Life Cycle Assessment (LCA) methodology. In case of early design stages and regarding estimation of environmental impacts of a product, the simplified LCA study stands out. A simplified LCA is used for quick assessment with realistic approach to the product design. This type of study is suitable when we are planning to use already available data. Interpretation of the LCA results can potentiate improvement in the design of the product, and also it can serve as a good foundation and guidance into the transition to a cleaner energy and usage of the less environmentally harmful materials. Wooden exterior doors are a complex product that consists of numerous elementary components and large number of auxiliary materials and products. Reviewing the literature which deals with this topic it is evident that more and more designers and engineers have recognised the LCA as an important tool in identifying the product with better environmental performances. The purpose of this paper is to study the possibilities of the simplified LCA in the early design stages that can improve production process of a wooden exterior door. The emphasis is also on improving the eco-efficiency of the product which is right step to sustainable innovation.
Keywords: wood industry; wooden products; Life Cycle Assessment (LCA); wooden door; SimaPro

1. INTRODUCTION

The consequences of a long-term economic growth and human prosperity directly manifests itself on the quality of our environment which primarily refers to the air and water quality, reduction of natural resources, degradation of ecosystems, decline in biodiversity, increased pollution, and climate change. However, exploiting natural resources aids in lowering the degradation of the environment owing to the needed removal of hazardous substances into the air, water, and land (Peng et al., 2023). Efficient resource use means making the most of available resources to maximize output while minimizing inputs.

According to Peng et al. (2023) rapid industrialization has posed obstacles on the path to sustainable development. This organizing principle has gained significant acceptance and recognition in recent years. Sustainable development in industrial production refers to the practice of utilizing resources efficiently and sparingly to minimize negative environmental impacts while ensuring long-term economic viability. It implies implementing processes and technologies that reduce waste generation, energy consumption, and pollution emissions, while also optimizing resource usage. Such concept aligns with Life Cycle Assessment (LCA) methodology which is now well-known method for better understanding the production processes. The ISO 14040 standard defines LCA as a compilation and evaluation of the inputs and the potential environmental impacts of a product system throughout its life cycle. LCA has become one of the most widely applied scientific and industrial methods for estimating environmental impacts of products and services (Frostel, 2013). LCA has broad spectrum of applications but specific use, adaptation and practice of LCA for all potential applications are based on ISO 14044: 2006 (Pric Barčić et al., 2022).

The wood industry has a potential to contribute to a more sustainable and resource-efficient future. Through responsible forestry practices, efficient use of wood, recycling and reuse initiatives, and the development of wood-based materials, the industry can reduce waste, conserve resources, and minimize its environmental impact. Wood is a well-known and immensely valuable renewable natural resource that has been utilized for numerous applications in various sectors. With high potential for reusing and recycling, wood residues and by-products can also be a source of biomass for energy generation. Another notable advantage of wood is carbon storage. Wood products have the advantage of storing carbon throughout their lifespan. By utilizing wood in construction and other applications, the industry can contribute to carbon sequestration and help mitigate climate change.

Based on the European Comission it is estimated that over 80% of all product-related environmental impacts are determined during the design phase of a product, but environmental footprint calculations are rarely available to product designers (*PRé Sustainability*, 2023). Opportunities to reduce environmental impact present themselves when the focus is shifted on early design stages of a product. In recent years, there has been a shift towards a more comprehensive and holistic approach to sustainability that encompasses the entire value chain of a company.

Based on the *EeBGuide* Project guidelines (2012.) a simplified LCA, with an adapted methodology, can be used for quick assessment of a product, based on already available information in the planning process. The goal here is to improve the product design by assessing the energy and fuel consumption hot spots, but also to investigate the possibility of using more eco-friendly materials. Regarding a bit more complex application of LCA, on calculating life cycle of a product, the opportunity for developing environmental product declaration (EPD) arises, which is becoming increasingly important demand in today's market.

The object of this study is practical use of simplified LCA in the early design stages that can improve production process of a wooden product (in our example a wooden exterior door). Environmental impacts of this product are assessed trough raw material extraction and processing, and also through its manufacture phase. This simplified study will be the basis for more detailed LCA analysis and very likely the foundation for obtaining the environmental product declaration (EPD) of the mentioned product.

2. MATERIALS AND METHODS

2.1. Simplified LCA

Simplified LCA is an approach that aims to provide a streamlined or condensed assessment of the environmental impacts that are in this case associated with a wooden product. It is a more accessible and less resource-intensive version of the full LCA, designed for situations where a quick assessment is needed or when limited data is available. The simplified LCA has to be interpreted as an 'adapted' LCA, depending on the effort that the LCA practitioner wants to put in for every life cycle stage and contributor (*EeBGuide* Project guidelines, 2012). While the level of detail and accuracy may be reduced compared to a comprehensive LCA, simplified LCA still follows the basic principles of considering the environmental impacts across the life cycle stages. The reason for using this adapted LCA analysis is because the product is still in its early design stages, and not all data is available. Furthermore, the focus here is to identify the major contributing input materials, energy and fuel use, and their potential impact on environment. Properly calculated impact assessment forms the baseline for suggesting improvements in product design, and therefore ultimately saves money and resources, but also potentially the energy and fuel consumption on top of the reduction of environmental damage.

2.2. Functional unit and system boundaries

Wooden exterior doors are a complex product that consists of numerous elementary components and large number of auxiliary materials. The functional unit of this LCA analysis is the wooden exterior door, which are comprised of a door leaf and door frame, with its dimensions of 970 x 220 x 60 mm.

System boundaries determined for this type of the assessment is cradle-to-gate approach, which implies that this is partial wooden product life cycle. This approach includes raw material extraction, transportation to the factory gate, and manufacturing the product up until the point of being transported to the consumer. In this case, the use phase and disposal phase of the product life cycle are left out, which are essential parts of the full life cycle assessment.

2.3. Description of the raw material extraction and manufacturing process

A simplified graphic representation of the raw material extraction, transportation and door manufacturing process can be seen in Figure 1.

The material extraction begins in the forest stand with the felling and tree processing with the chainsaw. The logs are then extracted with the forwarder vehicle to the load transportation truck that will deliver the logs to the factory gate. In the factory, the logs will primarily be debarked and sorted before entering the sawmill. The primary processing in the sawmill includes planks production, after which the planks are transported to dry naturally in the air. Secondary processing in the sawmill includes final plank processing for the purpose of getting the elements that will be submitted to the kiln drying process. After 60 days the dried elements are ready to enter the final door leaf and frame manufacturing. Final assembly of wooden exterior door includes the numerous elementary wood components and auxiliary materials. Besides the documented material consumption, the energy and fuel consumption from transportation between processes has also been included.

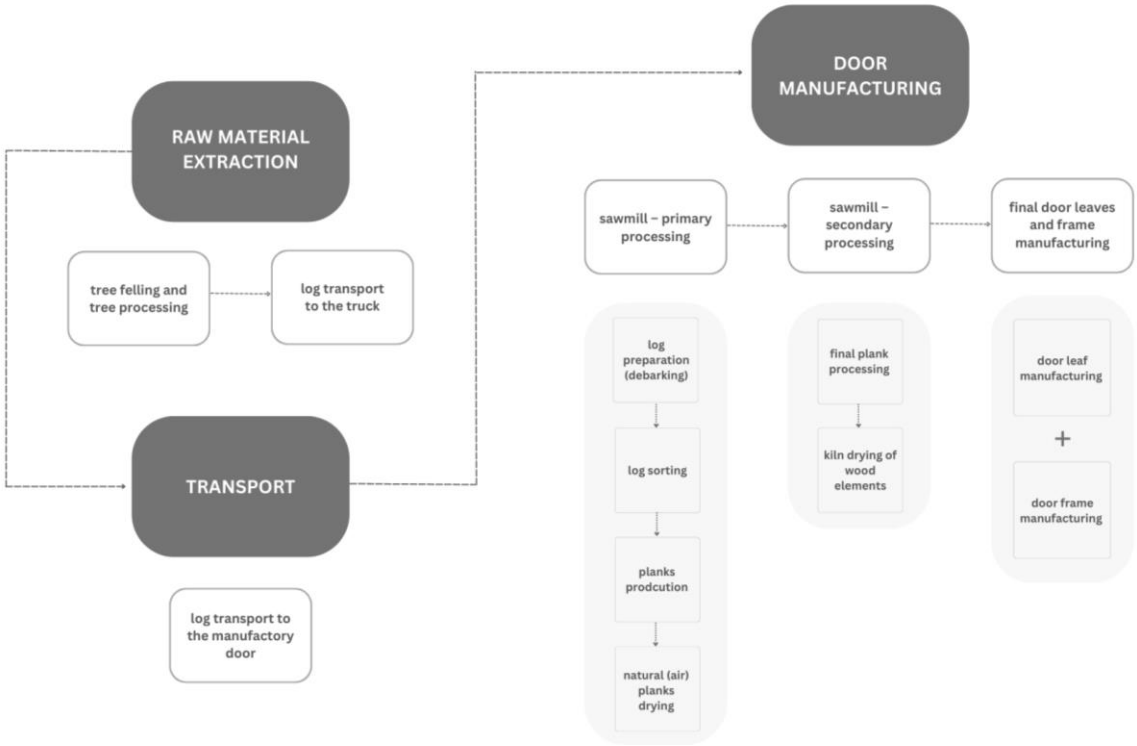


Figure 1. Simplified graphic representation of raw material extraction, transportation and door manufacturing process

2.4. Data collection

The wooden exterior door production process data was collected from various sources, such as: door manufacturing company employees, experts of the field of forestry and wood technology, literature, LCA database and internet. The tree felling and processing with the forwarder transportation were estimated with the help of experts and literature. The calculations are made in a way to obtain the most similar data to the real conditions. The transportation values were calculated based on the load capacity of the transporting vehicles and the real distances that were given by the manufacturing company. The data regarding the door manufacturing (material, energy, and fuel consumption) were gathered on the production site and in communication with the technologists that are directly involved in the process. The exact mass of the wood needed to produce the door were calculated based on the final dimension of the wood leaf and frame, taking into the account the relative moisture of the wood used in the process. The exact type and number of auxiliary materials were given by the manufactures, and latter complemented with the product information researched from the different documents and product declarations. Energy consumption was calculated based on the mass of the wood needed for the door construction and the strength of the machines that were processing the wood. The only omitted data were wood residues and by-products, due to the lack of information on exact mass amount.

2.5. Impact Assessment Methodology

For the purpose of this analysis the *SimaPro* (version 9.3.0.3, Expert user package) software was used in combination with *Ecoinvent* database. Due to its extensive features and user-friendly capabilities, *SimaPro* has gained recognition as a valuable tool in the field of sustainability assessment and LCA. Based on the *PRé Sustainability* (2023), the creators of the software, the *SimaPro* was designed to be a source of science-based information, providing full transparency, and avoiding black-box processes, with its purpose to collect, analyse and monitor the sustainability performance data of products and services. *ReCiPe 2016* was chosen an impact assessment method, which includes both midpoint (problem oriented) and endpoint (damage oriented) impact categories, available for three different perspectives (individualist (I), hierarchist (H), and egalitarian)) (PRé Sustainability, 2020). Egalitarian perspective (E) was selected due to the fact that it is the most precautionary one.

3. RESULTS AND DISSCUSION

3.1. Impact Assessment (LCIA) results

3.1.1. Impact assessment: Characterization at ReCiPe 2016 midpoint (E) level

ReCiPe 2016 method, at midpoint impact category level, includes 18 characterisation factors. Figure 2 displays the percentages of environmental impacts of the different materials and processes used for manufacturing the (1 kg of) exterior wooden door with respect to the various midpoint impact categories. It is evident that the highest impact, for almost all impact categories, is accounted to the process of getting kiln dry elements.

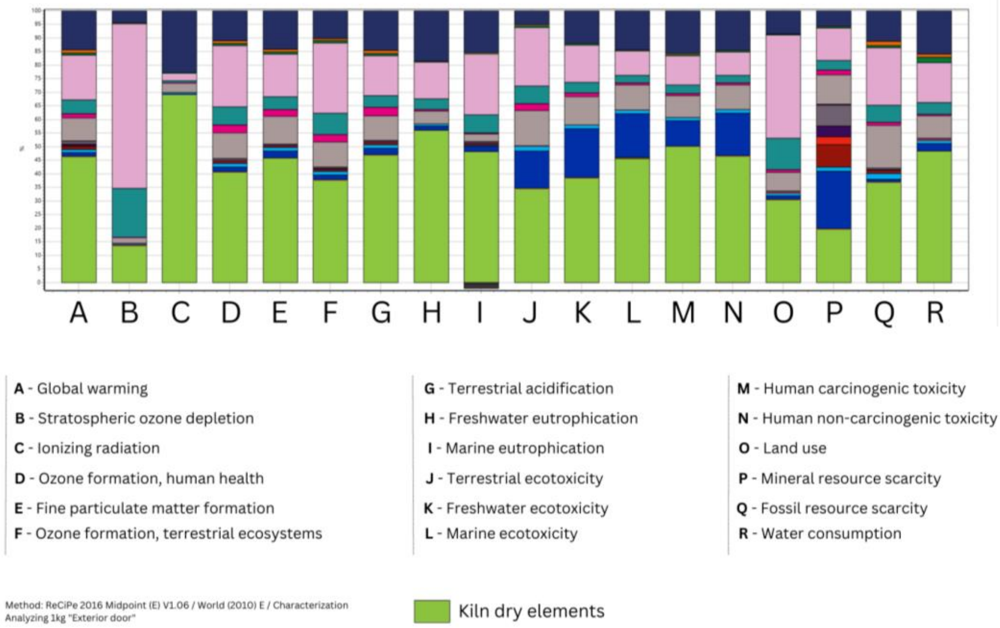


Figure 2. Characterisation results at midpoint level for wooden exterior door (Source: SimaPro, Version 9.3.0.3)

3.1.2. Impact assessment: Damage assessment at ReCiPe 2016 Endpoint (E) level

Three endpoint categories (damage to human health, ecosystems and resources) are comprised of cumulative midpoint categories multiplied by damage factors. Figure 3 shows that the production of kiln dry elements also has the largest contribution to human health, ecosystems and resources.

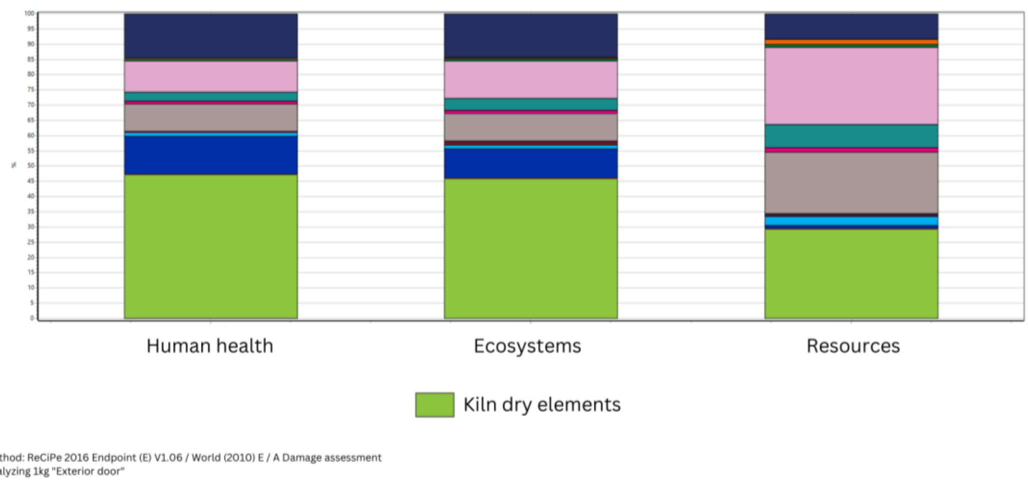


Figure 3. Damage assessment at endpoint level for wooden exterior door (Source: SimaPro, Version 9.3.0.3)

3.1.3. Overview of the process contribution as network

Figure 4 allows us to inspect the network flow chart which displays the processes with highest environmental impacts, while the processes that contribute the less than 8,45% (cut-off value) are not shown.

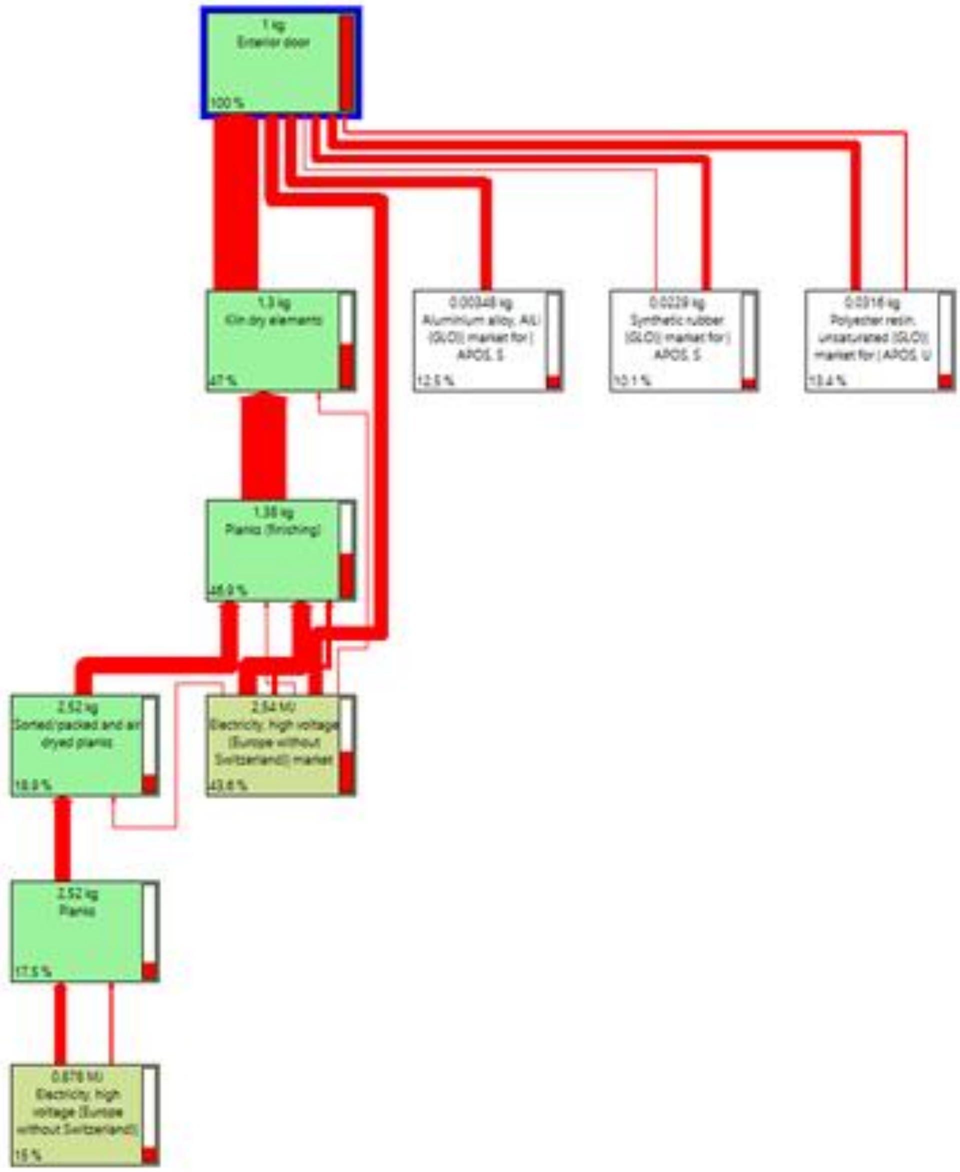


Figure 4. Overview of the production process of the wooden exterior door as a network (cut-off value = 8,45%) (Source: SimaPro, Version 9.3.0.3)

As indicator type the Single Score option is selected, which presents the single score environmental impact of 1 kg of exterior doors. Further inspections of the red bars ('thermometers') displayed on the right side of each box indicates how many points each material/process contributes to the wooden exterior door production impact. In this case the kiln dried elements have the largest contribution with 47%. The red arrows are presenting the direction of the flows, while their thickness presents the total environmental load flowing between processes. Regarding the materials, notable contribution has the Aluminium alloy (12,5%), Synthetic rubber (10,1%) and Polyester resin (13,4%).

3.2. Study results and their representativeness

Analysing the results by both sets of impact categories of the *ReCiPe 2016* method it is evident that the kiln dry elements have a biggest negative impact. Results such as these are understandable due to the fact that production of mentioned elements is quite complex and lengthy process. The process of drying wooden elements was identified as a problematic even by the manufacturing company due to its prolonged duration, significant energy consumption, and notable greenhouse gas emissions. The high amount of energy consumption and greenhouse gas emissions are significant contributors of the negative impact on the environment. Kiln dry elements, in the form of the elementary components, represent one of the final inputs for the door frame and leaf assembly.

It is also important to mention that the wood co-products and residues generated in this production process are not documented in this study. Such products could potentially have notable effects on the results. The authors are also pointing out that, during the study development, it was not always possible to do the calculations with the precise amount of wood mass, due to the lack of the data (for example the loss of the moisture from the wood that caused the change of the mass).

The results of this study will be the foundation for conducting the more detailed LCA analysis that will include use and disposal phase. It is also important to amplify that this LCA analysis did not go under any revision, and therefore the real name of the product (and production company) is undisclosed, and authors cannot guarantee the absolute accuracy of the results.

4. CONCLUSION

By employing efficient and sparing resource use practices, industries can contribute to a more sustainable future by reducing environmental degradation and preserving resources for future generations. This can be achieved through various measures such as improving production techniques, adopting cleaner technologies, and implementing waste reduction strategies. By using resources efficiently, industries can reduce their ecological footprint and minimize the depletion of natural resources.

LCA takes into account the various stages of a product's life cycle, including raw material extraction, manufacturing, transportation, product use, and end-of-life disposal or recycling. By quantifying the environmental impacts associated with each stage, such as greenhouse gas emissions, resource depletion, water usage, and waste generation, it becomes possible to understand the overall environmental footprint of the product. Once the impacts are identified, suggestions for improvements in product design can be made. This could involve optimizing material choices, reducing energy consumption during manufacturing, improving product durability, minimizing waste generation, or implementing recycling initiatives. The goal is to identify strategies that can minimize the negative environmental impacts while maintaining or improving the product's functionality and performance.

Simplified LCA can be a valuable tool, especially for organizations or individuals with limited resources, time, or expertise in conducting a full LCA. It allows for a preliminary assessment of environmental impacts and can help raise awareness and initiate discussions around sustainability considerations. However, it's important to recognize its limitations and that more detailed assessments may be necessary for comprehensive and accurate evaluations.

In door production, the drying process has proven to have the most significant impact on the environment. Therefore, it would be necessary to analyse and optimize the drying process, including the implementation of new and more efficient regimes that would shorten the duration of the process, reduce energy and water consumption. Furthermore, it would be beneficial to consider special drying methods such as vacuum and high-frequency drying. Generally, vacuum drying and high-frequency drying can have some advantages in terms of reducing environmental impact, but a comprehensive life cycle analysis and specific conditions need to be considered in order to make final assessments.

The production processes, transportation vehicles and machinery have a significant impact on the environment. Replacing older, inefficient machinery with energy-efficient models reduces energy consumption and greenhouse gas emissions. Using environmentally friendly components and efficient exhaust systems also lessens the negative effect. Effective waste management, including recycling, mitigates overall impact on our environment. Similarly, in door production, replacing older vehicles with energy-efficient models, optimizing fleet and route management, and also promoting efficient driving techniques can help in reduction of fuel consumption and emissions. The combination of these measures can potentiate a creation of more environmentally friendly products and materials, especially in a case of wooden product manufacturing.

It's important to note that impact assessment and improvement suggestions should also consider other factors beyond environmental impact, such as social and economic aspects. A holistic approach that takes into account sustainability from multiple angles is crucial for creating truly sustainable and responsible product designs.

Acknowledgements: This article was published as a part of the project "*Istraživanje i razvoj inovativnih drvnih zidnih obloga, pregradnih i nosivih zidova za održivu gradnju u poduzeću Spačva d.d.* – KK.01.2.2.02.0244" (Research and development of innovative wooden wall coverings, partition and load-bearing walls for sustainable construction in the company Spačva d.d.) by Spačva d.d. and partner University of Zagreb Faculty of Forestry and Wood Technology. The project was co-financed by the European Union from the Operational Program Competitiveness and Cohesion 2014-2020, European Fund for Regional Development.

REFERENCES

1. European Commission (2023): Sustainable Product Policy: The Ecodesign of Energy-Related Products (ErP). URL: https://joint-research-centre.ec.europa.eu/scientific-activities-z/sustainable-product-policy_en#:~:text=It%20is%20estimated%20that%20over,throughout%20their%20entire%20life%20cycle (Accessed on May 19th 2023)
2. Frostell, B. (2013). Life Cycle Thinking for Improved Resource Management: LCA or?. In: Kauffman, J., Lee, KM. (eds) Handbook of Sustainable Engineering. Springer, Dordrecht.
3. ISO 14040 (2006): Environmental management – Life cycle assessment – Principles and framework.
4. Peng, L; Li,Y.; Raza, S. A.; Shahzadi, I. (2023): *Natural resources and environmental sustainability: COP26 targets from resources-based perspective*. Resources Policy, Volume 83, 103623, ISSN 0301-4207
5. Pirc Barčić, A.; Klarić, K.; Kruhak, T. (2022): THE ROLE OF LIFE CYCLE ASSESMENT IN BUSINESS AND PRODUCTION PROCESSES IN WOOD INDUSTRY: A LITERATURE REVIEW. Controlling of Business Production Processes in Forest Based Industry 2022: pp. 47-64
6. Pre Sustainability - Various authors (2020): *SimaPro database manual. Mathods library*. Version: 4.15
7. PRé Sustainability (2023): *SimaPro: About SimaPro*. URL: https://simapro.com/about/ (Accessed on May 21st 2023)
8. PRé Sustainability (2023): SimaPro: Putting sustainability front and center in product design. URL: https://simapro.com/customers/putting-sustainability-front-and-center-in-product-design/ (Accessed on May 20th 2023)
9. The EeBGuide Project. (2012*): EeBGuide: 2.4.2 Simplified LCA*. (Accessed on May 16th 2023)

Authors address:
Kruhak, T; Pirc Barčić, A; Klarić, K, Motik, D;
[1]Department of Production Organization, Faculty of Forestry and Wood Technology, University of Zagreb, Svetosimunska 23, HR-10000 Zagreb, Croatia
*Corresponding author: tkruhak@sumfak.hr; apric@sumfak.hr; kklaric@sumfak.hr

THE IDEA OF SYLVICULTURA OECONOMICA AS A TOOL TO THE UNIVERSITY RENEW AND PROMOTION FOREST SCIENCES FOR THE BIOECONOMY DEVELOPMENT

Wanat, L.

Abstract: The study discusses whether the path of integration and cooperation is an opportunity or a threat to the newly created Faculty of Forestry and Wood Technology at the University of Life Sciences in Poznań, which follows the tradition of separate faculties combining both disciplines. The comparative analysis was based on a literature study, as well as on own research and personal experience relating to forestry and the wood-based sector. As a result, using the descriptive approach in mesoeconomics, conclusions and recommendations were formulated.
Keywords: forestry, wood technology, sylvicultura oeconomica, university, Poznań, Poland

1. INTRODUCTION

In 1716, Hans Carl von Carlovitz published Sylvicultura oeconomica [5]. This is one of the first works to explain natural, economic and social phenomena in forestry. The von Carlovitz model promotes sustainable forest management [6]. This means harvesting and processing only the amount of productive wood that can be re-generated through forest renewal, especially natural regeneration. But is mere "sustainability" enough? Is such a model optimal? As early as early 2020, it was understood that previous economic theories need to be revised. The Polish forest and timber sector also found itself in a new situation. Questions were posed as to how the business, institutions and individuals that make up, the wood market, should behave. After all, this market has been subjected to irregular and asymmetrical factors. So, should the changing wood-based market be "balanced" or "integrated"? Using the experience of the past, one might ask what Kurt Mantel (1973), the forerunner of modern wood market science, would have done [20]. He is the author of the first integrated compendium of forest management in Europe. He saw forestry and wood-based relations primarily in integral terms. It is a common good, so the natural function of forests cannot be separated from their economic purpose. Mantel wrote: "The population, especially those living in industrial agglomerations, depends on recreation in nature and free access to the forest" [20].

In addition, Mantel pointed out that "it is necessary to preserve the forest in its natural beauty and economic values and to protect it from the dangers of open access" to forest areas [19]. The relationship between the wood industry and forestry was considered inseparable. These issues were addressed successively by Cieszkowski (1842) [7], Pączewski (1924) [24], Rivoli (1926) [27], Molenda (1965) [22] and Podgórski (1974) [25], Kroth and Bartelheimer (1993) [12], Bergen et al (2013) [3]. The diversity of forestry research was discussed in their studies: Broda (2007) [4], Pachelska (2013) [23], Ilski (2014) [9]. The directions of research development in the wood-based sector were analyzed by, among others: Ratajaczak (2013) [26], Adamowicz and Szramka (2017) [2], Młynarski and Kaliszewski (2018) [21] and others.

It has been shown that forest management is very special in nature. Within it, economic, technological, natural (environmental) and social aspects intermingle. Yes, they are determined by sustainable development paradigms [26]. Meanwhile, "sustainability," as an economic category, has become ambiguous and therefore little understood. Particularly in forestry, the idea of "sustainability" is understood in integral terms [8, 17, 33]. The forestry and wood-based sector must overcome the conflict between the productive, protective and recreational functions of forests [29].

In a modern economy, will only competition based on traditional resources determine the development of industries? This thesis falls in the face of scientific criticism and experience of practice. So what are the prospects for the coexistence of forestry and lumbering in university structures? Is the "Green Deal" model [1] needed here as well? Is the path of cooperation and development an opportunity or a threat to forest sciences?

2. MATERIAL AND METHODS

The research questions were formulated by verifying an academic experiment. The issue is the creation, or rather reactivation, of a "new" Faculty of Forestry and Wood Technology in Poznań. Institutional measures were taken within the academic structure of the Poznan University of Life Sciences. An attempt to obtain a preliminary answer was made in this paper, referring to the study of selected items of literature on the subject and own research. In addition to the analysis of secondary data, individual in-depth interviews were conducted with a group of purposively selected 20 experts from the science and practice of the forest and wood-based sector. The analysis was conducted in comparative and descriptive terms [10].

The purpose of the study was to answer the question of whether the path of integration and cooperation is an opportunity or a threat to the new academic institution. How to assess the potential of the established Faculty of Forestry and Wood Technology at the Poznan University of Life Sciences. This faculty follows the long-standing tradition of separate faculties combining the two disciplines. After compiling the results, reference was also made to our own experience. In the conclusion, using a descriptive approach, the most important conclusions and recommendations were formulated. These conclusions are understandably general in nature. It seems that they can inspire further research in this area. This is especially important in view of the challenges that the circular economy and bioeconomy model poses to forestry and the wood-based sector.

3. RESULT AND COMPETITIVE SITUATION

In the 2020-2021 academic year, new (old) research units have appeared in the structures of the University of Life Sciences. One of them is the Faculty of Forestry and Wood Technology. Formed from two previously independent units, the separate names were joined by a conjunction "and." Was this just a housekeeping action of an administrative nature?

Referring to tradition, it should be pointed out that Poznan's Faculty of Forestry originated from the structures of the Faculty of Agriculture and Forestry (1920) within the Piast University (Wszechnica Piastowska). This was the predecessor of the University of Poznan, then the Forestry Department (1949) of the same university, and finally an independent unit of the Higher School of Agriculture (Wyższa Szkoła Rolnicza, 1951). The then Faculty of Forestry was composed of 12 scientific chairs. The faculty's profile combined forestry issues with technological aspects concerning the wood industry. So it also included wood technology. It was a natural symbiosis [15]. However, the need for a partial separation was recognized quite quickly. The Division of Wood Technology was created within that Forestry Department. A full divorce soon followed. The division was turned into a separate Department of Wood Technology (1954). Of course, the Forestry Department continued to function independently [13]. This state of affairs thus lasted for 66 years. It appeared that after crossing the threshold of the 100th anniversary of agroforestry studies in Poznań [18], the time for change had come.

In 2020, the university's units and its name were merged. Does extending the name necessarily guarantee success? Not necessarily. Has the potential for development only mathematically increased? The administrative decision can only play a maintenance role. However, it should be acknowledged that it does not exclude the chance of a new opening. The new department is formed by departments with a related, similar scope of activity. But at the same time, there are scientific teams with a specific subject area, having a peculiar distinctiveness. In addition, there remains, both in forestry and wood technology, a space to be developed. It can be identified among those departments that, for various reasons, have abandoned or failed to develop their activities. This space should constantly remain open for further initiatives that have not yet been undertaken. So let more be created! This can be determined by assessing the overall competitive situation.

4. DISCUSSION

The new situation is a good inspiration for discussion. It seems that the two merged units should constantly identify new challenges. They should be subjected to open, critical debate in the university space. Bold decisions are needed, at least in the basic dimensions: scientific, teaching and practical. The scope of the subject (this is how the collective of stakeholders is sometimes referred to), however, should not be typically "business-like". The academic community remains the subject. It is formed by all participants (here one can think of the entire forestry and wood-based sector), regardless of the dimension of this participation and the role played. And in terms of subject matter? Despite the apparent separateness of forestry and wood technology (a two-part name), the consensus may be forest management, or... Sylvicultura oeconomica. This concept goes back to the source of economics, however, understood in a different way than instrumentally. It is admittedly possible, with absolute measures, to assess the space of economics under conditions of scarcity and uncertainty. But this space is also... a law (ancient Greek: nomos), and more - the resulting care and responsibility for... the home (ancient Greek: oikos). It's a whole, seen increasingly in the model of a closed-loop sector economy, called circular economy [16].

After all, a university faculty is not just a place for acquiring knowledge. It is a space of personality formation (lifelong learning) and a space of meeting. It is easy to forget the master-student relationship when talking about actors, stakeholders. At the center of the logo of the new department is a grouse, the symbol of Poznan foresters [28]. In turn, the drawing of wood reminds us of the connection between the special character of the forest space and the dynamics of the wood industry. Today, the wood-based industry is a collective of all related industries, which together determine the quality of forest economy.

Such an integral popularization of science was dreamed of by the pioneer of forest science in Poland, Professor Jozef Rivoli. His work argues that: "The scientific movement, however formally with the practice of life in only distant contact, has nevertheless always been and will be its most effective stimulus" [14]. This challenge awaits rational, practical implementation. After all, it is probably not just about the position in the ranking of scientific units, expressed by a numerical measure (scores). How to make scientists publish works that are a stimulus for practice? Monographs, articles, handbooks: read, discussed, criticized, improved and implemented, stimulating the development of forestry, of which wood technology is an integral part - just a dream?

It should be emphasized that based on selected literature sources, on expert opinions gathered in individual in-depth interviews, as well as research and own experience [30, 31, 34], one cannot uncritically formulate a ready-made strategy. Rather, it is a starting point and even a provocation for open discussion, a polemic. Any community, including an institutional one, that does not engage in debate, does not create or change anything. It becomes static. It's not just a matter of artificially imitating today's fashionable learning organizations. Isn't the real prospect of growth in learning to adopt the attitude of being a learner? Perhaps it is precisely about the courage to learn, and the ability to have an authentic discussion and even an argument. Such discussion can only be undertaken by freethinking people. An entrepreneurial university can be institutionally established, as well as a next-generation faculty [11, 32]. However, does the administrative decision guarantee that it will not only be a structure, but a living community?

A university that has no space for discussion, that denies nothing, is dying. What does it live by then? The academic community is made up of people. What kind of people? Those capable of learning and cooperating. They are professors, academics, students, employees at all levels, or collaborators in the forestry and wood-based sector. The subjectivity of all members determines whether the organization is alive. It's also about the respect that comes from academic dignity. There can be no dignity if responsibility for other community members does not follow. How to build a new quality? Maybe we need to abandon individualism and create together (that's more than just "being creative"). A unique academic department, appropriate for the Department of Forestry and Wood Technology, is the forest. In this "cathedral of nature" it is necessary to educate successors. How? Perhaps by inviting them to join, simply admitting: with you I can be a student, for you a teacher.

5. CONCLUSION

Based on the results of retrospective studies, diagnostic survey, own experience, and then the results of comparative and descriptive analysis of selected sources, the following conclusions were formulated:

1) The new institutional situation, resulting from the establishment of the Faculty of Forestry and Wood Technology within the structures of the Poznan University of Life Sciences, is an opportunity for development on an integral and individual level.
2) The constitution, for forestry and the wood-based sector, of a unified, large organization (department), does not violate the specifics of the scientific process, nor the logic of methods and research tools. Through cooperation, it is an opportunity for development, measured not only by greater efficiency, but by obtaining new and additional results.
3) The aggregated potential of the new faculty allows for the integration of common areas of research and spaces for scientific, teaching and practical cooperation. The strength of development may be not so much competition,

but coopetition.

4) It seems necessary to preserve the distinctiveness of forestry and wood technology in terms of the special, specific issues of the two sub-disciplines. There is a need to support the identity and distinctiveness of even small units and to preserve the individual, unique nature of their operations.

REFERENCES

1. Aggestam, F., Giurca, A. (2021). The art of the "green" deal: Policy pathways for the EU Forest Strategy. Forest Policy and Economics, 128, 102456.
2. Adamowicz K., Szramka H. (2017). Gospodarka leśna a wolny rynek. [In:] W. Gil (ed.) Wyzwania leśnictwa wobec zachodzących zmian w środowisku przyrodniczym, oczekiwań społecznych, uwarunkowań ekonomicznych i prawnych, Instytut Badawczy Leśnictwa, Sękocin Stary, 14-16.03.2017, ISBN 978-83-62830-63-3, pp. 301-315.
3. Bergen, V., Löwenstein, W., Olschewski, R. (2013). Forstökonomie. Volkswirtschaftliche Ansätze für eine vernünftige Umwelt- und Landnutzung, Vahlens Handbücher der Wirt-schafts- und Sozialwissenschaften. Vahlen Verlag, München.
4. Broda, J. (2007). Dzieje najnowsze leśnictwa w Polsce 1918-2006, v.2, PTL, Warszawa.
5. von Carlowitz, H.C. (1713). Sylvicultura oeconomica: Anweisung zur wilden Baum-Zucht / Hans Carl von Carlowitz.-Reprint der Ausg. Braun, Leipzig, 1713.
6. von Carlowitz, H.C. (2013). Sylvicultura oeconomica oder haußwirthliche Nachricht und naturmäßige Anweisung zur wilden Baum-Zucht. München, ISBN 978-3-86581-411-1.
7. Cieszkowski, A. (1842). Organizacja handlu drzewem i przemysłu leśnego, Biblioteka Warszawska, Yearbook 1842, v. 1-2.; v. 3, n. 1-3; v. 4.
8. Francis (2015). Laudato Si' - Encyclical of the Holy Father Francis on Care for the Common Home, Liberia Editrice Vaticana.
9. Ilski, K. (2014). Rola lasu w cywilizacji z punktu widzenia historyka. [In:] Lasy i gospodarka leśna w kulturze i dziedzictwie narodowym, IBL, Sękocin Stary.
10. Kaja, J. (2009). Geneza metodologii deskryptywnej, Zarządzanie i Marketing, nr 15.
11. Klus, S., Wanat, L. (2013). Konkurencyjność uniwersytetu przyszłości. [In:] Burawski D. (ed.), Uniwersytet trzeciej generacji. Stan i Perspektywy rozwoju. Poznań ECWP, 40-58.
12. Kroth, W., Bartelheimer, P. (1993). Holzmarktlehre. Pareys Studientexte 77. Hamburg-Berlin: Paul Parey.
13. Kozłowska, M. (2019): Uniwersytet Przyrodniczy w Poznaniu. Historia i luminarze nauki. Wydawnictwo Naukowe UAM.
14. Kusiak, W. (2016). 90-lecie śmierci Józef Rivoli, Przegląd Leśniczy, 2, .14-15.
15. Kusiak, W., Mikołajczak, E., Wanat, L. (2018). Institutional and Industrial Symbiosis Case Study of Cooperation for Development in Forestry and Wood-Based Sector. [In:] Increasing the use of wood in the global bio-economy. Glavonjic B. (ed.), September 26th-28th, 2018, University of Belgrade, Belgrade, Serbia, pp. 388-399.
16. Kusiak, W., Wanat, L., Klus, S., Styma-Sarniak, K. (2019). Circular Economy from the Perspective of Scientific Research Papers jn the Forestry and Wood-Based Sector in Poland. [In:] Chobanova R.(ed.) Digitalisation and Circular Economy: forestry and forestry based industry implications, USB and WoodEMA, i.a., 33-38.
17. Łakomy, P. (2018). Wystąpienie Dziekana Wydziału Leśnego. Przegląd Leśniczy, 28(08), p.11.
18. Mantel, K. (1965). Forstwirtschaft sollte in Marktstrukturgesetz einbezogen werden. AFZ-Interview. [In:] Allgemeine Forst Zeitschrift (AFZ). Heft 23, p. 356.
19. Mantel, K. (1973). Holzmarktlehre. Lehr- u. Handbuch d. Holzmarktökonomie u. Holz-wirtschafts-politik, Melsungen Neumann-Neudamm. Berlin, Basel, Wien.
20. Młynarski, W., Kaliszewski, A. (2018). Efektywność gospodarowania w leśnictwie-przegląd literatury. Leśne Prace Badawcze, 79(3).
21. Molenda, T. (1965). Zarys ekonomiki drzewnictwa, PWRiL, Warszawa.
22. Pachelska, H. (2013). Przemysł drzewny na ziemiach polskich w latach 1870-1939, Biblioteka Uniwersytecka Warszawa.
23. Pączewski, L. (1924). Lasy. Przemysł i handel drzewny w Polsce, Instytut Wydawniczy „Bibljoteka Polska" [original spelling], Warszawa.
24. Podgórski, M. (1974). Zarys ekonomiki gospodarstwa leśnego. Wyd. AR w Poznaniu.

25. Ratajczak, E. (2013). Sektor leśno-drzewny w zielonej gospodarce. ITD, Poznań.
26. Rivoli, J. (1926). Ogólny zarys geografji leśnictwa według wykładów uniwersyteckich [original spelling],, Fiszer i Majewski Księgarnia Uniwersytecka, Poznań, pp. 157-162.
27. Szaban, J. (2015): Głuszec z cyrklem tokujący na otwartej książce-symbol poznańskich leśników. Przegląd Leśniczy, 25(12).
28. Sujová, A., Marcineková, K., Hittmár, Š. (2017). Sustainable optimization of manufacturing process effectiveness in furniture production. Sustainability 9(6), 923, https://doi.org/10.3390/su9060923 .
29. Wanat, L. (2009). Wood market science a new discipline of economic sciences supporting knowledge-based economy development, Intercathedra, nr 25, Poznań, ss. 149-151.
30. Wanat, L., Klus, S. (2015). Sytuacja konkurencyjna branży i mezoekonomiczne aspekty polityki sektorowej państwa na przykładzie rynku drzewnego w Polsce. Rynek-Społeczeństwo-Kultura „Przedsiębiorstwo na rynkach", 1 (13): 41-45.
31. Wanat, L. (2016). Gospodarka leśna: zrównoważona czy integralna? Dylematy badawcze z perspektywy polskiego rynku drewna okrągłego. Przegląd Leśniczy, 26(09), 26-27.
32. Wanat, L., Potkański, T., Chudobiecki, J., Mikołajczak, E., Mydlarz, K. (2018). Intersectoral and Intermunicipal Cooperation as a Tool for Supporting Local Economic Development: Prospects for the Forest and Wood-Based Sector in Poland. Forests 9 (9), 531, 1; https://doi.org/10.3390/f9090531.
33. Wanat, L., Sarniak, Ł., Dadek, K. (2019). Programowanie rozwoju nauk leśnych w Polsce według nowego indeksu czasopism naukowych, Przegląd Leśniczy, 8, 24-26.

Authors address:
Wanat, L.1*.
1 Department of Information Technology and Data Analysis, Faculty of Applied Sciences, Collegium Da Vinci, Poznań, Poland.
* Corresponding author: leszek.wanat@up.poznan.pl

REGIONAL DIVERSITY OF SELECTED WOOD BY-PRODUCTS SUPPLY AS AN ENERGY FEEDSTOCK – THE CASE OF POLAND

Sarniak, Ł.,Wanat, L., Wieruszewski, M., Kusiak, W.

Abstract: The paper discusses regional variations in the supply of selected wood by-products used as green energy feedstock (RES). Using secondary data available in databases of Polish public statistics as well as professional websites, an econometric analysis and modelling attempt was made. It was based on selected analytical tools, including open-source tools. It concludes with practical recommendations for the development of wood-based industries.
Keywords: wood-based sector, wood by-products, green energy, Poland

1. INTRODUCTION

The question of the real supply of woody biomass generated in forestry and the wood-based sector is an important economic issue. After all, the answer, based on institutional classification, can determine the actual use of a valuable raw material such as wood. It's not a problem to burn the wood, justifying that this is how the production of wood-based green energy works. It's much more difficult to make a rational selection of wood by-products so that their value and utility increases.

How to encourage practitioners to obtain finished products from wood raw material and of the highest quality, Is it possible to have a multi-stage selection of wood by-products? Only real wood waste, which cannot be used for another useful purpose, should be allocated for energy purposes. Otherwise, the strategic goals of the circular economy, as well as the "Green Deal" [1], will only be empty slogans. An ideology that allows you to look only for easy, convenient and not economically efficient solutions will not change anything in the forestry sector [15].

As a basic rule, biomass created in forestry is considered to be primarily firewood, harvested through thinning and maintenance cuts. Biomass arising in the wood industry, on the other hand, is all kinds of by-products and wastes from production processes. In this view, forest energy biomass is produced on forest land, and wood biomass is the product of wood processing in industry (in the sawmill, furniture and other wood-based industries) [13]. However, this is a very simplified classification.

After all, the place of roundwood processing is not only the forest. Also, the place of processing of wood assortments (round, sawn, semi-finished wood), is not always a processing factory. Another oversimplification is the alleged need to consider woody biomass as a suitable "raw material" for the production of thermal energy - for these wood industry enterprises, and sometimes for nearby households. Of course, various considerations determine such use of wood waste. This approach means that already the general classification of the raw wood (roundwood) in the forest, determines its purpose. After all, no one wants to do extra work (for free), making a detailed classification. Thus, a certain amount of valuable wood is irretrievably lost. Is this the only possible way out of this situation?

Indeed, the structure of woody biomass determines to a large extent the possibilities of its management. The issue is first of all the costs associated with its storage, as well as the costs of possible transportation. The easiest way to apply biomass is at the point of generation, i.e. at factories that processes the raw wood material.

For the wood industry, this is an opportunity to reduce dependence on external energy suppliers, In addition, even an ordinary sawmill can change from an energy consumer to a prosumer. It can be a competitive supplier to local consumers. But does this take into account the real value and utility of the wood by-products "converted" into energy, called waste for simplicity?

Of course not. These arguments alone convince us that it is worthwhile to undertake research to determine the real supply of wood waste (or in essence: wood by-products). However, such a valuable raw material as wood, although a renewable material, should not be wasted, but used for its best possible purpose [2, 3, 9].

2. MATERIAL AND METHODS

Would the only source of information on the offer of wood and wood-based by-products for energy purposes, then, be only industry databases of public statistics? Not necessarily. The starting point for identifying the supply of wood-based energy feedstock is an assessment of the potential ability to rationally process wood waste from harvesting or sawmilling.

The aim of the study was to assess the potential competitive ability (measured by the volume of supply) of the Polish timber market, to meet the needs of the green energy market, through the supply of wood by-products. This ability was assessed on a regional basis (administrative provinces in Poland), in 2020-2021 (year-on-year comparison), based on total roundwood harvest (wood raw material) in Poland (public and private forests), through the construction of the author's synthetic measure.

Why does it seem reasonable to adopt such a view? Since it was only for energy security that it was deemed necessary to include so-called firewood, it may be worth considering other economic objectives as well. After all, one must always see the prospect of opportunity costs. By allocating valuable wood raw material for fuel, we give up other possible uses, perhaps more efficient for the economy.

What scale of supply is being referred to? Previous studies of the Polish wood market show [11, 18] that in 2017-2021, the supply of wood for energy purposes (according to the classification of the Central Statistical Office), on average, did not exceed 7 million m^3 per year [14, 18]. One may ask, is this a lot or a little?

In order to find at least a rough answer to such a question, several data sources were consulted. Secondary data from sources of public statistics [14] were analyzed. The volume of raw wood (roundwood) harvested in Poland, in 2020 and 2021, was collected and aggregated. The volume of total wood was taken into account, including coarse (merchantable) wood, small-sized wood and stumpwood. Based first on a study of professional literaturę [5, 10, 12], and then by conducting an expert individual in-depth interview, a simple proprietary formula was proposed for calculation and econometric modelling [6, 16].

The potential supply of wood-based energy feedstock (EW) was determined by considering a total of: 2% share of coarse (merchantable) wood by-products, 70% share of smallwood by-products, and 25% share of stumpwood by-products. The volume of total wood harvesting was verified [m^3] on a regional basis (by Polish administrative provinces).

The size of the forest area in each province [ha] was also taken into account. On this basis, a synthetic measure (XEW) was constructed, relating the regional share of wood potentially destined for energy purposes (REW), to the region's forest area [m^3/ha], or *per unitas area*. Using this synthetic measure (XEW), an analysis of regional diversity of potential supply of wood by-products was then carried out for all Polish regions (administrative provinces). Regions were divided into classes (looking for a trend), taking into account similarities in the scale of potential supply differentiation. On the basis of comparative analysis (numerical values obtained) and descriptive analysis [4] (trend analysis), the results were discussed, and conclusions and recommendations were formulated.

3. RESULTS AND DISCUSSION

Performing the assumed scenario of the analysis, the results were collected, which are summarized in Table 1. Thus, regional diversity in the potential supply (volume) of wood-based by-products (woody biomass) for energy purposes in Poland in 2020 and 2021 was taken into account, according to the aggregate total measure (REW) and the unit synthetic measure (XEW).

The value of the unit synthetic measure (XEW), determined for the 2021 data, made it possible to draw up a visualization of the results on a regional map of Poland (by administrative provinces). The data on the synthetic measure of potential supply (XEW 2021), is illustrated in Figure 1 by separate classes.

Table 1. Regional diversity of potential supply of wood by-products for energy purposes in Poland in 2020 and 2021.

Region (voivodeship) in Poland	REW 2020 [m³]	REW 2021 [m³]	XEW 2020 [m³/ha]	XEW 2021 [m³/ha]
DOLNOŚLĄSKIE	114 825,42	126 381,61	0,1928	0,2118
KUJAWSKO-POMORSKIE	163 188,21	138 556,59	0,3865	0,3284
LUBELSKIE	69 722,82	90 365,18	0,1187	0,1536
LUBUSKIE	172 791,42	179 883,26	0,2504	0,2606
ŁÓDZKIE	72 239,92	75 415,32	0,1851	0,1933
MAŁOPOLSKIE	33 164,42	35 113,88	0,0763	0,0809
MAZOWIECKIE	111 638,24	126 621,52	0,1340	0,1521
OPOLSKIE	43 031,56	48 594,32	0,1714	0,1937
PODKARPACKIE	70 569,58	80 324,70	0,1035	0,1176
PODLASKIE	95 896,22	102 599,42	0,1535	0,1640
POMORSKIE	227 256,53	168 629,71	0,3406	0,2523
ŚLĄSKIE	56 818,74	65 261,46	0,1436	0,1645
ŚWIĘTOKRZYSKIE	46 866,58	48 141,26	0,1415	0,1450
WARMIŃSKO-MAZURSKIE	150 892,44	150 332,30	0,1968	0,1960
WIELKOPOLSKIE	236 704,24	246 563,46	0,3078	0,3209
ZACHODNIOPOMORSKIE	219 923,18	218 246,92	0,2685	0,2664

Source: Own elaboration based on CSO [https://stat.gov.pl/, accessed 13.05.2023] [14].

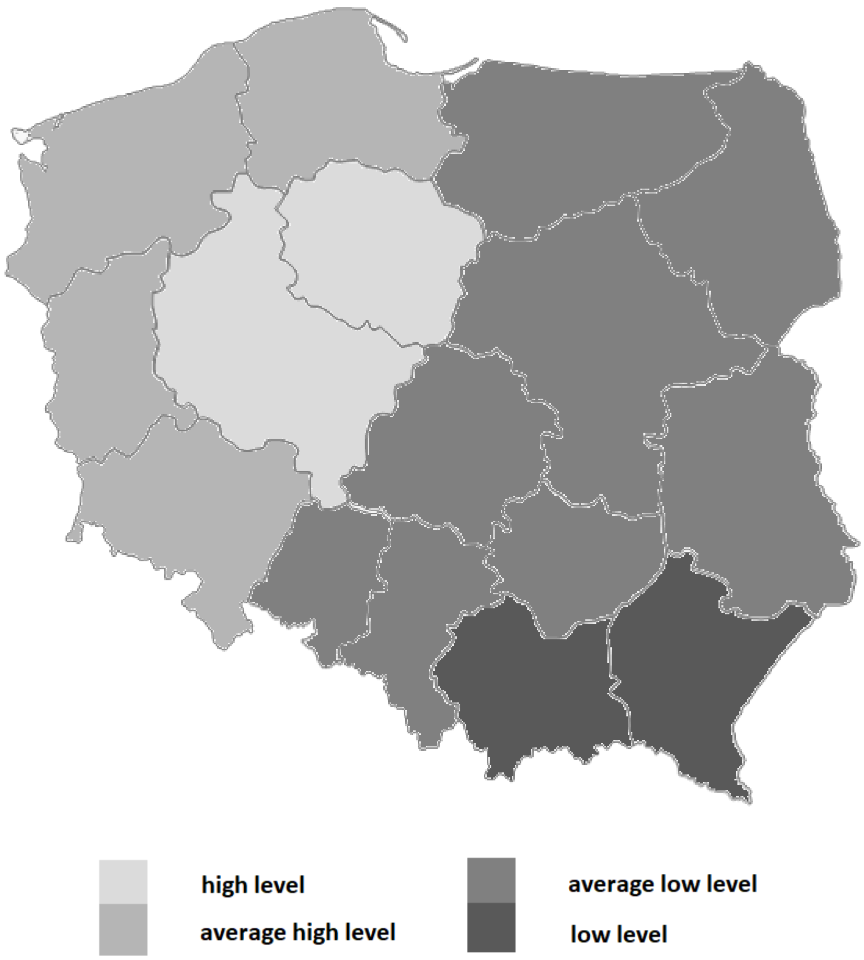


Figure 1. Trends (levels) of regional diversity of potential supply of wood by-products for energy purposes in Poland in 2020 and 2021. Source: Own elaboration based on [14].

More specifically, the potential supply (PS) data was ranked into four classes: high level (regions: wielkopolskie, kujawsko-pomorskie), average high level (regions: pomorskie, zachodniopomorskie, lubuskie, dolnośląskie), average low level (regions: lubelskie, łódzkie, mazowieckie, opolskie, podlaskie, śląskie, świętokrzyskie) and low level (regions: małopolskie, podkarpackie).

Significant differentiation in the potential supply of wood-based by-products (woody biomass) for energy purposes was noted, i.e. distinctiveness for the western and eastern parts on the territory of Poland. From the perspective of such ex-post analysis of competitive capacity, the leading regions are the voivodeships: wielkopolskie and kujawsko-pomorskie. These are also regions with significant (though not the largest) forest area potential, but primarily economically strong, innovative regions. Similarly, the regions identified at the average high level, have a very well-developed wood industry and rich forest resources. It is this visualization of trends that allows us to tentatively confirm that intelligent management of wood by-products (also aimed at green energy, but in a rational way), is possible in those Polish regions that are leaders in innovation and technological development [17]. In this way, green and innovative economy can be integrally connected [8], referring to the circular economy model [7].

4. CONCLUSIONS

Based on the calculated results, trend evaluation, as well as comparative and descriptive analysis, the following conclusions and recommendations were formulated:

1) The volume of potential supply of wood-based by-products (woody biomass) for energy purposes in Poland varies significantly by regional level.
2) Highly competitive capacity in the supply of wood for energy has regions located in western and northern Poland. These areas are characterized by high technological development and are referred to as smart growth regions.
3) Adopting an "expert" model for assessing competitive ability in the supply of wood-based by-products for energy purposes identifies a significant difference. Data from public statistics indicate that the volume of supply of energy wood averages 7 million m^3 per year. Meanwhile, the own research indicates that the intelligent use of wood raw material makes it possible to use the supply potential (in terms of value and utility) more efficiently, allocating an average of 2 million m^3 of wood per year for energy purposes. This is a significant "difference" that can be allocated to the production of at least wood finished products. Any decision other than burning wood will create much higher (than for so-called energy wood) added value in the forest-wood value chain.

REFERENCES

1. Aggestam, F., Giurca, A. (2021). The art of the “green” deal: Policy pathways for the EU Forest Strategy. Forest Policy and Economics, 128, 102456.
2. Bergen, V., Löwenstein, W., Olschewski, R. (2013). Forstökonomie. Volkswirtschaftliche Ansätze für eine vernünftige Umwelt- und Landnutzung, Vahlens Handbücher der Wirt-schafts- und Sozialwissenschaften. Vahlen Verlag, München.
3. von Carlowitz, H.C. (1713, 2013). Sylvicultura oeconomica oder haußwirthliche Nachricht und naturmäßige Anweisung zur wilden Baum-Zucht. München.
4. Kaja, J. (2009). Geneza metodologii deskryptywnej, Zarządzanie i Marketing, nr 15.
5. Kroth, W., Bartelheimer, P. (1993). Holzmarktlehre. Pareys Studientexte 77. Hamburg-Berlin: Paul Parey.
6. Kusiak, W., Mikołajczak, E., Wanat, L. (2018). Institutional and Industrial Symbiosis Case Study of Cooperation for Development in Forestry and Wood-Based Sector. [In:] Increasing the use of wood in the global bio-economy. Glavonjic B. (ed.), September 26th-28th, 2018, University of Belgrade, Belgrade, Serbia, pp. 388-399.
7. Kusiak, W., Wanat, L., Klus, S., Styma-Sarniak, K. (2019). Circular Economy from the Perspective of Scientific Research Papers jn the Forestry and Wood-Based Sector in Poland. [In:] Chobanova R.(ed.) Digitalisation and Circular Economy: forestry and forestry based industry implications, USB and WoodEMA, i.a., 33-38.

8. Lessem, R., Schieffer, A. (2016). Integral economics: Releasing the economic genius of your society. CRC Press.
9. Mantel, K. (1973). Holzmarktlehre. Lehr- u. Handbuch d. Holzmarktökonomie u. Holz-wirtschafts-politik, Melsungen Neumann-Neudamm. Berlin, Basel, Wien.
10. Młynarski, W., Kaliszewski, A. (2018). Efektywność gospodarowania w leśnictwie-przegląd literatury. Leśne Prace Badawcze, 79(3).
11. Mydlarz, K., Wieruszewski, M. (2022). Economic, Technological as Well as Environmental and Social Aspects of Local Use of Wood By-Products Generated in Sawmills for Energy Purposes. Energies, 15(4), 1337.
12. Ratajczak, E. (2013). Sektor leśno-drzewny w zielonej gospodarce. ITD, Poznań.
13. Sujová, A., Marcineková, K., Hittmár, Š. (2017). Sustainable optimization of manufacturing process effectiveness in furniture production. Sustainability 9(6), 923, https://doi.org/10.3390/su9060923 .
14. Statistical Yearbook of Forestry (2022). CSO Warszawa. Available online: https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3328/12/5/1/statistical_yearbook_of_forestry_2022.pdf [accessed on 13.05.2023].
15. Wanat, L. (2016). *Gospodarka leśna: zrównoważona czy integralna? Dylematy badawcze z perspektywy polskiego rynku drewna okrągłego*. Przegląd Leśniczy, 26(09), 26-27.
16. Wanat, L., Mikołajczak, E., Chudobiecki, J. (2018). The Value and Profitability of Converting Sawmill Wood By-Products to Paper Production and Energy Generation: The Case of Poland. Pulp and Paper Processing, 109. DOI: 10.5772/intechopen.80044 .
17. Wanat, L., Potkański, T., Chudobiecki, J., Mikołajczak, E., Mydlarz, K. (2018). *Intersectoral and Intermunicipal Cooperation as a Tool for Supporting Local Economic Development: Prospects for the Forest and Wood-Based Sector in Poland.* Forests 9 (9), 531, 1; https://doi.org/10.3390/f9090531 .
18. Wieruszewski, M., Górna, A., Mydlarz, K., Adamowicz, K. (2022). Wood Biomass Resources in Poland Depending on Forest Structure and Industrial Processing of Wood Raw Material. Energies, 15(13), 489, https://doi.org/10.3390/en15134897 .

Authors address:
Sarniak, Ł..[1]; Wanat, L.[2*]; Wieruszewski, M.[3]., Kusiak, W.[4].
[1] Department of Finance and Accounting, Faculty of Economics, Poznań University of Life Sciences, Poznań, Poland.
[2] Department of Information Technology and Data Analysis, Faculty of Applied Sciences, Collegium Da Vinci, Poznań, Poland.
[3] Department of Wood-Based Materials, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[4] Department of Forest Engineering, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[*] Corresponding author: leszek.wanat@up.poznan.pl

CERTIFICATION OF PERSONNEL IN THE WOODWORKING INDUSTRY – A NEED OR AN OVER-STANDARD?

Nováková, R.,Skýpalová, R.

Abstract: The management system certificate gives organizations a guarantee of credibility towards third parties. Similarly a personnel certificate can mean that employees of organizations in the woodworking industry are competent and skilled in fulfilling quality policies and goals in which they participate within their organization. In our contribution, we will deal with the certification of personnel as a form of evaluation of the personnel performance of employees in the woodworking industry.
Keywords: management system, personnel certificate, evaluation

1. INTRODUCE

Quality certificates have become an important part of declaring the competence of management systems, products, but also the skills and knowledge of employees. Certificates focused on the consumer chain, which are based on the principle of tracing the origin of certified wood from its harvesting to the final consumer of wood and paper products, are among the most well-known and most used in practice. The starting point for such certification was the PEFC (Programme for the Endorsement of Forest Certification Schemes) and FSC (Forest Stewardship Council) standards. Both certificates are considered equivalent. Minor differences are only that PEFC takes more into account international requirements and criteria, and FSC is more expensive due to the involvement of auditors from international organizations. In general, it can be said that certification based on the above-mentioned standards has several advantages, for example:

- the market advantage
- increasing the value of the trade name
- obtaining certainty about the purchase of wood legally and from suitable sources
- integration of the consumer chain into the company's management system, etc.

We can find the most products marked with the FSC logo in the world. It can be said that from beverage cartons, hygiene products, toys, home and garden furniture, floors, food packaging to books and paper products, even houses and bridges are built from FSC-labelled materials. Marking products with the FSC or SFCS 1004 logo means that wood and paper products come from forests managed in an environmentally appropriate, socially beneficial and economically viable way.

Part of every management, production, logistics and business system are people who should also demonstrate the necessary knowledge and skills in such a specifically focused area. Therefore, organizations should place great emphasis on staff training and require employees to be able to prove themselves with certificates focused on their specific skills. In practice, we are familiar with several normative documents that are a guide to what requirements are placed on increasing skills, namely ISO 17024 - Personnel certification and ISO 10015 - Guidelines for competence management and employee development.

1.1. Standard ISO 17024 Certification of personnel

The ISO 17024 standard and its application refers to the requirements that must be met by certification bodies that have the right to issue certificates for personnel. In practice, we can often meet organizations that like to issue various types of certificates. In reality, however, they are not authorized to issue them. Accreditation for personnel certification can only be obtained after meeting certain conditions, and the accreditation declares verification that the organization meets the requirements for activities, achieves the professional level that is specified for the certification of persons in accredited areas, and this for the entire period of validity. This information is important because the validity of certificates is limited in time, both for an authorized and accredited certification body and for a certificate granted for a specific job position or acquired skill. It goes without saying that if the certificate is used correctly, it becomes an important tool for personnel policy and work in the organization.

Credibility and content of the certificate

It is a paradox that the term "certificate" itself is not protected by a trademark or in any other way. This has the effect that in practice certificates are issued to anyone and for anything. This is also the reason for us to be able to orientate ourselves in a meaningful way, which certificates have a real value for personnel needs and which, on the other hand, are more or less worthless. It is clear from the above that certificates issued by a certification body that works according to the ISO 17024 standard must also meet several conditions that are supposed to guarantee the credibility of such a document. The personal certificate must contain:

a) Declarative name of the certified function (area of certification)
b) There must be a link to a source where the interested party can familiarize himself with the conditions of certification and the detailed specification of the certification
c) It must clearly state the identification of the certification body
d) It must contain a reference to the accreditation on the basis of which the certification body works
e) There must be a reference to a standard or other binding document that regulates the activity of the certification body
f) The date of validity of the certificate must be indicated. (1)

The function of the certificate as evidence of maintaining the professional level and professional quality of the holder is supported by the limited validity of the certificate, and the validity of the certificate must be renewed at specified intervals. The validity period is not longer than 5 years.

1.2. Standard ISO 10015:2019 Guidelines for competence management and employee development

This updated ISO standard provides guidance for an organization to establish, implement, maintain and improve competency management and workforce development systems to positively impact outcomes related to product and service conformance, as well as the needs and expectations of relevant stakeholders.

In this standard, competence is understood as the ability to use knowledge and skills to achieve intended results.

Competency management should consider all processes, functions and levels of the organization. When considering competence needs, the organization should determine the required competence to achieve the intended results, at the organizational, team, group and individual level, considering

a) Context of the organization, changes in external and internal affairs, needs and expectations of relevant stakeholders with a significant impact on competence needs
b) Potential impact of the lack of competence on the processes and efficiency of the management system
c) Recognition of individual levels of competence in relation to the ability to perform specified roles.
d) Opportunities to use the specified available competence in the design of work functions, processes and systems.

The standard contains chapters aimed at determining competence needs, organizational competence, assessment of current competence and development needs, competence management and employee development.

These requirements are also a prerequisite that if the organization wants to certify its system of management of competence and development of workers, it must declare how it implements their higher education, further training and gives space for obtaining relevant certificates. (2)

2. CERTIFICATION OF PERSONNEL IN THE WOOD PROCESSING INDUSTRY

A total of 39,957 employees work in the sector of forestry and woodworking industry in the Slovak Republic. The largest number of employees in the sector work in the Banskobystrica region (23.0%), followed by the Nitra region (17.1%) and the Žilina region (15.9%). The most numerous class is Operators and assemblers of machines and equipment (main class - hereafter only "HT" 8) with a share of 19.5%, Skilled workers and craftsmen (HT 7) with a share of 14.6%. Overall, the majority of employees work in lower-skilled HT and they make up 67.2% of the workforce in the sector. Of the mentioned number of employed persons, 71.5% are men and 28.5% are women.

From the point of view of the age composition of the sector's employees, the age group of 40-44 year old employees prevails. Overall, the sector's employee population is aging, as more 45-59-year-olds work in it than the younger generation aged 20-34. A substantial group is also made up of employees over 60 years of age, who make up 7.4% of the sector's employees.(5)

2.1 Dynamics of the level and specialization of skills of the sector-specific workforce in 2019 and 2021

From the point of view of economic activities, within which the combination of means of production, skilled labor, technological procedures and intermediate products create products or services, the following divisions of SK NACE Rev. 2:

- Forestry and logging,
- Wood processing and production of wood products except furniture,
- Furniture production.

At the same time, the forestry sector and the wood processing industry ensure the improvement of hunting grounds and the care of forest animals.

As of 12/31/2021, sector-specific employees accounted for approximately 1% of total employment for all sectors, while a decrease of approximately 0.1 p.p. was recorded during the pandemic period from 12/31/2019 to 12/31/2021.

From 31/12/2019 to 31/12/2021, there was a decrease in the number of sector-specific employees, especially in jobs:

- Machine operator in furniture production,
- Assistant worker in woodworking production,
- Wood processor,
- Woodworking machine setter and operator,
- Assembly worker in furniture production.

On the other hand, from 31/12/2019 to 31/12/2021 there was a slight increase in the number of sector-specific employees in jobs:

- Auxiliary worker in forestry,
- Manager (manager) of the forestry production unit,
- Plant manager in forestry.

The forestry and wood processing industry sector was characterized by approximately 63% representation of employees with work activities at a medium skill level from the total number of sector-specific employees, while this skill category also represented the largest part of sector-specific UoZ. As of October 31, 2021, people with previous work tasks at a medium skill level made up approximately 53% of the total number of sector-specific UoZ. The fewest sector-specific UoZs were with previous sector experience at a high level of skills, namely only about 3% of the total number of sector-specific UoZs.

Similar to other industries, we can divide the personnel on the basis of organizational structures. Although modern approaches point to the application of flat organizational structures and the creation of a process map that should largely correspond to the organizational structure, in practice there are still classic hierarchical organizational structures based on several levels of management. The number of management levels largely depends on the size of the organization operating in the wood processing industry and on the scope of its activity.

For this reason, we can also divide the needs for further training of employees into:

- The needs of courses, training and obtaining certificates for top management
- The needs of courses, training and obtaining certificates for middle management
- The needs of courses, training and obtaining certificates for lower levels of management and execution of specific specific works.

Before we focus on the professions that need to prove themselves with a certificate for the performance of their work, it will probably be necessary to explain why the terms course and training often appear side by side in professional literature. The explanation is that the course has a short-term character and the training should have a long-term character. (5)

2.1.1. Requirements for professional skills of selected professions in the woodworking industry

Table 1. Specific key competencies and professional skills maintenance specialist in wood processing (own processing)

Proposals for retraining and certification opportunities:

Specific key competencies	Professional skills
Organizing and planning work	control of robotics principles
The ability to make decisions and bear responsibility	mastery of basic knowledge of regulations to ensure safety and health protection at work, public health protection and fire protection; principles of safe work and health protection at work, principles of safe behavior at the workplace and safe work procedures
Strategic and conceptual thinking	planning and inspection of costs for the maintenance of machines, equipment and production lines in wood processing
Creativity	checking the operability of machines, equipment and production lines in wood processing
Leadership	creation of statistics and reports related to the maintenance of machines, equipment and production lines in wood processing
Analytical thinking	selection of employees for the team
Manual skills	ensuring the selection, purchase and delivery of machines, equipment, production lines and spare parts for machines, equipment and production lines in wood processing
	orientation in standards, technical documents and documentation related to the maintenance of machinery during wood processing
	solution of projects of technical and technological development and innovation in the field of wood processing
	managing cooperation with external organizations/institutions in the field of wood processing

Training focused on overall equipment effectiveness - OEE Overall Equipment Effectiveness
Internal auditor ISO 27001:2022 and ISO 19011 – information security management system
TISAX Trusted Information Security Assessment Exchange
Project management (beginners, advanced, experts)
Risk management
Internal auditor ISO 14001, ISO 45001, ISO 19011 – integrated management system
Training on the harmonized FMEA method
Environmental legislation in practice

An example of a typical profession that is carried out in the wood processing industry is the profession of lumberjack. Although this is almost the lowest level of work performance, certification is required here. It is recommended that loggers take courses aimed at felling trees, or courses aimed at observing safety measures. If a woodcutter wants to obtain a specialist woodcutter certificate, he should pass an examination focused on the following three areas:

a) technical design of power saws
b) methods of wood harvesting
c) safety rules

It includes a practical skills test. According to the new law, only workers with the qualification 6. according to ECTS can cut down trees. (4)

In the area of the woodworking industry, there are many professions that directly impose requirements for proof of the relevant certificate. In our example, we will discuss the profession of maintenance specialist in wood processing. No specific certificate is required for this profession.

However, the requirements for professional skills provide a prerequisite for the possibility of increasing one's qualification level also through personnel certificates.

Input information:

For the performance of this profession, higher education II is assumed degree. The performance of this job is not regulated by a special legal regulation. o certificate or written certificate is required by law to perform this job.

3. CONCLUSION

Personnel certification was the first to be promoted in the area of quality management. In the ISO 9000 standards, requirements related to human resources and requirements for competences, skills and professional competence were directly incorporated. Even if in some companies employees are replaced by artificial intelligence, robots and cobots, people still remain as the bearer of innovation and change as the most important asset of any organization. In order for the organization to declare that not only its systems, products and services meet the high demands and demands of customers for quality, it must regularly help its employees improve their skills and knowledge. Completed training should be of a high quality level and set up to bring general benefit to all participants, and their output should be personnel certificates.

REFERENCES

1. Dočkal, Z., Martínková, I.: Příručka pro certifikaci personálu v oblasti dalšího vzdělávání. In: Kvalita v dalším profesním vzdělávaní, apríl 2008
2. Norma ISO 10015:2019 Návod na manažérstvo kompetentnosti a rozvoj pracovníkov
3. https://www.tuvsud.com/sk-sk/cinnosti/odborna-sposobilost-zamestnancov/sfcs-1004-certifikacia-vyrobkov
4. https://www.sustavapovolani.sk/sektorove-rady/sektorova-rada-pre-lesne-hospodarstvo-a-drevospracujuci-priemysel/o-sektore/vplyv-pandemie-koronavirusu-na-trh-prace-z-hladiska-urovne-zrucnosti-uplatnovanych-na-pracovnych-miestach-v-sektorovej-strukture-nsp-sri/
5. https://www.sustavapovolani.sk/register-zamestnani/pracovna-oblast/karta-zamestnania/496270-%C5%A1pecialista-%C3%BAdr%C5%BEby-v-spracovan%C3%AD-dreva/
6. https://hnonline.sk/prakticke-hn/42987-personalne-certifikaty-a-ich-prinosy

Authors address:

Nováková, R.[1], Skýpalová, R.[2]
Department of Economy and Management, Ambis university , Prag, Czech republic
*Corresponding author: re.novakova@gmail.com

AGENDA 2030 FOR SUSTAINABLE DEVELOPMENT AS A STARTING POINT FOR THE ENVIROMNENTAL GOALS OF SUSTAINABLE DEVELOPMENT AND BIOPROCESSES IN THE WOOD PROCESSING INDUSTRY

Nováková, R, Pauliková, R.

Abstract: The 2030 Agenda is focused on 17 Sustainable Development Goals, which are elaborated into 169 related sub-goals. Their ambition is to guide the structural political, economic and social transformation of individual countries of the world in response to the threats and crisis situations that many economies are currently facing. In our paper, we will deal with the impact of the environmental goals of sustainable development on bioprocesses in the woodworking industry.
Keywords: sustainable development, bioprocesses in the woodworking industry, economic

1. WHAT IS THE CONTENT OF AGENDA 2030? ORIGINAL AGENDA 2030 FOR SUSTAINABLE DEVELOPMENT

The document "Transforming our world: Agenda 2030 for sustainable development" is so far the most comprehensive set of priorities for achieving the goal of sustainable development. Philosophically, it is based on the Millennium Development Goals1 (MDGs) from 2000, which were the first ever common vision, the first widely accepted framework for global development and the creation of development policy. The 2030 Agenda highlights the need to build a new strong partnership for development. It is a call for cooperation based on mutual responsibility, common interest and true national ownership. The interest of all actors with the aim of mobilizing human resources, finances, as well as the support of the general public, will be a key factor in the implementation of the agenda.

The basic idea of the document was the preservation of nature with its diversity and self-regulating abilities to future generations, to pass on enough sparingly used natural resources and a quality environment. At the same time, the premise of moving towards a functioning, nature-saving economy, based on the principles of efficient use and fair distribution of resources and towards a healthy, meaningfully functioning society, enabling the satisfaction of social, spiritual and cultural needs was established. The national strategy determined orientation towards 8 long-term priorities (integrated goals) of the sustainable development of the Slovak Republic elaborated into 28 goals and almost 300 measures.

Part of the implementation of the goals of sustainable development is also the establishment of a set of evaluation indicators and a mechanism for regular monitoring and reporting on the achieved results. (3)

The transformative power of the 2030 Agenda is represented by the 17 Sustainable Development Goals (SDGs), elaborated into 169 related sub-goals (see Appendix 1), whose ambition is to guide the structural political, economic and social transformation of individual countries in the world in response to the threats that humanity faced today.

The integration element manifests itself in the 2030 Agenda as a connection of all three dimensions of sustainable development: economic, social and environmental. In this sense, universality means "leaving no one behind" and fulfilling its goals is expected from everyone, including developed states.

Agenda 2030 is not legally binding, but respecting it is a natural duty of developed countries, among which Slovakia belongs. It expresses the intention of UN member states to lead their development towards sustainability and to set their national policies, strategies and planning to contribute to the achievement of global goals. (3)

In Slovak conditions, the implementation of Agenda 2030 will therefore be governed by the following principles:

the principle of permanence – The national priorities for the implementation of Agenda 2030 in the Slovak Republic should be based on a broad consensus, the conclusion of which should involve all interested actors and the public. The durability of the vision, resulting from its society-wide mandate, will immediately enable long-term

effective strategic planning in various areas of sustainable development of society.
the principle of long-term and multigenerational implementation – the implementation of the 2030 Agenda should take place over a long-term horizon, exceeding political cycles, and residents across generations must be included in it

principle of indivisibility – When implementing the 2030 Agenda, it is not possible to build two parallel worlds, one for sustainable development and the other for all other de facto functioning public policies. The 2030 Agenda should become an integral part of all public policies and should be reflected in the development and investment plans of central state administration bodies, as well as regional and local self-government.

the principle of coherence of policies for sustainable development - the implementation of the 2030 Agenda should be a tool for finding synergies between public policies and balance between their economic, social and environmental aspects. The 2030 Agenda thus has the potential to significantly contribute to sectoral equality and balance between the agendas of the economically, socially and environmentally focused departments. Synergies must also be found between the internal and external dimensions of sustainable development, while it is crucial to take into account the impact of domestic policies and decisions on the global environment

the principle of vertical synergies – For the effective implementation of the 2030 Agenda, it is necessary to find the right balance between the competences and responsibilities of state authorities at the national, regional and local levels.

the principle of a government-wide approach – the implementation of the 2030 Agenda is possible only in the case of intensive interdepartmental cooperation. The coordination of activities must come from a supra-departmental level in accordance with the recommendations of the Organization for Economic Cooperation and Development (hereinafter referred to as "OECD") and the European Commission.

adoption principle – It is necessary that the 2030 Agenda be consulted, formulated and implemented in such a way that the government, municipalities, the private, non-governmental and academic spheres, as well as the public, adopt it as one of their own priorities.

the principle of open governance - As part of the implementation of the 2030 Agenda, it is essential to observe the principles of open governance, which are mainly transparency, citizen participation, public administration responsibility and openness through new technologies. In the field of participation, the "Rules for involving the public in the creation of public policies" developed by the Office of the Plenipotentiary of the Government of the Slovak Republic for the Development of civil Society and approved by the Government of the Slovak Republic, or the methodology of the international Transition network movement, are useful tools

the principle of decision-making based on evidence - Decision-making on all public policies, and thus also on issues related to the implementation of the 2030 Agenda, should be based on relevant, verifiable and comparable data.

principle of value for money – Activities aimed at implementing the 2030 Agenda should be characterized by high efficiency and value for public funds spent. (3)

1.1. Environmentally and socially sustainable production and consumption

The pressure on the consumption of natural resources and rising energy prices, together with the tightening of international standards in the field of greenhouse gas emissions, are strong incentives for increasing the efficiency of the economy, reducing the consumption of inputs and minimizing waste.

Pollution of environmental components (primarily air and soil) will be possible to prevent in the future, provided that it is possible to change the production structure in the direction of weakening energy, raw material and environmentally demanding industries. It will be important to transform the usual methods of industrial production into ecologically friendly production based on sustainability and efficient use of resources. The result will be a significant reduction of environmental risks and prevention of environmental damage. Intelligent choice of materials, eco-design, taking into account the life cycle of products and materials and appropriate production procedures can significantly reduce the negative effects of production and consumption on the environment. In addition to consumer protection, the consumer policy will focus on educating them towards a responsible and sustainable consumption model.

Adaptation measures must be aimed at areas whose stability, functionality and productivity are significantly dependent on the climate, namely land management (agriculture, forestry, fisheries) and water management
In terms of forest area, Slovakia is among the countries with the highest forest cover in the EU. Forests are a basic component of the natural and landscape environment, they are multifunctional and serve economic, social and environmental purposes.

Agriculture and forestry must ensure self-sufficiency in the current sustainable production of high-quality local food, feed, biomass and resources for bioproduction. Emphasis must be placed on sustainable landscape management, efficient and sustainable use of domestic natural resources, a gentle approach to the environment and support for rural areas. It is necessary to give preference to the valorization of limited domestic natural resources, for example in the form of processing biomass into biomethane, thereby achieving a better environmental use of this renewable resource compared to its burning.

It is also necessary to support the implementation of innovative practices in agriculture, which will mean an increase in biomass production without indirect changes in land use (especially changes in the crop cultivation scheme). At the same time, it is important to take into account the ecological functions of forest stands, including soil protection and water management, which significantly affect the quality of the environment. (2)

2. BIOPROCESSES IN THE WOOD PROCESSING INDUSTRY

Bioprocess means a specific process by which the desired products are obtained with the help of living cells or their components. The UN Convention on Biological Diversity defines biotechnology as the use of living systems and organisms to create products, or any technology that uses biological systems, living organisms or their derivatives to produce or modify products or processes. (4)

Wood is a renewable and universal raw material that is widely available. You can make practically anything out of it. The wood is easy to process, has excellent structural properties, is strong and flexible. In addition, it has good thermal properties, it radiates energy and heat. Wood is a beautiful, natural and noble material. It is the most promising raw material and ecological material of the future. It offers perfect options for waste-free processing. Wood is recyclable and does not burden the environment either during production or disposal.

All wood processing industries producing cellulose, paper, paper packaging, sawmill products, wood-based panels, furniture and bioenergy have with regard to raw materials that use a common denominator: it is either wood or recycled paper and wood. The production chain starts with logging in the forest and ends with the final wood product. The overall competitiveness of production is significantly influenced by the competitiveness of individual phases of the production process. In the activities of the forestry-timber complex, all three pillars of sustainable development are fully respected: economic efficiency, social acceptance and usefulness, and environmental performance.

Currently, the forestry and woodworking industries are facing many problems and challenges. They are directly affected by climate change, competition in obtaining wood resources, changing consumer demand, increasing economic competition and increasing complexity of production processes. Despite the mentioned problems, a big opportunity for the traditional forestry-timber sector using non-food renewable natural resources in a sustainable and responsible way is the increasing use of biomass resources - dendromass compared to fossil resources. The sector is an important part of the developing economy, but also of the whole society, a new prospective direction based on biotechnology.

Several documents referred to as "green policies" have been adopted on the ground of the international organizations of the UN and the EU, with varying degrees of binding for the member states. These found their addressee also in the sector of forestry and woodworking industry. Their creators are aware of the growing influence of the forestry sector, not only towards the policy of green buildings or public procurement, but from the broad point of view of their ecological, economic and social impacts. This also includes green energy, as renewable and sustainable energy: solar, water, geothermal, wind and biomass energy, which are used as alternatives to conventional sources. (2)

2.1. Vision 2030 for the European forestry and timber sector ((Proposal developed by the Technology Platform of the forestry and timber sector)

In the aforementioned vision for the year 2030, it is stated that the forestry and timber sector will be an important element of a bio-based society. The real added value of its production and services will double compared to 2010. The basis of the development of the sector will be the demands of consumers, the intelligent and sustainable use of forest resources. The sector will continuously strive for new business activities that will create job opportunities and improve the rural economy.

According to the vision, innovation will create a "new forestry and timber sector" that will play a decisive role in providing society with renewable energy, housing and home furnishings; in the replacement of plastics derived from oil in the production of packaging and other uses. The innovation and competitiveness support scenario assumes the creation, support or expansion of markets, cost reduction and increase in profitability. In the area of products, they are e.g. improvement of construction systems from composite wood products, biorefineries and so-called "smart paper". in the production of healthy food ingredients and pharmaceuticals, as well as providing an alternative raw material in the clothing industry in competition with current synthetic fibers and cotton.(3)

3. CONCLUSION

In Slovakia, there is still a lack of larger deliveries of the most valuable assortments I. and II. quality class, as a result of little interest in the domestic market and weaker marketing to place these goods abroad. In the case of wood products, a high volume of wood panels and paper is exported, which can be evaluated positively, as it is a production with a high added value. On the other hand, a relatively high share of lumber exports (with a lower added value), which in some years reaches up to 50% of lumber production in Slovakia, is a negative phenomenon. The absence of a comprehensive strategy and its implementation, mainly due to the non-alignment of the policies of the departments involved, has caused the following problems in recent years:

- discrepancy between the spatial distribution of economically available sources of forest fuel biomass and the places of their consumption,
- the effort of energy producers to obtain the cheapest possible fuel leads to increasing pressure on the energy use of higher quality wood,
- financial support to energy producers (covering part of the investment costs, purchase prices of electricity) is insufficiently reflected in increasing the economic availability of forest fuel biomass in the form of fuel chips,
- there are persistent barriers preventing a more effective mobilization of sources of fuel wood biomass on forest and non-forest land,
- missing or uncoordinated support for the development of the fuel biomass market, cooperation between biomass producers and users. (5)

Acknowledgements: This paper was written with the financial support of the granting agency KEGA of The Ministry of Education, Science, Research and Sport of the Slovak Republic as a part of the project No. 025STU-4/2023 "Building a modular laboratory for the development of management systems auditing skills".

REFERENCES

1. Finnish Forest Association: Durable optical fibre made of methyl cellulose, 2021a, Forest Bioeconomy Future Catalogue, Innovations. URL: https://forest.fi/productsservices/durable-optical-fibre-made-of-methyl-cellulose/#44563940NPVPD SR
2. NPVPD SR
3. Weiss, G. (2011): Innovation in Forestry: Territorial and Value Chain Relationships. CAB International. MPG Books Group. UK
4. https://www.minzp.sk/agenda-2030/
5. http://kchsz.sjf.stuba.sk/download/Procesne_strojnictvo/Kapitoly/PS2_13_Bioprocesy.pdf
6. https://www.istp.sk/clanok/16129/drevospracujuci-priemysel-inovuje

7. https://osha.europa.eu/cs/publications/green-jobs-and-occupational-safety-and-health-foresight-new-and-emerging-risks

Authors address:
Nováková, R.[1], Pauliková, A.[2]
[1] Department of Economy and Management, Ambis university, Prag, Czech republic
[2] Department of Industry management, Faculty of Matherial and Sciences, Slovak university of Technology, Trnava, Slovakia
[*]Corresponding author: re.novakova@gmail.com

POTENTIAL USE OF STUMPWOOD AS AN ENERGY RAW MATERIAL - THE CASE OF POLAND

Kusiak, W., Sarniak, L., Wanat, L., Wieruszewski, M.

Abstract: The paper discusses the potential use of stumpwood, as an energy feedstock. Stumpwood is an underutilized and undervalued part of tree biomass. It is now being explored as a potential source of raw material for the Renewable Energy Sources (RES) sector. In Poland, it is possible to harvest pine stumpwood, and the potential of this raw material is estimated at about half a million cubic meters per year. This is an important area for forestry development. In the study, based on literature and own observations (case study), a pilot research was designed. The purpose of this research is to preliminarily identify the possibility of harvesting pine stumpwood in the Notecka Forests area in western Poland.
Keywords: stumpwood, wood by-products, green energy, Notecka Forests, Poland.

1. INTRODUCTION

Stumpwood is a woody resource, harvested from the roots and stump formed after a tree is felled. It is estimated that stumpwood can account for up to several percent of a tree's total biomass. The economic use of stumpwood, mainly pine, for energy and industrial purposes has been used with varying intensity in the past. Interestingly, since the 1990s, the use of stumpwood has almost totally disappeared. Today, mainly due to deforestation of land for road construction, about two thousand cubic meters of stumpwood are harvested annually.

This underutilized and undervalued portion of tree biomass is now becoming a focus due to the development of Renewable Energy Sources (RES) [8, 16]. Of course, an additional reason is also the limited supply of wood and the search for valuable materials for extractive compounds for the chemical industry.

The species structure of Poland's forests identifies numerous pine stands, suitable for stumpwood harvesting, which occupy more than 60 percent of the forest area. Pine grows predominantly on sandy soils, It occupies bole habitats, the share of which is about 50 percent of the area. Estimating the total annual volume of pine logging close to 30 million cubic meters, it can be estimated (taking into account specific natural conditions) that the stumpwood resource that can be harvested is about 0.5 million cubic meters [12].

Previous research related to the evaluation and efficiency of stumpwood harvesting, and the subsequent possible use of this raw material, is limited [6, 7, 9]. Meanwhile, there are economic, natural and social arguments in favor of undertaking such activity in Poland, related to the activation of rural regions [10, 15]. At least several important reasons can be identified. First is the need to seek additional sources of income and use underground wood resources as: Renewable Energy Sources (RES), raw material for industrial production (in the pulp and board sector), or extraction of certain chemical components (for the chemical and pharmaceutical industries) [5, 7, 11].

Second: the available stumpwood resources represent an opportunity to create a new market (within the wood market), guaranteeing potential customers a steady (and not just incidental) supply of wood-based raw material [2, 4, 13]. Third: there is an opportunity to develop and implement in forestry an innovative technology for harvesting stumpwood and roundwood - in a single technological operation.

This can be done with a harvester (ease of moving the head in the machine). It's a chance to make better use of the stub material, by lower cutting off the root part (stump). And finally, fourth: it's an opportunity to improve conditions for the growth of forest natural regeneration (the depression after the removed roots "naturally" prepares the soil, promotes water retention, creates micro-shading - important in hilly areas). Moreover, flat logging areas can be differentiated (unnaturalization effect) [3]. Stumpwood also plays an important role in soil stabilization. Thus, it has a biological function (dead wood) and is a reservoir of nutrients for the environment. When designing the use of stumpwood, it is therefore necessary to assume only a partial harvest of it.

2. MATERIAL AND METHODS

The datasources for the design of the stumpwood application research were literature studies (within the framework of available research results) [5, 6, 9, 11], information from public statistics [12, 17, 18], as well as fieldwork and own observations, conducted in the Notecka Forests [1] in Wielkopolska region (western Poland). To this end, a participatory observation technique (within the framework of the diagnostic survey method) was used, as well as a case study method. A feasibility study of the research was carried out, leading to verification of the usefulness of stumpwood harvested in the Notecka Forests in practice.

3. RESULTS AND DISCUSSION

In implementing the pilot scenario of the study, the following goals were defined:

- preliminary verification of the practical feasibility of obtaining stumpwood chips (so-called "bio-chips", as a raw material for the renewable energy sector;
- exploration of the possibility of using stumpwood for other tasks (e.g., as a source for obtaining chemical compounds to counteract the depreciation of the wood raw material and produce bio-components for biological filters).

The results, obtained by different researchers, were compared. It was found [7, 11, 14] that stumpwood from trees growing in harsh natural conditions (Notecka Forests), showed better properties than stumpwood from trees growing on fertile soils, including former farmland. The final product for the RES sector can therefore be so-called "bio-stumpwood" and "bio-chips", obtained from treated stumpwood.

As part of the own research, practical opportunities for stumpwood harvesting in the Notecka Forests were identified. A participatory observation technique was used. The results were documented in photographs (see Figures 1 through 4). Not only is the machine-assisted combined harvesting of roundwood, including stumpwood, been illustrated (Figure 1). Also shown are the occurrence of raw wood along with stumpwood in forest damage areas (Figure 2), as well as a view of the post-felling area in the forest and stumpwood (Figure 3), and the storage of raw wood from stumpwood by the forest transport route (Figure 4).
.

Figure 1. The machine-assisted combined roundwood harvesting, including stumpwood.
Source: Own elaboration based on [author's photos by Wladyslaw Kusiak, Notecka Forests]

Figure 2. The raw wood along with stumpwood in forest damage areas
Source: Own elaboration based on [author's photos by Wladyslaw Kusiak, Notecka Forests]

Figure 3. Stumpwood raw material in the forest post-felling area
Source: Own elaboration based on [author's photos by Wladyslaw Kusiak, Notecka Forests]

Figure 4. Stocking of stumpwood raw material by the forest transport route
Source: Own elaboration based on [author's photos by Wladyslaw Kusiak, Notecka Forests]

The general scenario of research and technology has been designed. It is assumed that the research will be carried out on one - typical areas (logging) with the extraction of stumpwood. This means in practice that 50-60% of the total number of stumps can be extracted. The use of large machines (e.g., JD 1270-type harvesters) is envisaged. During stumpwood harvesting, it is possible for the harvester's head to capture the arrow of the tree at a height of about 2 meters. This will make it easier to tilt it, and consequently uproot the tree along with its roots. In the final stage, the harvester head moves to the place where the root part (stump) is cut off. This will enable further manipulation of wood sorties. The harvested stumpwood will be taken to the logging depot. Then it will be chipped there, and further transported to the recipient. In the case of short distances, it will be taken out of the forest in unprocessed form.

Stampwood resources will be estimated by weighing them fresh (measuring device in the head of the harvester). In this way, the potential on the territory of the forest district and the Promotional Forest Complex "Notecka Forests" will be determined (resources on an annual basis /number of stumps per unit area/ and a 10-year forecast). There will also be a measurement of labor intensity (time and cost), machine productivity, as well as overall harvesting costs with the separation of total stumpwood harvesting costs.

4. CONCLUSIONS

Based on the comparative and descriptive analysis, the following conclusions and recommendations were formulated:

1. Harvesting stumpwood as a raw material for the green energy sector in the Notecka Forests is possible. This is an underestimated and untapped potential of forestry and the wood-based sector. Research in this area should be continued.
2. An economic alternative could also be the use of treated stumpwood for the production of wood-based panels, as there is a large production center in the examined territory.

REFERENCES

1. Anders, P., Kusiak, W. (2022). Puszcza Notecka. Przewodnik krajoznawczy (Notecka Forest. A sightseeing guide). G&P Oficyna Wydawnicza Poznań, 3rd ed. updated.
2. Banaś, J., Utnik-Banaś, K. (2022). Using timber as a renewable resource for energy production in sustainable forest management. Energies, 15(6), 2264.

3. Bergen, V., Löwenstein, W., Olschewski, R. (2013). Forstökonomie. Volkswirtschaftliche Ansätze für eine vernünftige Umwelt- und Landnutzung, Vahlens Handbücher der Wirt-schafts- und Sozialwissenschaften. Vahlen Verlag, München.
4. Kusiak, W., Mikołajczak, E., Wanat, L. (2018). Institutional and Industrial Symbiosis Case Study of Cooperation for Development in Forestry and Wood-Based Sector. [In:] Increasing the use of wood in the global bio-economy. Glavonjic B. (ed.), September 26th-28th, 2018, University of Belgrade, Belgrade, Serbia, pp. 388-399.
5. Laitila, J., Yrjö, N. (2015). Efficiency of integrated grinding and screening of stump wood for fuel at roadside landing with a low-speed double-shaft grinder and a star screen. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, 36(1), 19-32.
6. Laurila, J., Lauhanen, R. (2010). Moisture content of Norway spruce stump wood at clear cutting areas and roadside storage sites. Silva Fennica, 44(3), 427-434.
7. Mendes, V.T., C., Moreira, R., Portugal, A., Graça VS Carvalho, M. (2021). Biorefining of Pinus pinaster stump wood for ethanol production and lignin recovery. Chemical Engineering & Technology, 44(6), 1043-1050.
8. Mydlarz, K., Wieruszewski, M. (2022). Economic, Technological as Well as Environmental and Social Aspects of Local Use of Wood By-Products Generated in Sawmills for Energy Purposes. Energies, 15(4), 1337.
9. Mikolajczak, E. (2015). Possibilities of using stump wood for energy generation purposes. Intercathedra, 31(4), 51-58.
10. Nawrot, H., Wanat, L. (2022). Las i coaching. Moda czy innowacja? Forest and coaching. Fashion or innovation? Paideia / Παιδεία, 4: 293–313.
11. Rahman, A., Khanam, T., Pelkonen, P. (2019). Is stump harvesting for bioenergy production socially acceptable in Finland?. Journal of Cleaner Prod., 229, 1233-1242.
12. Statistical Yearbook of Forestry (2022). CSO Warszawa. Available online: https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3328/12/5/1/statistical_yearbook_of_forestry_2022.pdf [accessed on 18.05.2023].
13. Wanat, L. (2016). *Gospodarka leśna: zrównoważona czy integralna? Dylematy badawcze z perspektywy polskiego rynku drewna okrągłego*. Przegląd Leśniczy, 26(09), 26-27.
14. Wanat, L., Mikołajczak, E., Chudobiecki, J. (2018). The Value and Profitability of Converting Sawmill Wood By-Products to Paper Production and Energy Generation: The Case of Poland. Pulp and Paper Processing, 109. DOI: 10.5772/intechopen.80044 .
15. Wanat, L., Potkański, T., Chudobiecki, J., Mikołajczak, E., Mydlarz, K. (2018). *Intersectoral and Intermunicipal Cooperation as a Tool for Supporting Local Economic Development: Prospects for the Forest and Wood-Based Sector in Poland.* Forests 9 (9), 531, 1; https://doi.org/10.3390/f9090531 .
16. Wieruszewski, M., Górna, A., Mydlarz, K., Adamowicz, K. (2022). Wood Biomass Resources in Poland Depending on Forest Structure and Industrial Processing of Wood Raw Material. Energies, 15(13), 489, https://doi.org/10.3390/en15134897 .
17. *** https://ec.europa.eu/eurostat/, [accessed on 18.05.2023].
18. *** https://stat.gov.pl/ [accessed on 18.05.2023].

Authors address:
Kusiak, W. [1]; Sarniak, Ł. [2]; Wanat, L.[3*], Wieruszewski, M. [4].
[1] Department of Forest Engineering, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[2] Department of Finance and Accounting, Faculty of Economics, Poznań University of Life Sciences, Poznań, Poland.
[3] Department of Information Technology and Data Analysis, Faculty of Applied Sciences, Collegium Da Vinci, Poznań, Poland.
[4] Department of Wood-Based Materials, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[*] Corresponding author: leszek.wanat@up.poznan.pl

HARVESTING DILEMMAS IN POLISH PRIVATE FORESTS - SELECTED EXAMPLES RELATING TO THE BIOECONOMY

Wanat, L., Wieruszewski, M., Kusiak, W., Sarniak, L.

Abstract: The study discusses selected examples of raw wood harvesting and utilisation in Polish private forests. A comparative analysis was applied, based on data from public statistics databases and industry reports. Secondary data available on websites were also used, using selected open-source analytical tools. In conclusion, the most important challenges to timber production in private forests and potential consequences for Poland's wood-based sector have been identified.
Keywords: wood-based sector, private forests, wood harvesting, removals, Poland

1. INTRODUCTION

Private forests in Poland account for almost 20% of the country's total forest area. The vast majority, are forests owned by individuals. According to the Agricultural Census (Powszechny Spis Rolny) [2], the area of forests on individual farms was about 1.2 million hectares. They were mostly formed by 2-3 plots of land [3], forming part of about 900,000 farms in Poland. Slightly different data was published for individual farms by the Central Statistical Office (CSO). According to the CSO, the area of private forests was 863 thousand hectares, belonging to 543 thousand farms [12]. The average area of forest land on a farm was, depending on the data source, from about 1.41 hectares [3] to about 1.59 hectares.

The results of the Large Area Forest Inventory (Wielkoobszarowa Inwentaryzacja Stanu Lasu) indicate that the economic condition of private forests is good [3]. Again, the statistics vary by source. Timber harvesting in private forests, according to the Central Statistical Office [12], reaches a level well below the data of the Large Area Forest Inventory [2, 3]. These differences are most likely the result of farmers using wood for immediate farm needs. The volume of timber harvested in this way (usually single trees) is generally not recorded by the forestry supervisory services.

Despite the growing importance of private forests in Poland, interest in them as a subject of research is still small and incidental [1]. Not even the important contribution of these forests to the creation of environmental quality and economic potential, which is relatively poorly exploited, is convincing [5]. This is determined by the characteristics of private forest farms, including their small average area and low profitability [4]. These indicators mean that private forests are not a source of significant income for their owners.

The lack of real economic benefits means that farmers who own a forest do not pay special attention to it. They concentrate on farming. This is also determined by supply competition from the monopolist - the State Forests (Państwowe Gospodarstwo Leśne – Lasy Państwowe). This is because the main supplier of raw timber in Poland is the public forestry sector [12].

2. MATERIAL AND METHODS

The relatively small volume of information on the economic potential of the private forestry sector in Poland prompts research in this area. Indeed, this potential appears to be poorly exploited, especially in the areas of bio-economy, efficient use of wood, wood by-products and other applications [6, 7, 10, 14]. For these reasons, the present study was also undertaken. The purpose of the study was to identify the most important dilemmas faced by private forest owners in Poland who intend to develop economic activity in the wood-based sector, rather than just traditional agricultural activities [13, 14].

As a first step, data available in public statistics databases were used. However, a serious limitation of the analysis turned out to be the incompleteness of the data [2, 3, 12]. This is because private forest owners do not report as accurately as State Forestry units do. This limitation alone made it necessary to use approximate, estimated methods. First of all, the data with the highest reliability (share of forest area by ownership form, raw material abundance, and only then the volume of timber harvesting) were relied on.

The basic information on forest and wood resources at the disposal of private owners was verified. The legal situation was analyzed. A literature study [2, 3, 10, 18] was used, available statistical data [12, 17, 18] was verified, and individual in-depth interviews were conducted with selected private forest owners in Poland. On this basis, key conclusions and recommendations for further research were formulated.

3. RESULTS AND DISCUSSION

Based on available public statistics, it can be said that the area of private forests in Poland is 1.786 million hectares (2021). This represents 19.3% of the total forest area. However, it is necessary to consider the need for additional data as well. According to measurements published in the report of the Large Area Forest Inventory (2016-2020), the area of areas with forest vegetation that are not included in the land and building records is: 912.5 thousand hectares [2, 3, 12]. So, should this area be treated as additional private forests? This dilemma needs to be resolved.

Whatever it may be, it is worth noting that Poland has more private forests than the total forest area in, for example, Belgium, Ireland or Slovenia. The forest area at the disposal of private owners has remained more or less constant in recent years. However, the share varies strongly regionally. The largest percentage of private forests is found in the eastern part of Poland, particularly in the regions of Mazowieckie, Lubelskie, Podlaskie and Małopolskie (see: Figure 1). It is also in these regions that the highest volume of wood harvesting was recorded.

However, it should be noted that data reporting in private forests is inaccurate, so the data obtained are approximate. Therefore, the potential of the forest-wood private sector in Poland is most simply referred to just the percentage of forest area. Obtaining more complete information would require intensive field surveys. An alternative is to introduce additional statistical obligations, obliging private forest owners to report on their economic activity in the forest-wood sector on an ongoing basis. However, the prescriptive system has its weaknesses. As a general rule, it does not work.

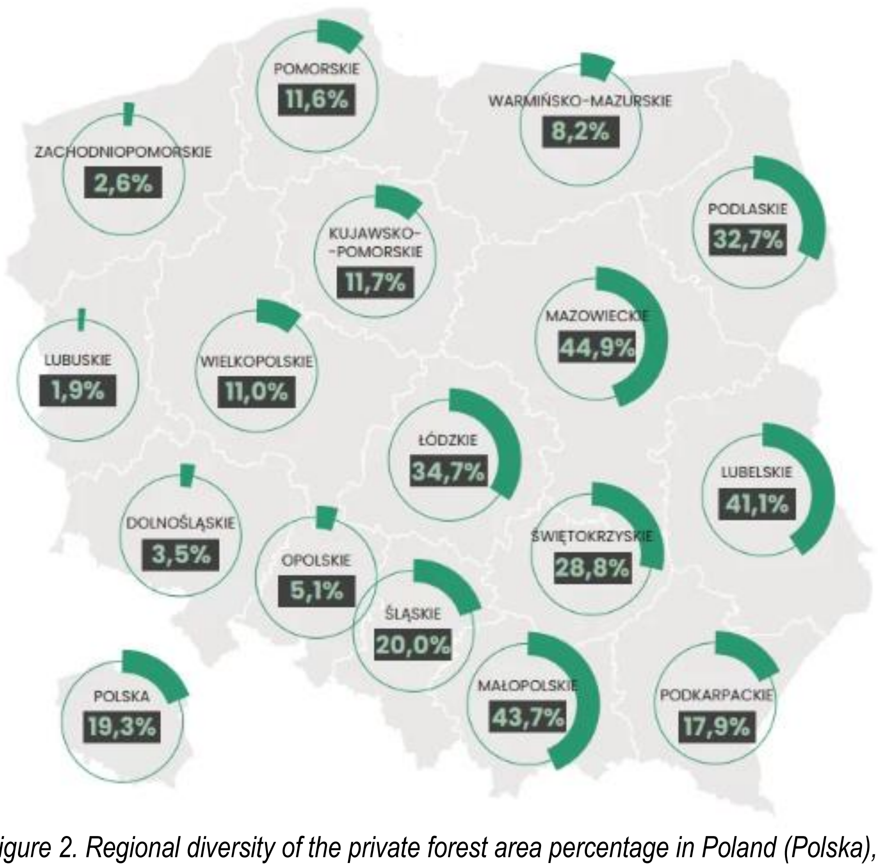


Figure 2. Regional diversity of the private forest area percentage in Poland (Polska), by administrative voivodeships (2021) [12]
Source: Own elaboration based on [https://www.stat.gov.pl/, accessed on 13.05.2022]

Of course, the Forest Law imposes a number of obligations on owners, including forests that are not owned by the State Treasury. They concern the principles of universal forest protection, sustainability of forest maintenance, continuity and sustainable use of all forest functions, as well as the principle of increasing forest resources [3]. A characteristic feature of non-public forests in Poland is their high fragmentation and dispersion. This very characteristic definitely hinders the management and supervision of forest management carried out in private forests.

Based on individual in-depth interviews and professional publications, the average size of a private forest owned by a single owner is 1 hectare. How to estimate the bio-economic potential of this sector? It is formed by about 900,000 private forest holdings, which are owned or co-owned by about 3 million individuals [2, 3]. As already mentioned, the parcels of land included in private forests are, as a rule, fragmented. In addition, they often have unregulated ownership. This potential remains poorly exploited.

Private forests in Poland are characterized by low intensity of raw wood processing. The wood resources of private forests amount to 459 million m³, and their average abundance is estimated at 257 m³/ha (for comparison, in the State Forest Holding 'State Forests' this indicator is 290 m³/ha) [17, 18]. In private forests, on the other hand, the proportion of deciduous species is higher. II and III age classes (20-60 years) predominate [2, 3, 11]. Study visits to private forests confirm, unfortunately, the numerous neglect of stand maintenance.

Table 1. Wood (timber) removals in Poland in selected years (2010-2021) [thousand m³]

SPECIFICATION	2010 [thousand m³]	2015 [thousand m³]	2020 [thousand m³]	2021 [thousand m³]
REMOVALS [total in Poland]	35 467	40 247	39 669	42 244
Timber	33 568	38 327	38 064	40 692
*public forests	32 325	36 920	37 032	39 402
*owned by the State Treasury	32 194	36 695	36 802	39 161
of which:				
**managed by the State Forests	31 882	36 497	36 621	38 962
**national parks	201	179	155	161
*gmina owned	131	131	125	135
*other	-	94	105	107
***private forests**	**1 243**	**1 407**	**1 032**	**1 289**
Small wood (only public forests)	1 899	1 920	1 604	1 553
Stumpwood (by the State Forests)	0,1	0,3	4,4	1,6
Timber [in m³ per 100 ha] (Poland)	**368,0**	**415,9**	**411,0**	**439,2**
*Public forests	434,7	495,6	495,4	526,9
**of which by the State Forests	450,8	514,1	514,2	546,8
***Private forests**	**73,8**	**79,7**	**57,8**	**72,2**
Timber [in m³ per capita]	0,87	1,00	1,00	1,07

Source: Own elaboration based on [https://www.stat.gov.pl/, accessed 03.05.2022] [18].

Table 1 summarizes data on removals in Polish forests, in selected years of the 2010-2021 period. Against the background of total wood removals, the economic activity estimated in private forests is shown, comparing it with more precise data made available for state forests.

The general dilemma, arising from the discussion of residual and underestimated results for Poland's private forests, remains the same. It is a significant potential that remains poorly exploited. Its fragmentation may encourage more economic activity in the green energy sector than large-scale industrial wood processing.

4. CONCLUSIONS

Based on the comparative and descriptive analysis, the following conclusions and recommendations were formulated:

1) The economic potential of Poland's private forests is significant but poorly exploited.
2) The main barriers to the development of the private forestry and wood-based sector include:

- high fragmentation of forest parcels, their dispersion, relatively small area per owner;
- intermingling of private and state land;
- the lack of marking the boundaries of forest properties;
- unregulated legal status of many forest properties;
- a deficit in the knowledge and experience of private forest owners on forest management and knowledge of current regulations.

It seems that some opportunity may lie in the creation of networks and associations of private forest owners [3, 9, 15]. It would also be necessary to take measures to improve the quality of forest management supervision in private forests. However, this needs not only systemic solutions and financial resources, but also systematic research, conducted in this specific forestry sector. Combining the knowledge of practice, as well as the experience of state forestry, provides an opportunity for the integral development of both forest-based sectors in Poland.

REFERENCES

1. Bartczak, A., Metelska-Szaniawska, K. (2015). Should we pay, and to whom, for biodiversity enhancement in private forests? An empirical study of attitudes towards payments for forest ecosystem services in Poland. Land Use Policy, 48, 261-269.
2. Gołos, P. T., Ukalska, J., Wysocka-Fijorek, E., Gil, W. (2021). How much is the abandonment of forest management in private forests worth? A case of Poland. Forests, 12(9), 1138.
3. Gołos, P., Wysocka-Fijorek, E., Gil, W., Wójcik, R., Orzechowski, M. (2021). Jakość nadzoru nad gospodarką leśną w lasach prywatnych oraz wiedza ich właścicieli w zakresie gospodarki leśnej. Sylwan, 165(2), 91-100.
4. Grzywiński, W., Skonieczna, J., Jelonek, T., Tomczak, A. (2020). The influence of the privatization process on accident rates in the forestry sector in Poland. International journal of environmental research and public health, 17(9), 3055.
5. Konczal, A. A. (2020). Why can a forest not be private? A post-socialist perspective on Polish forestry paradigms–an anthropological contribution. Forest Policy and Economics, 117, 102206.
6. Kusiak, W., Mikołajczak, E., Wanat, L. (2018). Institutional and Industrial Symbiosis Case Study of Cooperation for Development in Forestry and Wood-Based Sector. [In:] Increasing the use of wood in the global bio-economy. Glavonjic B. (ed.), September 26th-28th, 2018, University of Belgrade, Belgrade, Serbia, pp. 388-399.
7. Kusiak, W., Wanat, L., Klus, S., Styma-Sarniak, K. (2019). Circular Economy from the Perspective of Scientific Research Papers jn the Forestry and Wood-Based Sector in Poland. [In:] Chobanova R.(ed.) Digitalisation and Circular Economy: forestry and forestry based industry implications, USB and WoodEMA, i.a., 33-38.
8. Lessem, R., Schieffer, A. (2016). Integral economics: Releasing the economic genius of your society. CRC Press.
9. Mantel, K. (1973). Holzmarktlehre. Lehr- u. Handbuch d. Holzmarktökonomie u. Holz-wirtschafts-politik, Melsungen Neumann-Neudamm. Berlin, Basel, Wien.
10. Mederski, P. S., Borz, S. A., Đuka, A., Lazdiņš, A. (2021). Challenges in forestry and forest engineering–Case studies from four countries in East Europe. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, 42(1), 117-134.
11. Mydlarz, K., Wieruszewski, M. (2022). Economic, Technological as Well as Environmental and Social Aspects of Local Use of Wood By-Products Generated in Sawmills for Energy Purposes. Energies, 15(4), 1337.
12. Statistical Yearbook of Forestry (2022). CSO Warszawa. Available online: https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3328/12/5/1/statistical_yearbook_of_forestry_2022.pdf [accessed on 03.05.2023].
13. Wanat, L. (2016). *Gospodarka leśna: zrównoważona czy integralna? Dylematy badawcze z perspektywy polskiego rynku drewna okrągłego*. Przegląd Leśniczy, 26(09), 26-27.
14. Wanat, L., Mikołajczak, E., Chudobiecki, J. (2018). The Value and Profitability of Converting Sawmill Wood By-Products to Paper Production and Energy Generation: The Case of Poland. Pulp and Paper Processing, 109. DOI: 10.5772/intechopen.80044 .

15. Wanat, L., Potkański, T., Chudobiecki, J., Mikołajczak, E., Mydlarz, K. (2018). *Intersectoral and Intermunicipal Cooperation as a Tool for Supporting Local Economic Development: Prospects for the Forest and Wood-Based Sector in Poland.* Forests 9 (9), 531, 1; https://doi.org/10.3390/f9090531 .
16. Wieruszewski, M., Górna, A., Mydlarz, K., Adamowicz, K. (2022). Wood Biomass Resources in Poland Depending on Forest Structure and Industrial Processing of Wood Raw Material. Energies, 15(13), 489, https://doi.org/10.3390/en15134897 .
17. *** https://ec.europa.eu/eurostat/, [accessed on 03.05.2023].
18. *** https://stat.gov.pl/ [accessed on 03.05.2023].

Authors address:
Wanat, L. [1*] , Wieruszewski, M. [2]; Kusiak, W.[3]., Sarniak, Ł. [4].
[1] Department of Information Technology and Data Analysis, Faculty of Applied Sciences, Collegium Da Vinci, Poznań, Poland.
[2] Department of Wood-Based Materials, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[3] Department of Forest Engineering, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[4] Department of Finance and Accounting, Faculty of Economics, Poznań University of Life Sciences, Poznań, Poland.
[*] Corresponding author: leszek.wanat@up.poznan.pl .

INNOVATION POTENTIAL AND INNOVATION NETWORKS IN THE FOREST BIOECONOMY: THE CASE OF BULGARIA

Georgieva, T.

Abstract: Many factors, such as the challenges associated with the fossil economy and the EU's strategic shift towards the use of renewable biomass, have brought the forest bioeconomy into focus. Innovation is key to achieving such structural changes, as many types of modernization are needed to develop an efficient economy that is less dependent on fossil fuels. The aim of this paper is to select a set of indicators to measure the innovation potential by also exploring the role of innovation networks in the production of innovation in forest bioeconomy. Geographically, we localize our research in the region of Bulgaria. The paper summarizes the theory dealing with indicators of innovation potential, as well as the use of different types of collaboration networks in search for forest bioeconomy innovation in a regional context. We compare the values of the selected indicators with average values for the European Union. The methodology presented here is applicable to future research on drivers of forest bioeconomy innovation in other national or regional contexts.
Keywords: innovation potential, innovation networks, forest bioeconomy

1. INTRODUCTION

The new challenges to the sustainable development of the forest sector in the EU require increasing the contribution to the green economy and overcoming the adverse effects of climate change, protecting biological diversity, balancing the growing use of biomass as an energy source with the requirements for efficient use of resources. The New EU Forest strategy for 2030 takes a new holistic approach to strategic planning by emphasizing that "Europe needs its forests" not only for rural development, but also for the environment, biodiversity, economic activities in forests, bioenergy and to combat with climate change. Renewable energy sources as important local renewable resources are defined as a priority of the National energy policy in Bulgaria. In this regard, an assessment of innovation potential and innovation networks in the forest bioeconomy in Bulgaria is a useful addition to existing research on some ecological practices in the forest sector in the region (Turlakova, T., 2021; Kirechev, D. et. al., 2022; Slavova, G. et al., 2019).

The aim of this paper is to select a set of indicators to measure the innovation potential by also exploring the role of innovation networks in the production of innovation in forest bioeconomy.

2. INNOVATION POTENTIAL, INNOVATION NETWORKS AND FOREST BIOECONOMY

The concept of innovation potential for the growth of the system at the expense of innovations was firstly introduced by K. Frimenom in 1970-80s (Valitov, S. et al., 2015) . Innovation potential refers to the capacities in applying innovative procedures. It is a fundamental capability that entails the efficacy and reliability of the processes that an organization uses in developing and implementing innovations. To measure innovation potential, it is common to use proxies such as patent and R&D expenditure. Closely related to the concept of innovation potential is the notion of innovation networks. The idea behind the innovation networks is that the organizations are unable to meet the increasing demand for complex knowledge using solely their own internal resources. Consequently, they rely on external resources to supply their knowledge and technological competencies (Morrar, R. et al., 2012). The positive influence of networking behavior on innovation output is confirmed by many studies. Innovation is the result of an interaction between local actors, government and research institutions, and although the literature emphasizes the importance of territorial proximity for the exchange of tacit knowledge, innovation networks can be considered both at the national and international level (Pinto, H. et al., 2014).

According to European Bioeconomy Strategy (EC, 2018) the bioeconomy is a more innovative and low-emissions economy, reconciling demands for sustainable agriculture and fisheries, food security, and the sustainable use of renewable biological resources for industrial purposes, while ensuring biodiversity and environmental protection. Some researchers point out that the concept strongly appeals to the forest-based sector, which consists of all the industrial activities that use forest biomass in general. (Wolfslehner, B., 2016). In addition, some recent studies have revealed that the concept of forest bioeconomy is not really a field of its own. Almost completely different organizations along the supply chain are characterized by a low level of collaboration between actors in the different categories (Lovrić, M. et al. 2017).

3. MATHERIALS AND METHODS

Data on the innovation potential in the forest sector has been retrieved from the Mediterranean forestry research framework database (http://www.foresterra.eu/tablas/investigacion_sumario.php), created under the FORESTERRA International Project "Enhancing FORest RESearch in the MediTERRANean through improved coordination and integration ", which is part of the ERA-NET initiative. The indicators for the innovation potential of the Bulgarian forest sector have been compared with the average values for the other seven European Union member states, covered by the project - Slovenya, Croatia, France, Greece, Italy, Portugal and Spain. The innovation potential of the forestry sector is characterized by three input of research indicators (Overall Budget per year; Budget of Forestry projects per year (M€) and Forestry Permanent Staff Number) as well as two indicators of innovation activity (ISI Papers per year (Nr) and Forestry projects per year (Nr)). In addition, two derived indicators for employee innovation activity (papers per person and average number of projects per person) have been calculated and commented. Secondary data on forest bioeconomy research and innovation in Europe, obtained in the study carried out by the European Forest Institute (Lovrić, M.and others 2017) , were used to assess the comparative position of Bulgaria in terms of key indicators of innovation potential and innovation networks. To characterize the comparative position of Bulgaria according to the "research capacity" and " EC's research funding in the field of the bioeconomy " indicators, results were used regarding the country's position according to the value of a normalized index of research capacity, summarizing the capacity in four forest bioeconomy categories (forest systems, forest biomass and raw materials, primary processing and secondary processing). Each member state is ranked according to these criteria. Data on the strength of interactions in international innovation networks is accessed from from the interaction map derived from the same study. In cases of implemented from 1 to 30 project interactions with partners from another country, the relationship is characterized as "very weak"; the relationship is assumed to be "weak" for the number of realized collaborations in the range of 31 to 90; "strong" - with the number of realized collaborations in the range from 91 to 120 and "very strong" - with more than 120 realized project collaborations. Data from strategic policy documents, such as the latest Strategic Plan for the Development of the Forestry Sector and the National Strategy for the Development of the Forest Sector, have also been analyzed.

4. RESULTS AND DISCUSSION

Table 1 presents the values of the selected indicators for the innovation potential of the forestry sector in the member states of the European Union, covered by the Mediterranean forestry research framework database.

The indicators of financial investments in forest research characterize the innovation potential in the country as weak - the annual budget allocated for research is the lowest compared to all the member states of the European Union for which information is contained in the database - the amount of these costs for Bulgaria is more than 15 times smaller than the average (Table 1). The absolute amount of expenditure on Forestry projects per year and the Average budget per project are significantly lower compared to thevalues for the rest of the member states for which information was collected through the FORESTERRA International Project. The indicators of innovation activity also testify to weaknesses in the innovation potential of the forest sector in the country - ISI Papers per year (Nr), which have significantly lower values for all member states from Central and Eastern Europe, has the lowest values for Bulgaria (the number is more than 6 times smaller than the average for the studied member states). The number of projects in which researchers have participated is the smallest for Bulgaria. Alarming results are also shown by the data on the productivity of the human factor engaged in scientific research in this field - the share of ISI Papers and the number of projects per permanent employee are significantly lower than the average values. The country is at the bottom of the ranking for these indicators among the E U countries included in the database.

The top ten countries of the European Union with the highest research capacity in the field of forest bioeconomy are Western European (Lovrić, M.and others 2017). In this regard, Bulgaria lags behind most of the countries of Central and Eastern Europe, ranking one of the last places (24th). Bulgaria's capacity has been identified in several research areas, and more specifically - in forest systems (on the research topic "Forest inventory and economics"); in Forest biomass & raw materials ("Forest management" and "Tree breeding and forest biotechnology"); in Primary processing ("Pretreatment technologies") as well as in Secondary processing ("Chemical conversion", "Biopolymer processing" and other bio based final products). The available scientific potential is perceived as not fully used to solve significant practical problems in the sector (Ministry of Agriculture and Food, 2014).

Table 1. Innovation potential indicators in the forest sector in some member states of the European Union

Indicator	Bulgaria	Slovenya	Croatia	France	Greece	Italy	Portugal	Spain	Average
Overall Budget per year (M€)	1,8	6,6	10,1	87,4	6,7	50,8	8,0	54,1	28.19
Budget of Forestry projects per year (M€)	0,7	3,3	3,0	21,2	2,1	16,4	2,2	17,0	8.23
Percentage of the budget allocated to Forestry projects (%)	39	50	30	24	31	32	27	31	-
Mean budget per forestry project (M€/project)	0,02	0,09	0,04	na	0,05	0,19	0,20	0,15	0.11
Forestry Permanent Staff (Nr) (Res.+Tech.+Adm)	245	64	286	878	143	551	114	481	345
ISI Papers per year (Nr)	21	38	24	261	135	226	108	221	129
Forestry projects per year (Nr)	34	35	73	na	46	87	11	111	57
ISI Papers per permanent staff member (Nr/ employee)	0.09	0.59	0.08	0.30	0.94	0.41	0.95	0.46	0,48
Forestry projects per permanent staff member (Nr/ employee)	0.14	0.55	0.25	na	0.32	0.16	0.10	0.23	0,25

Differences in EC's research funding in the field of the bioeconomy explain to a large extent the divergence in the innovation potential of the Member States in this field. These research investment figures are consistent with the ranking of Member States according to their research capacity. The leading twelve countries according to this criterion are Western European. In Central and Eastern Europe, Slovenia, Poland and the Czech Republic are ranked first. Again, Bulgaria occupies one of the last places according to this indicator for investments in forest bio-innovations. Funding for scientific research in the forestry sector is provided almost entirely from the budget of the Ministry of Agriculture and Food and the State Forestry Executive Agency, which is assessed at the political level as insufficient to finance significant scientific research and development with a practical effect on the forestry sector (Ministry of Agriculture and Food, 2014). The funds for the development of science in the forestry sector are provided by the budget of the Forestry Executive Agency in line with the financing of the activities of the experimental stations in a total amount of about BGN 800,000 on average per year and BGN 130,000 – for investment in the development of scientific and applied topics related to the forest sector.

Data on collaboration between countries in Forest systems are shown in Table 2.

Table 2. Collaboration between countries in forest systems (predominant strength of interactions)

Countries in Western Europe	Predominant strength of interactions in networks	Countries in Central and Eastern Europe	Predominant strength of interactions in networks
Austria	weak	Bulgaria	very weak
Belgium	weak	Croatia	very weak
Denmark	weak	Cyprus	-
Finland	weak, strong, very strong	Czech Rep.	weak
France	weak, strong	Estonia	very weak
Germany	weak, strong, very strong	Hungary	very weak
Greece	weak, very weak	Latvia	very weak
Ireland	very weak, weak	Lithuania	very weak
Italy	weak, strong	Malta	-
Luxembourg	very weak, weak	Poland	very weak, weak
Netherlands	weak	Romania	very weak, weak
Portugal	weak	Slovakia	-
Spain	weak,strong, very strong	Slovenia	very weak
Sweden	weak, strong		

Bulgaria is part of the larger group of member states from Central and Eastern Europe that have built only very weak links with actors in other countries (there are no participants in other countries with which more than 30 project interactions have been implemented) and there is not a single case in which an organization from Bulgaria was a project coordinator. In this group, only the organizations in the Czech Republic, maintain stronger ties with actors from more than one country including Norway, Spain, Italy and Romania.

In conclusion, as a result of the low research potential of the forest sector in Bulgaria, the potential for innovations in the forest bioeconomy is weak, and the existing one is underutilized. Public funding is relatively low, and interactions in innovation networks, both international and within the state actors, are weak. The contribution of science to the development of the forest bioeconomy is insufficient due to the low level of investment in scientific research and development activities (R&D) and lack of developments with practical effect.

REFERENCES

1. Kirechev D.; Kirecheva E. (2022): *Model for Crisis Management in the Forest Sector of Bulgaria*, Crisis management and safety forestight in forest-based sector and smes operating in the global environment, WoodEMA 2022
2. Lovrić, M.; Lovrić, N; Mavsar, R (2017): *Synthesis on forest bioeconomy research and innovation in Europe.* EFI.
3. Morrar, R.; Faïz Gallouj; Hakim H. (2012): *Public-private innovation networks and innovation activities in French service firms,* Journal of Innovation Economics & Management, vol. 10, no. 2, 2012, pp. 191-217.
4. Pinto, H. (2014): *Knowledge and Cooperation Determinants of Innovation Networks: A Mixed-Methods Approach to the Case of Portugal*. Journal of technology management & innovation, vol. 10, pp. 83-102
5. Slavova, G.; Ivanova, M. (2019):*Someone's garbage is someone else's treasure"-Cross-sectoral integration in circular economy*. Digitalisation and circular economy
6. Turlakova, T. (2021): *Bioeconomy as an Innovative Approach to Rural Development in the Context of Common Agricultural Policy in EU:* [Електронен ресурс]. Sixth International Scientific Conference: Business and Regional Development, EDP Sciences, 2021, 01008 - 1-7. - (SHS Web of Conferences; 120). / DOI 10.1051/shsconf/202112001008
7. Valtov, S.; Khakimov A.. (2015): Innovative potential as a framework of innovative strategy for enterprise development. International Conference on Applied Economics, ICOAE 2015, 2-4 July 2015, Kazan, Russia
8. Wolfslehner, B.; Linser, S. et al. (2016): *Forest bioeconomy– a new scope for sustainability indicators.* From Science to Policy 4. EFI.

9. *** European Commission (2018): EU Bioeconomy Strategy URL: https://op.europa.eu/s/yITt
10. *** Mediterranean forestry research framework database URL: http://www.foresterra.eu/tablas/investigacion_sumario.php

Authors address
Georgieva, T.
Department of Agricultural Economics, Faculty of Economics, University of Economics, Varna, Bulgaria
*Corresponding author: t.georgieva@ue-varna.bg

COMPETENCES FOR THE DIGITAL AND SUSTAINABLE TRANSITION OF WOOD AND FURNITURE SECTOR

Goropečnik, L., Remic, K., Jošt, M., Oblak, L., Kropivšek, J.

Abstract: The wood and furniture industry is at the forefront of achieving the objectives of the European Green Deal, as wood is recognized as a key strategic raw material and the industry therefore has great potential for long-term development. However, we need to ensure that resources are used in a sustainable way, with minimal environmental impact during production and consumption, which can also be achieved through the digitalization of processes. But this digital and sustainable transition will not be possible if employees will not have suitable competences. The aim of this study is to identify key competencies for digital and sustainable transition of the wood and furniture industry. With this aim we formed a focus group of diverse experts who assessed the importance of each competence. Based on the results, we could evaluate which topics and to what extent should be included in the curricula, to equip students and employees in the wood and furniture sector with the necessary competences.
Keywords: bioeconomy, wood and furniture industry, sustainable, digital, competences

1. INTRODUCTION

The world today faces numerous challenges that transcend borders and impact societies on a global scale. These challenges are interconnected and require joint efforts to address them effectively. This has also been recognized by the United Nations (UN), as never before have world leaders committed to joint action and effort on such a broad and universal policy agenda as with the 17 integrated and indivisible Sustainable Development Goals (SDGs), which balance the three dimensions of sustainable development: economic, social, and environmental (Baeyens & Goffin, 2015). The European Union (EU) plays a supporting role in the design and adoption of new policies, strategies, and actions, such as the SDGs. For example, through the bundles of policy initiatives as part of the European Green Deal issued by the European Commission (EC) in 2019, the EU and its members aim to become climate neutral by 2050 (EC, 2020b). Leading initiatives of the European Green Deal also include: a strategy for European industry, in which they highlight a fair, green and digital transformation as key to a competitive and more resilient Europe (EC, 2016), an action plan for a circular economy (EC, 2020a), and a strategy for a sustainable bioeconomy (EC & DG RTD, 2018). In Slovenia, most of the adopted strategic documents also support the transition to a circular bioeconomy (Juvančič et al., 2021). Although the concepts of circular economy and bioeconomy are not new, they have gained prominence in industry, research discussions, and among policy makers over the past decade (Bugge et al., 2016). The circular economy is defined as a regenerative system in which inputs, waste, emissions, and energy losses are minimized by closing material and energy flows (Geissdoerfer et al., 2017). The bioeconomy refers to an economic system that uses renewable biological resources such as plants, animals, and microorganisms to produce goods, services, and energy (EC, 2012). It mainly refers to conventional industries with existing biomass-based value chains (agriculture, forestry, food industry, fisheries, aquaculture, wood products manufacturing) and less conventional industries (energy, pharmaceuticals, chemicals) where biological raw materials and processes are replacing non-renewable raw materials of fossil origin (Ollikainen, 2014). The wood and furniture industry is at the forefront of achieving the goals of the European Green Deal, as wood is recognized as a key strategic raw material (EC & DG RTD, 2018) and therefore the industry has great potential for long-term development (MGRT, 2021). But even though wood products are produced with relatively low energy input compared to other building and furniture materials (Koch et al., 2022), that wood has excellent properties that allow it to be used in a wide range of applications, that is an environmentally friendly material because of carbon storage, that is a renewable resource, that wood products can be designed according to the principles of the circular economy, and that wood is a fully degradable material, etc. wood products still often follow a linear process (Forrest et al., 2017). We also need to ensure that materials are used thoughtfully and efficiently, as the consumption of raw materials sharply increasing and also ensure that the supply value chain and production is in line with sustainable principles, as the whole EU industry still accounts for 20% of EU greenhouse gas emissions (UN & IRP, 2019). More efficient use of wood for the development of wood products and composites is a key principle of the circular economy (Antov et al., 2021; Janiszewska et al., 2016), which companies can also achieve through the digitalization of processes and optimize the use of raw materials, improve waste management, and contribute to green development. Digital solutions can thus contribute to a faster transition from a traditional fossil-based economy to a circular bioeconomy (Watanabe et al., 2019). However, organizations will not be able to implement this digital and green transition if employees do not have the right knowledge and skills (Koch et al., 2022), because besides high labor costs, the biggest barrier to technology adoption is the lack of employee knowledge and skills (CSM, 2017). This research aims to find out how important certain competences of employees are for the transition of the wood and furniture industry to a digital and sustainable circular economy.

2. METHODS

2.1. Surveying experts

Based on the European competence frameworks DigComp (EC et al., 2022) and GreenComp (Bianchi et al., 2022) and the implementation document for the development of the Slovenian wood industry until 2030 (MGRT & Direktorat za lesarstvo, 2022), we have developed a set of digital and sustainable competences. For key digital and sustainable competences from the priority areas of the document for the development of the Slovenian wood industry, individual experts gave their suggestions. To determine which competences from our list are important for the digital and sustainable transformation of the wood and furniture industry, we formed a focus group of diverse experts who are in some way connected to the wood and furniture sector. The experts were individuals from all levels of educational institutions in the wood and furniture sector, representatives of the wood and furniture sector, and expert consultants in the wood and furniture sector (from the Institute of the Republic of Slovenia for Vocational Education and Training). For the assessment of competences, 12 experts were asked to fill out the online survey. Using a 4-point Likert scale, the experts rated the importance of each competence.

2.1. Data analysis

To display the results, we used a "Box and Whiskers Plot", a graphical method to visualize the distribution of data. It consists of a rectangular box representing the interquartile range and the median. Extending from the box are the whiskers, which represent the range of data without outliers or extreme values. Outliers are shown as individual data points. We used MS Excel to perform the necessary calculations and create the charts. The DigComp and GreenComp competences are presented as areas containing an arithmetic average of the experts' ratings for each competence within the respective area (Figure 1 and 2), and in picture 3 we have presented individual competences from the priority areas of the above-mentioned strategy document.

3. RESULTS

For the digital and sustainable transition of wood and furniture sector, there are many competences that employees need so companies can make a transition to digital sustainable bioeconomy. Experts in the focus group have assessed the importance of different competences for the digital and green transition of the wood and furniture industry. The results shows that all listed competences are more or less important for the green and digital transition.

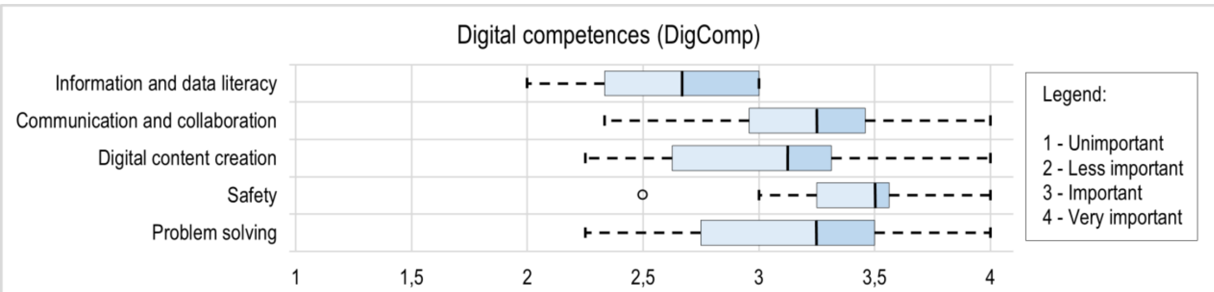


Figure 1: Importance of digital competences (by areas)

Figure 1 shows the high importance of all areas from the DigComp digital competences, as the median in all areas is above "important", with exception of information and data literacy. Among all areas, safety stands out, which has the highest minimum value in comparison with other areas in this domain. Problem solving is the second most important area followed by communication and collaboration. The area of digital content creation and communication and collaboration have the lowest uniformity of importance among the experts. The competences from the area of information/digital literacy are (comparatively) the least important, as no expert rates them as very important, but 25% of them still consider them important.

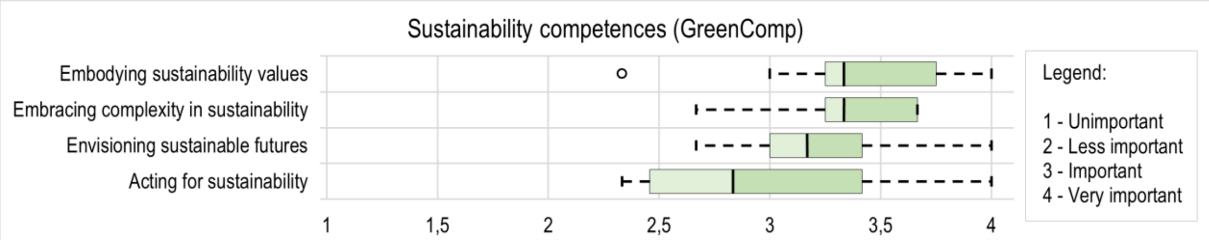


Figure 2: Importance of sustainability competences (by areas)

In Figure 2, we can see the high importance of all areas of sustainable competences from the GreenComp, as at least half of the experts rank these competences as important, except for competences from the area of acting for sustainability, which are slightly less important and have the lowest uniformity from this domain. Otherwise, all other areas have high uniformity among the experts and are somewhat more important compared to the competences from DigComp.

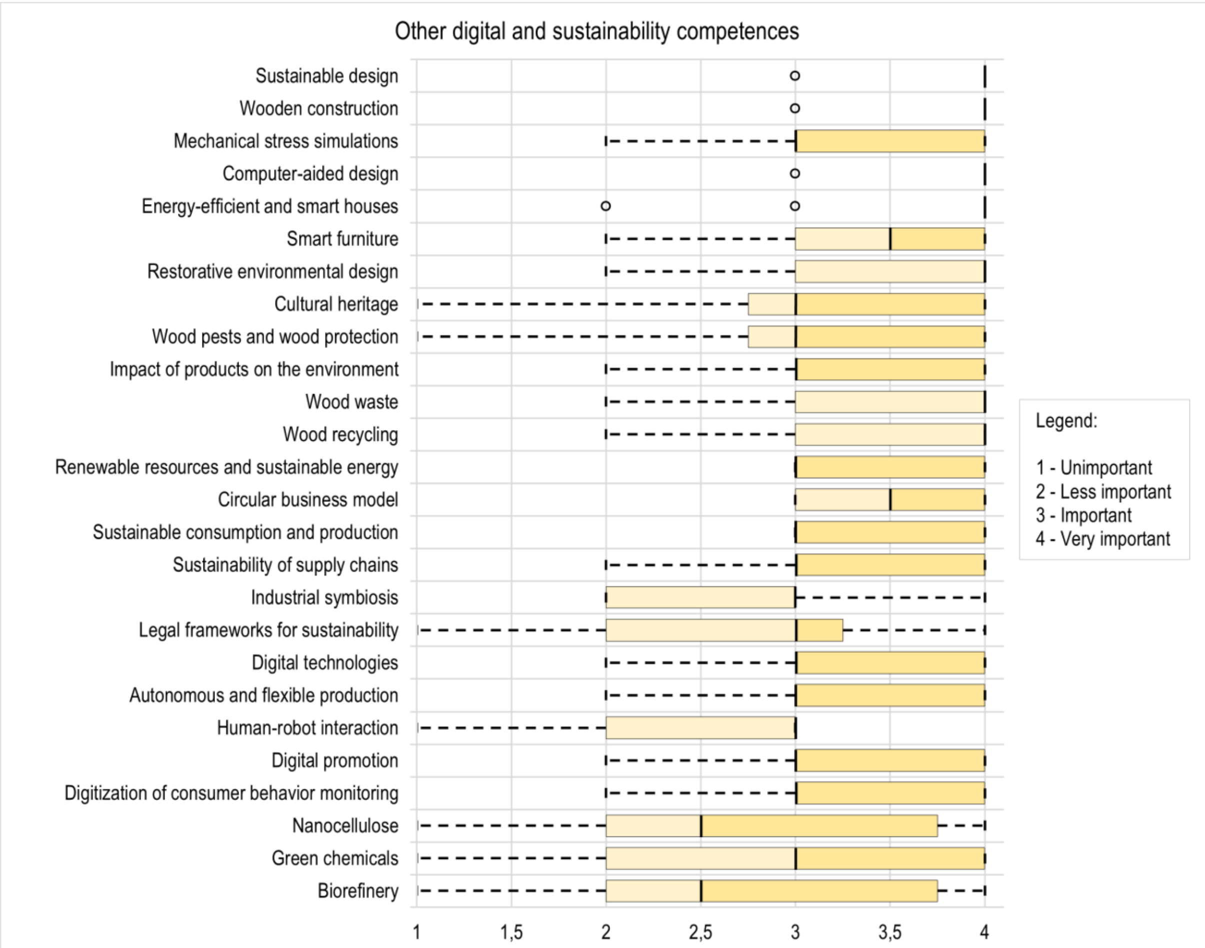


Figure 3: Importance of other digital and sustainability competences

Figure 3 lists all other individual digital and sustainable competences identified by the expert group in the first phase. These were subsequently also rated in terms of importance. All experts in the focus group, except for outliers, rated some competences (sustainable design, wooden constructions, computer-aided design, energy-efficient and smart houses) as very important. For quite a few competences, half of the experts found them to be important, as shown by the median. Green chemicals were rated least consistently of all competences, with 25% of experts rating them as less important and 25% rating them as very important. Apart from the latter, some other competences were rated as less important by 25% of the experts (biorefinery, nanocellulose, human-robot interaction, legal frameworks for sustainability, industrial symbiosis), but they were quite inconsistent as some experts rated them as very important.

4. CONCLUSIONS

In the face of increasing global challenges, sustainability and digitalization are becoming increasingly important to policymakers, researchers, and industry. The bioeconomy can address some of these challenges because of the benefits of renewable biological resources. However, we need to ensure that we adhere to sustainable principles, and digitalization can play an important role in this. Therefore, we need to ensure that everyone is thinking sustainably as soon as possible and has the appropriate knowledge and skills. This can be achieved by including sustainability and digital topics in education, because the digital and sustainable transition of the wood and furniture industry is only possible with the appropriate competences.

The results show that all competences examined in this study are important to some extent for that transition. The experts rated some competences quite uniform, while the variability of ratings for others was quite high. Based on their assessments, we could evaluate which topics and to what extent should be included in the curricula, to equip students in the wood and furniture sector with the necessary competences. The competences where the experts showed low uniformity could be reviewed with additional experts from the respective field. In further research, the importance of individual competences could also be assessed by wood and furniture companies, the results of which could be compared with the experts' assessments, but more importantly find out which competences are important for which level of education. Achieving the goals requires a comprehensive renovation approach when renewing the curricula, where the entire vertical of education and training in the sector should be unified, with the individual levels of education complementing and reinforcing each other.

Acknowledgements: We would like to acknowledge the Slovenian Research Agency (ARRS) for financial support within the program “Wood and lignocellulosic composites” (P4-0015). We would also like to acknowledge Ministry of Economic Development and Technology (MGRT), since research was conducted within the project DigLES 5.0 (V4-2269), which is financed by the ARRS and MGRT.

REFERENCES

Antov, P., Kristak, L., Réh, R., Savov, V., & Papadopoulos, A. (2021). Eco-Friendly Fiberboard Panels from Recycled Fibers Bonded with Calcium Lignosulfonate. *Polymers*, *13*, 639.

Baeyens, A., & Goffin, T. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. *United Nations*, *22*(5), 508–516.

Bianchi, G., Pisiotis, U., & Cabrera, M. (2022). *GreenComp The European sustainability competence framework* (Y. Punie & M. Bacigalupo (eds.)). Publications Office of the European Union.

Bugge, M. M., Hansen, T., & Klitkou, A. (2016). What is the bioeconomy? A review of the literature. *Sustainability (Switzerland)*, *8*(7).

CSM. (2017). Report of the need of the furniture industry regarding KET of I4.0. *IN4WOOD*, 85.

EC. (2012). *Innovating for sustainable growth : a bioeconomy for Europe*. Publications Office.

EC. (2016). Conclusion, on behalf of the European Union, of the Paris Agreement adopted under the United Nations Framework Convention on Climate Change. *Publications Office of the European Union*, *12256/16*, 7.

EC (2020a). A new Circular Economy Action Plan “For a cleaner and more competitive Europe.” *Publications Office of the European Union*, *6766/20*, 21.

EC. (2020b). A recovery advancing the transition towards a more dynamic, resilient and competitive European

industry. *Publications Office of the European Union*, *13004/20*, 13.
EC & DG RTD. (2018). A sustainable bioeconomy for Europe : strengthening the connection between economy, society and the environment : updated bioeconomy strategy. *Publications Office of the European Union*, 107.
EC, JRC, Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2, The Digital Competence framework for citizens : with new examples of knowledge, skills and attitudes*. Publications Office of the European Union.
Forrest, A., Hilton, M., Ballinger, A., & Whittaker, D. (2017). Circular economy opportunities in the furniture sector. *European Environment Bureau (EEB)*, 55.
Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768.
Janiszewska, D., Frąckowiak, I., & Mytko, K. (2016). Exploitation of liquefied wood waste for binding recycled wood particleboards. *Holzforschung*, *70*(12), 1135–1138.
Juvančič, L., Mešl, M., Križnik, N. B., Lovec, M., Osojnik Črnivec, I. G., Arnič, D., Oven, P., Berne, S., Rac, I., Kocjančič, T., & Novak, A. (2021). Zapiranje snovnih in energetskih tokov biomase – presoja scenarijev in podpornih ukrepov države. *Bridge2Bio*, 91.
Koch, V., Mallahnia, T., Mouazan, E., Steinmetz, D., Antov, P., Gavrić, I., Cañavate, G., & Fernández, C. (2022). Twin transition in the wood-furniture value chain. State-of-the-art on Environmental Certifications Practices and Industry 4.0 in the Wood and Furniture Sector. *INTRUST*, 85.
MGRT. (2021). *Slovenian industrial strategy 2021-2030*. 1–106.
MGRT, & Direktorat za lesarstvo. (2022). *Izvedbeni dokument ukrepov razvoja lesnopredelovalne industrije do 2030*.
Ollikainen, M. (2014). Forestry in bioeconomy - smart green growth for the humankind. *Scandinavian Journal of Forest Research*, *29*(4), 360–366.
UN & IRP. (2019). *Global Resources Outlook 2019: Natural Resources for the Future We Want*.
Watanabe, C., Naveed, N., & Neittaanmäki, P. (2019). Digitalized bioeconomy: Planned obsolescence-driven circular economy enabled by Co-Evolutionary coupling. *Technology in Society*, *56*, 8–30.

Authors address:
Goropečnik, L[1*]; Remic, K[1]; Jošt, M; Oblak, L[1]; Kropivšek, J[1]
[1] Chair of Management and Economics of Wood Companies, Biotechnical Faculty, University of Ljubljana, Ljubljana, Slovenia
[*]Corresponding author: luka.goropecnik@bf.uni-lj.si

MARKETING STRATEGIES OF THE WOOD-BASED SECTOR COMPANIES

Kaputa, V., Táborecká, J.,Maťová, H.

Abstract: The article deals with the identification, analysis, and evaluation of the strategies of companies in the wood-based sector aimed at achieving environmental and social goals. We point out how the "green values" of companies influence not only the creation of the marketing mix, but also corporate strategy as such. Within Europe, the Nordic countries traditionally excel in their approach to the bioeconomy, or circular economy. These paradigms are incorporated into company strategies and the excellence of wood products is communicated to stakeholders.
Keywords: marketing strategy, wood-based sector, green values of company

1. LITERATURE REVIEW

Societal concerns over environmental degradation are increasing. These facts push corporate managers to reconsider their current business practices and look for ways to mitigate their firms' environmental impact (Porter and Reinhardt, 2007). Many scientists and politicians see the way to solve climate change in new technologies, we agree with Klöckner (2015) that a technology-centred (technophilic optimism – belief that technology will save the world) approach to environmental problems is often not sufficient to eliminate the environmental problem. This approach needs to be combined with behavior change to be effective (e.g. to avoid of creation of a rebound effect).

Klöckner (2015) also states that behavior change requires communication activities because these activities are crucial and vital. This implies that some kind of marketing activities or promotion campaigns is necessary to make consumers likely to adopt the new technology.

Peattie and Charter (2003, p.727) define green marketing as a holistic management process responsible for identifying, anticipating, and satisfying the needs of customers and society, in a profitable and sustainable way and also proactive green marketing strategists tend to focus on pre-emptive communication with all stakeholders.

2. METHODS

Since the Nordic countries traditionally excel in their approach to the bioeconomy, or circular economy, to demonstrate best practices in this field, four companies from Finland (Metsä Group, Stora Enso) and Sweden (SCA, Södra) have been chosen for further analysis. These companies are operating in forest- and wood-based sectors. Data were collected from the relevant secondary resources and are based on desk research in the form of case studies. Each of the cases is revealing in which way these companies successfully incorporated green practices into their strategies, such as utilisation of renewable Nordic wood, waste elimination, full utilisation of the tree and all its parts and of by-product etc. To ascertain the true integration of these practices within a company's strategies, it is essential to examine whether they are deeply embedded in the organization's vision, mission, values, company culture, involved in strategic objectives and R&D priorities, or used as a competitive advantage, rather than being merely operational or tactical in nature, often associated with the marketing mix.

3. ANALYSIS OF STRATEGIES OF SELECTED COMPANIES IN THE WOOD-BASED SECTOR

3.1. Metsä Group (Finland)

Metsä Group is a Finnish company in the forestry industry that operates in international markets. As claimed, they utilize responsibly and efficiently the world's best renewable resource – Nordic wood – as the main raw material used in Metsä Group's products. Felled trees are fully utilized to minimize waste. Every part of the tree is used in a way that creates the highest value. The parent company is a cooperative that owns more than 90,000 Finnish forest owners. The strategy of Metsä Group is based on renewable raw materials and recyclable products, where wood from northern sustainably managed forests and deep expertise provide a competitive advantage. The company's vision is to be the preferred partner in sustainable business development. They rely on nine Operating principles: Increase the value of forests for our owner-members. Implement sustainability goals and ethical corporate culture. Develop key personnel competencies. Grow profitably together with customers. Increase industrial efficiency. Renew products and services. Strengthen the competitive position through careful market and customer selection. Make full use of shared, efficient business processes, group services, and synergies. Efficiently utilize capital in investments (http://metsagroup.com).

Metsä Group's research and development activities focus on two priority areas: creating added value through biological products and supporting a resource-efficient circular economy. Metsä Group actively collaborates with universities, research institutes, technical solution providers, and growing companies. Metsä continues to actively improve energy efficiency and environmental performance. Production by-products such as bark, sawdust, and sanding dust are considered "ideal for energy production" by Metsä. Fossil fuels are only used in exceptional situations, such as maintenance and start-ups. Under normal conditions, energy production is exclusively based on biological sources. Metsä Group adopted also seven goals from Agenda 2030 involving: (1) SDG 6 Clean water and sanitation; (2) SDG 7 Affordable and clean energy; (3) SDG 8 Decent work and economic growth; (4) SDG 9 Industry, innovation, and infrastructure; (5) SDG 12 Responsible consumption and production; (6) SDG 13 Climate action; (7) SDG 15 Life on land (protection of biodiversity, promotion of forest growth, planting four saplings for every harvested tree) (http://metsagroup.com).

3.2. Stora Enso (Finland)

Finnish company Stora Enso develops products and technologies based on renewable materials. Their products replace those made from fossil or other non-renewable materials. The company develops and produces wood and biomass-based products for a wide range of industries worldwide. They are a leading provider of renewable packaging, biomaterials, and wooden constructions, and one of the largest private forest owners in the world. The company's goal is for all their products and solutions to be 100% renewable by 2050. Their proclaimed focus is on: (1) combatting climate change, (2) protecting biodiversity and (3) incorporating circular economy.

The concept of bioeconomics contributes to mitigating climate change through using renewable materials and resources, energy-efficient manufacturing processes, and sustainable forest management practices. Stora Enso claims that their products, as alternatives to non-renewable materials, help reduce CO2 emissions. The company has committed to scientific targets in line with the Paris Agreement's 1.5-degree goal. Stora Enso aims to reduce 50% of their greenhouse gas emissions from their own operations. They have set interim targets for 2030 as part of the Science Based Targets initiative (SBTi), which supports ambitious climate action in the private sector. The company's goal, contributing to climate change mitigation, is to reduce carbon dioxide emissions and work towards a positive impact of renewable materials. It is estimated that by replacing fossil materials, Stora Enso's goal is not only to mitigate biodiversity loss but also to increase it. Working to enhance biodiversity ensures the long-term availability of wood. Stora Enso strives to achieve the United Nations' Sustainable Development Goals (SDGs). They voluntarily share a set of scientifically based biodiversity performance indicators at Stora Enso, which serve to measure their progress and success in this area (http://storaenso.com).Goal by 2030 is to achieve 100% performance in all indicators. Stora Enso supports biodiversity through a general consideration method, meaning they rescue trees on the logging site. They also work on supporting biodiversity for specific species, aiming to increase the number of existing rare and endangered species in their forests (http://storaenso.com).

Stora Enso offers a range of services to support circular economy. They collaborate with customers and partners to develop new circular solutions and business models that replace fossil-based plastics and reduce waste throughout the supply chain. They study and test how their products behave in different recycling systems, analyse the recycling of packaging materials in various markets, assess the life cycles of their products, and support their customers' life cycle studies. Stora Enso collaborates with industrial partners to organize and support recycling efforts. They test their entire product portfolio to ensure compliance with the best recyclability tests, using the widely used Packaging Technology Standard (PTS) in the European market. They provide customers with test results along with an overview of collection and sorting systems. They also contribute to the further development of recyclability assessment methods and circularity guidelines through 4evergreen, a value chain alliance for optimizing the circularity of fibre-based packaging, which can be recycled at least 5-7 times, sometimes even up to 20 times. When the fibres are too degraded for recycling, they can be used for bioenergy production (http://storaenso.com).

3.3. SCA (Sweden)

It is the largest private forest owner in Europe, and its 2.7 million hectares of forests contribute to the sequestration of a significant amount of carbon dioxide. They conduct various initiatives regarding: (1) Biodiversity conservation; (2) Fossil-free world; (3) Carbon dioxide emissions; (4) Valuable forests; (5) Efficient resource utilization; (6) Sustainable development; (7) Profitable growth. The development and preservation of biodiversity are the most important goals of sustainability in SCA. This means that forests must contain a variety of different habitats, and therefore, they strive to develop, protect, and recreate habitats for species with special requirements. The goal is for SCA's value chain to become fossil-free. SCA's industrial processes are 95% fossil-free. SCA has intentionally worked on replacing fossil fuels with biofuels. Processed biofuels, wood pellets, and unprocessed biofuels such as bark, sawdust, and residues from harvesting are used from external suppliers. The majority, approximately 75%, of emissions come from the transportation of raw materials and finished products, despite having a highly efficient transportation system. Wood is transported by rail for long distances. SCA forests must be at least as rich in biodiversity, natural experiences, and resources in the future as they are today. The group's goal by 2030 is for 100% of the wood raw material to come from responsibly managed forests. The aim of SCA's innovative efforts is to develop new materials, services, and business models that contribute to a circular society without fossil fuels. The group's goal by 2030 is zero waste – nothing goes to waste. SCA contributes to sustainable development in the communities where it operates. Success and sustainable development depend on dedicated employees and partnerships within local communities. Long-term profitable growth is a prerequisite for sustainable development (http://sca.com).

SCA creates a culture based on values. The goal of the group by 2030: All employees adhere to the SCA Code of Conduct. SCA is a trustworthy company with a high level of integrity among employees and suppliers. SCA has developed a Code of Conduct to ensure that SCA employees uphold the core values of the group and do not engage in unethical activities. It includes principles that encompass business ethics, employee relations, health and safety, respect for human rights, and the environment. The Code serves as a tool to translate the fundamental values of SCA – responsibility, excellence, and respect – into actions. Around the growing forest resource, SCA has built a well-invested and efficient value chain that maximizes the value of every tree. Investments help strengthen the integrated value chain and achieve favourable returns. The forest is a source that provides stable profitability and value enhancement. Active and sustainable forestry maximizes forest growth (http://sca.com).

3.4. Södra (Sweden)

Södra is the largest Swedish association of forest owners and an international forest industry group whose operations are based on processing forest resources. Södra can present its positive impact on climate. The net impact is positive due to forest growth on the properties owned by 52,000 members and the use of forest products to replace products and energy with higher emissions. The Södra value chain also reflects the negative impact of climate change. Since their plants are almost entirely fossil-free, these emissions mainly come from the production of input products such as technological chemicals and packaging materials, as well as the transportation of raw materials to the plants and products to customers. They invest in liquid biofuels and wooden building systems (http://sodra.com).

They are engaged in: (1) New Sustainable Alternatives; (2) Responsible Employer and Engaged Employees; (3) Sustainable Forestry; (4) Nature Conservation; (5) Resource Efficiency. The company invests heavily in research and development. This includes the next generation of biofuels, replacing chemicals from fossil sources with bio-based chemicals, and exploring new material concepts. The areas of innovation for Södra include Forests: increased forest production, higher levels of productivity and protection, forest management methods, better planning, and digitalization. Wood: wood processing, product development, design, and logistics. Paper: higher product quality and more efficient resources. Textiles: fabrics based on wood replacing synthetic fibres or cotton. Chemicals: bio-based chemicals replacing fossil sources. Energy and fuel: increasingly refined forms of energy with broader applications and new energy carriers for future energy sources (http://sodra.com).

The company focuses on workplace safety and health protection (OSH), succession planning and performance management, as well as creating an inclusive culture. Södra's members are committed to responsible forest management. Certification is a key tool for sustainable forestry, and approximately 70% of members have FSC® and/or PEFC™ certification. Their goal is to support biodiversity. Almost all of their electricity is produced from renewable fuels. Energy is generated in their pulp mills and sawmills, primarily from their wood raw material.

Their various industrial operations produce a significant surplus of green energy, which is sold to external customers in the form of renewable electricity, district heating, and biofuels (http://sodra.com).

Södra has decided to focus on seven sustainable development goals. (1) SDG 7: Affordable and Clean Energy - They actively working to reduce electricity and heating consumption in their operations, supplying green energy to local communities in the form of electricity, district heating, and biofuels. They also develop new energy-related products and services. (2) SDG 8: Decent Work and Economic Growth - their contribution is a commitment to a higher rates of innovation, active work on occupational health and safety. Their Code of conduct and Supplier Code specify the rights of employees in their own operations and supply chain. They contribute to growth in the regions where they operate. (3) SDG 9: Industry, Innovation, and Infrastructure - Focus on transitioning to fossil-free operations and continuous improvement in the utilization of wood raw material. Committed to higher rates of innovation for sustainable products with improved sustainability performance. (4) SDG 11: Sustainable Cities and Communities - They actively working on increasing the use of wood as a construction material through the development of their products and services. (5) SDG 12: Responsible Consumption and Production - Their operations are based on bio-based raw materials and apply an ecosystem approach. Continuously working on reducing their negative impact on the environment and improving resource efficiency throughout their entire value chain. Collaborating with stakeholders across their value chain to reduce their negative impact and drive change. (6) SDG 13: Climate Action - They are implementing both long-term and short-term initiatives to achieve fossil-free production and fossil-free transportation. (7) SDG 15: Life on Land - Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss. Their contribution: Committed to sustainable forest management that balances production and environmental aspects and preserves biodiversity through protection of areas (http://sodra.com).

4. DISCUSSION AND CONCLUSION

The analysis of the strategies and marketing communications of the studied companies indicates that they contribute to sustainability through their activities. These companies have their sustainability initiatives supported by real goals, indicators, annual reports, and certifications. Through the analysis, we have evaluated benchmark companies that can serve as examples and inspirations for firms.

The selected companies are part of the forest-based sector and process renewable raw materials, thereby contributing to the bioeconomy. Each of these companies participates in the UN's Agenda 2030 program, which sets 17 sustainable development goals. Their marketing communication, presented to the general public, is focused on contributing to the bioeconomy and sustainability, which have become prominent topics in recent years. All companies are transparent and publish their annual reports. It is worth highlighting that these companies supposed to be benchmarks mainly due to their responsible approach to their activities. Companies seeking to enhance their engagement with sustainable practices in their strategies can utilize Agenda 2030, also known as the Sustainable Development Goals (SDGs), as a robust guide and framework to align their business strategies and operations with sustainable development principles. They can do it in several ways: (1) to identify which SDGs are most relevant to their business and align their strategies and objectives accordingly; (2) to integrate the SDGs into their core business practices; (3) for reporting of their progress towards the SDGs and communicate their sustainability efforts to stakeholders; (4) through partnerships and collaboration with various stakeholders to address complex sustainability challenges and to share best practices; (5) to bring innovations and develop sustainable solutions and practices into their business models.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 "Environmental Consumer and Environmental Citizen", and grant number 1/0036/21 "Determinants of eco-innovation activities in the context of changes in the external economic environment".

REFERENCES

1. Klöckner, C. A. (2015). The psychology of pro-environmental communication: beyond standard information strategies. Springer.
2. ***:Metsä Group [Webpage]. Retrieved from https://www.metsagroup.com/

3. Peattie, K., & Charter, M. (2003). The Marketing Book (5th ed.). Butterworth Heinemann.
4. Porter, M., & Reinhardt, F. (2007). A strategic approach to climate. Harvard Business Review, 85(10), 22-26.
5. ***:SCA [Webpage]. Retrieved from https://www.sca.com/
6. ***:Södra [Webpage]. Retrieved from https://www.sodra.com/
7. ***:Stora Enso [Webpage]. Retrieved from https://www.storaenso.com/

Authors address:
Kaputa, V.[1*], Táborecká, J.[2], Maťová, H.[1]
[1] Department of Marketing, Trade and World Forestry, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Slovakia
[2] Department of Corporate Economics and Management, Faculty of Economics, Matej Bell University in Banská Bystrica
[*]Corresponding author: kaputa@tuzvo.sk

WOOD PRODUCTS CUSTOMER – CONSUMER OR CITIZEN?

Rácz, A., Kaputa, V. Loučanová, E.

Abstract: The wood-based industry should be successful in encouraging customers to replace consumer goods with goods made from wood. To correctly identify the factors influencing environmentally motivated purchasing decisions, it is necessary to find out how civic attitudes and activity are reflected in it. This paper's target is also related to the knowledge of the discrepancy between the attitudes expressed by consumers and their real buying behaviour. It is tricky if just substitution of material would lead to careful use of resources and expected state of economy. The paper also wants to contribute to the global discussion on the relationship between man (as a citizen and a consumer) in relation to the environment and the well-being of society.
Keywords: consumer, citizen, purchase decision, sustainability, environmental citizenship, attitudes

1. INTRODUCTION

Companies contribute significantly to macroeconomic stability, but also to the social development of society. This is also the reason why many countries are currently encouraging companies to engage in innovative activities for the sake of sustainability. More and more often, innovations introduce procedures that reduce negative impacts on the environment. Such eco-innovations support sustainable development and are found in a variety of industries, including the forest and wood processing industry complex.

There are estimations that almost 70% of the planet's greenhouse gas footprint depends on which products customers choose and whether they use and dispose of them in a sustainable manner (White et al. 2019). Thus, consumers are becoming more interested in environmental topics and reflecting their interest in their decision to buy green products (Dernall 2012). The United Nations Environment Programme (2011) has estimated that the green products market doubles annually.

The article points to the complex issue of the manifestation of a person's civic attitudes in his shopping behavior. Analytically, it focuses on the previous findings and reflects them in the light of the attitudes of consumers of wood products.

2. DEFINING GREEN PRODUCT, GREEN PRODUCT CONSUMER AND ENVIRONMENTAL CITIZENSHIP

There is no internationally recognized definition, a green product (or ecological product/eco-friendly product/sustainable product) is "a sustainable product designed to minimize its environmental impacts during its whole life-cycle and even after it is of no use" (Sathyapriya 2020). In essence, a green product has two main characteristics: reducing waste and maximizing resource efficiency (Das 2023). The green products consumers use contribute to the protection of the environment by consumers' refusal to buy products that are harmful to the environment. A green consumer can be defined as an individual who adopts environmentally-friendly behaviors and buys green products rather than standard products.

Citizenship is a fundamental principle of participatory democracy (McCowan 2009). Understanding citizenship as only a legal entitlement conferred by nation-states is a limited approach that overlooks that citizens can "participate in, identify as, and belong to our communities" even without legal entitlements (Hayward 2012).

Environmental citizenship is the "responsible pro-environmental behavior of citizens who act and participate in society as agents of change in the private and public sphere, on a local, national and global scale, through individual and collective actions, in the direction of solving contemporary environmental problems, preventing the creation of new environmental problems, achieving sustainability, as well as developing a healthy relationship with nature" (ENEC 2018). Studies of environmental citizenship highlight ecological concerns and activism as major drivers in citizenship processes (Isin and Nyers 2014; Cheah and Huang 2019) and the importance of intragenerational education and empowerment (Hadjichambis and Paraskeva-Hadjichambi 2020). Environmental citizenship entails the right to participate in environmental policy making, choose sustainable personal actions, obey just environmental law, and promote sustainable arrangements (Bel 2005).

Through the integration of people's knowledge, skills, economic interests, and moral values, science and the social order are “mutually constitutive”; the citizen is both consumer and generator of knowledge (Jasanoff 2004).

Dobson (2007) argues that changing attitudes is fundamental to cultivating environmental citizenship and that active involvement with environmental projects is an effective way to change attitudes. Although we cannot take for granted that changed attitudes lead to changes in behavior (Krasny 2020), first-hand experience and observation anchor knowledge into people's everyday lives, thereby transforming knowledge into a tool for environmental action. Fostering environmental citizenship provides individuals and communities a toolbox they can draw on to change attitudes and behaviors.

A key component of citizenship is participation in the collective (Schild 2016). Environmental citizenship calls citizens to address the structural roots of environmental challenges, particularly the uneven distribution of environmental burdens (Bullard 1993) and the lack of inclusion of minorities in environmentalist organizations (Taylor 2016). Moving individuals to think about the big picture is one pathway to global environmental citizenship.

3. OBJECTIVE AND METHODS

In order to achieve the aims of the paper, the authors carried out a literature review and defined the conceptual boundaries. The principle approach for processing the issue of wood products customer is the analytical-synthetic method. The main identified research directions are composed of consumer behavior regarding green products and environmental citizenship. To achieve the goal, the authors present the main factors influencing consumer behavior toward green products and environmental citizenship observed by the authors in the reviewed studies, and a brief analysis of each determined dimension.

4. THE MAIN FACTORS INFLUENCING CONSUMER BEHAVIOR TOWARD GREEN PRODUCTS AND ENVIRONMENTAL CITIZENSHIP

A series of factors that can influence consumer behavior toward green products. Several factors were analyzed in literature review on consumer behavior, with most of them being quite similar in form and meaning. We can group these factors according to their form and meaning into eight main categories: social norms, natural environmental orientation, a company’s perceived green image, green product characteristics, perceived risks, and inconvenience of buying green products, perceived benefits of buying green products, institutional trust, sociodemographic characteristics, and consumer confidence.

Even if the subjective norms directly affect consumer behavior toward green products (Wasaya et al. 2021), there is evidence to support the fact that this factor does not directly impact green purchase intention, but it indirectly relates to future purchase intention (Kamalanon et al. 2022). This relationship is mediated by a company’s perceived green image when a green corporate image is a long-term goal for the management. In a competitive market, the green image could play a key role in building a company’s brand, which can differentiate a company’s offerings from competing ones (Ham et al. 2022), with the image of a company being valuable for increasing customer satisfaction. Thus, companies should focus on communication and green marketing techniques which deliver information that influences consumer behavior to be more eco-friendly.

Also, making consumers aware of green product information can be a key determinant of green purchase behavior. Most of the time, when customers are concerned about the environment and its preservation, they tend to buy green products if these products have eco-certifications or are produced under eco-certification schemes and respect rigorous regulations (Zhang and Dong 2020).

Sociodemographic characteristic seems to also be an important factor that can influence consumer behavior regarding green product acquisitions (Witek and Kuźniar 2020; Zhang and Dong 2020). This dimension was represented in the specialty literature by items such as age (Ham et al. 2022), gender, education, number of children (Tan et al. 2022), place of residence, or financial situation (Witek and Kuźniar 2020). Income (Tan et al. 2022) and personal financial situation are factors that can influence green behavior too, as the personal financial situation highly influences the consumers' willingness to pay more for green products (Witek and Kuźniar 2020). The number of children has an impact on the frequency of green product purchases as well, as mothers are very concerned about their children's health and safety, which is why they tend to buy more green products (Witek and Kuźniar 2020).

When it comes to green product buying behavior, perceived risk is also a factor that should be analyzed (Wasaya et al. 2021; Wang 2017). This perceived risk is consumers' valuation, which is associated with the possible consequences of wrong decisions. The risks and uncertainty regarding green products negatively influence potential customers' buying behavior, with environmental awareness being an important factor that can affect green perceived risk (Wasaya et al. 2021). Therefore, in order to reduce risks, consumers can use different strategies, such as pre-purchase deliberation, seeking additional information, reliance on brand image, personal recommendations, or the security of warranties (Wang 2017).

Also, the perceived benefits of buying green products can influence consumers' behavior toward green products (Kamalanon et al. 2022; Tan et al. 2022). Perceived consumer effectiveness refers to the consumer's belief that the efforts of his/her actions can make significant differences in solving environmental problems. Therefore, consumers who think that their choices to buy green products will bring benefits to the environment tend to buy more green products (Tan et al. 2022).

Although trust is considered to be an important factor that can influence consumer behavior, there is still a lot of debate about how institutional trust can affect consumer behavior toward green products, especially when trust levels may be influenced both positively and negatively. Ricci et al. (2018) highlight the fact that institutional trust can influence consumer risk perception and attitudes, with the level of trust negatively affecting those variables. Concerning the relationship between trust and consumer attitudes, several studies have shown that the higher the level of consumer trust, the higher the probability to develop a positive attitude and, thus, choosing products with eco-friendly characteristics (Govindasamy 2001).

5. CONCLUSIONS

People are significantly influenced by society's actions regarding pro-environmental issues and the way society presents normality in this context. All the identified factors influence consumer behavior toward green products and environmental citizenship. Thus, to make positive changes in people's behavior toward green products, it is necessary to make changes at a societal level regarding the attitudes toward environmental issues and to educate people in this regard.

The key distinction between citizens and consumers lies in their roles and responsibilities. While citizenship involves broader social and civic obligations, consumerism focuses primarily on individual preferences and consumption choices. Citizenship encompasses active participation in the democratic process, advocating for social and environmental issues, and contributing to the well-being of society. Consumers, on the other hand, exercise their purchasing power to fulfill their individual needs and desires.

However, it is important to recognize that citizens can also be consumers, and consumer choices can have an impact beyond individual satisfaction. The decisions made by consumers can influence the behavior of businesses, drive market demand, and shape the availability and production of goods and services. Recognizing the interplay between citizen and consumer roles can lead to a more conscious approach to consumption, where individuals consider the broader societal and environmental implications of their choices.

Both society and the business environment, as well as the forestry-timber complex, are constantly facing challenges that require prompt responses. Consumers have become more demanding. It is no longer enough for them to provide innovative products of higher quality, at affordable prices and in convenient locations, but they also demand a more active approach in the field of supporting civic activities at the local or wider level. They are interested in solving the problems of society and the environment. They are becoming more active and expect the same from the commercial sector.

In summary, being a citizen involves fulfilling rights, responsibilities, and active participation in society, while being a consumer pertains to individual choices and preferences in the marketplace. Balancing the roles of citizen and consumer can lead to more informed and responsible decision-making, considering the broader impact on society and the environment.

Acknowledgements: The authors would like to thank the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number 1/0475/22 "Environmental Consumer and Environmental Citizen".

REFERENCES

1. Bell D.R. (2005): Liberal environmental citizenship. Environmental Politics 14:179–194.
2. Bullard R.D. ed. (1993): Confronting environmental racism: voices from the grassroots. South End Press, Boston, Massachusetts.
3. Cheah S.L., Huang L. (2019): Environmental citizenship in a Nordic civic and citizenship education context. Nordic Journal of Comparative and International Education 1:88–104.
4. Darnall N.; Ponting C.; Vazquez-Brust D. (2012): Whameehy Consumers Buy Green. In: Vazquez-Brust D.; Sarkis J.; editors. Green Growth: Managing the Transition to a Sustainable Economy. Springer Science + Business Media; Dordrecht, The Netherlands: 2012. pp. 287–308.
5. Dobson A. (2007): Environmental citizenship: towards sustainable development. Sustainable Development 15: 276–285.
6. Govindasamy R.; Italia J.; Adelaja A. (2001): Predicting Willingness-to-Pay a Premium for Integrated Pest Management Produce: A Logistic Approach. Agric. Resour. Econ. Rev.;30:151–159.
7. Hadjichambis A.C.; Paraskeva-Hadjichambi D. (2020): Education for environmental citizenship: the pedagogical approach. Pages 237–261 in Hadjichambis A et al., editors. Conceptualizing environmental citizenship for 21st Century education. Springer, Cham, Switzerland.
8. Ham C.-D.; Chung U.C.; Kim W.J.; Lee S.Y.; Oh S.-H. (2022): Greener than Others? Exploring Generational Differences in Green Purchase Intent. Int. J. Mark. Res. 64:376–396.
9. Hayward B. (2012): Children, citizenship and environment: nurturing a democratic imagination in a changing world. Routledge, Abingdon, United Kingdom.
10. Isin E.F.; Nyers P. (2014): Routledge handbook of global citizenship studies. Routledge, Abingdon, United Kingdom.
11. Jasanoff S. (2004): Science and citizenship: a new synergy. Science and Public Policy 31:90–94.
12. Kamalanon P.; Chen J.-S.; Le T.-T .(2022): "Why Do We Buy Green Products?" An Extended Theory of the Planned Behavior Model for Green Product Purchase Behavior. Sustainability, 14 :689.
13. Krasny M.E. (2020): Advancing environmental education practice. Cornell University Press, Ithaca, New York.
14. McCowan T. (2009): Rethinking citizenship education. A curriculum for participatory democracy. Bloomsbury Academic, London.
15. Ricci E.C.; Banterle A.; Stranieri S. (2018): Trust to Go Green: An Exploration of Consumer Intentions for Eco-friendly Convenience Food. Ecol. Econ. 148: 54–65.
16. Sathyapriya P.; Sekar P. (2020): Green product and consumer behavior: An analytical study. EPRA Int. J. Res. Dev. IJRD. 5: 536–540.
17. Schild R. (2016): Environmental citizenship: what can political theory contribute to environmental education practice? Journal of Environmental Education 47:19–34.
18. Tan Z.; Sadiq B., Bashir T.; Mahmood H., Rasool Y. (2022): Investigating the Impact of Green Marketing Components on Purchase Intention: The Mediating Role of Brand Image and Brand Trust. Sustainability,14: 5939.
19. Taylor D. (2016): The rise of the American conservation movement: power, privilege, and environmental protection. Duke University Press, Durham, North Carolina.
20. The United Nations Environment Programme (2011): Decoupling Natural Resource Use and Environmental Impacts from Economic Growth. The United Nations Environment Programme; Nairobi, Kenya: 2011.
21. Wang H.-J. (2017): Determinants of consumers' purchase behavior towards green brands. Serv. Ind. J. 37:896–918.
22. Wasaya A.; Saleem M.A.; Ahmad J.; Nazam M.; Khan M.M.A.; Ishfaq M. (2021): Impact of green trust and green perceived quality on green purchase intentions: A moderation study. Environ. Dev. Sustain. 23:13418–13435.
23. Witek L.; Kuźniar W. (2020): Green Purchase Behavior: The Effectiveness of Sociodemographic Variables for Explaining Green Purchases in Emerging Market. Sustainability, 13:209.

24. Zhang X.; Dong F. (2020): Why Do Consumers Make Green Purchase Decisions? Insights from a Systematic Review. Int. J. Environ. Res. Public Health. 17:6607.
25. *** Das P. Feedough (2023): What Is a Green Product? - Examples, Advantages, & Challenges. 2023. URL: https://www.feedough.com/green-product/
26. *** ENEC (European Network for Environmental Citizenship). (2018): Defining "environmental citizenship. ENEC, Lemesos, Cyprus. URL: http://enec-cost.eu/our-approach/enec-environmental-citizenship/.
27. ***White K., Hardisty D., Habib R. (2019): Harvard Business Review–The Elusive Green Consumer. 2019. URL: https://hbr.org/2019/07/the-elusive-green-consumer

Authors address:
Attila Rácz[1], Vladislav Kaputa[2*], Erika Loučanová[2]
[1] UNESCO Chair on Sustainable Development and Ecological Awareness, Technical University in Zvolen, Masaryka 24, 960 53 Zvolen, Slovakia
[2] Department of Marketing, Trade and World Forestry, Technical University in Zvolen, Masaryka 24, 960 53 Zvolen, Slovakia
[*]Corresponding author: kaputa@tuzvo.sk

ASPECTS OF THE GREEN USE OF WOOD BY-PRODUCTS FROM THE SAWMILL INDUSTRY

Wieruszewski, M. Wanat, L., Kusiak, W., Sarniak, L.

Abstract: The paper discusses selected aspects of the green use of wood by-products generated in the sawmill industry. In this context, first of all, the competitive potential of the sawmill industry was analyzed. It was assumed that the directions of use of wood-based by-products will be determined by the development of the sawmill products market in Poland. This includes wood uses in the green energy industry. Based on the analysis of the price changes of wooden materials and the market trends identification, the most important conclusions and recommendations were formulated.
Keywords: wood-based sector, wood by-products, green energy, sawmill industry, Poland

1. INTRODUCTION

The starting point in programming the green use of wood by-products remains the dream of relative stability in the Polish, European and global wood market. In view of the economic uncertainty resulting first from the time of the pandemic, then from the time of the war right on Poland's borders, this dream still remains unfulfilled. Another dilemma is the unresolved dispute over the destination of wood by-products, generated not only in the forest, but especially in the sawmill industry [1, 2]. The by-products of wood-based industries are most easily allocated for energy purposes. One can even point to a very important goal: the production of green energy [8, 11]. But is this the most efficient solution for the economy and the environment? Doubts arise [5, 7, 9].

It is therefore reasonable to search for alternative use of the wood material, called a by-product for simplicity [14]. How to solve this problem? It seems to be decided by the economic condition of the sawmill industry [4]. For these reasons, this study refers primarily to the competitive situation of the sawmill industry in Poland [6, 12]. It seems that it is only on this basis that it is possible to talk about the directions of application of by-products of the sawmill industry, not vice versa.

The situation in European and global markets in 2020-2022 indirectly contributed to an increase in wood prices in Poland. Round pine wood (Polish designation WC0) in the second half of 2021 was purchased for as much as PLN 800/m^3 (the average price was about 460 PLN/ m^3). This is a significant increase from the level of 250-320 PLN/ m^3 (early 2021) [10]. Medium-sized coniferous timber (Polish designation S2B), whose initial price averaged 120 PLN/m^3, already reached 280 PLN/m^3 in the second half of 2021 [10]. In addition, new rules for the sale of raw timber, introduced in 2022 by the monopolist: State Forest Holding 'State Forests' (Lasy Państwowe), contributed to a further increase in average roundwood prices in Poland.

A consequence of the changes in the roundwood market, was an increase in the price of sawnwood and other wood-based materials. This has caused dynamic changes in global markets as well. For example, lumber prices in the US have increased by up to 300%, compared to previous periods of relative stability. The most noticeable price changes occurred in the case of structural lumber (rising to nearly 700 USD/m^3) [10].

Also in Europe, the price of finished structural glulam has increased in the short term (2021) from 400 to almost 800 EUR/m^3 (e.g., glulam beams in Germany and Italy). In addition, in 2021, the main customer for Scandinavian and German spruce lumber was the United States (steady growth in demand and a price of more than 620 USD/m^3) [10]. Despite periodic signs of stabilization, conifer sawnwood prices continue to rise. Coniferous wood, especially lumber, has become a scarce commodity on the European market. Thus, the supply of structural timber has declined, while sales of garden wood products, planed products, and finishing materials and wood flooring have increased.

Despite the price increase, new wood industries based on softwood are developing. However, they are not taking full advantage of their production capacity, due to high prices and supply constraints. In turn, a significant increase in wood supply is not possible. This is due to the regulation of the forest policy of some countries (including Poland), as well as EU directives (plans to exclude certain forest areas from economic use). It also relates to restrictions and trends in international trade (Europe, especially central and eastern Europe, is not a leading export direction for roundwood and sawnwood). Thus, out of necessity, the forest-wood value chain model is changing [5], representing an opportunity, including in the sawmill industry, for wood by-products.

2. MATERIAL AND METHODS

In identifying the most important aspects of the green use of wood by-products generated in the lumber industry, the following assumptions were made. First: before deciding to allocate sawmill waste to green energy, economically efficient alternative uses should be sought. Second, the choice of alternative processing of so-called sawmill waste will be determined primarily by the price of wood and wood materials.

In addition, the structure of the processing of wood by-products in the sawmill (that is, the scale of the share of wood semi-finished products, finished products, wood products and final green energy - in the volume of total production), will be defined by the factors determining the Polish wood market. Thus, the background of the analysis was made the main measures that constitute the condition of the sawmill industry, the synthesis of which is the relationship between the volume of supply and the price of sawmill materials.

The purpose of the study was to analyze the ability to use the wood waste by-products of sawmilling for energy purposes. Thus, it is reasonable to find alternative uses for wood material (also as a by-product). It was assumed that these applications would be determined by the development of the competitive situation of the sawmill industry in Poland. It seems that only on this basis it is possible to talk about the directions of the use of sawmill industry by-products, including in the green energy industry.

In performing the research task, reference was made primarily to changes in the prices of the main wood products (sortiments) of the sawmill industry in Poland [15]. Secondary data were obtained from sources of sectoral public statistics [13], confronting the main trends with the results of other studies available in the literature [10, 17, 18]. In time scope, the key years of economic uncertainty, i.e. the period 2020-2022, were taken into account (of course, where data was available). Based on the results obtained, as well as comparative and descriptive analysis [3] (trend analysis), conclusions and recommendations were made.

3. RESULTS AND DISCUSSION

The strategic assumption of the Polish wood industry is the processing of most wood (especially roundwood) by local entrepreneurs [18]. Implementation of this plan is not easy. Economic uncertainty, including Russia's war with Ukraine, has increased wood supply problems in the Polish wood market. Imports of wood and semi-finished wood products from Russia and Belarus have been halted, while trade with Ukraine has been curtailed (this applies to as much as 25% of the market share of lumber and panel materials, based on wood) [10].

It was noted that a possible increase in the wood supply at so-called open auctions and the removal of export restrictions, could cause further price increases and chaos in the market. A similar effect is caused by a reduction in imports and a de facto significant shortage of wood supply. In a situation where, despite high prices, demand for wood remains relatively high, no symptoms of change and a return to equilibrium can be identified. Prices in the wood market have been increasing generally (see Figure 1).

The upward trend, despite periodic price fluctuations, is maintained for both the Polish currency (PLN) and the US dollar (USD). In such a situation, it is difficult to forecast any changes in the directions of destination of by-products generated at sawmills for green energy.

Anticipating possible changes in the segment of the wood market created by the sawmill industry, two important elements must be taken into account: the policy of timber sales carried out by the State Forests (an increase in supply - wood harvesting by about 3 million m^3, a reduction in the export of unprocessed wood). Another direction will be to reduce the burning of wood by the power industry and to facilitate the use of post-consumer wood.

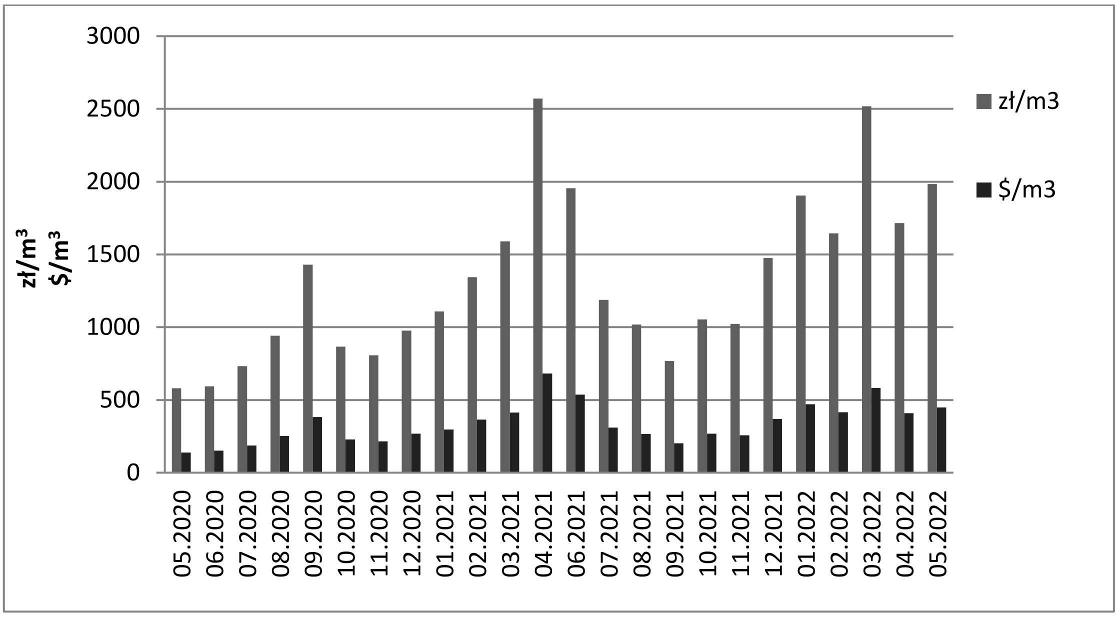


Figure 1. Changes in sawnwood prices in Poland (2020-2022) on the background of PLN and USD exchange rates [19].
Source: Own elaboration based on [https://ec.europa.eu/eurostat/, accessed on 13.05.2022]

It might seem that the possible destinations of wood by-products generated at sawmills will be determined by the prices of individual sawmill assortments. However, even in this area, the upward direction of changes in sawmill material prices is generally dominant (Figure 2).

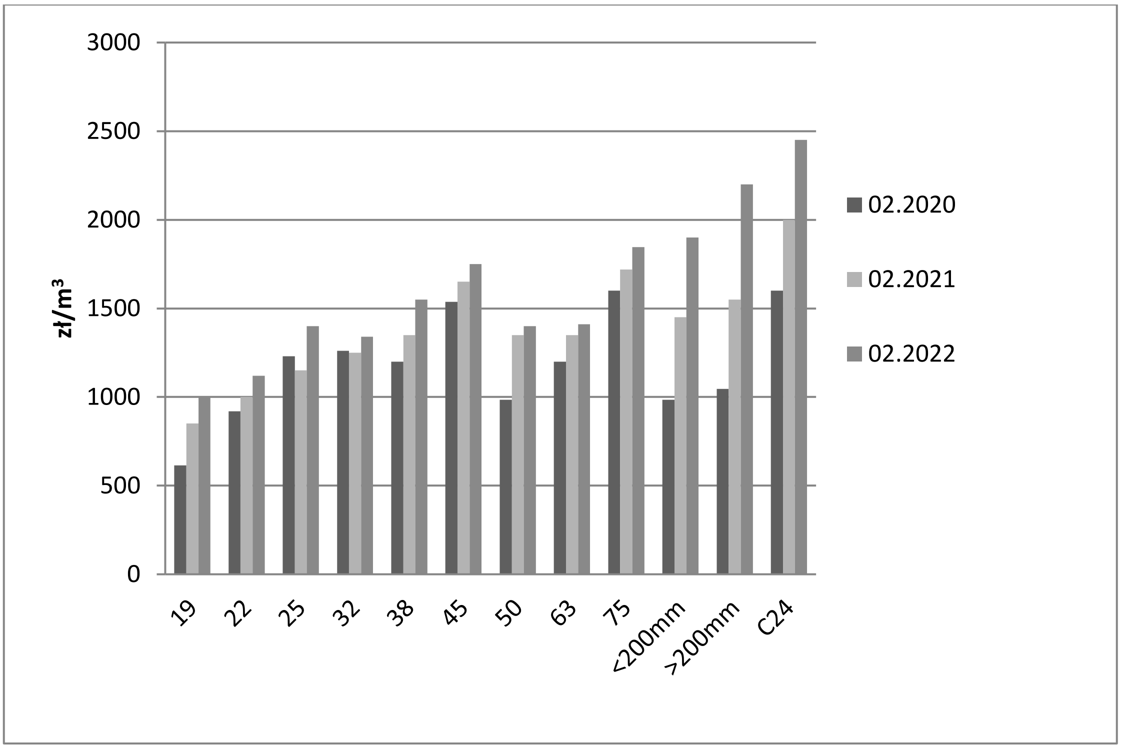


Figure 2. Price changes [PLN] of pine sawnwood assortment [mm] in 2020-2022.
Source: Own elaboration based on [https://stat.gov.pl/, accessed on 13.05.2022] [20].

In such an identified competitive situation, determined by the dominance of high wood prices, in the analyzed market segment (we are talking about wood by-products and biomass), one must also take into account the influence of qualitative factors [16]. The first of these is the rivalry between the energy and heating industry, on the one hand, and the wood-based sector, on the other. The issue in dispute is wood, by-products and wood recycling. This conflict, by the way, concerns not only Poland, but also other EU countries. It is wood biomass that is constantly being sought as a raw material for alternative sources of electricity and heat. It seems that in addition to the problem of optimizing the use of domestic biomass, importing post-consumer wood to Poland will also be an important challenge. This is a research direction that could be an extension of the analyses proposed in the study.

4. CONCLUSIONS

Based on the comparative and descriptive analysis, the following conclusions and recommendations were formulated:

1) The possibility of green use of wood by-products generated in the sawmill industry will be determined primarily by market conditions: the price and supply of basic wood materials.
2) The sustained, relatively high price of wood is driving more towards the production of wood products with higher use value, rather than the simple "conversion" of wood by-products into energy.
3) A possible increase in the supply of wood raw material to the Polish sawmill industry may reduce the deficit of sawnwood on the local market, but, given the situation on international markets, is unlikely to reduce prices.
4) Intervention to reduce the wood export appears to have little effect, given the secondary wood trade carried out by wood industry companies.
5) It seems that a sustained increase in sawtimber prices over the long term may result in a gradual reduction in wood processing. This will probably lead to a decline in demand for wood raw material, but will not significantly affect the growth of green energy production based on wood by-products.

REFERENCES

1. Bamwesigye, D., Hlavackova, P., Sujová, A., Fialova, J., Kupec, P. (2020). Willingness to pay for forest existence value and sustainability. Sustainability, 12(3), 891.
2. Bergen, V., Löwenstein, W., Olschewski, R. (2013). Forstökonomie. Volkswirtschaftliche Ansätze für eine vernünftige Umwelt- und Landnutzung, Vahlens Handbücher der Wirt-schafts- und Sozialwissenschaften. Vahlen Verlag, München.
3. Holmes, T. J. (2010). Structural, experimentalist, and descriptive approaches to empirical work in regional economics. Journal of Regional Science, 50(1), 5-22.
4. Klus, S., Topczewska, A., Urbanowicz, Z., Wanat, L. (2022). Mesoeconomic market analysis based on selected Big Data tools - the case of wood market trends in Poland under economic uncertainty. Annals of the Polish Association of Agricultural and Agribusiness Economists, 24(3), 94-107.
5. Kroth, W., Bartelheimer, P. (1993). Holzmarktlehre. Pareys Studientexte 77. Hamburg-Berlin: Paul Parey.
6. Kusiak, W., Mikołajczak, E., Wanat, L. (2018). Institutional and Industrial Symbiosis Case Study of Cooperation for Development in Forestry and Wood-Based Sector. [In:] Increasing the use of wood in the global bio-economy. Glavonjic B. (ed.), September 26th-28th, 2018, University of Belgrade, Belgrade, Serbia, pp. 388-399.
7. Kusiak, W., Wanat, L., Klus, S., Styma-Sarniak, K. (2019). Circular Economy from the Perspective of Scientific Research Papers jn the Forestry and Wood-Based Sector in Poland. [In:] Chobanova R.(ed.) Digitalisation and Circular Economy: forestry and forestry based industry implications, USB and WoodEMA, i.a., 33-38.
8. Kusiak, W., Wanat, L., Czarnecki, R., Wieruszewski, M. (2021). Economic Use of Wood Resources in Selected Forest Areas, Varied in Terms of Production and Protection Availability - the Case of Poland. [In:] The Response of the forest-based sector to changes in the global rconomy, M. Jošt (ed.). WoodEMA, i.a. and University of Ljubljana, Koper, Slovenia, pp. 173-178.
9. Lessem, R., Schieffer, A. (2016). Integral economics: Releasing the economic genius of your society. CRC Press.
10. Mydlarz, K., Wieruszewski, M. (2022). Economic, Technological as Well as Environmental and Social Aspects of Local Use of Wood By-Products Generated in Sawmills for Energy Purposes. Energies, 15(4), 1337.
11. Ratajczak, E. (2013). Sektor leśno-drzewny w zielonej gospodarce. ITD, Poznań.

12. Sujová, A., Simanová, Ľ., Kupčák, V., Schmidtová, J., Lukáčiková, A. (2021). Effects of foreign trade on the economic performance of industries. Evidence from wood processing industry of Czechia and Slovakia. Economies, 9(4), 180.
13. Statistical Yearbook of Forestry (2022). CSO Warszawa. Available online: https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3328/12/5/1/statistical_yearbook_of_forestry_2022.pdf [accessed on 13.05.2023].
14. Wanat, L. (2016). Gospodarka leśna: zrównoważona czy integralna? Dylematy badawcze z perspektywy polskiego rynku drewna okrągłego. Przegląd Leśniczy, 26(09), 26-27.
15. Wanat, L., Mikołajczak, E., Chudobiecki, J. (2018). The Value and Profitability of Converting Sawmill Wood By-Products to Paper Production and Energy Generation: The Case of Poland. Pulp and Paper Processing, 109. DOI: 10.5772/intechopen.80044 .
16. Wanat, L., Potkański, T., Chudobiecki, J., Mikołajczak, E., Mydlarz, K. (2018). Intersectoral and Intermunicipal Cooperation as a Tool for Supporting Local Economic Development: Prospects for the Forest and Wood-Based Sector in Poland. Forests 9 (9), 531, 1; https://doi.org/10.3390/f9090531.
17. Wanat, L., Wieruszewski, M., Kusiak, W. (2022). Wood materials market in Poland–selected development dilemmas in conditions of economic uncertainty. [In:] Crisis management and safety foresight in forest-based sector and SMEs operating in the global environment, ed. R. Nováková, pp. 435-440.
18. Wieruszewski, M., Górna, A., Mydlarz, K., Adamowicz, K. (2022). Wood Biomass Resources in Poland Depending on Forest Structure and Industrial Processing of Wood Raw Material. Energies, 15(13), 489, https://doi.org/10.3390/en15134897 .
19. *** https://ec.europa.eu/eurostat/, [accessed on 13.05.2023].
20. *** https://stat.gov.pl/ [accessed on 13.05.2023].

Authors address:
Wieruszewski, M. [1]; Wanat, L.[2*]; Kusiak, W. [3]., Sarniak, Ł. [4].
[1] Department of Wood-Based Materials, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[2] Department of Information Technology and Data Analysis, Faculty of Applied Sciences, Collegium Da Vinci, Poznań, Poland.
[3] Department of Forest Engineering, Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Poznań, Poland.
[4] Department of Finance and Accounting, Faculty of Economics, Poznań University of Life Sciences, Poznań, Poland.
[*] Corresponding author: leszek.wanat@up.poznan.pl

Technological papers

LIFE CYCLE IMPACT ASSESSMENT OF A TIMBERFRAME HOUSE WITH VAPOUR-PERMEABLE EXTERNAL ENVELOPE

Búryová, D., Vaňová, R., Sedlák, P., Uhrín, R.

Abstract: Wood structures represent a sustainable way of construction with minimal impact on the environment, due to renewable raw material use. This paper focused on assessing the life cycle impacts of a residential building, with vapor-permeable external envelope structure based on timber elements. The evaluation assessed the product phase from the extraction of raw materials to the production of building materials, including two scenarios of the envelope thermal insulation types. Building materials were evaluated by using the IMPACT 2002+ method, as a part of SIMAPRO simulation software package. Endpoint impact categories were included in the assessment. The discussion and results showed the importance of the wood raw material origin, apart from other reasons.
Keywords: Impact 2002+, damage categories, vapour permeable external envelope

1. INTRODUCTION

Natural materials usually have less impact on the environment compared to commonly available silicate materials.

Modern methods of construction (MMC), to which modern houses based on wood belong, promote the idea and application of environmentally and energetically efficient constructions.[6]

Environmental economics and sustainable development have become central concerns to people from all disciplines and in all countries.[1]

Non renewable energy sources—Energy from the ground that has limited supplies.[2]

An important part of resource depletion and emissions is caused by the energy consumption of building production systems. For eco-friendly building materials, it is important to define their damage approach.

SimaPro and GaBi are the leading software tools used for life cycle assessments. The software performances are compared based on a random sample of 100 unit processes. SimaPro and GaBi are used by many Life Cycle Assessment (LCA) practitioners worldwide as a decision-support tool.[3]

For the purposes of this article, the scientific software SimaPro was used. Data was taken from the Ecoinvent v3 database, that covers more than 10000 processes. For the purposes of the analysis, the IMPACT 2002+ method was used with the implementation of the midpoint/damage approach combination. The IMPACT 2002+ life cycle impact assessment methodology proposes the implementation of a combined midpoint /damage approach that combines all types of life cycle inventory results. Elemental flows and other interventions (LCI results) are combined through 14 midpoint categories into four damage categories. The IMPACT 2002+ concept and method mainly compares human toxicity and ecotoxicity. The mentioned new approach is presented by the IMPACT 2002+ method. Human damage factors are calculated for carcinogens and noncarcinogens using intake fractions, best estimates of dose-response slope factors, and severity. The transfer of contaminants to human food corresponds to the level of agricultural and livestock production.

Effect factors for human toxicity and ecotoxicity are based on average responses. Other midpoint categories are adapted from existing characterization methods (Eco-indicator 99 and CML 2002). All mean values are expressed in units of reference substances and refer to the four categories of damage to human health, ecosystem quality, climate change and resources.[5]

Normalization can be done either at the centre or at the damage level. We chose the assessment on the damage categories. This article presents the impact of the choice of building material on the environment and human health. Pursuant to the Act on Energy Efficiency of Buildings, each building is classified into an energy class according to the criterion - primary energy as a global indicator. Primary energy [kWh/ (m^2.a)] is energy in the form in which it is first included in the statistical energy balance, before being transformed into secondary or other forms of energy. We are interested in the value of the global indicator of the building's energy efficiency. The materials used are generally considered to be of natural origin. The subject of the contribution is the verification of this statement by using the impact 2002+ method while complying with the building physics and energy requirements for buildings.

2. MATERIALS AND METHODS

The simulated object is a single-story wooden building with a vapour permeable external envelope. Such an envelope is a assembly, in which the layers have gradually decreasing diffusion resistance towards the exterior, and this assembly does not use highly impermeable plastic vapour barrier. The order of the layers allows moisture to diffuse through the structure to the exterior without risk of vapour condensation. The favourable humidity regime of the interior air creates a pleasant internal environment of the building. In structures with highly effective vapour barriers, the process of possible reverse water vapor diffusion or the phenomenon of convection can cause excessive condensation inside the building structures.

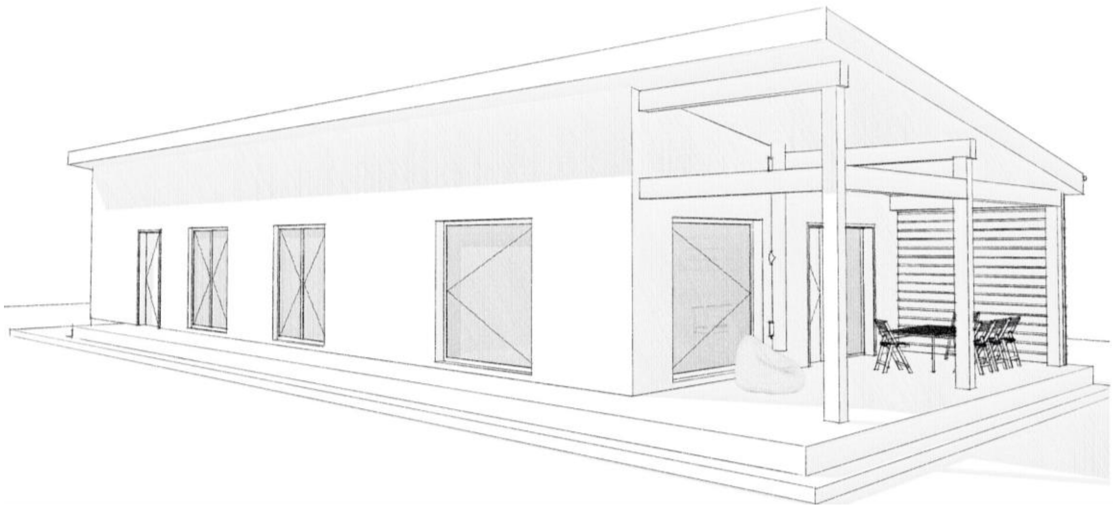


Figure 1: Visualization of a simulated house

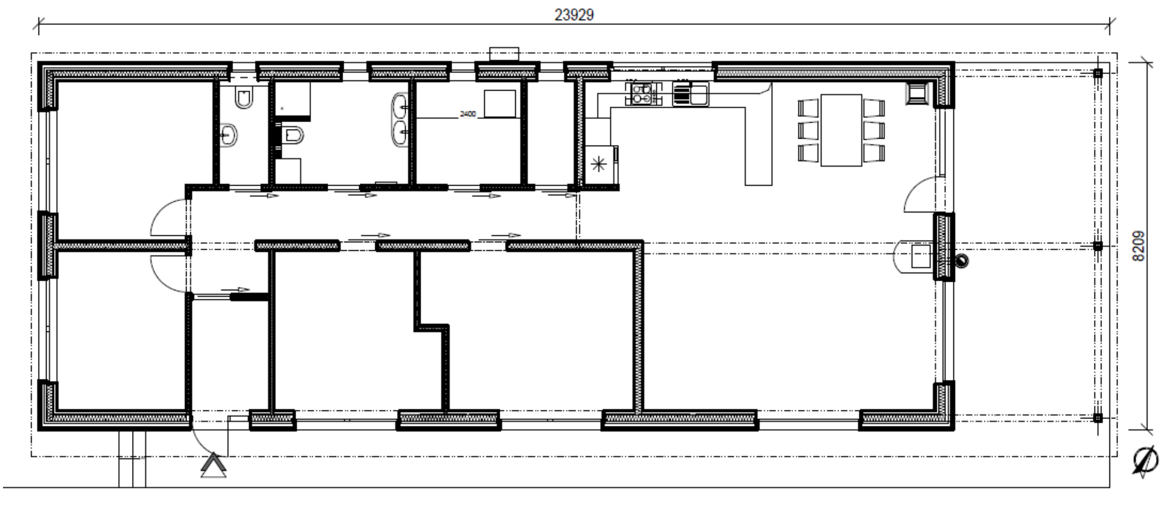


Figure 2. Floor plan of a simulated house

The main factors affecting the energy category are: the building's thermal insulation, the appropriate shape of the building, south orientation of the main facadec and the method of ventilation. All these factors must be evaluated comprehensively and their impact on the energy balance of the building must be taken into account during the design.

Basic building characteristics of the considered house: the net floor area is 165 m^2 and the external volume is 552 m3. The building is located in the 3rd (medium) temperature region of Slovakia. External envelope / volume ratio is 0.931. The average intensity of air exchange "n" according to STN 73 0540-2 due to natural infiltration through the building joints is n = 0.37 1/h.

Table 1: Material composition and weight distribution within the construction

MATERIAL	kg	%
Timber – wooden main structure elements	11 400	19,2
Reinforcing steel – connecting elements	163,7	0,3
Concrete - concrete foundation structures	6 940	11,7
Thermal insulation - mineral insulation	13 097	22,0
	31 600 kg	***53,2%***
Board and foil supplements	***27 909 kg***	***46,8%***

Material composition and weight distribution within the construction (Table 1) were described in their respective tables. Environmental impact was expressed via midpoint and endpoint impact categories.

Environmental impact was expressed by midpoint and endpoint impact categories. The impact was calculated on the selected major parts of the house – load bearing system, foundation structures, thermal insulation, board and foil cladding, supplements of main structure and dividing partitions. The environmental impact of the roofing and infill structures were not taken into account. We focused on building structures characteristic for wood houses.

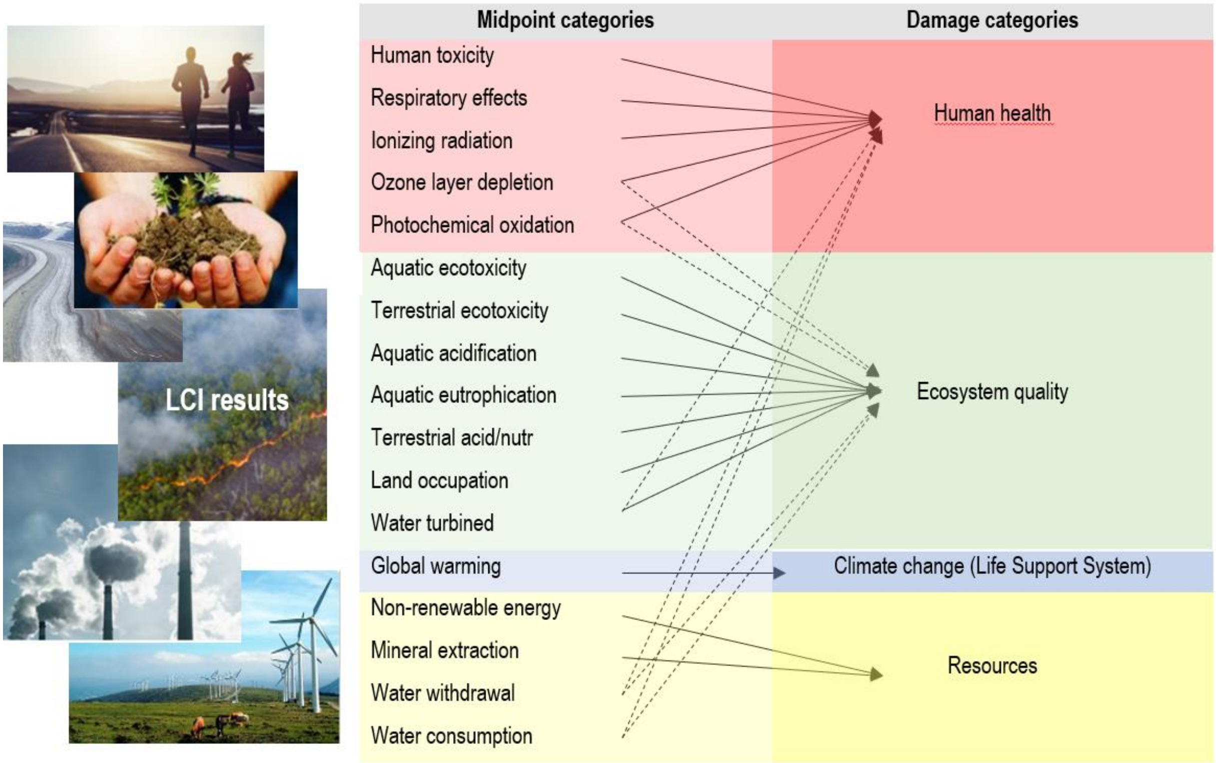


Figure 3. Overall scheme of the IMPACT 2002+ vQ2.2 framework2, linking LCI results via the midpoint categories to damage categories, IMPACT 2002+: general concept

As shown in Figure 3, LCI results with similar impact pathways are allocated to impact categories at midpoint level, also called midpoint categories. A midpoint indicator characterizes the elementary flows and other environmental interventions that contribute to the same impact. The term 'midpoint' expresses the fact that this point is located somewhere on an intermediate position between the LCI results and the damage on the impact pathway. In consequence, a further step may allocate these midpoint categories to one or more damage categories, the latter representing quality changes of the environment. A damage indicator result is the quantified representation of this quality change and calculated by multiplying the damage factor with the inventory data. The damage indicator result is often named as damage impact score - damage category.[4]

3. RESULTS AND CONCLUSIONS

STN 73 0540 and STN EN ISO 13790 standard procedures were used for building physics and energy calculations. In accordance with the STN 73 0540 - 2 standard, it is necessary to achieve a value of the global indicator (GU) of less than 54 kWh/m^2 (energy class A0). The mentioned house achieved a GU value of 51 kWh/m^2. It is appropriate for the building to have at least one renewable source of energy. In this case, we considered solar panels, as solar systems significantly reduce monthly costs of electricity and dependence on the electrical network. The selection of the most appropriate energy source should be based on basic economic, environmental and safety aspects - heating of the simulated house is designed as a combination of a heat pump, a wood stove and solar panels.

The thermal and technical properties of the house ensure thermal protection and the heating demand to a sufficient level., and the house meets the requirements of technical and legal regulations. 44 kW/m^2.year of the heating energy meets the criteria of current standards STN 73 0540 and STN EN ISO 13790 for new buildings. Heating of an energy efficient house has therefore significantly smaller impact on the environment than other buildings.

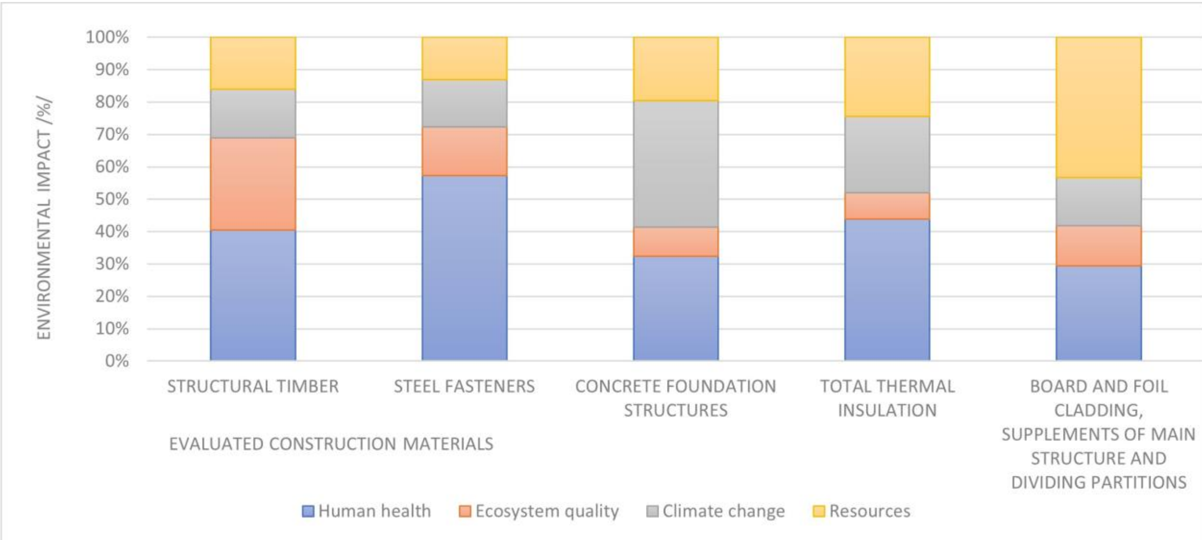


Figure 4. Damage assessment of construction materials within each endpoint impact category (human health, ecosystem quality, climate change and resources). Numbers refer to construction materials listed in Table 1

Figure 4 shows the impact on human health (HH) - due to the distribution of the weight of the materials in the construction, the wooden structural system shows a one-third lower impact on HH compared to metal fasteners. The disproportion of values may be caused by the adverse effect of the production and final treatment of steel fasteners on the ozone layer. In comparison, wood before cutting has a positive effect on the ozone layer.

An interesting result is the impact of steel fasteners on Climate change (CC) compared to the impact of a wooden main structure. It is an interesting result, when considering the amount of material that is incorporated in the construction. The impact on CC is comparable, but the built-in metal fasteners make up only 0.3% of the total assessed built-in building material.

Figure 5 shows the adverse effect of plasterboard and gypsum fibre board on the depletion of non-renewable energy. The adverse impact on resources is determined by the method of production. A significant reduction in the depletion of resources can be considered through the use of recycled materials for their production. In the production of building foils, the risk of possible water pollution is 75% lower than in the production of plasterboard and gypsum fibre boards. Unfavourable values of resource depletion, which are shown for construction foils, probably as a result energy demanding production.

The assessment of damage categories - Ecosystem quality (EQ) - is directly influenced by many Midpoint categories and a similar number of indirect influences. According to the results of the simulation of water permeable external envelope in the SimaPro application, the use of solid areas of the earth's surface and the subsequent threat to biodiversity appear to be an important Midpoint category. The EQ result correlates with the amount of wood and wood mass incorporated in the structure of the building.

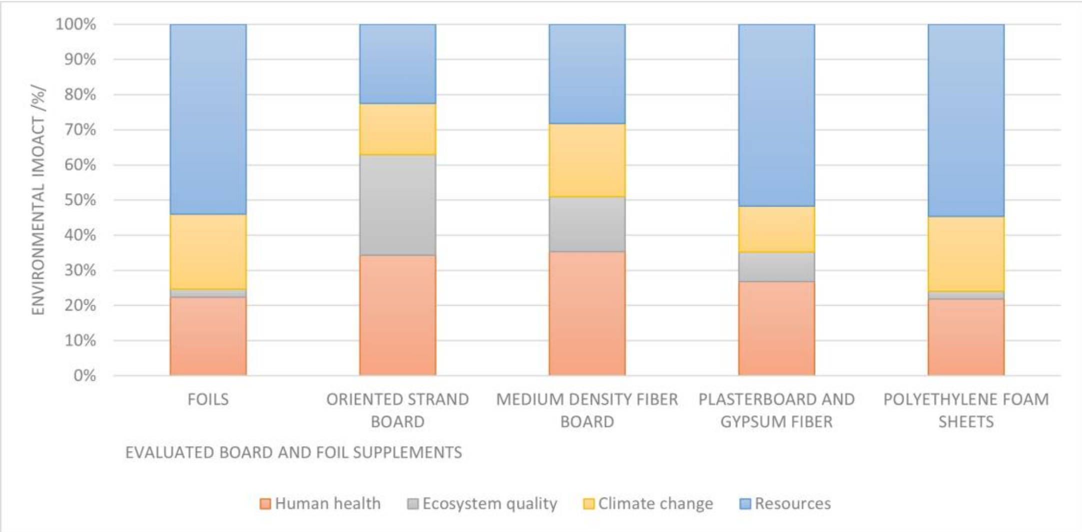


Figure 5. Damage assessment of evaluated board and foil supplements within each endpoint impact category (human health, ecosystem quality, climate change and resources).

An interesting item during the construction is the choice of the method of foundation of the building. In view of the moisture management of the construction of water permeable external envelope, the method of isolated spread footing is preferable. This method does not significantly change the terrain. However, in the construction of ordinary dwellings, there are usually wall footing foundations or concrete slab structures used. The mentioned shallow types of building foundations significantly affect the terrain and the surroundings of the building.

Acknowledgements: This paper was also supported by APVV 17-0206

REFERENCES

1. COLE, R. J. Building environmental assessment methods: clarifying intentions. *Building Research & Information*, 1999, 27.4-5: 230-246.
2. FORSBERG, Ch. W.; MCDANIEL, P. J.; ZOHURI, Bahman. Nuclear Air-Brayton Power Cycles with Thermodynamic Topping Cycles, Assured Peaking Capacity, and Heat Storage for Variable Electricity and Heat. *Nuclear Technology*, 2021, 207.4: 543-557.
3. HERRMANN, I. T.; MOLTESEN, A. Does it matter which Life Cycle Assessment (LCA) tool you choose?–a comparative assessment of SimaPro and GaBi. *Journal of Cleaner Production*, 2015, 86: 163-169.
4. HUMBERT, S., et al. IMPACT 2002+: user guide. *Draft for version Q*, 2012, 2.
5. JOLLIET, O., et al. The LCIA midpoint-damage framework of the UNEP/SETAC life cycle initiative. *The International Journal of Life Cycle Assessment*, 2004, 9: 394-404.
6. ŠVAJLENKA, J.; KOZLOVSKÁ, M. Houses based on wood as an ecological and sustainable housing alternative—Case study. *Sustainability*, 2018, 10.5: 1502.
7. ****: STN 73 0540* Thermal protection of buildings. Thermal performance of buildings and components. Part 2: Functional requirements
8. ***: STN EN ISO 13790 Energy performance of buildings. Calculation of energy use for space heating and cooling (ISO 13790:2008)

Authors address:
Búryová, D.[1], Vaňová, R. [2], Sedlák, P.[3], Uhrín, R.[3]
[1234] Department of Wooden Constructions, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovak Republic
*Corresponding author: buryova@tuzvo.sk

WOOD FUEL IN PASSIVE HOUSES – THE WAY TO CARBON NEUTRALITY?

Sedlák, P., Búryová, D., Vaňová, R., Uhrín, R.

Abstract: Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere. As CO2 emissions relates to global energy use and the fuel type, it is important to understand the energy structure in detail. Buildings generally consume app. 40 % of final energy, cause 30% of CO2 emissions and produce 40 % of waste. Although only 20% of the world population lives in developed countries, they use almost 80% of global energy sources.
It is therefore essential to lower the energy use as much as possible while using renewable sources and store the energy in short or long term ideally.
Well insulated building envelope of passive houses is part of the solution to reduce heating energy, together with low carbon biomass fuel to reduce CO2 emissions. But, it also brings new challenges for traditional wood/pellet burning heating systems, and especially for light timberframe houses due to risk of overheating. This, in combination with systems for domestic hot water (DHW) preparation create very specific and sensible complex with conflicting demands.
This paper analyses energy use in a passive house and its systems specification, aimed to achieve carbon neutrality in operational energy for space heating and DHW preparation annually. Though there are significant limits in structure, room sizes, solar panel location and the system combination, the total balance can be accomplished.
Keywords: heating energy, heating system, DHW system, passive house

1. INTRODUCTION

Basically, the heating energy demand of a building reflects balance of thermal losses through the envelope and by ventilation, vs thermal gains, mainly passive solar gains through windows. There is a number of factors affecting the heating energy – thermal insulation level (U-values), airtightness, heat recovery, south orientation and many other. Thermal transmittance – the U-value considers the material parameters of the envelope; thus, it relates directly to the material properties of the building [5].

Before any highly sophisticated heating systems are installed in the building, it is the most important to reduce the thermal losses as much as possible in first place. To do this, there are several standards set to achieve the desired heating energy reduction.

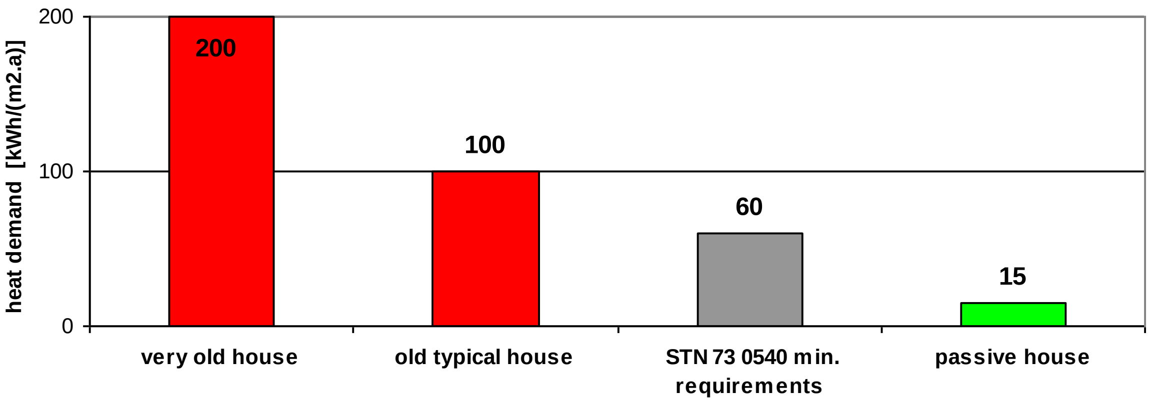


Figure 1. Heat demand for different house types (annually per m2 of net floor area)

Passive House is the world's leading standard in energy efficient construction [9], originated from Bo Adamson, Sweden, and Wolfgang Feist, Germany. The Houses require very little energy to achieve a comfortable temperature, making conventional heating and air conditioning systems obsolete [9]. Passive house standard has been significantly reducing the operational energy of buildings for 30 years already [7]. It may not be that complicated, but we have much work to do to reduce energy related to buildings [2].

Heating and DHW systems are inseparable part of a building, and they directly affect operational CO2 emissions and primary energy, depending on its technology and fuel. The CO2 production is related to so-called Primary Energy Factor of a fuel, which reflects production, transportation and renewability and it weights the different energy carriers, comparing them to the corresponding energy sources. The 2010/31/EU Directive establishes that the building energy performance should be expressed by a primary energy index.

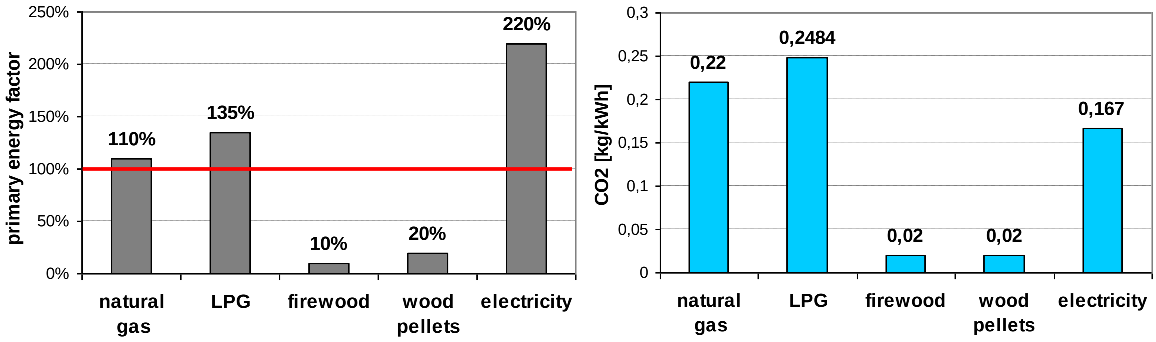


Figure 2. Primary energy factors and CO2 emissions for fuels [8]

The primary energy factor benchmark is set to 1.0 (or 100%) and shows how much primary fossil energy is used for an energy provided by certain fuel at particular location – in a house. The factor varies from the best 0.1 (10%) for wood (as it consumes CO2 during growth) – to 2.2 (220%) for electricity (as for 1kWh on site there is 2.2kWh of symbolic coal burned in a powerplant). Natural gas value 1.1 (110%) reflects additional 10% for transportation.

2. WOOD FUEL FOR HEATING AND DHW SYSTEMS

As seen from Fig. 2, renewable fuel types as firewood and wood pellets have minimal primary energy factor, and therefore induce the lowest CO2 emissions. The fuel is closely connected to heating system, and usually there are conflicting parameters for each considered option, e.g. - direct electric heating systems are easy to install, but the most expensive to run – heat pump is highly effective, but the equipment is complicated and costly – wood stove requires maintenance and manual transportation of fuel.

The problems with wood fired appliances are crucial for passive houses while selecting the most appropriate solution, mainly due to high risk of the habitable space overheating. The most important factors are max. output to the room where the stove is located (Fig. 3), availability to heat DHW, flexible output power control and automatic operation option.

One of the very few systems qualified for this purpose would be wood pellet stove with water heat exchanger and output power over 70% to water – for sufficient redistribution to other zones and for DHW preparation. This system is later considered in the assessment, though some may oppose the disadvantages of the system (higher primary energy factor than firewood, noisy operation, chimney installation).

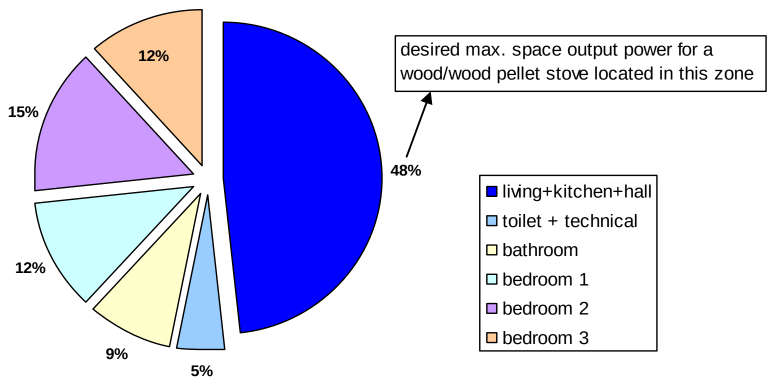


Figure 3. Structure of thermal loss for typical well insulated single-storey house

3. CASE STUDY HOUSE

Calculations and modelling were performed on a passive house EcoCube MAX [1] in central Slovakia, which has been monitored since the beginning of the construction process (Fig.4). The house is a timberframe double-storey building and represents Modern Methods of Construction (MMC), to which modern houses based on wood belong, promoting the idea and application of environmentally and energetically efficient constructions [6], and their advantage in terms of high thermal resistance while maintaining relatively small thickness is undeniable [3].

Figure 4. The case study house (left-during construction, right – finished house)

Table 1. Case study house – basic information, U-values

Building - basic information	
Net usable floor area	152,44 m^2
External dimensions - floorplan	12,60 x 8,35 m
Building envelope total area	477,6 m^2
Ventilation	mech. ventilation with heat recovery
Heating energy demand (building)	2194 kWh/(m^2.a)
Energy demand (DHW)	2603 kWh/(m^2.a)

U - values (thermal insulation level)		
external wall	0,10	W/m^{2}K
roof / sloped ceiling	0,08	W/m^{2}K
floor slab	0,14	W/m^{2}K
windows (declared value)	0,78	W/m^{2}K
entrance door (declared value)	0,80	W/m^{2}K

Calculations of energy demand were performed in Passive House Planning Package (PHPP) certified for passive houses, primary energy and CO2 emissions were determined by related Slovak standards [8].

4. RESULTS

There were four scenarios modelled, while using different house heating and DHW systems with related fuel types (Table 2). Each scenario is then considered with solar photovoltaic panels to demonstrate feasibility of such option and overall effect. Fig. 5 presents solar panels installed on the roof of this building.

As seen from Table 2 and Fig. 6, scenarios with wood pellet stove showed significantly low values of CO2 emissions and related primary energy if compared to natural gas fired boiler. The basic problem is that wood stove cannot be used for hot water heating during summer, and therefore secondary DHW system is required. As a result, combination of wood pellet stove with heat pump proved to be the most sustainable while producing as low as 162 kg of CO2, without auxiliary solar system. When it comes to scenarios with solar panels, the best option seems to be heat pump system combinations, as the electric energy can be provided by the panels, and can even be carbon neutral for solely electric systems (scenario 4). Noticeably, scenario 3 with the stove and heat pump combination plus solar panels may be remarkably low on CO2, but cannot be carbon neutral, as energy extracted from wood cannot be supplemented by electricity.

Table 2. Results overview for the modelled scenarios

			Alt 1. natural gas boiler	**Alt 2. wood pellet stove + nat. gas boiler (DHW)**	**Alt 3. wood pellet stove + heat pump (DHW)**	**Alt 4. heat pump**
heating system	space heat demand	kWh/a	2194	2194	2194	2194
	system / fuel		condens. boiler / natural gas	stove with water heat exch./ wood pellets	stove with water heat exch./ wood pellets	heat pump / electricity
	primary energy	kWh/a	2540	549	549	1664
	CO2 emissions	*kg/a*	*508*	*55*	*55*	*126*
DHW system	hot water heat demand	kWh/a	2603	2603	2603	2603
	main system/ fuel		condens. boiler / natural gas	stove with water heat exch./ wood pellets	stove with water heat exch./ wood pellets	heat pump / electricity
	secondary system/ fuel		----	condens. boiler / natural gas	heat pump / electricity	----
	primary energy	kWh/a	3014	1832	1313	1975
	CO2 emissions	*kg/a*	*603*	*334*	*107*	*150*
total	**primary energy**	kWh/a	**5554**	**2381**	**1861**	**3639**
	CO2 emissions	*kg/a*	***1111***	***389***	***162***	***276***
house with optional auxiliary system	aux. system type		solar panels, photovoltaic			
	avail. area / location	m2	96m2 / roof			
	typical gain /energy	kWh/a	9386 / electricity			
	available heating/DHW system primary energy that can be supplemented	kWh/a	0	0	987	3639
	can all system energy be supplemented = carbon neutral?		no	no	no	**yes**
	surplus el. solar energy	kWh/a	9386	9386	8937	7732
	primary energy total	kWh/a	**5554**	**2381**	**874**	**0**
	CO2 emissions total	*kg/a*	***1111***	***389***	***87***	***0***

Figure 5. Solar panels installed on roof of the model house, partially covered by snow

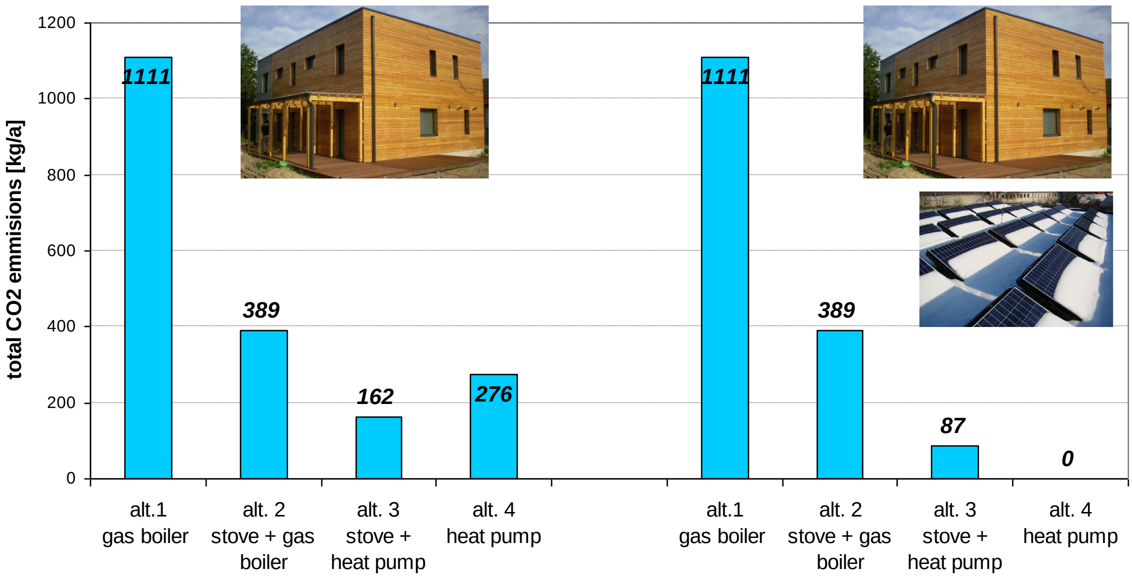


Figure 6. CO2 emissions for the house systems (without and with solar panels)

5. CONCLUSION

As discussed earlier - though biomass fired appliances produce unusually low CO2 emissions, these systems cannot be carbon neutral, unless it is possible to grow the biomass on the roof of the house – which is highly unreasonable.

Electric systems have significant advantage, as technology for electric energy harvesting is widely available even in small scale, suitable for smaller dwellings. On the other hand, the high-capacity energy storage is not viable at reasonable costs – and carbon neutrality is achieved only in a year's period, and even carbon/energy neutral house still needs energy supply during winter, when solar systems are incapable due to weather (Fig. 5) and high demand.

Therefore, the focus should not be solely on carbon neutral operation systems, but it is important to consider entire process of life cycle of a building (e.g., by LCA method), where timberframe structures perform exceptionally well. Therefore, increased use of wood and bio-based materials is often seen as an important contribution to resource conservation and climate protection [4].

Acknowledgements: This paper was also supported by APVV-17-0206 project.

REFERENCES

1. CREATERRA Architects, https://www.createrra.sk/
2. Kinnane, O.; O'Hegarty, R.; Lennon, D.; Colclough, S.; (2020). Are nZEBs nearly near zero enough?
3. Michálková, D., Ďurica, P. Experimental Verification of Thermal Insulation in Timber Framed Walls. Materials 15 (6): 2040, 2022.
4. Ouellet-Plamondon, C. M., Ramseier, L., ... & Frischknecht, R. (2023). Carbon Footprint Assessment of a Wood Multi-Residential Building Considering Biogenic Carbon. Journal of Cleaner Production, 404, 136834.
5. Szul, T. (2022). Application Of a Thermal Performance-Based Model to Prediction Energy Consumption for Heating of Single-Family Residential Buildings. Energies, 15(1), 362.
6. Švajlenka, J., Kozlovská, M. (2018). Houses Based on Wood as An Ecological and Sustainable Housing Alternative—Case study. Sustainability, 10(5), 1502.

7. Zbašnik-Senegačnik, M.; Koprivec, L. (2022). Timber Passive House in The Light of New European Bauhaus– An Answer to Crisis Management and Safety Foresight in Forest-Based Sector. Crisis Management and Safety Foresight in Forest-Based Sector and SMEs Operating in The Global Environment, 447.
8. ***: Ministerial Decree no. 364/2012 Coll. on the energy performance of buildings and on the amendments to certain laws, Slovak Republic
9. ***: Passive House certification criteria, IPHA, 2023

Authors address:
Sedlák, P[1]; Búryová, D[1]; Vaňová, R. [1]; Uhrín, R[1]
[1] Department of Wood Constructions, Faculty of Wood Sciences and Technology, Technical University in Zvolen, Zvolen, Slovakia
*Corresponding author: sedlak_pali@yahoo.com

EFFECT OF CNC MACHINING PARAMETERS ON SURFACE QUALITY OF DIFFERENT KIND OF WOOD

Ibrisevic, A., Busuladzic, I., Mihulja, G., Obucina, M., Hajdarevic, S., Smajic, S.

Abstract: Computer Numerical Control (CNC) machines are increasingly popular in the production of furniture and wood products. The effective use of CNC machines depends on the processing parameters, which also affect the quality of the processed surface. This study aimed to determine the effect of feed rate and spindle speed on surface roughness of various type of wood. Three wood spacies (fir, beech, oak) were cut with three different spindle speeds (9600, 11200, and 12800 rpm) and four different feed rates (4000, 5000, 6000 and 7000 mm/min) using end mill tools on the CNC machine. An analysis of variance (ANOVA) was performed to evaluate the impact of cutting parameters. To determine the surface quality of wood the surface roughness measurements were performed and two surface roughness parameters (Ra and Rz) were determined.
According to the results of this study, it can be concluded that milling with same processing parameters, the lowest surface roughness values are obtained for oak wood, while the highest values are obtained for beech wood.
Keywords: CNC milling, surface raughness, spindle speed, feed rates, wood

1. INTRODUCTION

Computer Numerical Control (further as CNC) machines are increasingly popular in the production of furniture and wood products, especially since the trends in furniture production increasingly require shapes that are almost impossible to make on classic woodworking machines. Modern computer numerical controlled (CNC) machine tools are equipped with control systems ensuring them to manufacture elements with desired shape and high dimensional accuracy (Iskra and Herna´ndez 2012).

The application of high technology such as CNC machines and automation systems is one of the main reasons of the growth for the furniture industry (Demir et al. 2022). In particular, with the use of CNC router machines in the furniture industry, production quantities have increased rapidly, while the production costs and labour have decreased (Pelit et al. 2021, Koc et al. 2015). In the furniture industry, CNC machines have been preferred considerably in the processes such as patterning, milling, drilling and grooving (Sofuoglu2017, Thoma et. al. 2017, Çakıroğluet al. 2022).

In comparison to traditional woodworking machines they have several advantages, including smooth regulation of rotational speed and feed speed, constant rotational speeds maintained even at changing cutting conditions, etc. At constant machining parameters it is possible to maintain a constant quality of the machined surface (Pinkowski et al. 2012).

The use of CNC machines in wood processing and wood-based panels increases the dimensional accuracy of the manufacturing elements, increases the quality of processing and increases productivity. The effective use of CNC machines depends on the processing parameters, which also affect the quality of the processed surface (Koc et al. 2015). Several key factors influence the precision and surface quality of the final workpiece: the interpolator, the feed drive system, machine dynamics, and the machining process (Petracek et al. 2022). In addition, the path of the tool, and the type and quality of the processing tool directly affect the structure of the processed surface (Koc et al. 2015, Curti et al. 2018). High surface quality in machining is very important, for it can influence the cost of the final product (Deua at. al. 2015). The surface roughness of wooden elements determines not only the esthetic features of a final product, but in many situations it is an important quality parameter required for further processing (eg gluing, finishing) (Iskra and Herna´ndez 2009). Wood surface roughness is a crucial indicator of the quality of CNC processing parameter (Hazir and Koc 2019), and it is affected by cutting speed, depth of cut, tool conditions and the workpiece (Chen at al. 2012). Machine tool vibration mainly affects surface roughness (Iskra and Herna´ndez 2009). For the milling of beech wood with CNC, it's been found that the cutting angle, feed rate and fiber direction affect the surface roughness, and cutting width does not have any impact on the surface roughness despite the increase in the sound intensity (Karagöz et al. 2011). It's been stated that cutting depth and cutting angle do not impact surface roughness in wood processing, but it is changed significantly by changing the spindle speed and feed rate (Koc et al. 2015). The general information indicates that the roughness values would reduce when operated with a lower feed rate and higher spindle speed (Prakashan and Palanikumar 2010). The surface roughness of wood and wood engineering materials was determined by methods based on using surface-measuring equipment, both by contact and contactless (Gurau et al. 2021). Generally, the average roughness (Ra), the maximum height of profiles (Rz) and the root mean square deviation (Rq) were the roughness parameters used for the evaluation of the processed surface quality (Sütcüa and Karagöz 2013).

The aim of this study was to determine the effect of the rotational tool speed and feed speed on surface quality after CNC milling three types of wood with different densities.

2. MATERIAL AND METHODS

Three types of wood, beech (*Fagus sylvatica L.*), oak (*Quercus robur L.*) and fir (*Abies alba Mill.*) with thicknesses of 20 mm, were studied because they are widely used in woodworking and furniture industry. Milling operations were performed along the grain direction. A combination of three rotational speeds (9,600 rpm, 11,200 rpm, 12,800 rpm), and four feed rates (4 m/min, 5 m/min, 6 m/min and 7 m/min) were determined for CNC processing. Four samples for each combination of cutting parameters were used. Before CNC processing, the samples were conditioned at 20 ± 2 °C and 65 ± 5% relative humidity (RH). Materials were processed with a CNC router in the laboratory at the Faculty of Mechanical Engineering, University of Sarajevo. The CNC router, with 4 axes was used to cut the samples, to the cutting depth of 5 mm by face milling procedure. Each sample was milled with one rotational speed. The cutting tool (diameter 8 mm) used in this study, is presented in Figure 1. The tool was monuted using **ISO30 ER32 tool holder. Milled elements were mounted on the table using vacuum system.**

Figure 1. Samples and cutting tool

Surface quality measurements were performed using Mitutoyo Surftest SJ-201 (Fig. 2). The wide measurement range of instrument are 350 µm (-200 µm to +150 µm). Two roughness parameters Ra (absolute arithmetic mean), and Rz (arithmetic mean deviation of the profile) were measured to evaluate the surface roughness of the treemiled surface on one sample.

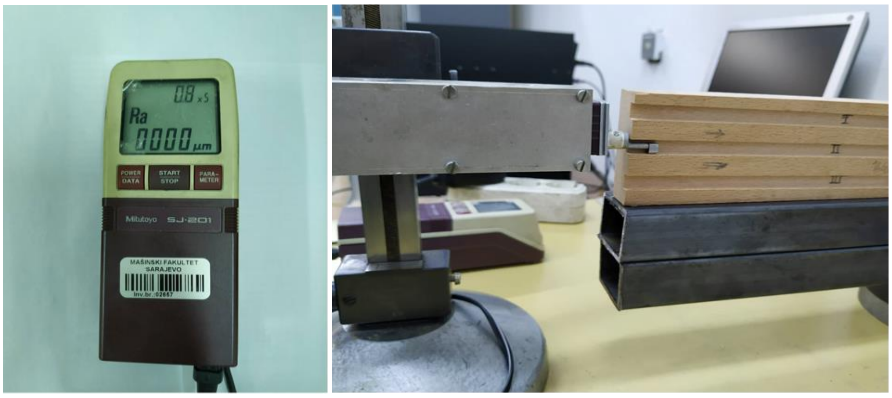


Figure 2. Mitutoyo Surftest SJ-201

Analysis of variance (ANOVA) was performed for the statistical evaluation of changes in the surface roughness parameters (Ra and Rz) depending on the spindle rotational frequency and feed rate. After ANOVA, Tukey Pairwise Comparisonstest with 95 % confidence level was used to compare the mean values of variance sources.

3. RESULTS AND DISCUSSION

The results of surface roughness are shown in figure 3. Figure shows that when processing oak with the same processing parameters, lower surface roughness values are obtained compared to beech and fir. The highest surface roughness is obtained when processing beech.

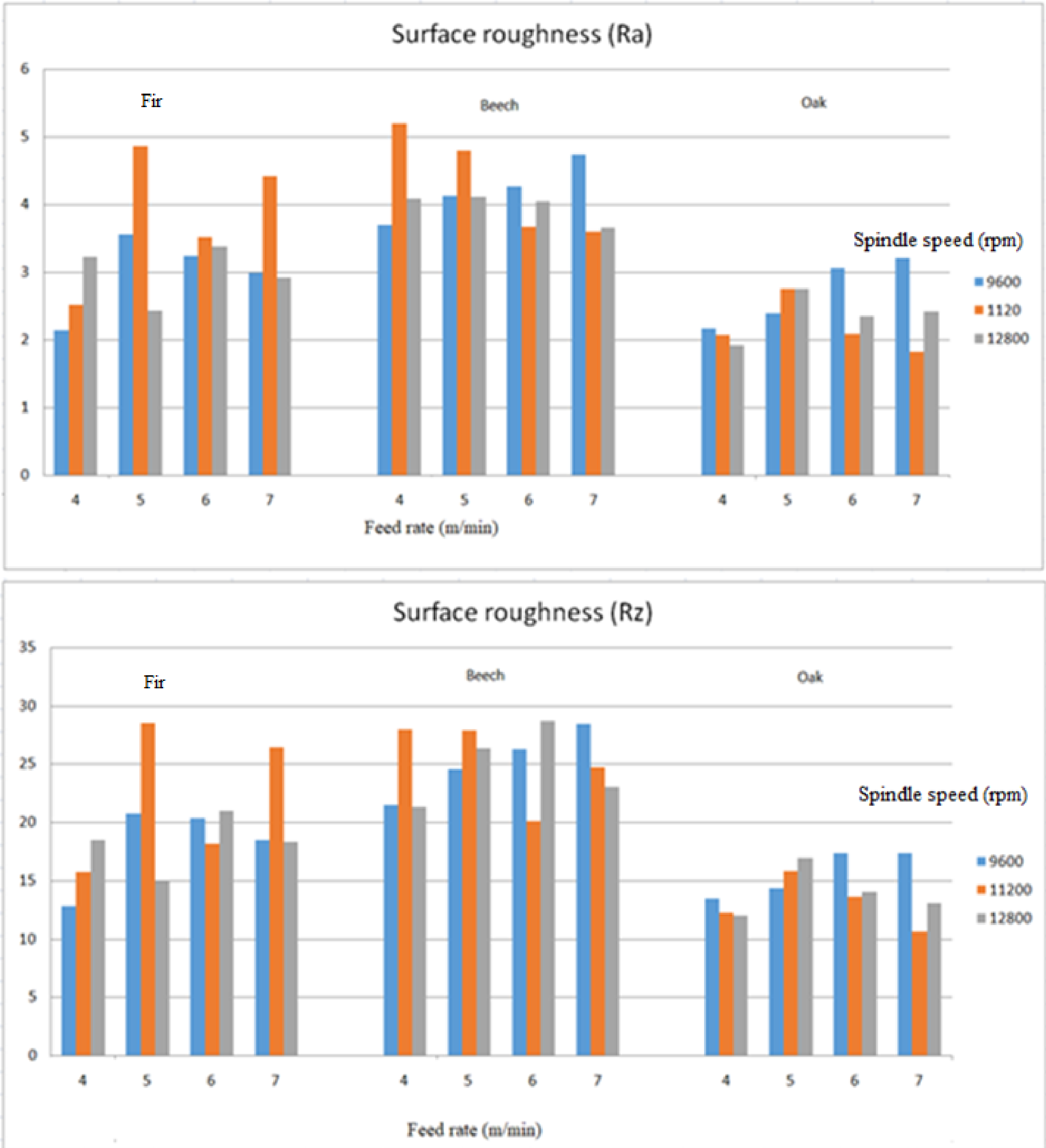


Figure 3. Surface roughness of oak, beech, and fir processing with different parameters

The surface roughness values of oak wood are lower than the values of beech wood at the same processing parameters. The surface roughness values of oak wood are lower than the values of fir wood, and the surface roughness values of firwood are lower than the values of beech wood.In general, the surface quality of machined wood is affected by many factors related to the processing conditionand wood properties. The most important factors related to the properties of the wood are the density, moisture content, and anatomical structure. The degree of surface roughness of the wood is directly related to the combination of the processing conditions and the anatomical structure of the wood (Pelit et al. 2021).

According to the research with fir wood, the lowest surface roughness is obtained at a feed rate of 4 m/min and a rotation speed of 9600 rpm. In the case of beech, the lowest surface roughness values were obtained at a feed rate of 6 m/min and 11200 rpm, while in the case of oak, the lowest roughness values was obtained at a feed rate of 7 m/min and a rotation speed of 11200 rpm.

Statistical analyses (ANOVA) were performed by using MINITAB R14 software, and for aconfidencelevel of 95 % (e.g., significance level of 0.05). The analysis of variance and Tukey Pairwise Comparisonstest showed that the data obtained by experimental testing oak wood with different processing parameters do not significant effect, i.e. the data belong to the same group. The same result was obtained by testing beech wood. The analysis of variance and Tukey Pairwise Comparisonstest showed that some data obtained by experimental testing on fir wood with different processing parameters make a significant effect.

4. CONCLUSION

This study aimed to determine the effect of feed rate and spindle speed on surface roughness of various types of wood. The feed rate, spindle rotation and wood species are important and effective factors. Results show that when processing oak with the same processing parameters, lower surface roughness values are obtained compared to beech and fir. ANOVA showed that the data obtained by experimental testing do not significant effect for a 95 % confidence level. In order to determine the statistical difference between the data, it is necessary to increase the number of tested samples, increase the difference between feed rates and increase the differences between spindle rotation.

REFERENCES

1. Çakıroğlu, E. O.; Demir, A.; Aydın, I.; Büyüksarı, Ü. (2022); Prediction of optimum CNC cutting conditions using artificial neural network models for the best wood surface quality, low energy consumption, and time savings. BioResources 17(2): pp. 2501-2524.
2. Chen, C.C.; Liu, N.M.; Chiang, K.T.; Chen H.L (2012): Experimental investigation of tool vibration and surface roughness in the precision end-milling process using the singular spectrum analysis. The International Journal of Advanced Manufacturing Technology63: pp. 797–815
3. Curti, R.; Marcon, B.; Denaud, L.; Collet, R. (2018): Effect of Grain Direction on Cutting Forces and Chip Geometry during Green Beech Wood Machining. BioResources 13(3): pp: 5491-5503.
4. Demir, A.; Cakiroglu, E.O.; Aydin, I. (2022): Effects of CNC Processing Parameters on Surface Quality of Wood-Based Panels Used in Furniture Industry. Drvna industrija 73(4): pp. 363-371.
5. Deus, P.; Alves, M.; Vieira, F. (2015): The quality of MDF workpieces machined in CNC milling machine in cutting speeds, feedrate, and depth of cut. Meccanica 50(12).
6. Gurau, L.; Cosereanu, C.; Paiu, J. (2021): Comparative Surface Quality of Larch (Larix decidua Mill.) Fretwork Patterns Cut through by CNC Routing and by Laser. Applied Sciences 11(15).
7. Hazir, E.; Koc, K.H. (2019): Optimization of wood machining parameters in CNC routers: Taguchi orthogonal array based simulated angling algorithm. Maderas,Ciencia y
8. tecnologia 21(4): pp. 493-510.
9. Iskra, P; Herna´ndez, R.E. (2012): Toward a process monitoring of CNC wood router. Sensor selection and surface roughness prediction. Wood Science and Technology 46: pp. 115-128
10. Iskra, P; Herna´ndez, R.E. (2009): The influence of cutting parameters on the surface quality of routed paper birch and surface roughness prediction modeling. Wood and Fiber Science 41(1): pp. 28–37
11. Karagöz, U.; Akyıldız, M. H.; Isleyen, O. (2011): Effect of Heat Treatment on Surface Roughness of Thermal Wood Machined by CNC. Pro ligno 7(4).
12. Kilica, M.; Hiziroglub, S.; Burdurlu, E. (2006): Effect of machining on surface roughness of wood. Building and Environment 41: pp- 1074–1078

13. Koç, K.H.; Erdinler, E.S.; Hazır, E.; Öztürk, E. (2015): Effect of CNC Application Parameters on Wooden Surface Quality. In: Proceedings of the 58th International Convention of Society of Wood Science and Technology "Renewable Materials and the Bio-Economy". USA. June, 2015.
14. Pelit, H.; Korkmaz, M.; Budakçı, M. (2021):Surface roughness of thermally treated wood cut with different parameters in CNC router machine. BioResources 16(3): pp. 5133-5147.
15. Petraček, P.; Fojt, P.; Kozlok, T.; Sulitka, M. (2022): Effect of CNC Interpolator Parameter Settings on Toolpath Precision and Quality in Corner Neighborhoods. Applied Sciences 12(19).
16. Pinkowski, G.; Szymański, W.; Nosowski, T. (2012): Analyses of surface roughness in selected wood species after machining on a CNC woodworking centre. Forestry and Wood Technology 79: pp. 164-169.
17. Prakash, S.; Palanikumar, K. (2010): Modeling for prediction of surface roughness in drilling 526 MDF panels using response surface methodology. Journal of Composite Materials 45: pp. 1639-1646.
18. Sofuoglu, S. D. (2017): Determination of optimal machining parameters of massive wooden edge glued panels which is made of Scots pine (Pinus sylvestris L.). European Journal of Wood and Wood Products75(1): pp. 33-42.
19. Sütcüa, A.; Karagöz, U.(2013): The Influence of Process Parameters on the Surface Roughness in Aesthetic Machining of Wooden Edge-Glued Panels (EGPs). BioResources 8(4): pp. 5435-5448
20. Thoma, H.; Kolaa, E.; Perib, L.; Latoa, E.; Ymeric, M. (2013): Improving Time Efficiency using CNC Equipments in Wood Processing Industry. International Journal of Current Engineering and Technology 3(2): pp. 666-671..
21. Thuy, T.V; Loc Nguyen, H.L. (2018): Investigation on influence of cutting parameters on spindle vibration of CNC wood milling machine. In: Proceedings of6th Asia Conference on Mechanical and Materials Engineering (ACMME). South Korea. June, 2018.

Authors address:
Ibrisevic, A[1]; Busuladzic, I[1]; Mihulja, G[2]; Obucina, M[1]; Hajdarevic, S[1]; Smajic, S[1].
[1] Department of Wood Technology, Faculty of Mechanical Engineering Sarajevo, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
[2]Department of Wood Technology, Faculty of Forestry and Wood Technology University of Zagreb, Zagreb, Croatia
*Corresponding author: ibrisevic@mef.unsa.ba

ANALYSIS OF CNC MILLING PARAMETERS ON ROUGHNESS OF ORDINARY, STEAM TREATED AND HEAT-TREATED BEECH WOOD, USING SPIRAL CUTTER

Busuladzic, I., Ibrisevic, A., Obucina, M., Hajdarevic, S.

Abstract: Different types of milling cutters can be used to process wood objects. Some of them are simplest to manufacture but may be less efficient in milling wood. In this study, CNC machine with spiral milling cutter as tool is used having the possibility to vary the processing parameters (spindle speed, depth of cut, displacement speed). Three types of beech wood are processed; normally dried, steamed and heat-treated beech wood. This paper analyses influence of different cutting speed used to test the best milling parameters on all tested types of beech wood. Spindle speeds used for those tests are 8400 rpm, 9600 rpm, 10800 rpm, 12000 rpm, 14400 rpm, with feed speed of 5m/min. To assess the quality of processing, the roughness is observed using a contact method with electromechanical profile meter Mitutoyo SJ-201.
Keywords: beech wood, steamed beech wood, heat treated beech wood, roughness, CNC milling, cutting speed

1. INTRODUCTION

Very important characteristics of beech wood are its density, anatomical structure, hardness and therefore it is used to make massive wooden furniture, especially table bases, chairs and sets. Producing all types of furniture, final processing of the wood is very important, especially when milling. The roughness of the processed wood surfaces is an important indicator of the processing quality [1]. The surface roughness after milling wood depends on many different factors; processing parameters [7] and of course the type of wood (i.e., the same kind of wood but differently treated) [6]. Three types of material, that we use in this study, is normally dried, steamed or heat-treated beech wood, finally heaving different structural properties.

Processing parameters such as cutting speed [2] and displacement [4] are mainly important to obtain the decent quality of treated surface i.e. surface with lowest roughness. Also the type of milling tool and its geometric properties influences a lot the surface roughness [3].

To assess the surface roughness and finally the quality of processing, one can use different methods whether direct or indirect [5,8,9]. In this study direct method such as contact method with profile meter is used to measure surface roughness.

2. TOOL

Different tools for milling on CNC machines can be used for different operations and shapes of processed material. Some of that tools, depending on the geometries and materials used, are more or less difficult to produce. Depending on the needed operation one or more types of milling tools can be used. Sometimes different tools give better or worse quality of processed material surface depending mostly on sharpness of cutting edge of tool, the milling parameters of CNC machine and of the geometry of the tool. With the development of new technologies, new advanced tools for woodworking appears, known as "spiral routers".

Regarding the geometry, spiral milling cutters appear very similar to standard spiral drills, but one can notice significant differences. The top of the milling cutter is always displaced from the central point for a small distance. It results that the spiral cutters cut in a hybrid path that is a mixture of cutting with classic straight cutters and drilling with spiral drills. The spiral path of the knives is what makes this router special compared to classic straight routers.

In this work, we have used the spiral milling cutter shown in Figure 1., with a diameter of 8 mm. It is a small diameter of the cutting part and that almost always works like spindle mills. The small diameter of the cutting circle, with these milling cutters, is due to their use. This tool is made of high-speed steel (HSS) tool.

Figure 1. Spiral cutter

The bevel cut with spiral milling cutters gives much less unwanted effects, and the resulting profile is cleaner and less exposed to heating. The next big advantage is that the spiral milling cutters continuously remove the sawdust, so it does not get further crushed.

3. MATERIALS

Beech (Fagus sylvatica) is a coniferous tree from the Fagaceae family. It grows in hilly and mountainous locations, in central, western Europe, and southeastern Europe. It grows up to 40 m. The thickness of the trunk can be over 1 m in diameter. The crown is broadly rounded. Hardwood such as beech wood has a more complex structure, better mechanical properties, and higher density than coniferous wood. Beech wood produces a useful wood that is strong but dimensionally unstable and is used to produce numerous furniture objects. Three types of treated beech wood were used in this work: ordinary, heat-treated and steamed beech wood (Figure 2.).

The term ''steamed beech'' designates the purple beech which has been steamed while still green, at the latest two weeks after its cut. Two steaming methods are practiced: the first consists of immersing the trunks in a pit of almost boiling water for two days; the second is to hang it over a steam bath for up to six days. The steam releases the beech wood of large extent from its internal tensions, then facilitates the drying in the open air and intensifies the coloring of the wood (initially white-reddish, to give it a reddish-brown base color). To guarantee an intense and uniform coloring, the beeches must not come from hillside regions. Often, tension grows in the wood, which is located in the places of glucose accumulations, which become more intensively colored during heat treatment. From experience, a visually more attractive color is obtained when the tree trunks are parboiled with their bark.

Figure 2. Steamed (left) and heat treated (right) beech wood

Heat modification of wood is a process that ensures the improvement of certain properties of wood, without imposing an additional burden on the environment. Thus, heat modification improves dimensional stability and biological durability of wood, although some mechanical properties seem to deteriorate. In the modification process, only heat and water vapor are used, without the use of any chemical preparations or additives, which makes it completely environmentally friendly and harmless to the environment. For this purpose, temperatures between 100°C and 230°C are used, in specially designed chambers equipped with fully automated systems for managing the entire heat-treated process.

4. SOURFACE ROUGHNESS

Finishing treatment, is a subjective term that denotes surface smoothness and general quality. It includes small, local deviations of the surface from the ideal plane (corresponding plane). In broad usage, surface finishing is often used as a synonym for surface roughness. Surface roughness represent the totality of micro geometrical irregularities. Irregularities are reflected in the form of smaller or larger elevations. In wood processing, the surface roughness depends on processing parameters, tool geometry and sharpness, wood species (hard and soft wood), wood moisture and the direction of cutting.

Surface roughness is a calculation of the relative roughness of the surface profile based on the numerical parameter Ra. Ra is arithmetic mean deviation of the profile across the surface (Figure 3.). A profile meter or surface profile measuring instrument, is used to measure surface roughness. It is the average height of the roughness irregularity of the part from the center line. Arithmetic mean deviation of the profile Ra can be calculated by the formula:

$$R_a = \frac{1}{n}\sum_{i=1}^{n}|y_i| \quad (1)$$

where:
l [μm] - length on which the surface roughness is measured,
y(x), yi [μm] - the heights of the roughness profile with respect to the middle reference line,
n - number of points for assessing the heights of the profile along the measuring length.

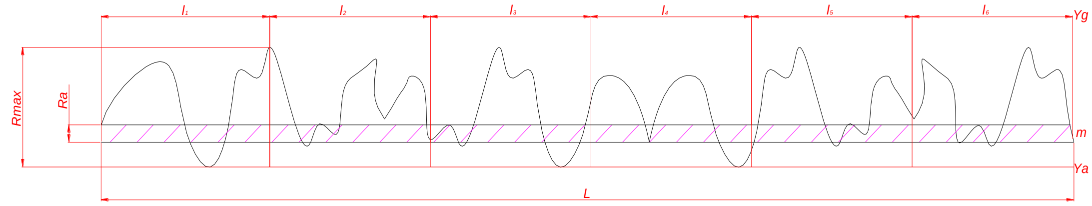


Figure 3. Mean arithmetic deviation of the profile Ra

One can use also the mean height of bumps Rz, as a parameter of surface roughness. It is equal to the sum of arithmetic mean of the heights of the five highest peaks and arithmetic mean of the values of the five largest valley depths, on the length l, on which the surface roughness is measured (Figure 4.). The International ISO system defines Rz as follows:

$$R_z = \frac{1}{n}\left(\sum_{i=1}^{n} y_{p_i} - \sum_{i=1}^{n} y_{v_i}\right) \quad (2)$$

where:
y_{p_i}[μm] - height of the i_{th} highest peak,
y_{v_i}[μm] - depth of the i_{th} lowest valley.

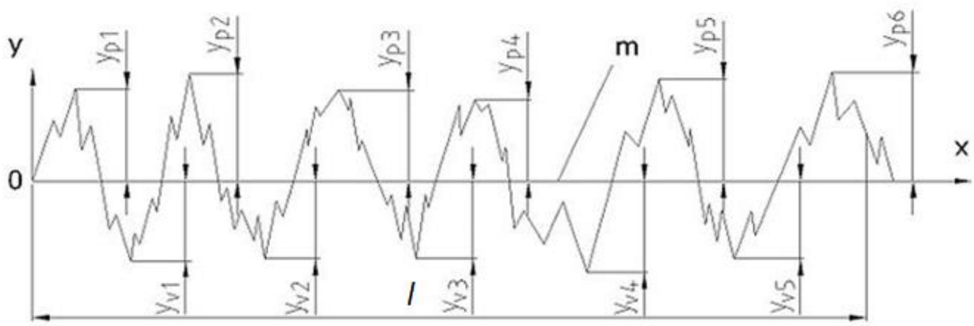


Figure 4. Estimating of mean height of unevenness Rz

5. EXPARIMENTAL SETUP

The processing of the notches on samples are made with the CNC machine, as shown in the picture (Figure 5). Several spindle speeds are randomly chosen to analyze their influence on the quality of processing i.e. the surface roughness. The displacement speed was constant, equal to 5 m/min.

The following spindle speeds are chosen within the machine's operating range: 8400 rpm, 9600 rpm, 10800 rpm, 12000 rpm, and 14400 rpm.

Figure 5. Experimental set-up

6. MEASUREMENTS OF SURFACE ROUGHNES OF SAMPLES

In this study we have used profile meter Mitutoyo SJ-201, to measure surface roughness. We distinguish two types of methods to test surface roughness: quantitative methods (optical and contact) and qualitative methods. The surface roughness, in this work, was measured along the processed surface, using an electromechanical profile meter Mitutoyo SJ-201 (Figure 6.).

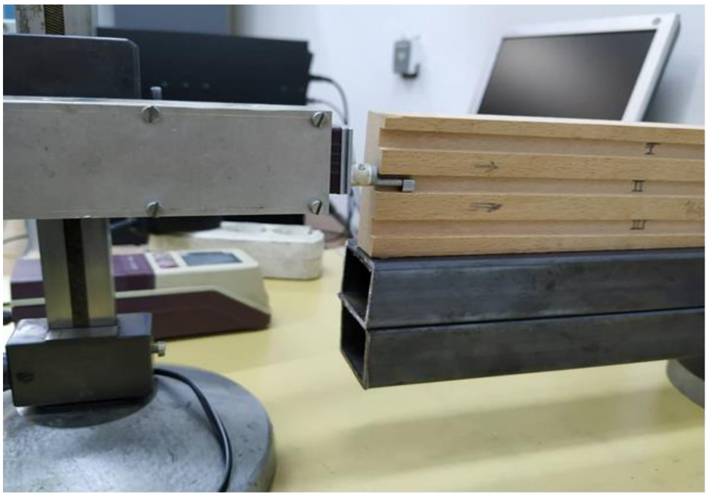


Figure 6. Measurement of surface roughness

Profile meter Mitutoyo SJ-201 has next main characteristics; portable for easy use wherever you need to measure surface roughness, the drive unit can be separated from the display for easier measurement even when it is difficult to access the measurement position, wide measurement range of 350 µm (-200 µm to +150 µm), a total of 19 analysis parameters are given, including the frequently used Ra, Rz, Rq and Ry parameters and automatic dynamic calibration function.

7. RESULTS

After performing the milling process on CNC machine with spiral router, the results are read on the measuring device Mitutoyo SJ-201. Arithmetic mean deviation of the profile Ra and mean height of unevenness Rz are used to quantify the surface roughness results for three different types of beech wood. The results are presented on the next graphs with different spindle speed tests (Figure 7.,8.,9.). For those tests the rotational spindle speeds are 8400, 9600, 10800, 12000 and 14400 rpm. Twelve measurements were made for each sample.

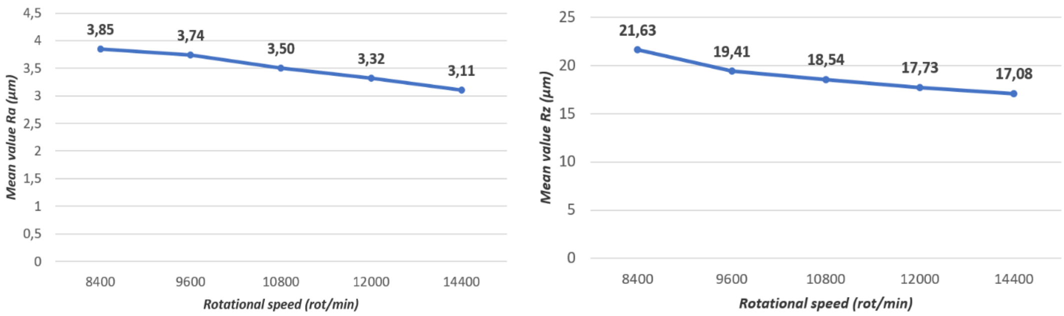


Figure 7. Beech wood

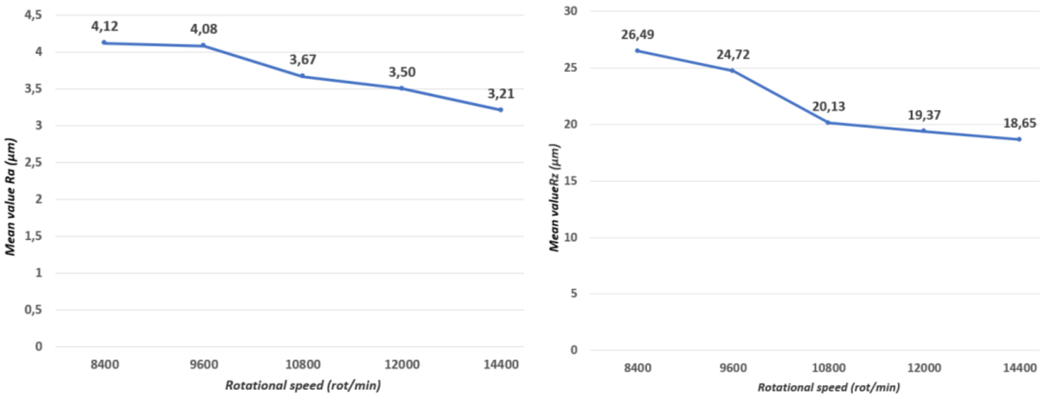


Figure 8. Heat-treated beech wood

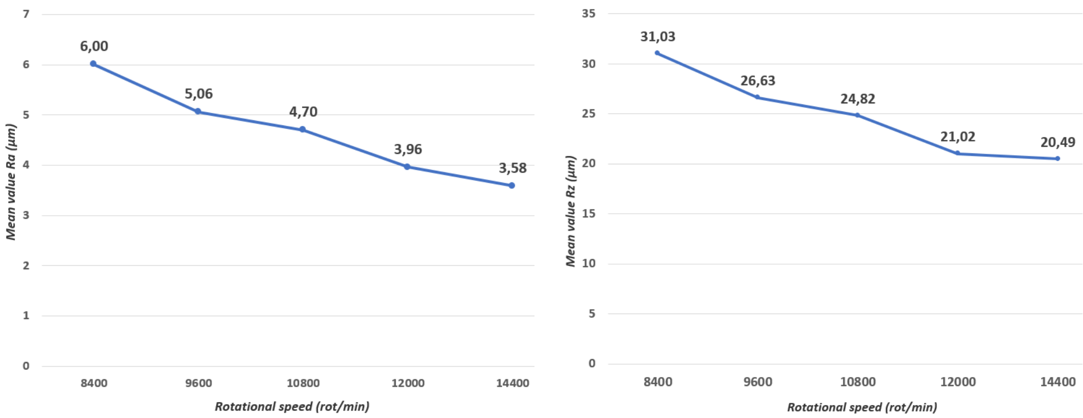


Figure 9. Steamed beech wood

8. DISCUSSION

In this study, CNC machine with spiral cutter was used, to test different spindle speeds of the milling process on different wood materials. Three different beech wood species are used for it: ordinary, heat-treated, and steamed beech wood. After performing the milling process and the surface roughness measurement on beech wood samples, the following observations can be recorded.

If we look at the type of processed wood, we can conclude that the lowest surface roughness was achieved on ordinary beech wood, then on heat-treated and the highest on steamed beech, leading to the poorer processing quality. Looking at the results in relation to the spindle speed, we can see that as the spindle rotation speed increases, the surface roughness decreases for all three types of wood. The best surface quality, i.e. the lowest roughness of the processed surface, was achieved at a spindle speed of 14400 rpm, while the highest roughness was at the spindle speed of 8400 rpm.

Also, the difference of surface roughness is insignificant between ordinary and heat-treated beech wood, and compared to steamed beech wood, surface roughness is significantly smaller for the ordinary and heat-treated beech wood.

REFERENCES

1. Azemovic E.; Horman I.; Busuladzic I.(2014): Impact of Planning Treatment Regime on Solid Fir Wood Surface. Procedia Engineering 69, pp. 1490 – 1498.
2. Barcik Š.; Pivolusková E.; Kminiak R. (2009): The influence of cutting speed and feed speed on surface quality at plane milling of poplar wood. Drvna Industrija 54(2), pp.109-115.
3. Darmawan W.; Azhari M.; Rahayu I.; Nandika D.(2018): The chips generated during up-milling and down-milling of pine wood by helical router bits. Journal of the Indian Academy of Wood Science 15, pp. 9–12.
4. Demir, A.; Cakiroglu, E.O.; Aydin, I. (2022): Effects of CNC Processing Parameters on Surface Quality of Wood-Based Panels Used in Furniture Industry. Drvna industrija 73(4): pp. 363-371.
5. Gadelmawla E.S.; Koura M.M.; Maksoud T.M.A.; Elewa I.M.; Soliman H.H.(2002): Roughness Parameters. Journal of Material Processing Tachnology 123, pp. 133-145.
6. Karagöz, U.; Akyıldız, M. H.; Isleyen, O. (2011): Effect of Heat Treatment on Surface Roughness of Thermal Wood Machined by CNC. Pro ligno 7(4).
7. Pelit, H.; Korkmaz, M.; Budakçı, M. (2021): Surface roughness of thermally treated wood cut with different parameters in CNC router machine. BioResources 16(3): pp. 5133-5147.
8. Sütcüa, A.; Karagöz, U.(2013): The Influence of Process Parameters on the Surface Roughness in Aesthetic Machining of Wooden Edge-Glued Panels (EGPs). BioResources 8(4): pp. 5435-5448
9. Zhong Z.W.; Hiziroglu S.; Chan C.T.M. (2013): Measurement of the Surface Roughness of Wood Based Materials Used in Furniture Manufacture. Measurement 46, pp. 1482-1487.

Authors address:

Busuladzic, I[1]; Ibrisevic, A[1]; Obucina, M[1]; Hajdarevic, S[1].
[1] Department of Wood Technology, Faculty of Mechanical Engineering Sarajevo, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
*Corresponding author: busuladzic@mef.unsa.ba

BENEFITS OF (RE)USING WOOD IN THE CONCEPT OF CIRCULAR CONSTRUCTION

Koprivec, L., Zbašnik-Senegačnik. M.

Abstract: Global population reached 8 billion people in 2022. Demands for raw materials, vast energy consumption, GHG emissions and the amount of waste are rising. To protect our natural environment the circular building strategy suggests implementing 3R concept to reduce, reuse and recycle building materials. To analyse the frequency of reusing materials we conducted a survey among Slovene architects that attended Annual Symposium of Passive housing in Ljubljana. According to the survey results, architects would like to reuse building materials in their projects although currently this is not a common practice yet. A Slovenian role model of applying wood in the circular construction strategy is Planica Pavilion that was assembled for the FIS Nordic World Ski Championships 2023 in Slovenia. The benefits of (re)using wood in the concept of circular construction are discussed.
Keywords: Circular construction, wood, design for disassembly, reuse, Slovenia

1. INTRODUCTION

Buildings consisting of many materials, are considered today as carbon sinks (Arehart et al, 2021). EU member states produce more than 450 million tons of construction waste per year. They are made of many materials that can be recycled or reused (Niu et al, 2021). Wood represented 33 percent of the materials in the C&D waste and metal (5%) was the only material recovered at a significant percentage of estimated generation (Diyamandoglu, Fortuna, 2015). The European Commission has developed the Circular Economy Action Plan and the Buildings as Material Banks (BAMB) to regenerate natural environment, design out of waste and keep the products in closed loop cycle. BAMB adopted the concept of Design for Deconstruction/Disassembly (DfD) that is based on repair, reuse, and recovery of materials instead of extracting virgin materials (BAMB, 2020). Despite efforts, Design for Adaptability or Deconstruction/Disassembly is very limited in the construction sector (Munaro, Tavares, Braganca, 2022). Wood has high DfD potential in comparison to other building materials such as masonry, bricks, and concrete. Main reason for that is that it can easily be processed, the level of prefabrication is high, and adequate joint configuration can offer multiple assembly and disassembly processes. This shifts a paradigm from building demolition, which is now a common practice and has a negative impact on the environment, to building deconstruction, which will allow structural elements to be easily dismantled and reused (Akinade et al, 2017). The reuse of materials after the deconstruction of the building at the end of its life cycle requires an optimal design of details in the conceptual planning phase (Teischinger et al, 2016).

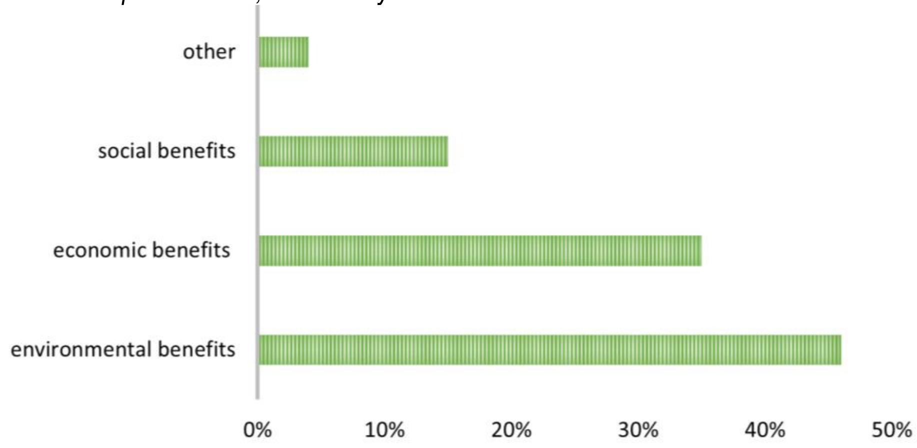
To analyse the frequency of reusing materials as a source for new buildings we conducted a survey among Slovene architects that attended Annual Symposium of Passive housing in Ljubljana. In Slovenia wood is a local material, there is a lot of knowledge passed down from previous generations while contemporary wooden architecture is in time with latest developments.

A representative case study is Planica Pavilion, designed by studio abiro (authors Blenkuš Matej; Cimperman Katja).

1.1 Questionary results among Slovene architects

A total of 70 Slovene architects were invited to participate in the study while 50 architects responded. We were mainly interested in the frequency of reusing building elements in their projects. The survey was published in 1KA arnes platform in May 2022. Access to the survey was available for 24 hours. According to the survey results, architects would like to reuse building materials although currently this is not a common practice yet. 41% respondents are currently not reusing building materials at all and 37 % at least not very often. If, then mostly wood from old buildings that were renovated such as windows, doors, wooden rafters, boards, and wooden furniture. Respondents would like to reuse building materials in their future projects primarily because of the environmental benefits (46%), secondly because of economic benefits (35%) and as last for social benefits (15%) (Table 1).

Table 1. Survey results: environmental benefits of reusing building materials are predominant, followed by economic benefits and social benefits.



1.2 Upgrading ecological building concepts

According to the circular construction principles, the reuse of the building components is becoming indispensable link of the sustainable built environment. Reuse will not only reduce the total environmental impact of a building, but it also has economic and social benefits (Riosa et al, 2015).

1.2.1 The environmental benefit

The environmental benefits of closing the loop include 1) extending the life of raw materials mines; 2) lower the cost of materials (if the supply chain is mature); and 3) reducing the embodied energy and carbon emissions of the construction industry. (Riosa et al, 2015). From environmental perspective reusing saves the use of virgin raw materials and embodied energy for producing these building materials. The symbolic meaning and importance of environmental benefits of reusing wood undoubtedly represents the façade of the New headquarters of the Council of the EU. The new double façade was made of a harmonised patchwork of reused oak windows from the different European countries (Samyn, 2016).

1.2.2 The economic benefit

Economic benefits are, amongst others, the creation of a new market for salvage materials and cost reduction. The market of salvaged building materials is not mature yet (Kanters, J., 2018), but great opportunities could arise. As projects become well accepted, the benefits of reusing materials would become more popular. Key driver to reuse salvaged wood in a Primary School in Brezovica (Slovenia) was an economic one (Figure1). From the deconstruction of the existing school various building materials were reused not to exceed the budget funds. Wooden beams were reused for the evacuation staircase.

Figure 1. Reused wooden beams as a new evacuation staircase of the Primary School Brezovica (Osnovna šola Brezovica). Author of the project: Slavko Gabrovšek (foto Slavko Gabrovšek).

1.2.3 The social benefit

One of a social benefit is creating jobs for unskilled workers. Unlike demolition, deconstruction work should not require heavy equipment of specific skills. Engaging everyone into the building process, deconstruction should be possible with common tools and equipment (Kanter, J., 2018). Architect Francis Kere, the Pritzker Architecture Prize Winner has a passion to use local materials in his native homeland Burkina Faso. He engages local communities into the building process, spreads knowledge while encouraging innovations (KÉRÉ FOUNDATION e. V., 2023). Actions of Self-build arouse feeling of togetherness, increase self-esteem, provide security and care for buildings. The knowledge gained by communities opens new possibilities for their income. Wood is easy to process, easy to assemble and disassemble, whereby the whole community can participate.

2. DfD – THE POTENTIAL OF WOOD

Any wooden architecture is a temporary structure, made without waste or harmful emissions. It is essentially degradable, as easy to assemble as to disassemble, transport and reassemble, and as such more durable than massive construction (Koželj, J., 2009). Adequate joint configuration can offer multiple assembly and disassembly processes of the wooden elements. Constructions can be considered unproblematic when detachability does not play a role due to monomateriality, such as wooden dowels in wooden beams (Riegler-Floors, Hillebrandt, 2018). In the past, wooden elements were connected without using metal connections.

However, due to earthquake and wind loads, mechanical bonding agents are used to such joints (Žarnič, Dujič, 2009). A simple but recognizable form is a Pavilion Planica in Slovenia (Figure 2).

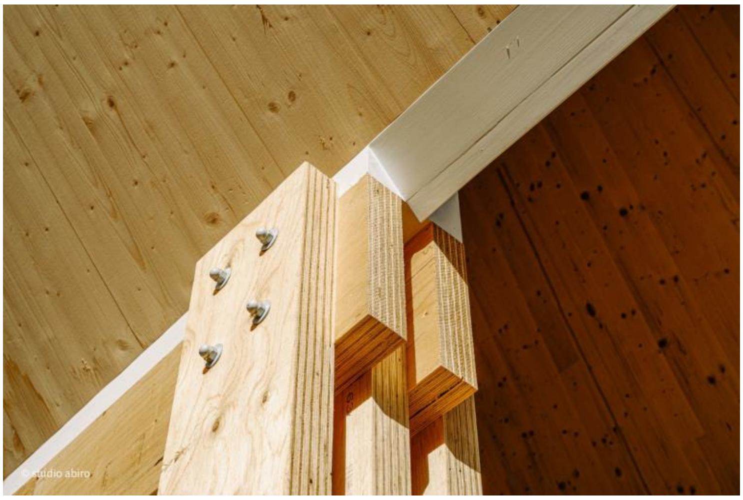


Figure 2. Mechanical joints in Pavilion Planica 2023, Slovenia. Authors of the project: Blenkuš Matej, Cimperman Katja (Foto Miran Kambič).

2.1. Promotion Pavilion Planica 2023, Slovenia

A Slovenian role model of applying wood in the circular construction strategy is Planica Pavilion assembled for the FIS Nordic World Ski Championships 2023 in Slovenia (Figure 3). As described by the authors of the project Matej Blenkuš and Katja Cimperman the starting point for designing the promotional pavilion was given by the main sponsor Stora Enso. Their vision was to build a pavilion in a way that the wooden elements could be reused for other constructions in Slovenia after the championship. According to the authors, pavilion has a simple but recognizable form. The geometry of the pavilion is determined by a set of isosceles triangles with equal legs but different base lengths. Three basic wooden materials were used, CLT panels for the roof and walls, LVL beams for the frames and Thermowood for the floors and façade. The pavilion was disassembled after the championship and will be assembled again as a timber superstructure of an apartment building in Ljubljana (studio abiro, 2023). Pavilion Planica shows full potential of reversible building design that enables reusing wood for the future projects and as such has an added value as a sustainable architecture.

Figure 3. Pavilion Planica 2023, Slovenia. Authors of the project: Blenkuš Matej, Cimperman Katja (Foto Miran Kambič).

3. CONCLUSION

Wood has a specific role in the circular construction strategy since it covers both strategies defined by Ellen McArthur Foundation as a Renewable material that can be cascaded and as a Finite material that can be shared (maintained/prolonged, reused/redistributed, refurbish/remanufactured, recycled) (Ellen Macarthur Foundation, 2023). If wood has not been contaminated with toxic preservatives, paints, or adhesives, wood can be reused, recycled, bio-degraded or burned for utilization of its energy. A usage of simple forms and structures combined with exposed connections with minimal partitioning elements will result in an expression that will communicate the visual data about the building's disassembly potential (Guy, Ciarimboli, 2005). So instead of hiding the fact that the building is built with wood the true selling point of contemporary wooden architecture could be its fully exposed potential of multiple assembly and disassembly possibilities. Allowing the building to freely express all layers of architectural design in favour of today's numerous purposes and needs of the society.

Acknowledgements: We wish to thank the Dean of the Faculty of Architecture, University of Ljubljana, prof. dr. Matej Blenkuš for his valuable inputs and graphic material of the Slovene Pavilion Planica.

REFERENCES

1. Akinade, O. O.; Oyedele, L. O.; Ajayi, S. O.; Bilal, M.; Alaka, H. A.; Owolabi, H. A.; Bello, S. A.; Jaiyeoba, B. E.; Kadiri. K. O. (2017): *Design for Deconstruction (DfD): Critical success factors for diverting end-of-life waste from landfills*. Waste Management 60: pp. 3–13.
2. Arehart, J. H.; Hart, J.; Pomponi F.; D'Amico, B. (2021): Carbon sequestration and storage in the built environment. Sustainable Production and Consumption 27: pp. 1047–1063.
3. Buildings As Materials Banks (2020).
4. URL: https://www.bamb2020.eu
5. Diyamandoglu, V.; Fortuna, L. M. (2015): Deconstruction of wood-framed houses: Material recovery and environmental impact. Resources, Conservation and Recycling 100: pp. 21–30.
6. Ellen Macarthur Foundation. (2023): *It's time for a circular economy*.

7. URL: https://ellenmacarthurfoundation.org
8. Guy, B., Ciarimboli, N., et al. (2005): *DfD Design for Disassembly in the built environment: a guide to closed-loop design and building*.
9. URL: https://www.lifecyclebuilding.org/docs/DfDseattle.pdf
10. Kanters, J. (2018): *Design for Deconstruction in the Design Process: State of the Art*. Buildings 8(11), 150: pp. 2.
11. KÉRÉ FOUNDATION e. V. (2023).
12. URL: https://www.kerefoundation.com/en/practices/resources
13. Koželj, J. (2009): *Wooden Architecture for Sustainable Future*. Gradnja z lesom, Izzivi in priložnost za Slovenijo. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za lesarstvo: pp.221.
14. Munaro M. R., et al. (2022): *The ecodesign methodologies to achieve buildings' deconstruction: A review and framework.* Sustainable Production and Consumption 30: pp. 566-583.
15. Niu, Y.; Rasi K.; Hughes, M.; Halme, M.; Fink, G. (2021): Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland. Resources, Conservation & Recycling 170: pp. 105555.
16. Riegler - Floors, P.; Hillebrandt, A. (2018): *Lösbare Verbindungen und Konstruktionen Detachable Joints and Constructions*. DETAIL Zeitschrift für Architektur + Baudetail/ Review of Architecture + Construction Details Re-use Re-cycle. 10/2018: pp 79.
17. URL: https://issuu.com/detail-magazine/docs/bk_det-2018-10-recycle_issn0011-957
18. Riosa, F. C.; Chonga, W. K.; Graua, D. (2015): *Design for Disassembly and Deconstruction - Challenges and Opportunities.* Procedia Engineering 118: pp. 1296 – 1304.
19. Samyn, P. (2016): 494 – EUROPA – New headquarters of the Council of the EU.
20. URL: https://samynandpartners.com/portfolio/europa-new-headquarters-of-the-council-of-the-european-union
21. Studio abiro (2023): *Promocijski paviljon v Planici*.
22. URL: https://www.abiro.net/pavilion-stora-enso-v-planici
23. Teischinger, A.; Kalcher, J.; Salzger, E.; Praxmarer, G.; Vanek, M. (2016): *General systematic for a design for recycling-guideline for wooden windows and wood aluminium windows.* In: CD-ROM Proceedings of the World Conference on Timber Engineering (WCTE 2016). Vienna. August 2016.
24. Žarnič, R., Dujič, B. (2009): *Connections in Timber Structures*. Gradnja z lesom, Izzivi in priložnost za Slovenijo. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za lesarstvo: pp.183.

Authors address:
Koprivec, Ljudmila[1]; Zbašnik-Senegačnik, Martina[2]
University of Ljubljana, Faculty of Architecture, Ljubljana, Slovenia
*Corresponding author: ljudmila.koprivec@fa.uni-lj.si

USE OF DIGITAL SOLUTIONS IN ARCHITECTURE AND TIMBER CONSTRUCTION

Kitek Kuzman, M., Haviarova, E., Kariž, M.

Abstract: Inspiration for creating innovative and exciting structures has always been nature with its flowing, organic forms, which have evolved for maximum optimization and efficiency. Organic architecture is based on studies of nature-based forms, which as a rule, are seldom straight. The design and implementation of such flowing shapes are more complex than working with orthogonal shapes. It requires good spatial performance, geometry knowledge, and suitable design tools and techniques. Digitalization has facilitated the development of complex geometric and free-form shapes that were not manageable before with simple design tools. Thanks to the broadened potential of computing, parametric design, and digital manufacturing, it is now possible to design more complex structural elements and structures that deviate from orthogonal practices. Architects and engineers consider using computers and computation techniques for planning and looking for solutions to a given design problem. The traditionally used materials and newly engineered wood products (EWPs) offer greater design freedom for ambitious construction and advanced manufacturing processes. Educational programs and student outputs dealing with digitalization processes will also be presented.
Keywords: digital solutions, architecture, timber construction

1. DIGITAL SOLUTIONS

Digital solutions have become increasingly prevalent in architecture and timber construction, revolutionizing how professionals design, construct, and manage projects. Key areas where digital solutions are commonly utilized:

1. Building Information Modeling (BIM): BIM is a digital representation of the physical and functional characteristics of a building. It enables architects, engineers, and construction teams to design and analyze projects collaboratively in a virtual environment. BIM software allows for 3D modeling, clash detection, quantity takeoffs, and accurate cost estimation. In timber construction, BIM can optimize the use of timber elements and ensure structural integrity.
2. Computer-Aided Design (CAD): CAD software enables architects and designers to create detailed 2D and 3D models of buildings and components. It provides precise control over dimensions, materials, and visualizations. CAD allows for faster iterations, improved accuracy, and enhanced communication between project stakeholders.
3. Parametric Design: Parametric design tools facilitate the creation of complex architectural forms and geometries. Architects can define parameters and relationships between design elements, allowing for rapid exploration of design alternatives. This approach is instrumental in timber construction, as timber's versatility and flexibility can be fully utilized.
4. Virtual and Augmented Reality (VR/AR): VR and AR technologies offer immersive experiences that allow architects and clients to visualize and interact with designs before construction begins. VR can simulate walkthroughs of buildings, while AR overlays digital information onto the physical environment. These technologies aid in design evaluation, spatial understanding, and client communication.
5. Prefabrication and Digital Fabrication: Digital solutions are vital in timber prefabrication and digital fabrication processes. Computer-controlled machines like CNC routers b can precisely cut and shape timber elements based on digital models. This enables efficient mass production, reduced waste, and improved quality control (Figure 1).
6. Structural Analysis and Optimization: Advanced structural analysis software assists architects and engineers in evaluating the performance and safety of timber structures. It can simulate and optimize loads, stresses, and material usage, leading to more efficient designs and cost savings.
7. Project Management and Collaboration: Digital project management tools streamline communication, document sharing, and scheduling among project teams. Cloud-based platforms enable real-time collaboration, even for geographically dispersed stakeholders, facilitating efficient workflows and reducing errors.

8. Sustainability Assessment: Digital tools can evaluate the environmental impact of architectural designs and timber construction. Life cycle assessment (LCA) software analyzes different design options' energy consumption, carbon footprint, and embodied emissions, helping architects make informed decisions.

1.1. Recent innovations in computational techniques have revolutionized the design

Recent innovations in computational techniques, material systems, and fabrication processes have revolutionized the design and construction of surface structures. Powerful analytical tools now enable architects and engineers to create new surface forms, predict their behavior, and devise efficient manufacturing strategies. Digitally supported design and fabrication echnology has unfolded new potential to realize complex structural surface shapes (Figure 2).

Figure 1. Developing the geometry, designing the supporting framework, and generating production data are all decentralized yet interconnected processes. An integrated data exchange with clearly defined interfaces makes seamless project management possible.

The traditionally used materials are now combined with newly engineered wood products (EWPs). The term Engineered Wood Products is extended to structural wood-based materials and embraces the whole spectrum of wood materials engineering with respect to specific purposes and performances. It is, however, becoming virtually impossible to summarise and compile the whole spectrum of engineered wood materials and products that are now established on the market. There is an ongoing dynamic innovation process in the wood materials and wood-product engineering field, and the broad spectrum of engineered wood materials and products is continuously expanding (Glavonjić et al., 2022).

Figure 2. An adaptive robotic fabrication process makes possible a necessary scaling-up and handling of complex interrelations between the pattern shapes and the behaviour of novel materials. In contrast to repetitive manufacturing processes where automation relies on the execution of predetermined and fully defined steps, sensing technology enables a workflow that synthesizes material computation and robotic fabrication in real-time. In this process, the shape of the tailored workpiece is repetitively scanned.

Recently built Urbach Tower is a unique example of contemporary wood structure; its design emerges from a new self-shaping process of the curved wood components. This pioneering development constitutes a paradigm shift in timber manufacturing from elaborate and energy-intensive mechanical forming processes that require heavy machinery to a process where the material shapes entirely by itself, as shown in Figure 3.

Figure 3. The Urbach tower in Urbach, Germany; a timber tower made of 14 metre long elements shaped by a self-shaping process to achieve curved timber elements

Tectonics – the interplay of architectural expression, efficiency and the construction of support structures – is the focus of our research and teaching nowadays. New wood-based materials and processing technologies and new possibilities for depicting and calculating the support structures play an important role here. The aim is an efficient interlinking of design and construction that integrates the architectural, support-structure-related, and production requirements, leading to sustainable and high-quality solutions

1.2. Methods applied in the teaching of wood products design classes

Figure 4. Students designs examples: Created in the CNC Manufacturing class at Purdue University, Department of Forestry and Natural Resources, where variety of digital methods are learned and then applied in products design and its fabrication.

Innovative surface structure methods provide techniques necessary to design folded plates, shells, and tensile membranes in various materials. Some of these technologies demonstrating the use of wood-based materials in creating successful surface architecture are shown in case studies. Some of these methods are also applied in the teaching of wood product design classes by instructors and their students. Below are examples from the US (Figure 4) and Slovenia (Figure 5).

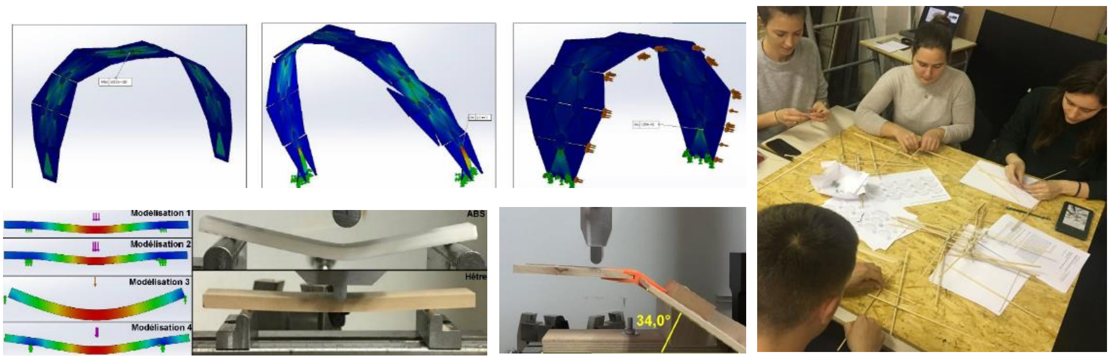


Figure 5. Students designs examples: Construction and design class at University of Ljubljana, Department of Wood Science and Technology, BF, where nature-inspired sustainable solutions for an architectonic environment are teaching learning by doing.

The classic construction methods are joined with a novel 3D printing technology, including 3D printing with wood filaments combined with PLA material. 3D printing already allow the creation of large and advance building structures. Digitalization solutions in architecture are presented with examples of recently realized projects and their involvement in different design stages (Figure 6).

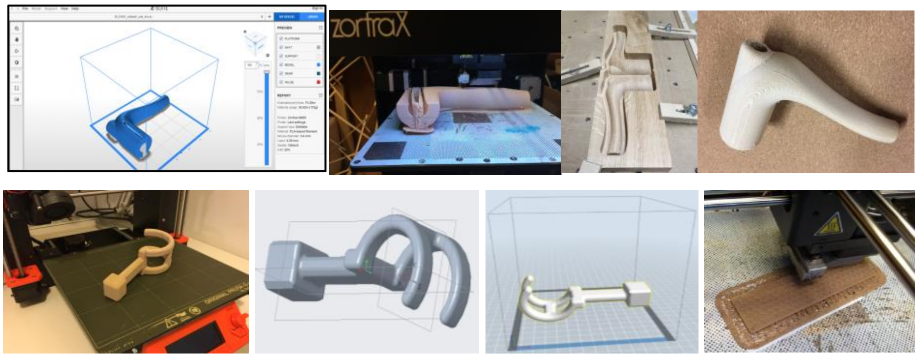


Figure 6. Students designs 3D printing examples: development of hand safty device for protection against COVID-19 infection.

2. CONCLUSIONS

Digitalization has revolutionized architecture by enabling the creation of complex, organic structures inspired by nature. Parametric design, Building Information Modeling (BIM), Computer-Aided Design (CAD), and sustainable assessment tools have played a significant role in this transformation. Architects and engineers now have the ability to explore innovative solutions, predict design behavior, and optimize construction processes. Integrating engineered wood products (EWPs) with traditional materials offers greater design freedom and enhanced construction possibilities.

There are several innovative ways to utilize wood in combination with other materials, capitalizing on its lightweight properties and suitability for refurbishment and redesigning. Wood is coming back to the town as it was before: in medieval towns we had a lot of wooden buildings that then disappeared, and now it is coming back because of this redensification of towns (Kaufmann, 2023). Wood's advantages include speed and efficiency in constructing new buildings and extensions due to its lightweight nature.

In addition to professional practices, educational programs and student projects centered around digitalization processes have been instrumental in advancing timber construction. Through hands-on experiences and experimentation, students are pushing the boundaries of architectural design with timber. Combining digital tools and engineered wood products (EWPs) offers many opportunities for innovative and sustainable timber structures.

Acknowledgments: We wish to thank Slovenian Research Agency, Program P4-0015.

REFERENCES

1. Glavonjić, B., Kitek Kuzman, M.; Sandberg, D. (2022). *Engineered Wood Products- Wood as an engineering and architectural material.* Engineered wood products in contemporary architecture: new ways to use timber in future. Kompozitni proizvodi od drveta u savremenoj arhitekturi: novi načini korišćenja drveta u budućnosti. Luleå: Luleå University of Technology, p. 272.
2. Niemz, P., Teischinger, A., Sandberg, D. (2023). *Springer Handbook of Wood Science and Technology.* Springer Nature Switzerland AG, p. 2094.
3. Hofmeister, S. (2023). *Herman Kaufmann Architecten- Architecture and Construction Details*. Detail, p.192.

Authors address:
Kitek Kuzman, M[1], Haviarova[2], E, Kariž, M[1]
[1] Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana, Slovenia
[2] Purdue University, Department of Forestry and Natural Resources, West Lafayette, IN, USA
*Corresponding author: manja.kuzman@bf.uni-lj.si

INFLUENCE OF WOOD DEFECTS AND DIMENSIONS OF OAK ELEMENTS ON THE SUCCESS OF MACHINING FINISHED PARQET LAMELLAS

Smajić, S., Herceg, A., Obućina, M., Beljo Lučić, R., Antonović, A., Ištvanić, J.

Abstract: The main aim of this study was to research the influence of wood defects and dimensions of Oak elements on the success of machining finished parquet lamellas. For this purpose, in one Croatian sawmill, two dimensions of the elements were sawn into raw lamallas. The raw lamellas were then dried in classic wood drying kilns. After that, they are finished by planing and sawing into ready-made dry lamellas for the production of finished parquet. From elements with dimensions 2450x220x57 mm, dry lamellas with dimensions: 2220x191x3.4 mm, 1950x156x3.4 mm and 1200x156x3.4 mm were made, and from elements 1350x180x57 mm dry lamellas with dimensions: 1200x156x3.4 mm and 1200x128x3.4 mm. All lamellas were classified into three quality classes. During machining and drying, the following defects appeared on one part of the lamella: end cracks, surface cracks, cracked and falling out knots, deformations and discoloration of the natural color of the wood. More wood defects were observed on lamellas made from 2450x220x57 mm elements. Despite that, greater quantitative, qualitative and value yields were achieved by processing elements with dimensions 1350x180x57 mm.
Keywords: Wood defects, kiln drying, oak elements, lamellas of finished parquet, quantitative, qualitative and value yield.

1. INTRODUCTION

The entire technological process of oak sawmill processing was subordinated to obtaining a high-quality product from oak. Mostly logs with a diameter of 40 to 100 cm were processed, and sorting was done into classes of 5 cm diameter. For good drying, it was necessary to stack the timber in a high-quality way, and the drying itself took a year (Gregić, 1987). Sawmill wood processing, the production of sawn material, is from several points of view the most important way of processing wood veneer. Today, the production of lamellas is very common in the wood industry, lamellas are used not only for parquets, but their application is also expanding in the production of massive multi-layer panels.

Since the natural drying of wood is an extremely long process, nowadays almost all raw materials in the wood industry are dried artificially using classic chamber dryers. The main aim of this paper is to investigate the influence of the dimensions of oak elements on the occurrence of drying defects on the lammelas. Also, in this connection, another aim is to determine success of making lamellas from elements with two different dimensions. It is not possible to dry wood without defects, but the aim should be to make them as small as possible. Defects occur due to shrinking, fungi and changes in extractive substances. In connection with shrinking, various types of defects occur, such as cracks on the surface and faces, collapse, deformations or changes in dimensions, cracking and falling out of bumps, discolorations or changes in the natural color of the wood, rotting and resin leakage (Krpan, 1965). Milić et al. (2021) investigated the possibility of drying oak lamellas in a condensation dryer. They also investigated the drying of oak lamellas in a climate chamber with a higher initial temperature. The results showed that the higher initial temperature did not cause any changes, the only thing that occurred was the lamination of the slats because they were not loaded. Güngör et al. (2010) investigated how different methods of drying lamellas can affect the surface roughness and bonding strength of multi-layered parquets. Main aim of their research was to determine the surface roughness and shear strength of the lamellas of the upper layer of multi-layer parquet. The lamellas were made from raw wood and dried using different drying methods. Milić et al. (2021) investigated the drying of oak lamellas that are used as the upper-wearing layer of multilayer parquet. Baranski et al. (2020). investigated and analyzed the drying process in relation to the influence of parameters on the deformation and color changes of the surface layer of beech wood (*Fagus sylvatica* L.) and holm oak (*Quercus robur* L.).

2. MATERIAL AND METHODS

The researched wood elements were made from oak sawn logs of class I, II and III. The length of the logs was 2 meters and more, and the diameter 20 cm and more (Figure 1). The process of making lamellas consists of five stages. In the first phase, it starts with sawing logs into sawmills. In the second phase, sawnwood is cut crosswise and longitudinally into elements for making lamellas. In the third stage, the elements are sawed by thickness into raw rough lamellas. In the fourth stage, artificial drying of the raw rough lamellas is carried out.

Figure 1. Oak logs used in the research

Figure 2. Log band saw used for sawing

Finally, in the fifth stage, planing, cutting, sorting and packing of finished lamellas follow. Logs are sawn on a log bandsaw (Figure 2), manufactured by Primultini, using the technique of live sawing, where sawnwood with a nominal thickness of 50 mm are made. The finished sawnwood are then transported to circular saw for crosscut sawing, where it is cut to the fixed length. The lengths of elements for this research were 2450 and 1350 mm. They are then transported using roller conveyors to a single-blade circular saw for longitudinal sawing, where they are cut to the fixed widths. The width of researched elements was 180 and 220 mm.

On the structure of the circular saw there is a laser that shows the sawing line and facilitates the most favorable placement of the saw blade in relation to the position of a possible wood defects (Figure 3).The elements made in the given dimensions are further sawn on a line of multiple horizontal narrow-blade band saws for sawing thin veneer, manufactured by RE-MAX 500 CNC NEVA-OGDEN, specification given in table 1. The line consists of three horizontal band saws (Figure 4).

Figure 3. Circular saw with laser for longitudinal sawing.

Figure 4. Line of multiple horizontal narrow-blade band saws

During sawing, the lamellas are sorted by thickness, width and length. Further classifications according to quality are made after the drying and planing process of the lamellas. Figure 5 shows the method of stacking the lamellas on the underlying profiled slats. For the purposes of this research, drying was carried out in a classic chamber dryer. During drying, the moisture content in the lamella samples was controlled using probes inside the drying room, i.e. using the electrical resistance method. The drying process was followed by the planing of the lamellas. Figure 6 shows the line on which this processing takes place. Calibrating milling machines manufactured by Ledinek, model Rotoles 400 PD - SV, which circularly processes the upper and then the lower side of the lamella, a machine for longitudinally sawing lamellas that has lasers to visually show where the circular saw will make a cut, and a machine for cutting lamellas to the desired length using a circular saw.

Table 1. Technical characteristics of machine, RE – MAX 500 CNC NEVA – OGDEN

Horizontal band saw, RE – MAX 500 CNC NEVA - OGDEN	
Tool cutting heads	1 or more
Voltage	3x 400V/50Hz
Main power	22kW (30KS)
Cutting speed	Adjustable to 50m/s
Feed speed	Adjustable 16 m/min
Production capacity	500 – 1000 m2/shift
Wheel diameter	1000mm
Cutting width	to 330 / 500 mm
The largest thickness of the element	150 mm
Minimum element length	800 mm
Minimum element thickness	2mm
Saw cut	from 1.1 mm
Compressed air	min. 6 bar

Table 2. Technical characteristics calibrating planers, LEDINEK ROTOLES 400 PD

LEDINEK ROTOLES 400 PD	
Working width	Max 400mm
Working height	Max 150mm
Processed sides	2
Working width	40mm
Working height	2mm
Length of element	Min 150mm
Workpiece feed	Belt conveyor
Feed speed	Max 30 m/min
Power	58kW

Figure 5. The way of sorting lamellas

Figure 6. Calibrating milling machines-model Rotoles 400

The dimensions of the lamellas are as follows: 2220 x 191 x 3.4 mm, 1950 x 156 x 3.4 mm and 1200 x 156 x 3.4 mm, (permissible deviation +/- 1 mm). The moisture content of the lamellas must be 7-8% (permissible deviation +/- 1%). Flatness: 90% of the product must be a flat lamella without feathering and other deformations.

3. RESULTS

For this research, two dimensions of elements from which lamellas are produced were sawn: elements with dimensions 2450 x 220 x 50 mm and elements with dimensions 1350 x 180 x 50 mm. According to Brežnjak (1997., 2000.), all yield calculations were made based on the expressions given in his works. Table 3, part I shows the quantitative yield of elements in the form of rough raw lamellas, and then dry processed lamellas. In part II of the same table 3, the quantitative yield of rough raw lamellas in the production of finished dry lamellas is shown. Table 3, part III show the qualitative yield of elements in the form of dry processed lamellas. In part IV of table 3, the value yield of elements and rough raw lamellas in the form of dry processed lamellas is shown.

Table 3. Quantitative, qualitative and value yield of elements in the form of raw and dry lamellas

	Elements		Vol. of raw lam	Vol. of dry lam.	Quantitative yield of elements in the form of raw and dry lamellas			
I	Dimension	Vol.			Im elem-raw lam		Im elem dry lam	
		m3	m3	m3	Coeff.	%	Coeff.	%
	2450 x 220 x 57	4,800	3,680	1,364	**0,767**	76,70	**0,284**	28,40
	1350x180x57	2,700	2,000	0,930	**0,741**	74,10	**0,344**	34,40
	Average	3,750	2,840	1,147	0,754	75,40	0,314	31,40
	Total	7,500	5,680	2,294				
	Elements		Vol. of raw lam	Vol. of dry lam.	Quantitative yield of raw lamellas when making dry lamellas			
II	Dimension	Vol.			Im row lam-dry lam			
		m3	m3	m3	Coeff..		%	
	2450 x 220 x 57	4,800	3,680	1,364	**0,371**		37,10	
	1350x180x57	2,700	2,000	0,930	**0,465**		46,50	
	Average	3,750	2,840	1,147	0,418		41,80	
	Total	7,500	5,680	2,294				
	Elements		Vol. of raw lam	Vol. of dry lam.	Qualiitative yield of elements in the form of dry lamellas			
III	Dimension	Vol.			Ik		N	
		m3	m3	m3	Coeff..		EUR/m2 dry lam	EUR/m3 dry lam
	2450 x 220 x 57	4,800	3,680	1,364	**0,735**		21,30	6266,00
	1350x180x57	2,700	2,000	0,930	**0,899**		15,29	4496,76
	Average	3,750	2,840	1,147	0,817		18,30	5381,38
	Total	7,500	5,680	2,294				
	Elements		Vol. of raw lam	Vol. of dry lam.	Value yield of elements in the form of raw and dry lamellas			
IV	Dimension	Vol.			Iv elem-dry lam		Iv raw lam-dry lam	
		m3	m3	m3	Iv	EUR/m3 elem	Iv	EUR/m3 raw lam
	2450 x 220 x 57	4,800	3,680	1,364	**0,209**	1780,54	**0,272**	2322,44
	1350x180x57	2,700	2,000	0,930	**0,310**	1548,70	**0,418**	2090,74
	Average	3,750	2,840	1,147	0,259	1664,62	0,345	2206,59
	Total	7,500	5,680	2,294				

4. CONCLUSION

At the beginning, the lamellas had an initial moisture content of about 37.5%. The wanted moisture content in the lamellas is 7 +/-1% and this percentage was achieved in 8 days. During drying, it is not possible to completely dry all the lamellas without the occurrence of defects, and those that were observed after the drying process are: surface cracks, frontal cracks, hollowness, color change, changes in shape, i.e. curvature of the lamella, deformation of the knots as well as falling off and cracking of the knots. It can be stated that the drying defects were observed to a greater extent on lamellas with greater width and length. Quantitative yield for elements with dimensions 2450x220x57 mm in the form of raw lamellas was 76.70%, while in the form of dry processed lamellas it was 28.40%. With the dimensions of the elements 1350x180x57 mm, in relation to the raw lamellas, the quantitative yield was 74.10%, in the form of dry processed lamellas, it was 34.40%. Quantitative yield for lamellas made from elements with dimensions 2450x220x57 mm was 37.10%, while for lamellas made from elements with dimensions 1350x180x57 mm it was higher and amounted to 46.50%. Qualitative yield for elements with dimensions of 2450x220x57 mm was 0.735 or 21.30 €/m2 dry. lam. For dimensions of the elements 1350x180x57 mm, the qualitative yield was 0.899 or 15.29 €/m2 dry. lam. The value yield for elements with dimensions 2450x220x57 mm in the form of dry treated lamellas was 0.209 or 1780.54 €/m3 of elements, while for elements with dimensions 1350x180x57 mm it was 0.310 or 1548.70 €/m3 of elements. The value yield of rough raw lamellas in the form of dry processed lamellas made from elements with dimensions 2450x220x57 mm was 0.272 or 2322.44 €/m3 of raw. lam., while for dry processed lamellas made from elements with dimensions 1350x180x57 mm it was 0.418 or 2090.74 €/m3 raw. lam. In general, higher yield was achieved by processing shorter and narrower elements, and the reasons for better yield are that shorter lamellas deform less during drying and have a less number of defects compared to longer lamellas. When it comes to longer elements, it is not possible to produce a larger proportion of long clean lamellas, while with shorter elements it is possible to obtain a larger quantity of better quality shorter lamellas.

REFERENCES

1. Barański, J., Konopka, A., Vilkovska, T., Klement, I., and Vilkovsky, P. (2020). "*Deformation and surface color changes of beech and oak wood lamellas resulting from the drying process,*" BioRes. 15, (4): 8965-8980.
2. Brežnjak, M. 1997: Sawmiling technology part I, Šumarski fakultet Zagreb.
3. Brežnjak, M. 2000: Sawmiling technology part II, Šumarski fakultet Zagreb.
4. Gregić, M. 1987: Razvoj prerade i iskoriščavanja hrasta lužnjaka i drugih vrsta drva u Hrvatskoj od 1699 do 1984 godine, Drvna industrija, 38, (9-10): 195-209.
5. Güngör, M.; Korkut, S.; Kantay, R. 2010: Effects of Drying Methods of Lamellas Used in Multilayer Parquet Manufacturing on Surface Roughness and Bonding Strength, African Journal of Biotechnology, Vol. 9, (32): 5099-5107.
6. Krpan, J. 1965: Sušenje i parenje drva. Šumarski fakultet Zagreb, Hrvatska
7. Milić, G., Todorović, N., Veizović, M., Popadić, R. 2021: Possibility of drying oak lamellas in dehumidification kilns 5th International Scientific Conference, Wood Technology & Product Design, 2021, Ohrid, Republic of North Macedonia, 126-130.
8. Milić, G., Todorović, N., Veizović, M., Popadić, R. 2021: Sušenje hrastovih lamela,1. dio – Analiza procesa sušenja u kondenzacijskoj sušari, Glasnik Šumarskog fakulteta, (124): 45 – 58.
9. Pervan, S., 2000: Priručnik za tehničko sušenje drva. SAND, Zagreb, Hrvatska.

Authors address:
Smajic, Selver[1]; Herceg, Antonijo[2]; Obućina, Murčo[3]; Beljo-Lučić, Ružica[4]; Ištvanić, Josip[4*]
[1] PhD student at Faculty of Forestry and Wood Technology Zagreb; University of Zagreb.
[2] Mag. ing. tech. lign. at MMM Vukelic d.o.o.; Novska-Brestaca; Croatia
[3] Full Professor at Mechanical Engineering Faculty Sarajevo; Bosnia and Herzegovina,
[4] Full Professor at Faculty of Forestry and Wood Technology Zagreb; University of Zagreb,
[5] Assistant Professor at Faculty of Forestry and Wood Technology Zagreb; University of Zagreb,
[*]Corresponding author: jistvanic@sumfak.hr

USING RECYCLED PAPER IN PRODUCT DESIGN APPLICATIONS

Zach, M., Tauber, J., Svoboda, J.

Abstract: This paper discusses methods and options for interconnecting applied research, experimental development, and unconventional machining technologies within product design to facilitate integration of the relevant outcomes in items of everyday use. The applied research focuses on the properties of paper, cardboard, and recycling, while the systematic experimental development focuses especially on unconventional technologies (Laser / CNC plotter). For the purposes of recycling and circular economy, the preferred materials are corrugated board, paper, cardboard, and similar items. The basic applied features are presented on concretely designed and manufactured products that feature attractive design. These comprise, above all, everyday products such as hangers, clocks, interior accessories, and furniture. All of these components are made with respect to the requirements of recycling and circular economy , as they utilize already recycled materials. The research presented herein therefore has an impact on product design and interior accessories in terms of the social outreach of these domains.
Using modern methodologies in sectors and subareas where they are currently employed only marginally brings a potential for interrelating technology, the arts, and fine arts. Such innovative approaches bring competitive advantages to the market both economically and socially; the central potential of the outputs lies in product design, fines arts, and progressive technologies.
Keywords: Recycling, circular economy, cardboard, product design, non-conventional technologies.

1. PAPER RECYCLING

Recycling recovered paper and corrugated cardboard exceeds 70% in Europe, and up to 10 cycles are applicable in reusing sorted material to produce new corrugated board. Such limitation is due to degradation, namely, the shortening of the cellulose fibres during reuse, a problem arising from the fact that the material goes through the recycling procedure roughly 10 times (TERMIL Cartonage, 2016).

Another definition (by Petr Grusman INISOFT s.r.o.) characterizes recycling as one of the fundamental activities of "circular economy", a set of steps that have accompanied the material since its very beginnings. Generally, at present, paper is to be assumed to be recyclable seven times, but there is no evidence to positively corroborate this presumed property (Grusman - INSOFT, 2022).

Recycling paper or corrugated board embodies an inherently challenging process whose requirements reach far beyond the idea that old paper is merely left to soak water to produce new paper, after being dried. By contrast, the recyclate needs to be stripped of unsuitable components, including waxed, chalked, or otherwise treated paper; supplementary paper-based materials of visibly poor quality; and heavily colored papers. Starch, wood admixtures, and other substances are added to the recyclate blend (especially if the aim is to produce better quality recycled paper) to improve the characteristics (Tavobal, 2022).

Cyclical management requires recycling conserving primary resources while ensuring production from renewable sources (Corrugated Board Manufacturers Association, 2021).

In the Czech Republic, 83.6% of paper and cardboard was recycled in 2018. In the year 2021, the content of new corrugated packaging reached 89% of the recycled material, significantly reducing the exploitation of primary resources and thus limiting the negative impact on the environment. Across Europe, corrugated board is, on average, recycled at 89% (Corrugated Manufacturers Association, 2021).

Until recently, the majority of recycled paper was acquired from industrial and commercial companies because collecting paper in this manner embodied the easiest and most economically most viable option. In recent years, the demand for recycled paper has been increasing, and thus other participants, such as households, schools, and nurseries, have become involved in the process (Assmann, 2014).

In addition to the direct recycling of paper and cardboard and the subsequent manufacturing of new products, there are also companies that handle previously used packaging materials (boxes and bags, for instance), which are then offered for further employment, provided they are of adequate quality. An example of such a subject is the company: MS - obaly s.r.o. https://www.ms-obaly.cz/.

Smooth and corrugated cardboard finds use as not only packaging material (cartonage, boxes, and other items) but also product design element: In interior accessories, for instances, it functions as a secondary raw material (during recycling) or as a flat material, where the recycled material itself has already been used during production.

2. MATERIAL: PAPER AND CARDBOARD

Cardboard is single- or multi-ply hard paper with a grammage exceeding 150 g/m2, often often referred to as paperboard; the correct term, however, reads plain cardboard. Corrugated board is also available on the market and finds application together with plain board, i.e., cardboard, to produce multi-ply paperboard (corrugated board). This type of fabric allows producing cardboard boxes and cartons, which are otherwised termed *cardboard* (Obalnet, 2023).

Cardboard embodies a multi-layered sheet material available in the form of plain cardboard, namely, cardboard, or paper with a large surface weight for the production of cardboard and bookbinding; and corrugated board, denoting a two to seven-layer structure in which layers of smooth and corrugated board alternate (INPAP PLUS, 2023).

Corrugated board is defined as an environmentally friendly and sustainable packaging material (Corrugated Board Manufacturers Association, 2021). MODEL HOLDING AG, a multinational company, uses closed-loop paper to help reduce energy and resource waste by applying circular economy as well as joint efforts.

2.1. Cardboard

The relevant adhesives are basically composed of a multi-layered sheet material. Their application options involve, above all, overlaying protected areas against contamination; ensuring damage protection; and, last but not least, filling boxes. These items comprise two to seven layers of paper, which include smooth and corrugated paper.

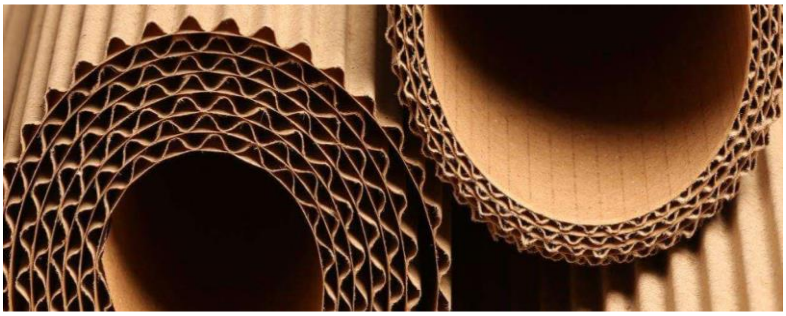


Figure 1. Samples of corrugated board; Source: (Corrugated Board Manufacturers Association, 2023)

The corrugated board material can be easily shaped, providing multiple shaping options (Fig. 1).

2.1.1. Features

The most important parameters of corrugated board subsume in particular edge compressive strength (the BCT and the ECT values). The BCT (Box Compression Test) value indicates the stackability or resistance to compression, while the ECT (Edge Crush Test) rate is defined as the maximum force per unit length that the test strip can withstand when loaded perpendicularly in the direction of the waves. The next parameter monitored is the flexural strength (TPM), a characteristic monitored using the three-point-bending test method. This method simulates the reality where the walls of the packaging initially bend and then deform under load (Corrugated Board Manufacturers Association, 2021).

2.1.2. Dimensions

Corrugated board finds use in the manufacturing of sheets and rolls. The basic product are boards and rolls; the latter consist of two layers. According to the height of the wool, we classify corrugated board into types that are available on the market: A, B, C, E, and fine wool F, G, and N. The height of the cardboard therefore ranges from only a few mm to 10 mm.

2.1.3. Layers

Two to seven layers of paperboard are accessible on the market, comprising layers of cover (smooth) paper and corrugated paper. In product design and interior accessories, 5-ply corrugated board has proven to be the most utilizable.Corrugated boards are classified into:

2-layer corrugated board (2VVL) 5-ply corrugated board (5VVL)
3-layer corrugated board (3VVL) 7-layer corrugated board (7VVL)

3. TECHNOLOGY

When processing paper, cardboard, or cartonboard, we employ cutting as one of the basic technological operations. This step can be executed manually (with scissors, knife) or on cutting machines that work on the principle of either cutting or section;.the difference lies in that in the former two knives operate against each other, while the latter involves a single knife acting against a pad (Macháň, 1998). State-of-the-art methods for material cutting include laser, CNC plotter, and waterjet cutting.

3.1. Laser beam cutting

The CO2 laser is most commonly used in production, operating at a wavelength of 10.6 μm, with suitable absorption capabilities for cutting paper, cardboard, and board. The speed depends on the thickness of the material to be cut and the power of the laser. There is no need to clamp the paper or cardboard in the machinen during the cutting. Laser cutting is a very fast, precise, and high-quality procedure where even very complex shapes can be materialized (Macháň, 1998; Bauer, 2018).

The disadvantage is that when cutting thicker material, such as five-layer corrugated cardboard, the cutting surfaces are burnt and then smeared with ash; the ash can be wiped off using a damp cloth.

3.2. CNC plotter cut

The basic cutting methods include the flat knife cut and the circular knife cut; this principle is applied in CNC plotters. The cutting is guided by a specific cutting force, variable during the cutting process. The procedural stages are affected by the angle of the knife edge, condition of the knife blade, height of the cut stack, width of the cut, condition of the stack compression, moisture content in the material, and whether the cut is across or along the grain.

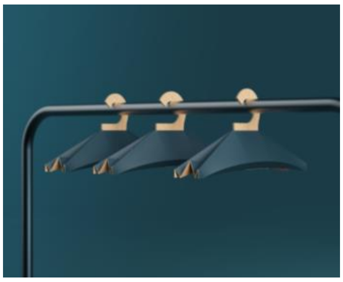
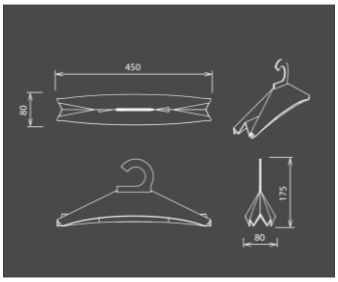
4. DESIGNING PRODUCTS FOR DAILY USE, INTERIOR ACCESSORIES, AND FURNITURE

By utilizing new, unconventional technologies and devices, such as laser-based equipment or the CNC plotter, the product shaping options are markedly expanded, also in terms of incorporating and understanding innovative design approaches. The enhanced shaping versatility then facilitates the efficient use of material and fast fabrication of parts through cutting, enabling original products to be designed quickly and smoothly.

The subsections below introduce items selected from a set of concepts that have been structured and materialized by students and professional designers, each of whom has adopted specific creative procedures. The underlying method then rests in processing already recycled material with advanced technologies, laser cutting in particular.

4.1. Noon hanger

The author was inspired by the Japanese origami culture. Similarly to the origami designs arising from a single piece of paper, the Noon requires only one slice of cardboard to be fabricated. The advantage over a traditional wooden or plastic hanger lies in the simple manufacturing and reduced environmental impact. The applied shapes ensure positive tension in the hanging garments; further, the hanger tightens itself progressively with increasing load, and thus it will not disintegrate. When decorated with the graphics, the component embodies a playful, functional, and environmentally friendly product. The hanger was nominated for the Czech International Student Design Award 2021.

Figs. 2 and 3. The Noon hanger by Martin Coufal (2021).

4.2. BimBam pendulum clock, and rocking horse

The BIMBAM pendulum clock utilizes ten sheets of five-layer cardboard with a thickness of 6 mm. The item is offered in a wide variety of colors and dial design options. The color is applicable to the face of the clock body and/or to the inner surface behind of the hands, and the actual hands can be tinted too. The clockwork mechanism is protected with a cover, which easily fits the driving groove after being inserted and rotated to lock.

The rocking horse is made of five-layer corrugated packaging cardboard. Generally, this fabric consists of raw paper, a material based on recycled paper with a share of virgin fibres and starch glue. The horse features light weight due to the material used and can be easily and safely carried by children. For a greater variability, the product is designed in three sizes. This ensures suitable ergonomy for a wider group of users.


Figure 4. The pendulum clock; authored by *Martin Holas (2021).*
Figure 5. The rocking horse; authored by Jiří Tauber *(2021).*

4.3. Play Box

The product, aptly named the *Play Box*, demonstrates that there is a beauty and variability in simplicity. Designed for children and developing their creative thinking, the item can be used as, for instance, a table, chair, shelf, stool, carrying box, and moving box. The 3 basic elements can be used variably and are storable in a single crate. The Play Box exploits one type of material, namely, 5-ply corrugated cardboard; the product is strong, durable, and re-recyclable.

Figure 6,7. The Play Box, Author (2022)

5. DISCUSSION AND CONCLUSION

The paper outlines alternative approaches to product design, exploiting specific practical examples and recent achievements within the domain to illustrate the overall problem. The presented student-made artifacts were fabricated at Mendel University in Brno under supervision by the authors of the paper. The set of these products includes, among other items, the outcomes of the systematic efforts pursued by the above-mentioned nominees for the Czech International Student Design Award 2021. The design respects the current ecology-related requirements, utilizing recycled corrugated board, paper, and cardboard. The general design, especially as regards the applied material, allows further recycling and application of the principles of circular economy. The actual concept of the products integrates applied research, experimental development, and unconventional machining technologies (Laser / CNC plotter) to deliver a unique and fully functional design. At present, environmentally friendly products are relatively easily available to customers; however, their prices often markedly exceed those of conventional items. This drawback is partially eliminated by state-of-the-art technologies, which render the merchandise competitive both economically and socially.

REFERENCES

1. Bauer, K. (2018): *The use of laser in the production of carved postcards.* Bachelor thesis. Prague: Czech technical university in Prague
2. What is cardboard / cardboard?. In: *Obalnet: The Kingdom of Packaging* [online]. Praha: INPAP PLUS, 2023 [cit. 2023-05-01]. Available from: https://www.obalnet.cz/co-je-to-karton-lepenka/
3. Coufal, M. (2021): Hanger Noon. *Brno*
4. Types of cardboard and applications. In: *Inpap* [online]. Praha: *INPAP PLUS*, 2023 [cit. 2023-05-03]. Available from: https://www.inpap.eu/druhy-lepenky-a-pouziti
5. Ecological cardboard hanger. *Czech International Student Design Award 2021* [online]. Prague: Design Cabinet CZ, 2021, 1 [cit. 2023-05-06]. Available from: https://www.studentskydesign.cz/cs-cz/detail/315/
6. Grusman, P. (2022): There is no paper like paper. In: *INISOFT* [online]. Liberec - Staré Město. Available from: https://www.inisoft.cz/poradenstvi-a-skoleni/odborne-clanky/odborne-casopisy/neni-papir-jako-papir
7. Holas, M. (2021): Pendulum clock - BIMBAM*, Brno*
8. How recycling affects the quality and use of paper. In: *Packaging material* [online]. Prague 4 - Libuš: TAVOBAL, 2022 [cited 2023-04-20]. Available from: https://www.obalove-materialy.cz/o-nas/clanky/jak-recyklace-ovlivnuje-kvalitu-a-vyuziti-papiru
9. *Cardboard paper, its recycling and reuse for production* [online]. Vsetín: Kartonáž TERMIL, 2016 [cit. 2023-04-26]. Available from: https://obaly-krabice.cz/kartonovy-papir/
10. Macháň, J. (1998): *Processes of paper and paperboard production*. ISBN 80-902540-1-2.
11. *MS - packaging* [online]. Nechanice: MS - obaly, 2020 [cit. 2023-05-12]. Available from: https://www.ms-obaly.cz/
12. Advantages of corrugated board. In: *Association of Corrugated Board Manufacturers* [online]. Prague: Association of Corrugated Board Manufacturers, 2021 [cit. 2023-04-10]. Available from: https://svvl.cz/prednosti-vlnite-lepenky/
13. Paper recycling process. In: *Assmann: containers and waste* [online]. Prague: Assmann & SYN Waste, 14.04.2014 [cited 2023-04-16]. Available from: http://www.assmann.cz/blog-proces-recyklace-papiru-detail-14
14. Tauber, J. (2022): *PLAY BOX,* Brno; Tauber, J. (2021): *Rocking-horse*, Brno
15. Production and processing of corrugated board. In: *Association of Corrugated Board Manufacturers* [online]. Prague: Union of Corrugated Board Manufacturers, 2021 [cit. 2023-05-09]. Available from: https://svvl.cz/vyroba-a-zpracovani-vlnite-lepenky/

Authors address:
Zach, Martin[1*] ; Tauber, Jiří[2] ; Svoboda, Jaroslav[3]
[1] Expert Engineering Department, Institute of Lifelong Learning, Mendel University in Brno, Brno, Czech Republic
[2] Department of Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, Brno, Czech Republic
[3] Department of Design and Furniture, Faculty of Forestry and Wood Technology, Faculty, Mendel University in Brno, Brno, Czech Republic
[*]Corresponding author: martin.zach@mendelu.cz

FOREST BIOECONOMY TEAM
Faculty of Forestry and Wood Sciences (FLD), Czech University of Life Sciences Prague (CZU)
(https://www.fld.czu.cz/en/r-9413-departments/r-9474-faculty-units/r-19054-team-for-forest-bioeconomy)

Bioeconomy and forest bioeconomy have become an important topic of research and teaching activities at the FLD CZU. With the objective to support knowledge transfer aiming at the deployment of a sustainable bioeconomy in the Czech Republic, the faculty established the Forest Bioeconomy team as a dedicated unit. The Team specializes in bioeconomy-related projects, publications, and teaching of undergraduate and graduate students with emphasis on forest bioeconomy. The team is also active in cooperation with foreign specialists. The team is led by Martin Jankovský and unites experts from several faculty departments (Dep. Of Forestry Technologies and Construction – M. Jankovský, M. Hájek and R. Löwe; Dep. of Wood Processing and Biomaterials – R. Fojtík and Dep. of Forestry and Wood Economics – P. Palátová and R. Rinn).

BIOECONOMY PLATFORM OF THE CZECH REPUBLIC
(https://bioeconomy.czu.cz/en)

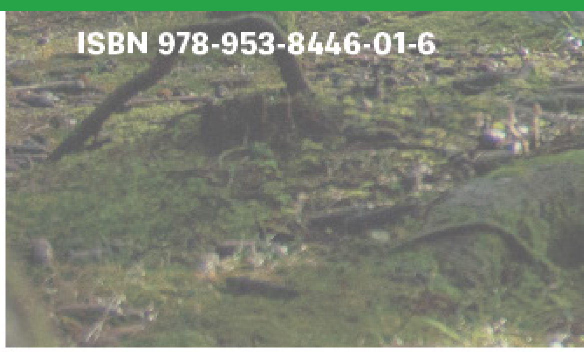
The Platform was established in cooperation with the Czech University of Life Sciences Prague and the University of South Bohemia in České Budějovice as a response to societal challenges in sustainable development, the need to modernize industry and increase global competitiveness of the Czech Republic. The goals of the Platform are to deepen knowledge in bioeconomy by means of research and education and to promote their use in practice at the level of enterprises and public administration while respecting principles of sustainable development. The Platform coordinates activities related to the bioeconomy, organizes professional discussions, workshops and seminars for various stakeholders and asserts the latest knowledge into practice in collaboration with industries. Currently, the platform has 26 institutional and ten individual members.

Publisher:
WoodEMA, i.a. – International Association for Economics, Management, Marketing, Quality and Human Resources in Forestry and Forest Based Industry
Savska cesta 50, Zagreb, Croatia

Czech University of Life Sciences Prague
Kamýcká 129, 165 00 Praha 6 – Suchdol, Czech Republic

Print:
powerprint s.r.o.
Brandejsovo nám. 1219/1
165 00 Praha Suchdol

Edition: 150 copies
ISBN: 978-953-8446-01-6



ISBN 978-953-8446-01-6

9 789538 446016