

SWOT ANALYSIS AND GOOD PRACTICES ON SIDE STREAM UTILIZATION AND WASTE MANAGEMENT IN WOOD CONSTRUCTION VALUE CHAIN IN FOUR-MACRO-REGIONS IN EUROPE

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Abstract:

Transitioning from a linear to a circular economy is an important part of Europe's strategy to counteract climate change, boost green transformation and accomplish new business and welfare. Through the introduction of the European Green Deal in December 2019, this transition has received greater attention and activity to analyze and implement circularity throughout Europe.

WoodCircus project of European Horizon 2020 program (2018–2021), a consortium of seven research centers, eight industry stakeholders, two EU networks and seven countries, aimed to increase knowledge, raise awareness, and improve conditions for an uptake of resource efficient processing, recycling and circularity in wood construction value chains, and foster competitiveness of the European woodworking sector. The project was based on an extensive fact finding and state-of-art process with a focused literature review and internet search, expert interviews of 99 stakeholders in ten countries in four macro-regions in Europe and three workshops with invited experts.

The thematic focus was in wood-based side stream utilization and waste management systems, availability and suppliers of raw materials, bio-circular product solutions and markets, and resource efficiency, recovering, recycling, reuse and processing technologies. In addition, organization and set-up of

different value chains, with specific attention to material flows, industrial ecosystems as well as composition and collaboration of stakeholders were mapped. The data were used for elaboration of SWOT analysis in the macro-regions, identification of good practices and development needs, and individuation of potential for novel bio-circular applications and cross-border transfer of practices. An invited review panel selected 25 of them for a European good practices catalogue. This paper summarizes this part of the project with recommendations for industry and policy development.

Key words: circular economy; construction industry; woodworking industry; side streams; wood waste.

INTRODUCTION

Transitioning from a linear to a circular economy is an important part of Europe's strategy to counteract climate change, boost green transformation and accomplish new business and welfare. Through the introduction of the European Green Deal in December 2019, this transition has received greater attention and activity to analyze and implement circularity throughout Europe. In this context, construction industry is undergoing significant strategic and operational changes, seeking also solutions of circular wood and hybrid construction in the value chain.

Circular economy is defined as an economic system that aims to keep the economy operating within the limit of the carrying capacity (Ellen MacArthur Foundation 2023). The approach attempts to keep materials and products in circulation for as long as possible to retain their value and to minimize waste in production and consumption. Circular economy has both biological and technical dimensions, with each pursuing economic and environmental impacts.

While construction industry is highly important for EU28 economy, providing 18 million direct jobs and 9% of GDP, it is an essential part of circular economy because it uses half of extracted materials and energy and generates half of all wastes, including demolition, packaging and bulky wastes. Wood construction activity holds share of 19% of labor and 15% of turnover of business of all construction sector. Roughly one third of wood-based wastes from wood construction value chain are used as materials, incinerated or landfilled, each of them. Wood industries supply more than 70% of their products to construction sector, and they provide a diversity of by-products to both material and energy uses. Construction, demolition and new bio-based products represent two of the five priority areas of EU action plan for the Circular Economy (European Commission 2018).

To boost the implementation and progress of circularity among wood construction value chain in Europe, it is important to identify the state-of-art and current good practices in each region and country and evaluate the development needs and potential for cross-border transfer of the best practices. Regarding the improvement of side stream utilization and waste management, the following key issues can be concluded from the former research, among others: resource efficiency, material collection, handling and logistics, product and market diversification, management of harmful agents in the material, cascading and bio-energy balance, stakeholder integration, legislation and regulation (Ruuska and Häkkinen 2014, Mantau 2015, Antikainen et al. 2017, Mair and Stern 2017, Borzecka 2018, Kunttu et al. 2019, Verkasalo et al. 2019).

OBJECTIVE

The objective of this paper is to summarize the results from the European Horizon 2020 project WoodCircus (2018-2021) as regards the state-of-art and SWOT analysis and good practices evaluation on wood construction value chain in four-macro regions, Southern, Central, Northern and Eastern Europe, with an emphasis on the utilization of industrial side streams (by-products) and management of wood-based wastes. Based on the results, the potential for cross-border transfer of good practices is evaluated and recommendations for industry and policy development are provided. WoodCircus was a consortium of seven research centers, eight industry stakeholders, two EU networks and seven countries in Europe (WoodCircus 2021).

MATERIALS AND METHODS

The state-of-art in the research area was compiled applying a fact-finding process of focused literature review and internet search, 99 selected interviews among stakeholders in ten EU countries and three workshops with invited experts during 2019-2020. The stakeholders and experts covered relevant companies, industry associations or federations, public development organizations, municipalities and other actors involved in the value chain of side streams and wood waste management: wood products manufacturing, construction, demolition, recycling, waste collection and processing. Semi-structural interview forms were used, and they were pre-mailed to the interviewees. The interviews were done parallelly in the European macro-regions South (Italy, Spain), Central (Germany, Austria, Switzerland, Belgium, France), North (Finland, Sweden) and East (Slovenia, Poland), and the workshops were organized in Warsaw, Helsinki and Cologne. The data were compiled and analyzed using qualitative methods, and the main

conclusions were drawn as researchers' desk work. Preliminary mapping of good practices in each macro-region was included.

SWOT analysis, also known as internal analysis, involves analysis of the internal and external environment of the organization for strategic planning (Thompson *et al.* 2007). The analysis can allow the organization to better understand the dynamics of its environment and find solutions based on the strengths, to limit the impact of its weaknesses, to exploit the emerging opportunities, and to transform the threats into challenges. We applied both causal reasoning (managerial thinking) and effectual reasoning (entrepreneurial thinking) in the analysis (Sarasvathy 2008). We did not fully implement the SWOT analysis methodology because of the complexity to give relative weight to the various information or to prioritize them while stakeholders have different affinities on them.

Based on the before-mentioned works, the researchers selected a total of 80 cases, ca. 20 of them from each macro-region, for a detailed evaluation to choose the best practices. The researchers defined with the assistance of the industry partners a rating system of 13 criteria to compare the cases for circularity with regionality and cross-border transferability aspects (Figure 1). The cases were classified to four thematic categories with different prioritization of the criteria and to systematize the comparison of cases: Circular Operational Concepts, Efficiency and Processing, Reuse and Recycling, Waste and side stream valorization. The researchers made a pre-evaluation of the cases, and the best practices with justifications were selected in a workshop of researchers and the industry partners. WoodCircus Good Practice Catalogue was collected and published on the website <https://woodcircus.eu/Index.php/publications>.

The circularity rating system developed by WoodCircus

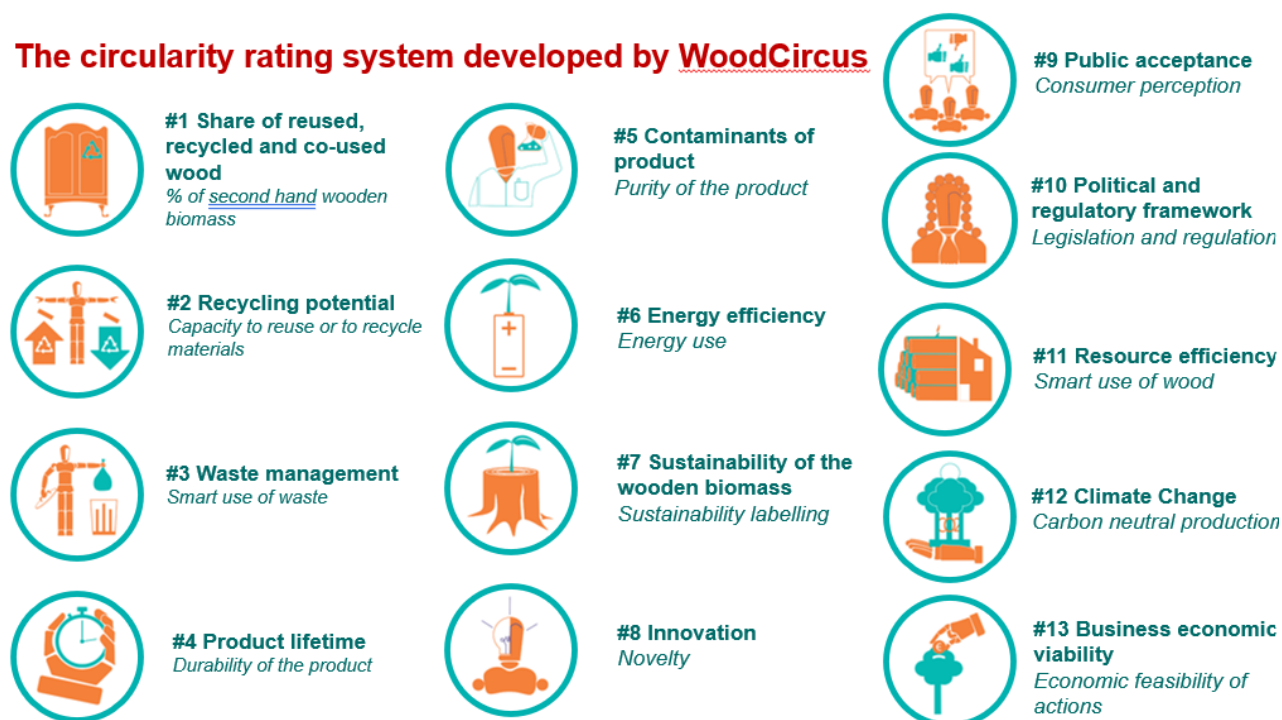


Fig. 1.
Evaluation criteria of company cases to select the best practices.

RESULTS AND DISCUSSION

SWOT analysis

According to the fact finding, all WoodCircus macro-regions proved specific features with strengths and weaknesses that showed either potential or obstacles to drive circularity. Tables 1a-4a and Tables 1b-4b summarize the current and potential strategic performance of side-stream utilization and waste management according to the SWOT analysis in Southern and Central and Northern and Eastern regions, respectively.

Southern-Mediterranean region was characterized with public perceptions and procurement processes boosting innovative recovery networks and post-consumer production where numerous active stakeholders and well-functioning value chains are the engine of efficient recycling and reuse of wood wastes and side streams of wood panel industries.

Table 1a

**Strengths in wood-based side stream utilization and waste management:
Southern Europe and Central Europe**

SOUTHERN	CENTRAL
High recycling, resource and wood waste efficiency Well-functioning value chain in waste collection: active companies and stakeholders High-level, long experience in machine manufacturing (Italy) Large total volumes of side-streams and renewable raw materials High quality products from wastes Inherence in forest and bioenergy sectors Increasing interest in research Positive perception of policies in environmental terms	Plentiful lignocellulosic materials and side streams (certified) High resource efficiency and markets, e.g., wood chips, pallets Sorting broadly implemented for by-products from wood, less for packaging or demolition wastes High self-sufficiency in heating industry plants High quality and partly sophisticated products from fresh side streams Recycling of washing water Good perception of policies Analytical quality control of wastes by third party Eco-organization for the extended responsibility schemes Leading technology in innovative machine engineering and plant design (Germany, Austria) "Fair-priced" recycled materials for wood panels and energy Almost no landfilling

Central-Western region (German and French speaking countries) showed high value-added production integrating effective reuse and recycling that steer the innovation processes. Recycling and waste management companies produce here a large portfolio of products and adapt novel technologies and manufacturing processes for recycled products into value-added construction and furniture products.

Northern region (Finland, Sweden) showed a competitive advantage of industrial symbiosis and business model innovations with supportive governmental environment and good access to forest and side stream resources. The sector is characterized by multi-actor co-operation between forest industries, public authorities, financiers and investors. Well-functioning value chains with almost closed loops of materials, energy and water as a result of high-level integration of industries is a big strength.

Table 1b

**Strengths in wood-based side stream utilization and waste management:
Northern Europe and Eastern Europe**

NORTHERN	EASTERN
Deep circular and sustainability approach in the society and among decision makers Large volumes of side-streams, renewable raw materials and bioenergy sources (certified) High-quality, uniform by-products for industrial and bioenergy uses Shared procurement and delivery with other wood assortments, efficient comminution and bioenergy technology High resource efficiency and almost closed material, energy and water loops Well-functioning markets for chips Efficient integrated forest products companies Versatile markets in energy sector Regional solutions and public support in RDI, investments and regulatory work (Triple Helix) Knowledge and expertise, future-oriented product development (esp. forest industry corporations, industry parks, municipal and private energy companies) Many companies of different size in the business	Implementation of slim production processes Implementation of material efficiency procedures Use of new processing technologies Lower labor costs Central role of forest sector in economy Diversity of forest resource types and manufacturing strengths Direct foreign investments in forest value chain Good incentives by public bodies Smart specialization alignment on topics related to circularity

Table 2a

**Weaknesses in wood-based side stream utilization and waste management:
Southern Europe and Central Europe**

SOUTHERN	CENTRAL
High logistics costs and delivery delays High delivery costs for wood cleaning Small, scattered amounts of more specified materials Lack of reliability on the legislative systems Lack of specific technical know-how, e.g., on fuel gas filtration plants, High energy consumption in production processes and high maintenance costs Implementation of efficiency practices still limited High presence of SMEs	Markets mainly restricted to natural wood and clean residues Limited recycling options, except for particle boards Saturated competition on side streams, unpredictable costs and low profitability of waste treatment Long distances, limited storage room Dust emission issues, high filtering costs of combustion Missing regional public policies Missing company objectives and lack of supporting expertise Value chains not well organized Insufficient innovation potential and lack of RDI investments Undeveloped export (some countries) Protectionism and control based on national views Low customer perception of product quality from recycled materials

Central-Eastern region (Slovenia, Poland) has a strong but insufficiently used potential for green industrial growth and business innovations, with access to diverse forest resources which can potentially be valorized in various industrial processes. Further development of the circular economy concept, in relation to reuse, recycling and side stream utilization, shows potential to be realized via multi-actor collaboration and adaptation of standardization processes and new business models.

Table 2b

**Weaknesses in wood-based side stream utilization and waste management:
Northern Europe and Eastern Europe**

NORTHERN	EASTERN
Varying interests and resource potential for incentives, both among integrated forest product companies and SMEs Varying profitability and lack of capital, investments and RDI in wood product and bioenergy industries, except corporations and large energy companies Lack of proofs-of-concept and slow upscaling from research to commercialization Lack of knowledge on valorization and pricing of alternative products (SMEs, further processing) Logistics costs and scattered sources of some raw materials, semi-finished products and side streams Unstable markets and low prices for side streams, except chips (for suppliers), saw dust depreciation in material uses Few wood panel industries provide scarce demand for side streams Competition and costs of side streams are critical in some regions (for users) Unprofitability of wood-based electricity generation, esp. CHP plants Landfill materials (most of ashes, painted and glued wood) and contaminated wastes Short life and weak durability of some side stream products	Lack of technological development in recycling waste wood and valorization of side streams Unawareness of circular bio-economy among SMEs and stakeholders Lack of strategies among wood-based industries High price of wooden products High costs of complying with regulations Few industry actors willing to invest, waiting governmental support Split forest value chain, primary processing mostly outside the countries limiting available recoverable side streams Export of wood wastes for energy limits local value add Industrial interests not focused on circular or environmental goals Historically risky and adverse sector

Table 3a

**Opportunities in wood-based side stream utilization and waste management:
Southern Europe and Central Europe**

SOUTHERN	CENTRAL
Lots of unexploited residues High value-added products Eco-approach and circular economy growing in the society Green deal agreements between private and public parties Target of 100% circular economy involving post-consumer wood Improve waste management for energy production Investments in biomass boilers Environmental certification, professional qualification Reducing costs of recycling through the improvement of processes	Globally limited biomass resources call for cascading and growing demand of side-streams Improving sorting and requalification Full passage to clean production processes Reducing wastes and hazardous agents (LCA) Upgrading cogeneration Reducing transportation distances and creating producer-user circuits Growing pre-fabrication industry (houses and products) Improving recyclability by natural components Sustainable managed forests: high-end social- environmental products Implementing low carbon strategy Raising awareness of consumers on products from recycled wood Developing European harmonization for uniform application of legislation and regulation Implementing product-specific standards (CE marking, EPDs)

Table 3b

**Opportunities in wood-based side stream utilization and waste management:
Northern Europe and Eastern Europe**

NORTHERN	EASTERN
Positive perspective for circular economy Carbon neutrality approach, green policies Business value from carbon storage, climate change mitigation and emission trading Positive, predictable regulation development Green deal private-public agreements towards sustainable development goals New side-stream based products and users: value-added biorefining products, chemical and composite products, bioplastics, biochar, biogas, pellets and other wood-based bioenergy, renewable liquid fuels, off-cut pieces uses, building element and furniture billets, construction insulation products Trustful company relationships and collaboration Optimized integration: industry park approach, industrial ecosystems of large companies and SMEs Better classification, sorting and knowledge of side streams and end-of-waste criteria (suppliers, users) Longer life cycle and better durability, LCAs and EPDs for side-stream products Developing recyclability and re-usability of building products Developing cascade market and technology Economic assessment of alternative products, new proofs-of-concept Increasing and disseminating knowledge, esp. for secondary wood processing Adoption of new practices from other industrial sectors, and Europe and Eastern Asia	Active participation of EU to support transition to circular economy Raise awareness of consumers Knowledge transfer to wood value chains Raise visibility of forest sector Support networking and partnering Improve classification and standardization systems Quality and environmental certification Promotion of wood use by public sector Implementation of tools like labelling Encourage incentives to promote transition to circular economy (refund systems, ecotax systems) Forest growth is larger than wood harvest – resource availability is increasing

Table 4a

**Threats in wood-based side stream utilization and waste management:
Southern Europe and Central Europe**

SOUTHERN	CENTRAL
Resource supply bottlenecks of side streams Forest diseases affecting the raw material supply Demanding legislation and complex administration Bad image of recycled materials and products Price dumping by new market players Slow and expensive development of new products Late catching up of public bodies about circular economy	Unstable markets and unpredictable, low prices for side streams Specific requirements of different markets for recycled products Lack of demand of recycled products Lack of professionals and entrepreneurship Missing risk investments Environmental risks Strict regulations with multiplicity High waste disposal taxes Lack of valorization strategies at national level Low knowledge and few good practices to recover materials Lack of cohesion and agreement between the actors in forestry Negative image of wood harvesting

Table 4b

**Threats in wood-based side stream utilization and waste management:
Northern Europe and Eastern Europe**

NORTHERN	EASTERN
Slow reactions to changing product and customer markets in company strategies and public policies Slow and costly development of new side stream products Low profitability and investment capacity of wood products and wood-based electricity industries continue Scarce RDI resources and lack of proofs-of-concept continue, especially among SMEs of wood product and biorefining industries Unpredictable regulation and subsidizing policies of bioenergy and waste management (EU and national) Decreasing district heating outside urban districts Large production units and increasing transportations add to the environmental loads Lack of trust and collaboration between companies to build industrial ecosystems Disagreement of different producers and interest groups about the priority uses of side-streams, regulation and subsidizing policies (sawmills – bioenergy – wood panel industries) Neglecting societal requirements, renewable raw material and carbon sink approach in strategies and engagement of different stakeholders and big audience Lack of professional workers and entrepreneurs in the supply and manufacturing stages of the value chains	Lack of data and information Lack of harmonized regulations Regulations are not actually practiced or followed Lack of coordination policies within regional, national and European markets Low perception among consumers about potentiality of recycled products Lack of demand of circular products Overall perception of policies is usually felt complex Lack of awareness on circular economy strategies Lack of awareness on environmental impact and sustainability Lack of transparency of policies, governmental instability

Good practices

The Good Practice Catalogue collected presents regional diversity and performance of the European wood construction value chains regarding side stream utilization and waste management. In total, 25 cases were accepted as good practices to be presented in this catalogue. The examples were realized with a strong engagement of the key stakeholders of the value chain. They give an idea of how widely woodworking industries and wood construction cover the circular economy concept already now. The good practices are listed by thematic category in Table 5, and described in detail in the catalogue.

Table 5

Good practices selected in the collection and evaluation process

Thematic category	Good practice	Origin
Circular operational concepts	National recycling network for wood wastes	Italy
	National recovery system for treated wood	Finland
	Local industrial symbiosis of SME companies covering full wood construction value chain	Finland
	Large scale integrated symbiosis of sawmill, biorefining and by-products utilization	Finland
	Multi-product production by integrating solid wood, wood panels and cascading of by-products on site	Finland
Efficiency and processing	Ash and wood fibers for light-weight concrete	Finland
	Reuse of low-density fiberboards for insulation use	Central E.
	Enhanced circular use of hardboards	Central E.
	Structural engineered wood for construction	All E.
	Carbonizing wood	All E.
	Intelligent sorting system for all wastes, incl. wood	Finland
	Integrating resource efficiency for circular operations	Finland
	Upcycling sawmill residues to valuable fiber products	Central & North E.
	Upcycling and upscaling in furniture value chains micro-ecosystems for cascading use of wood	France
	Particle boards from side and waste streams	South E.
Reuse and recycling (continued)	New life for windows and doors	Slovenia
	Reuse, recycling and refurbishment of furniture	All E.
Side stream valorization	Recycling system for bio-composite decking	All E.
	Circularity in manufacturing of pre-fabricated houses	Central & North E.
	Antibacterial composite materials from wood side streams	Central & North E.
	Pencils made resource efficiently	Germany
	Biogas from fresh wood-based residues at waste management centers	All E.
	Biochar as soil amendment	Finland
	From saw dust to packaging and tissue	Finland
	From saw dust to mycelium for insulation and packaging	All E.

CONCLUSIONS

The European wood sector shows a certain dynamism starting from very good prerequisites in terms of eco-sustainability and circularity, the stakeholders along the wood construction value chain becoming more and more aware about the potential related to the adoption of a circular economy model. The achievement of this ambitious objective is possible thanks to generally efficient and well-functioning value chains of side streams and waste management, as well as a good overall management of raw materials. Moreover, while there are efficient and inclusive collaboration systems among stakeholders of value chains and other actors that provide economic and environmental benefits, the progressive introduction of targeted policies and regulations represents an element of great attention among public institutions. Obviously, it is still necessary to solve many issues: development needs are obvious in several areas such as research, testing, piloting, proofs-of-concept and branding of side streams and their business and market potential, as well as resource efficiency, logistics, regulation, standardization, communication, promotion, education, value chain management and stakeholder collaboration, four-angle sustainability and societal thinking.

European regions and countries have different opportunities and specialities, pros and cons in side stream utilization and waste management, as regards industrial and operational environment, industry structure and history, supply and markets, knowledge and expertise and local conditions, infrastructure and economic opportunities. Different set-ups of side stream products and raw materials lead to different supply and value chains and stakeholder networks in the utilization and material and energy flows as well as the collection and roles of companies, their responsibilities, ownerships, logistics and mill locations varying

largely. The specifics of the regions and countries should be appreciated in public decision-making and legislation when outlining future development steps. Good functioning of the Triple Helix collaboration across the whole Europe is then one of the most relevant challenges for the sector.

The more advanced products are manufactured, the longer the value chains and the more companies or other stakeholders involved, the more important trustful industrial ecosystems, well-functioning collaboration and easy links between the participants and clear ownerships and responsibilities in the network. The degree of integration, concentration and decentralization should vary depending on the scale of production and volume of raw materials, orientation to basic, customized or specialized products, interactions between raw materials and products, logistical issues in transportation and storage, breakdown of value chain operations between the companies and needs of collaboration and responsibilities of the participants.

Scaling of production volume and company size affect essentially the organisation in sourcing raw materials or semi-finished products, manufacturing, deliveries and logistics. Pathway of a new product or service idea to the customer market lasts typically 10-15 years in wood-based industries and partly in wood construction: develop manufacturing technology and knowledge, create product or service standards, verify matching to regulatory requirements, build the value network of actors. Therefore, research, development and innovation policies with a foresight are of utter importance.

Political tools such as regulations, standards and public RTDI and investment support are rated important to attract industries into resource and energy efficient strategies with material circulation of all side-streams, not only commercially viable by-products. Debate on cascading vs. bioenergy continues heavily in Europe, but advanced bioenergy raises interest in all macro-regions.

We observed in this study that effectual reasoning that aims to reflect entrepreneurial thinking is a suitable technique in this kind of RTDI work where several alternatives of product or service pathways are available to utilize existing or prospective resources which are labelled with scarcity. Causal reasoning can then help in selecting the choices. SWOT analysis is a necessary tool to understand the dynamics and impacts of the strategic and operative environment.

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