INTRUST

TRAINING SOLUTIONS FOR WOOD CERTIFICATION

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

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ABOUT INTRUST

Forests are essential for our health and wellbeing, and the health of the planet. They are rich in biodiversity and are hugely important in the fight against climate change.

As the global demand for wood and wood-based materials is projected to increase threefold between 2010 and 2050, using wood more efficiently to meet projected demands for development of value-added wood-based products is a key circular economy principle. The growing environmental concerns and recent legislative regulations, related to promoting the 'cascading use' of wood, i.e., prioritising value-added non-fuel applications of wood resources, have posed new challenges to both industry and academia, related to the optimization of the available wood and lignocellulosic raw materials, recycling and reusing wood and wood-based composites, and search for alternative resources.

INTRuST project targets professionals from the wood value chain (forest operators, managers and employees from wood-based and furniture-related companies) to increase their professional skills and competences in relation to the twin transition of the sector. On one hand, the project aims to support the sector in recognizing, choosing, and implementing the right sustainable certifications. On the other hand, INTRuST aims to support the sector in developing a relevant body of knowledge associated with the digital transition.

For more information go to intrust-project.eu

INTRODUCTION

1.INTRODUCTION

1.1 Context of the report

Over the recent years, public opinion awareness on the issues of sustainable forest management in light of climate change has increased. Forests are indeed an important factor in mitigating climate change. They provide a wide range of ecosystem services, such as carbon sequestration, protection of soil from erosion and, beyond creating economic value, offer opportunities for recreation.

Currently however, 30% of the wood used in the EU comes from countries where illegal logging and partial deforestation is usual. In this context, certified forests, wood and products, combined with eco-design and framed within a circular economy can be considered as the most appropriate approach to deal with this issue.

Moreover, in today's market, environmentally friendly products have a clear competitive advantage due to the rapid increase of consumers concerned about the environmental impact of their activities and goods they purchase. This in turn, results in a market trend to buy certified products instead of non-certified products. For instance, at the end of 2019, approximately 97% of the wood used by IKEA came from sustainable sources.

In this context, different certifications have been created to manage forest-based products, like the Forest Stewardship Council (FSC) and EU Timber Regulation (EUTR). Such schemes are normally integrated into environmental management systems, based on standards like ISO 14001 or EMAS, that, along with other tools and schemes like life cycle assessment and Ecolabels, help companies in the processes and procedures related to the use of certified wood in construction or furniture manufacturing.

Meanwhile, the rise of Industry 4.0 (I4.0) leads to the discussion of how forestry and the wood sector in general can benefit from this development. The economic potential of Industry 4.0 in forestry could lead to an increased 15% value. Smart wood supply chains are slowly reshaping the industry with several new applications in use or in research and development. This revolution can lead to significant changes and new value creation.

The combined **green and digital transition** thus offer a promising avenue for manufacturing enterprises of the sector.

1.2 Objectives and expected results

The following report provides an overview on the **current environmental and digital trends and practices** affecting the wood value chain in its entirety. Taking a value chain perspective, the report outlines regulatory trends, new digital and technological development, as well as emerging practices that are to affect the sector as a whole.

This state of the arts will ultimately be used as a basis to develop a dedicated training curriculum - the key objective of the INTRuST project - that can support stakeholders of the wood value chain in integrating digital and green practices in their operations. More precisely, an overview of **key sustainable certifications** in each step of the value chain, as well as a review of **emerging Industry 4.0** practices relevant to the sector form the body of this report.

The report is organised as follows. In the next chapter, we outline the methodological approach used to review trends and practices emerging from the twin transition in the wood sector. A dedicated twin wood transition framework is introduced and used as the backbone of the report. The following chapter provides an overview of the EU wood-furniture landscape. Next, the following chapter introduces the key learnings in each step of the value chain. Finally, in the conclusion chapter, recommendations are synthesised.

METHODOLOGY

2. METHODOLOGY

To analyse the current development of digitization and sustainable certifications in the forest-wood supply chain, a literature review was conducted identifying relevant literature over the last 10 years (2012–2022).

This review included peer-reviewed academic articles as well as practitioner literature as an information source, since many of the articles on I4.0 in forestry have been written for practitioners.

To cover both, the search databases were chosen accordingly: a systematic search in Science Direct limiting the search to title, abstract and keywords covered mainly academic articles, whereas a standard Google Scholar search covered gray literature of practitioners and business as well. In Google Scholar we restricted the search to a title-search rather than full-text search to focus on the most relevant hits available.

The search strings were used in various combinations applying a Boolean operator (OR). Wild-card characters (*) and automatic stemming were used to cover terms with similar word stems like the terms "forest" and "forestry". The search strings were combined to combine relevant search terms in the context of I4.0, with common search terms to identify forestry related articles using another Boolean operator (AND).

To filter the relevant articles after the search was executed, the articles were screened starting with the titles and scanning their abstracts. After removing duplicates and non-relevant articles, key messages of the identified literature were consolidated. After the data collection was completed, the data was evaluated qualitatively by categorising the set of data and finally thematically analysing the data in depth.

The framework below (Figure 1: Twin wood transition framework) describes how the data was organised, taking a dual approach (digital-green transition) throughout the value chain steps of the forest-wood-furniture.

Figure 1:Twin wood transition framework

In order to clarify how digital and sustainable practices are currently emerging and being implemented in the forest-wood-furniture value chain, a more detailed phasing was proposed (Figure 2: Forest-Wood-Furniture value chain) including as well *Retailing, Consumption and Post-use* phases. This phasing will be followed out in the next chapter.

Figure 2: Forest-Wood-Furniture value chain

THE WOOD-FURNITURE EU LANDSCAPE

3. THE WOOD-FURNITURE EU LANDSCAPE

3.1 Forest industry at a glance

Forest industry plays an important role worldwide. It is one of the major industries in many countries, such as Canada, Russia, Brazil, the US, Sweden, Norway, Finland, and New Zealand. Business related activities employ more than 50 million people and generate over US$ 600 billion dollars per year (based on 2011 prices) (Food and Agriculture Organization of the United Nations, 2014). In addition to the economic contributions, the forest industry also contributes significantly to environmental, social, and ecological wellbeing that are essential to regional sustainable development.

There are an estimated 16 million private forest owners in the EU, and 40% of forests are under different public ownership schemes. In 2018, in the EU, 2,1 million people were working in the traditional forest-based sector (forest management, logging, sawmilling, wood-based products, cork, pulp and paper), generating a gross value added of EUR 109 855 million.

In 2018, 397 000 enterprises were active in wood-based industries, representing 20% of manufacturing enterprises across the EU. Adding to these activities the sectors of edition for printed documents, wood-based heat and power as well as wood-based construction, the extended forest-based value chains supported 4 million jobs in the green economy. This number decreased by about 20% from 2008 to 2013 and remained quite stable since then.

3.1.1 Forest Industry Challenges

Forest industry has been traditionally regarded as a low technology and low value industry. It relies heavily on labour operations using chainsaws and conventional machinery for harvesting, processing, and transportation to move timber from forest sites to processing mills, and domestic and international markets (D'Amours et al., 2016; Choudhry & O'Kelly, 2018). Although this traditional forest operational approach is transforming over the years with new technologies, new management approaches, new business models, and advanced decision support systems, in general the transformations have been slow.

The use of information and communication technologies by forest operators are limited. The applications of automation, digitization, and remote control of machinery is scarce. This slow advancement can likely be due to several reasons. Firstly, most forest resources are publicly owned in many countries. Public forest owners tend to be relatively more conservative in their management styles. They particularly need to balance commercial benefits with social and environmental considerations. Secondly, most commercial forests are located in remote areas which typically lack technological expertise and qualified personnel. Thirdly, forest operations are typically contracted to small contractors who have limited resources for major change. Fourthly, although many digital technologies are available on the market, relatively few people are dedicated to applying these technologies in the forest domain (Choudhry & O'Kelly, 2018). As global industries are advancing towards the adoption of the Industry 4.0 concept and are gaining benefits from its implementation at different paces, the forest industry as part of the global supply chain is following its trends.

3.1.2 Forest industry Opportunities

In 2021, The European Commission has adopted the New EU Forest Strategy for 2030 as a flagship initiative of the European Green Deal. The strategy sets a vision and concrete actions to improve the quantity and quality of EU forests and strengthen their protection, restoration and resilience. It aims to adapt Europe's forests to the new conditions, weather extremes and high uncertainty brought about by climate change. This is a precondition for forests to continue delivering their socio-economic functions, and to ensure vibrant rural areas with thriving populations.

The new EU forest strategy will support the socio-economic functions of forests for thriving rural areas and boosting forest-based bioeconomy within sustainability boundaries. It will also protect, restore and enlarge the EU's forests to combat climate change, reverse biodiversity loss and ensure resilient and multifunctional forest ecosystems by:

- promoting the sustainable forest bioeconomy for long-lived wood products
- ensuring sustainable use of wood-based resources for bioenergy
- promoting non-wood forest-based bioeconomy, including ecotourism
- developing skills and empowering people for sustainable forest-based bioeconomy
- protecting EU's last remaining primary and old-growth forests
- ensuring forest restoration and reinforced sustainable forest management for climate adaptation and forest resilience
- re- and afforestation of biodiverse forests, including by planting 3 billion additional trees by 2030
- providing financial incentives for forest owners and managers for improving the quantity and quality of EU forests

The strategy also focuses on:

- strategic forest monitoring, reporting and data collection
- developing a strong research and innovation agenda to improve our knowledge on forests
- implementing an inclusive and coherent EU forest governance framework
- stepping up implementation and enforcement of existing EU acquis

In the sections below we focus on the woodworking and furniture industries.

3.2 Woodworking industries at glance

Woodworking industry is an important economic sector in the European Union countries, including about 184 000 companies, generating an annual turnover of around 122 billion Euro and an added value of over 31 billion Euro. The woodworking sector consists of sawmilling (15%), wood construction products (37%) and furniture manufacture (48%). Some 102,9 million m^3 of sawn wood were produced in the EU in 2015, close to two thirds of which came from the five largest-producing EU Member States: Germany (20,9%), Sweden (17,7%), Finland (10,3%), Austria (8,6%) and France (7,3%). About 70% of the wood in the EU is used in construction and furnishings. The vast majority of these companies, providing employment to more than 1 million workers in the EU, are small and medium-sized enterprises, with the exception of the wood-based composite sector and a number of large sawmills (SWD/2013/0343, 2013). The main subsectors include manufacturing of sawn wood; wood-based panels, i.e. composites like plywood, particleboard, fiberboard, including medium-density fiberboard (MDF), oriented strand board (OSB), and other engineered wood products, widely used in the construction sector, such as glue-laminated timber (glulam), laminated veneer lumber (LVL), laminated strand lumber (LSL), cross-laminated timber (CLT), etc.; floorings and other wooden products.

3.2.1 Woodworking challenges and opportunities

The main challenges encountered by the woodworking industry with regards to the supplies are:

- the legal and/or sustainable availability of wood raw material
- round wood and other material costs, whether from EU or imported sources
- the lack of optimised wood mobilisation strategies
- relatively high energy and labour costs
- the ageing workforce.

These problems can be overcome by increased productivity through constant technological development. Some of the most important challenges on the demand side are:

- competition from low-cost imports
- increasing scrutiny of wood sources, especially for public procurement
- an increasing need for product and process innovation in the face of costly finance
- low profitability and hence low investment in plant and skills.

In addition, using wood more efficiently to meet projected demands for development of wooden products and wood-based composites is a key circular economy principle (Janiszewska et al. 2016; Antov et al. 2021). The growing environmental concerns and recent legislative regulations, related to promoting the 'cascading use' of wood, i.e., prioritising value-added non-fuel applications of wood resources, have posed new challenges to both industry and academia, related to the optimization of the available wood and lignocellulosic raw materials, recycling and reusing wood and wood-based composites, and search for alternative resources (Vis et al. 2016; Campbell-Johnston et al. 2020; Pedzik et al. 2021).

Voluntary chain-of-custody certification, indicating the origin of wood from sustainably managed forests via an identified supply chain, has been an increasing feature of EU wood supply over the last 20 years. Since March 2013, the EU "Timber Regulation" (Regulation (EU) 995, 2010) has banned illegally harvested wood from the EU market and required legal wood which is placed on the market to undergo a due diligence process, with traceability upstream to its source and downstream to traders. A small but significant number of other developed markets make comparable legality requirements (USA, Australia, Japan, Switzerland). However, such measures should not lead to unintended and unforeseen implications for timber trade flows. All wood and wood-based products placed on the EU market are subject to the EU "Timber Regulation", but low-cost imports often have an added market advantage over their EU counterparts if their production is subsidised and/or they do not have to meet the stringent EU environmental and social standards. In some cases, even mandatory EU technical standards are not observed, e.g. in the case of building materials, such as imported plywood.

3.3 Furniture industry at glance

The furniture industry is a labour-intensive and dynamic sector dominated by small and medium-sized enterprises (SMEs) and micro firms. EU furniture manufacturers have a good reputation worldwide thanks to their creative capacity for new designs and responsiveness to new demands. The industry is able to combine new technologies and innovation with cultural heritage and style and provides jobs for highly skilled workers.

The sector employs around 1 million workers in 130 thousand companies with an annual turnover of around €96 billion. About 12% of designs registered in the European Union Intellectual Property relate to this sector. Nearly two out of every three high-end furniture products sold in the world are produced in the EU.

3.3.1 Challenges of the sector

The furniture sector has been severely hit by the recent crises and has faced a significant drop in the number of companies, jobs, and turnover. The main challenges are:

- **Competition** – the EU furniture sector faces enormous competition from countries having low production costs. China's penetration into the EU market is growing rapidly and it is now the largest furniture exporter to the EU, accounting for over half of total furniture imports to the EU.
- **Innovation** - the reliance on innovation and design combined with an increase in global trade and digitalisation, makes the sector more vulnerable to weak protection of intellectual property rights. Boosting research and innovation also requires finances that are often inaccessible to SMEs.

- **Structural problems** - the ageing workforce combined with difficulties in attracting young workers may lead to disruptions in maintaining skilled workers and craftsmanship.
- **Trade - protectionist** measures on international markets create market distortions and decrease the sector's competitiveness. EU furniture producers face both duties on imports of raw materials and tariffs on exports of finished products. Moreover, operational costs in the EU are higher due to high environmental, sustainability, and technical standards.

3.3.2 Opportunities in the sector

The EU furniture sector has undergone significant changes to make it more export-oriented and to focus on upgrading quality, design, and innovation. These changes include restructuring, technological advances, and business model innovations. The main opportunities ahead lie in:

- **Investment** - continuing investment in skills, design, creativity, research, innovation, and new technologies can result in new products which are in line with the changing population structure, lifestyles and trends, as well as with new business models and supplier-consumer relationships.
- **Research** - research in advanced manufacturing technologies can result in the creation of high technology and knowledge intensive jobs, which would give the sector the attractiveness it needs to attract employees from younger generations. This could help rejuvenate the sector while keeping it highly competitive on the world stage.
- **Access to new markets** – EU furniture manufacturers are recognised worldwide for their quality and design. This creates opportunities for the sector to further seize other markets, in particular in high-end segments and emerging economies.

RESULTS

4. RESULTS

This chapter offers an overview of the main concepts, challenges and practices along the Wood-Furniture Value Chain in relation to Industry 4.0 and Sustainable Management.

4.1 Forestry and twin transition

In this section we introduce forestry activities and the recent applications of industry 4.0 technologies and sustainable management practices in the sector.

4.1.1 Forestry activities

Forest industry can be broadly regarded as a series of business activities from forest management up to forest-based products distribution to markets and, for some products, a return for valorisation at the end of its useful life. These activities form the forest industry supply chain that supply timber and biomass to different forest product manufacturing sectors such as lumber, pulp and paper, wood products, and bioenergy to satisfy a wide range of market needs. Figure 3 below illustrates the main business activities associated with forestry.

Figure 3: Main business activities in forestry (Source: Feng & Audy, 2020)

Forest resources are mostly managed by provincial/territorial governments who are responsible for developing strategies and making policies to ensure a sustainable forest management. Forest inventory management of tree stands, silviculture, plantation, pest and disease control, fire monitoring, and strategic, tactical and operational planning of forest resource usage for industrial harvesting allocations are also part of the forest management responsibilities. Forest resource planning determines when and which parts of the forest will be harvested and how this will happen according to the sustainable forest management policies. Forest management units and forest zones are divided for effective forest management and industrial allocations. Timber supply and forest management agreement (TSFMA) is typically issued to local forest product companies, such as sawmills, pulp and paper mills, and wood product companies. This agreement provides the TSFMA holders the harvesting right to cut the designated volumes and tree species at the designated forest areas. It also enforces the TSFMA holders to reforest after their cut. Forest harvesting is typically carried out by logging contractors based on harvesting plans (Feng & Audy, 2020).

4.1.2 Industry 4.0 and Forestry

Since the first Industrial Revolution, following revolutions have resulted in manufacturing, from water and steam-powered machines to electrical and digital automated production which makes the manufacturing process more complicated, automatic and sustainable so that people can operate machines simply, efficiently and persistently (Qin et al., 2016). The term Industry 4.0 stands for the fourth industrial revolution. Industry 4.0 was initially introduced during the Hannover Fair in 2011; afterwards, it was officially announced in 2013 as a German strategic initiative to take a pioneering role in industries which are currently revolutionising the manufacturing sector (Xu et al., 2018).

Industry 4.0 is an approach based on the integration of the business and manufacturing processes, as well as the integration of all actors in the company's value chain such as suppliers and customers. The technical aspect of this approach is the application of the generic concepts of Cyber-Physical Systems (CPS) and industrial Internet of Things (IoT) to the industrial production systems. The execution system of Industry 4.0 is therefore based on the connections of CPS building blocks. These blocks are embedded systems with decentralised control and advanced connectivity that are collecting and exchanging real-time information with the goal of identifying, locating, tracking, monitoring and optimising the production processes (Rojko, 2017); for details about the utilisation of system see therein.

Over the last few years, Industry 4.0 has emerged as an up-and-coming technology framework used for integrating and extending manufacturing processes (Xu et al., 2018). A growing number of enterprises worldwide have explored the benefits of digitising and adopted industry 4.0 to be able to be one of the leading digital enterprises in tomorrow's complex industrial ecosystems (URL-2, 2016).

The forestry sector, characterised by long- term capital commitments, might be more hesitant than others at this point. To cope with this hesitation, it is an important task of applied research to demonstrate, e.g., in the form of case studies, how high the added value of Industry 4.0 applications can be (Müller, 2019). Another forestry specific challenge is the complexity of the forest stand itself. A major challenge of the forestry sector is its high stakeholder fragmentation. Forest owners, forest enterprises, harvesting contractors, timber transport contractors and customers must increase their collaboration not only with each other but also with players from other industry sectors and support early stages of innovation processes (Kubeczko et al., 2006).

In transition to Industry 4.0 due to changing work environments and work organisation losses of jobs are feared on the labour side. Labour qualification is another labour specific challenge. Forest enterprises mostly have not yet sufficiently qualified their workforce for new digital applications (Ittermann et al., 2015; Kagermann et al., 2013; White et al., 2016). Qualifying labour is important in all sectors, however in forestry which is one of the traditional sectors, qualification needs to be higher than in advanced industries e.g., in the automotive sector (Kagermann et al., 2013; Müller et al., 2019).

Forestry 4.0 framework

Forest industry plays an important role in the global economy and has significant influences in our lives and the environment that we live in. With the rapid advancement of digital technologies and industrial transformations towards Industry 4.0, a similar trend has been found in the forest industry and especially on its forest procurement side. Forestry 4.0 has been proposed within several research initiatives in recent years. However, publications have largely focused on digital technologies. This section is aimed at presenting a framework to provide a holistic view of Forestry 4.0 from a forest supply chain perspective. The framework consists of four major components including the digital technologies pertinent to each of the supply chain business activities; the network infrastructure; the next generation system intelligence; and the collaborative forest supply chain digital ecosystem (Feng & Audy,2020).

Figure 4: Forestry 4.0 conceptual framework (Source: Feng & Audy, 2020)

The transition toward Forestry 4.0 is not merely a matter of digitization and automation and it cannot be achieved by a single company or a single supply chain player. **For the forest industry to become fully connected and integrated moving forward towards Industry 4.0, a supply chain view of Forestry 4.0 is needed**. Thus, we extend the definition of Forestry 4.0 as a new paradigm of the forest industry towards total digitization, automation, and precision with connected smart forest management, harvesting, and transportation logistics with downstream activities in the forest industry such as manufacturing and distribution to markets. In other words, it is the emphasis of an end-to-end digitization of all physical assets of the forest supply chain to become digitally connected and operationally integrated with suppliers, customers, and partners into a digital ecosystem. The ultimate goal to modernise the forest supply chain is to increase the forest industry competitiveness through higher efficiencies and reduced operating costs in the forest procurement side (Scholz et al., 2018).

Industry 4.0 technologies applied to forestry

The concept of Industry 4.0 can use various technologies or techniques in its implementation (Xu et al., 2018). Importantly, the new technologies included in Industry 4.0 stimulate changes in a wide range of business activities, leading to changes in supply chains (Frederico et al., 2020). They include Big Data, analytics, mobile technology, additive manufacturing, artificial intelligence, Cloud technology, IoT, radio-frequency identification (RFID), simulation, sensors, Global Positioning System (GPS), unmanned aerial vehicle (UAV) and blockchain (Dalenogare et al., 2018, Bai et al., 2020, Lu, 2017). In addition to these technologies, in some research papers the disruptive technologies related to Industry 4.0 have also been listed, which can be summarised as follows: virtual reality, 3D printing, cyber security, machine-to-machine communication, automatic identification, business intelligence and nanotechnology (Oztemel, 2020 , Tjahjono et al., 2017). The concept of the IoT was created based on RFID-enabled identification and tracking technologies (Xu et al., 2018). In this systematic review paper, a broad and inclusive definitional approach to this range of technologies was adopted to ensure relevant research could be identified and included. As a result, technologies related to Industry 4.0 were deemed to be those that supported collecting, storing, processing, analysing and sharing data.

In examining the forest industry, it is evident that the demand for forest products is increasing around the world (Baghizadeh et al., 2021). The forest supply chain refers to a temporal sequence of activities and processes from standing trees to the end-users that transform the woody raw material to final forest-based products (D'Amours et al., 2008, Scholz et al., 2018). The chain starts with raw material as the standing tree in the forest. In the forest supply chain, the woody material can be turned into logs, roundwood, lumber, panel and engineered wood, pulp and paper, biomass, bioenergy (for electricity and heat) and other forest products (Liu et al., 2017). The production processes transfer the woody raw materials through a biorefinery, pulp mill, sawmill, panel mill and pellet mill (D'Amours et al., 2008, Scholz et al., 2018). Based on the forest supply chain in the literature, as shown in Figure 4.3, the processes include procurement, production, distribution and sales/market (D'Amours et al., 2008, Scholz et al., 2018, Ouhimmou et al., 2021). The activities include forest management, harvesting and transportation (Scholz et al., 2018, Feng & Audy, 2020 , Muller et al., 2019). The independent entities involved in the forest supply chain are forest owners, harvesting enterprises, haulage companies, logistic (transportation) companies, storage sheds, terminals, power plants and bioethanol facilities (Scholz et al., 2018, Ouhimmou et al., 2021).

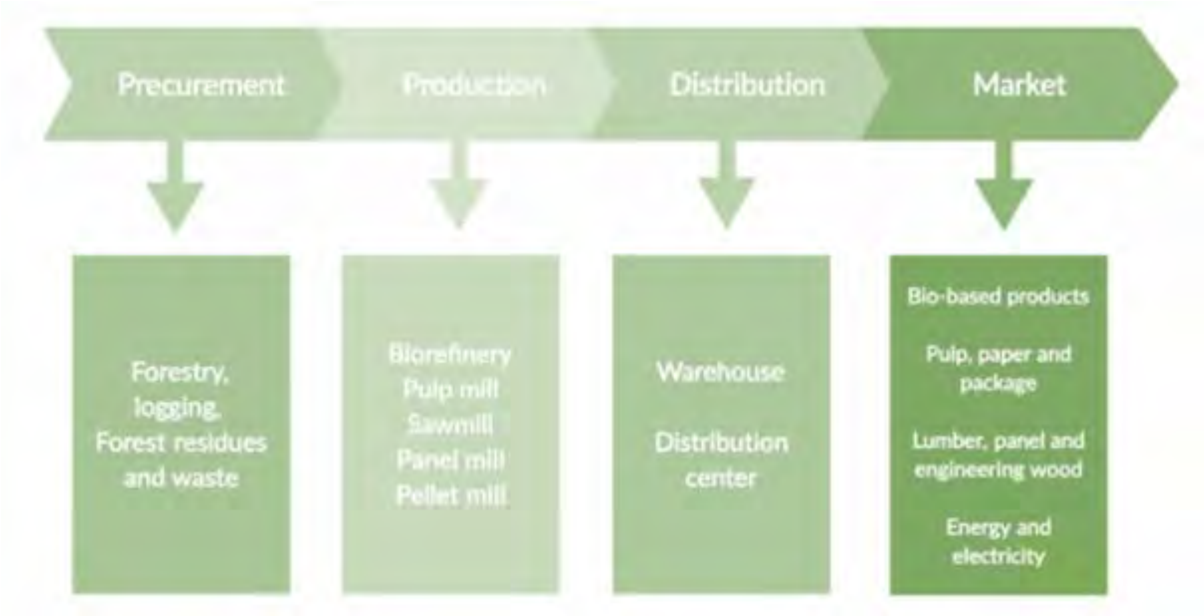

Figure 5: The processes of the forest supply chain (Source: D'Amours, 2008, Ouhimmou et al., 2021)

It is also evident that globally most forestry supply chains are not sophisticated using new technologies and the data that they produce. With the growth of the forestry industry around the world, there are some issues and challenges reported that are impacting the forest supply chain. For instance, there are some illegal activities in the forest supply chain. The Food and Agriculture Organization of the United Nations (FAO) reported illegal logging and timber trade, especially from Russia and China, for the processing and manufacture of final products (FAO, 2012). Illegal logging and wood laundering have also been reported in Mexico and the forest supply chain has inefficient low-tech practices (Torres-Rojo, 2021). Moreover, the non-optimal use of resources is also an issue in the forest supply chain (Pizzi et al., 2006). In this untrustworthy environment, parties in supply chains would like to perform transactions in a transparent environment. Customers would like to obtain information about the raw materials of forest-based products to know whether the products are eco-friendly (Appelhanz et al., 2016).

Recently, Industry 4.0 and technologies have been identified by some research as offering potential solutions to these types of issues and inefficiencies. Several studies have indicated that the implementation of new technologies could optimise the forest supply chain. For instance, the automated real-time tracking system could be the solution for the non-optimal use of resources in wood processing (Pizzi et al., 2006). Several technologies associated with Industry 4.0 have been used or studied to optimise the forest-based supply chain, including blockchain, IoT, RFID, and smartphone applications. However, to the best of our knowledge, there is limited research that has systematically investigated the benefits of Industry 4.0 and its technologies in supporting the forest supply chain.

4.1.3 Sustainable management in Forestry

Today, global deforestation rates are alarming, especially in the tropical latitudes, and the biggest threat to forestlands is agriculture. Around 80% of deforestation in the world occurs for the sake of farming. The impact is the most severe in Latin America, Africa, and Asia due to palm oil, soybean, or beef production. It is why sustainable forest management in developing countries summons particular attention.

Sustainably managed forests play an important role in mitigating climate change. They absorb CO_2 through photosynthesis and wood growth and store carbon in the long term (forest carbon stock). When wood is used, e.g. in furniture or buildings, the carbon remains stored in the resulting products (carbon stock in harvested products). In addition to these storage effects, using wood replaces finite fossil energy sources such as oil, gas and coal – through the burning of wood (energy substitution) and because wood products usually require less energy to manufacture and dispose of than products made from other materials (material substitution).

The substitution effects of using wood illustrate why it makes sense to manage forests sustainably and use the renewable resource wood to mitigate climate change. The positive climate effects of a well-managed forest – forest carbon stock and carbon stock in wood products, as well as material and energy substitution – outweigh the effect that would be achieved in the long term solely by increasing the forest carbon stock in an unutilised forest. In unused forests gases emitted during rotting offset the CO_2 stored in wood in the long term. The only way to tap the climate change mitigation potential of the forestry and wood sector on a lasting basis is to use forests sustainably (Federal minister of food and agriculture, 2016).

Principles Of Sustainable Forest Management

Sustainability in forestry is achieved through weighted decision-making that considers economic, social, and ecological aspects of development. The three aspects work best in combination. If at least one of them is underestimated or overlooked, sustainable forestry implementation won't be complete.

Nature Protection Principle

Ecologically sustainable forestry responds to environmental concerns caused by deforestation. In particular, environmentally sustainable forest management ensures the following:

- improves air quality thanks to oxygen production and capturing air pollutants by trees;
- decreases biodiversity loss by supporting abundant flora and fauna of forests;
- mitigates climate changes thanks to the accumulation of carbon in the forest soil and trees (dry tree mass is 50% carbon);
- prevents soil erosion by fixing the soil with forest floor and vigorous tree root systems;
- reduces flooding as trees make a natural barrier to water streams and slow them down.

Principle Of Economic Development

Economically sustainable forestry standards correlate tree harvesting with forest preservation and consider the commercial interests of all involved parties. The economic aspect of sustainable forestry improves:

- possibilities of employment;
- rise of the population's income;
- trade relationships between countries;
- attraction of investments, and more.

Social Development Principle

Socially sustainable forestry methods aim to perform the following tasks:

- improve living standards of local communities that rely on forests for a living;
- offer forestry-related jobs addressing unemployment;
- meet work safety requirements in forests;
- ensure gender and race equity, labour rights, and other social securities.

Examples of Sustainable Forest Management Practices

In Europe, the corresponding regional forest policy process for the sustainable management of the European forests is Forest Europe, formerly named the Ministerial Conference on the Protection of Forests in Europe (MCPFE). It was initiated in 1990 as a regional political initiative and has evolved into a high-level political forum for European inter-national forest policy (Linser & all, 2015). Forest Europe develops common strategies for its 46 signatory countries and the European Union on the sustainable management of their forests. Since 1990, eight high-level Ministerial Conferences on the Protection of Forests in Europe have taken place (Forest Europe, 2021). At the Second Ministerial Conference, held in Helsinki in 1993, SFM was defined in Resolution H1: "Sustainable management means the stewardship and use of forests and forest lands in such a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (MCPFE,1993).

Forest conservation in modern forestry utilises multiple techniques:

- Afforestation and reforestation enlarge forest areas on our planet.
- The ability to distinguish and treat tree diseases or pest infestations empowers forestry managers to save their farms and mitigate losses.
- Replanting forests after harvesting contributes to ecologically sustainable forestry.
- Selective logging and thinning prevent from felling the entire stand.
- Pruning saves from logging the whole trees for wood and stops pathogens' spreading.
- Clear-cutting or removal of mature trees contributes to forest health and stimulates offspring growth.

- Prescribed burning naturally revives forests – on condition the process does not go beyond control.
- Specific training boosts foresters' proficiency in sustainable forestry techniques.
- Weighted planning facilitates the solutions for more sustainable forestry.
- Satellite monitoring enables remote control of the forest state and timely response to deviations.

There is no universal recipe for every forest, and the list goes far beyond the above-mentioned practices. Each forestry management technique should consider commercial value, forest specifics, environmental aspects, communities' needs, and stakeholders' interests. Besides, the collaboration of forestry managers with local businesses, authorities, NGOs promotes more effective decision-making.

Continuous Monitoring of Forest Stands As A Sustainable Forestry Practice

Regular inspection determines an effective forest farm run. Yet, this is not always feasible, especially when it comes to vast, distant, or hard-to-reach locations. It is where remote sensing is particularly handy. Satellite monitoring is among the most effective forest management practices allowing foresters to greatly improve their businesses.

EOSDA (Earth Observing System Data Analytics) has developed the EOS (Earth Observing System) Forest Monitoring software to facilitate foresters' efforts – a smart tool for remote forest control and forestry management. In particular, EOSDA EOS Forest Monitoring users can enjoy the following:

- monitor forest stands remotely;
- assess overall forest health;
- track changes and receive regular problem area alerts;
- detect and report illegal logging with satellite-based deforestation maps;
- compare planned and actual tree felling scope;
- control forest regrowth;
- analyse AOIs (areas of interest) before and after deforestation, and more – all in one place.

Figure 6: Ensuring health of stands with EOS Forest Monitoring productivity map

EOS Forest Monitoring eases foresters' efforts to upkeep and regenerate forests, thus improving sustainable forest management practices. The EOS Forest Monitoring tool is helpful not only in forestry. For example, tracking palm oil supply chains enables manufacturers to meet their RSPO (Roundtable on Sustainable Palm Oil) commitments to stop palm oil deforestation. Insurance companies can assess the damage from forest fires with reliable satellite-based analytics. Joint efforts of forestry managers, governments, ecologists, and communities can remarkably improve forest conservation. Satellite monitoring is capable of promoting this noble mission by guarding the forest heritage and tracking tree growth.

Modern Sustainable Forestry Implementation

For decades, the state and future of the world's forests, including Europe's forests, have been a concern among scientists and forest experts but have also become an increasing matter of public concern. The efforts toward harmonised definitions and comparable national data on forests and their management-related issues having an impact on sustainability resulted in the development of a set of criteria and indicators (C&I) for sustainable forest management (SFM). This has contributed to the development of a joint vision of what constitutes SFM and has evolved as a powerful tool to promote and implement SFM (Linser & Wolfslehner, 2022).

In the Helsinki follow-up process (1993–1998), a first pan-European C&I for SFM set was developed and adopted based on the following definitions which are valid until today: "A criterion describes the different sides of sustainability on a conceptual level. It is a set of conditions or processes by which a forest characteristic or management is judged."

"The indicators show changes over time for each criterion and demonstrate how well each criterion reaches the objective set for it" (MCPFE, 1994).

Based on the Ministerial Declarations, Resolutions, and Decisions of the various MCPFEs, which can be seen as a common policy framework, all European countries had started initiatives to guarantee, monitor, assess and report on SFM (MCPFE,2003). The six criteria for SFM have remained the same since its adoption in 1994 (cf. Table 1). The set of indicators was improved several times in the meanwhile.

Table 1:Pan-European Criteria for SFM, source: MCPFE,1994

Pan-European Criteria for SFM	
Criterion 1	Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles
Criterion 2	Maintenance of forest ecosystem health and vitality
Criterion 3	Maintenance and encouragement of productive functions of forests (wood and non-wood)
Criterion 4	Maintenance, conservation, and appropriate enhancement of biological diversity in forest ecosystems
Criterion 5	Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water)
Criterion 6	Maintenance of other socioeconomic functions and conditions

In the course of emerging challenges for the sustainable management of forests, C&I for SFM gained increasing attention at the beginning of this century (Linser et al., 2018). Several countries, international organisations, and forest-related processes were initiated to develop indicator sets. For instance, the European Commission Standing Forestry Committee started an Ad Hoc Working Group on Sustainable Forest Management Criteria and Indicators (Standing Forestry Committee, 2015), the FAO led a global project on SFM indicators (FAO, 2015), and forest-related indicators for the United Nations Sustainable Development Goals were developed (FAO, 2013, United Nations, 2018) next to various national implementation activities. Thus, further work on the pan-European indicators for SFM was initiated in 2002 and in 2014 (Forest Europe, 2014&2015). There was a common appreciation of the necessity for Forest Europe to respond to the demands coming not only from the forest sector itself but also from other sectors such as energy, biodiversity, or bioeconomy.

For the assessment of the implementation of specific international commitments such as the European Goals for Forests and the European 2020 Targets for Forests (Linser, 2015), it was also seen as a need to complement the set of indicators with related issues so far not covered by the set, such as degradation. In the revision processes, Forest Europe consulted with a wide range of experts and stakeholders to ensure the adequate reflection of the diversity of national situations and experiences as well as the work undertaken by various bodies in Europe.

The following evaluation criteria were applied for the elaboration of adequate indicators based on Linzer (Linzer, 2002): Political relevance for MCPFE and other initiatives, visible significance, data availability, cost-effectiveness, technical feasibility, validity, and reliability. An improved set of 34 quantitative and 11 qualitative indicators was the result of the latest revision (Forest Europe: Madrid Ministerial Declaration, 2015).

In the Vienna Living Forest Summit Declaration and the Madrid Ministerial Declaration, the forest ministers endorsed the use of the improved and updated Pan-European Indicators for SFM (MCPFE,2003). In the Bratislava Ministerial Declaration, the forest ministers committed "to continue to work on the C&I for SFM, in cooperation with all relevant partners, with a view to further implement and strengthen monitoring, reporting, and assessment of forest resources and sustainable forest management in Europe and to continue to regularly report on the state of Europe's forests" (Forest Europe, 2021). The contemporaneously published five State of Europe's Forests reports are structured according to the pan-European C&I for SFM and are comprehensive descriptions of the situation and the management of European forests (Forest Europe, 2020).

The Forest Europe Expert Group on Implementation of the Updated pan-European Indicators for SFM initiated discussions in 2017 on the use of a selection of key indicators (Forest Europe, 2017), which were so far not realised. For the new Forest Europe period 2021–2024, it is planned to work toward a set of key indicators to improve the narrative capacity of the indicators, also in relation to the next State of Europe's Forests report (Forest Europe, 2021).

4.2 Woodworking and twin transition

In this section we introduce woodworking industries activities and the recent applications of industry 4.0 technologies and sustainable management practices in the woodworking sector.

4.2.1 Woodworking industries activities

The high levels of employment and income generated by the wood sector can be associated not only to the different finished products that can be obtained from forests, i.e. lumber, wood products, paper and pulp products, biofuels, etc.), but also to the various and diverse activities and processes that are carried out in this industry. An overview of these activities, from forest to finished wood-based products, is provided in Figure 7.

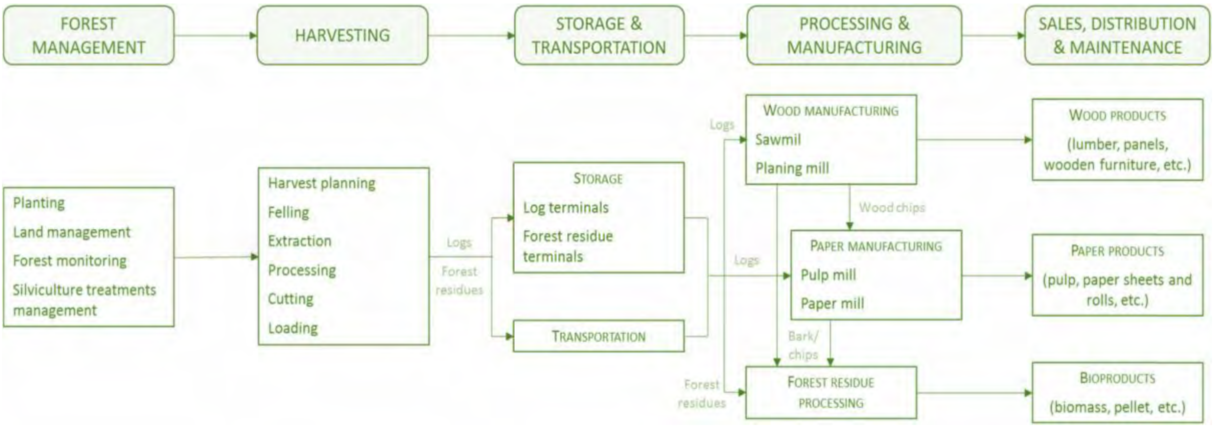

Figure 7: Wood supply chain (adapted from Zhang et al., 2020)

Three types of processing and manufacturing follow the transportation activity, depending on the desired final product (D'amours et al., 2008). Logs can be processed in sawmills and planning mills for the production of wood components (e.g., lumber, boards, panels, etc.) and finished wood products, e.g. wooden furniture, flooring, roofing systems, etc.). Alternatively, they can be used for the production of paper and packaging through pulp and paper mills. The last option is the creation of bioproducts through the processing of forest residues, as well as bark and chips discarded by wood and paper manufacturing (Molinaro and Orzes, 2022).

The huge amount of data generated along the wood supply chain process can be used to extract relevant information and improve the management of the entire supply chain, from forests to wood-based industries like woodworking, furniture, and pulp and paper industry (Zhang et al., 2020). Similarly, the new technologies can also create a cyber-physical environment for the design and manufacturing of wood products, thus optimising the relative processes (Chang and Chen, 2017).

4.2.2 Industry 4.0 emerging practices in the woodworking sector

In recent years, the woodworking industry, as a part of the manufacturing industry, has gone through rapid changes and passed from the traditional mechanisation and automation of technological processes to the fourth industrial revolution, i.e. Industry 4.0 (I4.0). Recent technological advances and increased digitization of the woodworking sector, as well as the opportunities, provided by the concept I4.0, have significantly increased its overall performance in terms of data retention, processing and transmission, which has resulted in improved productivity, flexibility, and customer orientation (Roth, 2016; Hermann et al. 2016; Bartodziej, 2017). The concept I4.0 in the woodworking industry is based on several key components, i.e. digital components, intelligent machines, horizontal and vertical networking, and smart workpiece (Ratnasingam et al. 2019).

Cyber-physical systems (CPS) are used to describe the merging of the physical with the virtual world (Kagermann, 2014; Xu et al., 2018), i.e. the creation of a digital image of reality that resembles it as much as possible. The main idea of this aim is that machines, objects and people are integrated into the virtual world with the help of sensors which "collect physical data and by means of actuators influence physical procedures" (Kagermann et al., 2013). These storage systems, production facilities, and smart machines are connected to each other, thus creating an embedded system (Zuehlke, 2010), in which autonomous machines are capable of interacting with other machines and humans (Mihuri et al., 2019).

Industrial Internet, i.e. **Internet of Things (IoT)** is the network in which cyber-physical systems interact (Hermann et al., 2016). In this context, objects are not only machines and equipment, but all devices and humans, equipped with sensing, identification, processing, communication and network capabilities (Lu, 2017). On the other hand, the **Internet of Services (IoS)** is regarded as the opportunity of offering services as well as production technologies via the Internet (Hermann et al., 2016).

The final aim and core concept of I4.0 is the so-called **Smart Factory**. It can be defined as a factory in which CPS serve as a basis for real-time communication and self-controlling production processes (Kagermann et al., 2013; Yildiz et al., 2020). Machines and equipment have the ability to improve technological processes through self-optimization and autonomous decision making (Bauernhansl et al., 2014; Roblek et al., 2016). The ongoing communication between machines in the CPS is an inseparable part of the Smart Woodworking Factory. Various sensors for generic physical variables of woodworking processes, e.g. pressure, speed, or temperature have been developed and widely adopted in industrial practice. Specific sensors capable of measuring and characterising wood, including destructive and non-destructive test methods, have been developed (Niemz and Mannes, 2012; Ross, 2015). For industrial use in manufacturing process control, non-destructive characterization is the most important. It allows monitoring and control of technological processes in real time. Smart sensors are used not only to collect signals but also to transform them into digital data and process them further. They process signals about the current state of the physical world into useful information. The interaction between machines, other machines or humans throughout the production process leads to a massive amount of continuously generated data and transported information which must be stored.

Big data technologies are linked to the availability of large volumes of data of different types and sources; these data can be analysed through appropriate analytic tools to extract relevant information and support the decision-making process (Ghobakhloo, 2020).

An important set of advanced computer-based techniques to analyse and process big data is offered by **artificial intelligence (AI)**, which includes a wide variety of machine learning algorithms that are able to automatically learn through experience (Moktadir et al., 2018).

Cloud technology, also called cloud computing is the basis for digital integration platforms where data is stored, analysed and made available for (collaborative) usage within and across organisation borders (Aldeen et al., 2015; Bartodziej, 2017).

In process-related technologies, an innovative contribution to the production can be provided by the **additive manufacturing (AM)**, such as 3D printing, that allows the production of small quantities of highly customised products (Ghobakhloo, 2018; Moktadir et al., 2018). Production efficiency and flexibility can be enhanced through the use of autonomous robots, which can either substitute or support the workers in the implementation of production processes (Rüßmann et al., 2015; Frank et al., 2019).

Examples of I4.0 in the woodworking sector

According to the published research works on I 4.0 technologies in the woodworking sector, they are mainly implemented to collect, manage and analyse the huge amount of data that are available in the different wood supply chain processes in order to support decision-making processes.

Artificial intelligence algorithms have been used to estimate and predict wood properties, such as fire resistance, moisture content, mechanical properties, and wood quality, which are important not only for the selection of raw materials (Iglesias et al., 2017), but also for pricing decisions (Daassi-Gnaba et al., 2017). Production process and sawing optimization is another relevant need of the woodworking sector. Nasir et al. (2019) proposed the use of artificial intelligence to correlate acoustic emissions data in the sawing process with the cutting power and waviness; an appropriate sensor was used to collect data on blade vibration. Jocelyn et al. (2016) combined artificial intelligence and machine safety techniques to develop a dynamic tool for risk identification and accidents prevention. Other researchers studied the efficiency improvement through fault diagnosis in industrial chemical processes (Ragab et al., 2018) and automated feeding (Cunha et al., 2015). There are also examples of AM application in the woodworking sector for cost and quality improvement (Chang and Chen, 2017; Murmura and Bravi, 2018). The positive effects of the introduction of IoT and cloud computing, used for developing a material management system, on production planning for panelized construction have been studied (Wang et al., 2020). In addition, Vialetto and Noro (2019) used machine learning algorithms to predict the energy consumption of a company operating in the wood sector, whereas Cheta et al. (2020) developed a system to monitor the production of wood products through the analysis of sounds with artificial intelligence algorithms.

Future perspectives of I4.0 in the woodworking sector

Virtual and augmented reality could be used in the sawing and production processes to train workers for both maintenance and process implementation. It can also be used in the field of wooden furniture assembly or the production of semi-finished products. Woodworking is characterised by a great deal of manual work and repetitive, physically stressful activities. The use of autonomous and collaborative robots could help create a more ergonomic and safer work environment by relieving operators of many physically demanding tasks (e.g., wood panels loading and handling, pallet nailing, etc.). In addition, robots could also substitute the workers in activities such as painting, polishing or smoothing. However, the woodworking industry represents a peculiar sector because wood, compared to other materials such as plastics or metals, is characterised by natural defects and abnormalities, e.g. knots, that pose special challenges to the manufacturing process. Failing to properly handle such aspects (e.g., through ad hoc vision systems) may result into the generation of excessive waste and, thus, into the loss of potential benefits of these technologies. Markedly, the adoption of I4.0 in woodworking enterprises could be used to develop innovative, sustainable "green" products, and enhance the overall environmental performance of the woodworking sector, stimulating its transition to low carbon, circular bioeconomy.

4.2.3 Environmental practices and certifications in the woodworking sector

Wood as a natural, renewable and eco-friendly raw material, has numerous advantages, making it a preferred material for a wide variety of industrial applications such as construction material and furniture. Wood and wood products sequester carbon and contribute to reducing CO_2 in the atmosphere, thus helping to mitigate climate change.

Further, wood products are produced in a relatively low energy production systems, with minimal emissions, compared to other construction and furniture materials. Bi-products from sawmills such as chips and sawdust do not present waste material, as they are further transformed into wood-based panels. Wood products can also be reused and recycled, therefore wood-based products represent a very good example of a carbon neutral or carbon negative material with its possible cascading use in circular bioeconomy. At the end of all their life cycles they are further used as a renewable energy.

However, wood is also a heterogeneous material, varying by species, dimension and quality. This variation in its physical and mechanical properties inevitably affects the various mechanical and chemical production processes. In manufacturing industries, process variables must be managed to achieve the required quality and productivity standards. In industrial systems, productivity and product quality are affected by multiple variables, and wood as a material adds an additional degree of complexity (Ramos-Maldonado & Aguilera-Carrasco 2021).

Wood-based materials and products certifications

- **CE - Conformité Européenne / European Conformity**

The CE marking indicates that a product such as construction product, furniture, toy, etc. is in conformity with its declared performance across the European Economic Area (EEA) and that it has been assessed according to a harmonised European standard or a European Technical Assessment has been issued for it. The CE mark affirms the good's conformity with European health, safety, and environmental protection standards. However, it does not qualify as a quality indicator or a certification mark. The CE mark on a product indicates that the manufacturer or importer of that product affirms its compliance with the relevant EU legislation and the product may be sold anywhere in the European Economic Area (EEA), regardless of its country of origin.

- **hEN - Harmonised European standards (CEN/CENELEC/ETSI)**

Harmonised European standards (hEN) are European standards developed by one of the recognised European Standards Organisation: CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization), or ETSI (European Telecommunications Standards Institute). It is created following a request from the European Commission to one of these organisations. Manufacturers, other economic operators, or conformity assessment bodies can use harmonised standards to demonstrate that products, services, or processes comply with relevant EU legislation. They enable manufacturers to draw up the Declaration of Performance (DOP) as defined in the Construction Products Regulation (CPR) and affix the CE marking. Harmonised European standards create a common technical language used by all actors in the construction sector to: define requirements (regulatory authorities in EU countries); declare the product's performance (manufacturers); verify compliance with requirements and demands (design engineers, contractors). Harmonised European standards on construction products are developed by technical experts from the European Standardisation Organisations. The Technical Committees of CEN/CENELEC/ETSI are working on completing the necessary set of harmonised European standards and test standards, and further improving existing ones. The benefits of harmonised standards for the construction sector are common assessment methods for construction products and a single European scheme for declaring product performance. These actions remove barriers to trade and thus help improve the competitiveness of the construction sector.

- **ETA - European Technical Assessment**

The European Technical Assessment (ETA) is an alternative for construction products not covered by a harmonised standard. ETA is a document providing information on the product's performance assessment. A manufacturer requests the European Technical Assessment for construction products that are not or not fully covered by a harmonised European standard (hEN) under the Construction Products Regulation (EU) 305/2011. The request is addressed to an independent Technical Assessment Body (TAB) for the respective product area. The Technical Assessment Body issues the European Technical Assessment based on a European Assessment Document (EAD) adopted by the European Organisation for Technical Assessment (EOTA). The main content of the European technical assessment is information on the intended use and performance of a product. The ETA procedure allows manufacturers to affix the CE marking to construction products for which no harmonised standard exists. ETAs are recognised throughout Europe in all countries participating in the ETA procedure.

- **EPD - Environmental Product Declaration**

An Environmental Product Declaration (EPD) is a comprehensive report that includes a life cycle assessment (LCA) developed to provide specific environmental information on a product in a common format. EPD is defined by International Organization for Standardization (ISO) 14025 (Environmental labels and declarations — Type III environmental declarations — Principles and procedures) and follows ISO 14040 standard to report information over the entire product life cycle with quantitative measures of key environmental impacts. In Europe, the European Committee for Standardization (CEN) has published EN 15804, a common Product Category Rules (PCR) for EPD development in the construction sector. In order to enhance harmonization, the main Programme Operators for EPD verification in the construction sector created the Association ECO Platform, with members from different European countries. The added value of EPD under the ECO Platform framework is the possibility to use these declarations in all European but also international markets. A verified EPD for building products can be used in several green building rating systems. EPD reports are available from The International EPD System database.

- **FSC - Forest Stewardship Council**

The Forest Stewardship Council (FSC) is an independent, non-governmental, not for profit organization established to promote the responsible management of the world's forests via forest certification system established for forests and forest products. It is an example of a market-based certification program used as a transnational environmental policy. FSC addresses issues such as illegal logging, deforestation and global warming and some reports indicate positive effects on economic development, environmental conservation, poverty alleviation and social and political empowerment. FSC certification signifies that the product comes from responsible sources—environmentally appropriate, socially beneficial and economically viable. The FSC label is used on a wide range of timber and non-timber products, from paper and furniture to medicine and aims to give consumers the option of supporting responsible forestry. The FSC Chain of Custody (CoC) system allows the tracking of FSC certified material from the forest to the consumer. In addition to its global certification standard, FSC develops national standards in selected countries. These standards are closely aligned to the global certification standard and its criteria but are adapted to local context conditions. FSC certified construction wood and construction products made from FSC certified wood can contribute to green building certification systems.

- **PEFC - Programme for the Endorsement of Forest Certification**

The Programme for the Endorsement of Forest Certification (PEFC) is an international non-profit, non-governmental organization dedicated to promoting Sustainable Forest Management (SFM) through independent third-party certification. PEFC acts as an international umbrella organization providing independent assessment, endorsement and recognition of national forest certification systems. It is considered the certification system of choice for small forest owners.

Relevant certifications in the context of wood-based construction

Green buildings have become an increasing area of focus for the built environment, aiming to address environmental and sustainability issues relating to energy, water, and waste. Green building certifications and standards have developed as a way to both showcase and evidence that a high standard of sustainable and eco-friendly practices were used to create and operate the building. The main benefits of green buildings can be divided in three groups: environmental, economic and social. Green buildings reduce or eliminate negative impacts on environment (by using less water, energy, natural sources) and also having a positive impact on built environment. On the other hand, they lower monthly costs through energy and water efficiency and increase property value for building developers, increase occupancy rates or operating costs for building owners. The third part of benefits are green building's impacts on health and well-being of people.

Wood-based structural materials (load bearing elements in buildings) and **non-structural materials** (flooring, façade, cladding, etc.) play a very important role and have lots of benefits in achieving the above-mentioned goals. There are a range of sustainable building certification systems which have been developed, some of which also focus more on the health and wellbeing of the people who use the building. The following certifications are of high relevance in EU countries:

- **Level(s) - European framework for sustainable buildings**

In the context of the global 2030 sustainable development agenda, Level(s) is an assessment and reporting tool for sustainability performance of buildings, firmly based on circularity. Level(s) provides a common language for the building transformation process in line with the European Union sustainable initiatives. The Level(s) common framework is based on six macro-objectives that address key sustainability aspects over the building life cycle. The sustainability indicators within each macro-objective describe how the building performance can be aligned with the strategic EU policy objectives in areas such as energy, material use and waste, water, indoor air quality and resilience to climate change.

- **DGNB - The German Sustainable Building Council**

The German Sustainable Building Council (DGNB) evaluates the life cycle of a building, from the production of raw materials to the recyclability of materials if the building is demolished. The DGNB has developed various certification schemes for all types of buildings based on 36 criteria. These weighted criteria rate buildings as Certified (only for existing buildings), Silver, Gold or Platinum.

- **LEED - The Leadership in Energy and Environmental Design**

Initially developed in the USA, it was introduced to the market in 1998. Participating builders and project managers must fulfil eight prerequisites that are given in five categories. The earned credits will result in a Certified, Silver, Gold or Platinum rating. 35% of the credits in LEED are related to climate change, 20% of the credits directly impact human health, 15% of the credits impact water resources, 10% of the credits affect biodiversity, 10% of the credits relate to the green economy, 5% of the credits impact community and 5% of the credits impact natural resources. The certification can be awarded to new builds as well as refurbishment works.

- **BREEAM - Building Research Establishment Environmental Assessment Method**

BREEAM is the oldest and most widely used certification system for green buildings. First conceived in 1990 in the UK, BREEAM awards a four-level quality seal based on a simple scoring system that covers eight evaluation categories. These criteria assess the edifice's effect on the global, regional and local environment, as well as the materials' influence on the interior architecture of the building. BREEAM is used to address the construction phases, from planning and implementation to the building's operation. The system has since been updated to include the project's life cycle, and it has also introduced new mandatory criteria to re-evaluate the environmental impact of the building. The ratings allow environmental performance to be benchmarked and evaluated against other similar buildings, and include Outstanding, Excellent, Very Good, Good, Pass, and Unclassified.

- **LBC - Living Building Challenge**

The Living Building Challenge is an ambitious standard that challenges buildings to innovate to create positive environmental impacts, rather than mitigating negative ones. To be classed as a Living Building, projects must demonstrate that they have achieved Net Positive Energy, Water, and Waste – essentially, these buildings must generate more energy than they consume to offset any negative effects of the building. This is measured through seven performance categories, including place, water, energy, health and happiness, materials, equity, and beauty. The end goal of the Living Building Challenge is to encourage the creation of a regenerative built environment.

- **Passive House**

Passive House is a stringent set of energy performance standards – as well as design and construction principles – which ensure that a building uses 80 percent less energy than traditional buildings. In addition, this provides superior air quality and comfort to the building occupants and maintains a consistent temperature despite the season using mechanical ventilation and high air tightness standards. Unlike other certifications, there are no ratings with Passive House – the standard is either met or the building does not qualify for certification.

- **ENERGY STAR**

ENERGY STAR is an energy rating system with strict energy performance standards. It compares a building's energy efficiency to the 2009 International Energy Conservation Code (IECC) and the building must gain a score of at least 75 out of 100 to earn the ENERGY STAR label. This must be verified during use rather than on predicted use at design stage and indicates that the building performs better than at least 75% of similar buildings – using at least 35% less energy and creating at least 35% fewer greenhouse gas emissions.

- **WELL**

The WELL Building Standard takes a different approach to sustainability in buildings, instead addressing user behaviour, operations management, and design factors to determine the impact on user health and wellbeing. To do this, seven concepts are measured, including: air, water, light, nourishment, fitness, comfort, and mind. WELL Certified buildings are those which improve the nutrition, fitness, mood, sleep patterns, and performance of their inhabitants. It can be applied to any construction project, and the levels of achievement are Silver, Gold, and Platinum Certification.

- **Fitwel**

Fitwel is aimed at optimizing the opportunities to improve building occupants' health. Using a range of scorecards depending on the type of project, Fitwel provides design and operational strategies that enhance buildings by addressing a range of health behaviors and risks. Points are allocated across seven health impact categories, with 1–3 stars being awarded depending upon the number of points scored.

4.3 Furniture and twin transition

In this section we introduce furniture industries activities and the recent applications of industry 4.0 technologies and sustainable management practices in the furniture sector.

4.3.1 Furniture industry activities

The furniture industry is a labour-intensive and dynamic sector dominated by small and medium-sized enterprises (SMEs) and micro firms. EU furniture manufacturers have a good reputation worldwide thanks to their creative capacity for new designs and responsiveness to new demands. The industry is able to combine new technologies and innovation with cultural heritage and style, and provides jobs for highly skilled workers. In today's market, environmentally friendly furniture has a competitive advantage due to the emergence of consumers concerned about the environmental impact of their activities and goods they purchase.

Modern furniture are complex products made by different types of materials and components: wood, plastics, polyurethane foams, textiles, metals, etc. Due to the social, legal and market requirement, the furniture companies are dealing with several certifications related to their products. For instance, voluntary products ecolabels that certify the minor impact on the environment of their entire cycle. Moreover, the different components can be certified: wood-based products, textiles and foams (especially important for mattresses and upholstery) or in case recycled materials are used. Also, the level of the quality of the air can be certified. Especially important for wood products which are composed of coatings and resins. In this section, the most demanded certifications are explained by category/type. The overview focuses on European standards but also includes international certifications which are commonly used in Europe.

4.3.2 Industry 4.0 emerging practices in the furniture industry

"*Today's furniture is now seen as a high-tech design object. Large-scale enterprises in the sector have become acquainted with the concepts of "Smart Factory" and Industry 4.0 and have started production processes with a new generation of project-based lines consisting of full automation and robotic processing. Branded furniture companies representing 75% of the sector are turning their production facilities to the AR-GE base. The use of full-automatic production lines with CNC-controlled and ERP systems has become a necessity, not a luxury, for brands anymore*." *Öztürk and Koç, 2017*

At present, the traditional furniture manufacturing industry is facing a challenge. It is becoming easier for people to obtain the necessary information. Consumers are looking for customised products and services. In order to meet people's living needs, Germany put forward the concept of "Industry 4.0". The Chinese government developed the concept of "China Made 2025" in 2015. At the same time, "Industrial Internet" was proposed by the United States in 2009. They all aim at transforming the traditional industries through the Internet (Zhihui,2016). Through the use of "Things of the internet "and" business networking (service Internet)", traditional industries can achieve flexible production, zero inventory and Internet marketing. As a traditional manufacturing industry, the furniture industry is based on a solid industrial base. Therefore, it should learn the strategic thinking of industrial 4.0, and explore the "Manufacturing + Internet" actively.

Furniture is closely related to people's lives. But the increasing cost, excess capacity and customised market all require a high degree of automation, intelligence, and flexibility of direction. The requirements mentioned above are in accordance with the requirements of the custom furniture factory. Intelligent plants connect the intelligent physical devices by industrial internet intelligent physical devices. Intelligent Devices can do computing, communication, precise control, remote assistance and autonomy (Jun, 2015). In the future, firstly we need to obtain the customer's customised information. Then the virtual factory which is based on cloud-based design and manufacturing will do the design and simulation. Finally, the customer confirmed the product and the computer integrated and sent the appropriate data to the appropriate equipment. Intelligent devices can read each other's tags to achieve the information transfer function. Based on the information, intelligent devices can complete the manufacturing, testing and other activities. The intelligent factory is a data-based enterprise. The daily operation of the intelligent factory mainly depends on following software and hardware: the industry thing networking, the industry network security, the industry big data, the cloud computation platform, the MES (Manufacturing Execution System) system, the virtual reality, RFID, 3D printing, machine vision, intelligent logistics and so on. The hardware includes industrial robots, data acquisition, industrial switches (Shu, 2014).

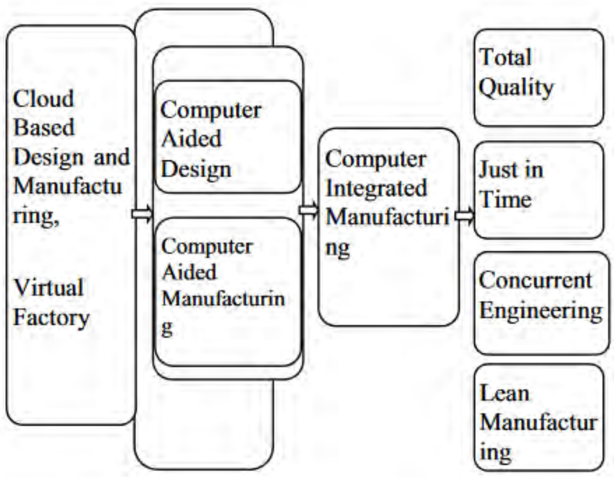

Figure 8: Main operating activities of intelligent furniture factory (Wang et al., 2016)

The use of MES (Manufacturing Execution System) in the furniture industry is still not widespread among small- and medium-sized companies. Often, the required manufacturing documents are still produced in ERP or PPS. Many manufacturers are satisfied with the creation of production orders and their rough scheduling in these pre-systems. For a better utilisation of production capacities, it would however be possible to transfer these orders from the ERP system to an MES solution. In a partially or fully automated production, MES ensures a direct connection of the information systems to the machine level. This enables the directing, controlling and monitoring of production in real time. Alternatively, production orders could be directly created or taken over from the used CAD/CAM systems. The MES also records machine and operating data and sends it back to the information systems. The use of an MES solution automates the following:

- sending information back to materials management and commercial order processing
- recording of operating, production and product data and transferring this to the reporting level
- controlling of production control stations and related resource utilisation
- creation of planning periods in manufacturing, depending on current prioritisation
- manufacturing processes and resource planning for production
- planning and execution of maintenance work
- administration of production means.

The intelligent custom furniture factory uses information communication technology (ICT) and cyber physical system (CPS) to link related equipment, production lines, factories, related parties and products together. The entire intelligent network is divided into two parts. The information transmission in the custom-made furniture factory is called M2M. It transforms dialogue among humans and machines. Factories exchange information through the Internet of Things which includes the factory's payment platform, intelligent logistics platform, and design platform to finish production (Wang et al., 2016). The process is shown in Figure 9.

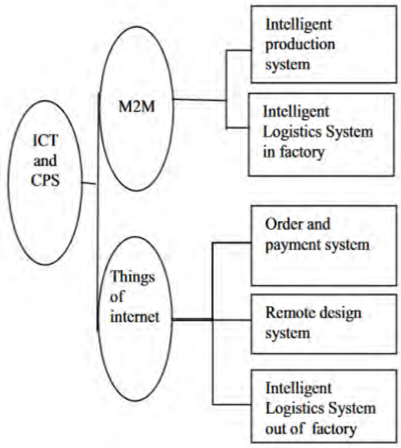

Figure 9: Intelligent network and main operating system of intelligent furniture factory (Wang et al., 2016)

Intelligent custom furniture factory is composed of an intelligent production line and network (financial enterprises, product design institute, production equipment factory, technical personnel training institutions, raw material suppliers, logistics companies, etc.). The intelligent operation system of the intelligent customised furniture factory can be divided into payment system, remote product development and design system, intelligent production system and intelligent logistics system:

1) Intelligent order and payment system: Through the system's intelligent ordering platform, the factory can accept the orders made by external factories. After the approval, the orders will be revised or negotiated according to order requirements.

2) Remote product development and design system: When receiving new products or customised product orders, they need to design products by computer simulation. The computer can set up a three-dimensional model in accordance with the real work of the operation. Then the product can be displayed on the screen. According to the views of customers, the designer will modify the model and print out new products to customers by the 3D printer.

3) Intelligent production system: Intelligent production system is the main system of intelligent machinery plants, involving the entire factory production processes, machinery, equipment and plant logistics management. In the intelligent factory, every part of the product is blank, spare parts, tools, transport boxes, machines are equipped with sensors.

4) Intelligent logistics system: The intelligent logistics system is a modern logistics system which is composed of barcodes, radio frequency identification technology, sensors, global positioning system and so on. Through the intelligent network formed by cyber physical systems (CPS), the logistics resources integrate and operate in the electronic commerce way. First, we collect the relevant data. Based on the data, we analyse and build the model. Then we establish an intelligent logistics base database.

Finally, we enhance the customer management and business process optimization (Wang et al., 2016).

Because the furniture manufacturing industry is faced with many problems, such as low efficiency of resource use, great pressure of environment and high labour cost, the intelligent manufacturing is the inevitable trend of the future furniture manufacturing industry. "Industrial 4.0" has the advantages, such as high efficiency of resource allocation, quick response to market demand, low labour cost and logistics cost (Wang et al., 2016).

With Industry 4.0, there is more and more room for large-scale product personalization manufacturing, with greater quality and no added costs or delays. Moreover, thanks to digitalization, IoT, and connectivity, companies can easily switch back and forth among the four manufacturing models that require more agility, require more information in order to respond in real-time to a changing demand.

A networked, data-rich production system also offers the potential to understand in minute detail the entire production process and what changes are necessary to unlock production efficiencies and savings. The potential gains from advanced analytics range from cost savings due to predictive maintenance operations to smaller work-in-progress inventory through to a more flexible and better-informed business strategy

Level of implementation of KET in the furniture sector

Different Key Enabling Technologies (KETs) have been determining for the growth and consolidation of companies of the furniture sector. Furniture is a manufacturing sector that actually encompasses very different subsectors with different needs between them. For example, an upholstery manufacturer factory can be very different from other manufacturing mattresses and far away from the ones manufacturing beds, despite the fact that all are obviously related.

IN4WOOD project offered some conclusions after the analysis of more than 600 surveys to industry expert and teachers all around Europe: the level of implementation of different KETs in EU countries (and UK) depends on the characteristics of the sector at national level: while in Germany, mainly represented by medium or big sized companies with specific needs related to a mass production (technologies applied to the production process and also maintenance and sales levels); in Spain and UK the approach to Industry 4.0 KETs is more related to the manufacturing process including logistics and delivery; in Italy, where the production process in the whole business of the furniture manufacturing sector counts a small % (most of companies are small in size and are concentrated on finishing instead of mass production) compared to the importance of other processes such as design, prototyping, sales, marketing.

The vast majority of the furniture manufacturers and Vocational Education and Training (VET) experts agree that the biggest barrier found during the implementation of I4.0 technologies has been the lack of knowledge and skills among staff, along with an insufficient training in the topic and the high cost of said technologies, while respondents from VET/HE highlight the difficulties in understanding the benefits deriving from their application as a barrier too. Moreover, most of the KETs experts who participated in the survey cite that they have not been involved in training programmes addressing KETs.

Projects such as IN4WOOD or DITRAMA developed more than 400 open videoclips to train CEOs, digital transformation managers and production managers in relation to I4.0 topics for the Forest and Wood sector. Nevertheless, there is still work to do in addressing the needs of enterprises for using KETs to support the twin transition and achieve green certificates.

4.3.3 Sustainable practices in the furniture industry: overview of ecolabel certifications

Environmental certifications in the furniture sector were developed due to the demand of markets that required companies to improve their environmental behaviour. The new needs were focused on demonstrating compliance with legislation, the application of good environmental practices in the company, or the adoption of criteria in product design that took into account the improvement of its environmental aspects to obtain a more efficient and environmentally friendly product.

Ecolabels can be classified into three types of systems according to the regulations developed by the International Organization for Standardization (ISO). These ISO standards define the general principles, objectives and procedures that must be implemented to comply with the different types of ecological labels and environmental declarations.

Types of Ecolabels according to ISO:

- *Type I ecological label (ISO 14024 standard) - Ecolabels.*
- *Type II ecological label (ISO 14021 standard) - Environmental self-declarations.*
- *Type III environmental declarations (ISO 14025 standard).*

The most recognized and implemented ecolabels based on these standards in Europe, as well as at international and national levels, are introduced below.

TYPE I eco-labels (Fulfil all requirements of ISO 14024)

Type I eco-labelling is a voluntary environmental rating system that officially identifies and certifies that certain products or services have a minor impact on the environment, taking into account their entire life cycle. In Europe the main ecolabel standard is the "EU Ecolabel".

- **EU Ecolabel**

Established in 1992 and recognised across Europe and worldwide, the EU Ecolabel is a label of environmental excellence that is awarded to products and services meeting high environmental standards throughout their life-cycle: from raw material extraction, to production, distribution and disposal. The EU Ecolabel promotes the circular economy by encouraging producers to generate less waste and CO_2 during the manufacturing process. The EU Ecolabel criteria also encourages companies to develop products that are durable, easy to repair and recycle.

More information: https://ec.europa.eu/environment/ecolabel/

At a national level, several labels are recognized and used in several EU countries:

- ❖ **Nordic Swan Ecolabel**

The Nordic Swan Ecolabel sets strict environmental requirements in all relevant phases of a product's life cycle, dets strict requirements for chemicals used in eco-labelled products, tightens requirements for goods and services continuously to create sustainable development, certifies and verifies that all requirements are met before a product is approved.

More information: https://www.nordic-ecolabel.org/nordic-swan-ecolabel/

- ❖ **Blue Angel | The German Ecolabel (Germany)**

The Blue Angel has been the ecolabel of the German federal government for more than 40 years. It is awarded to environmentally friendly products and services. No other label in the non-food sector covers such a wide range of products and services. Many everyday products carry the ecolabel: such as paints, furniture, washing detergent or recycled paper.

More information: https://www.blauer-engel.de/en/blue-angel/our-label-environment

- ❖ **Green Product Mark (Germany)**

Green Product Mark indicates the overall environmental preferability of products. The certification criteria behind this voluntary environmental labelling scheme are based on indicators arising from product life cycle considerations and aim to communicate verifiable and accurate information on environmental aspects of products. With the Green Product Mark certification, consumers and purchasers are provided with a clear guideline for environmentally preferable products with less environmental impact.

More information: https://www.tuv.com/world/en/green-product-mark.html

❖ Milieukeur: Dutch environmental quality label (Netherlands)

Milieukeur is the Dutch environmental quality label for products and services. There are Milieukeur criteria for a wide variety of food products, consumer products and services, ranging from vegetables, potatoes, fruit, beer, pork, trees and plants to concrete products, fire extinguishers, florists, butchers, green electricity and car washes.

More information: https://www.ecolabelindex.com/ecolabel/milieukeur-ecolabel-the-netherlands

❖ NF-Environnement Mark (France)

A voluntary certification mark issued by AFNOR Certification. To be issued the NF Environnement mark the product must comply with ecological and fitness for purpose criteria. These criteria are the result of negotiations between representatives of manufacturers, consumer, environmental protection and distributor associations and public authorities.

More information:

https://www.ecolabelindex.com/ecolabel/nf-environnement-mark-norme-francaise

❖ Good Environmental Choice (Sweden)

Good Environmental Choice is an independent eco-label with tough environmental requirements that is constantly evolving. Our label makes it easier to find the products and services that are least harmful to the environment.

More information: https://www.bramiljoval.se/artiklar/about-good-environmental-choice/

❖ Hungarian Ecolabel (Hungary)

Hungarian national ecolabel developed by the Ministry of Environment in 1994. Goals and procedures meet the requirements of ISO 14024 standard.

More information: https://okocimke.hu/nemzeti-okocimkerol

❖ Ekologicky setrny vyrobek / Environmentally Friendly Product (Czech Republic)

The ecolabel "Ekologicky setrny vyrobek" is the official registered label of The Czech ecolabelling programme (National Programme for Labelling Environmentally Friendly Products). It was launched on 14. April 1994. The programme is administered by CENIA, Czech Environmental Information Agency.

More information: https://ekoznacka.cz/ekoznaceni/ekoznacka-esv-a-es

❖ Environmentálne vhodný produkt "EVP" (Slovakia)

In Slovakia, environmental labelling has been implemented since 1997 through the national eco-label scheme "Environmentally Friendly Product". Aims to mitigate the negative impacts of consumption and production on the environment by promoting and prioritising products and services with lower negative environmental impacts.

More information: https://www.sazp.sk/zivotne-prostredie/environmentalne-manazerstvo/environmentalne-oznacovanie-produktov/narodna-znacka-environmentalne-vhodny-produkt.html

❖ Znak zaštite okoliša - Prijatelj okoliša (Croatia)

The Environmentally Friendly Labelling Program is implemented with the purpose of promoting products and services that, compared to similar products and services, have a lower negative impact on the environment throughout their life cycle and thus contribute to the efficient use of environmental components and a high level of environmental protection. The label belongs to the Type I ecolabel and declaration of the international standard EN ISO 14024:2000, which distinguishes it from the growing groups of various private ecolabels and self-declarations.

More information:

https://mingor.gov.hr/o-ministarstvu-1065/djelokrug-4925/okolis/eko-oznake/znak-zastite-okolisa-prijatelj-okolisa/1414

❖ The Vitality Leaf ecolabel (Russia)

The only one ecolabel in Russia recognized internationally by The Global Ecolabelling Network (GEN). The assessment is carried out by the accredited certification body that works in accordance with ISO 17065, registration number is RA.RU.11HB64.

More information:https://ecounion.ru/en/

❖ Green Crane: Ukraine (Ukraine)

Green Crane is a voluntary, multiple specifications based environmental labelling program that operates to international standards and principles. It is awarded to products with relatively less environmental impact compared to similar products, during their entire life cycle, from extracting and collecting the product materials, to the manufacturing, distribution, use and consumption, disposal, and recycling. Founded in 2002 Green Crane is the only Ukrainian environmental standard and certification mark. The Green Crane Program has been successfully audited by the Global EcoLabelling Network (GEN) as meeting ISO 14024 standards for eco-labelling in 2004.

More information:https://www.ecolabelindex.com/ecolabel/green-crane-ukraine

SEMI-TYPE I eco-labels (Not governed by the outline of standards 14020)

This group of labels are not governed by the scheme of standards 14020, since they arose much earlier to provide the necessary information on the environmental characteristics of products of some specific sectors. Wood industry is one of the main sectors where these types of ecolabels are highly recognized.

- **Certifications for wood and wood-based products:**

❖ FSC (Forest Stewardship Council)

Consumers want sustainable products, and furniture is no exception. FSC-certified wood is a trusted solution, showing your brand's commitment to deliver better outcomes for forests, people, and businesses – today and for future generations. By sourcing FSC-certified materials and adding the FSC label to their products, companies help consumers to make a responsible choice and ensure forests for all, forever.

More information: https://fsc.org/en/for-businesses/furniture

❖ Programme for the Endorsement of Forest Certification (PEFC) schemes

The Programme for the Endorsement of Forest Certification (PEFC) is an international non-profit, non-governmental organization dedicated to promoting Sustainable Forest Management (SFM) through independent third-party certification.

More information: https://www.ecolabelindex.com/ecolabel/programme-for-the-endorsement-of-forest-certification-schemes-pefc

Textiles and foams certifications are demanded in the upholstery and bed sector. For instance, some of these certifications ensure that certain substances used in the textiles are not harmful for human skin.

- **Certifications for textiles:**

❖ Oeko-Tex ®

STANDARD 100 by OEKO-TEX® is one of the world's best-known labels for textiles tested for harmful substances. It stands for customer confidence and high product safety. Find out here what STANDARD 100 means and why it is worth checking for this label when buying textiles.

MADE IN GREEN by OEKO-TEX® is a traceable product label for all kinds of textiles and leather products that have been manufactured in environmentally friendly facilities under safe and socially responsible working conditions.

LEATHER STANDARD by OEKO-TEX® is an internationally standardised testing and certification system for leather and leather goods at all production levels, including accessory materials.

More information: https://www.oeko-tex.com/en/

- **Certifications for foam:**

❖ **Certipur**

CertiPUR® is a voluntary standard to advance the safety, health and environmental (SHE) performance of flexible polyurethane foams used in bedding and upholstered furniture. The scheme takes into account existing standards and scientific studies related to emanations from foams, product criteria and risk assessments.

https://www.ecolabelindex.com/ecolabel/certipur

- **Certifications for recycled materials:**

❖ **Global Recycle Standard (Italy)**

Global Recycled Standard (GRS) certifies products obtained from recycled materials and manufacturing activities. Enhance products made with recycled materials, in compliance with environmental and social criteria extended to all stages of the production chain.

More information: https://icea.bio/certificazioni/non-food/prodotti-tessili-biologici-e-sostenibili/global-recycle-standard/

- **Air Quality Certifications:**

There is a tendency in architecture studies to request furniture manufacturers compliance with requirements for the improvement of air quality. For that, the manufacturers have to use specific materials with lower content in formaldehyde and other products with emissions. We show you some of the most widely implemented certifications in Europe, some of them are outside of Europe's entities.

❖ **Danish Indoor Climate Label**

The Danish Indoor Climate label is a tool for development and selection of indoor air quality friendly products and better understanding of the impact of products and materials on the indoor air quality in buildings.

❖ **Indoor Air Comfort**

Eurofins "Indoor Air Comfort" product certification is an innovative tool for showing compliance with low VOC emission requirements from construction products and furniture of all relevant European specifications on two levels: Standard level "Indoor Air Comfort - certified product" shows compliance of product emissions with all legal specifications issued by authorities in the European Union.

❖ **eco-INSTITUT-Label**

With substantial emission and toxicological testing living up to more than just the legal specifications, eco-Institut supplies clients a reliable and significant label for building products and textiles without any health hazards.

❖ **Other air quality certification outside Europe:**

The European furniture industry exported €1.61 billion in 2018. Related to EU external markets, the following certifications are also demanded for air quality: GREENGUARD (USA), SCS Indoor Advantage (USA).

- **Eco-design Certifications:**

The eco-design certifications confirm the value of the design methodology to lower the impact of the final product on people and the planet is fulfilled and is positive.

Cradle to Cradle Certified (CM) Products Program

The Cradle to Cradle Certified (CM) Products Program provides a company with a means to demonstrate efforts in eco-intelligent design. Cradle to Cradle Certification is a third-party sustainability label that requires achievement across multiple attributes.

ANAB - Architettura Naturale

A certification scheme that assesses the sustainability of building products and furniture. To qualify, building materials must be made primarily from renewable virgin resources, mineral resources and secondary resources for which recycling is logistically and energetically feasible.

OK biobased

OK biobased label offers a comprehensive guarantee about the origin of your products. The environmental awareness of customers means that there is a great need for high-quality, independent assurance of the renewability of raw materials. The "OK biobased" certification perfectly satisfies that need.

TYPE II eco-labelling (Self-declared environmental claims governed by ISO 14021)

This type of eco-labelling is accredited by the same manufacturer (self-declaration) and refers to a specific characteristic of the product or a stage of its life cycle. It is governed by ISO 14021.

- ❖ **Möbius loop**

The Möbius loop has become the international symbol of recycling, although it has given rise to different identifiers. When the ring appears simply, it means that the product or packaging is made with materials that can be recyclable. If the ring is inside a circle, it means that part of the materials of the product or container have been recycled. The symbol can specify the percentage of recycled product it contains. This figure is often found in containers and cardboard boxes.

- ❖ **Recyclable plastic**

There are seven different numbers found within triangles on plastic bottles and containers. These symbols were created in 1988 in conjunction with the Resin Identification Code or RIC to help promote plastic recycling through better material separation. All these symbols offer some information about the harmful chemicals used in producing the plastics, the safety of the plastic, how biodegradable the plastic is, and how likely the plastic is to result in leaching.

- ❖ **Green dot**

The green dot was created in Germany in 1991 and adopted in 1994 by the EU Member States as a brand for the European Directive on Containers and Packaging Waste. Its presence in packaging indicates that the products comply with this regulation that forces packaging companies to take responsibility for the recycling of their products. The containers that can wear this badge are plastic, metal containers and containers Brik type; cardboard and paper; and glass

TYPE III eco-labels (Environmental product declaration - regulated by ISO 14025)

The labels of Type III, also named as Environmental Product Declarations (EPD), are regulated by ISO 14025 and, like Type I, their certification is carried out by an independent body.

- ❖ **Environmental Product Declaration**

The overall goal of an Environmental Product Declaration, EPD, is to provide relevant, verified and comparable information to meet various customer and market needs. The International EPD® System has the ambition to help and support organisations to communicate the environmental performance of their products (goods and services) in a credible and understandable way.

❖ IBU Type III Environmental Declaration

This is a Type III declaration for building products. It is based on ISO 14025 as well as ISO 21930 and EN 15804 and declares environmental information on a pass/fail basis. It is meant to identify properties of building products that are relevant to the environmental performance of buildings, and it is based on a Life Cycle Assessment. There are currently 96 declaration holders that together have 230 Environmental Product Declarations (EPD), as they can obtain multiple EPDs for different products.

❖ ECOproduct

ECOproduct is a Norwegian method to choose environmentally friendly building materials and chemicals based on information in an Environmental Product Declaration (EPD) or a safety data sheet. The method has been developed in collaboration with several building industry organizations and contractors in Norway.

❖ DAPconstrucción®

The DAPconstrucción® Program is a program that brings together manufacturers of products and construction materials that are committed to sustainability and the environment and wish to advance in the analysis of the environmental impacts of their products. The DAPcons® Certification is an EPD eco-labelling program of pioneering construction in Spain following European guidelines and regulated by ISO 14025 and 15804 standards.

- **Carbon Footprint Certifications**

The carbon footprint declarations are other examples of Ecolabel type III. There are standards for the calculation of the carbon footprint of products, services, projects and enterprises at general level and also per sector promoted by several organizations. The most known ones are: i) Certification of Organisations and Projects and ii) Certification of Products and Services:

i) Certification of Organisations and Projects

- **ISO 14064-1:2018**. Greenhouse gases — Part 1: Specification with guidance at the organisation level for quantification and reporting of greenhouse gas emissions and removals.
- **ISO 14064-2:2019**. Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements.
- **ISO 14064-3:2019**. Greenhouse gases — Part 3: Specification with guidance for the verification and validation of greenhouse gas statements.
- **GHG Protocol Corporate Accounting and Reporting Standard.** This document provides a step-by-step guide for companies to use in quantifying and reporting their GHG emissions.
- **GHG Protocol Project Quantification Standard.** Forthcoming; a guide for quantifying reductions from GHG mitigation projects.

ii) Certification of Products and Services

- **ISO 14067:2018**. Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification.
- **PAS 2050:2011**. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services.
- **PAS 2060:2014**. Specification for the demonstration of carbon neutrality.

Label examples:

- **Carbon Trust**

CARBON TRUST

This product carbon footprint label is a clear identifier of products that have had their carbon footprints certified by the Carbon Trust. This is a validation of accurate footprints, providing customers with verified information about the carbon impacts of their purchasing decisions. Our label has appeared on thousands of products across the globe, positioning it as the leading label for product carbon foot printing.

The Carbon Trust is an independent organisation and an established expert on carbon foot printing. We ensure that our product carbon footprint label is underpinned by robust and credible analysis undertaken by our foot printing experts.

A life cycle product carbon footprint measures the total greenhouse gas emissions generated by a product, from extraction of raw-materials to end-of-life. It is measured in carbon dioxide equivalents (CO_2e).

https://www.carbontrust.com/what-we-do/assurance-and-certification/product-carbon-footprint-label

❖ Product Environmental Footprint (PEF)

Developed by EU Commission DG Environment, PEF has been tested with a variety of stakeholders for product environmental performance. The aim is to improve comparability among similar products that have the same function defined by predefined rules (PEFPCR).

PEFs can be seen as somewhere between Type I Eco-label and Type III Eco-label. For Type III Eco-labels, PEFs would bring comparability to EPDs so that the market could compare the products on environmental performance while giving also the opportunity to many sectors to assess environmental impacts of their products. For Type I Eco-labels, PEFs would bring almost any sector to environmental disclosures and overcome their limited/selected sector applicability.

PEF is currently in phase II of its development and its implementation as a policy option will be decided in coming years. Similar to EPDs, PEFs are prepared by using Life Cycle Assessment with PEFPCR guidance.

More information: https://eco-labels.uk/labels/pef/

- **Environmental management certifications**

❖ ISO 14000 family environmental management

For companies and organisations of any type that require practical tools to manage their environmental responsibilities, there's the ISO 14000 family. The certifiable standards are ISO 14001 and ISO 14006. Descriptions and websites are shown below:

ISO 14001 . Environmental management systems — Requirements with guidance for use.	https://www.iso.org/standard/60857.html
ISO 14006. Environmental management systems — Guidelines for incorporating ecodesign.	https://www.iso.org/standard/72644.html

In the ISO 14000 family of standards, there are some standards whose purpose is to guide the implementation of improvements and other questions, in the following table can be see these standards and the website for more information:

ISO 14002-1. Environmental management systems — Guidelines for using ISO 14001 to address environmental aspects and conditions within an environmental topic area — Part 1: General.	https://www.iso.org/standard/70138.html
ISO 14004. Environmental management systems — General guidelines on implementation.	https://www.iso.org/standard/60856.html
ISO 14005. Environmental management systems — Guidelines for a flexible approach to phased implementation.	https://www.iso.org/standard/72333.html
ISO 14007. Environmental management — Guidelines for determining environmental costs and benefits.	https://www.iso.org/standard/70139.html
ISO 14008. Monetary valuation of environmental impacts and related environmental aspects.	https://www.iso.org/standard/43243.html
ISO 14009. Environmental management systems — Guidelines for incorporating material circulation in design and development.	https://www.iso.org/standard/43244.html
ISO 14052. Environmental management — Material flow cost accounting — Guidance for practical implementation in a supply chain.	https://www.iso.org/standard/54811.html
ISO 14053. Environmental management — Material flow cost accounting — Guidance for phased implementation in organisations.	https://www.iso.org/standard/73338.html

❖ EU Eco-Management and Audit Scheme (EMAS)

The EU Eco-Management and Audit Scheme (EMAS) is a premium management instrument developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance. EMAS is open to every type of organisation eager to improve its environmental performance. It spans all economic and service sectors and is applicable worldwide.

EMAS is an environmental management system, it based on the ISO 14001 standard, which includes additional requirements, such as the obligation to edit an "Environmental Declaration", which has to be verified by an external audit, and also this declaration have to be published.

For more information, read the specific EMAS Regulations:

- **REGULATION (EC) No 1221/2009:** https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1221&from=es

- **COMMISSION REGULATION (EU) 2017/1505:** https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1505&from=ES

- **COMMISSION REGULATION (EU) 2018/2026**: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R2026&qid=1642440685663&from=ES

4.4 Retail and consumption

Circular strategies aiming at keeping products in circulation longer are being more and more implemented in the furniture sector. These strategies often rely on digital platforms creating a space to facilitate the use and reuse of furniture products.

Furniture rental for instance offers consumers the option to lease products of their choice without a long-term commitment while also providing greater flexibility to keep up with changing trends and requirements. This rental system approach also caters to the environmentally conscious consumer, as products typically discarded are re-used, refurbished, or recycled in the process.

The rise in urbanisation is a major driver in the adoption of furniture rental, as high population densities allow for concentrations of demand and supply. For those who relocate frequently, the hassle of moving or discarding furniture can be avoided. The rise of digitalization and the adoption of digital platforms by consumers is also enabling the provision of efficient rental services, as online product visualisation and purchasing become mainstream (Cleantech group, 2020).

In this section we introduce emerging business models in the sector that integrate environmental concerns with digital practices.

4.4.1 Upstream Circular Business Models

There are three primary upstream circular business models in this space: i) external furniture providers; ii) peer-to-peer; and iii) full-stack model approach.

i) External Furniture Providers: The most common upstream supply chain model used by innovators is to develop a marketplace with products from external furniture providers. Through strategic partnerships with furniture manufacturers, start-ups can source products depending on demand, thus reducing warehousing costs.
Examples of innovators using this model include:

- **Fernish** has sets itself out as an eco-friendly solution provider through its refurbishment and relocation services, with millennials as the core customer target. https://fernish.com

- **Feather** offers "fashionable" furniture to a primarily millennial customer base, with product aesthetic as its stand apart factor. It recently partnered with a reforestation organization to help offset its supply chain and logistics carbon footprint. https://www.livefeather.com

ii) Peer-to-Peer: Another emerging model is a **peer-to-peer** rental marketplace for household products such as furniture, garden tools, recreational vehicles and mobility scooters amongst others. One innovator offering furniture through this model includes Peerby: with free registration, it charges the lender a commission for products advertised. The platform allows users to "borrow" items from the nearest lenders and advertise need for product that may not be available. This model capitalizes on idle capacity of resources and does not involve the provision of logistic services.

iii) Full-Stack Model: Innovators are also looking into a full-stack model, where they design and manufacture their own furniture and rent it through an online platform.

- **Furlenco** offers furniture for entire homes on a monthly rental subscription model. https://www.furlenco.com

4.4.2 Downstream Circular Business Models

All start-ups currently on the market operate on a subscription-based rental model for consumers with a varying range of rental periods offered. This model helps retain long-term relationships with clients, an essential element due to the high costs of customer acquisition. This is a proven model adapted from other business areas such as software-as-a-service, food-box subscriptions, car rental etc. As stand apart factors, start-ups are incorporating different aspects into the model, including:

- **Subscription-based with return** – Products are returned at the end of the rental period or exchanged for different products.
- **Subscription-based with option to purchase** – Customers can buy rented products with amount already paid deducted from selling price.
- **Rental packages** – Start-ups are offering to furnish whole rooms with consumers either choosing from set-designs or personalizing the package.
- **Short-term rental** – Catering to event organizers and house stagers, this model gives clients the option to obtain their choice of furniture for a short period of time.

4.4.3 Incumbents experimenting with circular business models

Traditional furniture providers are also adopting circular economy models, embracing the rental trend. In response to changing consumer behavior, flat-pack furniture giant **IKEA** announced a testing phase for furniture rental starting in 2020 at stores in Europe, North America, India and Australia. With this pilot, IKEA aims to test the durability, ease of assembly/disassembly and transportation of its products. **Rent the runaway**, a rental service provider for high-end clothes, entered a partnership with **West Elm**, a furniture manufacturer and retailer in 2019 to expand its operations into furniture rental. Subscribers from Rent the Runway now have access to set products from West Elm for bedroom and living room furnishings. By partnering with start-ups, furniture corporates are offering their products for rental without having to adapt their digital platform and business model or extend their logistics capabilities.

4.4.4 Key learnings

For rental models to be successful, customer acquisition and retention costs need to be minimized. Start-ups need to understand their target demographic and ensure customers are engaged to overcome these costs. Given the relative novelty of furniture rental, start-ups need to develop and test different pricing models to find the best fit for their demographic, particularly as sharing models gain traction and changing lifestyles support their adoption. Factors such as base cost of furniture, furnishings, design service, last-mile delivery, assembly, relocation and exchange services all need to be taken into account when pricing each product. Start-ups need to work out their optimal offering between price and other services offered with the product. The cost of wear and tear combined with the fluctuating value due to changing trends also needs to be calculated and taken into consideration.

Bad debts or write-ups are another hurdle facing rental start-ups, as checks need to be put in place to ensure customers can pay regularly and care for the products rented out. For example, Feather has opted to use credit score checks to evaluate its customers before approving transactions, but for non-American-based start-ups, the hurdle remains.

The emerging success and adoption of furniture rental shows that there is a business case to move away from linear economy models in general. This is particularly relevant given the straightforward nature of traditional long-term ownership. Coupled with the advantages of incorporating a circular economy and promoting sustainable goals, the sharing economy seems set to not only to stay but to grow in the coming years.

4.5 Beyond use: closing the loop with circular wood strategies

Once furniture products are sold and used, they often follow a linear process: 10 million tonnes of furniture are discarded by businesses and consumers in EU Member States each year, the majority of which is destined for either landfill or incineration (EEB, 2017). Circular economy interventions have the potential to help counter these trends, with repair, refurbishment and remanufacture allowing value recovery, economic growth and job creation within the European furniture industry.

4.5.1 Framing wood practices with circular strategies

In order to limit its environmental impacts, several circular strategies can support businesses from the forest-wood value chain. Adapted from the Lansink ladder which ranks waste management approaches according to their environmental impacts, the 9Rs circular strategies offer various approaches to implement concretely circular thinking (Figure 10).

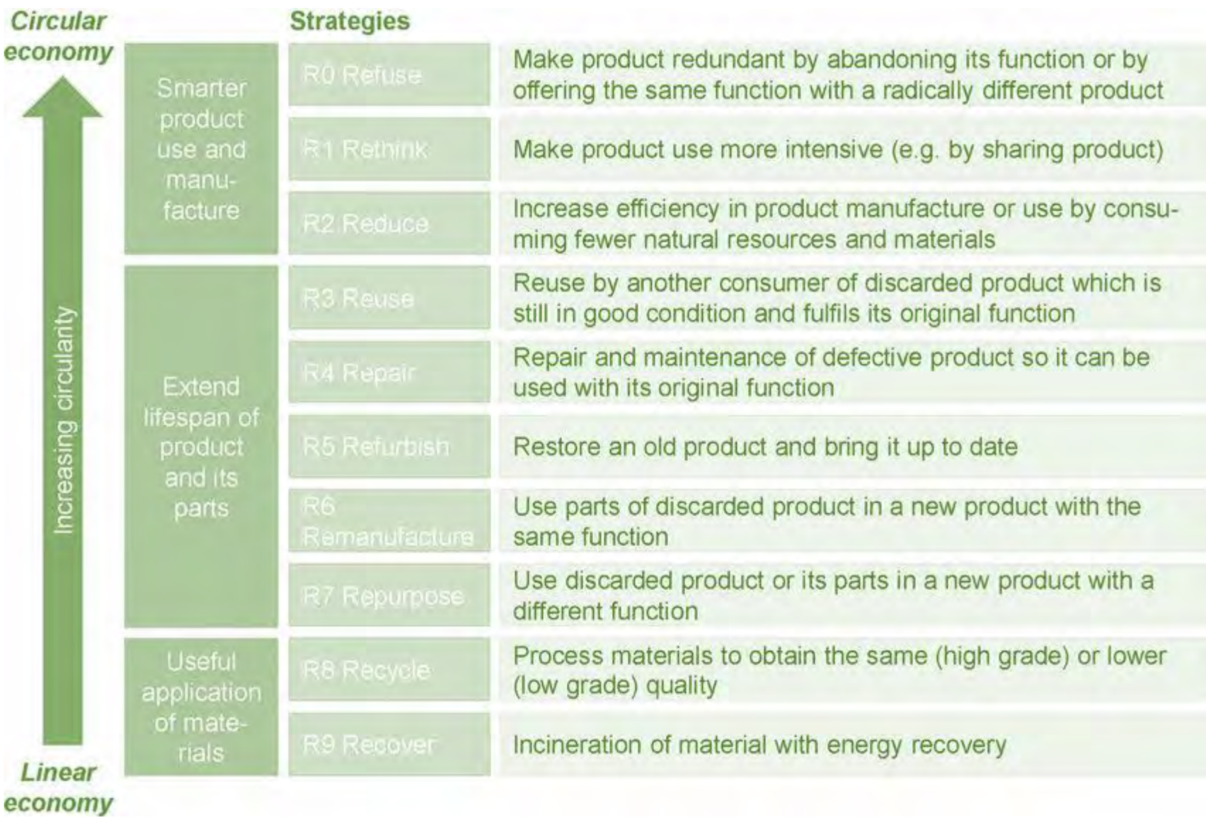

Figure 10: 9R Framework on the Circular Economy (Potting et al., 2017)

Refuse, Rethink and Reduce (R0 – R2) are the shortest loops in the R-framework. They eliminate the waste as the design stage itself through strategies like smart manufacturing, designing for disassembly, or material passports for the building products.

As an example of wood products taking a REFUSE and RETHINK approach. **Raimund Beck** produces wood-based nails (*Lignoloc wooden nails*) which perfectly integrate wooden constructions. In the future, the nails will not need a different treatment than the construction which will facilitate reusing and recycling.

Reuse, Repair, Refurbish, Remanufacture, and Repurpose (R3 – R7) are the medium loops in the R-model. These are applied to extend the lifespan of materials. Think of what might happen to the materials once the owner discards the building as waste. The doors, windows, service installations, and even furniture are flexible compared to the building structure. If dismantled carefully, they can be reused elsewhere for the same or different purposes. Although the recovered products may not be compatible with the new technology and market standards, repairing, refurbishing, or remanufacturing can elongate the material lifespan. In the timber and furniture industry, several REUSE initiatives are currently being implemented As an example, the French Ministry of Ecological Transition has created **Valdélia**, a company that collects professional furniture and organises their reuse by other companies. Extending the life cycle of a product through Repair/remanufacturing can also generate value for furniture companies**.** For instance, **Tricoya** produces acetylated fiberboard using the **Accoya** modified wood, which was originally wood used for outdoors installations.

Recycle and Recovery (R8 – R9) are the longest loops in the R-framework. Compared to other R-strategies, these do not maintain the original structure or value of the product and can be re-applied anywhere. As an example, **Westerkamp** produces wood-based flour that can be used in the food industry as well as in the construction sector. In order to facilitate the use of recycled wood, the **FSC Recycled Label** guarantees that a product is really produced with reused or recycled wood (or paper). This label was introduced to recognize the fundamental role of recycling/reuse of paper and wood for the protection of forests (FSC, 2022). Recycling wood can be complicated as wood is often mixed with many substances (some of which can be toxic) which makes the process very difficult (WoodCircus, 2021). This demonstrates the importance of wood traceability in order to collect data related to each product.

4.5.2 Circular economy certifications emerging practices: Certifying the reused wood product & materials

With the scale-up of "old-new" circular products in the furniture & wood sectors, consumers would need to be certain of the circular origin of their products. A circular mass-market industry therefore needs certifications to make sure the content and amount of reused or recycled material is legit.

Currently it may be difficult to distinguish real reused products with "fake reused" ones that look refurbished but are brand new. This has led to the emergence of circular furniture manufacturers establishing bottom-up certificates.

Truly Reclaimed for instance, is a peer-reviewed certification for refurbishing shops specifics to wood, with a use of a QR code to let consumers know of the previous life of the products they're buying.

Circular Reliability is an upcoming certification project developed by three local Belgian companies focusing on deconstruction processes in the Brussels region. Its objectives are twofold: gain customers' trust on their reused construction-related products (including wood) through transparency; develop new professions in the field of recovery, treatment, recovery and re-implementation of materials.

Those examples emphasise the value of trust gained through certification and product passports, further explained in the following section.

4.5.3 Emerging practices linking CE with digitalisation: tracking within a circular value chain

Digitalization can help improve access to information on the characteristics of products sold in the EU and enable a circular-based approach. **Digital product passports (DPP)** are intended to provide consumers with vital information on the products that they use– they collect data on products' value chain by clearly defining the materials within these products and outlining aspects such as their origin, safety, repairability, and recyclability. On a long-term basis, the aim of DPPs is to boost sustainable production, facilitate the transition to a circular economy, and provide new business opportunities, as well as allow authorities to corroborate businesses' compliance with legal requirements. Essentially, it is meant to act as an inventory of all materials used, which will aid consumers in making sustainable decisions and provide them with all vital information on the **right to repair**. In 2021, the EU established a new initiative requiring companies to make their products reparable for ten years after coming into market, further establishing a means to transition into a general sustainable behaviour.

Tracking materials through digital passports across the value chain might tackle three barriers identified within *closing the loop* challenges for the furniture sector (EEB, 2017), namely:

1. A poor demand for second-hand furniture: tracking materials and products will enhance customers' trust on the bought products;
2. Furniture is not managed in accordance with the waste hierarchy: eco-design and tracking will help reuse, refurbish product or upcycle some materials,
3. High cost of repair and refurbish: reducing time spent on it's end of life refurbish and upcycling through a better knowledge of the refurbish and upcycling potential

DPP innovative approaches thus help tackle the reliability of sustainable commitment and compliance with regulation, such as: chemicals used, carbon footprint, social impact, fair trade, certification and legal regulations (Circular Hub, 2021).

Today's DPPs are mainly based on two approaches, each of which is illustrated by an example:

1. **QR codes**: **Truly Reclaimed** provides a good example of basic information that figure on every material QR code associated with the furniture: geographical origin, deconstruction conditions of wood, previous usage of wood, environmental costs avoided through the reuse of wood. Those are indeed relevant information for materials. For products, extra information on spare parts, on dismantling process guides/best practices, and on different parts' material composition might further enhance such pioneering twin-transition certificates.

2. **Blockchain**: **ForestChain**, a blockchain tracking passport that includes the location the product is from, the different actors that worked on it, shipping, etc. in order to track sustainable practices with reliability.

The evolution towards a closed loop wood industry will need a double mindset shift from the manufacturers perspective:

- **Step 1:** Eco-designing wood products, to ensure a refurbished/upcycled end-of-life of product and materials;
- **Step 2:** Eco-design based on tracked refurbished material meeting the quality demanded, in order to close the loop.

A passport will support **Step 1** being put in place and provide visibility to product designers to put **Step 2** into motion (Figure 11).

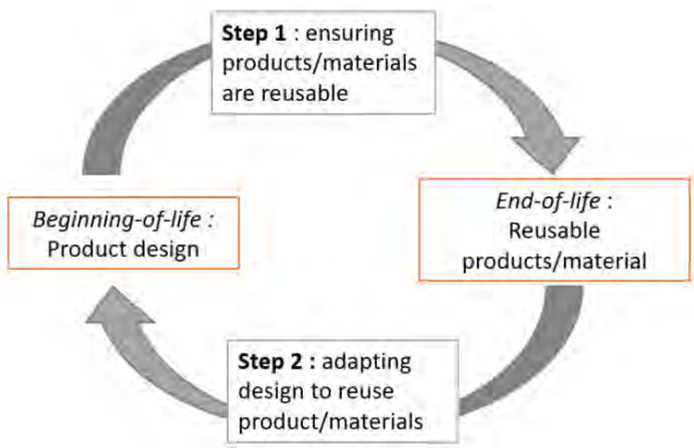

Figure 11: a two-step challenge to enhance closing the wood industry loop through eco-design

At practical level, the Swedish furniture industry has decided to jointly take the step of exploring what a product passport for increased circularity might look like. Together with the research institutions Chalmers Industriteknik and Rise, Antrop has recently started the project: "Product pass as an enabler for circular furniture flows" which runs over two years and has been granted support from Vinnova (Vinnova, 2021). The goal of the project is to create one or more product passports that will be tested in real life. In addition to creating user-friendly solutions for sharing the information, the project will also explore the type of additional information that can make the development of circular business models and services possible.

4.5.4 Circular approach of wood, an interwoven discussion with the Construction and Furniture sectors

Since wood-based products are linked to both furniture and construction sectors, product passports will enhance material exchanges between the two sectors, especially from the construction sector to the furniture one. Hence figure 11 above also applies in an intersectoral approach: eco-design in the construction sector will help the furniture anticipate the arrival of reusable wood materials on the market, at the end of its first "*end-of-life*" in the construction sector. The reused wood in the furniture will in turn need to anticipate its further use at the design face, in order to close the loop.

4.5.5 A holistic approach of sustainability, linking environmental aspects, CE with social fairness

Narrowing the Transition challenges to circularity and digitalization are certainly too restrictive in order to reach a "liveable world": a holistic approach for the wood industry transition would also include a **social dimension** such as **Fair-trade** products.

As an example, **Rec'Up label** has been set up for the furniture sector (including wood) to guarantee the refurbished and social aspects of products: the label has been set up by a social economy federation in Belgium, **ResSources**, to help its members to gather visibility product's quality, namely on circular and social criteria; the social company's accreditation is composed of 120 criteria list, and is controlled by a committee with public and quality control stakeholders.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Key learnings

Industry 4.0 is revolutionising the way companies manufacture, improve and distribute their products. Manufacturers are integrating new technologies, including Internet of Things (IoT), cloud computing and analytics, and AI and machine learning into their production facilities and throughout their operations.

This fourth industrial revolution presents great opportunities for the forest-wood-furniture value chain: Sensor's development, high computing capacity, industrial internet (Internet of Things, IoT) and learning algorithms can allow a much better handling of uncertainty and material variability.

As European SMEs of the wood and furniture industry must adapt to evolving legislations and standards at the international, European and national levels, the use of new, more sustainable technologies can allow companies to reduce their environmental impact according to new standards without increasing costs.

More than any other, the wood and furniture industry faces issues related to the management of natural resources. Dozens of certifications, labels and management systems are being offered to the industry to highlight and improve their environmental performance.

By implementing intelligent systems and new production processes, European SMEs can optimise usage of raw materials, improve their waste management and contribute to the development of a circular economy. This digital and green transition however will not be implemented if the staff among the value chain does not acquire the right knowledge and skills on the value offered by industry 4.0 in developing more sustainable management practices.

5.2 Recommendations and next steps

As part of the INTRUST project, the findings of this report will be organised in a training curriculum that should address the fundamentals of an integrated green and digital transition. The following conceptual knowledge should be highlighted at the core of this curriculum:

- *Understand the current challenges of forest-wood value chain from a sustainable perspective*
- *Have an exhaustive understanding on how the concept of industry 4.0 can be implemented in the forest-wood-furniture value chain*
- *Understand the current EU regulation surrounding the green and digital transition of the sector*
- *Recognize, prioritise and select the right environmental certification to monitor and improve environmental performance.*
- *Recognize, prioritise and select the key enabling technologies supporting a twin - green and digital transition*
- *Apply the concept of circular economy throughout the sector's value chain to generate sustainable value for the SMEs, the environment and society at large.*

These key learnings will be organised and detailed further in the next phase of the project.

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ANNEX 1: OVERVIEW OF CAPACITY BUILDING PROJECTS RELEVANT TO THIS STUDY

Several EU projects are focusing on the training of students in the **twin transition** in a **multisectoral environment**, providing students with green and digital skills in the business framework:

- Building Virtual Learning Platform for environmentally friendly Digital Transformation Management
- Single Market & Competition Law in the Digital and Ecological Transition Era
- Improved digital and sustainable future of young people in Europe through enhancing diversity and developing transformative skills and skills of the future
- BECOMIN. Being in Continuous Innovation and Growing

The following trainings are relevant to take into account when developing an integrated twin transition curriculum for the forest-wood-furniture industry:

- **Twin transition learning in furniture industry**

WOODIGITAL. Dual Learning for Improving Digital Skills of Young Woodworkers

Programme: Erasmus+ 2020-1-FR01-KA202-080104

Coordinator: INTERPROFESSIONNELLE AUVERGNE RHONE ALPES (France)

Start: 01-10-2020- End: 30-09-2022

Abstract: The Woodigital project aims to develop a digital training course to reduce the gap in digital skills specific to the **wooden furniture sector**, which is still very high in European countries today. Training courses will be developed that address the needs identified by companies in the sector, such as:

- **Circular economy** and sustainability
- **Digitization of processes and new technologies**
- Understanding of new lifestyles;
- globalization;
- New market trends and personalized customer orientation.

WOODigital will first identify the digital skills and competencies needed by young people who work or are interested in working in the wood and furniture sector.

INTRIDE. Soft, Digital and Green Skills for Smart Designers: Designers as Innovative TRIggers for SMEs in the manufacturing sector

Programme: Erasmus+ 612622-EPP-1-2019-1-IT-EPPKA2-KA

Coordinator: UNIVERSITA DEGLI STUDI DI FIRENZE (Italy)

Start: 01-01-2020- End: 31-12-2022

Abstract: INTRIDE aims at developing new innovative and multidisciplinary approaches and tackling future skills mismatches. In terms of specific results INTRIDE aims at:

- developing a Joint master's degree Curriculum for Smart Designers with added competences related to Soft**, Digital and Green Skills** that will become the future innovation triggers for SMEs in the **traditional manufacturing sector**

- building a co-creation structure under a HE-industry community platform which is supposed to be a virtual place for activation and monitoring of innovation, technological transfer, R&D processes under the cooperation between enterprises, HEIs and technical centres.

The project is oriented towards traditional manufacturing sectors, but two of its partners are entities related to the **furniture sector.**

SAWYER project: identifying skills and safety needs for the furniture sector's circular transition

Programme: European Commission call: Support for Social Dialogue VP/2018/001

Coordinator: CENFIM (Spain)

Start: 02/2020 - End: 03/2021

Abstract: The SAWYER project aims to facilitate the transition of European **furniture companies** to a more circular economy. The project ran from February 2020 to March 2021, studying the main legislative and voluntary instruments that can facilitate this **circular economy transition**. It also analysed how these instruments are expected to impact and transform the European **furniture sector** by 2030, alongside the **digital transformation ("twin transition").** Lastly, SAWYER will study how this transition can affect existing jobs, workers' health and safety risks, and their new training needs. The final report will be available in 10 languages.

The main results are:

- Mapping the state of play of circular economy legislative and voluntary instruments in the European furniture sector
- Identifying how the circular economy and digitalisation ("twin transition") could affect jobs and tasks
- Preparing recommendations for legislators and regulators, as well as Vocational Education and Training providers.

EQ-WOOD. Quality Qualifications for the European Woodworking and Furniture Industry

Programme: Erasmus+ 612622-EPP-1-2019-1-IT-EPPKA2-KA

Coordinator: UNIVERSITA DEGLI STUDI DI FIRENZE (Italy)

Start: 01-01-2020- End: 31-12-2022

Abstract: The project EQ-Wood tackles innovation capacity and competitiveness of **EU wood and furniture industry** by designing and delivering the curriculum of Innovation Advisor in the Wood and Furniture Industry. It helps managing innovation by merging **green, digital and marketing skills** and provide learners with specific competences required by the sector evolution in Europe.

FUNES. FURNITURE NEW EUROPEAN SKILLS 2020

Programme: Erasmus + 2014-1-ES01-KA202-004883

Coordinator: Aidimme (Spain)

Start: 09/2014 - **End:** 08/2017

Abstract: FUNES will generate a interrelationship among various the new skills demanded in the **furniture sector in** the future years, a system to evaluate whether a worker of this sector has the **future skills,** and a specific training material that will be generated in order to facilitate the acquisition of these specific skills, **recommending about the soft skills neededed** by the current and future workers for this sector. The training material generated will be in e-learning format to facilate the training at worplace or in a VET centre.

As a result of conducted work, new skills and competences were selected like environmental awareness; applying **the environmental and sustainability concepts** (incl. ecological concepts in the design of products and 'zerowaste' design) or the use of computers and the rapid development of **digital technology** and robotics

- **Digital transition learning in furniture industry**

DITRAMA – Digital Transformation Manager

Programme: Erasmus+

Coordinator: CENFIM (Spain)

Start: 01/01/2019 - **End:** 31/12/2021

Abstract: leading companies in Furniture value chain to implement their digital transformation strategy DITRAMA aims to provide an innovative MOOC for training managers (Digital Transformation Managers) to successfully lead and implement the **digital transformation** in furniture companies along the whole value chain

Digifind - Enhance Adult Learners Digital Skills for Furniture Industry

Programme: Erasmus+

Coordinator: UNIVERSITY OF NATIONAL AND WORLD ECONOMY (Belgium)

Start: 01/09/2018 - **End:** 31/08/2021

Abstract: The project aims to support adult trainers in acquiring the necessary competences for teaching **digital skills and Industry 4.0** to low-skilled adults in **Furniture industry**, in order to guarantee the future furniture sector sustainable development and to foster their employability, socio-educational and professional development. The objectives include developing a training program for trainers, educational materials, and innovative instruments for supporting the training on **digital skills for low-skilled adult employees in Furniture sector**.

- **Green transition learning in furniture industry**

ECO4VET - Improvement of Vocational Education and Training related to Ecodesign in the Furniture Sector

Programme: LEONARDO 539774-LLP-1-2013-1-ES-LEONARDO-LMP

Coordinator: CENFIM (Spain)

Start: 01/12/2013 - **End:** 31/03/2016

Abstract: The lack of an official curriculum on ecodesign and sustainable production directly affects the traditional manufacturing furniture industry, which is dominated by microenterprises (86% of EU enterprises have less than 10 workers) as their designers, production, purchasing and logistics staff, managers and responsible of management systems are not fully supported with these skills. The size and structure of these EU furniture companies do not help adapting the workers to these new requirements (legislation, environmental, market). Furthermore, taking into account the recent consolidation of **ISO 14006 regarding ecodesign**, it is necessary to address the training needs of the different enterprises that want to implement it.

ECO4VET aims at addressing the identified **educational gap in the furniture sector** developing tools and methods for **training workers in "Ecodesign and Sustainable Production".**