



‘Absorbing the Potential of Wood Waste in EU Regions and Industrial Bio-based Ecosystems — BioReg’

D2.4: RECOMMENDATIONS FOR INDUSTRY STAKEHOLDERS

To the attention of the Research Executive Agency

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More information on the project can be found at <http://bioreg.eu/project/>.

ABSTRACT

This document provides a series of practical information, recommendations, and an example for industry stakeholders about collecting, sorting and valorisation of waste wood. While in the past most of the wood waste was disposed into landfills, nowadays increasing volumes of waste wood are or reused and recycled. The two main end uses for waste wood are recycling for the panel board industry and energy. This report offers an overview of main issues regarding wood waste management and some recommendations on how to enhance wood waste valorisation practices in Europe. Germany and France have been selected as case studies to offer an overview of wood waste management system in these countries.

ABBREVIATIONS

EN: European norm

EPF: European Panel Federation

EU: European Union

GHG: Greenhouse gas

ISO: International Organization for Standardization

mm: millimeter

MS: Member States

R&D: Research and development



WRA: Wood recyclers association

XRF: X-ray fluorescence

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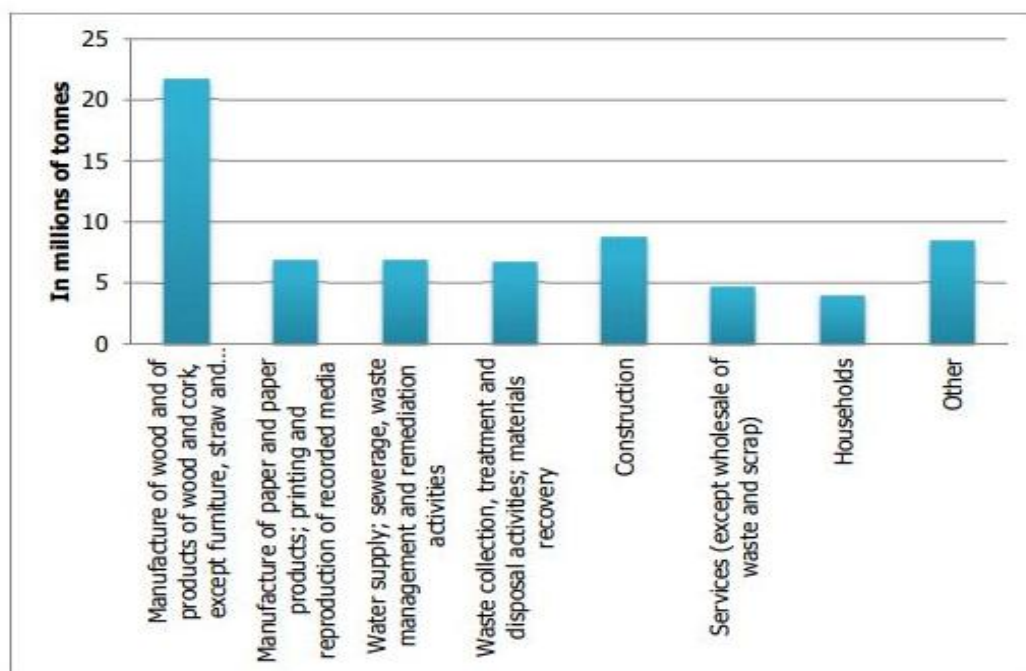
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1 INTRODUCTION

According to EUROSTAT data 57 million tons of wood waste was generated in 2010 in the EU 28. Over 94% of the aforementioned amount was produced by economic activities other than households, with the largest wood waste-producing sector being the manufacture of wood and of products of wood and cork (except furniture; manufacture of articles of straw and plaiting materials) with 32%, followed by construction (13%); waste management / water supply (10%); and manufacture of paper and paper products (10%) (EUROSTAT). Although 97% of the EU-28's wood waste generated was non-hazardous, there is still a small share of hazardous wood waste generated in Europe, generally used for energy production, which requires disposal at specialized facilities and causes a real threat for the environment due to toxic pollutants.

Figure 1: Generation of wood waste in the EU-28 by economic activity, 2010, Analysis of certain waste streams and the potential of Industrial



Source: Eurostat waste statistics (2010)

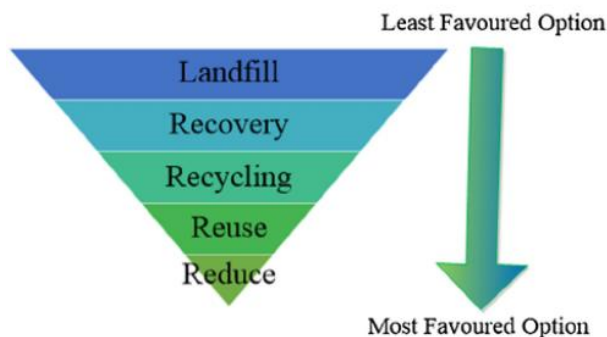


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More than half of the wood waste produced in 2010 was used for incineration with energy recovery, followed by material recycling (mainly particleboard production), while less than 5% was landfilled (EUROSTAT). The situation has changed dramatically compare to some years ago when most of the wood waste was destined to incineration facilities in order to produce energy in form of heat, steam or electricity. The demand for wood energy suppliers is quite significant in Europe and it expected to increase on the following years as biomass represents an important source for achieving EU targets on energy efficiency and renewable energy. However, factors such as environmental concerns, waste accumulation and consumer awareness have encouraged countries to introduce new measures enhancing or even imposing recycling of materials before disposing them as waste. In this sense material recycling industry needs to be competitive compare with using wood waste as a source for bio energy production, an industry that has been facilitated from state subsidies.

On November 2008, the European Union introduced an EU Waste Framework Directive imposing clear rules on waste management and binding targets for recycling wood waste among others. The Directive offers a definition of waste as “...any substance or object which the holder discards or intends or is required to discard...”. The EU Waste Framework Directive, part of the Circular Economy package, establishes a waste hierarchy to be followed on waste management:

Figure 2: Waste hierarchy according to Waste Framework Directive



According to the hierarchy the most favoured option on wood waste end usage would be recycling, followed by recovering while the least favoured option will be landfilling. This position was confirmed on 23d of February 2018, when the European Council endorsed the four legislative proposals on waste package establishing new rules for waste management and binding targets for recycling wood from packaging by 25% until 2025 and 30% by 2030, reuse and recycle municipal waste by 55% by 2025 and 60% by 2025, as well as reducing landfilling waste

(maximum of 10% of municipal waste by 2030). Furthermore, Member States (MS) will have to set up, by 1 January 2025, separate collection for hazardous waste from households (Council of the EU). Waste recycling must be prioritised as it provides several benefits for EU citizens such as reduction on: consumption of natural resources, landscape degradation, groundwater contamination and GHG emissions. The implementation of EU directives is leading to an increasing demand for WW and better separation of waste wood fractions from bulky waste and construction and demolition waste, but collection of used wood for recycling is not yet very well developed and great amounts of WW are still being landfilled.



2 RECOMMENDATIONS

2.1 TECHNICAL RECOMMENDATIONS FOR INDUSTRIES

2.1.1 IMPLEMENTING AN EFFICIENT WOOD WASTE VALUE CHAIN

A stable and reliable wood waste supply system is important in order to support a sustainable deployment of wood waste in high added-value applications instead of incineration for energy production. Factors such as peak availability, collection logistics (collection, transportation and treatment) and recycling facility location are important parameters to take in consideration when designing an efficient supply chain. Waste wood is available all around the year as it is produced from different activities, however in summer the production of energy is lower. Therefore, higher amounts of wood waste could be used for wood-based products such as particleboards.

The wood waste supply chain includes four processes: production and collection; sorting and processing; and valorisation.

Figure 3: Wood Waste Value Chain



2.1.2 IMPLEMENTING EFFECTIVE COLLECTION SYSTEM FOR WOOD WASTE

A better collecting system can have significant impact in terms of increasing the quantity of recycled wood; reduce costs and contribute to reduce landfilled wood. WW can be collected via several routes depending on its source, amount and grade. Household WW is usually collected at household waste recycling centers or via the council's bulky waste collection (in the case of furniture), where this is available. WW from construction and demolition and commercial and industrial sources can be collected either by waste management companies in skips (decentralized collection system) or can be taken to be processed directly by the producer (centralized collection system). The decentralized is widely used due to the high volume and low value of waste. There are also several informal WW disposal routes such as burning in small scale boilers either by the producing company or its employees.



Table 1: Impacts of best practices: Production and Collecting of wood waste

OBJECT/ AIM	MEAN	TARGET	POSITIVE IMPACTS
REUSE: furniture, beams, timbers	Repair centres, recycling centres	households and enterprises	Carbon storage, money savings, virgin biomass preservation
Encourage sorting on site (by optimising the place)	Compartmentalized skips	Enterprises	Increase valorisation rate
Forcing producers to recycle	Extended producer responsibility/ take back obligations	Producers of furniture such as: Eco-mobilier and Valdivia	Increase valorisation rate
Encourage producers to sort	Sorting platform and collecting centre for waste from construction and demolition	Enterprises of construction and demolition (production/collecting/sorting) and waste companies (collecting/sorting)	Increase valorisation rate

2.1.3 IMPLEMENTING A GOOD SORTING SYSTEM

After the collection process by wood recycling specialists, the wood waste is sorted and graded according to the wood quality. This process is particularly relevant as it determines the price of wood waste depending on its content. This gives waste producers and intermediaries price incentives to keep lower grade wood waste separate. More investment and overheads in processing are required to produce high value feedstocks whereas high throughput and low handling costs are necessary to produce a lower value, higher volume product. An efficient sorting system is necessary in order to remove contaminated material which can lead to environmental pollution and supply less contaminated and high-quality wood waste for panel production instead of energy production through incineration. Wood waste is often sorted according to its grade (DEFRA 2012):

- Grade A: “Clean” recycled wood – material produced from pallets and secondary manufacture etc and suitable for producing animal bedding and mulches.
- Grade B: Industrial feedstock grade – including grade A but mixed with construction and demolition waste; this is suitable for making panel board.
- Grade C: Fuel grade – this is made from all of the above material plus that from municipal collections and civic amenity sites and can be used for biomass fuel.



- Grade D: Hazardous waste – this includes all grades of wood including treated material such as fencing and track-work and requires disposal at special facilities.

Sorting process defines the most appropriate use of wood waste as it consents to separate wood waste from other materials, hazardous waste from non-hazardous waste, as well as separate fiber panel to meet requirements of panelboard industry. Clean wood can be recycled or converted into energy, contaminated wood can be sometimes used for energy or disposed into landfills, hazardous waste must be landfilled.

Processing of wood waste has two main objectives: one is to obtain a suitable granulometry for the end use and the second is to improve the final quality of the product in relation to the requirements of the end use. In large facilities for particle board manufacturing or for energy production, sorting occurs directly at the plant, upstream of the production or energy conversion plants and often at outdoor platforms. At these platforms, waste wood is handled, shredded, and screened.

Handling

Handling of bulk and heterogeneous material at sorting sites can be done with shovels equipped with a grapple or with bucket loaders (left). Bucket loaders feed the shredders and the screens, manipulate material (fine fraction, shredded material) and load trucks for evacuation.

Picture 1: Grapple (left) and bucket loader (right) feeding waste wood into shredder. (Source: CEDEN)



Shredding

The aim of grinding and shredding is to reduce the particle size of incoming wood waste and to facilitate the removal of iron. Grinding is often performed in two steps: a slow grinding first, in order to avoid breakage and to facilitate the recovery of metal contaminants, followed by rapid grinding to obtain the desired granulometry. The shredders are generally equipped with one or more magnetic rollers enabling the removal of ferrous contaminants.

Picture 2: Slow and fast shredders in series (left) and hammers (right). (Source: CEDEN)



Picture 3: Recovery of metals at the level of a slow shredder. (Source: CEDEN)

The two shredders are arranged in series with conveyor belts which convey the material from the slow shredder towards the fast shredder. The rapid shredder is generally equipped with a grid to calibrate the final product. The meshes are often as wide as 250 mm for waste wood but can be also of



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smaller size (up to 80mm). The smaller the mesh, the more "fine fraction" is produced and the more metals are recovered.

Picture 4: Mobile drum screen. (Source: CEDEN)



Screening

Depending on the requirements of the end user, the shredded material can be recovered directly, or submitted to screening, by which fine particles are removed and the output material is more homogeneous in size. This can be done with

simple drum screens, which separate the incoming material into a fine fraction and a coarser fraction. The meshes are round or square and in general between 10 and 30 mm. Adjusting the feed rate and drum rotation will influence the amount of fine fraction obtained.

In some cases, sorting can be performed at dedicated mixed waste collection centres usually held indoor, where mixed waste is collected and then separated into different groups depending on its quality and its final use. At these facilities, sorting can be either manual, mechanized, or also assisted by optical devices. Collection and sorting centres usually perform a pre-sorting of waste wood by means of a grapple or a clamp mounted-up on a shovel. The pre-sorted waste is then introduced into a hopper feeding a separation chain which separates different materials: wood, heavy inert, cardboard, plastics. Optical sorting and manual sorting make it possible to separate different categories of wood (based mainly on the colour). Conveyor belts allow different materials to flow from one piece of equipment to another. The mechanised sorting centres for mixed waste contain generally optical sorting equipment to separate the wood fraction from other types of waste. Two main techniques are to detect contaminants in wood and to separate different types of wood waste: Near Infrared spectroscopy and XRF (X-ray fluorescence). The optical sorting makes it possible to improve the quality of the resource, to respond as closely as possible to the requirements of the various users. Tests showed that NIR optical sorting can separate clean wood when it is mixed with glued wood waste (panel residues) and coated wood waste. For XRF, tests have shown that the technology can detect even wood inorganic preservative treatments (copper and chromium) (D1.2).

For a processor of waste wood, it is vital to be capable of sorting products into different classes in compliance with the classification system in place in its country, as this determines the end use that waste wood can have. New innovative technological solutions are needed for the chemical and mechanical contaminants sorting and removal such as: technologies for metal and non-wooden materials recovery from complex products; technologies (detection and removing systems) to improve the cleanliness of recovered wood; technologies to process and dispose contaminated removed parts and materials; technology for wood product components to be sorted by wood quality; technology for the introduction of the recycled component and materials in new products.

Economic environmental and benefits should exist to encourage companies to collect and sort waste.



Table 2: Impacts of best practices in value chain: Sorting and processing of wood waste



OBJECT/AIM		MEANING		TARGET		POSITIVE IMPACT
Improve product in view of meeting outlet requirements	Extraction of undesirables	Manual/ visual sorting	Manual, shovel equipped with pliers	wood waste undesirables	Framework windows, doors	Reduction Zn, Pb in sorted products
					outdoor wood waste	Reduction of heavy metals
					Sleepers, fences	Reduction of benzo (a)pyrene
	Separation of material	Mechanical sorting	Shredding, screening, over band, eddy current. Innovative solution for windows: mechanical treatment for (chipping, milling) for coating and chemical treatment for preservatives	Other undesirables	Plastics, glass, padded, ferrous, non-ferrous.	Visual improvement makes possible to achieve requirements of outlets and to separate wood from other materials
	Separation of material	Optical sorting	NIR	wood waste undesirables	MDF	possible to separate fibre panel to meet requirements of panel board industry
			XRF		Polluted wood	possible to separate polluted wood to meet requirement of outlet.
	Particle size reduction	Shredding	Low rapid shredder fitted with sieves, Specific low shredder	Rough wood waste		Lead to appropriate particle size. Consequence: avoid resorting to screening step- money saving
	Fine particle extraction	Screening	Trommel, stars screen	Shredded wood waste		Improve screened product, possible to meet requirements of outlet, % of particle smaller than 3.15 mm
Improve environmental impact and human health impact	Protect operators from dust	Stationary and electric equipment	Shovel, loader, shredders, screens	All along the step of sorting/ treatment		Reduction of consumption of fossil fuel / noise. Money savings. Reduction of dust emission. Improvement of human health
		Shredding, screening, loading	Confined equipment's, aspiration pipe system, water aspersion			
		Extraction	Endless screw			
		Individual protection equipment	Helmet category 3, glasses			
	Blending	Blends of different grades of wood waste	Loaders	Rough wood waste and prepared wood waste		Production of a mixed product: possible to meet certain conditions: moisture, solid wood rate, MDF rate, clean wood rate, fine particle rate

2.1.4 CLEAR AND COMMON CLASSIFICATION OF WOOD WASTE

Beyond the regulation of the Waste Framework Directive and the classification in the waste catalogue, there are different criteria that can be used to classify wood. Possible classification of waste wood could be according to its type, source, producer and/or recovery techniques used.

The distinction between different categories of wood can be based on international norms (ISO 117225 (biofuels)) or European norms standards such as: End of Waste decree in France; threshold for recycled waste established by EPF (European Panel Federation); German and Austrian Ordinances. The Wood Recyclers Association (WRA) in



United Kingdom for example classifies WW in four grades, with Grade A defining clean waste and Grade D defining “hazardous” WW. Different grading systems are adopted by MS however all classifications propose a clean wood category and a category of hazardous waste that must be disposed. Some classifications are set by law (Germany), or at least approved by public authorities (Finland), while in other cases the classification is set up by a professional organisation (United Kingdom) (D1.2).

In general, we can affirm that classifications on the EU 28 tend to favour the noblest classes for material recycling (panel industry) and other classes for energy. However, a harmonized regulation at European or International level seems necessary for classifying WW in categories. Having a common classification system at EU level would facilitate trading of WW from countries that generate more WW towards countries with highest recycling rate.

2.2 RECOMMENDATION REGARDING LOCATION AND CAPACITY OF THE PROCESSING FACILITIES AND TRANSPORTATION COSTS

The selection of the best processing location and the capacity of the recycling facility are two important factors which must be taken in consideration when designing a wood waste supply chain. For example, long transportation distance between the collection and processing centre may have a negative environmental impact due to the increase of GHG emissions and energy consumption making it less convenient to re-use wood waste. Furthermore, the transportation costs go up with increasing plant capacity due to the higher raw material demand. On the other side, part of the costs can be recovered during the production process as increasing the quantity of production will decrease production costs (economies of scale). In this sense, it is important to establish an optimal location and capacity of the recycling facility taking in consideration transportation costs. Furthermore, significant volume of WW is now shipped across Europe. WW trade predominantly takes place in Western Europe, countries with established wood recycling sectors and relevant consumer base - the panel industry, energy sector, or other users.

2.3 RECOMMENDATION ON VALORISING- RECYCLING AND CASCADE USE OF BIOMASS

The enhancement of recycling process is useful to further encourage the utilization of recycled wood for the manufacture of high-value products. Wood wastes are recycled in the form of particles and most of the recovered wood is used to make particleboard products (e.g. furniture components); moreover, the next most widespread method is to burn the recovered wood with energy recovery. Other end-uses include animal beddings and landscape mulches, but in general, the use of recovered wood in particle form has a very little added value. In this sense, the development of alternative recycling methods will add much more value to the recovered wood and this would provide more money for the recycling processes and, in turn, encourage more recycling. Recycled wood can be also combined with other recycled materials in order to obtain new products. Consequently, it will also be possible to develop new markets and increase the competitiveness of European production.



Depending on the ways of valorisation of wood waste, there can be different quality requirements for the feedstock. Nevertheless, there are many common parameters for the different end uses, in particular for the

Table 3: Limit values of contaminants for the panel industry (left table) and waste wood requirements for the pulp and paper industry (right table). (Sources: EPI and DEMOWOOD project)

content of heavy metals, chlorine and other contaminants. For the panel industry, the EPF (European Panel Federation) sets maximum levels of contaminants in the wood waste used in the composition of panels as well as in the finished products. The EPF standard also sets maximum levels of undesirable elements (2%) and moisture (20%), however, in some countries, national regulations can set more binding thresholds (ex. in Germany) (D 1.2).

Element	Limit values (mg/kg recycled wood)
Arsenic (As)	25
Cadmium (Cd)	50
Chromium (Cr)	25
Copper (Cu)	40
Lead (Pb)	90
Mercury (Hg)	25
Fluorine (F)	100
Chlorine (Cl)	1000
Pentachlorophenol (PCP)	5
Benzo(a)pyrene (Creosote)	0.5

Quality requirements for pulp and paper industry
Exclusion of wood preservatives
Exclusion of toxic metals in the cycle of matter
Separation of impurities (metals, plastics)
Origin of wood waste: softwoods are preferable (maximum hardwoods 2%)

The pulp and paper industry can also be an additional recycling route for waste wood; in this case the feedstock must be of very high quality.

Regarding the energy use of waste wood regulations differ across MS and depending on the type of installation. In general, waste wood is not considered as solid biofuel, such as woodchips or wood pellets. Therefore, the quality criteria regulating the use of waste wood for energy are related to the European Waste Catalogue, which applies to incineration and co-incineration plants. Regarding the quality of wood waste, the thresholds and parameters used to qualify clean wood are not the same from one country to another. For incineration, there are no thresholds for incoming wood waste.

Good waste management principles require waste hierarchy to be followed as established on the Waste Framework Directive: materials are first re-used and recycled into new products, before energy recovery and



disposal. This principle should also apply to WW. The cascading principle offers a kind of hierarchy of uses similar to the EU waste framework directive as it imposes recycle of materials before energy recovery. Cascading use of biomass takes place when biomass is processed into a bio-based final product and this final product is used at least once more either for materials or energy production. The cascade principle prioritizes material use of biomass rather than energy use, and energy production combined with co-products over energy production only. A cascading use of wood waste can contribute to decrease the GHG emissions in Europe, the development of bio economy and for mitigating climate change.

Table 4: Impacts of best practices for the valorization step in the value chain.

OBJECTIVE/ AIM		MEANING	TARGET	POSITIVE IMPACT
Improve supplied pre-treated wood wastes on the valorisation site (post-treatment)	Post-treatment (the wood waste supply does not always meet with final requirement of outlet)	Shredding, screening, ferrous and nonferrous removal, NIR, XRF...Blending. These treatment steps are like those encountered on sorting/treatment dedicated platforms.	Rough wood waste or pre-treated wood waste	Ensures the final achievement of requirements of the outlet. Especially requirements of combustion/incineration and production of used wood-based panels.
Energy recovery	Get a good energy efficiency	CHP: heating valorisation (industrial supply, district heating network...) Resort to condensation.	Operators (energy companies), technologies providers	Economies savings, positive environmental impact (fossil fuels substitution).
	Ensure gas treatment	Beyond classical equipment (boiler volume, staged combustion, SNCR, SCR, coal, lime, bag filters, electro-filters, resort to condensation.	Municipal authorities (tenders), energy companies (operators), consultancy	Respect of emissions thresholds, positive environmental impact.
	Ensure disposal of ashes: in agriculture or in forest, cemetery, concrete, ceramics, road infrastructures.	Improve quality of ashes: shredding, screening, ferrous and nonferrous removal (eddy current, over band), chemical extraction of heavy metals...	Operators (energy companies)	Positive environmental impact (preservation of virgin resources, substitution of chemical nutrients) and money savings (no resort to landfilling)
Recycling	Maintain quality of wood waste-based particle board panel (recycling "to infinity" could lead to pollution of recycled panel board).	Monitoring and control of wood waste supply on site (optical sorting XRF, NIR). Dilution with clean wood or virgin wood just in case, or valorisation in energy for process.	Operator (panel industry), technologies providers	Positive environmental impact (formaldehyde emissions...), respect of thresholds (panel board), sustainability/relevance of cascade use.

The cascade principle must be used as a guidance for policy makers in order to improve resource efficiency and limit unsustainable consumption of natural resources. The policies must define what kind of biomass must be used for what purpose, rather than regulating in detail.



2.4 RECOMMENDATION ON DEVELOPING EXISTING AND NEW MARKETS ASSOCIATED TO WOOD RECYCLING

Energy and particleboard manufacturing are two competing markets for wood waste, but their requirements can be different: the energy sector requires a material with low metal content, low chlorine and low contaminants, in order to ensure a sustainable energy generation with reduced atmospheric emission. The panel industry is interested more in the physical quality of wood waste, preferring solid wood in its supplies. Solid wood comes mainly from buildings (construction and demolition) and contains more pollutants than the waste wood from furniture (mainly reconstituted wood). Therefore, the separation between recycling and energy is not so clear. Often the operators on the sorting platforms dilute their waste wood with clean wood like pallets (or low treated wood like waste wood coming from household) in order to achieve requirements for the panel industry.

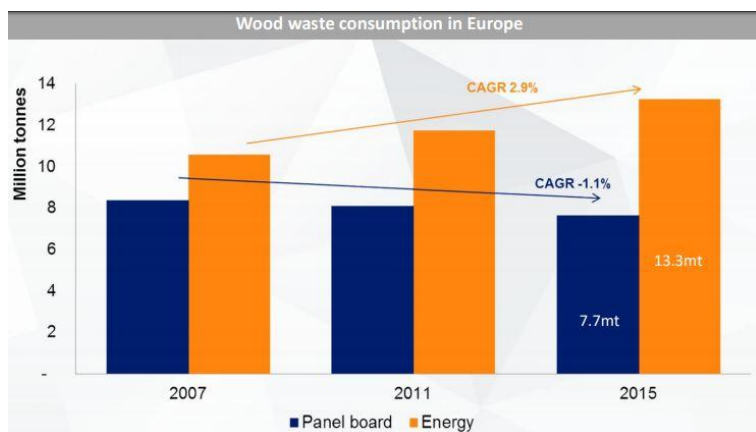


Figure 4: CIBE, Bois en fin de vie, Nouvel Essor pour l'Énergie, 30.09.2017, Le Havre

Clearer parameters are necessary in order to define what can be the ideal market of wood waste through a multicriteria analysis, the viability under the economic, social and environmental point of view of the proposed actions. The demand for wood waste from energy suppliers is quite strong, as biomass is one of the most important sources for renewable energy generation. Other important factors are encouraging the use of wood waste for

energy production rather than material production, such as:

- The sale price of wood waste for energy production which is higher than the sale price of wood waste for particleboard production. In this regard, a level playing field is needed among bio-energy and other industries producing wood waste based recycled materials.
- Logistical issues concerning separation of waste wood at many sites.
- Inefficiency of the sorting process which leaves residues such as metals and plastics which need further treatment, discouraging a cascade use of wood waste.



While aiming at fostering the wood waste recycling industry, as established by EU institutions, the implementation and design of new market products for recycled wood waste can be fundamental. Economic incentives in terms of product price could encourage the usage of recycled materials as raw materials.

2.5 ROLE OF GOVERNMENTS ON WOOD WASTE MANAGEMENT

Governments can contribute on enhancing the recycling wood waste industry rather than its usage for energy production. On previous years, the renewable energy targets set in the renewable energy directive incentivises the use of biomass for energy production (heat and power) without imposing a cascade use of biomass. Policies must encourage a high value usage of biomass resources, introduce ambitious targets for recycling and separate collection of waste; introduce economic incentives for the implementation of the waste hierarchy, R&D programs, tax reduction/ exemptions and investments subsidies. On the same time governments must impose binding obligations restricting disposal of waste, and imposing fees for companies not complying with the regulation. In France for example, a tax could be applied when panel don't contain enough recycled wood in their composition (eco modulation/eco participation). This tax could boost the panel industry to increase the rate of recycled wood in their panel. Recycling should be economic for a company instead of burning which means that the derived raw material should be cheaper than the primary one.

Policy makers can introduce legislative and infrastructural measures to develop an organized technical and logistic mechanism ensuring the recycling of large part of wood as well as the minimization of losses.

The European Union must provide guidelines to Member States on wood waste valorisation pathways, support them with technical assistance and monitor Member States' implementation efforts, as well as promote dialogue among them to exchange best practices on wood waste management.



3 WOOD WASTE VALUE CHAIN- GERMANY AND FRANCE AS CASE STUDY

3.1 GERMANY AS A CASE STUDY

Germany is the country with the highest production of wood waste in Europe (Eurostat 2015) followed by France and at the same time these countries are leading producers of particleboard in western Europe. Both countries have a good supply of virgin wood and have experienced increasing prices for all wood feed stocks, driven by increasing competition from bioenergy during the last decade.

In 2015, Germany produced 11.9 million tons of wood waste coming from wood packaging (21%), demolition and construction (26.7%), wood processing industry (14%), municipal wastes (20.7%), import wood (9.7%) and others - including private households and railway construction (8%) (GARCIA, C.A., HORA, G. 2017).

More than 20 years ago large part of the wood waste was used for energy production in incineration plants or disposed in landfills. The situation was due to different challenges the industry was facing, including regulations and inefficiencies on the wood waste value chain. Some years ago, the government started recognizing the importance of waste avoidance and recycling, therefore started implementing an environmentally friendly policy. On 15 of August 2002, the German government introduced an Ordinance of Requirements for the Recovery and Disposal of Waste Wood - Verordnung über Anforderungen an die Verwertung und Beseitigung von Altholz, establishing requirements for waste wood to be recycled or used for energy recovery. The Ordinance offered also a classification of recycled waste wood in four categories (Table 5).

Table 5: Recycled wood waste categories in Germany, GARCIA, C.A., HORA, G., 2017

Table 2
Recycled waste wood categories in Germany.

Category	Description	Applications
A I	Untreated or only mechanical treated wood	Chips and Shavings to produce wood-based materials, synthesis gas and activated carbon production (possible energy)
A II	Glued or painted wood (No halogen-organic compounds or preservatives)	Chips and Shavings to produce wood-based materials, synthesis gas and activated carbon production (possible energy)
A III	Wood containing halogen-organic compounds; no preservatives	It can be used as material if the varnishes and coatings are removed
A IV	Contaminated Wood, including halogen-organic compounds No PCB	Energy use in large combustion facilities
Polychlorinated biphenyls (PCB)	PCB treated wood	Non-hazardous disposal

Another important challenge for German enterprises connected to the value chain of wood waste consists on the low availability of clean waste wood and the inefficiency of waste sorting process with remaining material such plastics and metals which require a further treatment. As a result, in Germany 80 % of the wood waste (mainly category A III and AIV- figure 2) is used in incineration facilities for energy production and only 20 % of wood waste (category A I and A II- figure 2) is used to produce wood-based products such as particleboards (GARCIA, C.A., HORA, G. 2017).



Having an efficient sorting system on the recycling facilities is it highly important to separate the high-quality wood waste that can be used in applications such as wood-based materials, animal products and bioenergy, from the contaminated wood waste destined for bioenergy production.

An important parameter to consider when deciding on the end-usage of wood waste is its sale price. The sale price of A I waste wood for energy purposes is around 70/80 € per ton, while the sale price for particleboard production is 60 € per ton (GARCIA, C.A., HORA, G.. 2017). On these conditions, the recycling companies are encouraged to sale the wood waste category A I to incineration facilities for energy production due to the higher revenue. Furthermore, some incineration facilities are using contaminated waste wood (category A II and A III) for energy production due to low costs and the high availability instead of re-using and cascading (GARCIA, C.A., HORA, G. 2017).

Germany is promoting the cascade-use of wood waste in the wood-based industry in order to increase the amount of recycled wood waste used in the products. The recycling process of wastes can be carried out by the own company, as for instance the company Pfleiderer GmbH, or by a third recycling company such as Veolia Environmental Services. The company Pfleiderer GmbH, which main goal consists on producing wood-based panels from fresh wood, is re-using fractions of recycled wood waste to manufacture new products and remaining fractions for cogeneration to supply the energy requirements of the process (GARCIA, C.A., HORA, G. 2017). After the consumer end-use, the wood-based panels are collected, sorted and treated in order to reuse them back in the production process (1/3 of the wood used is recycled wood waste). The third-recycling companies have established a supply chain for the management of wastes such as plastic; paper and wood. The wood waste is collected by customers or third companies; delivered to transition centers collecting waste from different sources; transported to recycling facilities where is classified by source, sorted and treated; and submitted to incineration facilities such as Veolia Environmental Services for production of electricity and heat. The company burns around 65.000 tons of wood waste per year, producing 47.000 MWh of electricity and saving 110.000 tons of carbon dioxide per year (GARCIA, C.A., HORA, G. 2017).

3.2 FRANCE AS A CASE STUDY

Veolia Environmental is a French company operating on several European countries. Bioreg's project partners had the opportunity to visit the Seine multi-recycling centre in Oissel (France), is a high-performance sorting centre owned and operated by Veolia. Started in 2013, it employs 28 people and covers an area of 41,600 m². The centre treats 76.000 tons of mixed waste every year, 20.000 tons of which is represented by recycled wood (furniture, demolition, and construction etc.) The sorting centre is adjacent to an outdoor waste wood treatment platform which performs a first selection of wood waste for energy use, disposal, and recycling. The waste wood that can be recycled is transported from the platform to the sorting centre, for separation from inerts and contaminants. At the centre, the waste material undergoes the following processes:

- 1) Reception: the waste is initially received in a dedicated area where a first selection with a loader is performed;
- 2) Mechanical separation: the waste is separated mechanically by using a disposer, a mechanical sieve and an aerolitic separator;



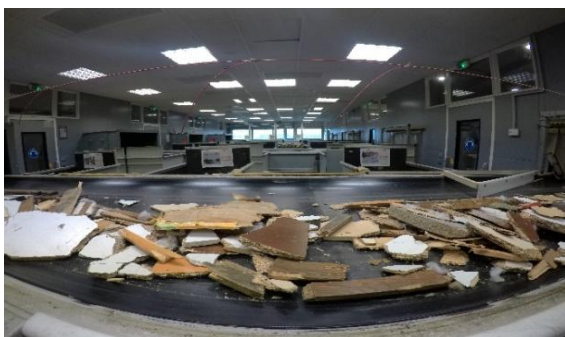
- 3) Selection of recyclable material: the material which can be recycled is screened through an additional sieve then is processed by optical sorting machine, followed by an overband and finally separated with Eddy



current.

- 4) Quality control and storage: at the end of the separation chain, the quality of the recycled material is checked by cabin operators and automatically stored in silos.





Picture 5: Veolia Seine multirecyclingcentre in Oissel. Reception area where the waste is selected with loader (up left) and fed into a conveyor belt (up right); separation with aerolitic system (middle left) and optical system (middle right); quality control.



4 CONCLUSION: LIST OF RECOMMENDATIONS

The following recommendations emerged from the paper:

- Good waste management principles require waste hierarchy to be followed: materials are first re-used and recycled into new products, before energy recovery and disposal. This principle should also apply to waste wood.
- Cascading use principle should be applied whenever national/local conditions allow (ex: if there is no panel industry locally, better to recover in energy in order to avoid long transportations)
- Know your market: the energy sector and the particle board sectors require different qualities of recycled waste wood: this affects the production process or waste wood.
- Efficient and effective collection and pre-treatment are essential steps to ensure local availability of sufficient quantities of high-quality waste wood and for stable end use markets.
- Different processing steps are necessary to obtain a suitable granulometry and to improve the quality of waste wood in relation to the requirements of the end use.
- Different equipment is available for handling, shredding and screening of waste wood. Accurate design of the process is necessary to minimize costs and maximize productivity.
- Screening (extraction of fine particle > 8-20 mm) improves the quality of products, even though this step entails the generation of 20 % of by-products (fine fraction), more polluted and very difficult to valorise.
- One or two-stages shredding? One stage of shredding is less expensive, is sufficient and avoids reducing the size of the products too much. It is sufficient to prepare products for energy use with a granulometry > 200 mm. Two-stage shredding generates smaller particles and improves the efficiency of removal of ferrous and non-ferrous contaminants from the feedstock.
- Separation of two types of wood on platforms before preparation for energy (reconstituted wood) and for panel industry (solid wood). This strategy is interesting to achieve the different requirements of industry and energy. Solid wood comes mainly from building and is more polluted than reconstituted wood: hence, the mobilization of solid wood can increase the amount of heavy metal or organo-halogen compounds.
- Set up of electric stationary equipments instead of mobile ones. This solution enables to save money during operation (low energy consumption) and has a very low impact on environment. Stationary equipment reduces dust emissions thanks to aspiration systems and confining.
- Different categories of waste wood can be utilized to different end uses. Clean wood can be recycled or converted into energy, contaminated wood can be sometimes used for energy or disposed of into landfills, hazardous waste must be landfilled.
- For a processor of waste wood, it is vital to be capable of sorting products into different classes in compliance with the classification system in place in its country, as this determines the end use that waste wood can have.





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