



Council of the
European Union

Brussels, 20 November 2018
(OR. en)

14544/18

ENV 791
CLIMA 230
COMPET 804
AGRI 575
TRANS 566
MI 866
IND 363
CONSOM 330
ECOFIN 1111
ENER 394
RECH 504
SAN 417

COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	19 November 2018
To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2018) 469 final
Subject:	COMMISSION STAFF WORKING DOCUMENT Guidance on cascading use of biomass with selected good practice examples on woody biomass

Delegations will find attached document SWD(2018) 469 final.

Encl.: SWD(2018) 469 final



Brussels, 19.11.2018
SWD(2018) 469 final

COMMISSION STAFF WORKING DOCUMENT

Guidance on cascading use of biomass with selected good practice examples on woody biomass

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Introduction

The Circular Economy Action Plan adopted in 2015 ⁽¹⁾ aims to turn Europe's economy into a more sustainable economy, boosting Europe's global competitiveness, promoting sustainable economic growth and generating new jobs. The actions in the plan seek to close the life-cycle loop of products and materials by keeping their value in the economy as long as possible, minimising the generation of waste and maximising recycling and reuse, i.e. "circularity". This benefits both the environment and the economy.

This guidance on cascading use of woody biomass addresses the circular economy commitment to '*promote efficient use of bio-based resources through dissemination of best practices on the cascading use of biomass and support for innovation in the bio-economy*'.

Non-binding, this guidance explains cascading and provides some principles and practices to inspire stakeholders when applying cascading. The practices presented in this document come from a range of stakeholders, EU research projects, studies and other sources. Although a large knowledge base on cascading is available, work on this guidance has brought to light some gaps in research.

Scope

Cascading refers to a resource-efficient and "circular" use of any biomass. However, here the focus is on woody biomass, abiding by the principles of subsidiarity and sustainability and optimising the value of this biomass in parallel and/or circular use schemes.

This guidance proposes principles for cascading use of biomass in general, but it also takes a closer look at developments in the forest-based sector and illustrates these principles with examples from the sector.

Forest-based industries include *inter alia*: (i) the woodworking industries, which produce wood materials and products visibly recognisable as derived from wood; (ii) pulp and paper manufacturing and converting industries; and (iii) multi-product integrated bio-refineries.

Further along their value chains, the chemical, energy, textile and construction industries, for example, use woody biomass as inputs and can therefore draw on this guidance.

This document does not cover sustainable wood mobilisation, as it has already been the subject of guidance ⁽²⁾. However, it does present relevant good practices covering new ground, such as linking wood suppliers with buyers by providing better information on the wood markets in order to improve mutual efficiency and competitiveness.

1() COM(2015) 614 final.

2() European Commission Directorate General for Agriculture and Rural Development and United Nations Economic Commission for Europe and the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (2010), available at https://ec.europa.eu/agriculture/sites/agriculture/files/fore/publi/forest_brochure_en.pdf

History

Cascading practices pre-date the industrialisation of wood processing, as resource constraints and economic logic often led to practices aimed at maximising utility and extending product use. Since the mid nineteenth century, larger sawmills have often been integrated with veneer and plywood production or the pulp and paper industries. However, ‘cascading’ *per se* only dates back to the 1970s, when environmental concerns and resource constraints became a concern of decision-makers, and the benefits of using the same raw material multiple times again became evident. In recent years, cascading has received a lot of attention, and the European Commission has produced a number of studies which focus on it, including ‘European Wood’ (2010), Indufor (2013), and ‘Cascades’ (2016).

‘European Wood’ ⁽³⁾ analysed cascading from the perspective of ‘wood flows’. It started with roundwood from the forest being processed by sawmills to make construction timber or packaging wood and continued with the by-products and residues from sawing used to make wood-based panels, paper pulp or bio-energy. The Indufor study ⁽⁴⁾ included simple calculations of ‘cascading ratios’ to indicate the relative levels at which fresh wood could be reused throughout its value chains. The Cascades study ⁽⁵⁾ attempted to define the cascading concept.

Most studies saw cascading as essentially linear, where one use follows another, followed by recovery and recycling to make the material available for another use, but often decreasing in value with each step, and ending with the wood being used as energy. However, the approach has gradually evolved now into a more ‘circular’ concept, covering multiple, often interlinked pathways that reflect technological developments, new products based on woody biomass, new markets and industrial and organisational changes such as industrial symbiosis.

Policy context

This guidance is relevant to the renewed EU Industrial Policy Strategy ⁽⁶⁾ of 2017, and in particular to forest-based value chains and the shift towards a more circular economy.

It is also relevant to the UN Sustainable Development Goals (SDGs) and the Paris Agreement on climate change. Forests play an important role in both climate mitigation and adaptation efforts (e.g. water retention; protection against erosion, air quality). Woody bio-based products can provide additional carbon storage services and a substitution for carbon-intensive materials and fuels.

The guidance is also relevant for the implementation of the EU Bioeconomy Strategy ⁽⁷⁾, which sets out the transition towards a sustainable and circular, bio-based, low-carbon economy by building on the sustainable

3() Mantau et al. (2010), European Wood (EUwood): Real potential for changes in growth and use of EU Forests.

4() Study on EU biomass availability and competitiveness of the EU F-BI.

5() EC (2016), Cascades: Study on the optimised cascading use of wood, ISBN: 978-92-79-57725-3 available at: <https://publications.europa.eu/en/publication-detail/-/publication/04c3a181-4e3d-11e6-89bd-01aa75ed71a1>.

6() COM(2017) 479 final.

7() EC (2018), A sustainable bio-economy for Europe: strengthening the connection between economy, society and the environment, Updated Bioecon-

use of biomass, all while retaining the services that forest ecosystems provide. Through bio-based innovation, new materials, fuels and chemicals can be made out of woody biomass, thus substituting fossil resources and avoiding their associated greenhouse gas release.

A diverse range of policy fields addresses forests and forest-based industries, such as: agriculture; forestry; the environment; climate; research and innovation; the bio-economy and energy. The following non-exhaustive list highlights some of the most relevant.

Agriculture

The Common Agricultural Policy's (CAP) Rural Development Policy promotes and supports the implementation of sustainable forest management. For the period 2014-2020, the total public expenditure allocated to the forest sector amounted to 8.2 billion €, used in modernising technologies, supporting the bio-economy, addressing climate change and protecting forests and the ecosystem services they provide.

Forestry

In the 2013 EU Forest Strategy, cascade use is mentioned as supporting the goal of resource efficiency, using 'forest resources in a way that minimises impact on the environment and climate, and prioritising the forest outputs that have higher economic added value, create more jobs and contribute to a better carbon balance' ⁽⁸⁾.

Environment

The EU "Timber Regulation" ⁽⁹⁾ governs the placing on the market of most types wood and wood-based products within the EU. It helps combat illegal logging world-wide by banning illegally sourced wood from the EU market. It also requires market operators to show due diligence for their legal wood, i.e. it should be traceable to its source whether in the EU or in non-EU countries and be traceable downstream through traders. For this, the Regulation authorises the competent authorities in the Member States to carry out checks on operators, traders and monitoring organisations which might assist them.

The revised Waste Framework Directive ⁽¹⁰⁾ and the Directive on Packaging and Packaging Waste ⁽¹¹⁾ prescribe separate collection and recycling targets for wooden packaging of 25 % by 2025 and 30 % by 2030 in the EU Member States. This will enable further cascading through reuse and recycling and retain the materi-

omy Strategy, ISBN: ISBN 978-92-79-94145-0.

8() COM(2013) 659 final.

9() Regulation (EU) 995/2010 of the European Parliament and of the Council of 20 October 2010 laying down the obligations of operators who place timber and timber products on the market.

10() Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

11() European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste.

al in the economy for longer.

Forests are precious environments that provide numerous services, including ecosystem services, and the Birds and Habitats Directives ⁽¹²⁾ lay down means to protect them. Also, over 21 % of EU forests are classified under Natura 2000 ⁽¹³⁾.

Climate

Some wood-processing activities, such as pulp and paper manufacturing, are energy-intensive and so covered by the EU Emissions Trading System ⁽¹⁴⁾.

The Regulation on Land Use, Land Use Change and Forestry (LULUCF) ⁽¹⁵⁾ sets accounting rules on greenhouse gas emissions by sources and removals by sinks. It covers forest land, afforestation and deforestation and harvested wood products. Carbon sequestration, through sustainable forest management practices that increase increment and new planting, are included in the overall balance. As carbon moves from the forest to a harvested wood product, the use of wood as material and a substitute for fossil fuels and materials has a favourable position in the overall EU accounting method.

Research

Cascading-related aspects also feature prominently on the Commission's research and innovation agenda, with a number of research and innovation projects funded through the Framework Programmes, in particular the Framework Programme for Research and Innovation Horizon 2020 ⁽¹⁶⁾, from which projects some are included in the Annex hereto.

Energy

As a renewable source of energy, wood also plays an important role in the transition away from fossil fuels. The EU's Directive on the Promotion of the Use of Energy from Renewable Sources ⁽¹⁷⁾ set European and national targets for increasing the shares of renewable energy by 2020 and allows Member States to introduce support schemes for renewable energy sources, including wood. In 2015, the amendment to this Directive addressed issues on indirect land-use change ⁽¹⁸⁾. Among other reporting requirements, Member

12() http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm,
http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

13() http://ec.europa.eu/environment/nature/natura2000/index_en.htm

14() https://ec.europa.eu/clima/policies/ets_en

15() Regulation (EU) 2018/841: https://ec.europa.eu/clima/lulucf_en#tab-0-1.

16() <https://ec.europa.eu/programmes/horizon2020/en/>

17() Directive 2009/28/EC.

18() Directive 2015/1513.

States have to take into account *'the biomass cascading principle, taking into consideration the regional and local economic and technological circumstances, the maintenance of the necessary carbon stock in the soil and the quality of soil and ecosystems'*.

The updated Renewable Energy Directive for the period after 2020 (RED II) ⁽¹⁹⁾ strengthens the EU's sustainability criteria for bio-energy, covering not only bio-fuels for transport but also solid biomass and biogas used to generate heat & cooling and electricity in plants with a capacity above 20 MW. RED II also requires large-scale bio-electricity generation (above 50MW) to meet minimum efficiency standards or use highly efficient combined heat and power technology. Member States are required to design their national renewable energy policies with due regard to the waste hierarchy, as set out in the Waste Framework Directive, in order to avoid undue distortive effects on the raw material markets.

Public schemes to support investment related to the cascading use of biomass and to help promote renewable energy must comply with EU state-aid rules for environmental protection and energy ⁽²⁰⁾.

19() Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources (recast) COM/2016/0767 final/2 - 2016/0382. A political agreement was found by the co-legislator endorsed by the Member States on 27 June. <http://www.consilium.europa.eu/en/press/press-releases/2018/06/27/renewable-energy-council-confirms-deal-reached-with-the-european-parliament/>

20() Communication from the Commission on Guidelines on State aid for environmental protection and energy 2014-2020, OJ 2014/C 200/1.

Cascading principles

The guiding principles below aim to clarify the cascading approach and help guide stakeholders in applying cascading. Examples of good practices from the forest-based sector illustrate the principles, while the annex provides details on each good practice and reports on developments in cascading in each value chain.

Guiding Principle 1. Sustainability

Any cascading solution to promote the highest economic added value must consider its impact on the other two pillars of sustainability: the social and environmental aspects.

Sustainability means balancing economic, social and environmental considerations, viewed from a long-term, cross-generation perspective. Assuming that cascading is always sustainable can be misleading — its implementation should optimise synergies between the cascading use of biomass and its externalities in each particular case, e.g. in terms of emissions, social harm, environmental damage, loss of biodiversity or other impacts.

Sustainably mobilised wood as one necessary condition for sustainable bio-based value chains

All woody biomass should originate from sustainable forest management or sustainable agriculture production (e.g. wood-energy crops, coppice, agroforestry) and wood waste from landscaping, horticulture and viticulture. Although sustainable wood mobilisation *per se* has already been the subject of separate guidance ⁽²¹⁾, and has been addressed by the agricultural European Innovation Partnership (EIP-AGRI) Focus Group on sustainable mobilisation of forest biomass ⁽²²⁾, relevant case studies covering new ground are included. As can be seen in the example of recent practices below, there are also ways for woody biomass to feed back into the forests after use. This improves sustainability and moves circularity up to a new level by enlarging the loop to encompass forests.

Example: return of ashes from woody biomass ashes as forest fertiliser

Spreading wood ashes can return nutrients to forests, improving forest productivity and reducing the amount of ash going to landfills. This practice is used in Latvia, Austria and Finland. A research project by the Latvian State Forest Research Institute, Silava, delivered recommendations on quality requirements for wood ash applied in forests and on the development of technical solutions for spreading material in forests. ⁽²³⁾

21() EC, MCPFE, MCPFE (2010): Good practice guidance on the sustainable mobilisation of wood in Europe, ISBN 978-92-79-13933-8.

22() <https://ec.europa.eu/eip/agriculture/en/focus-groups/sustainable-mobilisation-forest-biomass>.

23() <http://www.silava.lv/mainen/aboutus.aspx>

Box: Cascading and the SDGs



Maximising the climate mitigation potential of cascading actions

The cascading use of woody biomass can be a tool in the transition to a low-carbon economy.

By using woody biomass as material throughout its life cycle, carbon continues to be stored instead of released into the air. Also, the cascading use of biomass increases the availability of renewable materials that can substitute fossil-based products, such as bio-based biodegradable plastics or advanced bio-fuels.

Increasing the efficiency of materials processing and heat and power generation and distribution also reduces overall emissions. Sorting and recycling wood waste save emissions by returning material to the biomass stock and reducing the amount of incinerated or landfilled waste. This is cascading in action.

Where no other use for woody biomass is economically viable or environmentally appropriate, energy recovery helps to reduce energy generation from non-renewable sources. In some circumstances, energy recovery may be the only option.

Example: wooden construction — building the future

People have been building with wood for thousands of years. Even multi-storey buildings, such as churches and pagodas have been built with wood for centuries, but they required specific high-quality logs. Industrial prefabrication, the use of engineered wood products (EWP) and standardisation of wood construction now make it possible to build buildings that are much higher and more durable and can be built out of wood from lower quality, more ubiquitous raw material (e.g. compressed into cross-laminated timber (CLT) or glued-laminated wood (glu-lam)).

This construction method can help reduce emissions in a number of ways:

Wood used to build stores carbon for the lifetime of the building and, if properly taken down, can be easily recycled.

Wood is relatively light as a building material. This reduces the need for foundation work and saves fuel and reduces emissions when transporting materials.

Houses built of wood usually have a good energy-efficient performance.

Design incentives and disincentives to encourage the sustainable use of woody biomass in its environmental and social aspects

Local, regional and national policy measures level can stimulate cascading by providing incentives and disincentives to economic operators. These measures may concern information sharing, clustering, research and innovation funding, cross-sectoral learning, skills upgrading, availability of finance or targeted support for developing new businesses.

Example: Green Deals — creating opportunities for new business models

The Green Deals (the Netherlands) is a programme that provides non-financial government support for sustainable initiatives. It is a system where various companies, civil-society organisations, local and regional government bodies and interest groups work together to achieve green growth and tackle social issues. Green Deals facilitates and acts as a catalyst for the implementation of environmentally friendly processes and innovations. The programme is complementary to existing instruments, such as legislation, as well as market and other incentives.

Example: addressing skills needs

Worker and employer representatives of the European pulp and paper industries and the graphic industries have been able to carry out studies on their own sectoral skills mismatches and gaps and how these might be addressed at European level. Their work has included reviewing the education and training needed to address these mismatches and gaps. Thanks to their analyses, more detailed analysis to develop sectoral skills and recruitment strategies

for these industries may be eligible for EU support.

Assess the sustainability implications of using woody biomass

Data to analyse sustainability implications are key to assess whether the use of woody biomass is in line with the cascading concept. This is especially true at local and regional levels, since biomass markets tend to be local. Before scaling up and deploying new technologies and processes, their environmental and social impacts and possible implications, e.g. greenhouse gas emissions, energy use, local jobs and growth, should be carefully assessed. This should be done, if possible, from a life-cycle perspective.

Guiding Principle 2. Resource efficiency

Promote resource efficiency by focusing on uses with the highest economic added value and favouring a market-based approach

To maximise resource efficiency gains, efforts should be made to keep woody biomass in the material cycle of use for as long as economically viable and technically possible.

Harness all main and side streams of woody biomass in a resource-efficient way

While the use of the high-value parts of a tree (e.g. for sawn wood or veneers) is usually straightforward in the woody biomass context, the use of by-products and residues (e.g. small stem wood, sawdust, trimmings, bark, tree tops and branches) is more varied. These by-products and residues can be used in the manufacture of wood-based panels, wood pulps, wooden packaging and bio-energy. The biomass properties, availability and applicability as well as industrial structure, and in some cases the working costs, determine their utilisation in each specific circumstance.

Advances in technology and research can reduce the number of low-value products produced (e.g. more precise cutting methods or better assessment of the quality of wood before it is harvested) or reveal new ways of using low-value woody biomass streams (e.g. in textiles, medicines, chemicals). The use of side streams should also be encouraged through industrial symbiosis, research and innovation and by developing business models that allow agile and flexible production. The ability to respond to changing demands for woody biomass-based materials and products is essential.

Example: better assessment of the wood assortments available for processing industries

Sawlogs, pulpwood and energy wood from Finnish state-owned forests are sold centrally by Metsähallitus. This is done using comprehensive information on current and estimated demands for various grades of wood on the market and matching this information against data on the availability of wood from the reserve of planned forest stands. In order to achieve the maximum gross profit margin, management of these stands is also centrally optimised, as too are the wood sales and harvesting and transport capacities. Within this overall system, the cross-cutting of individual trees into different assortments of grades can be optimised in the forest, for the simultaneous benefit of several clients.

In this way, state forests have become more profitable, because the whole procedure — from forest planning to the delivery of wood — is better managed. Wood as a raw material can be used in the most valuable way. The ongoing development of information sources for the cost-efficient assessing of wood grades in forest management planning will make the whole procedure even more efficient.

Prevent and minimise waste

The resource-efficient approach helps implement the waste hierarchy, i.e. prevention, reuse, and recycling, as well as preventing disposal.

Innovation stimulates a more efficient use of resources — new technologies can improve their processing, so that fewer by-products and less waste are generated from the start, and new uses can be found for by-products that have higher added value than their predecessors. However, it is important to remember that there are already many established uses for by-products that make both economic and environmental sense. For example, the wood-based panel industries use not only small industrial roundwood but also sawdust, wood chips and recovered wood as their main raw materials for producing a wide range of products.

The use of residues as material enables further circularity in the system.

Modern bio-refineries can produce a variety of products from almost all parts of trees, including parts that would previously have been discarded as waste because it was difficult to process them. However, some of the products that can be derived from these residues have high market value and are in considerable demand — and to use these residues means truly turning ‘trash to treasure’.

Example: more precise cutting methods

State-of-the-art sawmills use 3-D and X-ray technology to sort logs into quality groups and determine in advance the successive re-positioning of each log during its sawing. When such technology is used in combination with thinner sawing blades, fewer by-products and much less waste are produced during the cutting process.

Example: Bark: waste to wealth

Bark has often had three main uses: animal bedding, energy recovery and mulching (in gardening and landscaping). These are generally low-values uses.

Bark is the main protection of a tree, and although non-woody, it is rich in nutrients and chemical compounds. With new technologies, these components can be extracted and used in higher-value applications, such as medicine and for food supplements.

Example: Biochar — high-value, climate-friendly soil improvement material made out of woody biomass

Another possible use of wood waste is biochar — a product of woody biomass residues made via pyrolysis or torrefaction (a process where organic material is exposed to high temperature and oxygen deficiency). When used in soil, biochar reduces the need to use energy-intensive soil fertilisers, since it provides excellent nutrients for plants in the right form and can also substitute peat as a growth and water-retaining medium.

Improve market functions to enable a resource-efficient allocation of biomass

A resource-efficient use of sustainably mobilised wood calls for a market-based approach. Market forces will normally determine the uses with the highest value. National legislation should not hinder the cross-border trade of primary and secondary raw materials and products derived from these materials. There should be free movement of goods both within and beyond the EU.

Digitalisation, if well governed, largely helps to make markets more transparent. 'Big data' solutions can increase productivity, decrease negative environmental impacts and facilitate sustainability, competitiveness and efficiency along entire value chains.

Example: electronic market roundwood platform — making the market work for all

The Central Union of Agricultural Producers and Forest Owners in Finland has developed an on-line platform that makes it easy for forest owners and roundwood sellers to put their products on the market and for buyers to get what they need. This improved connecting of buyers and sellers makes for better logistics and resource-efficient use of wood and often better pricing too. Sellers and buyers have been involved in building the platform. Besides making trading easier and less labour-intensive and cumbersome, this also improves market transparency for all those involved.

Encourage clustering, cooperation and industrial symbiosis

Cascading the use of woody biomass has been the backbone of integrated plants, usually operating geographically at the same place because of integrated materials and energy flows. The use of regional feedstocks in 'mega sites' helps industrial symbioses to emerge to provide a range of products, while offering economies of scale in wood procurement and also energy, water, other raw materials, and — not least — labour. In such a context, one of the important efficiencies is that of reducing haulage distances of woody and other raw materials, thus also greatly cutting the overall carbon footprint of a mega site. With new demands from the EU Circular Economy and Industrial Policies, traditional industrial ecosystems have evolved and intensified cooperation with universities and research institutions, and with surrounding communities.

Clustering across sectors and actors is a well-recognised method of continuous innovation that helps advance businesses. Significant efficiency gains can be derived from this form of economic activity.

Example: regional feed stocks and cooperation

Montagne Fiorentina Model Forest Association (FMMF) is an example of cooperation in the use of regional biomass feedstocks. The purpose of starting the regional cooperation was to set up suitable strategies for marketing, promoting and implementing the local wood-based value chain. To achieve that goal, many actors such as forest owners, logging companies, sawmills and private traders were involved. A dedicated web-site was created as an innovative tool to coordinate, integrate, and connect the segments of the wood production chain. The web-site not only familiarises the producers in the FMMF area with one another, but also makes it possible to reach a larger audience and encourages new business relations. This in turn enables a better matching of wood sellers and buyers, improving wood allocation, logistics and pricing.

Example: highly efficient softwood pulping — maximising efficiency and minimising emissions

The pulp mill in Äänekoski (Finland) showcases how combined heat and power (CHP), in addition to pulp, can be produced to fully meet a plant's own needs and still have some left for sale to local communities, all based on small roundwood and forest residues. The optimisation of the CHP is based on the high energy efficiency of the mill, which provides a huge amount of surplus energy. In fact, it generates 2.4 times the amount of electricity required for its own operation. Surplus electricity is supplied to the national grid. In addition, bio-pellets are produced from the pulping digestate and biogas from the pulp sludge. As the mill progressively develops, other bio-based products will be made from these pulping residues.

Innovate to find more efficient ways of using woody biomass

The key innovations in the sawmilling sector relate to the technological advances optimising the use of woody biomass and new techniques for the non-toxic treatment of wood. Likewise, advanced sorting technology for recovered wood allows its increased use in the manufacture of wood-based panels.

Forest-based industries are highly capital-intensive and operate in long investment cycles. Therefore, innovating to find better solutions also means finding solutions that are lasting and that will ensure a long-term payback on investments.

Example: prestige furniture from recovered sources

Italy is the third largest manufacturer of wooden furniture in the world. It does this with some of the most scarce commercial forestry resources in Europe. The solution comes from post-consumer and post-industrial wood waste and innovation. 80 % of Italian furniture consists of particleboard, and most of this is made of material that would otherwise be waste wood were it not separately collected, sorted, cleaned and introduced back into the manufacturing cycle of wood-based panels. Gruppo Mauro Saviola has been a leader in this field since the 1980s, pioneering the use of recovered biomass and marketing their products as 'The Ecological Panel'. Since the 2000s, all Saviola particleboards have been made solely out of recycled wood. This recovery of waste has

also created an important image for the consumer of an 'urban forest'

Example: producing ethanol from sawdust

The production of ethanol from sawdust began at the Cellunolix factory in Kajaani, north-eastern Finland at the end of 2016. It is the first industrial-scale production of its kind in the world. The factory is built in cooperation with a retail cooperative and an energy company and it obtains sawdust from a sawmill nearby.

Example: nothing is lost, nothing is created, everything is changed

Spawnfoam is a Portuguese biotech start-up created in January 2017. Using agricultural by-products and agroforestry residues, the start-up develops fully biodegradable and multi-faceted natural bio-composites such as thermal, acoustic and vibration insulation boards, as well as filling for containers and pots for plant and tree transplantation. Used for growing and transplanting plants and nursery trees, these pots are an alternative to plastic and other materials derived from fossil fuels. The plant or tree is planted in the ground with the pot, into which it is possible to incorporate natural fertilisers to boost the success of the transplant. The Spawnfoam project 'Increasing reforestation success with a novel fungi-based bio-compound material' was awarded the seal of excellence by the European Commission, which manages Horizon 2020.

Regulatory and infrastructural frameworks should create favourable conditions for innovation in using woody biomass in efficient ways. Research and innovation policies and public and private investments in innovation play important roles in fostering research, deploying innovation and technologies and supporting the implementation of measures and technologies that are more efficient.

In an increasingly interconnected world, best available technologies may come from all sectors. Big data and digitalisation are assets for the whole wood-based value chain, from the forest to recycling. "Blockchain" technology could possibly be used for market platforms in the future to facilitate exchanges. Collection schemes for other materials may give useful ideas and incentives.

Example: the shift towards wood-based textiles

Two companies are noteworthy for making eco-friendly, non-energy-intensive wood-based textile products: the Lenzing company in Austria, which turns sulphite wood pulp into standard and specialty cellulose fibres, while the Finnish company Spinnova produces textile fibres from spruce and pine cellulose, using mechanical nozzle technology and no added chemicals. These bio-based textiles can substitute for those made from oil or from unsustainable natural fibres, e.g. cotton grown beyond its sustainable range.

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Example: roadmap to the future

In November 2011, CEPI launched the Forest Fibre Industry 2050 Roadmap for a low-carbon economy. This was in response to the Commission's 2050 Strategy. Their aims were to reduce CO₂ by 80 % while creating more value. For this, breakthrough technologies requiring significant investments and research would be needed, knowing that their potential for saving costs and adding value would be significant. Amongst these processes so far developed at pre-commercial level are:

- **Deep Eutectic Solvents**

Deep eutectic solvents (DES) are produced in nature by some living plants. Synthesised DES open the way to produce pulp at low temperatures and at atmospheric pressure. Using DES, many types of woody biomass could be dissolved into lignin, cellulose and hemicellulose with lower energy use, emissions and residues. They could also be used to recover cellulose from waste and dissolve ink residues in recovered paper.

- **Flash condensation with steam**

Largely dry fibres are blasted into a forming zone with agitated steam and condensed into a web, using one-thousandth the volume of water used today.

- **Dry pulp for cure-formed paper**

To reduce water consumption in paper forming, fibres are treated to protect them from shear, and then suspended in a viscous solution at up to a 40 % concentration. The solution is then pressed out and the thin sheet cured with a choice of additives to deliver the product required.

- **Functional surface**

The key to unlocking greater added value from fewer resources depends on a shift to producing more lightweight products, and selling surface area and functionality rather than weight. Advances in sheet formation and new cocktails of raw materials will lead the way to the lightweight future.

Guiding Principle 3. Circularity in every stream and at every step

This principle aims at keeping in the loop all streams of woody biomass put to different resource-efficient uses in line with the previous principle. A favourable regulatory or non-regulatory environment for innovation, deployment of technologies and investment plays a crucial role in advancing the circularity of woody biomass.

Design for lifecycle

The design stages of products already strongly determine the availability of a resource after its first use. Materials and products that have been designed with consideration of their further possible uses will be easier to recycle or even to “upcycle” after they have done their job. Thinking about the life cycle of a product includes considering which wood to use initially and which treatment and material mix to use. Thought must also be given to the system the product will be placed in and the availability of collection systems after use.

Example: wooden nails

Using traditional metal nails makes it harder to recycle wood, especially high-quality building timber, as it is not always possible to separate these two materials, not to mention the fact that equipment designed to handle wood can be damaged by hitting metal. Thanks to special hardening treatments, it is possible to fashion wooden nails that are as hard as aluminium nails, but still make the timber much easier to reuse or recycle. As an added benefit, these nails will not bleed into or discolour the wood surfaces and are hardly visible.

Example: deconstruction

Furthermore, wooden structures designed with their life cycle in mind can be more easily dismantled than those which are not. This means that a greater part of their wooden and other materials can be recovered, thus reducing waste, lowering costs and increasing the amount of biomass available.

PerformWOOD is a project financed by the Horizon 2020 programme with the objective to kick-start the development of new standards so as to enable the service life specification of wood and wood-based materials for construction⁽²⁴⁾.

Example: non-toxic treatment of wood and woody biomass

Non-toxic treatment methods offer the possibility to improve wood's durability in a sustainable, harmless manner. For instance, wood-derived, natural adhesive and protective compounds (e.g. glues and coatings) ensure requisite sta-

24() https://cordis.europa.eu/project/rcn/104747_en.html

bility and protection. — They can be applied on or incorporated into various types of wood, such as plywood and lumber, where they substitute for more toxic, conventional chemicals. This non-toxic treatment enables their circularity.

- WOOD-FLARETCOAT is a project financed by the Horizon 2020 programme with the objective to solve the problem of producing improved flame retardant coatings for wood products. ⁽²⁵⁾
- The SustainComp project financed by the Horizon 2020 programme aims at the development of a series of completely new and sustainable, wood-based composite materials for use in a wide array of market sectors, ranging from the medical sector, transport and packaging to the construction sector. ⁽²⁶⁾

Encourage collection, recycling and reuse

Circularity depends on schemes that keep materials in their loop. Whether these can function effectively depends partly on support from society in adopting circular behaviour as well as on individual consumers having a sufficient level of awareness and information about specific products and services. A targeted collection system or an extended producer-responsibility scheme can help retain materials in the loop more easily and make recycling or upcycling easier and more economically viable. In addition, better information about the environmental impact of products and services during their life cycles, allows consumers to make better informed choices

Some woody biomass sub-sectors are more advanced than others in their collection and recycling rates. A circular utilisation of paper and cardboard relies on very efficient collection schemes in the Member States. The regional dimension also plays a role in the effectiveness of collection schemes — the closer the mills are to collection centres, the more recovered material is available for their processes.

Digitisation plays an important role in efficient collection, recycling and reuse. Software can locate material and its possible next destination, as well as communicate information on available circularity options to consumers. It is also a very efficient and cost-effective way to raise consumer awareness and improve their information.

Example: windows of old wood

Developed under WoodWisdom ERA-NET, the CareWood project in Slovenia is making new wooden windows and doors out of discarded wood from old wooden buildings. In addition to producing wooden doors and windows, the project has developed software and a mobile application to enable an optimal collection of old wood.

Example: Separate collection of paper

²⁵() https://cordis.europa.eu/project/rcn/111259_en.html

²⁶() https://cordis.europa.eu/project/rcn/89321_en.html

IMPACTPapeRec is a project financed by the Horizon 2020 programme to increase the collection of paper through participatory strategies, targeting in particular EU countries where paper recycling is below the EU's average rate. The project has produced a best-practice handbook and benchmarking tools, which are also in part available online⁽²⁷⁾.

Example: ACE recycling of beverage cartons

Beverage carton producers and their suppliers operate paper recycling processes which separate the paperboard from the carton's polymer and aluminium layers, enabling the high-quality fibre in the paperboard to be used for new products. The polymer and aluminium contents are also in high demand for industrial applications, either separated or agglomerated (e.g. as roofing tiles, construction panels). There are many recycling technologies available for this, and more technological alternatives are rapidly being developed. The industry is determined to further develop recycling through innovation in recycling technologies and through quality improvements of recycling (including extracting polymers and aluminium). Given that collection is a pre-requisite to recycling, in some cases the beverage carton industry supports the separate collection of beverage cartons. The recycling rate of beverage cartons should increase thanks to new EU waste legislation and the requirement to collect separately all packaging materials. The beverage carton industry's newly formed recycling platform will also contribute to this effort by better coordinating and supporting the recycling of beverage cartons in Europe.

Example: new portal on the circular economy

As a repository of knowledge for public institutions, companies and the community in general, and as an inter-action platform for the development of new projects in this field, the Portuguese ECO.NOMIA portal (eco.nomia.pt) is contributing to the transition to the circular economy. The portal is a space for sharing knowledge, informing consumers and companies about the advantages and opportunities of financing. However, it is also serving as a forum for interaction on collaborative investment projects in the circular economy.

Develop extended producer-responsibility schemes

Cascading that involves an extended producer responsibility (EPR) approach is evolving in many sectors but how this happens depends on local and regional circumstances. It may facilitate new business-to-business relations and also create new business opportunities for intermediaries — be it between businesses, business and academia or business-to-consumer. The implementation of EPR schemes also encourages a more widespread development of the design-for-life cycle, with durability in mind. EPR schemes can also create new repair and maintenance services and services for reuse, recycling and upcycling. Thanks to closer cooperation, new applications such as blockchain technologies are being introduced for the business-to-business communication practices.

²⁷() <http://impactpaperec.eu/en/best-practices/>

Example: Rilegno — a national wood packaging waste recovery and recycling scheme

Rilegno is a national consortium that coordinates and promotes the collection, recovery, reuse and recycling of wooden packaging waste. The consortium has created a cooperative scheme that links private and public entities, where responsibilities are shared between the municipality, its inhabitants and companies (consortium). Rilegno has already contributed to wood waste recovery, accounting for 6 % of the total weight of civic separated waste in Italy.

Strengthen the internal market for the circularity of woody biomass

Cascading has in any case to observe the principles of the EU Single Market — along with the EU's international obligations. Amongst these principles, the free movement of goods is particularly important. To this end, national legislation should not hinder trade of primary and secondary raw materials and products derived from them either between or within Member States. In this context, common standards can usually help. Although such standards have been highly developed at the European level for recovered paper (EN 643), the same is not true for recovered post-consumer wood. This gap poses difficulties, not only for classification and the designation of use but also generates problems for cross-border movements. Generally, if recovered wood cannot be accurately classified, its end use risks being downgraded, resulting in a loss of value. If the result is incineration, it is a loss of material from the loop. Wood contamination by chemicals or biotic agents may also make it no longer reusable or recyclable. In such cases, energy recovery may in any case be the only economically and environmentally viable option, provided the necessary precautions are taken to nullify or exclude contaminants. However in the absence of an agreed quality categorisation for recovered wood classification, more wood material is lost from the system.

Guiding Principle 4. New products and new markets

Stimulate uses of woody biomass with high added value by making new products and new markets

Considerable technological changes are taking place, with tremendous progress in the processing of wood and its utilisation for a multitude of purposes. Many innovative companies in the woody biomass sector say that their product mix may significantly change already in the next few years.

Searching for new highly added-value economic uses has become part of biomass-based businesses. High investment rates in research and keeping production flexible and agile, so as to be able to take advantage of new technological developments, are among the factors for success in the sector.

Efforts are needed to facilitate scale-up of innovations. These include developing appropriate standards, ensuring the availability of finance and cooperation. In many cases, new products based on woody biomass can compete on functionalities but not on a cost basis. Economies of scale are also needed to become price-competitive.

Innovate to use new technologies to turn side and waste streams into new products

Advances apply to all value chains: woodworking industries, pulp, paper and board manufacturing and especially multi-product bio-refineries. Woody biomass may be processed to obtain the same chemical building blocks that are obtained from fossil oil. But it may also be processed to create new, more environmentally compatible building blocks, or novel ones that can be used to produce pharmaceuticals.

Example: wood bark for glues, cosmetics and pharmaceuticals

Since bark residues from the manufacture of pulp and paper have fairly high heat values, they are commonly burned for bio-energy. However, today, there are more industrial opportunities to use the wood bark for new products. Because bark is rich in minerals, it is already being used for food supplements by the Ars Pharmae d.o.o. pharmaceutical company in Slovenia.

Another type of utilisation is emerging for glues and insulation materials. Wood adhesives from bark-derived substances, such as tannin and lignin, have been used already in wooden construction and panel industries.

Involve consumers to make new markets

Consumers play a pivotal role in creating markets for these new highly added-value goods (ex: wooden construction, textiles, pharmaceuticals and bio-plastics). Once new materials and products have been developed, awareness-raising and information campaigns can engage consumers and drive demand and also increase transparency of the market.

The transition to a circular bio-economy should be broadly supported by society as a whole and by individual consumers. Only then can manufacturers develop more resource-efficient products. The inclusion of all spheres of society in multi-stakeholder cooperation can create such support, and public-private collaboration will help ensure that innovative products and processes are not stranded in their development phases.

Example: Czech sustainable houses competition for architectural students

Each year, the Czech Sustainable Houses project organises a design competition for graduate students of architecture who have to design the house of the future using state-of-the-art technologies. This initiative helps support a wider material use of wood in construction, thus storing its carbon for longer. Its competitive nature incites ever more efficient use of wood and construction techniques, whilst also spreading knowledge about wood.

Guiding Principle 5. Subsidiarity

Cascading should respect not only national contexts but also regional and local ones in assessing the most economically viable use of biomass.

A different value may be assigned to the same material depending on, for example, on the national abundance of woody biomass resources, the availability of processing capacity and technologies and distance to markets. For this reason, the highest economic value of a given woody biomass stream may differ at local, regional and national levels. This fact may play a role in allocating biomass at the local and regional levels to the different material uses and/or energy use. However, such decisions should not be seen as the best approaches in all contexts.

There are also regional differences across the EU in the wood types and species grown. In this context, forest owners also remain free to decide to whom they sell their roundwood.

Wood production and the manufacture of most wooden products are often heavily regionalised. Uses of by-products are especially determined by prevailing logistics. Transport over long distances, especially of materials having a high bulk/value ratio, is often economically unfeasible and also often environmentally undesirable, e.g. if there are higher CO₂ emissions from transport than from the biomass retained.

An assessment of the feasibility of cascading should take the qualitative and quantitative availabilities of biomass into account. It should also consider regional and local geographical characteristics and legislation, the existence and transparency of markets, the availability of finance and key actors and their willingness to commit in the short and long terms. The existence of infrastructures and the availability of technologies are important considerations too. Action to stimulate the growth and diversity of local and regional markets would increase the efficient use of woody biomass.

Example: Italian Model Forest Association

A model forest is both a geographic area and an approach to the sustainable management of landscapes and natural resources. Geographically, a model forest must encompass a land base large enough to represent all of the forest's uses and values. Such a land base is a fully working landscape of forests, farms, protected areas, rivers and towns. The approach is based on flexible landscape and ecosystem management that combines the social, environmental and economic needs of local communities with the long-term sustainability of large landscapes.

After a preparatory period of three years, the Florentine Model Forest Association from Tuscany (Italy) officially joined the International Network of Model Forests. In the process, the association received the support of the European Agricultural Fund for Rural Development (EAFRD) to develop an action plan and projects around specific needs of the region, including regional and local stakeholders.

Annex: selected good practice examples of the cascading use of woody biomass

1. *Wood as wood*

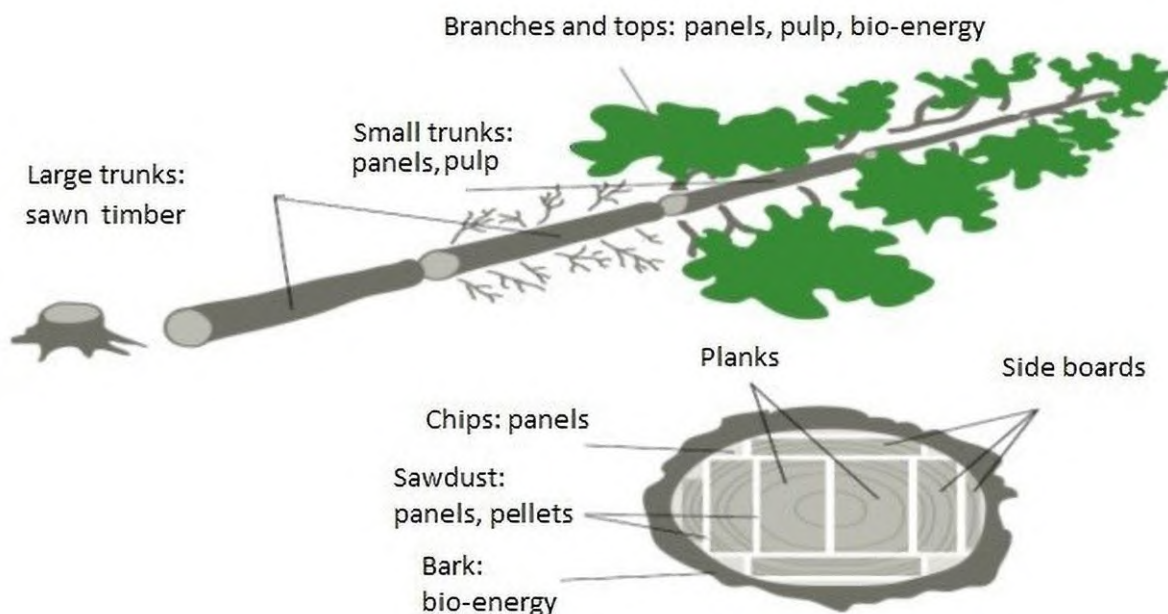
Versatile properties of wood, such as its structural strength and other functionalities, have allowed it to be used in a range of applications, including for construction of bridges, buildings, interior fittings (e.g. walls, doors, window frames, panels, parquet and other floorings), furniture, kitchen utensils, toys and in specialised applications, such as mussel-cultivation rafts and ropes ⁽²⁸⁾. All these applications also offer long-term carbon storage. Furthermore, after the end of their use, reuse, recycling or upcycling of such products may extend their carbon storage for even longer.

Different parts of a tree suit different purposes. While the large stemwood provides many of the applications mentioned above via the woodworking industries, the upper stem and branches can be used for other applications, such as manufacturing wood-based panels and pulping for paper and board manufacturing (see Figure 1). Their side streams in turn can be used to produce diverse chemicals or burned for energy. The added-value use of side streams has provided better profit margins and led to major progress in bio-based chemistry in pulp and paper mills.

The overall annual biomass growth (agricultural, woody, etc.) in the EU-28 Member States amounts to slightly more than a billion tonnes. Its pathways for generation and use are shown in the figure overleaf (JRC 2018). This biomass utilisation is a significant contribution to the transition from a fossil-based to a circular, low-carbon economy. However, it also requires large investments in new installations in order to achieve economies of scale. The EU Bio-economy Strategy estimates that by 2030 there will be a need for 300 large-scale integrated bio-refineries in the EU to fulfil the need for bio-based fuels, chemicals and other essential materials, including bio-based plastics, which may substitute fossil-based plastics.

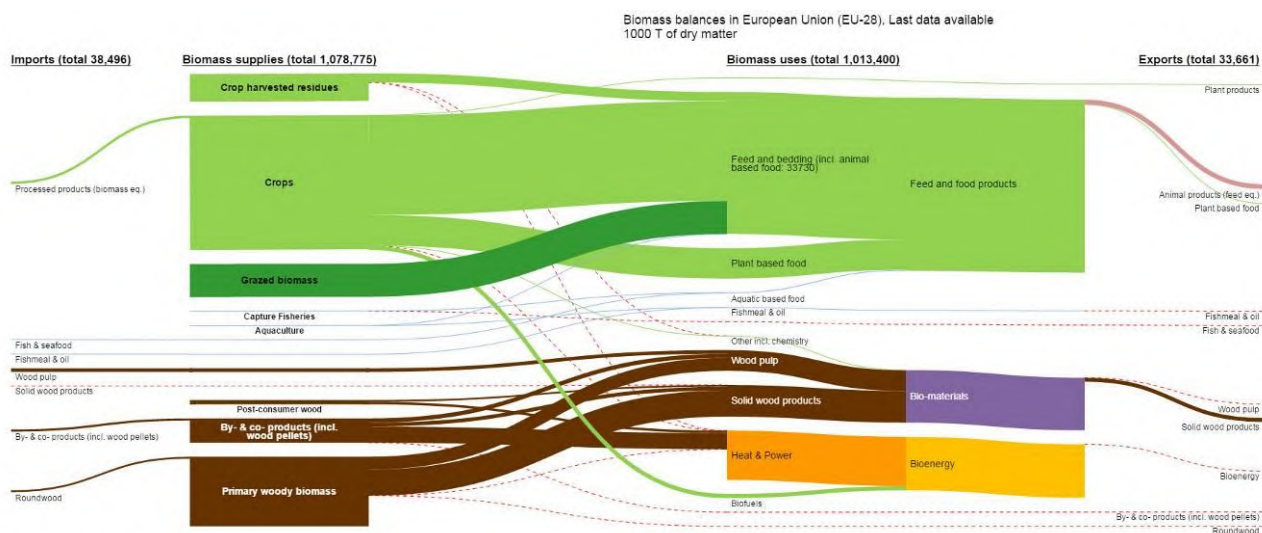
28() Though these are currently often substituted by fossil-based products.

Figure 1. Different parts of a tree suited for different purposes



© Skogsindustrierna

Figure 2. Biogenic material flows within the EU28 economy in 2013



Source: data from the Biomass project; European Commission – Joint Research Centre

The properties of biomass and its applicability to various end uses, and in some cases also its affordability, determine its utilisation in each set of specific circumstances. The contribution of woody biomass is approxi-

mately one third of the EU biomass total ⁽²⁹⁾ and represents around 60 % of net annual wood growth in EU forests.

In the EU and globally, the use of wood species, their dimensions and qualities have changed considerably since the 1980s as new processes, materials and products have emerged to meet changing patterns in demands. Wood functionalities and features suit very diverse applications. However, whereas all wood can be used for energy, most wood categories (species, dimensions, qualities, etc.) for materials and products have specialised end uses and cannot easily substitute for each other.

In general, wood offers long-term storage for carbon sequestered by the trees it is derived from. Compositionally, wood may offer the same chemical building blocks as fossil oil or even more.

Considerable changes in various technologies have led to significant progress in the mobilisation of wood from forests and its utilisation for a multitude of purposes. This applies to wood harvesting, the woodworking industries, pulp, paper and board manufacturing and especially, multi-product bio-refineries. For this reason, good practice examples on relevant technological advances are also included but these are not limited to these forest-based industries.

To a great extent, the forest-based industries have practised the cascading use of woody biomass for a long time. However, in recent years, as demands from the circular economy have intensified and new industrial-policy strategies have emerged ⁽³⁰⁾, industrial ecosystems have embraced more diversified value chains. These industrial ecosystems operate in close cooperation with universities and research institutes and with surrounding communities, which are also participating in and benefiting from such value chains. These complex inter-actions require new business models but at the same time leave less time to market promising innovations. Given these efficiency gains, this chapter also includes a section on cooperation.

Forest-related issues are often sensitive for EU citizens. Therefore, it is extremely important to ensure publicly available information and the engagement of the public — including consumers, especially in view of the increasing importance of woody biomass utilisation. This engagement contributes to the societal appreciation of bio-based products in general. These aspects are further addressed in the section on engagement of consumers and citizens.

Forest-based industries are highly capital-intensive and operate over long time-scales. Many of the investments made today will still serve in 2030. Therefore, it is useful to present examples of existing practices as well as examples of upcoming and emerging practices.

Sawmilling industries:

Saw logs, the trunks used for sawn wood or veneers (for making plywoods), usually form the most valuable parts of a tree, and their price often determines the market actions of forest owners. Traditionally, the woodworking industries have already used high-value wood in a circular manner, depending on the local condi-

29() However, the EU28 figures do not contain data on the 'embedded' woody biomass of imported goods.

30() Investing in a smart, innovative and sustainable Industry: A renewed EU Industrial Policy Strategy, COM/2017/0479 final.

tions and market situation.

Other parts of trees, such as smaller stem wood — often known as small industrial roundwood or ‘pulpwood’, together with by-products and residues, such as larger branches and (bark-free) wood chips, as well as recovered wood, usually have lower values. These are typically used by the wood-based panels industries to make a variety of particleboards and fibreboards.

Small sawnwood and sawing off-cuts, as well as some other residues can be used for other wood-based products, including some composite building products (e.g. laminated veneer lumber (LVL), glued-laminated timber (glu-lams), packaging (e.g. pallets), furnishings, furniture and other wooden articles.

Key innovations in the woodworking industries include more resource-efficient sawmills and wood-based panel mills, which reduce waste right from the start, and new non-toxic treatments for wood, both for adhesives and for wood preservation and protection treatments.

The rising use of wood for bio-energy has resulted in more efficient stove and boiler technologies, which get more energy out of woody biomass, while preventing the release of particulates into the air.

Wood-based panel industries

The manufacture of wood-based panels epitomises the cascade principles in that low-value wood and wood waste are converted into new materials and products, themselves reducing waste and adding value as they pass through downstream processors.

Bringing panels into mainstream construction and furniture has transformed how major building components are constructed and brought affordable furniture to the global mass market. These benefits have been delivered while reducing waste and reducing cost.

There are a variety of wood-based panels, with differing characteristics and physical properties, which utilise small roundwood, thinnings, sawmill residues (sawdust and chips) and reclaimed post-consumer and post-industrial waste wood.

These panels fall into two main categories, either particleboard or fibreboard. The principle distinction is the degree to which the wood is reduced in particle sizes before drying and then being pressed into the finished panel.

The production flow for particleboard (PB), oriented strand board (OSB), dry process fibreboard (MDF), rigid and flex-board, softboard (SB) and hardboard (HB) is summarised in Figure 3 and their circularity illustrated in Figure 4.

Figure 3: Cascading in the wood-based panel sector

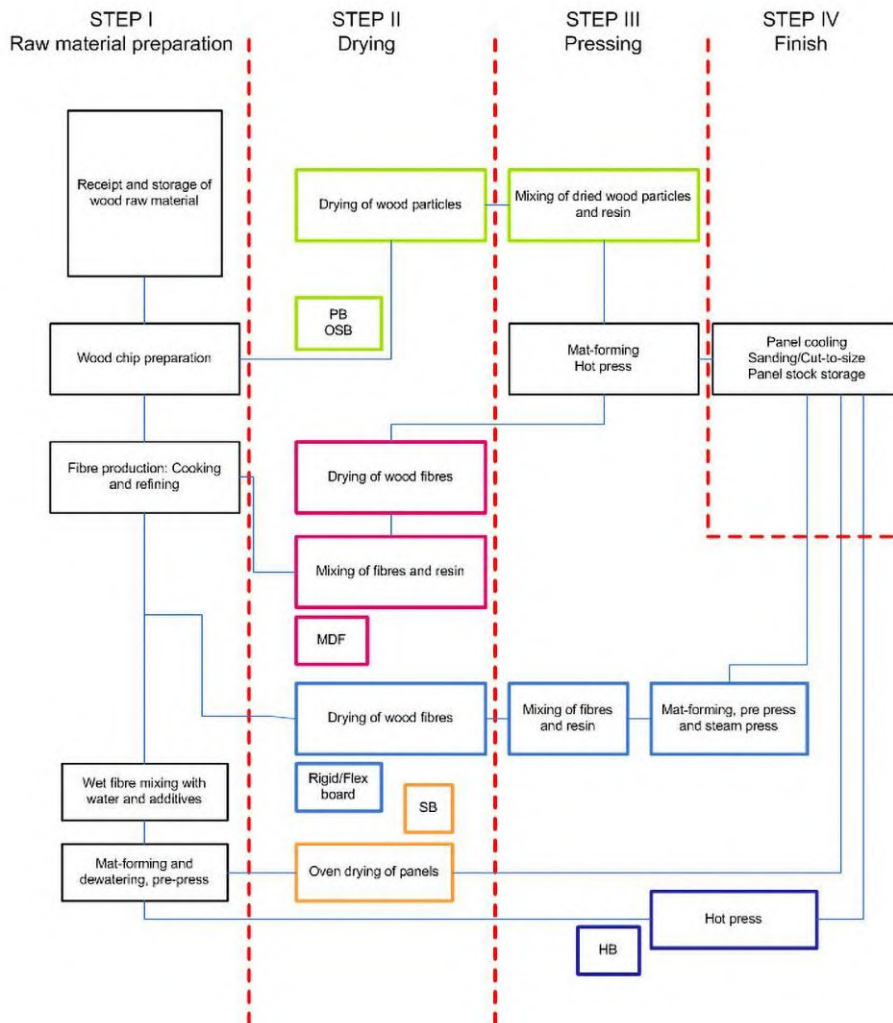


Figure 4: Wood and Wood-based panel products: sustainable and renewable



The manufacture of wood-based panels is both capital- and energy-intensive. However, most of the energy required for process heat comes from burning the process-derived fuels that arise during manufacture. This ensures that carbon emissions are reduced to a minimum and there is virtually no wood waste that leaves the site.

The particleboard industry in particular was the first sector to reprocess high volumes of post-consumer and post-industrial reclaimed waste wood. Today, particleboards can typically have a recycled wood content of 70 % or more. By retaining this as material, the carbon cycle is extended, and new opportunities for adding economic value are created.

The latest industry developments focus on process optimisation and increasing the value of the core board by providing outer boards with enhanced characteristics and enhanced surfaces. This is to respond to changing consumer demand and provide solutions previously offered by alternatives having a higher embedded carbon value.

With more than 50 % of its total woody biomass demand now being sourced from either industrial by-products or recovered wood, Europe's wood-based panels industries are a leading examples of the cascade principle in action.

1.1 Sawmills and industrial preparation of wood, including packaging

World's fastest sawmill

Name:	Actors:
Keitele Group	Private company
Country:	Funding:
Finland	Self-funded

One problem facing many EU sawmills is the age of the sawmill machinery, which may date back as far as the 1980s or 1990s. These sawmills run at low speeds and overall are of low productivity. They are not very attractive for young, skilled people because of the manual nature of much of the work. The extent of these challenges varies from one region to another.

Moreover, while portable sawmills offer a modern alternative, through flexibility to small customers and serve them efficiently, thus saving time and money for them by avoiding a double transport of logs, they do not allow for a large-scale use of wood biomass.

These were challenges the Keitele Group faced in the northernmost part of Finland a few years ago. The situation led the company to maximise the added value from logs and invest in the 'Veisto' design, applying modern, high-speed sawmill technologies in combination with environmental and worker safety arrangements. Their investment included a separate plant next to the sawmill to make laminated veneer lumber (LVL), utilising wood in an added-value product of high strength and with predictable building properties. Sawmill residues, such as bark, sawdust, trimmings and planing residues, serve as fuel in the kilns used to dry sawn timber or are sold to the pulp, panel or pellet industries.

Today, the sawmill in Kemijärvi is the fastest in the world, with a highly automated sawing line running at a speed of up to 220 m/min (normal 150-180 m/min) and handling 15 000 to 20 000 logs per shift (or 1500 m³/shift). The key factors limiting its speed are the design of the band saw, the quality and durability of its materials and its chipping capacity. The sawmill produces products of high added value, with quality beginning at the start of the process. That is why the logs undergo 3-D and X-ray scanning to sort them into quality groups before sawing. Moreover, the optimal re-positioning of each log during sawing is crucial for the best use of logs and high-quality outputs. These operations are crucial for the efficiency of the sawmill. When the scanning and repositioning are done well, there is a huge saving of the valuable raw material, the Lapland pine, which is one of the strongest tree species in the world because of its slow growth in harsh climatic conditions.

Due to its strength, much of the LVL is used for buildings in areas highly prone to earthquakes in Japan. The key factors explaining the successful design, planning and performance of the world's quickest sawmill are the high degree of automation, the efficient use of computer-aided analysis, sensor technologies, modelling and artificial intelligence and skilled personnel. The mill and the LVL plant are operating with their own renewable energy.

The annual production of the sawmill and LVL plant is around 700 000 m³, all manufactured according to

clients' various size demands and dried and sold ready to use. However, the company has had to invest very large amounts, and it is only through product diversification and high throughput that such investments will be profitable.

For more information, see: <http://www.keitelegroup.fi/>

Non-toxic treatment of wood and woody biomass products

Name:

Insignia Group,
Borregaard, VTT,
LUKE

Actors:

Two private companies, Public Technical Research Centre
of Finland, Natural Resources Institute Finland

Country:

Estonia, Norway,
Finland

Funding:

N. A.

To redress the biodegradable nature of wood, woody biomass products have to be treated by physical or chemical methods. For a long time, both natural and synthetic preservative substances were used. But now there is a growing demand for non-toxic treatments, especially for wood and wood-based products that come into contact with people or the environment.

The methods used to treat wood and wood-based products are selected not only on the basis of their respective purposes but increasingly in view of their end-of-life reusability and their potential for recycling, up-cycling or energy production. The type of treatment selected also determines the lifetime of a given wooden product in varying weather and climatic conditions. This is a very important aspect, as woody biomass products are increasingly preferred as substitutes for materials having high embedded greenhouse gas intensity. So the longer the lifetime, the stronger the contribution to carbon storage.

The logs used come mostly from sustainably managed forests. The wood or wood-based products treated may be in the form of entire logs, lumber, veneers, plywood, etc., and may undergo physical and/or chemical treatments. The other materials used, such as various types of glues and adhesives, surfacings or coatings, may also provide additional protection if needed. Often various innovations in material developments go hand-in-hand and provide combined treatments for customers' specific needs. Both current and forthcoming non-toxic treatment methods, which suit different purposes and offer the possibility to improve the wood's suitability for a selected purpose, are briefly described here.

The physical treatments are mostly heat treatments for the various uses of wood (e.g. internal and external, no-contact and close contact, etc.). Different treatments can be used in each case. Such treatments may also be for entire logs, sawn lumber or only their surfaces. Chemical treatment methods with non-toxic chemicals — and the conditions of the treatment may vary considerably — are mostly based on the natural protective compounds available in plants and trees:

- tall oil is a side stream of the kraft pulping method and contains wood's own protective compounds.

Treatment using the even application of tall oil to various kinds of wood is best suited to wooden products that are to be used outdoors and without contact with people (due to the staining and possible irritation caused by the oil).

- Tannins, stilbene and other protective compounds can be extracted from bark residues and applied together with nano-cellulose. Depending on which compounds are used, hot water or deep eutectic solvents may be used to extract them. Once extracted, the compounds may be used in preparations containing nano-fibrillated cellulose that fixes the protective compounds to the treated wooden materials. These may be used in glues or adhesive preparations, thus providing a protective layer for the entire glued surface e.g. in LVL, CLT, veneers or plywood or any other application.
- The compounds extracted from bark or other wood treatment agents may also be used with micro-fibrillated cellulose, reducing the need for other wood treatment agents and therefore keeping their use to a minimum.

For more information, see: <https://www.luke.fi/en/>, <https://www.vttresearch.com/>

Pallets on the move — bridging value chains and grasping new opportunities

Name: Mandriladora Alpasa S. L.
Actors: Family company

Country: Spain
Funding: Horizon 2020

The need for large-scale storage and handling of goods and their transport via ships, air, rail and lorries have created a huge demand for pallets to stack these goods but also keep them readily accessible. Pallets make it easier to build high stacks of goods, including heavy goods. Over the past decades, pallets of various standard sizes have been developed, depending on the loading purpose. These pallets are mostly made of thermally or chemically treated or painted wood and reused approximately 15 times. It is estimated there are several billion wooden pallets in circulation in Europe today. To transport their many millions of tonnes of weight around, lorries require over several hundred million litres of fuel and produce a corresponding level of CO₂ emissions.

Several specialist companies have created a commercial wooden pallet repair and reuse system to maximise the utilisation of pallets. This is called pooling. This operates with the payment of a deposit which a recipient of a pallet-based delivery receives back when returning the pallet to the reuse system. The system can never reach full efficiency, since some wooden pallets are inevitably damaged in handling and need to be replaced by new ones while they are repaired. Also, some losses may occur through theft or because the pallets are used for purposes other than storage and transport, e.g. commonly for fuel. These uses are another kind of reutilisation of the woody biomass. A Dutch study ⁽³¹⁾ indicates there is a profitable business

31() Van Dam J., Ugarte S., Spijkers S., Schipper E. (2013): The use of post-consumer waste wood for energy pellets in Europe,

in using rejected pallets to produce pellets for residential heating.

In addition to wooden pallets, a Spanish company has begun producing pallets made from recycled corrugated cardboard, called Upalets. The product is bio-based, has the same load capacity as many types of wooden pallets (1500 kg) but is shallower and lighter. Although the product is suited for heavy loads, it enables the CO₂ emissions from transporting the pallets to be reduced considerably. Also, fewer lorry, train, ship or plane loads are needed when using the cardboard pallets to transport the same amount of load material. The product is environmentally friendly and waterproof. This business model provides significant returns, and by 2023 the company plans to employ 20 more people in manufacturing and selling.

For more information, see:

https://upalet.com/index_en.html

Name:

CocoPallet
International

Actors:

Start-up company

Country:

The Netherlands

Funding:

Horizon 2020

Another interesting example of innovation is CocoPallet (CCP), a project funded under the Horizon 2020 programme, which seeks to supplement wooden pallets with pallets made from coconut husks.

Asia is the main driver behind the huge and growing world-wide demand for export pallets and needs several billion export pallets per year. For this reason, the CocoPallet International company has developed an industrial process to make pallets from coconut husk fibres, an abundant bio-waste from coconut production.

The pressing process uses the natural lignin in the coconut fibres as a 'bio-binder'. This means that 'coco' pallets, in addition to fulfilling a major function by being stackable, are completely organic and biodegradable and reusable, with a cradle-to-cradle design. This enables the company to load around 1 200 pallets per shipping container. These characteristics also reduce greenhouse gas emissions from transport, while using biotic waste material. As the CocoPallet is fully "circular" and free from harmful substances, it can be ground up after use and be used, for example, as soil improver to replace peat.

What makes the CocoPallet project very interesting is the addressable market the company has. The company buys the coconut waste from local farmers — who otherwise probably would have just burned it — and presses the CocoPallets in a very cost-effective way. The pallets can compete on price with most wooden export pallets in Asia. Making a sustainable solution more affordable than less or non-sustainable alternatives, the pallets can help retain carbon and create value for farmers at the beginning of the value chain.

For more information, see: <https://www.cocopallet.com/>

1.2 Panels, boards and woody composites

New innovations boost panel industries — environmental friendliness is key

Name: UPM and Stora Enso
Actors: Private companies

Country: Sweden and Finland
Funding: Private

The panel industry is continuously expanding the selection of wood biomass products used in construction, interior design, the furniture industry and in some other branches, like vehicle manufacturing and ship building. The glues and adhesives used in the gluing process of wooden veneer sheets to produce plywood are made from oil-based chemicals. The industry has been investigating bio-based alternatives that still match the quality and functionalities required in different, often demanding applications. Consumers are also increasingly interested in their environmental impact. Therefore, manufacturers are developing options with a lower carbon footprint than hitherto.

Leading forest industry companies UPM and Stora Enso have started to develop new sustainable solutions for the panel industry, using lignin-based products from kraft pulping. A stable, free-flowing brown powder, lignin is separated during the Kraft pulping process of softwood. It has a high dry content, superior dispersibility and long storage time. With a higher reactivity and purity, it is consistent from batch to batch and can be supplied at different levels of dryness, according to customer demand.

UPM has introduced a new lignin-based plywood bonding technology called WISA BioBond. This solution replaces fossil-based phenol with bio-based lignin in the adhesive used to produce plywood, making it a sustainable alternative. It displays the innovative use of industrial side streams in a circular economy. The lignin is obtained as a by-product generated during the kraft pulping process. WISA BioBond has been rigorously tested in various plywood applications, and it is now ready to be used to produce the plywood products.

Since 2015, Stora Enso has been producing lignin on an industrial scale at its Sunila mill, which has a capacity of 50 000 tonnes per year. LineoTM by Stora Enso is available to companies seeking more sustainable, bio-based alternatives.

Lignin is a renewable replacement for oil-based phenolic materials which are currently used in resins for plywood, oriented strand board (OSB), laminated veneer lumber (LVL), paper lamination and insulation material. LineoTM already replaces phenol, and there may be other applications for this very versatile material, like bio-based carbon fibres in the automotive, windmill and aviation industries or carbon for energy storage.

For more information, see: www.upm.com,
<http://www.storaenso.com/>

1.3 Wooden construction

Buildings from wood

Names:	Actors:
Träbyggnadskansliet, Waugh Thistleton Architects	Trade union, wooden building federation, school administration, private companies

Country:	Funding:
Sweden, Finland, UK	N.A.

Historically, wood construction was often the norm, especially in the EU's forest-rich rural areas. Most buildings tended to be small to medium-sized and were made of logs and planks. Although logs and planks were widely available as construction materials, design scope was fairly limited because of the heterogeneous, non-standardised materials and methods used. With the development of new, homogenised products having predictable performance, like cross-laminated timber (CLT), laminated veneer lumber (LVL), and glued-laminated timber (Glulam) ⁽³²⁾, and the improvement of assembly techniques, it is now possible to build larger and taller structures with wood. Prefabricated construction elements using these engineered wood products (EWP) can be manufactured adjunct to sawmills and according to the specifications of architects. This brings jobs and revenue to both rural and urban areas.

EWP — structurally stronger than traditional sawnwood and suitable for modular construction — can often be made of low-grade, small lumber from trees species that could not otherwise be used for construction. Modularity provides flexibility, whilst pre-fabrication shortens the on-site building time considerably compared with concrete which needs to dry. Moreover, EWP generally require fewer construction workers and improve occupational safety and health (e.g. less dust). Modular wooden buildings are also very well suited for deconstruction, as they can be designed and manufactured in a way that makes their dismantling for recycling easier, thus keeping them in the material loop longer.

The environmental benefits of building with wood are also substantial: prolonged carbon storage, lower weight — therefore requiring less fuel for transport and less foundation work — good acoustic qualities, good energy efficiency in use and reuse, recycling or biodegradability after their lifespan. The development of wooden construction has greatly benefited from simultaneous developments in many areas: in glues, advancements in non-toxic treatments, processing and quality assessment technologies.

In the past decades, a number of initiatives have promoted the use of wood for construction, most notably in Sweden, Finland, and the UK.

³²⁽⁾ CLT is made of alternate layers of sawnwood glued together at perpendicular angles to give greater structural rigidity to the material. For LVL, see the world's fastest sawmill. Glulam consists of layers of small pieces of lumber bonded together with adhesives, producing a large, strong structural member. Glulam can be produced straight or arched.

In 2005, the Swedish trade union, GS Facket, the forest industry employers' organisation, Skogsindustrierna, and the woodworking industry organisation Trä- och Möbelföretagen, together created the Träbyggnadskansliet organisation to promote wooden construction (Trastad) in all its possible forms. The aim was to create highly added-value wooden buildings that are sustainable and meet contemporary needs. In the wake of this, skills, technologies and machinery were upgraded and put to use in innovative and new modular designs. The partners also engaged with young people to highlight the sector's career attractiveness. Today, 30 % of the buildings in the initiator town Växjö are wood-based.

In Finland all new schools built after 2017 will be wooden constructions. This is due to health concerns and because of wood's sound-proofing qualities and pleasant and cosy environment which they help create. Wood, e. g. in log houses, is also an economic, climate-friendly material that is long lasting. When wood modules are used, they allow for greater flexibility and quicker adaptation to arising needs.

In 2009, a group of architects in the UK started promoting wooden high-rises in the London suburbs with the slogan 'Wood first'. Waugh Thistleton Architects, who have designed the largest cross-laminated-timber (CLT) building in the world, have assessed in detail the pros and cons of wooden and concrete houses. At every step in their respective lifecycles, wooden houses can outperform those made from other materials, by having a lower environmental burden and higher cost savings. Wooden high-rises are long lasting and consume less energy during their usage than buildings composed of other materials.

For more information, see:

<http://trabyggnadskansliet.se/> and

<http://www.trastad.se/>, <http://waughthistleton.com/>

ReWin — Wooden windows and doors made from old discarded wood

Name:

M Sora, University of
Ljubljana, University of
Primorska, InnoRenew
CoE,

Actors:

Universities, Private
company

Country:

Slovenia

Funding:

N.A.

Wooden windows are generally produced from new high-quality wood. After removal because of replacement or deconstruction, the window frames are usually chipped for energy recovery. New windows are again made from new wood. Even vintage or retro-style windows are made from new wood that has been artificially aged.

The aim of the ReWin project is to use the wooden parts from demolished buildings, selling wooden windows made from old, discarded wood and offering customers the opportunity to use their old wood to make new windows or doors.

Activities started in 2013 with involvement in the European project CaReWood (Cascading Recovered Wood, WoodWisdom Net+), which had 15 partners. For three years, processes and prototypes of windows were developed to turn old and discarded windows into new building parts, with partners from Slovenia (University of Primorska) and Germany (Fraunhofer WKI).

After the end of the CaReWood project, ReWIN continued its activities and focused on using wood from wooden buildings and constructions. The CaReWood Project revealed that such wood was in limited supply because not a lot was being collected. This prevented economies of scale and an optimal production of windows and doors. InnoRenew CoE, the Universities of Ljubljana and Primorska and the manufacturer M Sora are partners in the RecAPPture project and developing software and a mobile “app” for an optimal collection of old wood in Slovenia. Similar to the ‘letgo’ application, the user can take a photo of their old wood, select the wood species (softwood/hardwood) and volume and add the location and a contact number. The software includes a system to calculate the optimal driving route to collect wood from various places in Slovenia.

For more information, see:

<https://www.m-sora-blog.com/copy-of-rewin>

1.4 Harnessing wood residues

Biochar — high-value, climate-friendly soil improvement material made out of woody biomass

Name:

FI Biocore Ltd with
LUKE, NL TNO, SE IVL

Actors:

Trading Company with
Natural Resources
Institute Finland,
Independent
organisation, Swedish
Environmental
Research Institute

Country:

Finland, The
Netherlands, Sweden

Funding:

N.A.

Small-scale woody biomass residues, such as trimmings or branches, are common by-products of forest harvesting and the gardening and maintenance work carried out in city parks. Usually these small-scale woody biomass residues are burned or composted. However, both those processes release the stored CO₂ within a short period of time.

Through pyrolysis -- torrefaction, a process in which a substance is subjected to high temperatures without oxygen (to prevent combustion), these residues can be turned into biochar. This product absorbs ambient CO₂ very efficiently and ensures its assimilation into the soil for a very long time, increasing the carbon sink. Biochar also reduces the need for energy-intensive fertilisers, as it provides excellent nutrition for plants in an easily available form and may be used as a peat replacement. Such features are also very beneficial for the rehabilitation of old mining sites, because biochar mixed with clay stimulates the growth of vegetation.

Slow pyrolysis, i.e. carbonisation, of woody biomass residues may take place by low-temperature gasification between 350 °C to 450 °C. The process replaces fossil energy with renewable energy and produces sustainable and climate-friendly products, such as biochar, pyrolysis oil and pyrolysis gas.

As biochar can be produced locally and regionally, it has the potential to offer new, local jobs and easy initiatives for a multitude of applications in various sectors, therefore lowering transport and storage costs. Less densely wooded lands may also be used to produce quickly growing plants like willow for local biochar production.

For more information, see: <https://www.luke.fi/en/>

1.5 Utilising bark residues

Wood bark extracts for glues and pharmaceuticals

Name:

Ars Pharmae d.o.o.
with Abigenol and
Enduranza®

Actors:

Private company

Country:

Slovenia

Funding:

Private

Due to its fairly high heat value, much bark residue is commonly burned for bio-energy. However, bark contains 30 - 40 % extractable materials, such as tannin, suberin, stilbene, lignan, taxol, salicin, polyphenols, pectin and starch. The overall tree stem weight contains 10 - 20 % bark, while in small branches bark may represent as much as 60 % of the weight. Wood residues from sawmills, especially bark, are rich in nutrients and offer a good base for cultivating plants and medicinal mushrooms. The nutrients gradually leach into the soil in normal weather conditions instead of being released quickly like fertiliser.

Today, other industrial opportunities to exploit bark are opening up. For instance, silver fir bark can be used to produce patented food supplements which are proven to relieve stress. Bark from the European silver fir (*Abies alba* Mill), a coniferous tree, is rich in vitamins, minerals and special natural polyphenol substances that can be easily absorbed by the human body. The conifer's bark polyphenols are strong antioxidants and scavengers of free radicals, the most efficient operating in and between cells. Aqueous silver fir bark extract rich in polyphenols also has a strong cardio-protective effect and protective effects against atherogenic, diet-induced arterial wall damage.

Some of the new food supplements extracted from the bark of the European silver fir are already on the market, commanding a considerably higher price than bark used to produce energy. This 100 % pure water extraction can be replicated with other conifers, although their polyphenol content may vary. Standardisation will be necessary to market clinically researched food supplements and ingredients, which require a high investment in research & development, .

For more information, see:

www.arspharmae.com, info@arspharmae.com

Name:

FORESTSPECS
Project

Actors:

Public Technical Research Centre, independent research institute,
universities, private companies

Country:

Finland, Germany;
United Kingdom,
Russia, Switzerland

Funding:

FP7-KBBE

Tannins and other compounds in bark, which protect trees from pests and diseases, may open up another path for higher value uses of bark. With hot water, these compounds can be extracted to form protective additives for glues and adhesives used, for example, by the panel industry. The compounds can also be added to insulation foam for construction to make it more sound-proof and fire resistant. One tonne of bark yields up to 130 kg of tannin powder, leaving the remainder available for other extractions or for energy recovery.

This is an important opportunity for the industrial-scale exploitation of bark extracts in the value chains of the forest-based sector. Existing and new utilisations of bark offer competitive biological and functionally active compounds for the food, pharmaceutical, and cosmetics industries outside the forest-based sector, thus expanding the woody biomass value chains.

For more information, see:

https://cordis.europa.eu/project/rcn/91266_en.html

1.6 Woody bio-fuels

New stove technologies — better energy efficiency and lower emissions

Name:

Avebiom

Actors:

Private companies

Country:

Europe

Funding:

Mostly Private

The use of small-scale forest thinnings and wood residues from portable saws or sawmills for heating and energy production in rural communities is a well established practice. It enables the communities using them to be more self-sufficient and reduces their demand for fossil fuel. However, the burning conditions and energy efficiency of stoves and boilers may be neither optimal nor economic.

The increasing use of biomass for renewable energy generation, especially traditional woody biomass in rural areas, has led to advancements in stove technologies in Europe. The new technologies have resulted in better energy efficiency and compliance with more stringent requirements for air pollution and particulate emissions

(PMs).

The stoves are more energy-efficient, emitting lower levels of pollutants, thanks to more complete combustion from improved burning conditions. Investments in new heating technologies for residential heating with biomass or biogas may be recouped in a shorter time and have a positive environmental impact.

Increasing energy efficiency in stoves and small-scale biomass plants has the additional advantage of reducing the amount of biomass needed for the same amount of energy produced.

The ability to recover forest thinnings and residues for energy generation, even on a small residential scale, may also be an incentive for better local forest management and thus help reduce the risk and intensity of forest fires.

A large number of companies are developing new stove technologies, and the regional energy agencies are monitoring the situation. For instance, Avebiom, the Spanish association for biomass energy recovery, reports that their installed heating capacity has increased over five-fold in the last 10 years, from 1 510 MW in 2008 to 9 404 MW at the end of 2017, especially in Andalusia, Castile-Leon and Catalonia. In 2017, the number of biomass facilities increased by 23 %, generating energy which prevents emissions of 3.85 million tonnes of CO₂ (equivalent to the pollution emitted by 2.6 million vehicles over a year).

For more information, see: <http://www.avebiom.org/en/>

Utilisation of wood ash in forestry

Name:	Actors:
LSFRI Silava	Research institute, state forest company, private forest owners

Country:	Funding:
Latvia	Private

Ash from burning wood is commonly landfilled as household or dangerous waste or used in organic farms to replace conventional liming material and serve as a source of potassium and phosphorus.

Instead, wood ash can be spread in the forest. The project LSFRI Silava elaborated recommendations for this application and quality requirements for wood ash applicable in forests. It also developed technical solutions for spreading uneven materials in forests.

This method not only benefits energy producers, which now have an application for their residues that reduces the cost of wood ash management. It also benefits forest owners, who can increase their soil quality and forest productivity and redress imbalanced or insufficient forest soil nutrients.

The project brought together not only wood ash producers and users but also policy-makers responsible for fertilisation requirements.

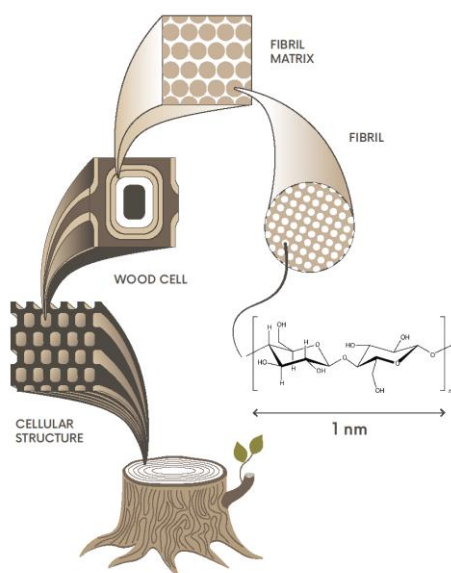
For more information, see: <http://www.silava.lv/mainen/aboutus.aspx>

2. *Wood as pulp, paper and board*

Wood is the ultimate source of cellulose fibre for the production of pulp, the precursor of paper and its derived products. To manufacture paper and board, fresh ('virgin') pulp has to be obtained from large amounts of small roundwood (pulpwood) from thinning forest trees as they grow, and/or sawmilling or other clean woody residues. The paper and board products may then be collected after use as 'post-consumer' or 'recovered' paper for processing (recycling) into recycled paper and cardboard.

Pulping includes a range of mechanical, chemical or thermal processes — or combinations of these — that separate out the cellulose fibres in wood which are needed for paper-making. These make up roughly half the wood's volume, its other constituents being mainly hemicelluloses, lignin — which gives wood its strength (and in some languages its name), volatiles and minerals. Depending on the pulping technique used, the yield, energy demand and quality of the pulp may vary considerably. This is also reflected in the current development of technologies to exploit the side streams of pulp manufacturing.

Figure 5



Pulp with longer fibres and less lignin will generally produce the strongest types of paper, which are very suitable for printing (in the case of graphic papers) and wrapping or stacking (in the case of packaging

grades), and ultimately recycling. They are also more resistant to ageing. Pulps can be made from both coniferous trees (generally 'softwood') and broadleaved trees (generally 'hardwood'). Eucalyptus trees, irrespective of their monocultures and possible impacts on water availability and biodiversity during cultivation in plantations, provide a good woody feed stock for pulp production.

Pulp, paper and board mills have also historically been highly energy-intensive but are now going for carbon-neutral solutions with the use of new technologies. This is reducing their costs and therefore providing greater profitability. Many of the site-specific solutions for stronger circularity also result in economically feasible and profitable products being sold to other parties.

Recovery and recycling represent a circular utilisation of paper and cardboard in this industrial branch, which relies on very efficient collection schemes in the Member States. So the mills using large quantities of recycled fibres or only recycled fibres are generally located in urban or peri-urban areas to be close to consumer markets and so facilitate collection and reduce transport. This may also help facilitate the uptake of the newest technological innovations in upcycling old, recycled pulp to new textiles.

2.1 Pulp production

Highly efficient softwood pulping — maximising efficiency and minimising emissions

Name:	Actors:
Metsä Fibre, Svenska Cellulosa Aktiebolaget (SCA)	Private companies

Country:	Funding:
Finland, Sweden	N.A.

During the last decades, conventional pulp mills have often operated at capacities below 400 000 tonnes per year, in close proximity to sawmills, paper and energy plants (serving all these). There may also have been additional processing units for the most profitable pulping side streams, either under the same company group or as separate legal entities.

However, the recent demand for highly resource- and energy-efficient processes, including a high utilisation rate of the side streams by developing new products, has not only been driven by climate and energy policies but also the diminishing incomes from some of the paper products, e.g. 'graphic' papers (for printing & writing) which see slowing or falling demand over time. These changed circumstances have motivated the very big-scale investments over the last few years in two large integrated plants, one in Äänekoski, Finland, which became operational in 2017, and the Östrand pulp mill in Sundsvall, Sweden. In both cases, the extension of existing plants into agile, multi-product plants with the flexibility to switch between various processes and product mixes has been a vital factor in their success. The plant in Finland has become the largest wood-processing facility in the northern hemisphere, while the mill in Sweden is almost on the same scale. This means that two highly efficient technological and commercial global frontrunners of the forest-based bio-economy are located in the EU.

Upcycling old recycled paper to soil texturiser or new textiles

Name:

Infinite Fiber

Actors:

Private company

Country:

Spain, Germany,
Finland, Sweden

Funding:

N.A.

Recycled paper contains valuable fibre, but after a few rounds of recycling, more and more fibres become worn and torn and lose their strength, making them no longer suitable for paper-making. Nonetheless, after removing printing inks and pigments, these recycled fibres may still have a value in a number of applications, especially when the quantity of fibres is significant.

Due to the detrimental effect on the climate of using peat through its release of carbon dioxide, its use in soil improvement has been forbidden in Sweden. However, since worn-out recycled pulp fibres have good fertiliser properties, their upcycling to become a soil improvement agent is offering a new life for large amounts of old recycled pulp in that country. Also, the pulp fibres are well suited to improving soil texture.

Another possibility is to upcycle old recycled pulp fibres into textiles. This is a very important opportunity to support the circular economy. As global demand for natural cotton increases, the scope to cultivate it sustainably is decreasing. However, synthetic fibres, the main alternative to cotton, are produced by the fossil-based industries. In this scenario, Infinite Fiber has invented a processing technology for using recycled fibres from paper, cardboard and/or textile waste to produce a viscose-like, soft textile fibre. The cellulose in those raw materials is dissolved and reshaped in a fibreusing nozzle to produce completely new fibres:

https://cordis.europa.eu/project/rcn/91266_en.html

These offer sustainable alternatives for synthetic textile fibres but at an affordable price for customers. Given their restructuring, these fibres also stand up to several recycling rounds of use in textiles.

The company's business model is to sell technology licences for producing such fibres. Because of the licensing sales model, the company does not need to invest capital in all of the production facilities that make use of the technology.

For more information, see: www.infinitefiber.com

2.2 Recycling beverage cartons

Recycling beverage cartons

Name:	Actors:
ACE	Alliance for Beverage Cartons
Country:	Funding:
Europe	N.A.

Beverage cartons are made of composite layers of paperboard and polymers and, in some cases, a thin layer of aluminium too. While this combination makes for very effective, hygienic and lightweight packaging for storing and protecting drinks, it nonetheless generates technical challenges for recycling cartons after their use. Therefore, beverage carton producers and their suppliers have developed a specific recycling system, including extraction of polymers and aluminium.

One pre-requisite to any recycling is collection. Thus, mandatory separate collection of beverage cartons (e.g. together with lightweight packaging or paper) will increase the volume of materials available for recycling. This in turn can help create greater certainty for investment in sorting and recycling technologies and in new materials and hence support green jobs in Europe.

For beverage cartons, the paper component — liquid packaging board — is made from pulpwood and sawmill residues, while most of the fuel needed in the paper production process comes from forestry residues such as bark, tree tops and branches. The virgin paper fibres used for beverage cartons are a valuable raw material for new paper-based products when recycled, such as cardboard boxes, packaging for consumer goods, stationery, gypsum board and tissue.

Laminated paper packaging is collected together with other fibre-based packaging. The collected material is sold as an important raw material for recyclers, such as Fiskeby Board in Sweden. When separated out from the laminate, the paper fibres are appreciated for their strength and purity, enabling production of high-quality paperboard, fully based on recycled fibre. The recycled fibres are used as raw material for various forms of consumer board, including new food packaging. This packaging is also collected after use and sent to the same plant for recycling.

The fibres are automatically sorted according to quality (fibre length) and can be used up to seven times. When the fibre length has degraded below technical requirements for recycling, it is used for energy recovery.

In this way, renewable raw materials from responsibly managed forests give a double contribution to the circular economy approach. They ensure a sound combination of forest regrowth and recycling that leads to an overall increase of available paper raw materials, and they reduce the dependence on finite primary mate-

rials. By using wood fibre as many times as possible after its use in the carton, cascading of the raw material - including value creation - is maximised.

The recovery and recycling processes of the non-fibre components can vary depending on the country and reprocessing infrastructure. There are many recycling technologies available for this purpose, and there is currently a rapid technological development of further alternatives. Separated aluminium can be used in a number of industrial applications. Some recyclers turn polymer into gas, in replacement of fossil fuels. Another option is to recycle the polymer (or the polymer-aluminium mix) into granulates for new plastic products, such as garden furniture.

In some Member States, the poly-aluminium matter is currently recovered as energy, replacing fossil fuels otherwise needed to generate the heat for manufacturing paperboard. Future potential investments can also enable material recycling of the poly-aluminium matter. The case mentioned above is a very good example of the cascading use of biomass. Fibres can be used in the packaging products in several cycles until recycling no longer is technically feasible, after which the biomass can be incinerated for energy. This approach has increased resource efficiency, lowered emissions, created jobs and increased availability of materials.

The recycling rate of beverage cartons should increase thanks to the new EU waste legislation requirement to collect separately all packaging materials and the beverage carton industry's newly formed recycling platform. The latter will aim at better coordinating and supporting the recycling of beverage cartons in Europe.

For more information, see: <http://www.ace.be/ace-priorities/recycling-2/recycling-performance>

Biodegradable packaging — goodbye to waste?

Name:	Actors:
Seda, ecoXpac, Huhtamaki, Paptic, Sulapac	Private companies

Country:	Funding:
Italy, Denmark, Finland	N.A.

Disposable plastic items for food packaging and consumption, such as bags, cups, bottles, cutlery or containers, cause massive waste management problems and also pollute rivers, oceans and land. About 100 billion plastic bags are used in the EU every year, with most of them used only once ⁽³³⁾.

In May 2018, the European Commission proposed a directive on reducing single-use plastics ⁽³⁴⁾, as part of the European Strategy for Plastics in a Circular Economy ⁽³⁵⁾. The proposal calls for limiting or replacing the

33() https://ec.europa.eu/environment/efe/themes/waste/breaking-bag-habits_en

34() Proposal for a directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment, COM(2018) 340 final.

35() Communication from the Commission to the European Parliament, the Council, the European Economic And Social Committee and the Committee of

use of single-use plastic items, such as beverage containers, drinking straws, food containers, wrappers, and more. This recent initiative provides an opportunity for paper and cardboard manufacturers to facilitate the transition from fossil- to bio-based materials. Renewable and recyclable cardboard products offer the possibility to replace plastics bags, cups, bottles.

Although the recycling of plastic linings is technically possible, in practice it requires expensive specialist processing plants. Some possible alternatives are presented below:

- water-based polymer dispersions create a grease- and moisture-resistant barrier through hot sealing: no separate coating is needed and the fibres can be reused or composted. The packaging material is fully recyclable either at the site of consumption or in specialised mills. Alternatively, it can be used for new production.
- PAPTIC® is a newly designed novel wood fibre-based material that is biodegradable, reusable and recyclable. It combines the renewability of paper with the functionality of plastic. It is heat-sealable, food-contact approved and lighter than paper. This makes it suitable for the flexible packaging market. Paptic is also durable enough for reuse, which means that one Paptic bag can replace 5-20 single-use plastic bags.
- Biodegradable bottles, made from wood fibre, like the ones developed by ecoXpac, may be the solution to replace plastic bottles and minimise material usage.
- Biodegradable packaging material can also be made of mouldable woody biomass with natural binding agents, giving the customers the possibility to design the material according to their needs. A barrier coating material preserves the products held inside for their intended life cycle.

For more information, see:

<http://www.sedagroup.org/home.php>;
<http://www.ecoxpac.dk/>; <http://www.huhtamaki.com/>;
<https://paptic.com/>; www.sulapac.com

2.3 Micro- and nano-fibrillated cellulose

Stronger corrugated cardboard using less fibre

Name:	Actors:
Stora Enso, Kemira	Private companies
Country:	Funding:
Austria, UK, Finland	N.A.

Paper and board waste collected after consumption is widely recycled by the paper and board industry and

used, together with some virgin fibre, for new products. However, due to quality and performance requirements, there have been difficulties using lower quality fibres (e.g. after a number of recycling loops) even in board production.

Stora Enso is a global producer of pulp, paper and board products, who took on the challenge of efficiently utilising recycled paper and cardboard waste. The company developed FennoBond in close cooperation with the chemical company Kemira. FennoBond improves the binding features of the pulp used for corrugated cardboards made by Stora Enso.

Using FennoBond enables either a higher usage of low-quality recycled fibre or lowering the grammage of the fibre while retaining the same strength, thus making the end-product – packaging – up to 10 % lighter. This innovation has provided considerable savings on raw materials in the manufacturing of corrugated cardboard, while also providing benefits to the users in reduced mailing costs, transport costs and carbon footprints.

For more information, see:

<https://www.kemira.com/products/fennobond/>

Micro- and nano-fibrillated cellulose — multi-purpose materials offering diverse solutions across industrial sectors

Name:

AT: Lenzing; DE: BASF; FI: Stora Enso, UPM; FR: Imerys, InTechFibers; NL: AkzoNobel, Sappi; NO: Borregaard; SE: Inventia, Ahlström-Munksjö; UK: CelluComp, FiberLean, Zelfro

Actors:

Private companies

Country:

Austria, Finland, France, Sweden, Norway, Germany, UK

Funding:

N.A.

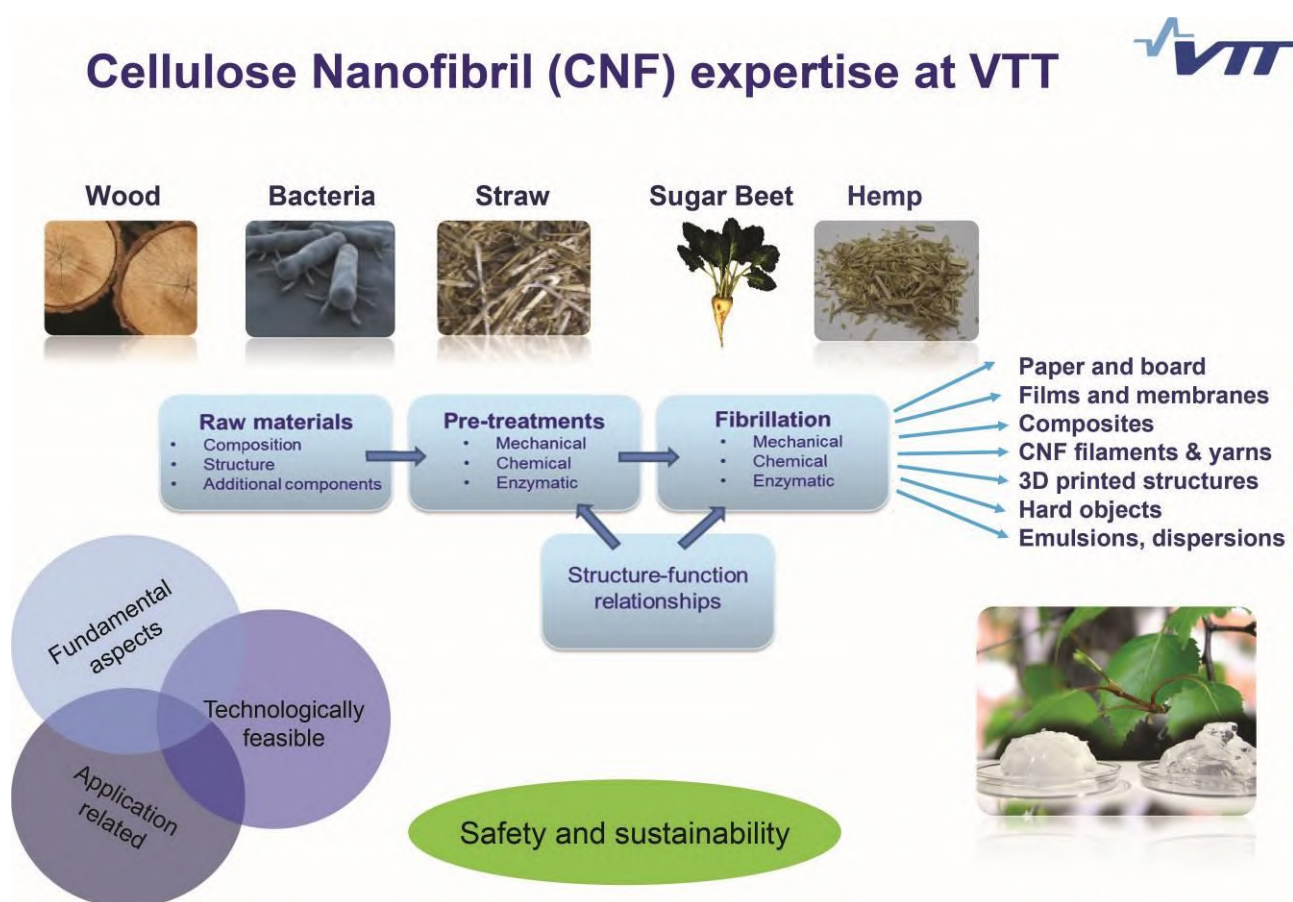
There are huge possibilities to exploit the side streams of the most widely used kraft pulping process and use them for a large variety of materials. Traditionally, depending on the market situation, the side streams were burned or partially used to produce chemicals. However, the down-turn of the paper market in 2005-2010 led the sector to embark on new research on side streams with a view to development and innovation.

Micro- and nano-fibrillated celluloses of 2-20 nm fibrils are produced by breaking down the amorphous regions of cellulose micro-fibrils (see Figure 7) of the side streams in kraft pulping. The same may take place for the crystalline part when producing micro-crystalline cellulose, e.g. for applications in the food and pharmaceutical industries.

Cellulosic micro- and nano-fibrils may be obtained from the cellulose fibres by mechanical, chemical or enzymatic methods, further broadening the variety of cellulose-based applications. Due to their high aspect ratio and specific surface area, micro- and nano-fibrils are highly reactive and form strong fibre-fibre networks and bundles with unique properties. They are suited to a large variety of applications because of their strength, surface properties, transparency and aerogel properties whilst being environmentally friendly.

Nano-technologies enable the manipulation of woody biomass cells, thus offering completely different properties and features for product developments. Thanks to many years of R&D cooperation between several forest industry companies and research institutions, there are now many opportunities for utilising micro- and nano-celluloses. These include such diverse commercial applications as non-toxic treatment of wood and woody biomass materials, paper and packaging, paints, adhesives, weed-control agents, food, medical treatments, automobile industry applications, flexible electronics, sensors, and construction uses, as well as filtering technologies for mining. These are made possible through traditional processing technologies or via 3-D printing manufacturing methods.

Figure 7



2.4 Bio-based plastics and composites

Additive manufacturing — 3-D printing, local manufacturing without waste

Name: VTT, EMPA, Fraunhofer, RISE, PFD-RISE; University of Minna
Actors: Research institutes, universities

Country: Finland, Germany, Portugal, Norway, Switzerland
Funding: N.A.

Composites from woody biomass-based materials play an important role in additive manufacturing. Additive manufacturing or 3-D printing is the creation of three-dimensional objects by successively layering material according to digital 3-D data. This allows the production of very complex geometries and the layering of very different materials. Also, manufacturing can be dispersed: printers may be located close to the user, locally or regionally, while the development and modelling can be done elsewhere. Well-specified, on-demand manufacturing minimises waste and environmental impacts. It is estimated that the market for 3-D printing will grow annually 15 % between 2015-2025. ⁽³⁶⁾

Bio-based lignocellulose composites have great potential as key materials for 3-D printing. This is especially the case for the multi-functional nano-composites, which can be used to print complex 3-D objects layer by layer. Multi-functionality through embedded nano-materials can also extend the features of nano-composites such as electrical conductivity, and increased strength and reduced weight.

Cellulose is a non-toxic material that has tunable properties (i.e. its response to electromagnetic waves can vary), high strength, stability and surface area, and it has numerous possibilities for chemical modification. For application in 3-D printing, four different sources of cellulose can be used: 1) sawmill powder and chips, 2) fibres, 3) fibrils, and 4) polymeric cellulose. Fibres and macro-size wood particles may be used in direct-paste printing of fibre suspensions or with a mixture of thermo-plastic polymers.

So, the combination of bio-plastics and nano-cellulose into composite materials offers an excellent upgrading from pulping side streams to high-value applications. This may take place regardless of the location of the printers and may open up new possibilities for regional development and manufacturing without waste.

36() Pietrowska, M., 2018, '3D printing of biomaterials', Pulpaper, 29 May 2018

2.5 Bio-based textiles from woody biomass

The shift towards wood-based textiles — the way towards “good-conscience” clothing

Already in the 19th century, wood fibre (from pulp) was used as a replacement for silk to produce viscose. The manufacturing process, however, was and still can be highly polluting due to the use of hazardous chemicals. Today, two thirds of the textile industry is based on synthetic fibres made from fossil fuels, while cotton makes up a quarter of the global market of 105 million tonnes of textiles. Meanwhile, wood-based textiles have a market share of about 6 %. Both synthetic and cotton fibres have big environmental footprints. The situation is further aggravated by micro-plastics' pollution from synthetic fibres and by the conflict arising from a rapidly growing world population and the pressure this puts on land and water use for cotton fibre vis-à-vis food.

Today, the technologies developed in Europe to process woody biomass provide an environmentally sound solution and may help revitalise textile manufacturing in Europe. The process can lend itself to industrial symbiosis with other industries.

Lenzing — Leader in wood-based cellulose fibres

Name:	Actors:
Lenzing	Private company

Country:	Funding:
Austria	Private

Lenzing produces sulphite wood pulp for standard and speciality cellulose fibres. The company's dissolving pulping technology makes it possible to choose, whether to produce paper or e.g. various textile fibres.

For more information, see: <https://www.lenzing.com>

Spinnova — New revolutionary cellulose-based fibre technologies

Name:	Actors:
Spinnova	Start-up private company

Country:	Funding:
Finland	Private

Spinnova's innovative method produces textile fibre from wood or waste stream-based cellulose, using a mechanical nozzle technology and without harmful chemicals, thus saving a lot of water and energy.

The method converts wood or other cellulosic fibres directly into textile fibre without any need for dissolving processes, harmful chemicals or energy or water-consuming steps. The finished fibre material can be used in the textile industry and because it is biodegradable, can be recycled.

The company will sell technology licences to fibre producers and will sell fibre to textile manufacturers. This will allow the product to be scaled up effectively. Production in the pilot plant starts at the end of 2018.

For more information see: www.spinnova.fi

3. *Wood for chemicals*

Integrated bio-refineries are facilities that convert biomass into multiple products. Various materials and residues from forestry and wood-processing industries (e.g. pulp and paper), households, communities and agriculture may be used as feed stocks for bio-refineries. Figure 8 presents the current distribution of bio-refineries across the EU (excluding conventional pulp and paper mills).

Figure 8: Forest-based and other bio-refineries in the EU, Nova-Institute, 2017.

Biorefineries in Europe 2017



© Bio-based Industries Consortium

The key innovations in woody biomass bio-refineries relate to technological developments in the utilisation of wood components other than cellulose, such as using hemicelluloses, lignin and refining their product flows. Globally, a wide variety of ways is being developed to utilise this biomass. Different conversion processes may be applied depending on the desired outputs. These developments can also provide very useful insights into ways to process woody biomass residues into multiple products.

The degree of integration in bio-refineries may vary, depending on the range of end products and associated installations for further refinement or utilisation. Building bio-refineries and associated installations is a highly capital-intensive and lengthy process and may take 7-10 years. Therefore, the optimal situation is where the existing processing methods and machinery (e.g. the Polylactic Acid - PLA production site) can be used to switch from fossil-based to bio-based production. The second best situation is when an obsolete manufacturing site can be switched over — with minor adjustments (i.e. change of feed stocks) — to process biomass and manufacture bio-based products (e.g. Novamonte). The third best situation is when an existing manufacturing site can be enhanced, so as to create a conventional bio-refinery having additional processing units, e.g. with further refined products (e.g. Borregaard LignoTech) or reprocessing residues to new valuable products (e.g. Metso LignoBoost). The most expensive scenario is when a wholly new plant has to be built (e.g. emerging DES).

The use of side streams of woody biomass for bio-refinery processing is only one example in a wide variety of developments occurring for biomass utilisation. One critical issue is how economies of scale can be attained and whether the production conditions allow for an adequate sustainable production of bio-based products and bio-fuels. Integrated food-energy systems may optimise land use and increase the use of biomass for energy (e.g. small-scale biogas generators).

The composition of biomass feedstocks, i.e. their relative amounts of cellulose, hemicellulose, lignin, starch, triglycerides and protein, vary. For closely related ligno-cellulosic plants, the bio-refinery activities are especially focused on these contents and on the calorific value of the various feed stocks for the production of energy (heat and power). Such bio-refineries also produce a range of products, including: briquettes, biogas, advanced bio-fuels, platform chemicals, added-value chemicals, bulk chemicals, polymers, pharmaceuticals and other substances of high value. The conversion technologies may use chemo-thermo-mechanical (CTMP), kraft or sulphite processing. However, the conversion technologies may also use less energy-intensive processing methods, such as super-critical and catalytic fluid extraction with organic solvents⁽³⁷⁾ at different temperatures. Different conversion processes could be applied, depending on the aimed for outputs, and the ongoing developments could provide useful technological advances to turn woody biomass residues into multiple products.

The most agile and resilient processes that produce multiple products are highly beneficial in volatile, market-driven businesses of the bio-economy. The markets for bio-fuels especially, either for ground transport or aviation, are constantly changing. This is due to the rapidly evolving shift to electric vehicles for ground transport and to biogas from agriculture (e.g. producing biogas as part of the treatment of agricultural waste) but is also linked to concerns about sustainability of biogas and other sources. Such concerns should be reduced from 2021 onwards, inter alia by using the new sustainability criteria for forest-based biomass. Although not covered by the Paris Agreement, the aviation industry has also committed to shift to bio-based fuels for some of its activities in 2020.

37() GR2018 2-Butanol and acetone as solvents and sodium hydroxide as catalyst.

Currently, the main factor driving the development of bio-refineries is the demand for bio-fuels, with co-produced bio-based chemicals and materials providing additional economic benefits. However, this situation may shift further towards the production of bio-materials, especially if more biodegradable bio-based plastics are produced following the specific demand introduced in the proposal for a plastics strategy in the Circular Economy Action Plan. Some final bio-refinery products, like bio-hydrogen, can also be used as energy carriers and as important auxiliary chemicals for e.g. CCU (Carbon Capture and Utilisation) technologies. The same applies to bio-ethylene and bio-propylene obtained from bio-ethanol production and to bio-based lubricants and surfacings obtained from bio-diesel production.

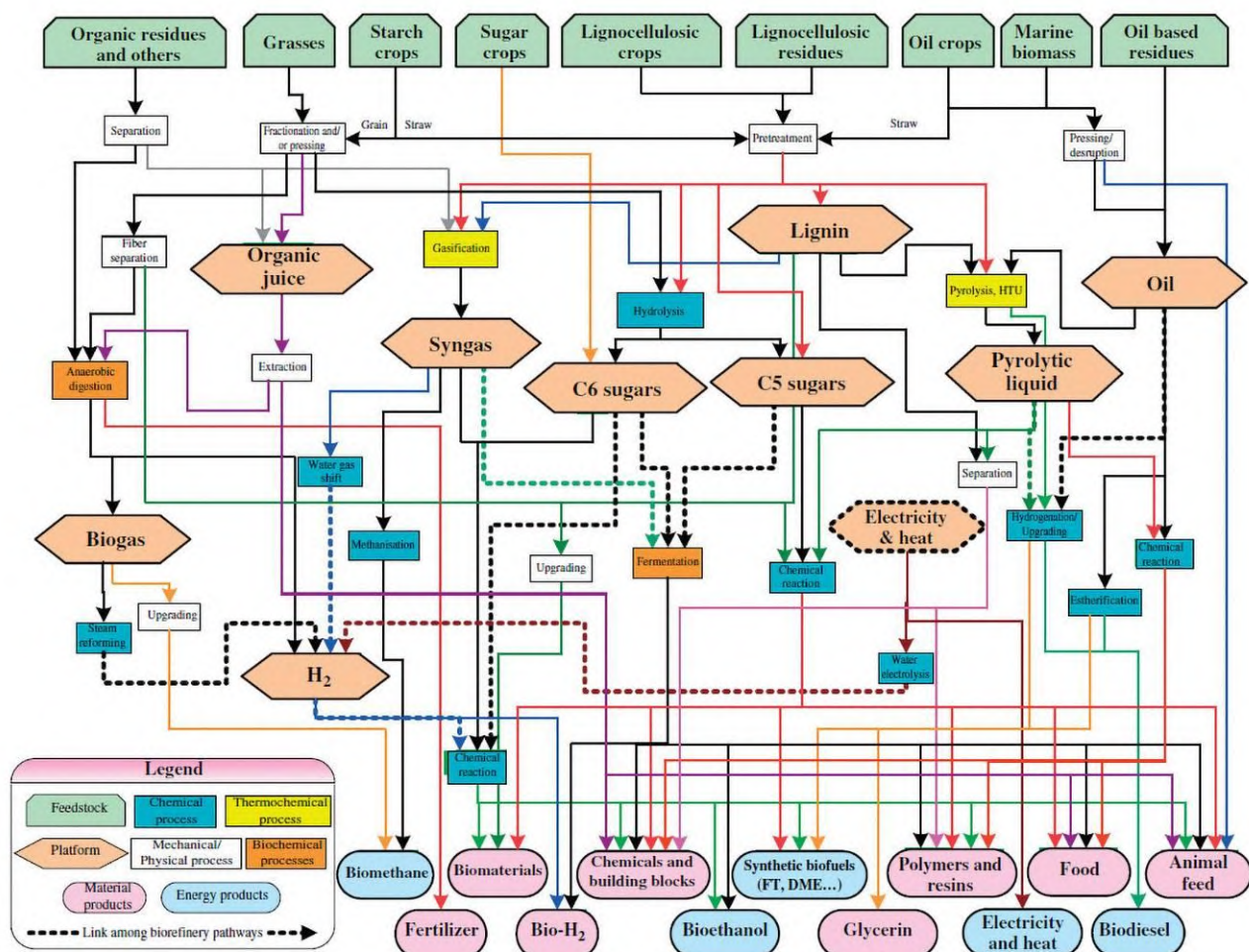
Other key innovations in bio-refineries relate to the technological developments in the fractionation of lignin and an efficient refining of its product flows. The technologies used may be traditional chemical paths or emerging innovations in ultrasound and microwave separation techniques. These offer possibilities for quicker, more resource-efficient separation of cellulose, hemicellulose and lignin from wood.

The major innovations in pulp and paper manufacturing are taking place in the intensified utilisation of hemicellulose and lignin. Hemicellulose provides the basic building blocks for bio-fuels and for plastics like polyethylene and polypropylene, while lignin fractionation provides a platform for aromatic chemicals. This enables a wide variety of applications to be developed, for example: carbon fibres for the automotive and aerospace industries, polyurethane glues or foams for wooden construction materials and the automotive sector, bio-based adhesives for a variety of industries, and lignin-based building blocks for the production of phenol and other aromatics for the chemical, pesticide, polymer and pharmaceutical industries.

To help replace the fossil-based economy, a network of bio-refineries utilising various feed stocks, efficiently provides both energy carriers and materials for large segments of the economy. This takes place either via production of the same chemicals (like substitution) or by using different materials with the same functionalities (unlike substitution). The fractionation of lignin also opens up new possibilities for new organic chemicals having lower environmental footprints than today's chemicals.

In the following section, the various types of bio-refineries are listed according to their platforms (feed stocks-chemicals-products). As indicated above, many of the examples below may be integrated into existing woody biomass processing production systems.

Figure 9: Network where alternative bio-refinery systems are combined ⁽³⁸⁾



3.1 From hemicellulose to chemicals and bio-fuels

Hemicellulose-based chemicals and bio-fuels — high added value from waste

Name: Danisco, Kotka mills, Lenzing
Actors: Private companies

Country:
Funding:

³⁸⁽⁾ Cherubini, F. et al., 2009, *Toward a common classification approach for biorefinery systems*, Bio-fuels, Bioproducts and Biorefining, pp. 534-546

Austria, Finland

Private

Both softwood and hardwood pulping side streams contain considerable amounts of hemicellulose and lignin. The separation of hemicellulose from wood's other components allows it to undergo further processing, such as enzymatic fermentation to make ethanol or other chemicals, and at a later stage to make other bio-based products. The prices for such commodities or 'drop-in' chemicals in global and regional markets determine which kind of products are made in a specific market situation, especially in the case of continuous dissolved pulping.

Hemicellulose can be separated from the side streams of pulping hardwood (e.g. from broadleaved trees). One possible output from hemicellulose is xylitol, a food additive for a large variety of applications, including 'candies without harm'. Xylitol is proven to prevent tooth decay. Xylitol is manufactured from xylose, a naturally occurring pentose which is obtained from the xylan-rich portion of hemicellulose. One of the biggest xylose production sites is that of the Lenzing company, where it makes woody biomass-based textiles. There the side streams of viscose textile fibre production are used to produce this xylose. The further processing of xylose to turn it into xylitol takes place in Europe at the Danisco plant in Austria and at the Kotka mill in Finland.

Producing xylitol from wood pulping side streams has a considerably smaller carbon footprint than that produced from corn cobs (maize) as the raw material, with a 90 % lower energy and materials consumption than such conventional processes.

Ethanol for bio-fuels

Name:

Leaders of Sustainable
Bio-fuels

Actors:

Private companies

Country:

Europe

Funding:

Private

A large number of bio-refineries in Europe produce bio-fuels, using both agricultural and other residues, such as side streams of woody biomass pulping which ferment hemicellulose mostly to make ethanol. These bio-refineries thus seldom refine biomass into other chemicals. Bio-fuel produced in this way offers the possibility to replace fossil fuels with a bio-based ethanol for land transport. However, bio-based aviation fuels from such processes are not yet generally available commercially, since their overall performance concerns have not yet been solved. ⁽³⁹⁾ Nonetheless, the aim of producing all of these bio-fuels is to replace imported fossil-based fuels and stimulate regional production in the EU.

39() <https://blog.alaskaair.com/alaska-airlines/news/nara-flight/>

For more information, see:

<http://www.sustainablebiofuelsleaders.com/wordpress/>

3.2 Tall oil for chemicals and bio-fuels

Crude tall oil - going for high added value or pure profits?

Name:	Actors:
Kraton	Public company
Country:	Funding:
The Netherlands	Public

Separating crude tall oil (CTO) and crude sulphate turpentine (CST) from kraft pulp as a side stream of the pulp and paper industries has been providing raw materials to produce bio-based chemicals since the early 20th century. The CTO refining industry thrives on industrial symbiosis with pulp mills, receiving CTO and CST from the pulp mills and using them as feedstock in their bio-refineries. CTO and CST are refined into innovative, functional and sustainable pine-based chemicals, such as natural rosins, fatty acids and their derivatives ⁽⁴⁰⁾. Such refining leaves a low-carbon footprint. The pine-based chemicals business has a strong sustainable value proposition and is a multiplier for job creation and economic growth ⁽⁴¹⁾.

Crude Tall Oil — the feedstock for high added-value and sustainable bio-based chemicals

Kraton Corporation (Kraton) has a rich heritage. At its manufacturing plant in Sandarne, Sweden almost a century ago, it pioneered the process of refining CTO and CST to make bio-based chemicals. Today, Kraton has the largest CTO distillation capacity in the world, developing, manufacturing and marketing bio-based chemicals that improve people's lives and ensure high-value and sustainable use of a limited biomass resource. As a leading bio-refiner of pine-based chemicals and operating in the business-to-business segment, Kraton has customers across a diverse range of end markets such as paints, adhesives, roads and construction, tyres, lubricants, and many more. Kraton's products enable customers to replace less sustainable, fossil-based resources with highly performing, renewable alternatives that improve the quality, resilience and sustainability of their products.

Many of Kraton's products are independently certified as bio-based against the EU standard EN 16785-1 ⁽⁴²⁾. They help achieve sustainability goals by enabling low-carbon solutions for society, facilitating the circular

40() Franklin Associates, Greenhouse gas and energy Life Cycle Assessment (LCA) of pine chemicals derived from CTO and their substitutes.30.8. 2013.

41() Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT: *Analysis Of The European Crude Tall Oil Industry — Environmental Impact, Socio-Economic Value & Downstream Potential*. Oberhauser, 11.5.2016.

42() <https://www.en-standard.eu/csn-en-16785-1-bio-based-products-bio-based-content-part-1-determination-of-the-bio-based-content-using-the-radiocarbon-analysis-and-elemental-analysis-2/>

economy and helping customers improve their sustainability performance.

For more information, see: www.kraton.com and: www.biobasedcontent.eu

3.3 From lignin to chemicals and bio-based products

Lignin — Eldorado of the near future?

Name:	Actors:
Borregaard	Private company
Country:	Funding:
Norway	Private

As stated in the introduction, conventional pulping processes are being extended further downstream to make efficient use of their various side streams and produce completely bio-based, aromatic and non-aromatic chemicals and materials. In particular, an efficient separation of lignin from the ligno-cellulose remaining in the black liquor residue from pulping — or from the ligno-sulphonates (in the case of the sulphite process), followed by several pre-treatment processes and then fractionation, offers a completely new platform for producing bio-based chemicals. It will soon be possible to use these bio-based chemicals to replace many products that today are made from fossil-based materials.

Sulphite processing — the ligno-sulphonate path to multi-product manufacturing

Due to its long-standing experience in the production of diverse chemicals using the side streams of sulphite pulping of spruce wood, Boregaard is seen as a kind of ‘ancestor’ of all bio-refineries. The company uses dissolving pulping technologies and deploys significant resources in R&D, thus advantageously combining what are referred to as ‘disruptive’ innovations across various sectors. One example is Exilva, a micro-fibrillated cellulose which enhances the performance of formulations such as adhesives, coatings and cement. For example, adding it to herbicides multiplies their potency and reduces the amount needed.

Borregaard has also developed lignin fractionation, which makes it possible to produce the only wood-based vanillin (a substitute for natural vanilla) in the world and to make ligno-sulphonates for diverse applications.

For more information, see:
<https://www.borregaard.com/>

Kraft pulping — Cracking the lignin-based platform for chemicals

Name:	Actors:
Stora Enso	Private company

Country:

Finland, SE

Funding:

Private

An efficient utilisation of ligno-cellulosic biomass is possible today, especially for obtaining lignin-based chemicals in applications where fossil-based materials are currently used. These include uses in specialty chemicals, construction, personal care and the food industry.

The bio-based lignin, Lineo™, made by Stora Enso, is a renewable replacement for oil-based phenolic materials of interest to companies seeking more sustainable, bio-based alternatives for binding resins in a range of wood-based products. Lignin is a non-toxic raw material and can therefore be used to make safer resins for: plywood, oriented strand board (OSB), laminated veneer lumber (LVL), paper laminates and insulation materials. Such resins make building with wood and other woodworking industry applications more circular, as wood treated with these resins is easier to recycle.

This and other lignin-based products can replace the fossil-based phenol. Also, research is being conducted on this very versatile material for many other applications, for example, in carbon fibres and energy storage.

For more information, see: <http://www.storaenso.com/>

Cost-effective, lignin-based carbon fibres — ultra-strong and ultra-light**Name:**

GreenLight Project

Actors:

Research institutes,
private companies

Country:

Sweden, Germany,
Italy, UK

Funding:

Horizon 2020

Reducing vehicle weight is a decisive factor in successfully fulfilling the future EU CO₂ emission targets for the automotive sector. Plastic reinforced with carbon fibre (CF) has been introduced as a low-weight material, replacing and/or complementing some of the existing uses of steel and aluminium. However, today's CF production is based on poly-acrylo-nitrile (PAN), a petroleum-based material, which is not only very expensive but also supplied from non-EU countries. Furthermore, its increased use in cars would not fulfil the EU goal of moving from a fossil-based economy to a low-carbon, bio-based economy.

In this context, the automotive sector has identified a need for a cheaper, lower-grade CF to meet the demand for components in normal passenger cars. Lignin from kraft pulping is a sustainable, abundant and cost-efficient source of a potential new CF precursor. The lignin can be supplied from the European pulp and paper industry's side streams, providing additional revenues which are welcome, given the declining demand

for printing and writing paper in the EU. Successful lignin applications like CF can create new business opportunities and new jobs, including in rural areas where many pulp mills are located.

The lignin-based carbon fibres have excellent properties and are suitable for many applications. It is estimated that only part of a typical kraft pulp mill production (+/- 650 000 tonnes per year) is needed for the production of carbon fibres which can be used for cars, making each of them 600 kg lighter than currently. This represents a huge opportunity for materials and energy savings, both in conventional and electric vehicles, as the lower weight complements the contribution from bio-fuels.

Lignin-based CF has so far only been developed in the laboratory. Now, the main challenge is to achieve material properties that meet the demands for a high-quality product. Thanks to a new technology in commercial operation, it is possible to produce lignin with new properties, higher purity and a lower impact on pulp mill operation. The idea is to tailor kraft lignin properties already in the lignin separation phase and customise the lignin for automotive applications. The consortium participating in the Greenlight Project has the complete value chain for creating this new bio-based, renewable and economically viable carbon fibre precursor, which will be produced in Europe with European raw materials.

For more information, see: <https://greenlight-project.eu/>

3.4 Bio-oil production

Fast pyrolysis bio-oil production in commercial scale

Name:	Actors:
Fortum	Private company
Country:	Funding:
Finland	Private and state

In 2014, Fortum commissioned a bio-oil plant integrated to Joensuu city's combined heat and power (CHP) system (Finland). This bio-oil plant based on fast pyrolysis technology is the first of its kind in the world on an industrial scale. The integrated plant produces electricity to the national grid and district heat to the city network, as well as renewable bio-oil to the market.

The plant has been designed to produce 50,000 tons/year of bio-oil from wood-based raw materials such as forest residues, wood chips and sawdust. This annual production corresponds to the heating needs of around 10,000 households. In addition to bio-oil, the co-products of the pyrolysis process are non-condensable gases and char, which are used for energy (power and heat) production in the highly efficient CHP boiler.

Fortum Otso® bio-oil can be used to replace heavy and light fuel oils in heating plants or in the production of industrial steam. Energy produced with bio-oil reduces net greenhouse gas emissions by more than 90%

compared to heavy fuel oil. In the future, bio-oil can also be used as a raw material for various bio-chemicals or traffic fuels. Fortum uses bio-oil at heating plants in Espoo and Joensuu, Finland.

Using fast pyrolysis technology, wood biomass is rapidly heated in oxygen-free conditions. As a result of the heating, the biomass forms gases that are then condensed into oil. Fortum has invested about 30 million Euros in its bio-oil plant and in modification work to its heating plants, and the project has received about 8 million Euros in government investment subsidies. Development and conceptualisation of the new technology has been done collaboratively between Fortum, Valmet, UPM and VTT (the Technical Research Centre of Finland). The research has been part of TEKES – the Finnish Funding Agency for Technology and Innovation's Bio-refine programme.

In Finland all bio-oil producers must have a sustainability system to be able to sell bio-oil as CO₂-free fuel. The sustainability scheme for the pyrolysis oil production at Joensuu CHP plant was approved by the national authority, the Finnish Energy Authority, in 2014. In terms of conformity, the authority is abiding by the guidelines given in 2009/28/EU (Renewable Energy Directive, RED).

For more information see:

<https://www.fortum.com/about-us/our-company/our-energy-production/our-power-plants/joensuu-chp-plant>

3.5 Bio-based plastics and composites

Degradable PLA reinforced with glass fibre — compostable to harmless minerals

Name:	Actors:
Arctic Biomaterials Oy	Private company

Country:	Funding:
Finland	Private

Bio-based polymers, resins and plastics can be produced from woody biomass. They can be the same as those produced from fossil fuels and without environmental benefits. However, they can also be different, like polylactic acid (PLA) which is genuinely biodegradable and transparent and complies with EU requirements, e.g. for materials in contact with food.

The demand to replace fossil-based materials, plastics in particular, with bio-based materials is very high. However, replacing plastics and composites with bio-based materials is a challenging task, since bio-materials do not generally tolerate high processing temperatures.

Arctic Biomaterials manufactures bio-based plastics and composites. It has developed an environmentally friendly, alternative composite for demanding technical applications. The company manufactures biodegradable plastic from PLA polymers, reinforcing it with degradable glass fibres. The formula varies slightly depending on the intended application and can tolerate processing temperatures of up to 165 °C. Compared to fossil-based products, the carbon footprint can be reduced by as much as 60 to 80 %. The bio-composite is compostable or can be broken down into lactic acids and reused as raw material; certification of this was

performed by DIN CERTCO. The material won the Bio-based 'Material of the Year' Innovation Award at the 11th International Conference on Bio-based Materials in May 2018.

For more information, see: <https://abmcomposite.com/>

4. *Technological advances*

As stated in earlier sections, various technological advances are essential to improve the cascading use of woody biomass. The most important developments are not the digitisation of manufacturing processes but the enormous information flows on woody biomass features and properties, from forests to sawmills and other downstream industries. These big data projects are also merged with satellite or drone technologies, providing information to forest owners about their forests via their smart phones, including advice on forest management measures.

Other innovations are in artificial intelligence and sensor technologies that serve to optimise sawmill and panel industry operations, for example, by providing information on incoming wood types and species. Laser-based measurement systems have become more accurate and speed up processing. The same applies to waste collection systems where technological advances facilitate optimisation of collection rounds and material sorting.

One very intensive technological development is the utilisation of woody biomass for residential heating using innovative stove and boiler technologies.

4.1 Big data — services for all in the value chain

Supplying wood for processing and end-products with the most value

Name:	Actors:
Metsähallitus	State forest organisation
Country:	Funding:
Finland	State budget

Sawmills, plywood mills, the pulp and paper industries, and wood-based energy producers are the main wood-buying clients of Metsähallitus. Saw-log, pulpwood and energy-wood prices differ depending on the sales margins of the products and their processing. The average prices earned by all forest owners are available in regularly updated public statistics, and are broken down for the different geographical regions of the country.

Information on forest resources is now better managed thanks to modern surveying and measurement methods and the geographic information system (GIS) in state forests. This provides a modern data-based approach for forest management planning. Up-to-date information on the reserve of planned forest stands and the potential supply enables forest owners to plan wood sales. The sustainable boundaries for harvesting

volumes are calculated and determined in regional natural resource plans via a participatory planning process involving several stakeholders (e.g. forest owners, forest-based industries, regional and national governments, public, etc.).

Sales of saw logs, pulpwood and energy wood are done centrally utilising thorough information on the existing and predicted demand of these wood grades on their respective markets and availability of wood from the reserve of planned forest stands. The reserve of planned stands, sales and harvesting and transport capacities are centrally optimised to provide the maximum gross margin. The cutting up of individual trees to different grades simultaneously for several clients is optimised on site in the forest.

Forestry in state forests has become more profitable thanks to better management of the whole procedure from forest management planning to the delivery of wood to clients. Wood as a raw material can be directed to the most valuable use. The ongoing development of information sources for assessing wood grades in forest management planning in a cost-efficient way will further improve the efficiency of the whole procedure.

A big data system for the forest-based sector

Name:

Efforte Project

Actors:

Research institutes,
private companies,
national forest offices,
work associations

Country:

Finland, France,
Sweden, UK,
Switzerland

Funding:

Horizon 2020

Diverse data, produced in various parts of the value chain of the forest-based sector, very often are not compiled, despite it being technically possible to do so. There are many reasons for this, one potential key reason being administrative restrictions on data-sharing between national institutions. The lack of a common data system prevents a more efficient utilisation of data. This situation also prevents the development of new business opportunities for various partners in the old or new value chains. Wood mobilisation is sub-optimal because forest owners do not receive information on time or lack necessary information about the market situation and the situation in their own forests. Better management of information about the forest-based sector as a whole would enable them to make their decisions on time and plan accordingly.

The EFFORTE project, funded through the Horizon 2020 programme, aims to merge data from various sources and provide a new platform for services. This will improve the precision planning and management of forests by forest owners and authorities, but it will also improve wood mobilisation and the supply of wood to industry.

The project's goal is to develop, customise and pilot modern 'Big Data' solutions that will increase productivity and reduce the negative impact on the environment (e.g. soil, water and fuel consumption). This is expected to make differences in efficiency, productivity and sustainability for an expanding bio-based economy

in Europe.

More detailed knowledge, better methods and technical developments combined with a better transfer of information and data from different sources will mean efficiency gains for all users of the system. Although the Big Data sources have been available for some years, it is not until recently that they have been used to their full potential. This is thanks to hardware, data communication and merging possibilities that have enabled new applications.

Big Data applications like this combine high resolution information sources with practices that increase efficiency in forest management and its connected value chains. This will be easy to replicate broadly across the EU.

For more information, see: <https://www.luke.fi/efforte/news/>

Electronic roundwood market platforms

Name:	Actors:
MTK ry — Central Union of Agricultural Producers	Non-profit organisation, forest owners

Country:	Funding:
Finland	N.A.

Quite often, roundwood sellers and buyers still e-mail or fax their respective offers and bids for lots of wood. As there are usually many offers (10-20) for one lot, the manually run system is very cumbersome for all users and slows down the availability of information on sellers and buyers, hence restricting the scope to match them and use woody biomass most efficiently.

An electronic roundwood market was developed with this situation in mind. The basic idea of the electronic roundwood market place is that it makes the market more transparent and the roundwood market activities more efficient. The digitisation allows building a platform with access for both roundwood sellers and buyers. The system was also in part publicly funded.

The electronic wood market place is open for everyone, and individual forest owners can market their lots for free. The service is expected to generate benefits both for forest owners and roundwood buyers. In addition to cost savings, the electronic market place is also expected to make roundwood markets more transparent and improve the way the markets and forest-based industries operate. The transaction costs of the Finnish roundwood markets are estimated to be around EUR 250 million annually. As the number of forest owners living far away from their holdings has been increasing, the electronic market place will also help mobilise them to the roundwood trade. Digitisation of the roundwood trade can also reduce the amount of manual work. Overall, the system has resulted in a more efficient use of resources, lower costs and more roundwood on the market. The system can be easily replicated in other countries as the programming language of the application is universal.

For more information, see: https://www.mtk.fi/en_GB/

4.2 Advanced processing technologies

Advances in processing technologies — like a rolling stone ...

Name: Hewsaw, Borregaard
Ligno, Enocell, Valmet,
LignoBoost, LignoFirszt

Actors: Private companies

Country: Finland, Norway,
Canada

Funding: N.A.

Developments in processing technologies go hand-in-hand with developments in materials innovations. Historically, the close cooperation between forest-based industries and the machinery industries has enabled leaps in technology, productivity and resource efficiency. With a multitude of various emerging technologies becoming available, the challenge is to take advantage of these new technologies and apply them for a variety of processing conditions and demands.

Digitisation, sensor technologies, artificial intelligence and high-speed computer modelling can be used in modern manufacturing, but the possibilities to apply them effectively widely vary between industries. This present guidance document gives examples. It shows how the advances start between a few companies and how this can then be expanded to a wider utilisation of technological advances, either in the same sector or in many related sectors, depending on the case. This strengthens mutual competitiveness, creates highly skilled jobs and possibilities for new regional development.

Some key examples of such technological development are:

- sawmills — high-speed technologies with huge requirements for machinery, laser technologies, AI, computerised imaging and modelling technologies (e.g. Veisto, HewSaw);
- panel industries — high-speed technologies with huge requirements for machinery, laser technologies, AI, quality measurement technologies, computerised imaging and modelling technologies (e.g. Raute);
- pulping technologies — from batch to continuous pulping technologies for agile production (Borregaard, Lenzing, Valmet);
- pulping technologies — forthcoming DES (Deep Eutectic Solvents) and US technologies;
- side stream exploitation — separation and fractionation technologies (LignoBoost, Borregaard);
- side stream exploitation — microbial and enzyme technologies maximising bio-fuels production from waste and residues;
- woody biomass — gasification and torrefaction technologies.

5. *Cooperation — a key to release untapped potential for industrial development*

5.1 Knowledge triangles

Nano-fibrillated cellulose — the way to build critical mass

Name:

VTT, UPM, Stora
Enso, Aalto
University, KTH

Actors:

Private companies,
universities

Country:

Finland

Funding:

Private, state, Seventh
Framework Programme
and Horizon 2020
programme

Gradual or disruptive innovation has traditionally been driven by strong interest from the private sector and individual countries in Europe. This kind of research work usually takes a long time and, however brilliant, faces great difficulties in moving from the laboratory to the pilot stage, from demonstration to market. Another hurdle when carrying out this kind of research is gaining market share and a timely return on the investment.

As demand for a number of paper products fell in the late 2000s, the pulp and paper industries, brought together key actors ready to invest in new fields of innovation and possible emerging business areas in their industry. The economic recession was an additional accelerator to build critical mass, turn ideas into innovation and create new business opportunities.

VTT has broad-scale expertise in technological issues. It brought together the pulp and paper companies, UPM and Stora Enso, and the research institutions, Aalto University and KTH (Kungliga Tekniska Högskolan). They have been carrying out R&D cooperation on nanotechnology and its potential for woody biomass.

Vital to their success has been the fact that technical knowledge on nano-cellulose properties and the possibilities for their manipulation was combined with the companies' expertise on the advanced and digitised processing of nano-scale materials in various conditions. The uptake of the technologies by the market has been considerably better for new applications due to the companies' involvement in the development process. This may also lead to a faster return on their investments.

The cooperation of industry, universities and research institutions in joint proprietary and/or public projects has pulled the critical mass together to bring disruptive innovations up to industrial scale. Business opportunities have started to arise through new competences and collaborative ways of working. Knowledge of various simultaneous developments have created synergies and high demand applications not only in the traditional woody biomass-based industries but also in the packaging, plastics, food and medical industries. 3-D printing with nano-fibrillated cellulose also provides a possible boost for regional economies.

5.2 Clustering

Clustering of partners around the same goal

Name:

Swedish Forest
Industries Federation,
Piteå Science Park &
Bothnia Bio-industries
Cluster, UEF Union of
European Foresters

Actors:

Trade and employers
organisations

Country:

Sweden

Funding:

N.A.

In forested regions, considerable benefits can be achieved by clustering industries that use different parts of the same resource.

The joint actions of various partners have increased energy efficiency in the forest industries and reduced wood waste: sawmills produce not only lumber but also chips from the remaining wood and sell them to the pulp & paper industries. Sawdust is used for pellet production, and bark can be recovered for energy in combined heat and power plants, industrial boilers or in district heating facilities, benefiting not only the industrial cluster but also the local population.

Pulp mills can use their by-products and residues or sell them to bio-refineries to produce bio-fuels, lubricants and bio-based chemicals.

Pooling of resources, both natural and financial, can make investments in more resource-efficient processes and equipment easier.

Today, most sawmills in Sweden are fossil-free (i.e. use no fossil-based energy), and the pulp and paper industries uses 96 % bio-energy for internal heat.

Clustering partners to add value to residues from the forest-based sector

Name:

Swedish Forest
Industries Federation,
Pitea Science Park and
Bothnia Bioindustries,
Union of European
Foresters Cluster

Actors:

Trade and employers
organisations, cluster
organisations

Country:

Sweden

Funding:

N.A.

To reduce emissions of carbon dioxide from heating in industry, private houses and buildings but at the same time maintain economic competitiveness, there has to be a transition from fossil to bio-based fuels. Forest harvesting residues and woody biomass that are by-products of various operations in the woodworking industries and in pulp and paper mills can be converted to bio-based chemicals, bio-fuels and lubricants.

A market-based approach, together with technological and raw-material neutralities are crucial for resource efficiency. E.g. setting the level of taxation is a delicate balance that must not unduly distort markets. If the price of wood for use as energy is too high, it will hinder advances in highly added-value woody biomass applications, such as in construction, packaging and new materials and products.

Sweden has the highest bio-energy rate (i.e. % of overall consumption) in the EU, with a competitive forest-based sector and active private forest owners. It is the third largest exporter of pulp, paper and sawn timber in the world. The forest-based industries account overall for 10 % of industrial turnover, added value and jobs.

The joint actions of various partners have increased energy efficiency in the forest industries and reduced wood waste. The investments by the forest industries in 2017 in new and improved capacity represented 23 % of their total investments. Some of these investments will result in even higher resource efficiency and provide possibilities to produce bio-fuels or new materials from side streams and by-products.

The process of producing bio-fuel has been further developed, with rosin and turpentine now being extracted for the chemical industries: 1 TWh of bio-fuels are produced from tall oil. Pulp mills in the northern Pitea area and the Bothnian Bay region are a good example of this. There, a better value for tall-oil facilitated technological advances which led to it having a higher yield, up to 100 % from previous results. Also, biomass gasification technologies have made it possible to produce chemicals in smaller scale reactors.

These activities have increased resource efficiency and lowered costs and emissions. For it to work in other markets, it is important to avoid regulating the use of wood. Sweden has stimulated a conversion to bio-based fuels by taxing fossil-based carbon emissions. This makes wood more valuable, increases competition and better supports active forest management and wood mobilisation. Higher costs for energy drive investments in increased resource efficiency and innovations into more valuable products.

For more information, see: www.skogsindustrierna.se

5.3 Sustainable financing

Green Deals — creating opportunities for new business models

Name:	Actors:
Green Deals	Governmental

Country:	Funding:
The Netherlands	N.A.

The Green Deals programme launched in the Netherlands in 2011 provides non-financial government support for environmentally friendly initiatives. The Green Deal is a mutual agreement or covenant under private law between a coalition of companies, civil society organisations and local and regional governments. The deal defines the innovative initiative and its related actions as clearly as possible (in quantitative aims or output, if appropriate) and defines the input of the participants involved as clearly as possible.

It is an accessible way for companies, other stakeholder organisations, local and regional governments and interest groups to work with central government on green growth and social issues. The aim is to remove barriers to help sustainable initiatives get off the ground and to accelerate this process where possible. Central government plays a key role in this area.

The Green Deal approach is one of the elements in a standard range of policy instruments. It is used to supplement existing instruments, such as legislation and regulation, market and financial incentives, and measures to stimulate innovation.

The Green Deal Board is responsible for monitoring and evaluating the progress and results of the Green Deals in place and for stimulating new initiatives. The Board's nine members meet once every three months. They come from business and industry, NGOs and government organisations. Five observers from different ministries represent the government, to which the Green Deal Board reports. Green Deals cover nine themes: energy, the bio-based economy, mobility, water, food, biodiversity, resources, construction, and climate. Nearly 200 Green Deals have been concluded so far, many of which relate to resource efficiency.

For more information, see:

<http://www.greendeals.nl/english>

5.4 National, regional or local cooperation

Regional cooperation — Montagne Florentine Model Forest Association (FMMF)

Name:	Actors:
Montagne Fiorentina Model Forest	Governmental, voluntary non-profit association, local authorities, associations, companies and single individuals
Country:	Funding:
Italy	ENRD

A Model Forest is both a geographic area and an approach to the sustainable management of landscapes

and natural resources. Geographically, a Model Forest must encompass a land base large enough to represent all of the forest's uses and values. It is a fully working landscape of forests, farms, protected areas, rivers and towns. The approach is based on the flexible management of landscapes and ecosystems that combines the social, environmental and economic needs of local communities with the long-term sustainability of large landscapes.

After a preparatory progress of three years, Montagne Florentine officially joined the International Network of Model Forests. In the process, with the support of the European Rural Development Fund, the association developed an action plan and projects around the specific needs of the region, bringing in regional and local stakeholders.

One of the purposes of joining this initiative was to understand better the dynamics of the wood-based sector in the territory of the FMMF and set up suitable strategies to promote the local wood-based value chain. For that, interviews were conducted with forest owners, logging companies, sawmills, private traders and companies for secondary processing located in the area of the FMMF or in close proximity.

Forests in the Florentine Mountain region are currently being logged to produce firewood and wood chips for energy production (about 80 %), and the products are sold both locally and outside the territory of FMMF: only 5 % of the logging companies sell exclusively locally, 30 % only outside and 65 % both. Sawmills also obtain wood both locally and from outside the region, while further processing is done predominantly outside the region. However, interest in the local raw material is significant, despite concerns about maintaining a steady wood supply.

Marketing of local forest and wood-chain products was stepped up by creating a brand that distinguishes products from the FMMF and launching a web-site connecting potential business partners. Keeping the value chain local has numerous benefits, including job creation in the region, reducing transport emissions and tackling the abandonment of local forest resources — which in turn decreases the risk and intensity of forest fires and hydro-geological instability.

Firewood and chips now account for the bulk of production, but the fact that most of the actors downstream get their supplies from external sources raises the question of whether more sawn timber should not be produced and to what extent this is possible.

The project was funded by the Tuscany Region, GAL Start (PSR 2007-2013, EAFRD https://ec.europa.eu/agriculture/cap-funding/funding-opportunities_en).

For more information, see:

<http://www.forestamodellomontagnefiorentine.org> and www.legno.forestamodello.it

Clustering through a small producers network

Name:

fmC — Forestal &
Medioambiente
Consultores
y Proyectos

Actors:

Portable sawmill
manufacturers,
entrepreneurs, public
bodies

Country:

Spain

Funding:

Private

The potential for wood production in Galicia, one of the most forested regions in Spain, has been estimated to be almost double the volume that has been recently harvested there. However, many material applications are not being fulfilled by wood but by non-renewable sources and less climate-friendly materials, and wood is not being used to stimulate the rural economy. This is partly because of a lack of tools and skills, so potentially valuable wood is used for firewood. Portable sawmilling and other low-cost tools and techniques to increase the utilisation of wood are used elsewhere but not yet in Spain or other EU Member States.

Local wood use and manufacturing have an extraordinary potential to contribute to rural and urban development. This initiative brings together equipment manufacturers, wood professionals (craftspeople, carpenters), public bodies as end-consumers, entrepreneurs as potential main players, and the wood technological centre in Galicia (CIS-MADEIRA). The goal is to increase access to small-scale, low-cost wood technologies (portable sawmills, moulders, planers, et al.) and develop necessary skills in wood manufacturing. Small businesses can take advantage of available wood resources, either as a business opportunity or a climate-friendly practice. Setting up a micro-producers' network to bring wooden products to the market, collaborate and share knowledge and ideas, is also part of the activity.

Circular economy and climate-friendly uses are central to the initiative, as only wood manufacturing by-products and recycled wood will be used to produce energy.

For more information, see: <https://madeiraenrede.wixsite.com/madeiraenrede>

6. *Engaging consumers and citizens*

Engaged consumers and citizens may give the market for bio-based, low-carbon products the push it needs to succeed. Keeping them informed of and matching innovation and developments to their evolving preferences is therefore key to an active role in the demand side and in opening up opportunities. This helps to bring better, environmentally friendlier and more durable forest-based products to the market.

Involving cities as population-dense hotspots in the transition to a low-carbon future is equally useful, as they are both centres of economic activity and of high consumption. Cities may influence future developments on a large scale: they are big consumers of materials and energy and big generators of waste, but they also offer financial and investment opportunities. Shifts in the social processes of cities and in the preferences of their inhabitants and changes in the urban planning and infrastructure projects of cities can impact our transition to a bio-based economy and the role the forest-based sector plays in it.

6.1 Certification and labelling schemes

Facilitating sound consumption choices for wood-based products

Name:	Actors:
FSC, PEFC, EU Ecolabel	EU and international organisations, private bodies

Country:	Funding:
EU, UN	N.A.

Consumers may base their buying choices on a number of criteria. Information about the origin and treatment of their potential purchases enables them to make informed choices that are not based on price alone. One way to provide information is through voluntary certification schemes, operated by external, private companies. These schemes are a way of tracking a product back to its origin. When companies require audited tracking from their suppliers, the schemes have greater impact.

There are many certification systems, and they operate in various manners. In the forest-based sector, FSC and PEFC are the certification systems most commonly used for designating sustainable forest management (SFM). When traced downstream, the origin of a wood-based product in SFM is referred to as “chain-of-custody” (C-o-C) certification. However, although most of the wood-based products on the EU market have originated from forests under SFM, so far relatively little of the wood is C-o-C certified.

Whilst FSC and PEFC C-o-C schemes for forest-based products certify that the woody raw material comes from sustainably managed forests, other frameworks, such as the EU ecolabels for various wood-based product groups, are needed to provide more comprehensive consumer labelling. The EU ecolabel criteria are revised on a regular basis, and ecolabels are granted for six years to companies complying with the specific criteria in their product category. The product categories and companies adhering to the EU Ecolabel

scheme may be found on the European Commission website ⁽⁴³⁾.

For bio-fuels derived from woody biomass, the Commission recognises the certificate from the United Nations Roundtable of Sustainable Biomaterials (RSB) ⁽⁴⁴⁾, which complies with the sustainability criteria of the EU Renewable Energy Directive. The sustainability of bio-fuels is assessed in this system on the basis of 12 principles assessing the raw-material value chain, production and use. Adherence to the principles is assessed on the basis of per-unit greenhouse gas emissions, biodiversity effects, the respect of human rights and social and environmental responsibility across the whole value chain.

For more information, see:

<https://www.pefc.org/>, <https://www.fsc.org/>,
<http://ec.europa.eu/environment/ecolabel/>

6.2 Platforms for wise consumer choices

Sustainable housing — designing the future

Name:	Actors:
Czech Sustainable Houses Project	Universities, governmental institutions, private companies

Country:	Funding:
Czech Republic	N.A.

To bring together state-of-the-art technology and innovative design, the Czech Sustainable Houses Project, which began in 2016, launches a yearly competition for graduate students of architecture on sustainable housing. The goal is to intertwine ‘fully functional, progressive and smart solutions into beautiful, self-sustaining and highly economical buildings of a new generation, whether off-grid, hybrid or active, making it possible to ensure more sustainable modern living standards.’ ⁽⁴⁵⁾

In the Czech Sustainable Houses Architectural Student Competition, the students come up with state-of-the-art building projects in a broad range of sizes and shapes, using today’s technologies so that anyone interested is able to buy such structures. Working with industry, the students create a publicly accessible off-grid house prototype. The project encourages households and businesses to draw on these solutions and implement them in their homes, thus making the transition to cleaner energy and more sustainable materials and consumption patterns.

In the process, architecture students get the unique chance to specialise in sustainability issues such as

43() http://ec.europa.eu/environment/ecolabel/index_en.htm

44() <https://rsb.org/>

45() <http://www.ceskyostrovnikum.cz/en/o-nas.html>

energy transition, use of renewable materials, water, etc., to share know-how and receive public visibility. The award winners have their proposal built on designated land with specific clients.

Since 2016, more than 20 sustainable houses have been built based on work done under the project and the students' designs. At least 40 students have found jobs in companies promoting sustainability after participating in the competition. Czech Sustainable Houses has also set up a think-tank bringing together 20 companies, three ministries, eight universities and 10 professional organisations. It organises exhibitions and workshops in the Czech Republic. The positive media attention has not only promoted the project but also the demand for sustainability housing features in general. Similar projects are being developed in Hungary, Poland and Slovakia.

For more information, see:

<http://www.ceskyostrovnikum.cz/en>

WiseGRID — a platform for renewable energy choices

Name:

WiseGRID Project

Actors:

Technology institutes,
private companies,
universities

Country:

Spain, Italy, Greece,
Germany, UK, Belgium

Funding:

Horizon 2020

Consumers often have problems finding energy providers with the most cost-competitive offer for renewable energy. Knowledge about whether individuals or communities can feed renewable energy from solar or wind into the national or regional grid is frequently lacking, due to administrative and/or information constraints rather than technical ones.

Funded through the Horizon 2020 programme, the WiseGRID project is a Spanish initiative to make the electricity network more intelligent, open and customer friendly. The project will develop nine solutions to improve the electricity grid, empower consumers and make the European electricity grid more intelligent and open. It will also make it more customer-oriented using digital technology that enables two-way communication between suppliers and customers. The solutions WiseGRID will be developing also include platforms to monitor and manage infrastructure. For this, the platforms will use applications that support demand-response, tools that optimise the charging of electric vehicles and integrate energy storage, and marketing services for unused generation capacity. The project is targeting, among others, distribution system operators (DSO), consumers, prosumers (people who produce and consume energy) and operators of electric vehicle fleets.

DSOs and energy cooperatives will test the WiseGRID solutions for at least 15 months, operating under real conditions in Belgium, Spain, Italy, UK and Greece. Different players will be involved, ranging from house-

holds and businesses to aggregators and car-sharing companies. The WiseGRID project will run until April 2020.

The purpose of the project is to empower consumers. Therefore, WiseGRID is pursuing the creation of an open market in which new operators such as SMEs or electric cooperatives play an active role. The project's aim is to make energy a more democratic system beneficial to both the network and consumers. The results of the project will be assessed and a manual published with guidelines. The commercialisation of WiseGRID products will create 1 800 jobs and give 860 000 people and 23 000 organisations access to new services. In the long term, it could save more than 20 million megawatt hours of energy and 14 million tonnes of CO₂ and help to achieve the EU's goal of increasing the proportion of renewable sources for energy generation by 35 % by 2030.

For more information, see: <https://www.wisegrid.eu/>

6.3 Platforms to share information on wood reuse, recovery, recycling and upscaling

Optimising the collection, sorting and recycling of post-consumer wood waste

Name:	Actors:
Opt-I-Sort	Regional authority; industrial federation

Country:	Funding:
Belgium	Subsidies from the Flemish Region

In the past, Flemish households and businesses every year produced around 600 000 tonnes of post-consumer wood waste. Though still of materially usable quality, most of this went to bio-energy plants.

With the support of the Belgian Federation of the Textile, Wood and Furniture industries (Fedustria) and the Flemish Region, the Opt-I-Sort project was set up to improve the collection and sorting of post-consumer wood waste, improve wood recycling knowledge and techniques and increase the percentage of wood waste that can be recycled.

Opt-I-Sort investigated optimal collection and sorting methods for post-consumer wood waste recycling in technical and economic senses. It examined, tested in the field and evaluated several scenarios in cooperation with collectors, sorters and users of post-consumer wood waste to find solutions for all parts of the value chain.

In the process, the key barriers identified were the following: a) the human factor (e.g. how to motivate people, how to give more value to waste wood), b) wood waste (e.g. very heavy administrative burden, unsuitable criteria for recycled wood and a 'low' value material), c) the technical capabilities to process the constantly changing wood waste stream, d) the lack of a level playing field with the bio-energy sector using recyclable or virgin wood (certificates system) and e) the lack of energy and material policies aligned at European level.

Focusing on research, the Opt-I-Sort project enabled 20-30 % more waste wood to go to recycling instead of energy recovery. This was mainly thanks to the shift in emphasis to communicating with consumers and encouraging them to sort wood waste at waste collection sites.

For more information, see:

<http://www.optisort.be/en-gb>