End-of-life transformation strategies of building materials

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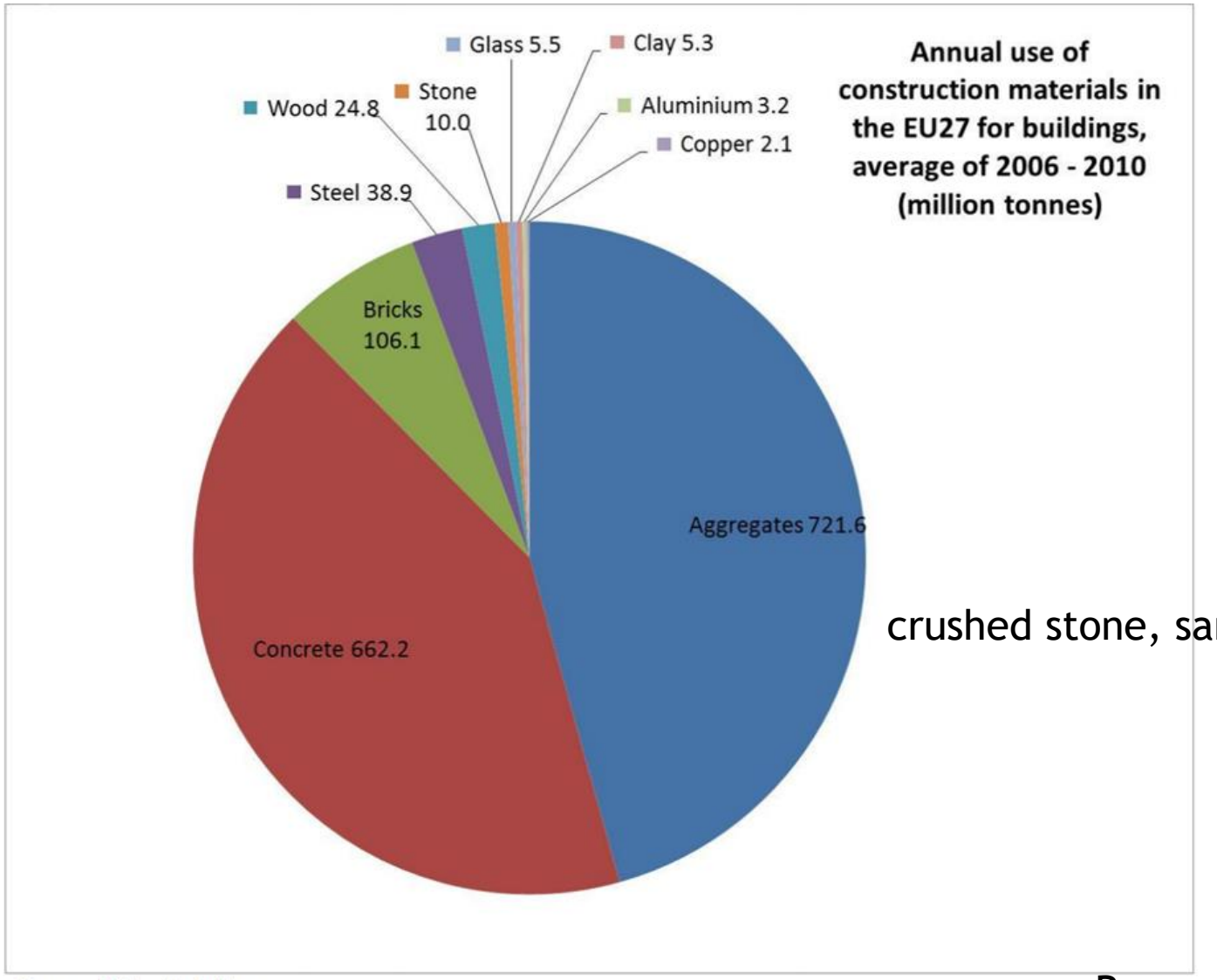
FP1407 Training School: Service life of modified wood - Understanding Test Methodologies

Construction market

- Is one of the major employment sectors across the EU (496 billion € of value added).
- The sector provides 20 million direct jobs and contributes to about 10 % of the EU‘s GDP
- Represents a large proportion of the consumption of the earth's non-renewable resources in terms of:
  - materials used for construction
  - energy consumption for operation of buildings

Annual use of construction materials

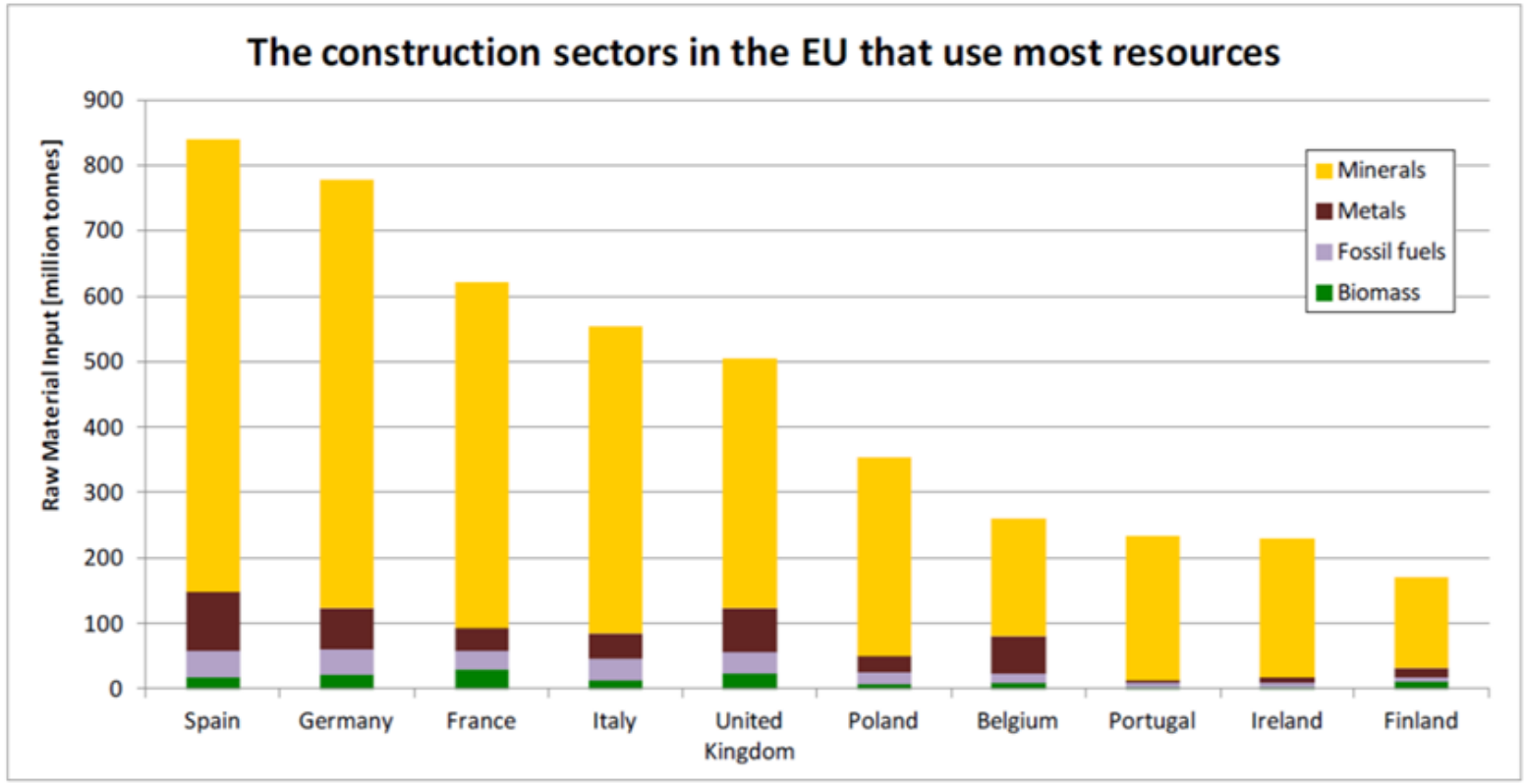


Source: CRI calculations.

crushed stone, sand, slag, recycled concrete

Resource efficiency in the building sector (2014)

Resource use by construction sectore



Source: BIO IS, 2013[13].

Resource efficiency in the building sector (2014)

Life cycle of a building

- Looking at the whole life cycle of a building, from the extraction of materials, the manufacturing of construction products, construction, use and maintenance, buildings in the EU amount for about:
  - 1/2 of extracted materials
  - 1/2 of energy consumption
  - 1/3 of water consumption
  - 1/3 of waste generated

Roadmap for a Resource Efficient Europe

- According to RREE, better construction and use of buildings could help making significant resource savings:
  - could influence 42% of our final energy consumption
  - about 35% of our total greenhouse gas (GHG) emissions,
  - 50% of the extracted materials,
  - could save up to 30% of water in some regions

Wates in Europe

- Construction and demolition generate one of the highest volumes (25% - 30% of all waste generated in the EU)

- Strategies for improvement of the efficient use of materials:
  - better project planning - ensuring greater use of resource and energy efficient products
  - promoting more resource-efficient manufacturing of construction products - using recycled materials
  - promoting more resource-efficient construction and renovation - reducing construction waste

Construction and demolition waste

- **One tone of construction and demolition waste is produced per person per year** – this means 500 million tones in the whole EU every year.
- **Valuable materials are not always identified and recovered**.
- Improving waste management in this sector can have a significant impact on the circular economy.

- It can be done by:
  - **ensuring recovery of valuable resources** and adequate waste management in the construction and demolition sector, as well as facilitate assessing the environmental performance of buildings.
  - development of **pre-demolition guidelines to boost high-value recycling** in the sector as well as voluntary recycling protocols aimed to improve quality of and build confidence in recycled construction materials.

EU Construction & Demolition Waste Management Protocol (2016)

Source of wood wastes

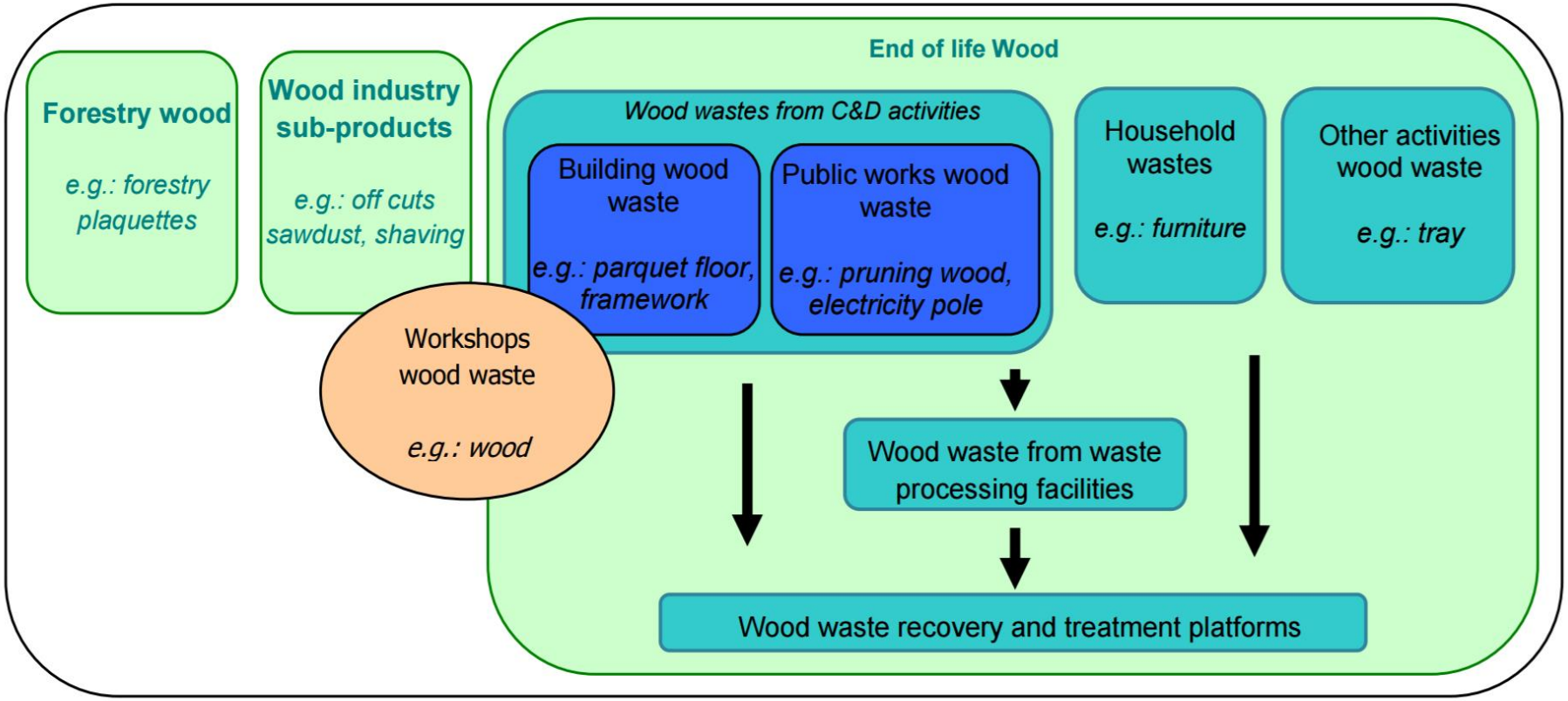


Figure 1: Wood wastes origins (CTBA, 2008)

Wood wastes and residues

There are tree main types of woody wastes and residues

- Untreated wood
- Treated wood wastes and residues
- Wood composites and laminates

#1 - Untreated wood

- include off-cuts and sawdust from those industries and processes that work with untreated wood.
- those wastes can be handled in the same way as other virgin wood

#2 - Treated wood

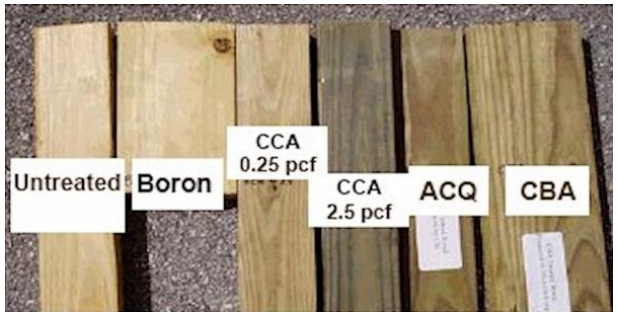
Type of treatment	Aim	Preservatives	Potential danger of preservative
Thermal treatment	Protection	None	None
Coating	Protection and decoration	Non metallic paintings or varnishes	None
		Metallic paintings or varnish (heavy metals, organic compounds)	Toxic in high concentration
Gluing	Assembling	Mineral glue, animal glue	None
		Synthetic resins (chloroacetate vinyl, urea formol)	Toxic, noxious
Fire Proofing	Resistance to fire attack	Metallic salts, isopropanol	Toxic in high concentration
Preservation by soak	Resistance to medium biological attacks	Boron and other heavy metals	Toxic in high concentration
		Diazole, pyrethroide, IPBC	Irritating, mutating, hazardous for reproduction
Preservation by impregnation	Resistance to high biological attacks	CCA, arsenic, organic copper, creosote	Carcinogenic, irritating, toxic

Table 2: Wood treatment and danger of preservatives (CSTB, 2005) (INERIS, Les réglementations relatives aux déchets industriels dangereux. Programme DCE-05 "propriéte des produits", 2006)

Treated wood wastes and residues

- include construction and demolition wood wastes, used pallets and waste wood, off cuts and co-products from the manufacture of furniture and other wood products that **may have received some kind of treatment, such as with preservative or stain or some surface finish like paint or varnish**.
- some material may also have become **contaminated by spills or other contact with chemical products during the course of its use**, and these will all have an impact on the range of ways in which they can be used.

Typical constituents of wood preservatives



Preservative name	constituents
Creosote	coal tar or distillate 50% petroleum oil 50%
Pentachlorophenol (PCP)	pentachlorophenol >95%
Acid Copper Chromate (ACC)	copper as CuO 31.80% hexavalent chromium, as CrO3 68.20%
Ammoniacal Copper Arsenate (ACA)	copper, as CuO 49.80% arsenic, as As2O5 50.20%
Ammoniacal Copper Zinc Arsenate (ACZA)	copper, as CuO 50% zinc, as ZnO 25% arsenic, as As2O5 25%
Borates	sodium octaborate, sodium tetraborate, sodium pentaborate, or boric acid
Chromated Copper Arsenate (CCA)	hexavalent chromium, as CrO3 65.50% 35.30% 47.50% copper, as CuO 18.10% 19.60% 18.50% arsenic, as As2O5 16.40% 45.10% 34.00%
Alkyl Ammonium Compound (AAC, DDAC)	didecyldimethylammonium chlorides 90% min dialkyldimethylammonium chloride 10% max
Ammoniacal Copper Quat (ACQ)	copper, as CuO 66.70% didecyldimethylammonium chlorides 33.30%
Ammoniacal Copper Citrate (CC)	copper, as CuO 62.30% citric acid 37.70%
Copper Azole (CBA-A)	copper, as CuO 49% boron, as boric acid (H3BO3) 49% tebuconazole 2%
Copper bis(dimethyldithiocarbamate) (CDDC)	copper, as CuO 17-29% SDDC 71-83% sodium dimethyldithiocarbamate
Copper Naphthenate (CuN)	copper naphthenic acid petroleum oil
Copper-8-Quinolinolate (Cu8)	copper-8-quinolinolate 10% min nickel-2-ethylhexoate 10% min hydrocarbon solvents 80% max
4,5-dichloro-2-n-octyl-4-isothiazolin--3-one	4,5-dichloro-2-n-octyl-4-isothiazolin--3-one 98% related non-volatile impurities <2% hydrocarbon solvents
3-iodo-2-propynyl butyl carbamate (IPBC)	IPBC 97% iodine as element 53.40%
Zinc Naphthenate (ZnN)	zinc 1.8-8% naphthenic acid petroleum oil

Limit values of elements and substances in recycled wood fiber used for production of wood-based product

Element and compounds	Limit value (mg/kg recycled wood material)
Arsenic	25
Cadmium	50
Chromium	25
Cooper	40
Lead	90
Mercury	25
Fluorine	100
Chlorine	1000
Pentachlorophenol (PCP)	5
Tar oils (benzo(a)pyrene)	0,5

Treated wood

- **Heavy metals such as copper, chromium and lead are widely present in preservatives.**
- If wood treated with such preservatives will be burned in a boiler or combustion, these **heavy metals will be present in both bottom ash and fly ash**, which will therefore need to be handled appropriately. The fly ash will need a high quality dust filter or cyclone to ensure there are no unacceptable emissions.
- **Halogens and halides will be released in the flue gas emissions** which may require a specialist scrubber or trap. **They can form** halogenated organic compounds, in particular **dioxins** (polychlorinate dibenzodioxins - PCDDs) and **furans** (polychlorinate dibenzofurans - PCDFs) which are persistent organic pollutants **that bio-accumulate over time**.
- **Polycyclic Aromatic Hydrocarbons (PAHs) may be formed during incomplete combustion and many are carcinogens**, though these can also be formed by the combustion of clean wood under non-ideal conditions.
- Emissions of Hydrocarbons and Volatile Organic Compounds (VOCs) should be minimized by careful storage, efficient combustion and sufficient residence time.

#3 - Wood composites and laminates

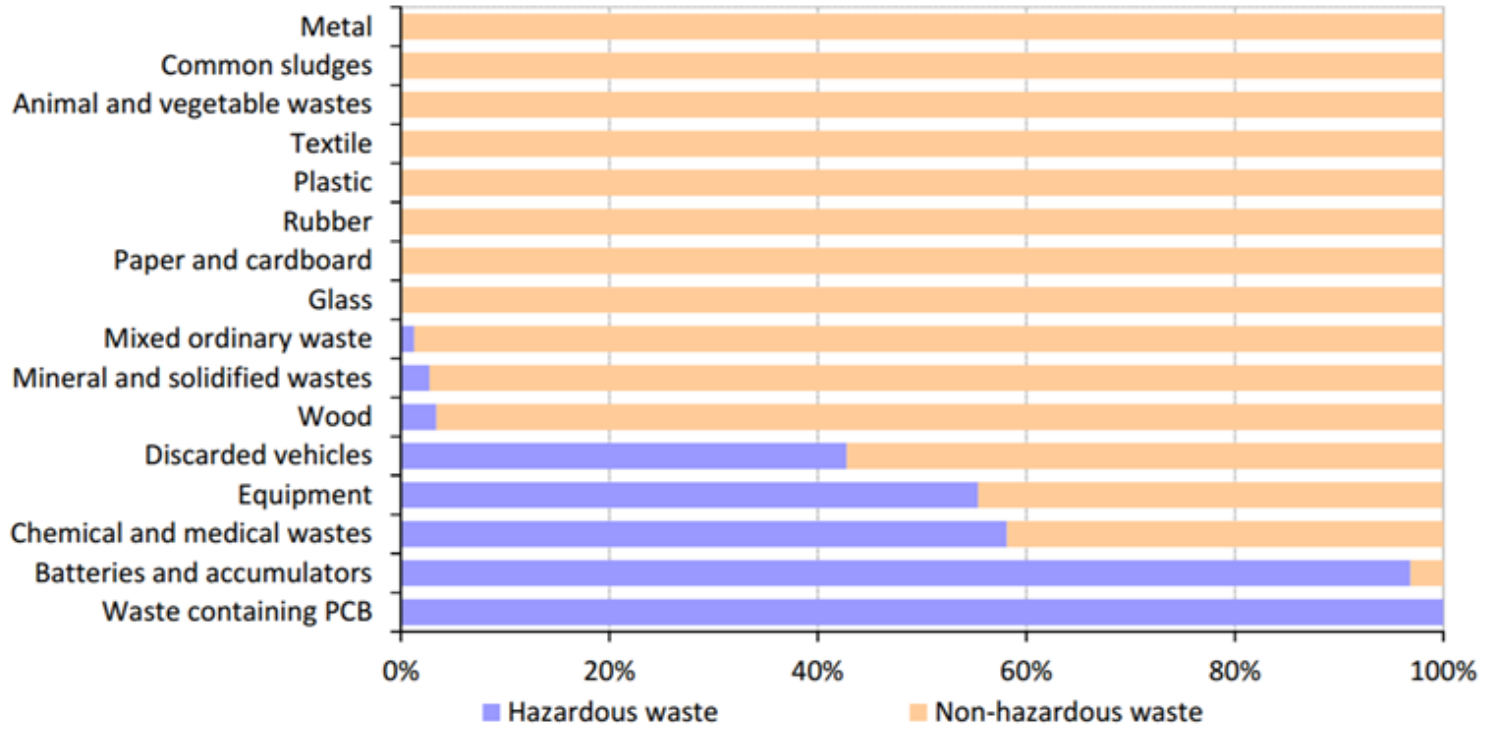
- contain resins, adhesives, fillers or other, non-wood components.
- Some such materials are placed under the jurisdiction of the Waste Incineration Directive (WID) and cannot be treated as untreated wood waste.
- However fiberboard, provided that it has not been treated with halogenated organic compounds or heavy metals, is still an exempt.

European Waste Catalogue

- **Class A cover virgin wood only mechanically treated.** For such class no Waste Incineration Directive has to be applied.
- **Class B contains coated or other way chemically treated wood but not containing halogenated organic compounds and preservatives.**
- **Class C** should be incinerated according to Waste Incineration Directive and **contain wood treated with halogenated organic compounds.**
- **Class D is classify as hazardous waste since is treated by preservatives** (in this category transmission and telephone line poles and railway sleepers are included)

Hazardous wastes

Figure 3 – Hazardous waste in waste categories in EU28, 2012



Data source: Eurostat (env_wastrt), 2015.

PCB - Polychlorinated biphenyl

Didier Bourguignon (2015) Understanding waste streams, EPRS briefing

Waste management scenarios

Lowering amonut of waste

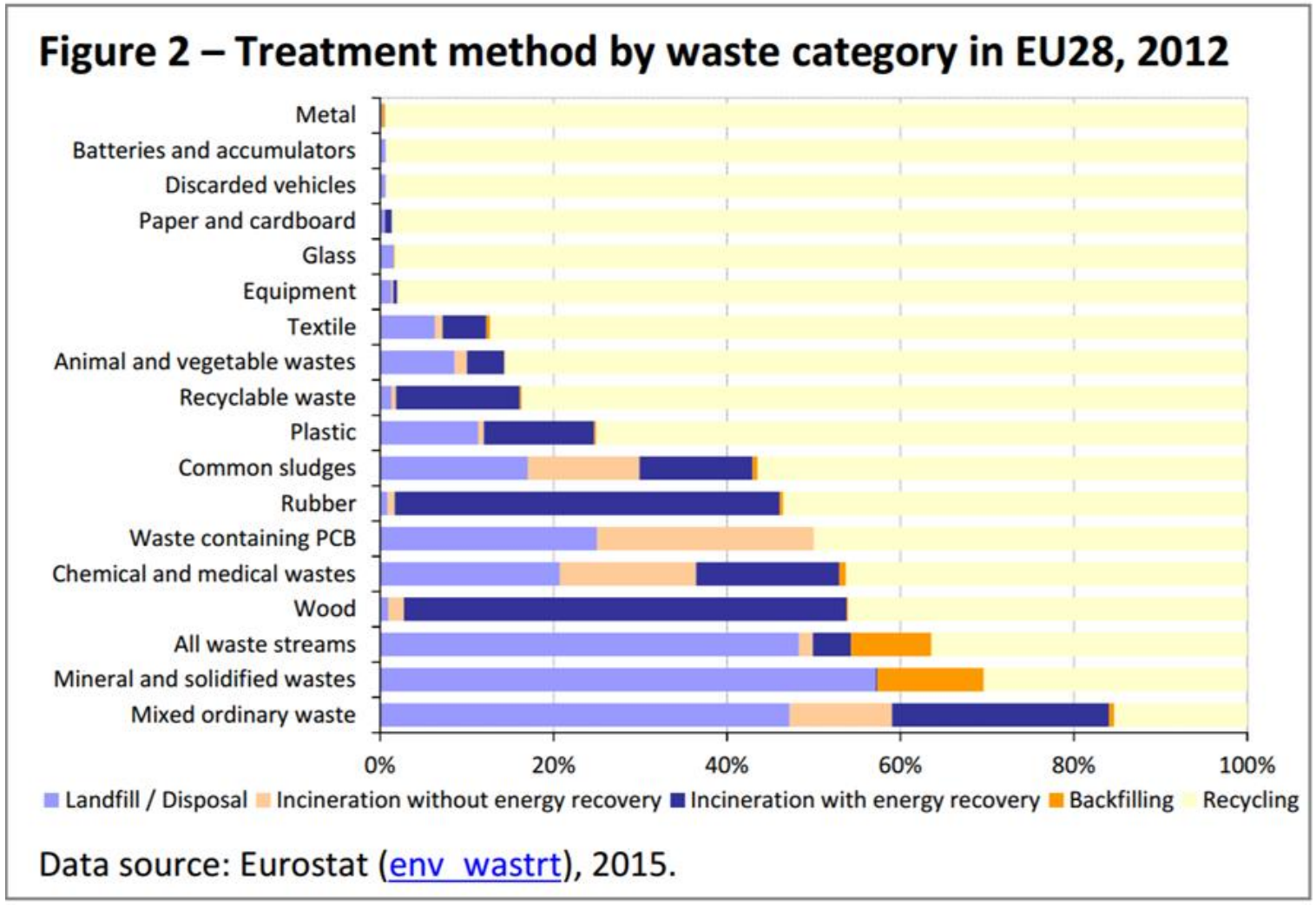
Using materials repeatedly

Using materials
to make new products

Recovering energy
from waste

Safe disposal of waste

Treatment method by waste category



Didier Bourguignon (2015) Understanding waste streams, EPRS briefing

Biomaterials recycling and recovery options

- **Direct recycle (timber products recycled to timber products)**
  - MDF, particleboar, wood plastic composites, finger jointing and lamination
- **Indirect recycle (timber products recycled to different products)**
  - Animal bedding, landscape mulch – control weeds, protect plants, surfacing products – children playground, composting, cement boards
- **Energy recover (calorific value of timber products is recovered)**
  - Fuel briquettes, pellets, cogeneration, stand allone biomass power stations

Recycling rate in different countries

Recycling rates	Countries
Above 70%	Denmark, Estonia, Germany, Ireland, UK, The Netherlands
60-70%	Austria, Belgium, Lithuania
40-60%	France, Latvia, Luxembourg, Slovenia
Below 40%	Cyprus, Czech Republic, Finland, Greece, Hungary, Poland, Portugal, Spain
No data	Bulgaria, Italy, Malta, Romania, Slovakia, Sweden

Source: CRI compilation based on BIO IS, 2011.

Most used methods used to treat wood wastes

- The five main methods used to treat wood wastes are recycling as **particleboards, composting, combustion, incineration and land filling**
- Recycling methods for wood waste include composting and material recycling as particle boards.
- In order to avoid any risks of contamination with hazardous substances, these methods ask for high levels of requirement for the type of waste they incorporate.
- For composting, only untreated fraction of wood can be accepted.
- For the manufacture of particle boards, a certain amount of slightly treated wood wastes can be accepted, added to untreated wood waste, according to the requirement of European Panel Federation (EPF) and of each producer.
- Highly treated wood wastes are definitely forbidden for recycling.

Particle board manufacturing

- In order to avoid any kind of problem in the industrial process or for the product quality, requirements are recommended by the European Panel Federation (EPF, 2010). These requirements are implemented in accordance with the various European standards on particle board. They include:
  - Mainly untreated wood wastes (essentially from pallets) must be introduced in the process. However, a small amount of mixed slightly treated wood waste can be accepted.
  - The fraction of wood waste must be crushed and exempt of any metal, plastic or cardboard, material that could damage the machines or lower the quality of the board produced. (The size of the crushed pieces depends on the manufacturing process).
  - The moisture content must be the lower possible.
- Particle board manufacturers can then provide with these products by purchasing the mixed and crushed material to wastes sorting and treatment facilities or directly from wood wastes producers.
- **Recycling of wood wastes as particle boards seems nowadays to be unstable because of the fluctuation of wood price.**

Incineration and combustion

- For a decade, incineration appeared in Europe to be one solution for efficient elimination of the majority of the wastes. Even if some incineration plants are today equipped to recover the energy (heat or electricity) produced during the burning process, this activity remains main method to eliminate wastes.
- This means that, usually, the energy recovery process is not effectively designed to recover the most of the wastes. Yet, an **efficiency of 65% is needed for an incinerator to be considered as a recovery process.**

- On the contrary, using wood waste in a combustion is considered as a recovery method. The **wastes are considered as raw material and can supplement or replace conventional fuels such as oil, coal or natural gas**.
- At the European level, the 2000/76/EC directive of 4 December 2000 on waste incineration regulates these activities. In order to promote wood waste recovery, **only the wood waste containing halogenated organic compounds or heavy metals are excluded**.

Combustion

- One advantage of waste treatment by combustion is the **high potential for volume reduction** that avoids to spread sanitary risks linked with wastes management.
- The very important advantage of wood combustion is that it **does not contribute to carbon dioxide emissions.**
- Indeed, **if the wood is grown in a sustainable way, and if combustion is complete, the amount of CO2 released during the combustion is actually almost the same that have been captured during the wood growth.**
- **Combustion of wood wastes implies the emissions of gaseous pollutants**, which must be treated after the combustion process.
- **The quantity of these pollutants varies depending on the type of burn wood waste.** Experiment proves as well that combustions of medium density fibre boards (MDF) and plywood emit more than combustion of raw wood or particleboard.

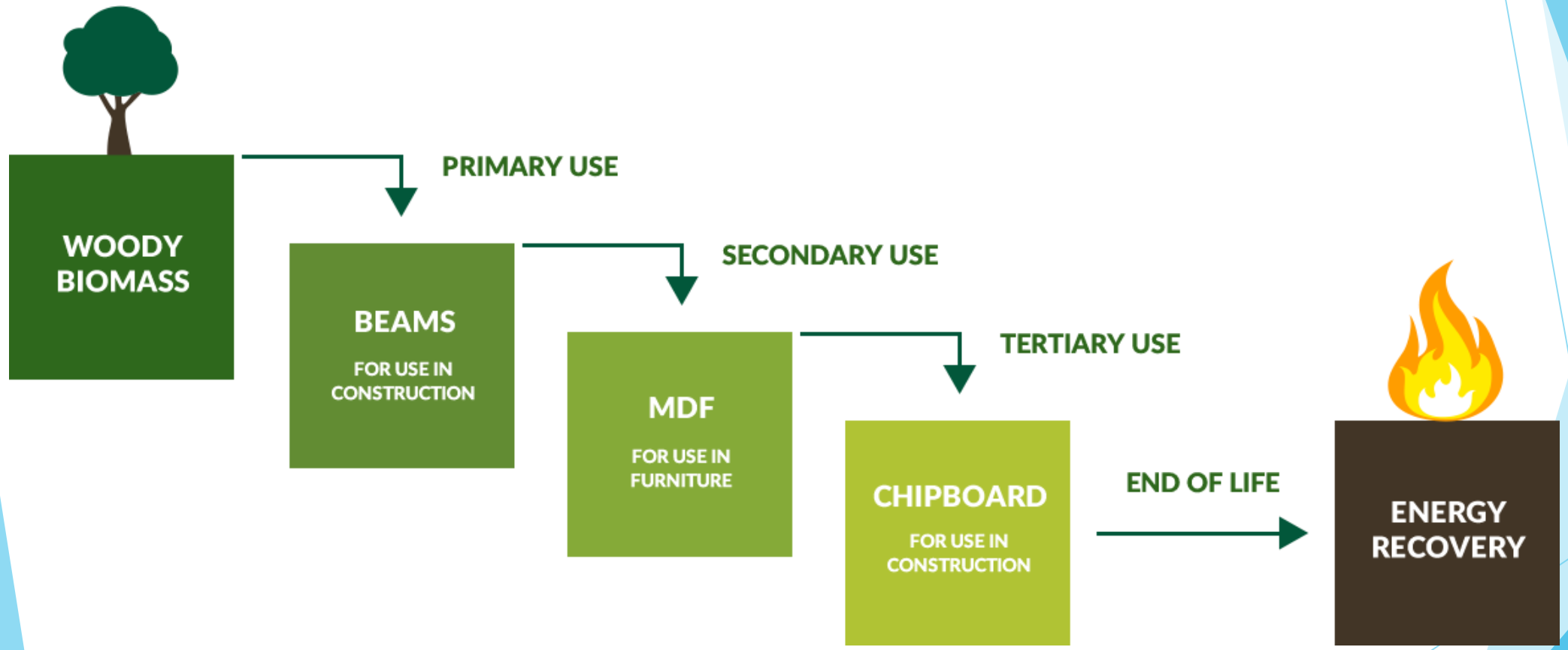
Land filling

- Land filling activities are regulated by the 99/31/EC directive of 26th April 1999. This text defines the procedures to run the landfill in the less harmful way possible. Three types of landfill are regulated:
  - Hazardous waste landfills
  - Non hazardous waste landfills
  - Inert waste landfills
- From the 1st of July 2002, because of the danger these elimination methods can generate for soil and air pollution those facilities can only be used for elimination of ultimate wastes. In other words, **recyclable or incinerable waste can't be treated in these plants.**
- **Financial incentives (very high and increasing prices for waste treatment in landfills) were implemented to promote the reduction of this practice.**

Alternatives?

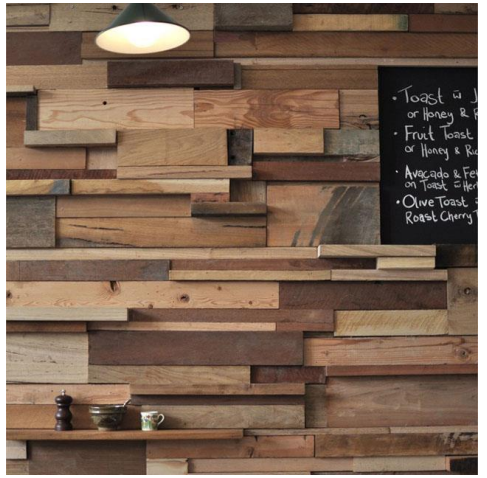
- Cascade use
- Upcycling
- Reuse
- Insects/fungal conversion

Cascade use of bioresources



http://www.usewoodwisely.co.uk/WhatCanBeDone/

Reclaimed wood



Reuse

Wood to food…?

- Trends **towards 2050 predict a steady population increase to 9 billion people**, forcing an increased food/feed output from available agro-ecosystems resulting in an even greater pressure on the environment.
- Scarcities of agricultural land, water, forest, fishery and biodiversity resources, as well as nutrients and non-renewable energy are foreseen.
- Edible insects contain high quality protein, vitamins and amino acids for humans. Insects have a high food conversion rate, e.g. **crickets need six times less feed than cattle, four times less than sheep, and twice less than pigs and broiler chickens to produce the same amount of protein**.
- Besides, they **emit less greenhouse gases and ammonia** than conventional livestock. Insects **can be grown on organic waste**. Therefore, insects are a potential source for conventional production (mini-livestock) of protein, either for direct human consumption, or indirectly in recomposed foods (with extracted protein from insects); and as a protein source into feedstock mixtures.

http://www.fao.org/edible-insects/en/

Insects conversion

3 months results

rating	Colour	classification	definition
0		No attack	No sign of attack
1		Slight attack	Superficial attack at some points or over small area
2		Moderate attack	Deeper and bigger area of attack (until 2cm2)
3		Severe attack	All samples under soil is attacked (over 2cm2)
4		failure	Destruction of sticks, transparency

BOX 1

91-11	92-12	99-11	88-12	85-10	29-11	14-12	97-10
100-10	90-11	48-12	93-12	84-11	18-10	49-10	95-10
74-12	14-11	11-10	91-10	13-12	15-12	109-10	65-10
89-10	81-10	62-12	16-12	83-10	85-11	89-11	100-11
29-10	31-10	84-10	48-10	47-11	73-10	40-11	93-10
105-10	42-10	63-12	110-11	53-11	70-11	55-11	66-11
74-11	85-12	77-10	76-12	57-10	101-10	37-10	77-11
66-12	50-10	3-12	106-12	36-11	114-10	104-11	7-11
96-10	2-10	113-10	103-10	120-11	34-10	69-11	117-11
93-11	14-10	49-11	42-11	84-12	109-12	9-12	102-12
		68-10	70-12	107-10	47-10		

BOX 2

35-10	91-12	99-10	60-11	39-11	36-12	70-10	43-12
72-10	100-12	43-11	69-12	102-10	117-12	107-12	119-12
59-10	60-12	26-10	76-10	1-12	7-10	101-11	77-12
11-11	8-10	2-11	110-12	113-12	6-10	67-11	80-12
42-12	112-11	63-10	40-12	115-12	5-12	118-10	107-11
119-10	6-11	37-11	106-10	39-10	120-10	81-11	44-10
52-12	15-10	71-12	75-10	72-12	11-12	17-12	86-11
36-10	41-11	32-11	96-12	98-11	64-12	90-10	92-10
61-11	35-11	31-11	86-10	110-10	29-12	71-11	72-11
17-10	18-11	83-12	34-12	43-10	41-12	88-11	81-12
		87-10	12-12	64-10	97-11		

BOX 3

61-12	28-11	55-10	104-12	34-11	52-11	114-12	79-11
51-10	73-12	87-11	38-12	8-12	108-11	118-11	55-12
2-12	27-12	32-10	44-11	7-12	51-11	117-10	61-12
113-11	74-10	61-10	108-12	63-11	32-12	75-12	92-11
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3-10	6-12	4-10	58-12	1-10	108-10	18-12	88-10
104-10	111-11	10-11	49-12	80-10	33-12	26-11	46-12
67-10	9-11	83-11	99-12	95-12	30-11	56-11	28-10
		64-11	82-11	26-12	45-11		

BOX 4

16-10	82-10	102-11	69-10	89-12	71-10	94-10	68-12
78-12	33-10	41-10	9-10	73-11	58-10	115-11	109-11
87-12	56-12	112-10	62-10	97-12	105-12	51-12	35-12
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103-12	57-11	98-10	90-12	76-11	95-11	45-12	86-12
114-11	78-10	56-10	17-11	15-11	1-11	82-12	119-11
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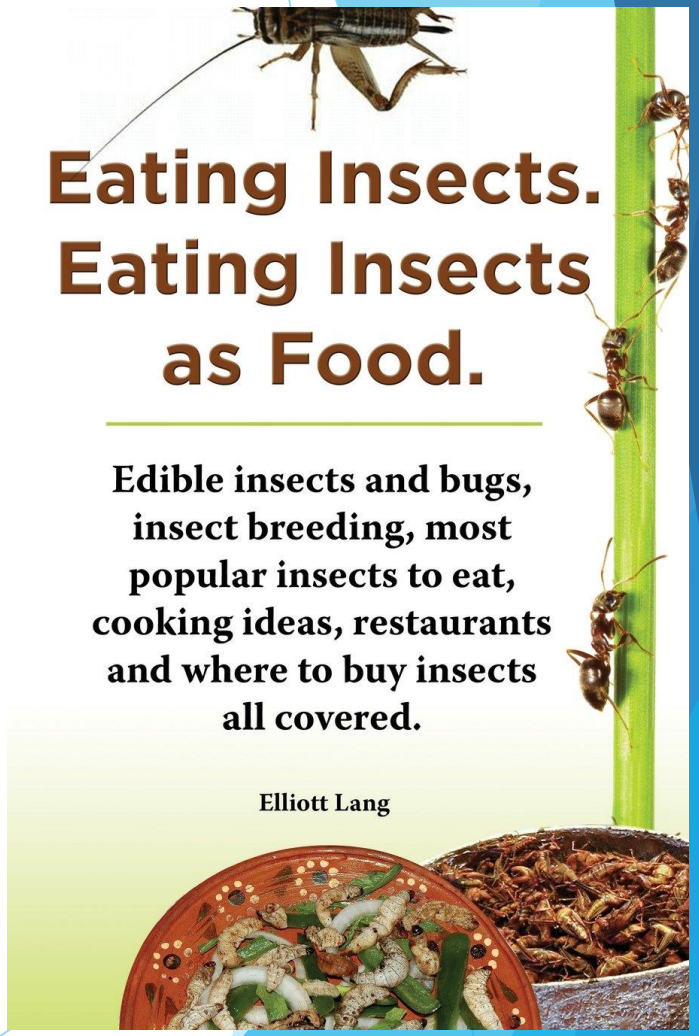
12-10	116-11	98-12	78-11	30-12	44-12	57-12	62-11
39-12	8-11	94-11	66-10	37-12	48-11	59-12	75-11
		68-11	31-12	4-12	45-10		

Volunteers?


Eating Insects.
Eating Insects
as Food.
Edible insects and bugs, insect breeding, most popular insects to eat, cooking ideas, restaurants and where to buy insects all covered.
Elliott Lang

Biomaterials end-of-life





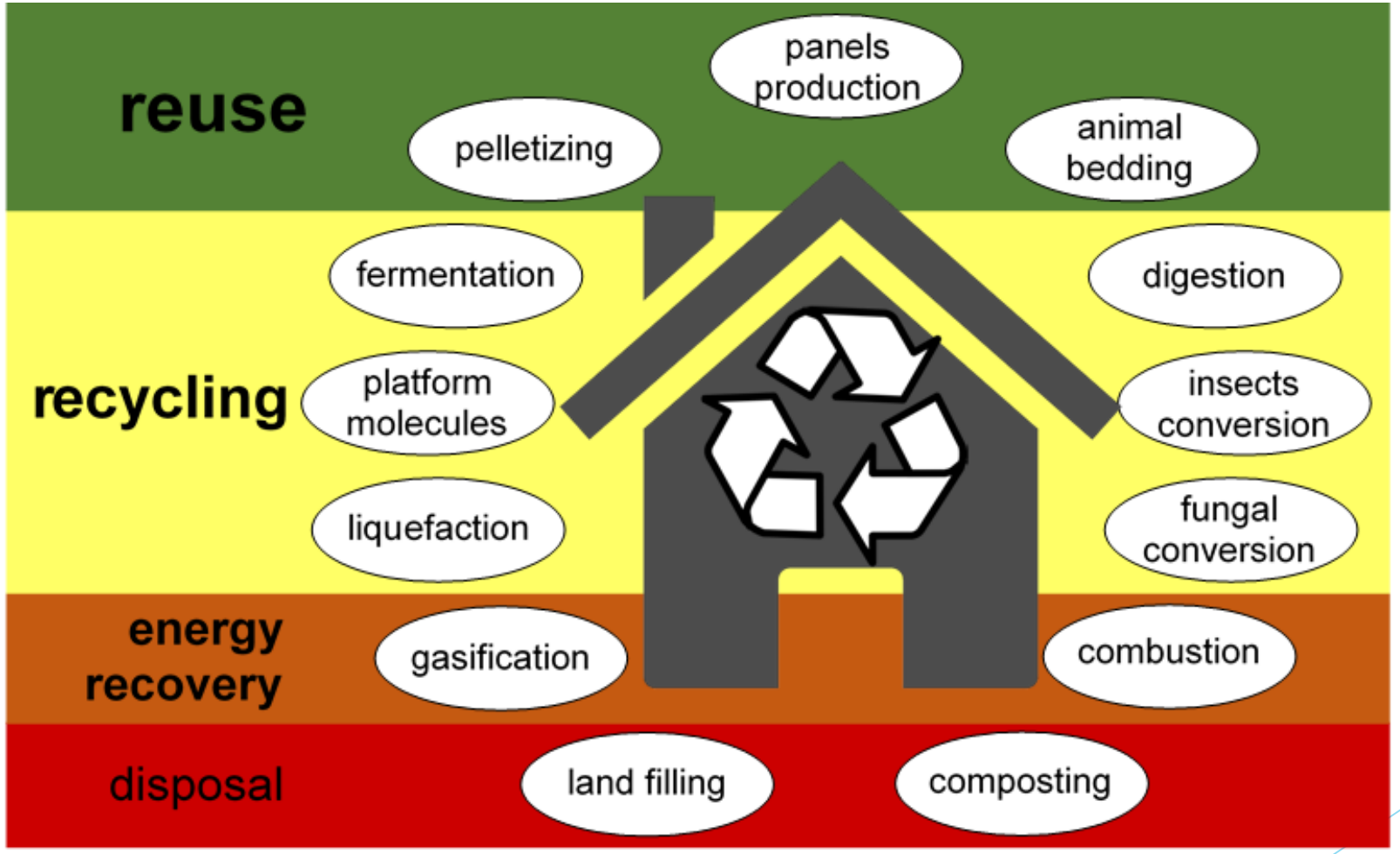








Pathways for end of life transformation



Patways flexibility and developmnet

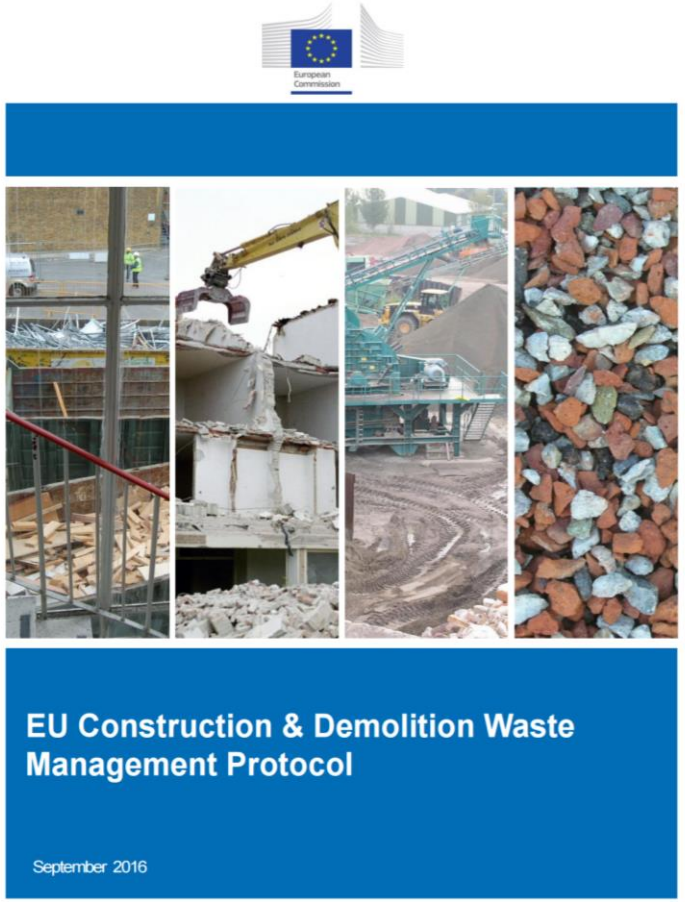
Processing technology	Feedstock flexibility	Conversion efficiency	Market value of product
combustion	high	low	low
digestion	low	medium	medium
fermentation	low	medium	high
pyrolysis	high	medium	medium
gasification	medium	medium	medium
platform molecules	medium	medium	high
liquifaction	medium	low	high
panels manufacturing	high	high	high
animal bedding	high	medium	low
peletizing	high	high	high
insects conversion	medium	medium	high
fungal conversion	medium	medium	high

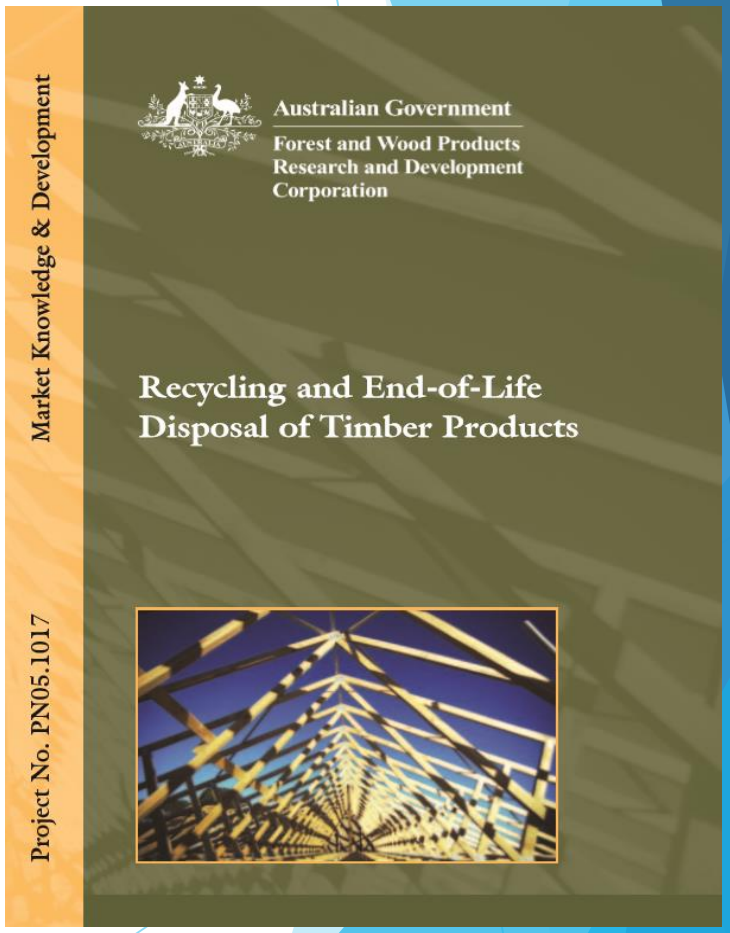
Source: BIOMASS TECHNOLOGY REVIEW: PROCESSING FOR ENERGY AND MATERIALS, modified

Is it really worth to recycle???

- 10000000000000 tons/year cellulose produced worldwide
- Population is growing rapidly. Until 2050 a population will increase to 9 billion people. There are 3 football fields per person of land, but only 1/3 of one is effectively used for food production.
- We also need houses for growing population….
- The competition between energy and non-energy users of biomass (especially wood panel and pulp industries) and using land for food production

Future readings





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BIO4ever

FP1407

ModWoodLife

Thank you

www.bio4everproject.com