D.2.7 Mapping the European wood education community

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Abbreviations

Abbreviations

BSc: Bachelor of science

ECTS: European Credit Transfer and Accumulation System

EQF: European Qualifications Framework

EU: European Union

GDP: Gross Domestic Product

HE: Higher Education

MSc: Master of science

PhD: Doctorate degree

RTO: Research and Technology Organisation

VET: Vocational Education and Training

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Executive summary

Executive summary

The wood industry is a cornerstone of the European economy, contributing significantly to various countries' gross domestic product (GDP). This sector consists mainly of small and medium-sized enterprises, reflecting its wide-reaching impact in terms of number of enterprises, turnover, and employment. Despite its importance, the wood industry faces challenges such as a notable deficit of skilled workers. Addressing these issues through robust quality programmes for education and training is essential for the industry's sustainability and prosperity.

In this context, we carried out this mapping study of the educational community that supports the wood industry at the higher education (HE) level. The aim was to identify as many wood related HE institutions and study programmes as possible across Europe. The purpose is to provide an overview of the size of this educational community, to highlight other disciplines involved, to show current study possibilities at the bachelor's, master's and PhD level, and to point out key characteristics of wood HE programmes. In addition, the aim is to create a coherent methodology that allows for regularly updating the findings. As wood products become increasingly important within the green transition, the industry will have to undergo significant changes in the coming decades, and skills and education will play a key role. Overall, this study was driven by the need to better understand the graduate profiles of students, and to gain insights how educational offers align with current and future industry needs.

We developed a 3-step identification methodology that is hands-on and practical timewise, so that it can be reapplied for regularly updating of the data and analysis. In 2024, we found 154 institutions active in wood education. In total, these offer 400 programmes of which 158 are bachelor's, 173 are master's and 69 are PhD programmes.

Wood is a complex raw material resulting in a vast range of products such as furniture, multistorey buildings, paper products, or even highly innovative applications such as computer flat screens. Wood is studied from various perspectives and at different levels, from the macroscopic to the molecular scale. This diversity is reflected in the range of programmes available, from very applied to highly theoretical, from highly specialised wood science programmes to broader interdisciplinary programmes where wood plays a supporting role. Thus, understanding the breadth of wood education involves considering a wide array of disciplines and study approaches. Moreover, today's educational landscape is dynamic and evolving. More recent programmes with promising titles such as "Green Building Engineering" or "Renewable Raw Materials" are emerging in many institutions.

In this study, some HE institutions and study programmes may have been overlooked - especially when considering broader and other disciplines where wood is one component, but not the core topic. Indeed, such HE institutions and study programmes are numerous, and it is difficult to verify all of them: the threshold up to which a certain programme can be considered "sufficiently relevant for the wood sector" remains to be defined. Simple criteria, such as setting a minimum number of ECTS credits directly related to wood, appear not to be very pertinent and quite time-consuming for verification.

One of the most important conclusions of this study is to further promote networking and cooperation between wood HE institutions and to actively involve those institutions that include wood as one component, but not the core topic (e.g. civil engineering, architecture, materials science). Moreover, all institutions should clearly present the existing wood related education and training opportunities for potential applicants. The two main challenges we encountered were missing information in English and the fact that because of the vast scope of application of wood, HE institutions rarely present their wood related programmes together. In contrast, they are often scattered across departments and using the search term "wood" on their websites rarely lists all programmes.

Future research should include surveying wood HE institutions to gain insights on evolving graduate profiles. It is further key to track the wood HE programmes mapped in this study over time to better understand the changes and adaptations of the study content and course profiles to new emerging topics in the context of the green and digital transition.

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Introduction

1. Introduction

1.1 Context and objectives

The wood industry in Europe plays an important role in the economy by contributing around 3% to the EU gross domestic product (GDP) [1]. For instance, in France, the sector contributes €28,7 billion, accounting for 1.1% of the GDP [2], while the entire French industrial sector represents 17% of the GDP [3]. Similarly, in Germany, the industry adds €55 billion in value, representing 2% of the GDP [4], while the entire German industrial sector represents 27% of the GDP [5]. The European Union's wood industries include woodworking, furniture manufacturing, construction, pulp and paper production, biorefinery, packaging and printing and extends across several NACE classifications while for some the limitations remain vague [6] (e.g. NACE Rev. 2 codes 02, 13, 16, 17, 31 and others). Hence, to provide an overview in terms of size and relevance it is helpful to count together NACE divisions 02 (forestry and logging), 16 (manufacture of wood and products), 17 (manufacture of paper and products) and 31 (furniture) even if e.g. furniture can also be produced excluding wood: In 2020, the EU counted around 393,000 enterprises in these 4 groups, accounting for 19% of all manufacturing enterprises. This highlights the dominance of small and medium-sized businesses. In terms of employment, wood industries employed 3.6 million people across the EU in 2022, making up 10.5% of total manufacturing employment [7].

However, the wood industry in Europe faces significant challenges, including a skilled labour shortage [8, 9, 10, 11] and the need to adapt to evolving consumer preferences and technological advancements [12]. Additionally, many professionals are nearing retirement, creating a knowledge and skills gap that threatens the industry's future [13].

Addressing these issues through robust quality programmes in education and training is crucial for the industry's future. To support the wood industry's role in the sustainable transition, it is essential to attract the new generation and offer updated educational programmes that incorporate the sector's digital and green transformation. Vocational education and training (VET) programmes and higher education (HE) curricula are critical for developing the necessary skills and competencies.

The European wood education landscape is integral to the continent's cultural, economic, and environmental landscapes and regions. For millennia, wood has been a crucial element in European history, serving as a material for buildings, tools and products, energy source, and artistic medium. Skills and knowledge in woodworking have been passed down through generations, first and foremost by historical guilds and trade associations protecting and developing the knowledge of wood-related crafts. Today, this legacy continues through vocational schools, technical universities, research centres, and other institutions. These organisations offer educational programmes that enhance appreciation for wood, foster innovation, and promote sustainability in wood-related sectors. As the wood industry continues to evolve in response to global challenges and prospects, wood education will continue to play a central role in shaping the future of this important industry.

Therefore, an understanding of the current wood education and training landscape in Europe and its further evolution is essential. Existing programmes must meet both current and future industry

demands while also being attractive to students. Today, beyond seeking good career prospects, students often value mobility, flexibility, and a sense of purpose, such as contributing to a more sustainable future.

Mapping wood HE institutions and study programmes across the EU is a crucial first step in understanding the landscape of wood related higher education. This will help identify the necessary actions to address the challenges mentioned earlier. There have been similar studies in the past, but recent data are not available. In 2010, a list of 37 European HE institutions offering curricula in wood science was published, with a particular focus on Eastern European institutions [13]. This list serves as the starting point for our mapping.

The objective of this study is to provide an overview of the educational community that supports the wood industry at the higher education level. The aim was to identify as many wood related HE institutions and study programmes as possible across Europe. The purpose is to provide an overview of the size of this educational community, to highlight other disciplines involved, to show current study possibilities at the bachelor's, master's and PhD level, and to point out key characteristics of wood HE programmes. In addition, the aim is to create a coherent methodology that allows for regularly updating the findings. As wood products become increasingly important within the green transition, the industry will have to undergo significant changes in the coming decades, and skills and education will play a key role. Overall, this study was driven by the need to better understand the graduate profiles of students, and to gain insights how educational offers align with current and future industry needs.

1.2   Scope and definition of wood related higher education

There are many definitions of the forestry and wood industries, varying in scope, but a standardised definition is not available. Forestry is classified separately in economic systems (e.g. NACE), while the wood industry spans multiple sectors (e.g., wood-based construction is part of the broader construction industry). An overview that has been used to study the economic impact of the forestry and wood industry in Europe in terms of the bioeconomy provides a four-step successive definition [15] (Figure 1):

Forestry: all goods and services related to the provision of wood (e.g. planting, rearing, harvesting).

1. Wood industry in the narrowest sense: forestry plus all sectors that purchase inputs directly from forestry (sawmills, paper and paperboard, …).

2. Wood industry in the narrow sense: wood industry in the narrowest sense plus all sectors receiving intermediate consumption from enterprises included in the narrowest definition (furniture, publishing, …).

3. Wood industry in the broader sense: wood industry in the narrow sense plus all sectors that purchase inputs from companies in the narrow sense or are thematically linked to timber industry (wholesale, retail, administration, research, recycling, …).
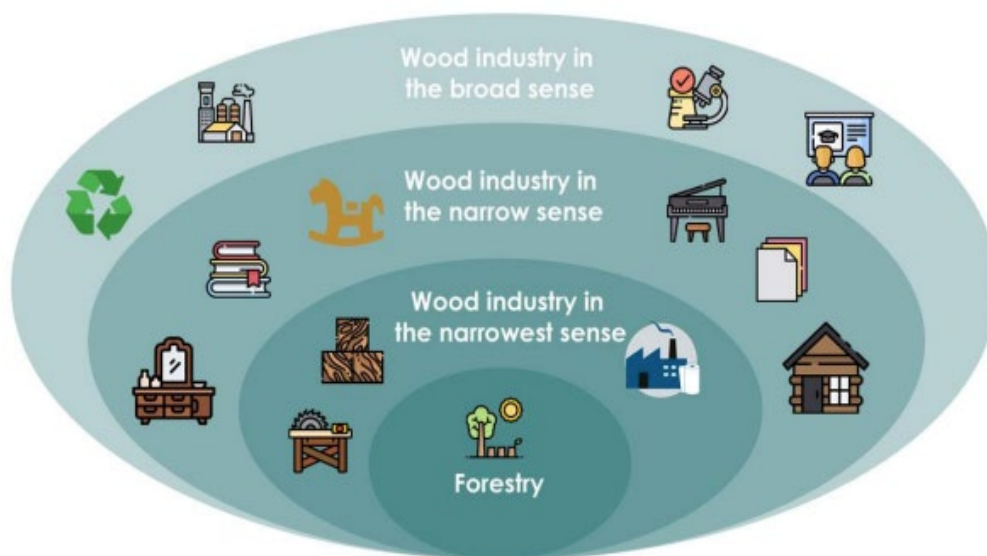

Figure 1: Four-step definition of forestry and wood industry. (source: Econmove GmbH).

Definition of the **wood sector** in this study:

This study focuses on 3 "wood industry in a narrow sense", but excluding the forestry and pulp and paper industries, as these are considered distinct areas for educational purposes. Thus, the wood industry in our scope encompasses sectors that directly obtain materials from forestry, such as sawmills, and all sectors that utilise the goods and services produced by these primary industries (wood-based panels, furniture, specialised construction work, civil engineering, architecture, chemical products, textiles, manufactured goods (e.g., musical instruments, toys, skis)). Accordingly, the terms **"wood education"** or **"wood HE programmes"** are used when referring to wood related bachelor's, master's or PhD programmes. The acronyms BSc/MSc are used for bachelor's and master's degrees (EQF levels 6-7) everywhere, even if in a few cases e.g. BA (Bachelor of Arts) would be correct.

Definition of 2 groups of **wood HE institutions**:

Institutions involved in wood HE education are divided into two main groups both of which offer bachelor's and/or master's degrees and/or doctoral programmes. **Group A** comprises those that offer academic programmes (at least one) where **wood is a primary focus** preparing students specifically for careers in wood industry and research (these institutions remain in group A even if they may also offer programmes that correspond to group B). **Group B** consists of institutions that offer academic programmes where **wood is included as part of a broader topic or another discipline** e.g. forestry, materials science, civil engineering, architecture, sustainable construction, environmental engineering, biorefinery, bioeconomy management, etc. The term "**wood related higher education *landscape***" was used to refer to all higher education institutions and programmes across Europe involving a large community of professionals, knowledge and skills providers, teachers and learners.

Definition of wood related study programmes:

Aligned with the definition of the 2 groups of HE institutions, wood related study programmes can be classified into **6 categories**: bachelor's, master's or doctoral programmes *either* where wood is a **primary focus**, e.g. wood engineering, preparing students specifically for careers in wood industry and research *or* where **wood is included as part of a broader topic or another discipline** e.g. forestry, materials science, civil engineering, architecture, sustainable construction, environmental engineering, biorefinery, bioeconomy management, etc.

The mapping spans a total of 41 European countries. All 46 to 49 countries with entire or partial territory in Europe have been considered. However, for some countries, our capacity for identifying wood HE institutions was limited and may have led to underestimations in terms of number of institutions and study programmes (cf. Chapters 2, 3 and 4). The mapping further **focuses on HE** (Bachelor and Master of Science, and PhD) and **excludes organisations active in VET and higher VET** (i.e. *professional* training up to EQF level 6). Research and **Technology organisations (RTOs) are excluded** as well because they cannot deliver degrees.

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2

Methodology of mapping

2. Methodology of mapping

To establish a coherent methodology for the continuous assessment of the higher education landscape related to wood science and industry, a three-step approach was designed with the aim to identify as many wood related higher education institutions and study programmes as possible in Europe, addressing the sector as defined in Chapter 1.2: "wood industry in a narrow sense", but excluding the forestry and pulp and paper industries. The three-step approach intends to search from different angles (identification steps) to go beyond the limitations of a single method.

2.1 Step 1: Identification of HE institutions

Step 1.1: Mapping institutions from studies and databases

The first phase of the mapping involved compiling a list of HE institutions already well known for their contribution to wood education, starting from the list previously established by Barbu et al. [14] in 2010 and compiling it with InnovaWood contact database.

Step 1.2: Scanning of conferences and consortia

Expanding our search, we included institutions from participant lists from key wood-related conferences and industry forums, such as the International Research Group on Wood Modification, the European Conference on Wood Modification, European Wood-based Panel Symposium, the World Conference on Timber Engineering, International Wood Construction Conference, Northern European Network for Wood Science and Engineering, the WoodRise Congresses, and wood related European project consortia.

Step 1.3: Scanning of scientific publications

To go beyond the institutions found in steps 1.1 and 1.2, and for aiming institutions where wood is not a primary focus, ResearchGate, a social networking site for scientists, was used to generate a compilation of publications between 2019 to 2024. We used the term "wood" in English as the only keyword in order to test the method and limit the number of search results (restricted to articles, literature reviews, and academic theses). From each publication, we listed all authors' affiliations to identify relevant institutions and departments.

Step 1.4: Scanning HE institutions per website search

For countries not appearing from the previous steps, we scanned the internet and websites of HE institutions through common search engines aiming to obtain the most complete overview of wood HE institutions.

2.2 Step 2: Identification of wood study programmes

Each identified institution's website was reviewed to verify the availability of wood study programmes and confirmed through the study programme descriptions. Information such as the names of the programmes and the level of education was collected and added to our database. This process ensured that the database contained accurate and up-to-date information across Europe.

2.3 Step 3: Validation of the database

Step 3.1: Cross-validation with national experts

Our database was then cross-validated together with Allview partners and InnovaWood members from eight different countries: Belgium, Denmark, France, Germany, Italy, Netherlands, Poland, Slovenia, Spain, United Kingdom. Each partner reviewed the database entries corresponding to their country, commenting on and confirming the accuracy and completeness of the listed institutions.

Step 3.2: Cross-validation using ChatGPT

The final cross-validation step consisted in asking ChatGPT for each country "list all wood related higher education programmes". The results were verified per website search.

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3

Results and discussion

3. Results and discussion

3.1 Wood related HE landscape in Europe

As of 2024, a total of 154 wood HE institutions were identified in Europe. Figure 2 shows the sizes of groups A and B defined in Chapter 1.2. 64 institutions (group A) offer HE programmes at the bachelor and/or master and/or PhD levels (at least one) in which wood is a primary focus and at 90 institutions (group B) wood is included as part of another or broader discipline. Figure 3 shows their distribution across Europe.
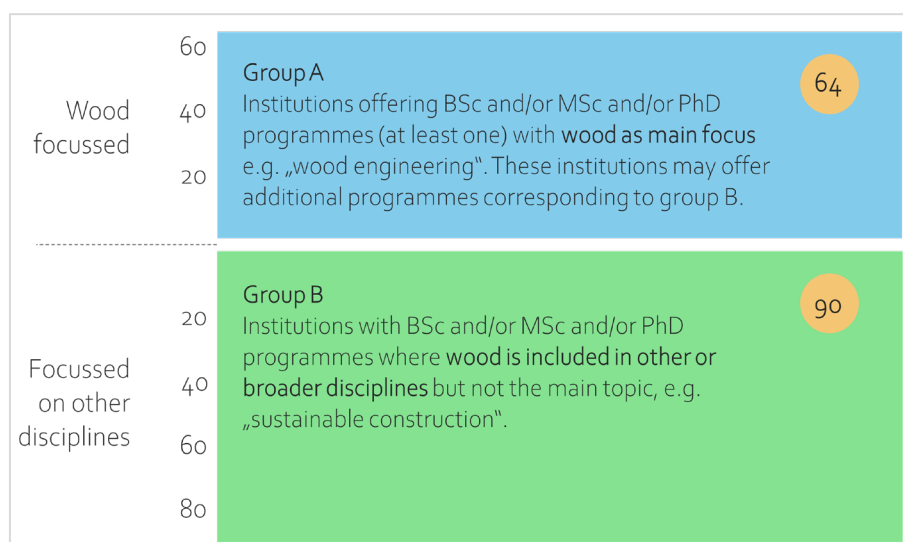

Figure 2: 154 wood HE institutions in Europe in 2024. 64 belong to group A offering at least one programme with main focus on wood and 90 belong to group B offering programmes where wood is included in other or broader disciplines.

The detailed scan for wood study programmes on each institution's website (identification step 2) revealed that their involvement into wood education varied significantly within each group. We observed a high diversity in ways of strategic positioning of HE institutions and an increasing inter- and cross-disciplinarity of study programmes. Therefore, classifying them into more groups than A and B might have entailed allocation issues because the information available online is too limited.

Still, the division into groups A and B helps to provide a broader picture of the diversity and extensive areas of application of wood, which entail very different approaches to studying wood. Indeed, wood is a complex raw material resulting in a vast range of products such as furniture, multistorey buildings or even credit cards and computer flat screens; if not used as a material it can be used as fuel, be it for conversion into electricity or heat.

Moreover, with the ongoing sustainable transition from a fossil-based industry towards a more circular, renewable, carbon neutral and digitalised economy and society, the importance and the roles of forests and wood change fundamentally. For instance, the substantial carbon storage

capacity of wood products is becoming a major issue in science, industry and on the policy level. In this context, the groups indicate:

1. the overall capacity for wood HE on EQF levels 6-7 (BSC/MSc) and EQF level 8 (PhD)
    →   groups A+B

2. the capacity of HE where wood is in the very centre, providing "core wood expertise"
    →   group A

3. the capacity of HE where wood is connected to other disciplines and where it can "play out" its versatility and relevance in multiple sectors and in the context of the sustainable transition
    →   group B

Hence, the division into groups reveals the sizes and ratios between the groups and also allows for tracking the changes over time to assess in what way this landscape of wood higher education is evolving. Chapter 3.2 looks at this structure more in detail and from an educational pathway perspective.
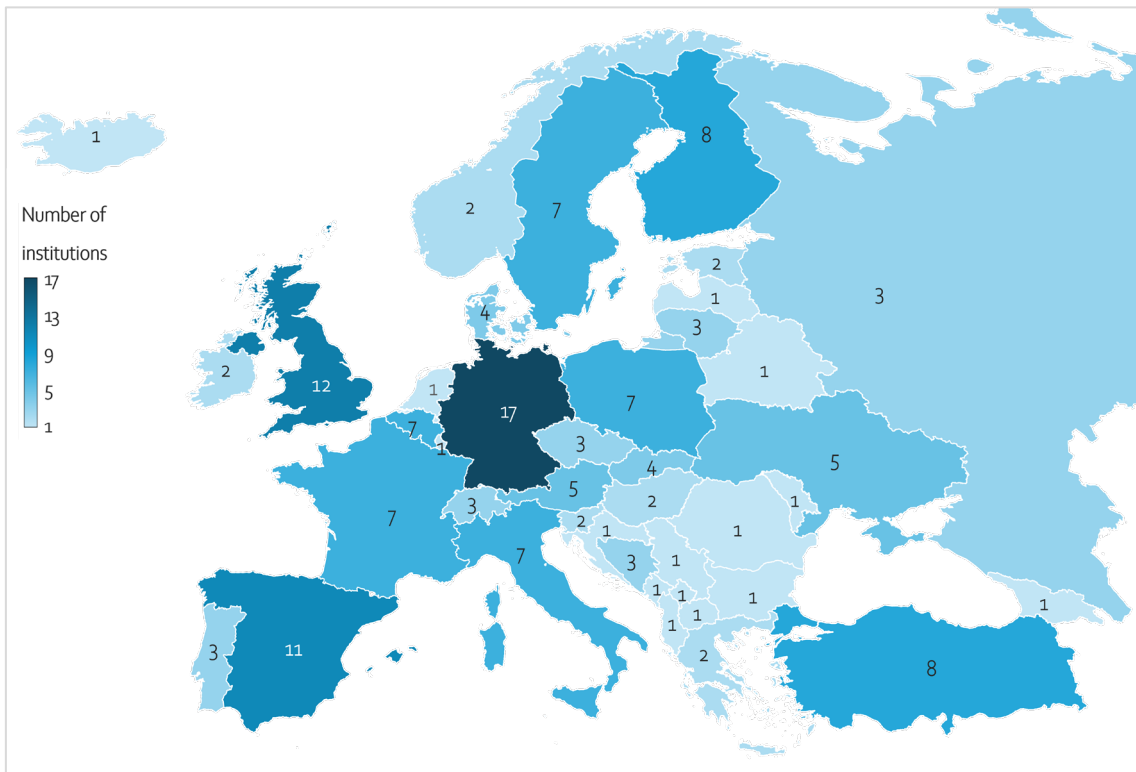

Figure 3: Number of wood HE institutions per country in 2024. 154 across Europe.

3.2 Wood HE programmes

Offer of wood HE programmes

For the 154 HE institutions of groups A and B a total of 400 wood related study programmes were identified. 158 bachelor's, 173 master's and 69 PhD programmes. Figure 4 shows the ratios between them and is split between programmes focussing mainly on wood (upper range, e.g. "wood engineering") and those programmes where wood is included in other or broader disciplines but not the main topic (lower range, e.g. "sustainable construction").
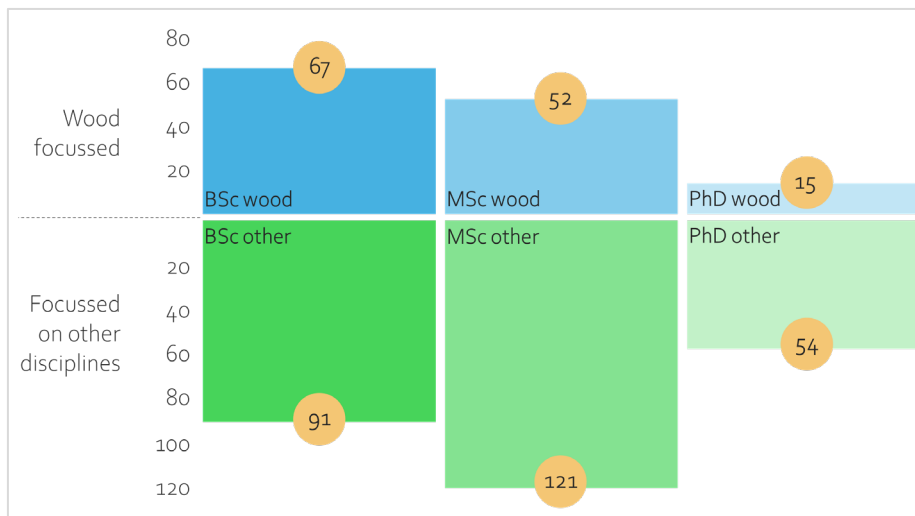

Figure 4: 400 wood study programmes in Europe in 2024 split by level (BSc, MSc, PhD) and between those focussing mainly on wood (134, upper blue range, e.g. "wood engineering") and those where wood is included in other or broader disciplines but not the main topic (266, lower green range, e.g. "sustainable construction").

The overall ratio between the upper and the lower range is 1 to 2 indicating both robust wood focussed HE and wood being widely anchored as a topic in other disciplines. Within the wood focussed study programmes, the largest group being BSc programmes followed by slightly less MSc and a few PhD programmes, shows *general* coherence with industry needs (i.e. more middle than upper management). MSc programmes of other disciplines being the most numerous of all mapped wood related study programmes corresponds to the fact that in other disciplines wood is a specialisation that comes after having acquired the basic knowledge of a discipline (i.e. BSc programme). Further interpretation of these data is limited as this assessment does not include additional information such as the number of graduates per programme.

Wood related PhD programmes that are described on the HE institution's websites have been included into this study. However, their number does only indicate how many wood related PhD programmes were identified, it should not be interpreted as an indicator of the number of universities where wood related PhDs can be awarded. Indeed, if funding is available, wood related PhD studies are basically possible in all universities that do research on wood and fulfil the general criteria that enable them to deliver the degree. Moreover, wood PhD students can also follow more general PhD programmes (these often account for only about 20% of their workload).
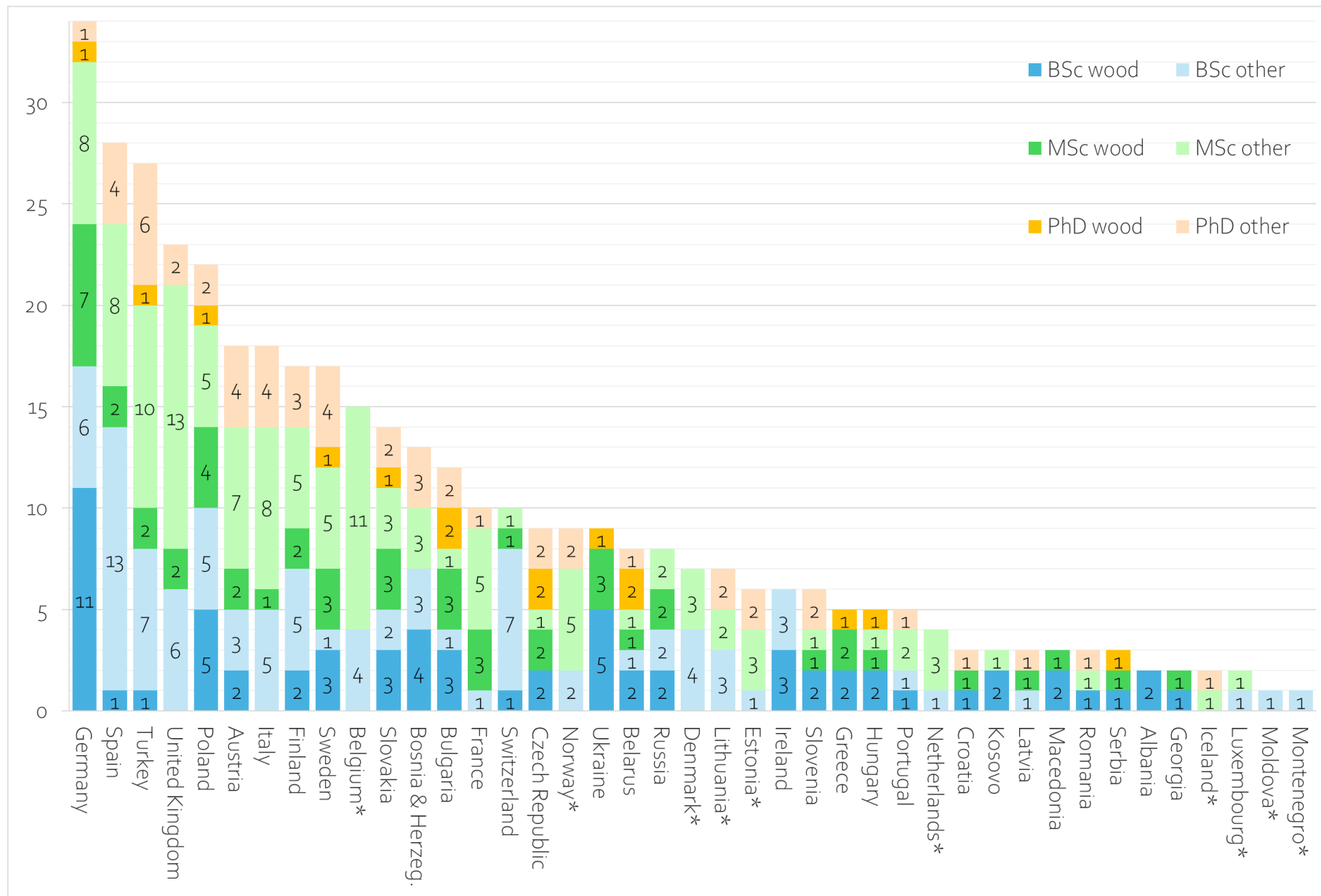
Figure 5: Number and level (BSc, MSc, PhD) of all wood HE programmes per country in Europe in 2024. Countries marked with * do not provide study programmes that are mainly focussed on wood.

Figure 5 shows the total number and distribution of wood related BSc, MSc, PhD per country across Europe. It provides an overview of the ratios between foundational education at the bachelor's level, advanced studies at the master's level and scientific studies at the PhD level. Wood HE is addressed in very different ways across Europe and the data do not allow to conclude which is the best to attract students and meet industry needs. In some countries wood focussed programmes prevail, in other countries wood is more widely integrated into other disciplines. Of all 154 institutions, 3 provide wood related PhD programmes only, but no BSc or MSc.

Further characterising wood HE programmes on a general level is key for both: for the students when considering possible wood education pathways and for HE institutions for their strategic positioning. On this general level, 2 dimensions are fundamental: "theory vs. practice" and "wood vs. other disciplines" (Figure 6). Beyond these 2 general dimensions, the diversity on a study programme level remains very high. A closer look at the study programs and names (Figure 7) provides notions of possible education pathways leading to competency profiles that could be qualified as an engineer, technical expert, business manager, sustainability expert, designer, etc. all focussed or related to wood. Lastly, the parameters EQF level and the aimed management level (middle or upper) as well as industry or research oriented remain decisive, too.

Theory vs. practice

In wood HE, two primary strategies stand out: the "theory-first" approach and the "practice-first" approach. Each of these strategies offer distinct advantages and align with different educational philosophies and industry needs. The theory-first strategy emphasises foundational knowledge, with a strong focus on scientific principles, engineering concepts, and material properties. This method prepares students for e.g. research and innovation by providing a deep understanding of the theories governing wood technology. Conversely, the practice-first approach integrates hands-on experience from the beginning, immersing students in real-world applications such as woodworking and carpentry (while remaining on HE level). This method, often seen in bachelor programmes, makes students immediately valuable to employers and enhances engagement by showing direct applications of their work. While theory-first programmes are ideal for those aiming for advanced research and diverse roles, practice-first programmes suit students eager to enter the workforce quickly and with more practice focussed skills.

Balancing theoretical knowledge with practical experience is crucial for the comprehensive education of future professionals in wood technology. To ensure this balance, HE institutions' wood programmes often have their doors open to an increasing number of students coming from vocational training VET. Furthermore, institutions, sometimes incorporate elements of both approaches, providing students with a well-rounded education that includes both rigorous theoretical coursework and ample practical training. This hybrid approach can ensure that graduates are not only skilled and knowledgeable but also adaptable and ready to meet the evolving demands of the wood industry.

Wood vs. other disciplines

The groups A and B and the levels BSc, MSc, PhD help illustrate the diversity of educational pathways, ranging from the "core type" with specialised wood expertise and the "interdisciplinary graduates" who bridge wood with other disciplines. Hence, in addition to the "theory vs. practice"

dimension, graduate profiles can be characterised through the "wood vs. other disciplines" dimension based on their educational background and expertise.

Core type graduates are highly specialised and well-equipped to address sector-specific challenges in industry and research. Interdisciplinary graduates from e.g. civil engineering, materials science, architecture, or forestry have a solid understanding of wood-related concepts, such as structural applications, material performance, and environmental impact, but within the context of their discipline. They can bridge the disciplines and bring a valuable perspective to the wood industry, applying their broader technical knowledge to wood-related projects or vice-versa. Their ability to integrate wood solutions within larger systems or multi-material projects makes them essential for roles that require cross-disciplinary collaboration. Of course, a given graduate profile described through "theory vs. practice" and "wood vs. other disciplines" (Figure 6) can also be a result of combinations of elective modules within a given study programme or of different consecutive study programmes e.g. a BSc in civil engineering followed by an MSc in timber structures.
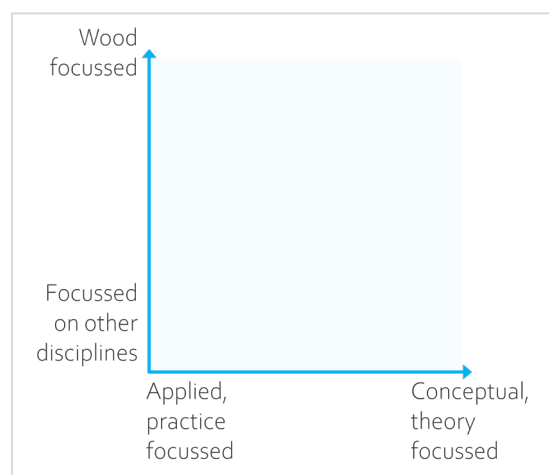

Figure 6: Matrix for general characterisation of wood HE programmes by the 2 dimensions "theory vs. practice" and "wood vs. other disciplines". To be considered by students for their education pathways and by HE institutions for their strategic positioning.

Wood higher education pathways

Figure 7 provides an insightful overview of terms used in the titles of all mapped BSc and MSc study programmes (i.e. excluding PhD). Most program titles are rather broad. "Wood Technology" is the most frequently used term with 45 programmes in 14 countries (27 BSc and 18 MSc). These programmes generally focus on the technical aspects of wood processing, material properties, and technological advancements in wood utilisation. "Wood Science" is represented by 11 programmes in 7 countries (4 BSc, 7 MSc), focusing on the fundamental properties of wood, its biological and chemical characteristics, and its applications. The greater emphasis on MSc programmes in "Wood Science" reflects the advanced knowledge and research focus required in this area. Wood scientists seek to understand the structure of wood from molecular to macroscopic levels, as well as its relationship with other materials and its response to various treatments and environmental conditions. Research in wood science often informs advancements in wood technology and engineering practices.
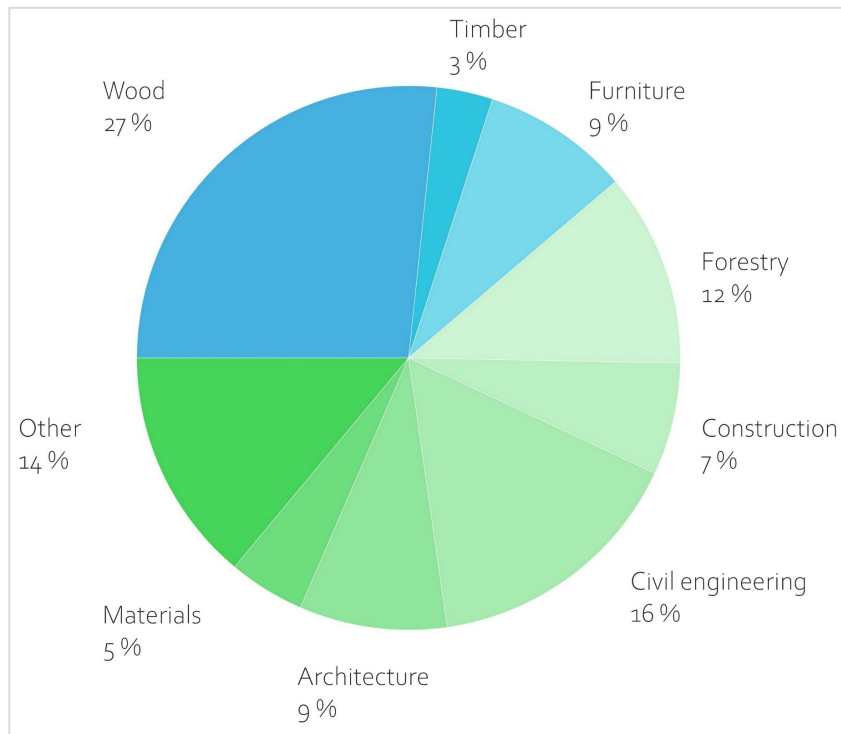
Figure 7: Terms used in the titles of wood BSc and MSc programmes (n= 330 programmes, excluding PhD). Section "Other" includes terms related to technical disciplines (e.g. biology, chemistry, engineering) and to management and design (e.g. sustainable, green, ecological, renewable, design).

Wood studies intersect with other disciplines in various ways, from the development of new wood-based materials to the integration of wood in sustainable construction practices. For instance, the forestry programmes often focus on sustainable forest management, conservation, and the supply chain of wood products, ensuring that future professionals understand the entire lifecycle of wood from the forest to the final product to recycling. This holistic approach is crucial for promoting sustainability within the industry. The inclusion of wood-related research in these diverse disciplines underscores the versatility and relevance of wood in multiple sectors. This contributes significantly to the body of knowledge in wood science and technology, often collaborating with industries to address current challenges and explore new opportunities for the wood sector.

More specific programmes, often tailored to a particular industry's needs, can also be found. For example, there are 9 programmes in Architectural Engineering/Technology and 6 in Timber Construction, signifying the integration of wood in architectural design and structural engineering. These fields are essential for developing sustainable, wood-based construction practices. In Furniture and Woodworking, there are 18 programmes focusing on the design and craftsmanship of wooden products. These programmes preserve traditional skills while incorporating modern and circular design principles. Wood Materials/Products/Chemistry is covered by 31 programmes, emphasising the properties of wood, composites and the development of new wood-based products. These areas are crucial for innovation in wood composites and bio-based materials.

Finally, the word "Sustainability" in the titles of 31 programmes reflects the growing importance of sustainability in construction and engineering practices. The wood sector is becoming increasingly

concerned with ecologically responsible production methods, waste reduction, and the use of locally sourced resources. As environmental concerns develop, young Europeans have the opportunity to design sustainable products, aiming to decrease the sector's negative environmental effects. This includes developing circular economy by reducing waste and promoting the reuse and recycling of materials.

Prospective students searching for wood-related programmes might need to use a variety of keywords to uncover the full range of available options (Figure 7). If they search using the term "wood", they will likely find about 60% of the programmes including programmes with closely related terms in their titles such as "timber", "forestry", or "furniture". Terms such as "construction", "civil engineering", "architecture", and "materials" are sometimes associated with wood education and account for another 20% of the programmes. For the remaining 20% of the programmes, wood is not directly advertised in the programme title or overview description. These programmes may fall under broader fields like materials science, civil engineering, or architecture, where wood is integrated as a key element but not the main focus.

3.3 Reflections on the mapping methodology

The objective of this study is to provide an overview of the educational ecosystem that supports the wood industry at the higher education level aiming to identify as many wood HE institutions and wood related study programmes as possible in Europe. The results rely on the three-step approach presented in Chapter 2 which was meant to search from different angles (cf. identification steps) to go beyond the limitations of a single method. As a result, this is the most comprehensive study published to date, counting 154 institutions offering 400 wood-related study programmes.

However, eventually all searches end at the individual study programme descriptions on the institution's websites. In many cases, these are difficult to find because of the vast scope of application of wood: HE institutions seldomly present their wood related programmes together. In contrast, they are often scattered across departments and using the search term "wood" on institution's websites rarely lists all of them. Especially study programmes of other disciplines that include wood were difficult to identify (often in the fields of forestry and construction/architecture). This most probably results in a substantial underestimation of the number of such programmes that include wood as a studied topic. Besides being too numerous to verify all of them, the threshold up to which a certain programme can be considered "sufficiently relevant for the wood sector" remains to be defined. Simple criteria, such as setting a minimum number of ECTS credits directly related to wood, appear not to be very pertinent and quite time-consuming for verification. This entails that we might have overseen some programs that are "sufficiently relevant for the wood sector" and vice versa that we have listed some that are of rather limited relevance.

In the context of web search, it must also be addressed that we cannot exclude bias through search language, browser search profiles, habits of website designs, habits of structuring content etc. This is complemented by the fact that exchange with national experts representing all 46 to 49 European countries with entire or partial territory in Europe was not possible due to our limited capacity in terms of human resources and time to identify programmes that are not or barely described in

English. This goes hand in hand with the number of keywords for searching and using mainly English language (combined with automatic browser website translation in some cases).

Identification step 1.3 using Research Gate helped identify many institutions doing research on wood or wood connected topics. We used the term "wood" in English as the only keyword in order to limit the number of search results, because it is time consuming to separate them into those HE institutions who provide wood related study programs and those who do not. Only about 10% of more than 700 search results were related to HE institutions providing wood related study programmes. However, related to the obvious focus on *research*, this method helped identify many institutions of group B that are less directly connected to wood *education*. Hence, this method is a useful complement to the website search (step 1.4).

The final crosschecking step using ChatGPT (step 3.2) did not identify additional HE institutions. On average, around 70% of the results of all previous steps were confirmed, and these were found more quickly. However, in comparison to the data from all previous steps, the completeness per country varied between 10% and 100% of wood HE institutions found. Moreover, using the exact same search question with different user profiles provided different answers. About 20% of the ChatGPT findings could not be confirmed by subsequent website search (institutions did not exist or were situated outside the aimed country).

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Conclusions

4. Conclusions

The educational HE framework supporting the wood industry in Europe extends well beyond institutions with specialised wood programmes. Given the complexity of wood and its wide range of applications, it can be studied from multiple perspectives, spanning from macroscopic to molecular levels, from very wood specific to broad topics such as "sustainability management". Combined with a range of educational programmes taking a more applied or a more theoretical approach, this diversity makes wood a broad and multi-dimensional field of study.

This study presents a detailed overview of the European wood related higher education landscape. Overall, distinguishing between wood HE institutions of groups A and B provides valuable insights into the developments in wood education. It shows the shift from traditional, specialised wood programmes to broader and other disciplines such as bio-based materials or architecture. This reveals two strategic positioning approaches of wood HE institutions: most of group A continue to focus on wood science and technology, maintaining the traditional "*wood* identity". In contrast, those of group B gradually embed wood education within wider interdisciplinary fields, most often connected to the sustainable transition. Accordingly, newer programmes are emerging with titles such as "Green Building Engineering" or "Renewable Raw Materials", which, although not explicitly titled as wood-related, may predominantly focus on wood and its manifold applications, especially in buildings. On the one hand, these broader programmes help students to better understand the relevance of their studies, and they are potentially more attractive to a larger group of young people choosing their study topics, and obviously aim to make a choice linked to a sense of purpose. On the other hand, the "*wood* identity" of more traditional wood science degrees creates a stronger sense of belonging to a community of professionals and a more direct connection to the wood industry.

Related to these strategic positioning approaches is the fact that wood is becoming part of a broader "sustainability narrative". Indeed, the wood industry increasingly prioritises sustainability, environmental impact, renewable and circular resources, including topics such as green building practices, biomaterials science and carbon storage. This shift underscores wood's importance as a sustainable material, but it also raises the possibility that wood science and technology programmes could decline as wood becomes one of many materials studied within the context of environmental solutions or multi-material systems. Hence, on the one hand, the "sustainability narrative" allows wood to play a pivotal role in emerging industries focussed on sustainability and eco-friendly materials. On the other hand, there is a risk that wood's unique properties and applications may become less emphasised within these broader academic frameworks, potentially leading to a decline in the number of specialised knowledge carriers although these are essential for the right decision making when using this complex material. For better understanding in what way wood education is adapting to these changes and whether it remains a core discipline or becomes part of a more generalised approach to bio-based materials, it is key to track how groups A and B develop over time (Figure 2).

The scope of this study was limited to BSc, MSc and PhD. However, the total wood HE and VET education landscape is much bigger and includes other degrees such as national diploma and different formats of more short-term continuing education courses provided by a variety of

institutions and companies. As a European initiative should be mentioned the New European Bauhaus Academy (NEBA) that aims to train, upskill, and reskill the construction ecosystem to achieve a carbon neutral building sector and a beautiful, sustainable, and inclusive transformation of the built environment. It is delivering courses through regional and thematic Hubs of institutions that are already involved and well anchored in national and regional education and training ecosystems. This decentralised Academy aims to become the European point of reference for skills and knowledge on bio-based, circular and digital solutions in construction. Hence, it is a new overarching initiative that will connect many of the HE institutions mapped in this study and contribute to more integrated wood education across Europe.

One of the main conclusions of this study is to further promote networking and cooperation between wood HE institutions and to actively involve those institutions that include wood as one component, but not the core topic (e.g. civil engineering, architecture, materials science). Moreover, all institutions should clearly present the existing wood related education and training opportunities for potential applicants. The two main challenges we encountered were missing information in English and the fact that because of the vast scope of application of wood, HE institutions rarely present their wood related programmes together. In contrast, they are often scattered across departments and using the search term "wood" on their websites rarely lists all programmes. The developed 3-step methodology proved to be successful though and can be reapplied for regular updates of the findings.

In total, we identified 400 wood HE programmes including 158 bachelor's and 173 master's programmes in 154 institutions. About a third of these programmes primarily focus on wood (delivered by group A institutions) and about two-thirds are connected to other disciplines (delivered by group A and B institutions). Hence, for the wood industry, the pool of graduates can be divided into 3 types of candidates:

1) a core group specialised in wood matters,

2) a group from broader or other disciplines that has a good idea about wood,

3) candidates from all other disciplines not considered in the present study who match the skills needs.

Obviously, the numbers of wood related HE programmes do not allow to conclude for the total number of students. However, in general, such study programmes tend to host less than 100 students and, in many cases, even less than 30 students per year. This indicates a comparatively low total number of students but a geographically vast network of research and education across Europe, with representation in 41 countries – a solid foundation to build upon.

Overall, this study highlights the complexity and interdisciplinary nature of wood education and research in Europe. The presence of dedicated wood programmes, active research teams, and the integration of wood studies into broader fields all contribute to a robust academic framework that supports the wood industry's efforts to be competitive, innovative, and sustainable. The community is well connected, nationally and internationally, which facilitates students' mobility and collaborative work between institutions.

Future research should involve further analysis of the study programmes identified in the mapping, including their development over time. On the one hand, this concerns the competency needs of the wood sector, and on the other hand, this concerns the study programme content and strategies to attract students. Better understanding of the current situation and understanding the evolution would be very valuable to anticipate trends towards new profiles, as well as potential future bottlenecks for the sector. This could include:

- **Curricula**: Examine how curricula change over time and identify emerging trends in wood education. This includes new courses and programmes that have been introduced, for instance those focusing on sustainability and innovative wood applications. With the evolving profile of the 'traditional wood science student', an overall balance needs to be achieved between new topics and traditional core subjects (e.g. wood anatomy) that must be maintained within academic programmes.

- **Student enrolment and demographics**: by analysing enrolment data, we can track student numbers, and demographics, understand the popularity of wood programmes and identify trends such as regional, national, international student origin, gender, skills background, the effect of study programme reforms, etc.

- **Industry alignment**: It is crucial to evaluate how well these educational programmes align with the needs of the wood industry and in what way they anticipate ongoing and future developments.

- **Employment outcomes**: Understanding the career paths of graduates from wood programmes will provide insights into the effectiveness of these programmes in preparing students for the job market. This includes tracking employment rates, types of positions secured, and sectors where graduates are employed.

- **Institutional challenges and innovations**: Identify any challenges that institutions face in delivering wood education, such as funding, resource availability, and technological advancement and competition with other disciplines. This should also highlight innovative practices and successful strategies implemented by institutions to overcome these challenges.

- **Expand mapping methodologies:** The scanning of scientific publications on Research Gate (identification step 1.3) proved to be a useful complement to the website search. In addition, it showed the potential for further exploitation using other search terms, other bibliographic databases and expanding it for instance to map wood related research institutions including their overlap with HE institutions.

- **Continue to explore the opportunities in tools based on artificial intelligence AI**: Although in this study the contributions of AI have been very limited (identification step 3.2), AI is improving very fast and could largely facilitate future mappings. Furthermore, AI tools will most likely become the main search tool for potential students.

Periodical updates will enable continuous monitoring of the educational landscape. Doing so would ensure that the programmes remain relevant and effectively contribute to the development of a skilled workforce capable of meeting the demands of the wood industry, particularly in the context of the Green and Digital transition towards a sustainable and carbon neutral society.

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