FTP Strategic Research and Innovation Agenda 2040 (FTP SIRA 2040)

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p	Promoting health, safety & consumer comfort	1. Offer consumers functional products and comfortable living	1. Designing high-performance functional products for textiles, packaging, hygiene and medical applications
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w			3. Innovating next-generation smart and sustainable wood interiors
w			4. Developing new modular building systems
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p		2. Solving challenges related to Substances of Concern (e.g. for REACH)	6. Developing and validating biobased additives and alternatives for biocides
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f+w+p			11. Upgrading jobs and organisations to an era of Artificial Intelligence (AI)
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p	Cutting emissions and energy use for climate mitigation and competitive advantage	4. Provide renewable energy for processes and society	13. Delivering innovative, renewable heating and cooling solutions for a recilient society
p			14. Producing advanced low-carbon transport fuels from biomass side-streams
w+p			15. Scaling up on-site renewable energy generation
p		5. Make significant energy and emission savings in production processes	16. Integrating smart drying and heat-recovery systems for energy-efficient production
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w		6. Achieve negative GHG emissions	20. Quantifying and enhancing carbon storage in bio-based materials and construction
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f+w+p	Optimising raw material and resource efficiency to boost productivity in Europe	7. Boost resource efficiency	22. Optimising biomass use by mastering its natural quality variations
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f			38. Empowering small-scale forest owners with new tools, services and innovation pathways
f			39. Co-developing next-generation forestry machines and tools with equipment manufacturers
f+w+p			40. Forecasting material flows and market dynamics to guide future decisions
f+w+p			41. Mobilisation and valorisation of low value biomass from the forest and beyond
f		12. Develop non-wood ecosystem services and forest governance	42. Expanding business opportunities for non-wood forest **products**
f			43. Unlocking additional value from non-wood ecosystem **services**
f			44. Enhancing forest-derived benefits for urban and peri-urban communities
f			45. Planning for forest expansion under changing land use and climate conditions
f+w+p			46. Improving forest governance through impact assessments and analysing policy coherence
w+p	Future-proofing processes across the value chain; AI, digitalisation, and robotisation	13. Diversifying production technologies and logistics	47. Adopting and advancing additive manufacturing technologies such as 3D printing
f+w+p			48. Enhancing traceability and chain-of-custody along extended value-chains
f+w+p			
w+p		14. Adopting AI and digitalisation for advanced processing	49. Deploying autonomous and electrified systems across the forest-based value chain
f+w+p			50. Applying software-driven energy management and digital twin solutions for process excellence
f+w+p			

Mission 1. Promoting health, safety and consumer comfort

The focus of this mission is innovations and research that lead to improvements of forest-based consumer products and precursors to consumer products.

OBJECTIVE 1: Offer consumers functional products and comfortable living

The objective is straightforwardly to develop better products. As meeting rapidly changing consumer expectations is fundamental to commercial success, the forest-based sector needs to invest more and smarter in its research and innovation. As most of the core products of the sector are mature and largely optimised, radical performance gains through conventional means are unlikely. The most promising innovation pathways are therefore adding new functionality to existing materials and pioneering innovative data sharing and digital applications that add value to the product for the consumer.

A distinctive challenge stems from the forest-based sector's unusual breadth. Because forest-based materials appear in everything from clothing to high-rise buildings, the sector rarely sells directly to end consumers. Instead, it mainly operates upstream, supplying materials or semi-finished products to other industries who handle branding and market contact. This means consumer insight is often filtered through intermediaries, making it harder to innovate with the end user in mind.

Action 1. Designing high-performance functional products for textiles, packaging, hygiene and medical applications

Research on the functionalisation and optimisation of fibre-based products, such as textiles, packaging, hygiene and medical products, focuses on adding advanced properties, for instance anti-microbial properties, moisture management, barrier performance, fibre modifications or sensing capabilities to renewable materials. This is crucial for consumer acceptance and for expanding the use of bio-based sustainable alternatives in high-performance and regulated applications where functionality is key. Examples of specific research questions include how to achieve durable and safe functionalisation using bio-based chemistry, how to maintain recyclability and processability, and how to scale these solutions cost-effectively for industrial use.

Action 2. Advancing Engineered Wood Products and Composite Materials

Engineered wood products are manufactured by fixing wood particles, fibres or sheets of wood together with different adhesives, or by modifying wood by physical or chemical processes. Recent advances in the material sciences - from nano to macro scale - allows for completely new products and composites that far out-perform traditional materials in terms of carbonneutrality, low weight and high-insulation factor. Adapting existing production processes to new wood species and developing composites of wood in combination with other materials, including renewable materials such as hemp and straw is also important avenues for research.

Products and adhesives that are intended to be used in construction, must be carefully verified for their fire behaviour. For new products and materials to be commercially viable, the production process must be efficient and economically feasible and preparations for future standardization and certification must start at an early stage. This action requires competences in many areas and good knowledge-sharing between different stakeholder groups, making collaborative research efforts particularly valuable.

Action 3. Innovating next-generation smart and sustainable wood interiors

Although wood used indoors is protected from the weather, durability is still a major issue. Wood flooring, panels and furniture face wear and tear from daily use and must be designed to last for decades.

Indoor wood must appeal to multiple senses; touch, smell, and influence on acoustics, all contributing to the overall impression and comfort. The provision of high quality and aesthetics start in a modern and efficient factory process.

Continuous studies of indoor air quality (humidity, temperature etc) and the effect of different volatile organic compound (VOC) are needed to satisfy questions on public health.

To make products with circularity in mind, new indoor wood products need to be designed for improved reusability and repairability as well as for end-of-life disassembly when possible.

Fire safety relies on active systems and passive protection (charring, fire-retardant coatings). Modern mass timber and engineered wood products are designed to char, creating a protective layer that slows burning, often outperforming steel. However, certification and testing are expensive, and public financing would help speed up market uptake.

Action 4. Developing new modular building systems

Wood-based building systems using modular and prefabricated concepts perform superior in view of non-renewable construction systems. They are lightweight, energy efficient, green, renewable, flexible and allow for extremely fast assembly at the construction site. However, due to the huge variety of wood-based products and the many ways they can be assembled, dimensioning of wooden construction systems is far more complex than systems for non-renewable materials. Building with wood systems are often company-specific, creating a very complex market for customers, designers and architects.

There is a clear need for European multi-stakeholder cooperation in the development of new sustainable building systems to advance their uptake by the construction sector in different countries. A market that is particularly suitable for modular wood building systems is solutions for build-up extensions of buildings and the fill up the gaps in dense communities and provide.

Lean manufacturing processes that are more resource efficient and building systems that compare better on complex attributes, such as indoor climate, fire or acoustic performance, need collaborative research and demonstration efforts.

Action 5. Strengthening partnerships across the building lifecycle

This action focuses on improving the integration of wood in modern construction through better interoperability between digital platforms for design and manufacturing. With the goal of enhancing the overall benefits of living and working in a wood building environment.

Tasks include development of BIM (Building Information Modelling) libraries for wood, digital twin simulations, parametric design tools, and updating structural calculation methods in Eurocodes. Another important area to investigate and develop practical solutions for is Digital Product Passports. Efforts in this action should also support the standardisation of performance criteria and data formats.

Broader uptake depends on expanding the pool of architects, engineers, contractors and developers who are familiar with wood buildings and hybrid constructions. New models for knowledge-sharing are needed to cut across traditional professional boundaries.

OBJECTIVE 2: Solving challenges related to Substances of Concern (e.g. for REACH)

Stricter health and environmental regulations make finding substitutes for several important compounds (or independently verifying their non-hazardous nature) a pressing objective for the forest-based sector. The creosote example illustrates the problem well. Used as wood preservative since the mid-nineteenth century, its use has been banned in the EU since 2023, with creosote-treated wood now classified as hazardous waste. Industry reports indicate that especially for heavy-duty applications (railway, utility poles), few, if any, viable market-ready alternatives exist.

Solving this challenge requires coordinated research into alternatives. Developing robust testing and certification pathways for these alternatives is equally important, as the absence of recognised standards is itself a barrier to market adoption. Where suitable alternatives do not yet exist, the forest-based sector has an opportunity to lead their development, turning a regulatory constraint into a competitive advantage.

Action 6. Developing and validating advanced bio-based additives and biocide alternatives

Bio-based additives are essential for enhancing the functionality, durability, and sustainability of materials across various applications. Biocides are used to protect products and processes against harmful organisms, with key roles, e.g. in extending the lifespan of wood in construction, runnability of paper machines. There is an urgent need to replace fossil-based and potentially hazardous substances with safe, sustainable bio-based alternatives. Research is needed to explore how wood-based and forest-derived compounds could offer effective, non-toxic functionalities for applications such as preservation, surface protection, and antimicrobial treatments. Advancing this field could position forest bioeconomy as a key provider of next-generation, safe chemical solutions for various industries.

Action 7. Generating innovative wood preservatives and wood treatment technologies

Untreated wood is by its nature biodegradable. Developing new environmentally sustainable and effective solutions for extending the durability of wood products has a very high priority for the woodworking sector.

Research efforts should focus on increased moisture resistance and reducing degradation from biological agents (fungi, insects, etc.) and replacing hazardous substances still in use with non-toxic preservation treatments.

Development strategies might include the application of nano-coatings, pressure treatments, barrier coatings and fireproofing. The task involves testing efficacy, environmental impact, and compatibility with existing processing systems.

Further on, new thermal modification techniques might be used to avoid the use of potentially hazardous substances and might also enhance wood strength, or make the wood product more fire-resistant.

Action 8. Creating high-functionality barrier systems for safe and sustainable food contact materials

Research on functional barriers for food contact materials is essential for enabling the safe and effective use of bio-based packaging solutions. These barriers play a critical role in protecting food from moisture, oxygen, and contamination, while ensuring compliance with strict food safety regulations. There is also an urgent need to replace PFAS and microplastic generating materials. Developing sustainable, recyclable, and industrially scalable barrier technologies is key to replacing fossil-based plastics in high-volume food packaging applications. Major research challenges include, for instance, achieving sufficient barrier performance with bio-based materials, ensuring regulatory compliance, and optimising compatibility with current manufacturing processes.

Action 9. Developing and validating new analytical methods for the forest-based industries and their products

The growing pressure to meet stricter regulatory standards has highlighted the need for advanced cost-effective and fast analytical techniques capable of detecting and distinguishing even trace levels of complex chemicals and materials in forest industry products. This includes challenges in identifying hazardous compounds such as those from the PFAS family and distinguishing them from non-toxic, commonly used inorganic fluorides in paper production. The detection and analysis of synthetic polymer microparticles add to the complexity, especially within bio-based and circular paper product matrices. The goal is to develop robust analytical methods that provide reliable, accurate results and minimise the risk of false positives, ensuring both safety and sustainability in production processes.

OBJECTIVE 3: Securing skilled professionals for purposeful, safe jobs

The future forest bioeconomy depends equally on people and technology. Ensuring competent, motivated, and safe employees requires strengthened collaboration between industry, research, and education in order to develop training that integrates digital skills, interdisciplinary competence, and lifelong learning. As artificial intelligence (AI) transforms operations, human-AI collaboration and adaptive management practices will need to empower workers. Operator safety remains critical, with research into smart protective equipment, real-time monitoring, and robotics reducing workplace risks in hazardous forestry operations. Investing in safety, education, and employee well-being will strengthen the sector's most valuable resource - its people - ensuring a resilient, skilled workforce for the bioeconomy beyond 2040.

Action 10. Adapting training and learning pathways to the needs of the future forest bioeconomy

A skilled workforce is essential for advancing a sustainable and competitive forest bioeconomy in Europe. To secure this, social sciences need to investigate how education can be reformed to better anticipate and respond to evolving labour market demands. Demographic changes and the aging workforce highlight the urgency of making forest-related careers more attractive to the younger generation. This calls for interdisciplinary research, e.g. educational, social and policy-oriented, into how to design forward-looking, relevant learning pathways for future professionals in the forest bioeconomy. The structural and planning challenges for the constructive use of wood should be an integral part of academic training, in order to ensure future professionals are equipped with the skills to design sustainable, wood-based solutions. Key priorities include modernising curricula to integrate emerging technologies and sustainable practices, strengthening industry–academia collaborations to ensure practical training and job readiness, and increasing youth engagement and awareness on career opportunities in the forest bioeconomy. Together, these measures can help ensure that educational pathways are not only aligned with future labour market needs but also appeal to the next generation of professionals.

Action 11. Upgrading jobs and organisations to an era of Artificial Intelligence (AI)

AI has begun to reshape jobs and tasks across sectors and the pace of the AI-revolutions will most likely increase. Every organisation in the forest-based sector will have to reflect on how AI is integrated in job tasks and processes across all its operations and the whole organisational structure and business model might have to change in order to adapt to the era of AI.

This requires strong business leadership with enough technical insight to grasp opportunities and avoid pitfalls. Keeping valuable employees when AI takes over their tasks requires shifting from a strategy of replacement to one of augmentation and re-skilling. Valuable employees possess institutional knowledge, critical thinking, and emotional intelligence that AI cannot replicate, even if AI can perform their daily technical tasks.

This very complicated process should be a subject of intense study and information exchange between FTP stakeholders. Research is needed to identify systemic risks, changing competence requirements, new training models, and support the integration of AI into operational environments such as wood procurement, sorting, quality control and logistics.

Addressing this requires transparent communication, participatory design of AI systems, and continuous upskilling programmes to build trust and demonstrate how AI can increase, rather than replace, human work.

Action 12. Improving operators' safety and ergonomics

Although occupational safety and ergonomics have improved and awareness has increased, many forest-based sector jobs still involve physically demanding tasks, challenging ergonomic conditions, and risk of accidents. There is a clear need for research into how the forest-based sector work environments and tasks can be redesigned to enhance safety as well as physical and mental well-being and job satisfaction. An aging workforce further underlines the importance of addressing ergonomic and safety challenges. This calls for interdisciplinary research combining occupational health, technology, work design and social sciences to develop safe, inclusive and sustainable solutions for future forest work. That includes investing in wearable technology and monitoring systems to enhance operator safety, redesigning tasks and workflows to reduce ergonomic strain, and implementing evidence-based interventions to improve both physical and mental well-being.

Mission 2: Cutting emissions and energy use for climate mitigation and competitive advantage

Climate change mitigation is a central driver of forest-based innovation.

OBJECTIVE 4: Provide renewable energy for processes and society

Europe's forest-based sector is crucial for advancing renewable energy solutions. It is not only a raw material supplier, but also Europe's largest renewable energy producer. Forest residues and process waste streams can be converted into biofuels for hard-to-electrify transports and the sector is actively working to increase the scalability and economic viability of these pathways. The sector also strives to develop sustainable heating and cooling solutions with smart thermal storage, reducing fossil fuel dependence within its own operations but also for surrounding communities and industrial clusters. Every step toward expanding renewable energy production is also a step toward European energy autonomy. Regional circumstances vary and must be taken into account. Northern Europe has access to primary biomass and a strong demand for heat energy in a cooler climate, while the industry in Southern Europe has less locally sourced primary biomass and a growing demand for cooling rather than heating.

Action 13. Delivering innovative, renewable heating and cooling solutions for society

Pulp and paper mills, biorefineries, and sawmills generate excess heat. This industrial excess heat can be distributed through district heating systems, supplying local communities with one of the most carbon-neutral alternatives for heating. At the same time, it offers forest-based industries an additional income stream within a renewable energy system. Creating smarter and more integrated energy systems requires significant infrastructure investments but also innovation and research on how best to integrate with existing energy infrastructure, manage demand fluctuations, and economic viability across seasons and locations. Policy support and public infrastructure investments are crucial to incentivise industrial investments, and innovation should focus on advanced heat recovery and storage technologies, smart energy management systems, and flexible grid integration.

14. Producing advanced low-carbon transport fuels from biomass side streams

In addition to cellulose fibres, wood contains lignin, a high-energy material that is typically removed and incinerated during the pulping process to recover the pulping chemicals. Lignin, however, has the potential to be converted into renewable transport fuels, which are in growing demand as alternative energy sources. To achieve this, efficient processes for separating lignin from pulping chemicals in the black liquor, are required. Research focuses on finding scalable and economically viable methods to convert lignin into transport fuels, with advancements in catalytic processes and chemical engineering being central to this challenge. Lignin's molecular structure varies depending on the type of wood and pulping method used. Therefore, robust conversion processes must be developed that can handle these variations. Other tree components, such as tall oil, can be used to convert to transport fuels.

Action 15. Scaling up on-site renewable energy generation

Pulp mills are already CO_2-neutral through the effective incineration of lignin-rich black liquor in recovery boilers, and other by-products from forest-based industries. Other side streams, such as sawdust, bark, and tall oil, (as well as sludges and solid rejects from paper mills processing paper for recycling) offer additional opportunities for on-site renewable energy production. Emerging technologies such as gasification, pyrolysis, and carbonisation can further improve energy recovery and open up new possibilities for valorising side streams. Biogas from anaerobic wastewater treatment and innovations in solar thermal and geothermal energy provide additional on-site pathways to reduce carbon emissions and enhance energy efficiency. In addition, metal fuels present an opportunity for co-producing steam and electricity without CO_2 emissions, requiring adaptations to current combined heat and power (CHP) systems and access to renewable hydrogen for regeneration. New innovations must significantly improve the cost-efficiency of these solutions and make it economically feasible also for smaller-scale facilities to install them.

OBJECTIVE 5: Make significant energy and emission savings in production processes

Achieving substantial energy and emission savings in the forest-based sector requires innovative manufacturing approaches. By capturing and reusing waste heat throughout production, mills could make dramatic energy savings while turning inefficiency into opportunity. Waterless papermaking has the potential to transform an industry historically dependent on water, cutting energy use and emissions in a single stroke. Electrification powered by renewables is replacing fossil fuels across operations, fundamentally reshaping the energy supply. Meanwhile, breakthrough pulping technologies could offer gentler methods that can match traditional performance while using far less energy and fewer chemicals. Together, these innovations are not just incremental improvements, they represent a complete rethinking of forest-based manufacturing for a carbon-neutral future.

Action 16. Integrating smart drying and heat-recovery systems for energy-efficient production

Drying processes in papermaking are highly energy-intensive, especially due to the large amounts of water that need to be evaporated. There is a significant need to reduce energy consumption while maintaining the efficiency of the drying process. Innovative heat recovery technologies, such as mechanical vapour recompression and heat pumps, can substantially lower the energy required for steam production. However, traditional drying methods are not designed for efficient heat recovery. Further research is needed on developing new drying technologies that allow for better heat recovery from the drying process, such as superheated steam drying or air/vapour separation techniques, which could dramatically improve energy efficiency.

Action 17. Papermaking without water evaporation

Traditional papermaking processes rely on water to form hydrogen bonds between cellulose fibres, a mechanism that has been central to the production of paper for centuries. However, removing this water requires large amounts of energy through evaporation, contributing to high energy consumption. To address this, new technologies are being explored that can isolate water from the wet paper web without the need for evaporation, such as using electric fields or electro-osmosis. Another potential solution is to eliminate water from the papermaking process, although this would necessitate entirely new methods for inducing the necessary hydrogen bonds in the paper fibres without relying on water evaporation.

Action 18. Accelerating process transformation and electrification for low-carbon manufacturing

Unit process optimisation and intensification in papermaking can significantly reduce energy consumption in various stages of production. Advances in mild repulping technologies, more effective fibre refining (e.g. compression refining), and mechanical dewatering can reduce the need for thermal drying, leading to lower energy demand. Furthermore, electricity-based technologies, such as microwave and ultrasound-assisted drying, are being explored as alternatives to traditional thermal drying methods. These innovations offer new ways of increasing energy efficiency while maintaining the required quality and performance of the paper product.

Action 19. Towards mild and efficient pulping technologies

Traditional pulping processes typically require high-energy input, but there has been significant progress in developing milder pulping methods that reduce energy consumption while maintaining fibre quality. Research into advanced solvents has shown promise in enabling pulping at milder conditions, although challenges remain in achieving high-yield and high-quality cellulose fibres suitable for papermaking. Ongoing research is focused on developing innovative processes to achieve higher efficiency and quality. Pilot and demonstration projects, as well as fundamental research, aim to tailor natural cooking liquids, catalysts and recovery processes to increase reaction rate and product yield of the pulping process and create higher-value products

OBJECTIVE 6: Achieve negative GHG emissions

The forest-based sector in Europe is in the unique position to be the first and only industry value chain to achieve net negative GHG emissions. Realising this ambition requires better methods for quantifying GHG storage and sequestration across materials, products and buildings. This includes maximising long-term biomass storage and extending the carbon storage period of wood in construction, supported by policy incentives that recognise the climate value of renewable materials. The sector should also develop and integrate Carbon Capture and Utilisation (CCU) and Bioenergy with Carbon Capture and Storage (BECCS) technologies into existing production processes. Together, these approaches create a circular, carbon-negative system, positioning Europe's forest-based sector as central to climate mitigation.

Action 20. Quantifying and maximising carbon storage in wood products and construction

Wood products are natural carbon storages. To correctly estimate the climate benefits of wood products, three factors must be considered: the sequestration, substitution and storage of carbon. Carbon sequestration refers to the absorption of atmospheric CO_2 by growing trees through photosynthesis. Carbon substitution captures the emissions savings achieved by replacing carbon-intensive materials, such as concrete and steel, with wood. Carbon storage refers to the long-term retention of biogenic carbon within wood products themselves.

Information about a products environmental impact is provided through Life-Cycle Assessment (LCA) and Environmental Product Declarations (EPDs).

This action deals with reducing the many obstacles that stakeholders encounter when preparing these documents. Primary data collection from forest to market, development and validation of methodologies for biogenic carbon accounting, quantification of carbon substitution factors, end-of-life modelling and the development of tools that simplify and reduce the cost of LCA and EPD preparations.

Action 21. Advancing carbon capture technologies optimised for process-integrated energy flows

The pulp and paper industry is well-positioned to adopt bioenergy with carbon capture technologies, given its significant emissions from point sources such as lime kilns, recovery boilers, and evaporation processes. Two complementary approaches - Bio-CCS (storage) and Bio-CCU (utilisation) - offer pathways to negative emissions. Bio-CCS involves permanently storing captured CO_2, while Bio-CCU transforms it into valuable products, enhancing resource efficiency and opening new market opportunities. Effective implementation requires tailored capture technologies adapted to varying CO_2 concentrations, purity and flue gas volumes, along with integration into the mill's energy system to optimise heat use and minimise energy penalties. Particularly for Bio-CCU, successful conversion relies on the availability of hydrogen and efficient chemical processes. Together, these technologies support climate goals by reducing emissions and boosting industrial circularity.

Mission 3: Optimising raw material and resource efficiency to boost productivity in Europe

This mission addresses the role of innovation to improve the raw material use and additional resources (such as water) used or consumed by the forest-based value chain.

OBJECTIVE 7: Boost resource efficiency

Being able to "make more from less biomass" is an objective as old as the sector itself, yet the natural complexity of trees and wood makes it genuinely difficult to achieve. Wood varies significantly in density, moisture, fibre orientation and structure, not just between species but between individual trees and even within a single log. Optimising the extraction of one bio-component can simultaneously compromise the yield of another, and the ideal of 100% biomass utilisation will never be fully reached. The goal is therefore not perfection but continuous improvement.

Advancing toward that goal today requires sophisticated sensing and predictive modelling that enables mills to adapt dynamically to constantly changing raw material properties, turning material that would previously have been wasted into valuable resources. In manufacturing, breakthrough technologies such as 3D-scanning reveal the hidden architecture of wood fibres and internal structures, allowing sawmills to waste less, and add value to secondary materials through enhanced automation. Closing the loop on water use is an equally important frontier, with intelligent treatment solutions capturing pollutants and significantly reducing freshwater consumption across production processes. These are not isolated improvements but interconnected innovations reshaping the entire value chain into a truly circular system where industrial competitiveness and environmental sustainability reinforce each other at every step.

Action 22. Optimising biomass use by mastering its natural variations

A more intelligent use of forest raw material enables higher yield. The natural variation in forest-based raw materials is significant due to tree species, growing conditions and several other parameters. This leads to both visible differences (log shape, density between growth rings and proportion of heartwood, how knotty the timber is etc) and hidden properties such as fibre length and orientation, wood density, moisture, lignin composition and much more. Industrial processes need refining to fully comply with the variation, ideally exploiting it as an advantage rather than a constraint. Upstream in the value chain, identification, forecasting and steering raw material to the most value-adding process based on wood properties are key. Downstream, technologies, for instance 3D-tomography is used today to optimise raw material use in sawmills. Despite continuous progress in mastering the natural raw material variations, the forest-based sector will continue to make significant research and innovation efforts on a pamphlet of technologies that can detect properties and link quality with silvicultural practices

This action area also includes strategies that allow for commercialisation of under-utilised tree-species.

Action 23. Improving raw material efficiency in wood-based manufacturing

Sawmills play a central role in the wood-based manufacturing ecosystem. Even small improvements in their process control, raw material efficiency and storage turnaround can lead to significant cost savings. There are several potential bottlenecks that require more research and innovation. A deeper understanding of the interplay between process settings and raw material variations is essential, particularly in refining the control and scheduling of wood drying. Alongside conventional kiln drying, alternative or complementary technologies, such as vacuum drying, radio frequency drying, and heat pump kilns deserve further investigation. AI and machine learning offer promising ways to improved process control to optimise material efficiency and product quality. Shared data standards and digital platforms along the value-chain would lead to further improvements. Finally, developing new technology and business models to convert side-streams and residues (such as saw dust, chips and bark) into higher added value products remains a clear priority.

Action 24. Improving water balance and process water treatment

Freshwater scarcity is a pressing global issue and the pulp and paper industry is highly dependent on water availability for its operations. Sustainable water management is crucial for maintaining operational continuity and meeting regulatory requirements. Optimising the water balance within the industry helps minimise environmental impact and ensures a sustainable water supply for both industrial processes and surrounding communities. The circular reuse of process water and raw materials has led to the accumulation of persistent compounds, necessitating the development of advanced separation and purification technologies. A critical issue is the salinisation of both recycled process water and surface waters into which treated wastewater is discharged. Advanced water treatment technologies must be developed to efficiently remove harmful substances from wastewater, allowing for water reuse in production processes. This contributes to achieving zero liquid discharge or discharging clean water into regional waterways. Water saving strategies should also include developing physics-based alternatives to the addition of chemical cleaning and processing aids, as well as preventing water losses to air via the vapour phase. Solving the latter challenge is also directly linked to recovery of evaporation energy.

OBJECTIVE 8: Substitute fossil-based with forest-based first-of-a-kind products

Action 25. Developing innovative biorefinery concepts for novel bio-based compounds

A key opportunity for forest-based industries lies in developing first-of-a-kind alternatives to chemicals and products that today are produced exclusively from fossil or non-renewable raw materials. Research on forest biomass - particularly wood - is the starting point for identifying and developing these new high-value compounds. A critical bottleneck remains the development of sufficiently efficient and scalable extraction techniques capable of isolating valuable molecules, with minimal energy input and, where required, in their native form.

The biorefinery approach offers a route to the sustainable production of drop-in and novel substitutes across a range of product categories, including pigments, adhesives and materials for additive manufacturing - all areas where fossil-based products currently dominate. In parallel, new synthesis methods are needed to produce nanomaterials such as graphene and carbon nanotubes from lignocellulosic feedstocks, opening the door to forest-based alternatives in advanced materials markets.

Together, these technologies could displace fossil-derived inputs across sectors including food and flavourings, specialty chemicals, construction and electronics. Where appropriate, flexible small-scale or decentralised processing units can support adaptation to variable feedstocks and reduce environmental impact.

OBJECTIVE 9: Produce zero waste in a circular society

In a truly circular bioeconomy, materials circulate through multiple uses for as long as practically possible — and only when further recycling becomes unviable do they generate renewable energy. The goal is a system where nothing becomes waste in the conventional sense. Europe's forest-based sector will achieve this through actions in five action areas. Underpinning all of these efforts is the need for robust cost and sustainability assessment methods that can identify the most resource-efficient pathway for any given material stream. Integrating these innovations across the value chain maximises resource efficiency, minimises environmental impact, and strengthens European competitiveness in a world increasingly shaped by circular economy regulation and expectations.

Action 26. Extending product lifetimes and enabling new circular uses for wood-fibre materials

Extending the lifespan of wood-fibre based products is a key innovation pathway for building a more sustainable and circular bioeconomy. The key challenge lies in designing products and processes in such a way that it not only maximises durability but also enable reuse, repair, and recycling without compromising quality - principles that must be built in from the outset rather than retrofitted.

Furthermore, scalable methods must be developed for repurposing products into new applications (a second life). It is critical that recycling innovation is developed in step with product innovation. Additional enabling conditions outside of the repurposing process is also needed. Market incentives and a supportive regulatory framework are essential to ensure that wood and fibres contribute maximum value across multiple lifecycles before final energy recovery.

Action 27. Developing advanced cost optimisation and assessment tools for circular recycling systems

Optimisation of recycling systems includes accurately capturing the full lifecycle costs, accounting for fluctuating market values of recyclables, and integrating environmental, health and safety, and social impacts into economic models. Innovation should focus on developing dynamic, data-driven modelling tools that offer multiple utilisation paths for wood, wood-composites, fibres, fillers, plastic materials, printing pigments, organic residues, etc. Additionally, creating standardised metrics and decision-support systems can help stakeholders evaluate trade-offs and optimise system-wide performance.

Action 28. Advancing collection, sorting and separation technologies for paper recycling

The European paper industry holds the world record in recycling efficiency, which greatly reduces the need for virgin fibre. Yet complete recycling remains out of reach: fibres degrade over successive cycles and lose their functional properties, while contamination from coatings, plastics and other materials complicates sorting and lowers recovered fibre quality.

The main challenge is to be able to accurately identify and separate diverse paper grades from mixed waste streams, removing contaminants effectively, and integrating advanced technologies cost-efficiently into existing waste management infrastructure.

Innovation could include smart sensor systems, and automation to improve material recognition and purity. As paper-based packaging and products become more complex, collection and sorting systems need to be designed with their eventual recyclability in mind

Action 29. Valorising non-fibrous recycling residues into new circular resources

Paper for recycling is often contaminated with non-paper components such as plastics, minerals, inks, chemicals, and staples, which are typically discarded or incinerated, thus limiting the potential for resource recovery. This includes processing waste, such as sludges from wastewater treatment installations. To close the recycling loop and contribute to a circular economy, it is essential to find ways to valorise these non-fibrous components and convert them into valuable products. The development of advanced separation and conversion technologies is key to isolating and reusing these contaminants. This requires innovations in material recovery, such as mechanical sorting, chemical separation, and cross-sector collaborations to create economically viable solutions for reusing non-fibrous residues.

Action 30. Increasing reuse and recycling of bio-based construction waste

When buildings are demolished, the amount of salvaged high-value wood that is reused or recycled is low. Increasing the amount of reclaimed wood from construction waste faces several hurdles; it is more labour-intensive to salvage wood than to use new, virgin materials; reclaimed wood often lacks documentation on its structural integrity and chemical treatment; variability in the dimensions and condition of reclaimed wood makes designing, engineering, and connecting components for new, efficient structures complex. Practical issues in the salvaging process, such as fine dust emissions, must also be addressed.

Connecting construction waste wood sources with new building projects requires coordinated action across the value-chain. New standards for testing and regrading reclaimed wood are needed, alongside greater awareness and education among architects, engineers and construction businesses are needed. Wood products and construction systems should be designed for disassembly and reuse from the outset. Material passports, new tracking systems and BIM tools must become regular tools for the construction sector to prioritise high-value reuse over lower-value recycling.

Mission 4: Innovation in Sustainable Forest Management

Sustainable forest management (SFM) is the foundation for the whole forest-based bioeconomy. Ensuring healthy ecosystems, more efficient wood mobilisation and developing non-wood ecosystem services and forest governance are the three objectives of this mission.

OBJECTIVE 10: Ensuring healthy and productive ecosystems

Healthy, biodiverse and resilient forests are the foundation of everything the forest-based sector produces and the services it provides to society. The objective is to strengthen the mutual reinforcement between forest health, biodiversity and productivity, ensuring that sustainable forest management (SFM) practices have the tools to protect habitats and maintain ecological integrity while supporting the sector's long-term resource base.

Achieving this objective requires advances across several interconnected areas: techniques that boost carbon sequestration, diversify forest structures at appropriate scales, and improve climate adaptability, landscape-scale monitoring that integrates ecological, industrial, and social indicators for comprehensive decision-making, and improved understanding of how forests sustain water supply and quality through watershed functions. Mitigating natural calamities such as wildfires requires informed proactive measures such as precision thinning, controlled burns, and firebreaks.

The objective supports a holistic approach that balances ecological health with economic and social benefits, safeguarding biodiversity, bolstering climate resilience, and ensuring forest multifunctionality for future generations.

Action 31. Strengthening functional biodiversity to enhance forest management productivity

Sustainable Forest Management (SFM) plays a critical role in maintaining ecosystem health and biodiversity, which in turn supports key services such as biomass production, carbon sequestration, and resilience to climate change. Functional biodiversity (the diversity of species traits that directly influence how ecosystems function) is increasingly recognised as a driver of forest productivity and stability, yet the complex relationships between management practices, species diversity, soil conditions and ecosystem processes are not yet fully understood. The main challenges include identifying the functional traits that link biodiversity to forest productivity and resilience, exploring the role of underutilised tree species and adapting silvicultural practices accordingly. To fully support biodiversity, these efforts must also consider ecological processes and habitat connectivity at landscape level. Innovation could include ecosystem modelling, genetic and species selection tools, and improved monitoring methods to guide forest management that enhances biodiversity and ecosystem services while supporting long-term ecological adaptation to regionally specific climate risks.

Action 32. Strengthening ecosystem resilience and fostering climate-smart forestry

Building climate-resilient forests requires approaches that not only boost productivity but help forests adapt to and mitigate the impacts of a changing climate. This involves managing risks from pests, droughts, and extreme weather, while promoting species mixes and forest structures suited to future conditions. A key focus is on tailoring forest strategies to local contexts and improving regeneration material. Innovation is needed in developing region-specific climate risk forecasts, tools for adaptive forest planning and strategies that balance short-term mitigation with long-term ecosystem adaptation, including improved approaches to forest restoration where needed.

Action 33. Safeguarding and enhancing forest contributions to water supply and water quality

Forests play a crucial (but often ignored) role in regulating water cycles, maintaining water quality, and reducing the risk of floods and droughts. As climate change and land use shifts increase water-related pressures, better understanding is needed of how forest composition, structure, and management influence water availability and quality on a regional and continental scale. Innovation should focus on hydrological modelling, forest-water interactions, and integrated planning approaches that position forests as natural assets in water management and climate adaptation strategies, particularly in the face of changing regional precipitation and drought patterns.

Action 34. Innovating approaches to reduce and manage wildfire risks in forest landscapes

The risk of wildfires is increasing due to climate change, land abandonment, and the buildup of unmanaged vegetation. These fires threaten ecosystems, carbon stocks, and human communities. Tackling this requires a shift towards integrated wildfire management that emphasises prevention, preparation, and post-fire recovery. Efforts must address both ecological and socio-economic vulnerabilities, especially in the wildland-urban interface (the zones where forests and unmanaged vegetation meet human settlements, and where the consequences of wildfire are most acute). Innovation should focus on improving fire prediction models, fuel management strategies, and the design of fire-resilient landscapes, supported by digital tools and long-term planning frameworks aimed at reducing the scale and severity of future wildfire impacts.

Action 35. Enhancing landscape-scale forest data and assessment to support integrated decisions

Robust, evidence-based decisions are essential to ensure the sustainability and competitiveness of the forest-based sector, from forest management to the woodworking industry and pulp and paper production. However, fragmented, non-standardised, and often outdated forest-related data, combined with overlapping regulations and limited coordination across sectors, hinders coherent policy and business development. This challenge calls for better data availability and rigorous analysis that reflect the interconnectedness of ecological, industrial, and social dimensions The goal is not to impose control on individual forest owners, but to support informed decision-making, identify and avoid goal conflicts, and enable synergies along value chains. Innovation should focus on harmonising forest data systems (including standards), improving cross-sector governance, and developing practical, decision-support tools that foster inclusive, transparent, and well-aligned strategies at all levels.

OBJECTIVE 11: More efficient wood mobilisation

A reliable, sustainable and cost-efficient supply of wood is the foundation of Europe's forest-based economy. The objective is to significantly improve biomass mobilisation from, seed to industry gate, while maintaining and enhancing the ecological integrity of Europe's forests.

Achieving this requires coordinated innovation across several areas. Improving seeds, seedlings, and plants increases productivity and resilience, ensuring biomass supply. Digital tools and AI enable precision forestry, optimising resource management and reducing environmental impact. Empowering small-scale forest owners through training, technology, and financial support encourages sustainable practices. Co-developing advanced machinery with manufacturers improves efficiency, safety, and environmental performance. Accurate prediction of material flows and market demand optimises resource use and investment decisions. Mobilising low-value biomass - residues, branches, and non-commercial timber - enhances supply while creating bio-based products or energy. Together these actions aim to establish a more efficient, resilient and sustainable wood mobilisation system that balances Europe's economic ambitions with its ecological responsibilities.

Action 36. Improving seedlings and planting material for better resilience and productivity

Future forests need planting material that can thrive under changing climate conditions, resist pests and diseases, and help secure high-quality wood supply. Meeting this challenge requires accelerating tree breeding programmes, selecting resilient species and genotypes, and refining cultivation techniques. A key challenge lies in aligning genetic diversity with productivity goals while safeguarding ecosystem integrity and better linking genetics to forest management. Innovation should support the development of improved propagation methods, tools for selecting climate-adapted and pest resistance traits, and strategies for conserving valuable genetic resources, including through assisted migration.

Action 37. Driving the digital revolution and AI for precision forestry

Digital technologies such as AI, remote sensing, and smart sensors are transforming how forests are monitored, managed, and harvested. Precision forestry enables site-specific decisions that boost productivity, sustainability, forest health and streamline operations. A key challenge is to connect real-time data with predictive models to guide everything from growth forecasts to future harvesting strategies. Innovation should support the development of intelligent planning tools, automated monitoring systems, and digital platforms that help forest owners and managers make informed, efficient, and adaptive decisions along the forest life cycle, while ensuring that these tools are widely accessible and provide valuable information for industrial customers.

Action 38. Empowering small-scale forest owners with new tools, services and innovation pathways

A large share of Europe's forests is owned by private individuals and families, ranging from long-established forest owners to a growing number of new and often inexperienced ones. These small-scale holders frequently face barriers to active and sustainable management, including limited access to knowledge, advisory support and markets, high entry costs for advanced technologies, and poor digital interoperability with other actors along the value chain. Addressing these barriers requires tailored digital tools and capabilities, advisory services, and new forms of cooperation. Innovation should focus on enabling smart forest planning, fostering knowledge exchange, and connecting smallholders to value chains and emerging business opportunities. Reducing unnecessary regulatory burdens is also key to encouraging active and sustainable management. Overly complex requirements can discourage the active management that both owners and society stand to benefit from.

Action 39. Co-developing next-generation forestry machines and tools with equipment manufacturers

Forestry machinery and systems supporting forestry operations must continuously evolve to meet demands on cost-efficiency, reduced environmental impact, operator safety and wellbeing and growing expectations from society at large. Meeting these demands requires close collaboration between forest owners, operators and equipment manufacturers from early in the development process, ensuring that real-world operational knowledge shapes technical solutions rather than being applied only at the point of adoption.

The digital transition offers an opportunity for leaps, with possible increase of attractiveness for operators. Transitioning to fossil-free drivelines and propulsion systems is another priority area, as is the development of autonomous vehicles capable of operating effectively in the variable and demanding conditions of forest terrain.

Action 40. Forecasting material flows and market dynamics to guide future decisions

Depending on consumer and industrial customer demands, markets and material flows are subject to constant change. Sometimes the change is fast, i.e. digitalisation's impact on the demand for printing paper, and sometimes it is slower. There is a need for systematic studies on possible consequences and impact on European forests and forest industries for scenarios based on foresight studies. Studies of this type enable preparation, which is important for forest owners, industry, policymakers, and the public.

Action 41. Mobilisation and valorisation of low-value biomass from the forest and beyond

When harvesting timber, the aim is always to obtain the highest possible yield of valuable products, both for economic and climate reasons. Yet even the best-managed harvests generate substantial side streams, including tops, branches, bark, stumps and roots. Additional low-value biomass arises from trees damaged by storms, insect infestations and other natural disturbances. Value-adding utilisation of the whole tree is a prerequisite for a truly sustainable bioeconomy, comprising profitability along the whole supply chain. Further development of productive supply systems and value-adding industrial processes for these side streams is therefore essential, both to improve profitability and to ensure that biomass which might otherwise go unused contributes meaningfully to the bioeconomy

OBJECTIVE 12: Develop non-wood ecosystem services and forest governance

Europe's forests deliver far more value than timber alone, but much of that value remains unrecognised, unquantified and unrewarded. The objective is to unlock the full potential of non-wood forest products, ecosystem services and to inform good governance frameworks, ensuring that forests contribute maximum value to forest owners, rural communities and the European society as a whole. Achieving this requires progress across several interconnected areas. Research and innovation should aim to uncover how digital applications and new business models can provide fair income for ecosystem services provided by forest owners and managers. A central question to be addressed is how to valorise long-term services such as carbon sequestration, habitat protection, and water regulation through new payment mechanisms. A further priority is to understand and demonstrate how forests can continue to provide recreational and cultural benefits for an increasingly forest-remote population. It is also important to understand how forest expansion and land-use trends will inform management models balancing biodiversity, productivity, and socio-economic needs. Underpinning all of these efforts, forest governance frameworks must be critically and continuously assessed to ensure they deliver their intended outcomes, fostering prosperity and competitiveness while maintaining social and environmental integrity.

Action 42. Expanding business opportunities for non-wood forest products

Cork, berries, truffles, honey, medicinal plants, mushrooms, fish and wild game are all examples of non-wood forest products that can significantly increase the added value generated by forests for owners and rural enterprises alike. As demand for these products grows, production is increasingly moving from wild harvesting toward more deliberate cultivation, in some cases overlapping with agroforestry systems that intentionally integrate trees with crops or other land uses, creating new opportunities for diversified rural livelihoods.

Research and innovation are needed to support market development across fragmented supply chains. Digital tools for resource mapping and market connectivity, standardised approaches to quality and traceability and improved cultivation techniques for high-value species, such as truffles.

Action 43. Unlocking additional value from non-wood ecosystem services

Forests offer several ecosystem services, both tangible and intangible, besides wood. For instance, freshwater regulation, air purification, soil erosion control, tourism and recreation. The effect of silviculture on various ecosystem services sometimes causes conflict but there are often synergies between different objectives, and these synergies should be further explored. A fundamental barrier to unlocking the economic value of these services is the absence of established markets and payment mechanisms. Unlike timber, most ecosystem services are public goods. Society benefits from them, but forest owners currently have no reliable way to capture that value. Research efforts to support unlocking the value of non-wood ecosystem services must consider the regional circumstances and start from the perspective of the service provider, the forester, rather than imposed top-down. Priorities include developing credible valuation methodologies, piloting payment for ecosystem services schemes, and building the policy frameworks needed to reward forest owners for the full range of value their forests provide.

Action 44. Enhancing forest-derived benefits for urban and peri-urban communities

Forests in urban and peri-urban areas play a key role in people's quality of life, offering opportunities for recreation, fostering awareness of forest ecosystems, and contributing to physical and mental health. As European demographics point to a continued depopulation of rural areas, management models to secure provision of forest benefits for urban and suburban citizens will remain important.

Evidence is also needed on emerging and less well documented benefits, such as heat mitigation, stormwater absorption, noise reduction, biodiversity corridors, and the measurable mental health benefits of green exposure. Digital tools that help forest managers monitor visitor flows, assess recreational infrastructure needs, and document the ecosystem services their forests provide could also strengthen the case for compensation and investment. Understanding how management objectives shift when forests are valued for amenity and wellbeing as well as for timber, and what silvicultural approaches best serve both goals simultaneously, is an important area for research.

Action 45. Planning for forest expansion under changing land-use and climate conditions

As climate change and shifting land-use patterns affect agriculture, grazing, and rural land abandonment, forested areas may expand - either naturally or through planned afforestation - particularly in the context of EU LULUCF reporting. These new forests often require different planning and management approaches than traditional production forests. Decisions about whether, where, and how to establish new forests must account for ecological suitability, climate goals, and local acceptance. Forest professionals and decision makers will need models and visualisation tools to explore different scenarios, support planning, and ensure alignment with objectives.

Action 46. Improving forest governance through impact assessments and studying policy coherence

Over the past decade, the EU has introduced a substantial body of forest-related legislation and policy including LULUCF, RED III, the EU Taxonomy for Sustainable Activities and the Habitats Directive. Each legislative initiative is pursuing legitimate but distinct objectives. Where these instruments interact, the result can be overlapping requirements, conflicting incentives, or ambiguity during implementation, creating uncertainty for both policymakers and the stakeholders of the forest-based sector alike, and potentially undermining the effectiveness of individual measures.Research is needed to map and analyse these interactions systematically, identifying where policy objectives reinforce one another and where they create friction. This includes examining trade-offs and synergies across ecological, social and economic dimensions, and assessing how forest-related policies translate into practice at global, European, national and regional levels. Research should point out where the gap between legislative intent and the is the widest. Impact assessment studies and outlook studies can help anticipate future coherence challenges on the EU level as well as the national level.

A particular priority is developing robust methodologies for ex ante and ex post impact assessment of forest-related policy, enabling evidence-based evaluation of what works, for whom, and under what conditions. The ultimate aim is to support a governance framework that is not only environmentally ambitious but also administratively coherent, economically viable, and legitimate in the eyes of the forest owners, industries and communities it affects.

Mission 5: Future-proofing processes across the value-chain; AI, digitalisation and robotisation

By 2040, the forest-based sector will operate in a landscape shaped by digital transformation. In order to remain competitive and sustainable, the industry is adopting AI and digitalisation as the twin engines of a future-proof value chain. While we aim to define concrete goals, we also recognise that the possibilities offered by AI and digitalisation go far beyond what we can currently imagine. The topics included under this Mission therefore represent only a selection of the many opportunities to explore.

Objective 13: Diversifying production technologies and logistics

The objective is to support the actors of the Europe's forest-based sector to develop and adopt the next-generation production technologies and logistics systems that will enhance competitiveness, flexibility and transparency across the value chain.

Additive manufacturing, including 3D-printing with wood-based materials, offers transformative potential, enabling the production of precisely engineered, high-value components for demanding applications in sectors such as healthcare and aviation. Realising this potential requires targeted research into bio-based printing formulations, hardware compatibility and post-processing techniques that meet the performance standards of these markets.

Digital traceability is an equally important frontier. Intelligent tracking systems that follow wood from forest to final product can provide verified chain of custody, strengthen consumer confidence and support compliance with tightening regulatory requirements. Developing the interoperable platforms, data standards and digital tools needed to make this a reality across diverse and fragmented value chains is a key research and innovation priority.

Together, advances in additive manufacturing, digital traceability and automated production systems will position the European forest-based sector as a technology leader, competitive, agile and supporting a robust European economy and EUs climate ambitions.

Action 47. Adopting and advancing additive manufacturing technologies such as 3D printing

Additive manufacturing offers significant design flexibility and opens up potential for local production and rapid prototyping. The forest-based sector has an opportunity to take the lead in additive biomanufacturing by using cellulose (including nano-cellulose), hemicellulose, wood powder and lignin, as well as other wood-based polymers, as raw materials for advanced products ranging from medical prosthetics and tissue engineering to advanced aeroplane components. Innovation should focus on developing tailored bio-based printing formulations, enhancing printer hardware compatibility, and creating post-processing techniques to improve functionality and durability. Cross-disciplinary research combining materials science, digital design, and sustainable manufacturing is essential to unlock new applications and markets for wood-derived 3D printing.

The additive biomanufacturing market represents a significant and growing opportunity, and the European forest-based industry is well positioned to capture a significant share of this market, thus strengthening the resource efficiency and resilience of the EU economy.

Realising this potential requires sufficient critical mass and collaboration across actors and competencies. By enabling company spin-outs and new business ideas to be tested within existing forest-based value-chains, a healthy European business ecosystem for additive biomanufacturing can be established.

Action 48. Enhancing traceability and chain of custody along extended value chains

New regulations, certification schemes, and trade relationships are driving growing demand for an unbroken chain of custody worldwide. The European forest-based sector can gain a competitive advantage by leading the development of standardised methods and digital integration along its extended value chains. Developing interoperable platforms and industry-wide standards is essential. This would involve deploying blockchain solutions, IoT sensors, AI agents, and digital twins to enable real-time tracking and verification of material flows from the forest to end product and their reuse. A key priority is agreeing on what data to collect and maintain throughout the chain of custody. This will improve speed, simplicity, and predictability while strengthening traceability and security.

Challenges to overcome include the cost of implementation, data collection, integration and standardisation, as well as the need for multi-actor engagement from governments, producers, traders and consumers. The concept of traceability must also extend to reused and recycled materials, which adds complexity. Efforts should work towards the introduction of EU-wide standardised digital product passports (DPPs) for wood products, covering information on origin, processing, repairability, and recyclability.

OBJECTIVE 14: Adopting AI and digitalisation for advanced processing

AI is transforming more and more aspects of our lives and society. Not taking initiative is accepting the risk to become obsolete. The objective is to support a successful integration of AI and digital technologies across the forest-based sector's operations, from forest management and harvesting to processing, logistics and product development, unlocking productivity gains, resource efficiency and innovation that would be unachievable through conventional means. The sector sits on an extraordinary volume of underutilised data: from forest inventory and remote sensing to mill process logs, quality measurements and supply chain records. AI and machine learning tools can transform this data into actionable intelligence, predicting wood properties before processing decisions are made, optimising cutting and sorting in real time, reducing energy consumption in drying and pulping, and anticipating equipment failures before they cause costly downtime. At the forest level, AI-powered precision forestry tools can support better silvicultural decisions, improve yield forecasting and enable more responsive raw material routing along the value chain. In processing, digital twins of mills and production lines allow operators to simulate, test and optimise without interrupting live operations. Across logistics, AI-driven demand forecasting and route optimisation can reduce costs and emissions simultaneously. Embracing these technologies today is essential for staying resilient, agile, and competitive in a rapidly evolving global economy.

Action 49. Deploying autonomous and electrified systems across the forest-based value chain

Productivity development enabling profitability along value chains is key in a sustainable supply of forest products. This includes technology and systems for forest operations (silviculture, felling and processing of trees, terrain transport) and road transport. Key drivers include labour recruitment and attractiveness, rising labour costs, and the need for continued productivity improvement in challenging operational environments.

Developments in field robotics will enable machines and drones to navigate, sense and operate autonomously in the unstructured and variable terrain conditions typical of forest environments, with significant potential to transform forest operations and activities along the value chain. Unlike industrial robots, which operate in controlled settings, field robots must contend with unpredictable surfaces, obstacles and weather.

The development of fossil-free operations is closely linked to field robotics, in particular airborne drones that will require light-weight propulsion systems. However, decarbonisation requires a portfolio of solutions ranging from bio-based fuels to electrification and hydrogen.

Electrification of heavy machinery must be developed alongside new infrastructure for charging and energy planning. A systems perspective is essential here: individual technology choices interact with operational patterns, supply chain logistics and infrastructure investment in ways that must be considered holistically rather than in isolation.

Action 50. Applying software-driven energy management and digital twin solutions for process excellence

Advancements in digitalisation and AI offer substantial opportunities to enhance pulp and papermaking processes, focusing on improving efficiency, synchronisation, and stability. Dynamic models and digital twins enable the simulation of production processes and the prediction of potential outcomes, including the integration of process innovations, without compromising product quality or productivity. These technologies allow for the harmonisation of energy consumption, better performance of equipment, and overall efficiency. However, the development of more intelligent sensors, data integration from all equipment and energy markets, and a seamless connection between data-driven models and physical systems are essential for achieving the full potential of digital twins and their ability to optimise energy use and process operations in real-time.

The aim of joint development efforts is to position the forest-based sector to take full advantage of the productivity that AI offers by developing systems that allow for flexible production concepts and business models, for instance to control high variability processes for small production scale (including mini-mill concepts).

Challenges such as human-AI collaboration and workforce transition, data privacy concerns and lack of success stories should be addressed. Research and innovation efforts should recognise that many industrial applications (robotics and process control) require a control system with very short time delays (latency time). Integrating data from different sources (sensors, legacy systems, IoT devices, etc.) is complex due to heterogeneity and interoperability issues and requires cost-effective solutions to reduce costs for the development, integration and maintenance of digital twins and AI systems.

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