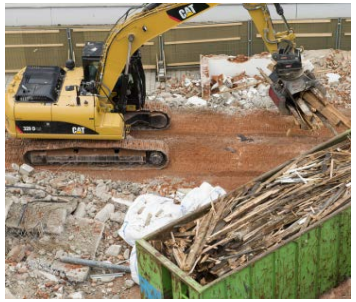
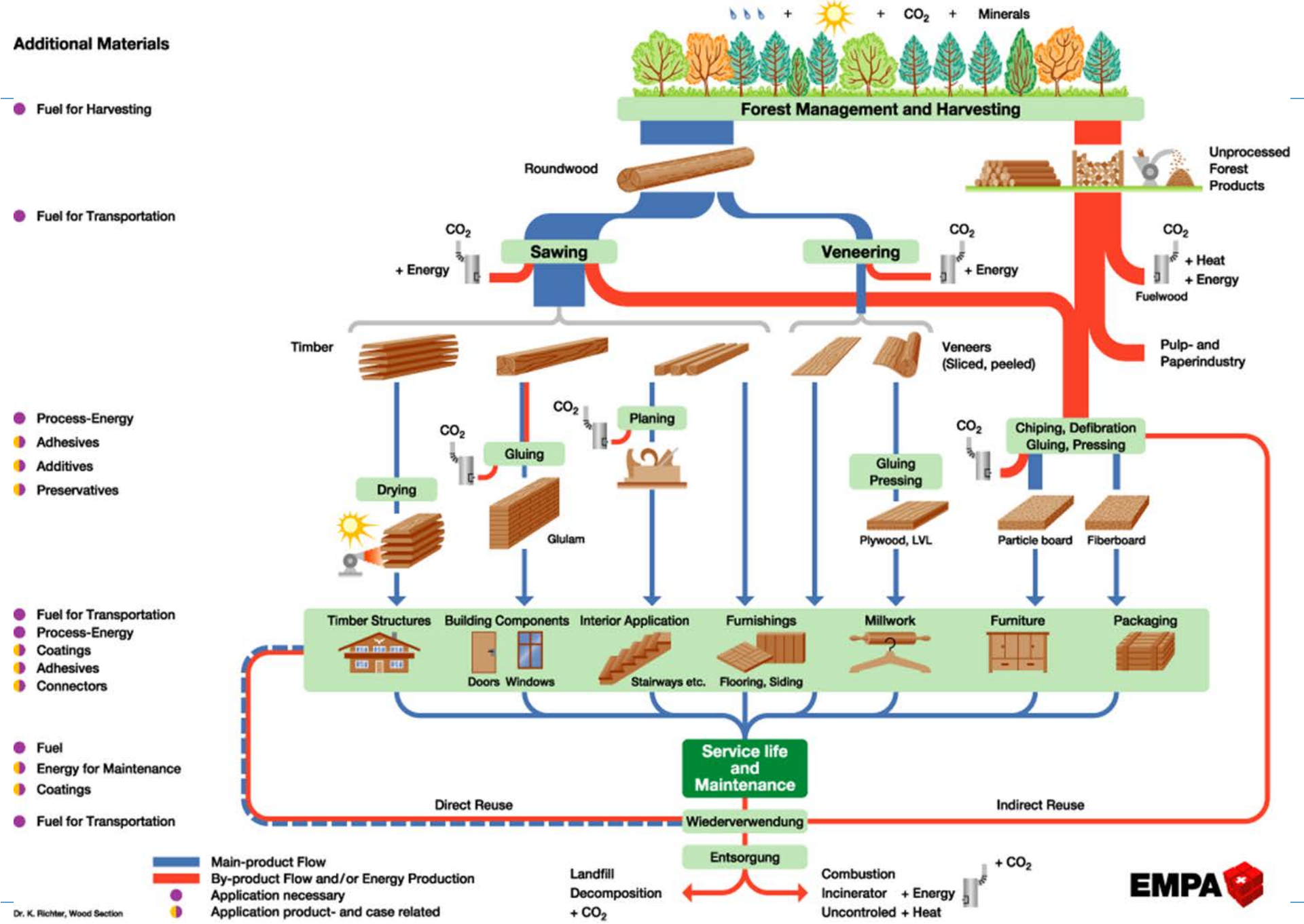
COST Action FP 1407

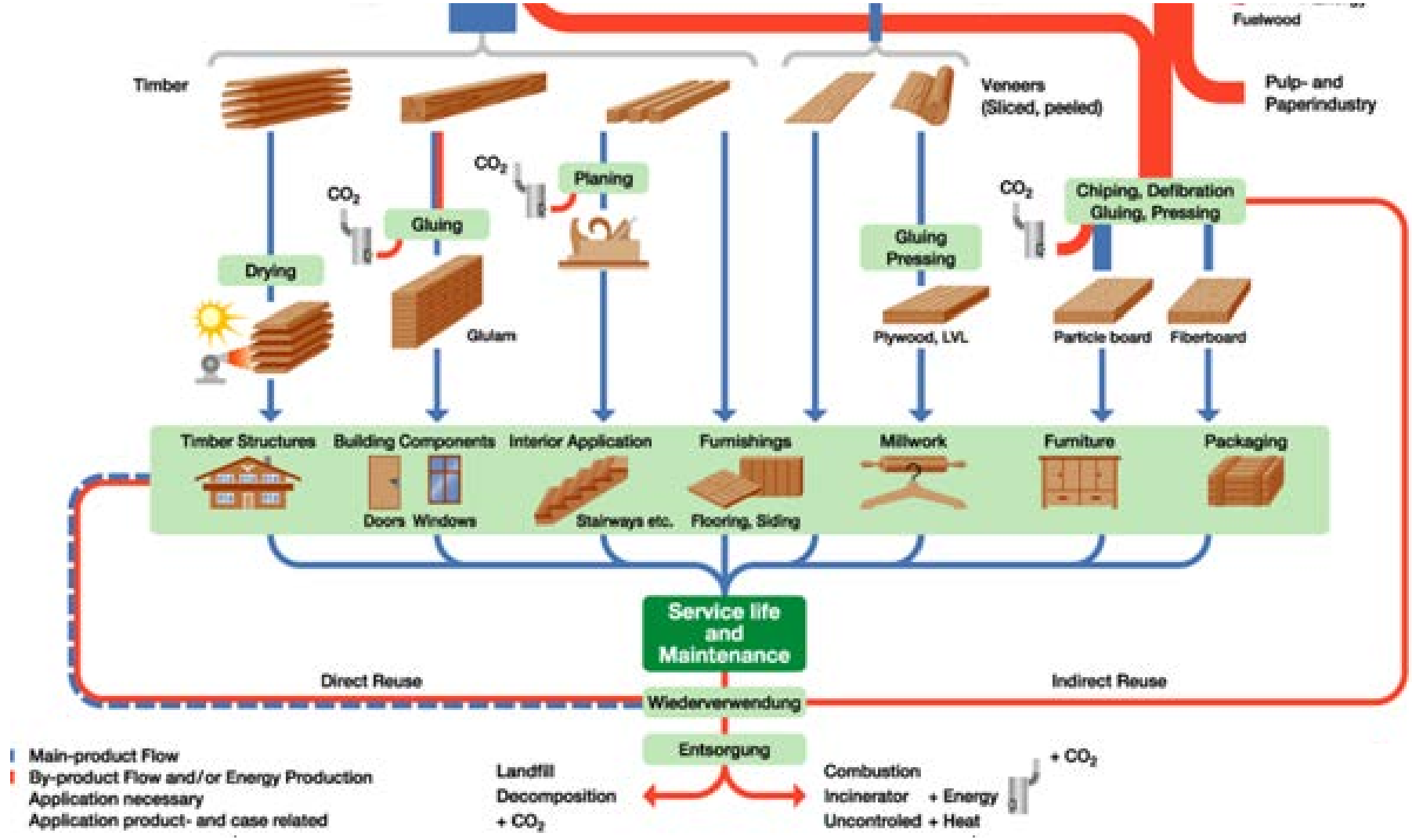
2 nd Workshop Brno

Cascade use of wood – illusion or silver bullet for sustainability ?

Klaus Richter, TU München

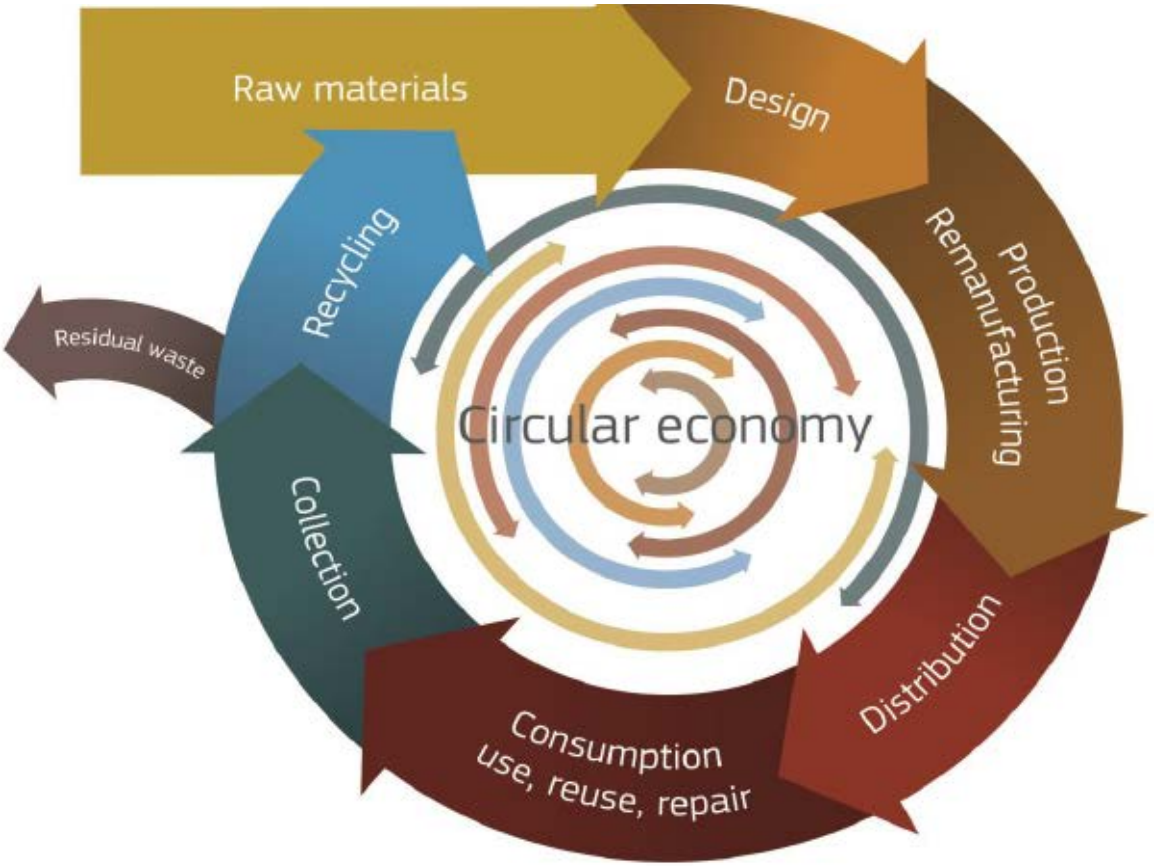

Additional Materials
Fuel for Harvesting
Fuel for Transportation
Process-Energy
Adhesives
Additives
Preservatives
Fuel for Transportation
Process-Energy
Coatings
Adhesives
Connectors
Fuel
Energy for Maintenance
Coatings
Fuel for Transportation
+ CO_2 + Minerals
Forest Management and Harvesting
Roundwood
Unprocessed Forest Products
CO_2 + Energy
Sawing
Veneering
CO_2 + Energy
CO_2 + Heat + Energy
Fuelwood
Timber
Veneers (Sliced, peeled)
Pulp- and Paperindustry
CO_2
Planing
CO_2
Gluing
CO_2
Chiping, Defibration Gluing, Pressing
Drying
Glulam
Gluing Pressing
Plywood, LVL
Particle board
Fiberboard
Timber Structures
Building Components
Interior Application
Furnishings
Millwork
Furniture
Packaging
Doors
Windows
Stairways etc.
Flooring, Siding
Service life and Maintenance
Direct Reuse
Indirect Reuse
Wiederverwendung
Entsorgung
Landfill
Decomposition
+ CO_2
Combustion
Incinerator + Energy
Uncontroled + Heat
+ CO_2
Main-product Flow
By-product Flow and/or Energy Production
Application necessary
Application product- and case related
Dr. K. Richter, Wood Section
EMPA

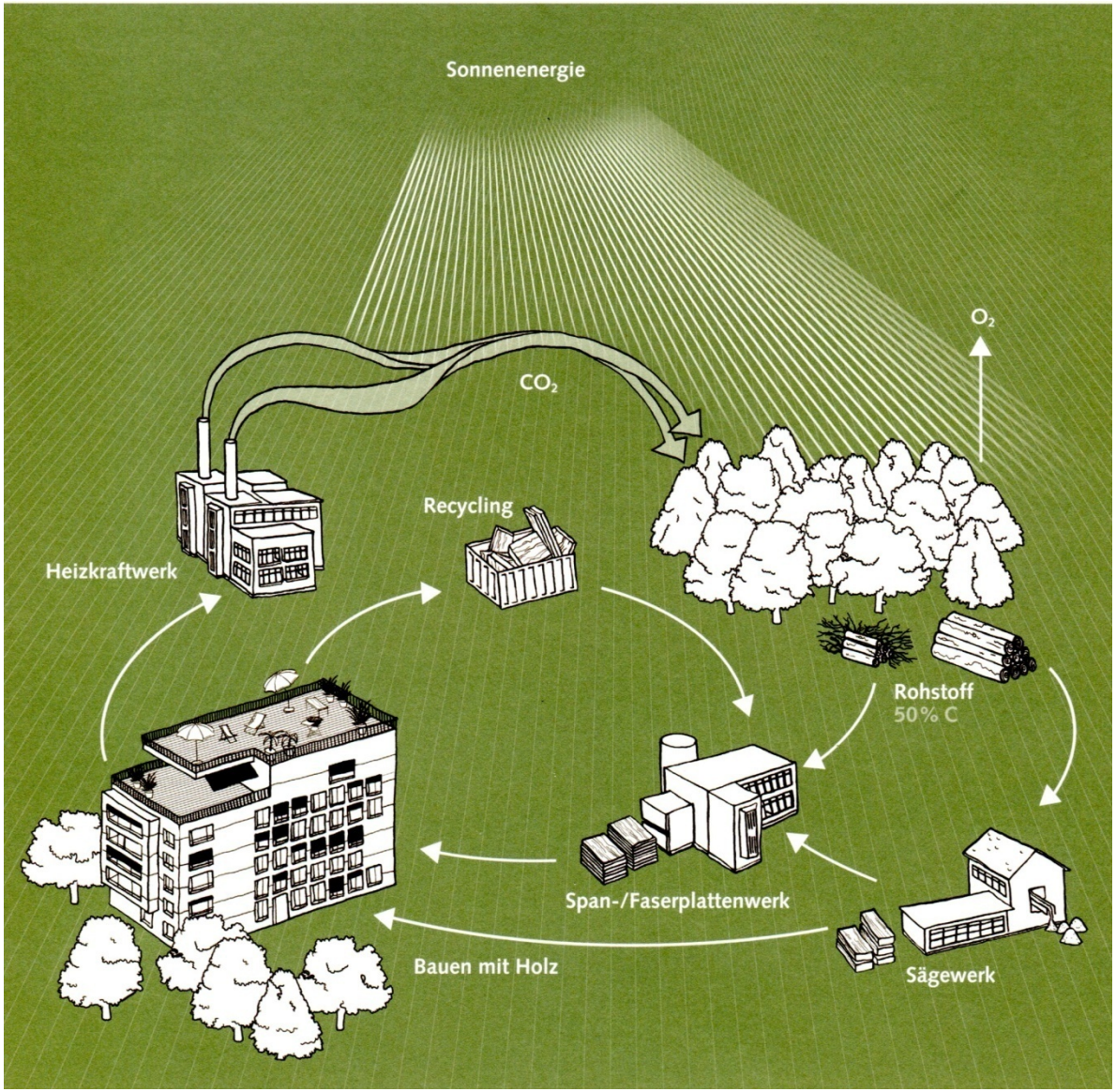


Richter 1991

Reduce **Re**use **Re**cycle

Closing the Loop: EU Action Plan on Circular Economy (Dec 2015)





Forest-Wood Industries Masterplan for sustainable economy

- Biobased raw material √
- C-pool √
- High energy efficiency √
- Low waste processes √
- Cascading potential ?

Knowledge, experience, technology

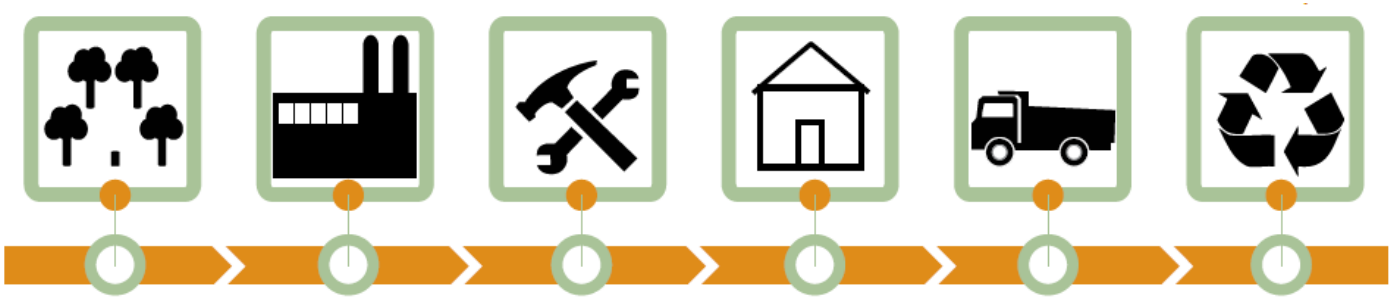
high

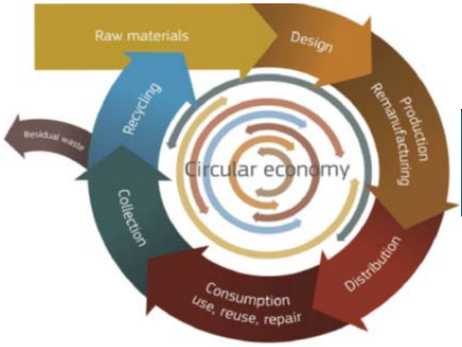
sufficient

low

Extraction, Production, Use

End of life

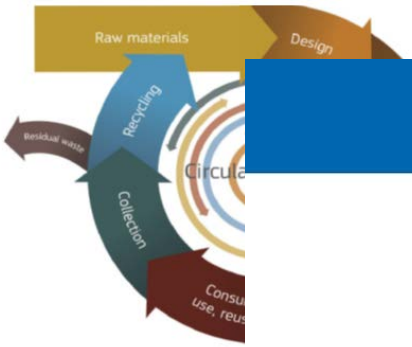




What is the Circular Economy?

- Maintaining the value of products, materials and resources in the economy for as long as possible while minimising waste generation
- To boost our economy and competitiveness with new business opportunities and innovative products and services.
- For economic, social and environmental gains

Kubicki M. 2016



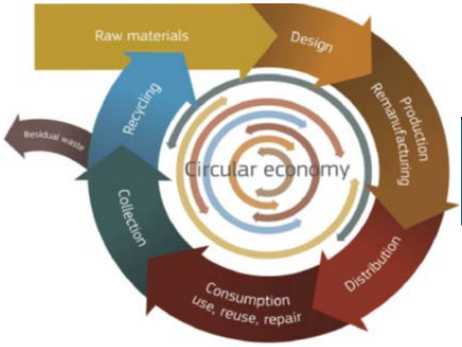
Action Plan

5 Main Areas of Action

Priority Sectors

- Plastics
- Food waste
- Critical Raw Materials
- Construction & Demolition
- Biomass & bio-based products

Kubicki M. 2016



Biomass & bio-based products

Objectives

- Support an efficient use of wood and bio-based products
- Increase recycling of bio-waste

Key Actions

- Promote an efficient use of bio-based resources through a series of measures, such as the promotion of the cascading use of biomass and support to innovation in the bio-economy
- New target for recycling wood packaging and a provision to ensure the separate collection of bio-waste

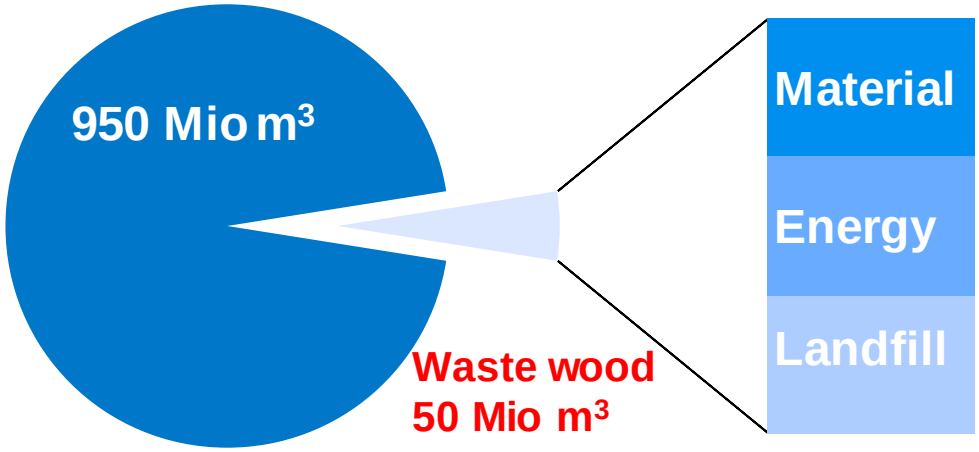
Kubicki M. 2016

Incentives for fostering cascade use of wood

- Safeguarding of resources in the biosphere
- Longer carbon storage and higher land use efficiency
- Maintain added value
- Create business opportunities by technological development
- Increase competitiveness of wooden products
- Reduce environmental impacts
- Political EU-Framework
  - Roadmap to a Resource Efficient Europe (EC 2011b)
  - Circular Economy and Zero Waste Program (EC 2011a)
  - Landfill ban by 2025 (EC 2014)
  - EU Action Plan on Circular Economy (EC 2015)

Motivation

Wood supply in the EU 27 in 2010



Source: Mantau et al. (2010) EUwood - Real potential for changes in growth and use of EU forests: Final report.

Challenge

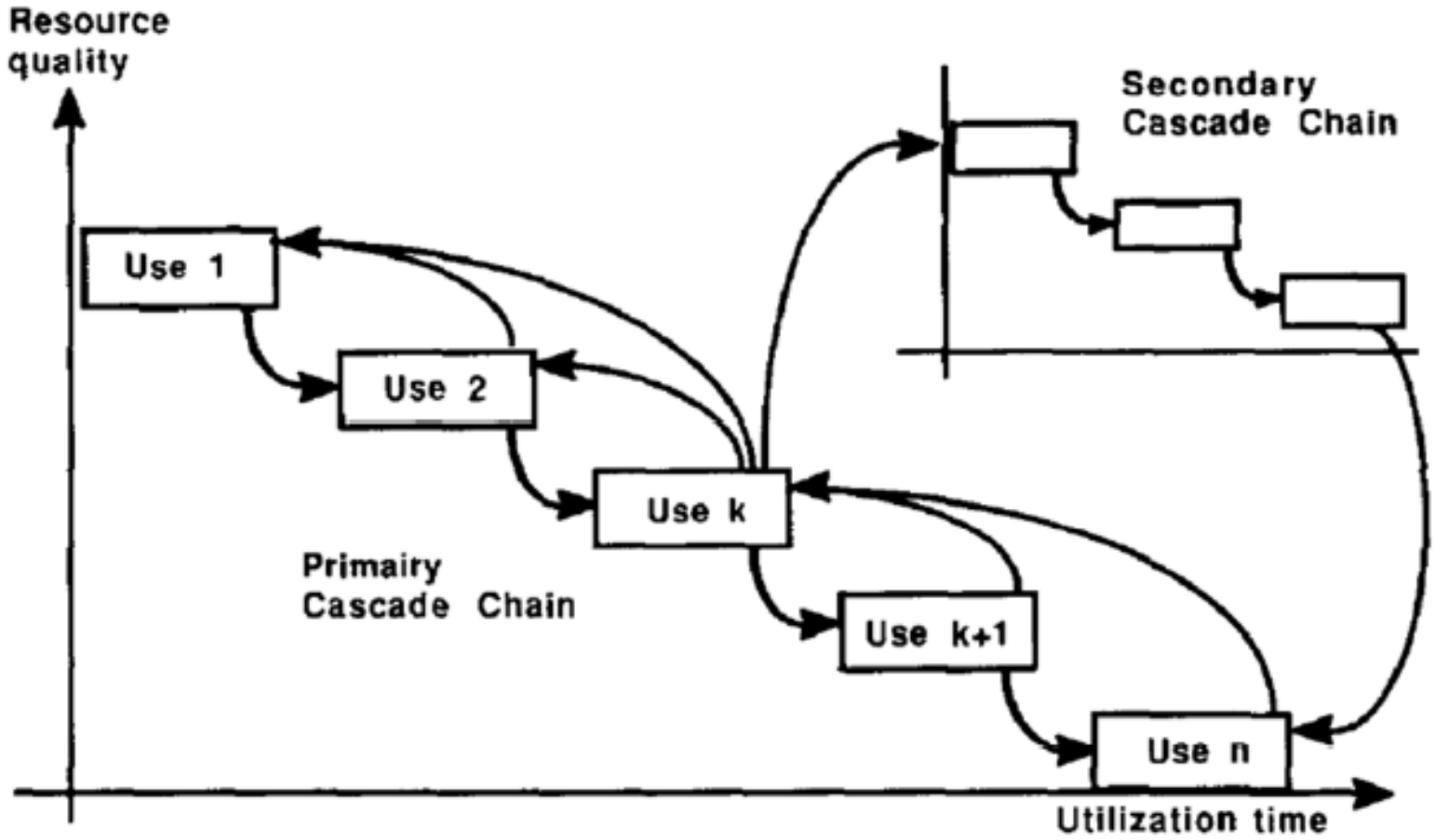
Demand exceeds supply in 2018 to 2030

Options

Increasing supply
Decreasing demand
Increasing efficiency of wood utilization

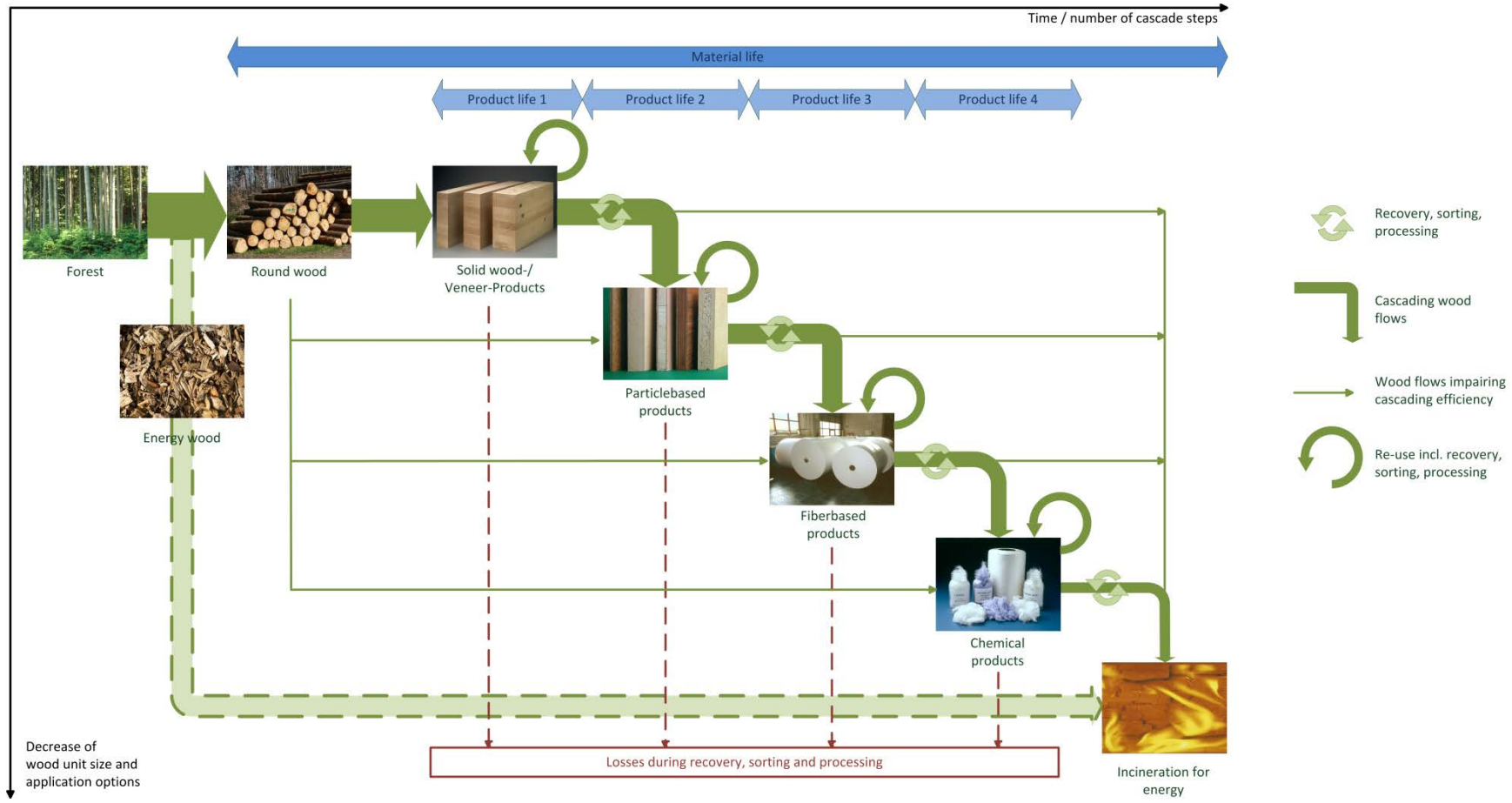
Cascading of wood

→ Definiton
→ Metrics to calculate cascade use
→ Environmental impacts
→ Efficiency of wood use
→ Barriers
→ Options for promotion



Source: Sirkin & ten Houten, 1994

Concept of cascading



(Höglmeier 2014)

Definition 1

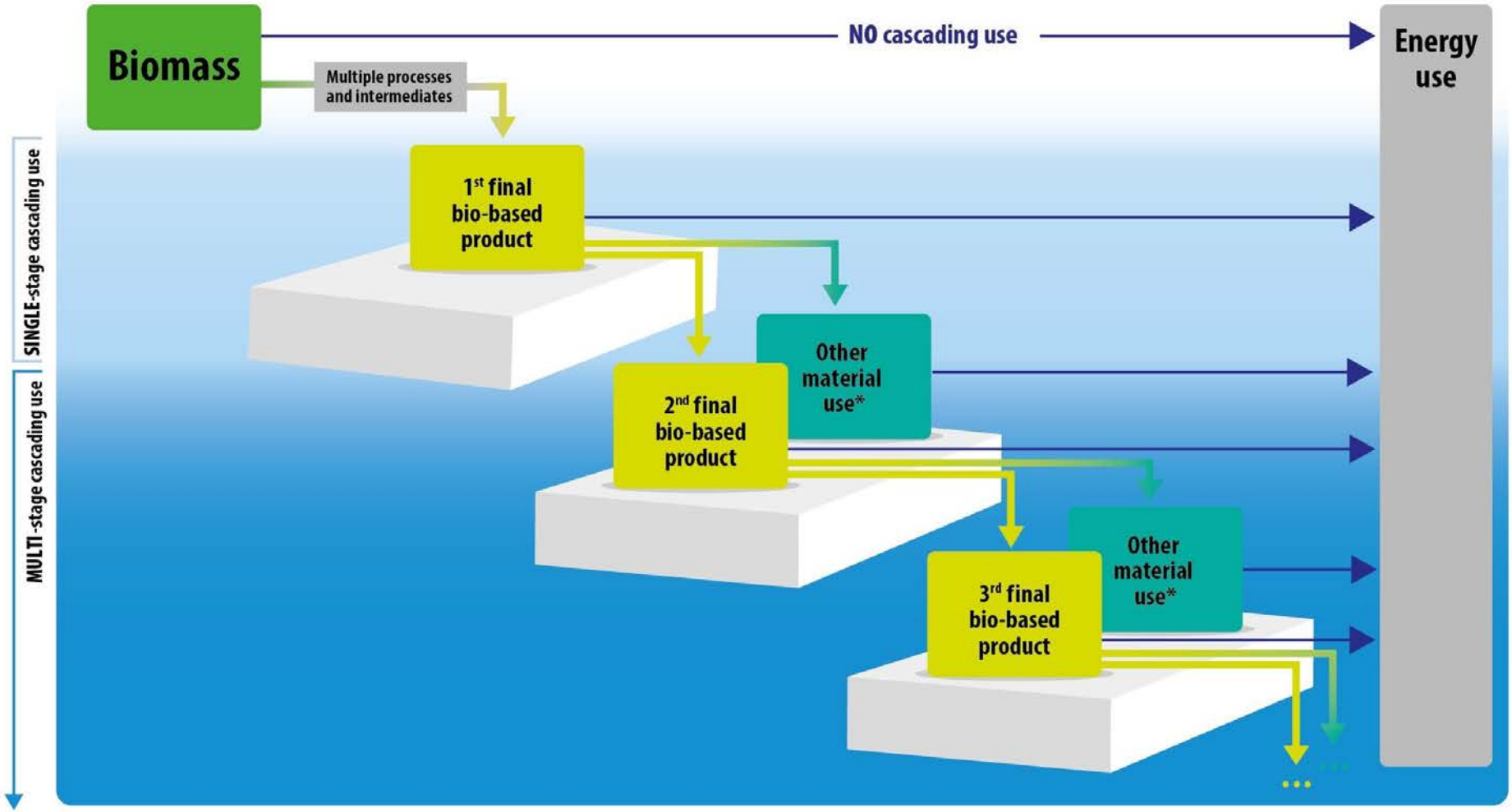
Cascading use is a strategy to use raw materials such as wood, or other biomass, in chronologically sequential steps as long, often and efficiently as possible for materials and only to recover energy from them at the end of the product life cycle.

The use of the same unit of wood for multiple successive applications with a gradual reduction of quality and particle size.

Definition 2

"Cascading use: biomass is processed into a bio-based final product and this final product is used at least once more either as a material or for energy production.
Cascading use of biomass is described as single-stage, when the bio-based final product is used directly for energy production. Cascading use of biomass is described as multistage when biomass is processed into a bio-based final product and this final product is used at least once more as a material. It is only after at least two uses as a material that energy use is permitted."

Increasing resource efficiency by cascading use of biomass



* other material use: biomass serves as raw material and filler for the production of all kinds of goods.

Sequential definitions of cascading use (multiple steps) are suitable for a factory or a technical process where all values/data are known and “simple” to calculate. Almost all definitions in literature are technical oriented defintitions.

→ Micro–level perspective : Material flow/LCA-based calculations (Arnold et al 2009, Gärtner et al 2014, Höglmeier et al. 2014/15)

They are not suitable for market flows (e.g. input flows in a furniture company) because market flows consist of several supplier, several products (particle board, MDF, HDF, OSB) at different times (changing resource mix) along several steps of the value chain in different factories for many different end-use products (difference between wood and paper).

→ Macro–level perspective : market based calculations (Mantau 2015, Carus 2014)

Cascades may be calculated at three different levels:

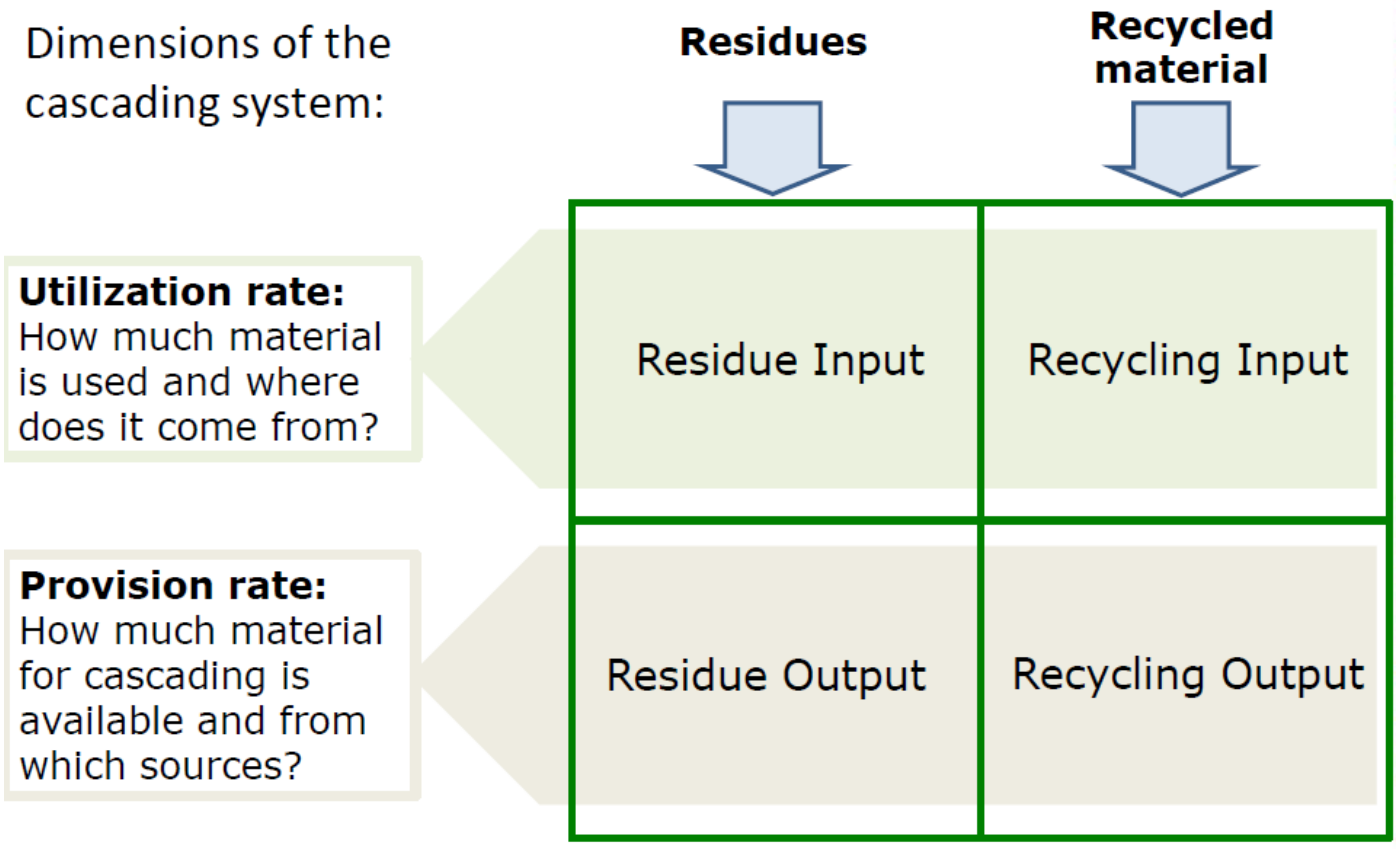
- The market as a whole (captures all interrelations, e.g. wood market);
- The submarket level (calculation on the basis of products groups, e.g. panel); and
- The manufacturing level (separates semi-finished products (e.g. particleboard) from finished products/final use (e.g. a cabinet)
- Calculation on the product level (particleboard)

Source: Mantau, U

Market perspective (Blanke, Mantau 2016)

Quantification concept of cascading use

Dimensions of the cascading system:



The utilisation rate summarises several input rates (residues and recycled material) in a production process (e.g.particleboard).Thus, it may include one or more inputs. Several utilisation rates cannot be combined because of the different bases for their calculation (i.e.input of primary biomass). For each aggregated level, the relation between biomass (denominator) and residues and recycled material (numerator) has to be newly calculated each time.

Cascading calculations include all residues and recycled materials along the whole value chain of a product or a market sector in a region that is transferred from one sector to another (sector = industrial classification category).

The "Two Dimensions of Cascading"

Residue input rate RIS_f: (RMA + RIS) / RMA

Recycling input rate RIC_f: (RMA + RIC) / RMA

Residue output rate ROS_f: $(RMA^S + ROS^S) / RMA^S + (PRD^F + ROS^F) / PRD^F$-1

Recovery output rate (ROC_f):

ROC_f= (RCOr* INMn+INMn)/INMn

The recovery output rate is calculated on the basis of the input material (INM) of a specific end-use sector (n), the recovery rate (RCOr).

The "Sector-Combinations"

Utilisation rate UTF: (RIS + RIC) -1

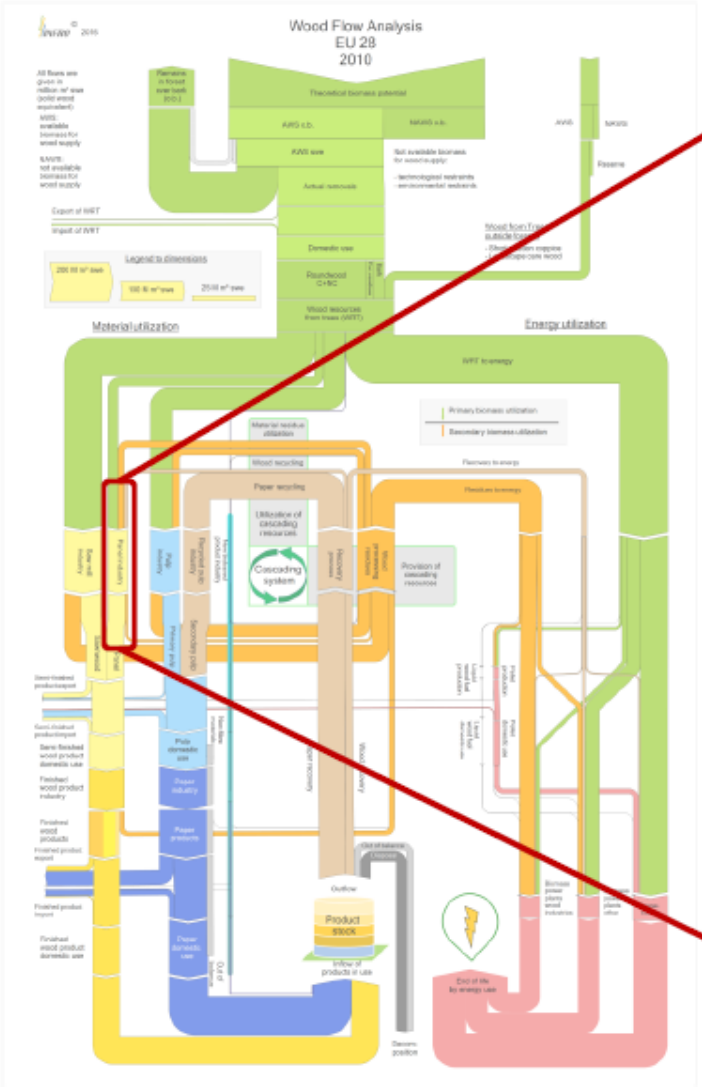
Provision rate PRV: $(ROS^S + ROS^F + ROC)$ -1

Dimensions of cascading system EU 28 in 2010

	Residues	**Recycled material**
Material utilisation 210.2 M m³	Residue Input: 67.5 M m³	Recycling Input: 142.7 M m³
Utilization rate: 1.62		
Total provision 347.5 M m³	Residue Output: 178.7 M m³	Recycling Output: 168.9 M m³
Provision rate: 1.75		

137.3 M m³ (difference) is used for energy

Quantification of cascading rates – semi finished



Including veneer and plywood

Panel (EU28)	in M m³
Utilization	
Raw wood input	45.2
Residue input	31.9
Recycling input	16.7
Inputvolume	93.8
Residue input rate	*1.71*
Recycling input rate	*1.37*
Utilization rate	***2.07***
Provision	
Residues output	10.9
Residue Output rate	*1.12*
Provision Rate	***1.12***

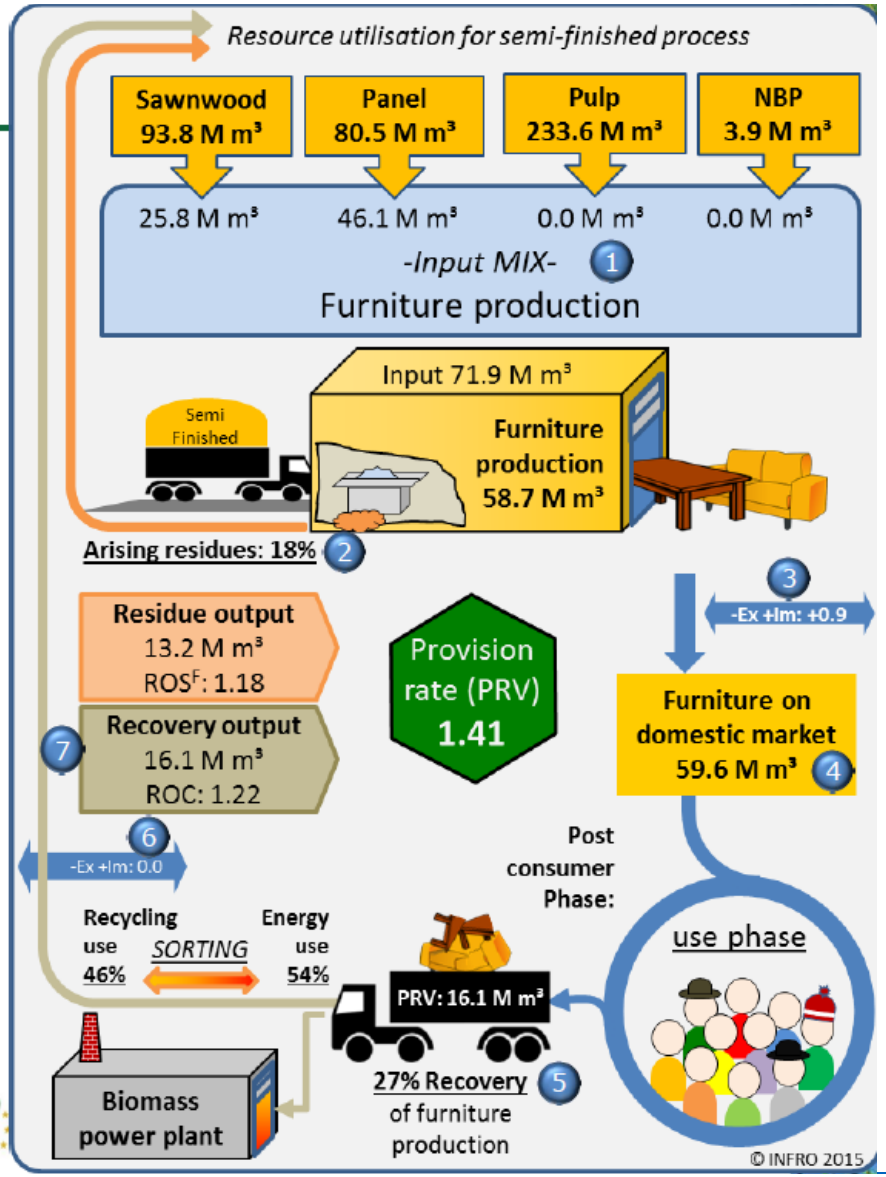
Quantification finished products

Cascading performance of finished sectors is the recyclability of finished products.

Calculation steps:

1. Input mix for furniture
2. Residues from furniture production
3. - Net export of furniture
4. Domestic use
5. Recovery
6. - net export of PCW
7. Domestic recovery use

No differentiation could be made between origin of PCW.

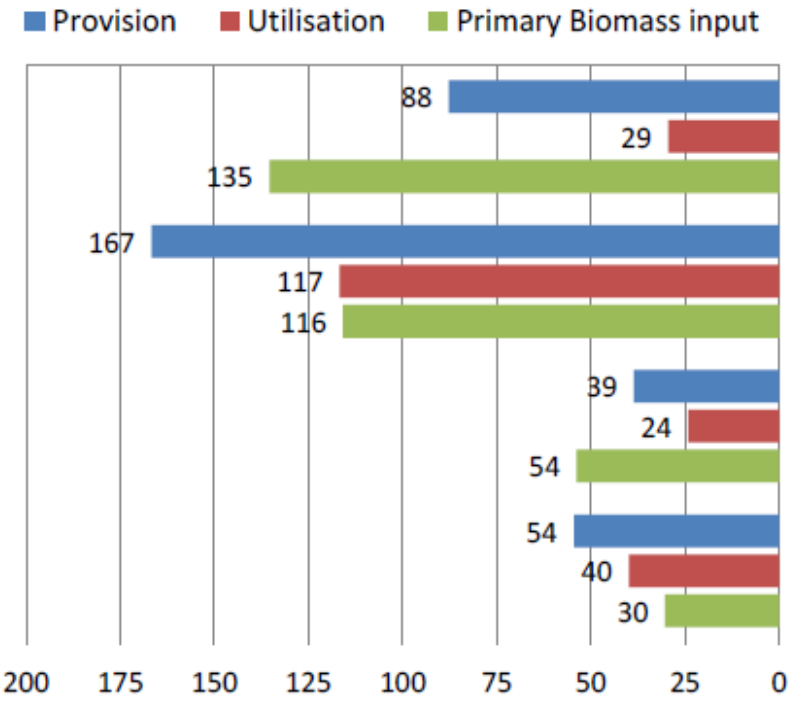


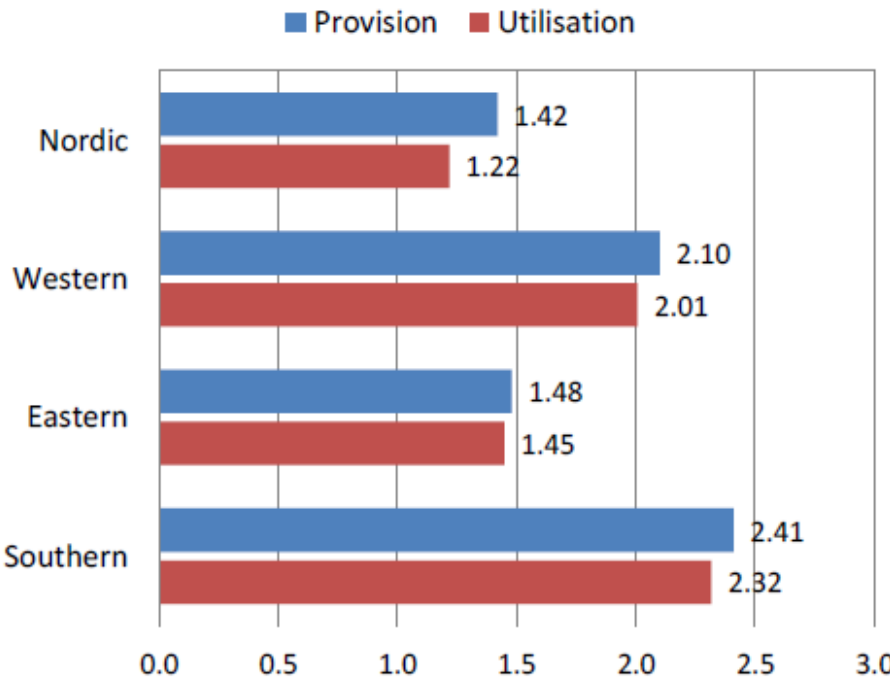
Quantification of cascading on a macro level (EU 28)

	Cascading dimension	Provision		Utilisation	
	Sector/product	in M m³	rate	in M m³	rate
Sector	**Sawmill industry**	**82.4**	**1.45**	**0.0**	**1.00**
Product	Coniferous sawnwood	74.0	1.45	0.0	1.00
	Non-coniferous sawnwood	8.3	1.46	0.0	1.00
Sector	**Panel industry**	**10.9**	**1.12**	**48.6**	**2.08**
Product	Particleboard	2.8	1.05	37.4	2.99
	Fibreboard	1.3	1.05	11.2	1.79
	Plywood	4.9	1.56	0.0	1.00
	Veneer	1.9	1.55	0.0	1.00
Sector	**Pulp industry**	**59.6**	**1.22**	**160.4**	**2.51**
Product	Chemical wood pulp	59.0	1.53	27.2	1.32
	Semi-chemical wood pulp	0.6	1.04	0.7	1.05
	Mechanical wood pulp	0.0	1.00	6.4	1.34
	Recovered pulp	0.0	1.00	126.0	∞
Sector	**NBP**	**2.0**	**1.59**	**1.2**	**1.57**
Product	Wood plastic composites	0.0	1.00	0.1	3.33
	Dissolving wood pulp	2.0	1.61	1.2	1.56
	Polymers	0.0	1.00	0.0	1.56
	Other NBPs	0.0	1.00	0.0	1.00
Production level	**Total semi-finished product industry**	**154.8**	**1.28**	**210.2**	**1.62**

Regional analysis

Countries have complete different prerequisites to achieve cascade rates: population, forest biomass, historically grown wood industries (particle board, used paper) ...





Source: Blanke C; Mantau U **Notes:** Nordic (SE, FI, LT, LV, EE); Western (AT, BE, DE, FR, GB, IE, LU, NL. DK); East (CZ, HU, PL, RO, SK, BG, HR, SI); Southern (CY, GR, ES, IT, MT, PT)

Hot spots of cascading system

(1) Used paper realised system of cascading use.

(2) Post-consumer wood (PCW) utilization

(3) PCW quality crucial for material use.

(4) Saw mill industry is a key provider of untreated high quality resources for cascading use.

(5) Producers in the end-use wood sectors affect PCW quality by the used of semi-finished products and other wood treatment.

(6) Cascading occurs mainly in the softwood flow because it is most applied in the material value chain.

(7) Subsidies for energy use of wood lead to higher raw wood flows toward the energy sector.

(8) Some wood assortments may not be marketable or cannot be used materially but have the possibility to substitute fossil fuels.

(9) Efficient energy wood use saves biomass by improving heating technology.

(10) Reliable data on wood availabiulity and consumption

Submarket / regional perspective (Nova 2015)

Biomass Utilization Factor

- Combines production efficiency on a analysed cascade stage with the upsteam cascade efficiency
- Intergrates energy use on the same level as product use. Only product use generates further cascade utilisation potential.

Biomass Utilisation Factor (BUF)

BUF_S = BUF for a biomass sector (in a specific region/country to a certain time)

BUF_{RP} = BUF for a specific raw material & product (and a specific region)

CoQ_n = Co-production Quotient on Cascade stage n

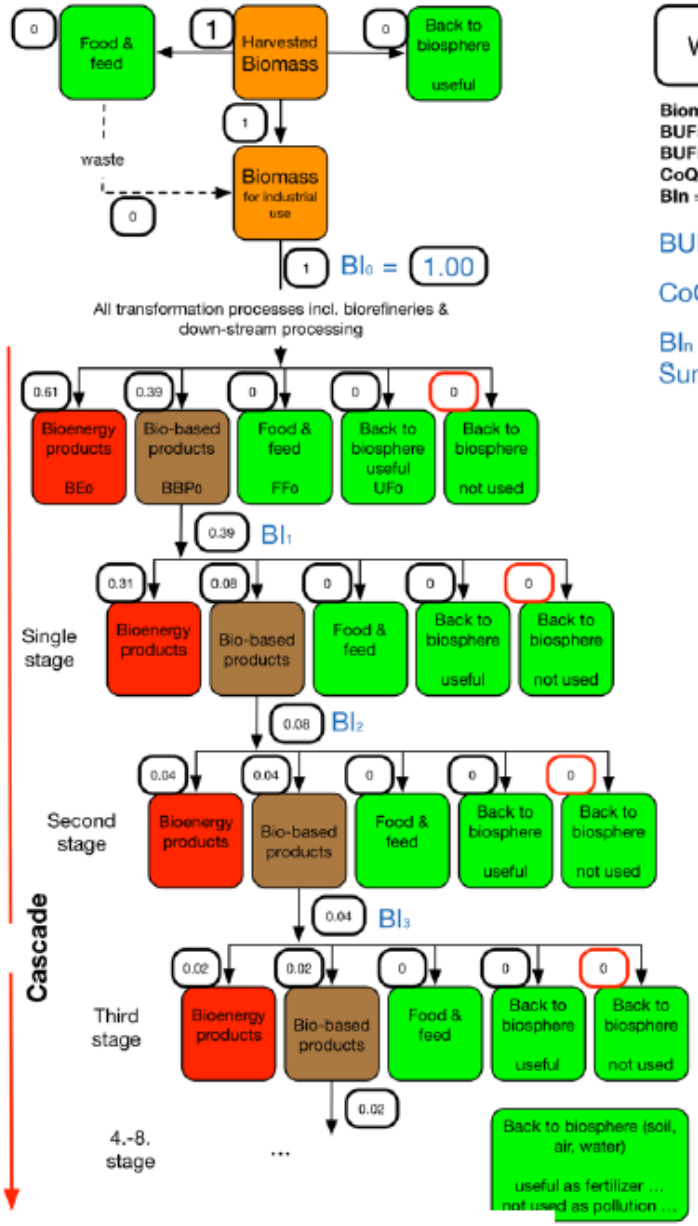
BI_n = Biomass Input on Cascade stage n in% of the original 100% biomass before cascade stage 0 (starting with $BI_0 = 1$)

$$BUF_n = BUF_{n-1} + BI_n \times CoQ_n$$

$$CoQ_n = \text{Sum}\ (BE_n+BBP_n+FF_n+UF_n) / BI_n$$

$$BI_n \times CoQ_n = BI_n \times \text{Sum}\ (BE_n+BBP_n+FF_n+UF_n) / BI_n = \text{Sum}\ (BE_n+BBP_n+FF_n+UF_n)$$

Source: nova 2015



Wood sector Europe (data from Mantau 2015)

Biomass Utilization Factor (BUF)
BUFs = BUF for a biomass sector (in a specific region/country to a certain time)
BUFRP = BUF for a specific raw material & product (and a specific region)
CoQn = Co-production Quotient on Cascade stage n
BIn = Biomass Input on Cascade stage n

$$BUF_n = BUF_{n-1} + BI_n \times CoQ_n$$

$$CoQ_n = \text{Sum}\,(BE_n+BBP_n+FF_n+UF_n) / BI_n$$

$$BI_n \times CoQ_n = BI_n \times \text{Sum}\,(BE_n+BBP_n+FF_n+UF_n) / BI_n = \text{Sum}\,(BE_n+BBP_n+FF_n+UF_n)$$

BI_0		CoQ_0		BUF_0
1.00	x	1.00	=	1.00

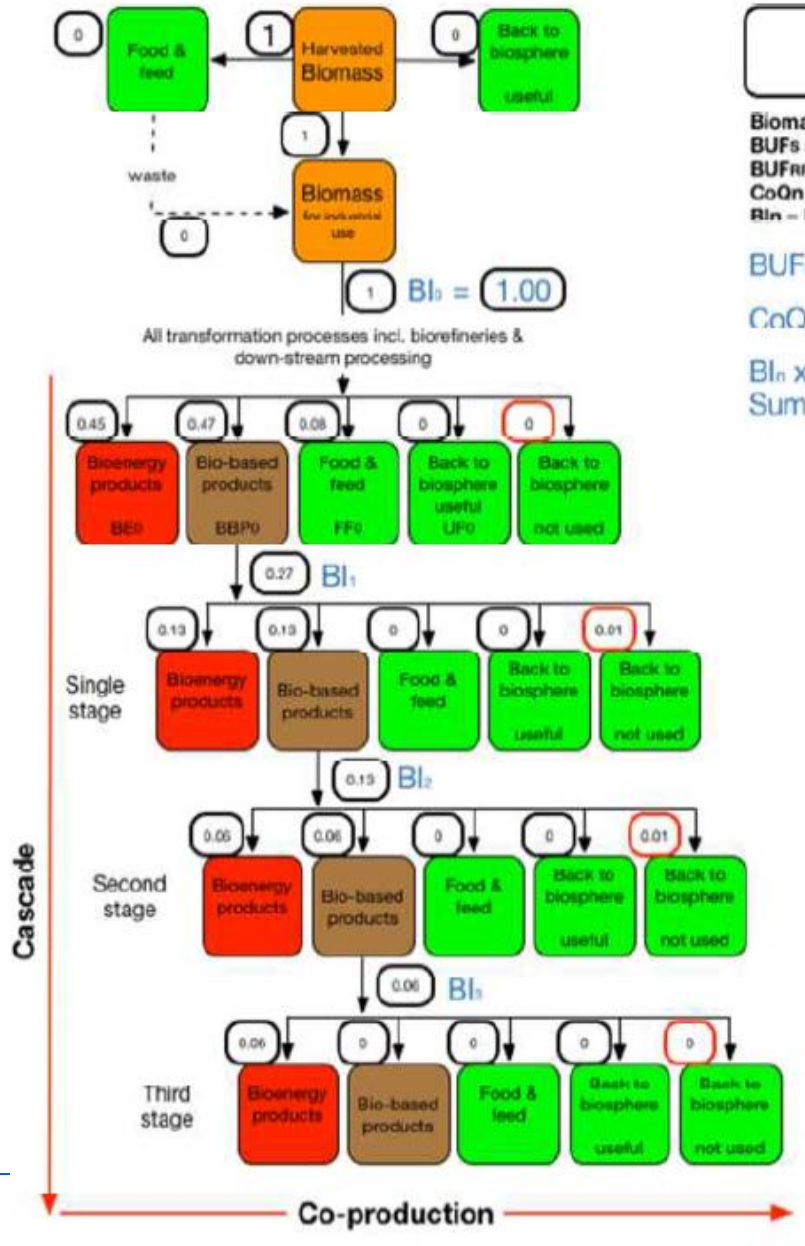
BI_1		CoQ_1		BUF_0		BUF_1
0.39	x	1.00	+	1.00	=	1.39

BI_2		CoQ_2		BUF_1		BUF_2
0.08	x	1.00	+	1.39	=	1.47

BI_3		CoQ_3		BUF_2		BUF_3
0.04	x	1.00	+	1.47	=	1.51

BUF_8 = 1.57

nova-Institute 2015-08



BUF: Biorefinery (Scenario 1)

Biomass Utilization Factor (BUF)
BUFs = BUF for a biomass sector (in a specific region/country to a certain time)
BUFRP = BUF for a specific raw material & product (and a specific region)
CoQn = Co-production Quotient on Cascade stage n
BIn = Biomass Input on Cascade stage n

$$BUF_n = BUF_{n-1} + BI_n \times CoQ_n$$

$$CoQ_n = Sum\ (BE_n+BBP_n+FF_n+UF_n) / BI_n$$

$$BI_n \times CoQ_n = BI_n \times Sum\ (BE_n+BBP_n+FF_n+UF_n) / BI_n = Sum\ (BE_n+BBP_n+FF_n+UF_n)$$

BI_0 (1.00) × CoQ_0 (1.00) = BUF_0 (1.00)

BI_1 (0.27) × CoQ_1 (0.96) + BUF_0 (1.00) = BUF_1 (1.26)

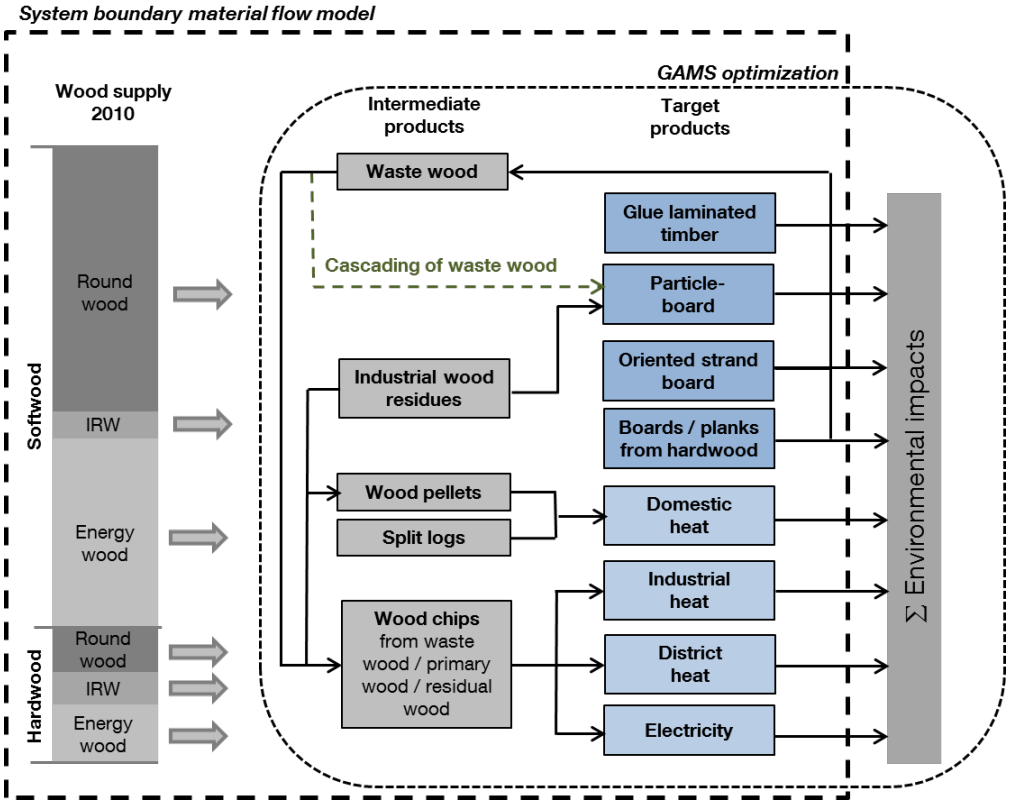
BI_2 (0.13) × CoQ_2 (0.92) + BUF_1 (1.26) = BUF_2 (1.38)

BI_3 (0.06) × CoQ_3 (1.0) + BUF_2 (1.38) = BUF_3 (1.44)

BUF_3 (1.44)

Product perspective (Höglmeier et al. 2015)

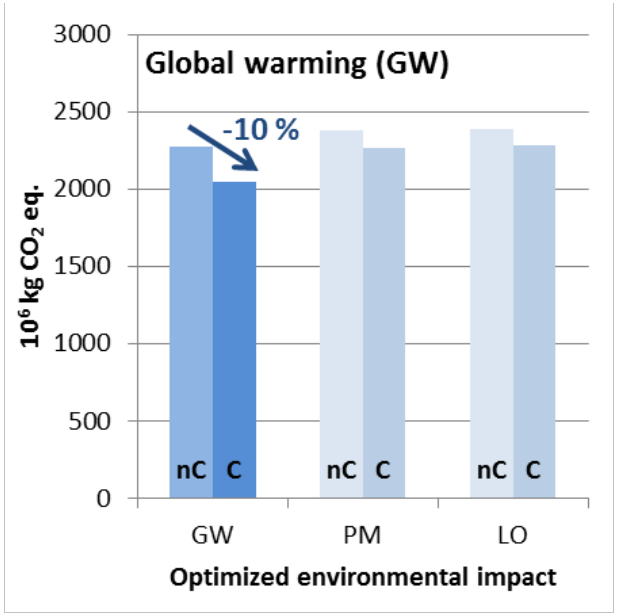
- Assessing effects of a **cascading use of wood** on
  - **environmental impacts** of wood utilization
  - Wood flow and utilization characteristics
- Application of an **LCA-based material flow model** of the wood utilization in Southeast Germany

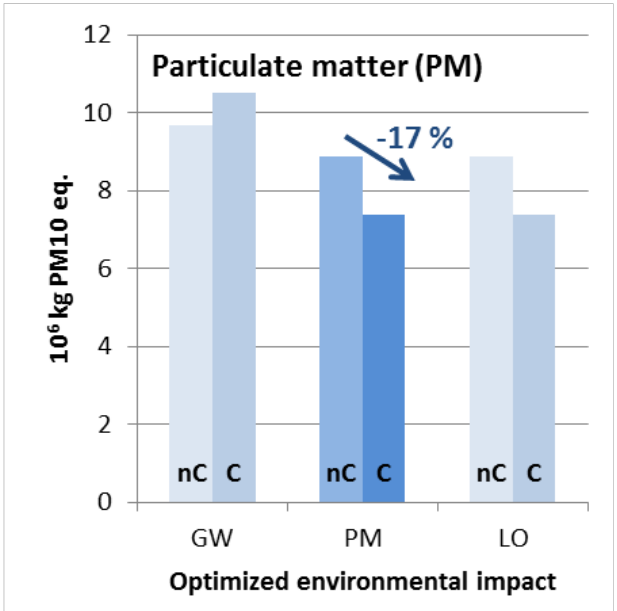


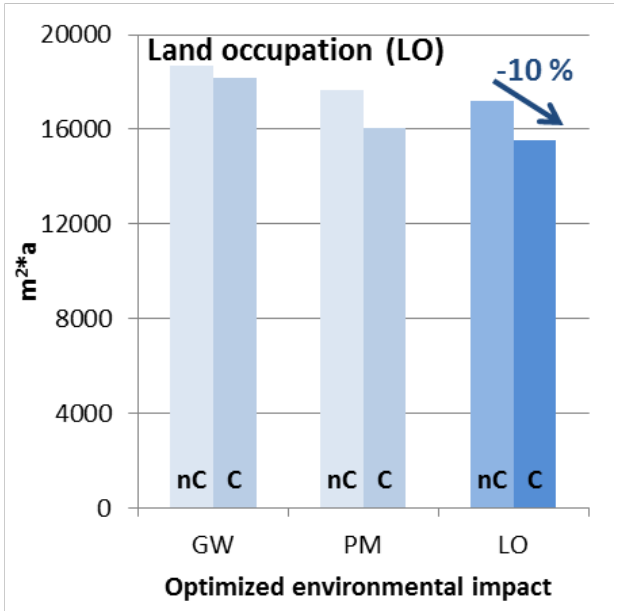
LCA-based material flow model of wood utilization

Model specification

- Material flow model for wood materials and energy combined with linear optimization via GAMS
- Optimization target: minimizing overall environmental impacts of wood utilization
- Minimum amounts per target product, derived from actual demand
- LCA impact categories:
  - GWP
  - PM formation (< 10 μm)
  - Land use







Environmental impacts of wood utilization in cascading (C) and non-cascading (nC) model runs for different minimized environmental impacts.

- **GHGs** reductions by **10 %,** equiv. to **22.000** per capita emissions/yr
- **PM** formation reduced by **17%**, equiv. to **800.000** per capita emissions/yr

Höglmeier et al. 2015

[% of total used or produced]	Optimized environmental impacts					
	Global warming		Particulate matter		Land occupation	
	nC	C	nC	C	nC	C
Primary wood for material use	68 ↘	66	74 ↗	81	74 ↗	81
Cascaded wood	--	13	--	16	--	15
Primary wood supply utilized	80 ↘	77	78 ↘	63	80 ↘	66

- **Savings of primary wood** between **3 and 15 %** of annual supply

Höglmeier et al. 2015

Preliminary conclusions

(1) Encouraging a multiple material use of wood is **beneficial from an environmental point of view**.

(2) Cascading **impacts on the whole wood utilization system** despite only directly adding one additional application of waste wood.

(3) An **efficient waste wood collection and sorting** with as few material losses as possible is a prerequisite for a cascading use, as it preserves the **potential for energy production at the end of the cascade**.

(4) Significance and the break-even point of technological investments and environmental **benefits of wood cascading depend on the system**

(5) Because wood (biomass) production is not credited in LCAs, the **conservation of biomass in cascading does not document as high benefits as in other material systems**

Cascading an Resource Efficiency impacts

1) Determine resource consumption of a cascading system compared to a reference scenario

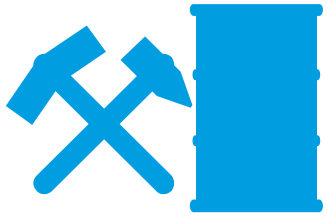
2) Determine resource efficiency of a cascading system compared to a reference scenario

3) Determine applicability of exergy analysis for multi-functional cascading systems

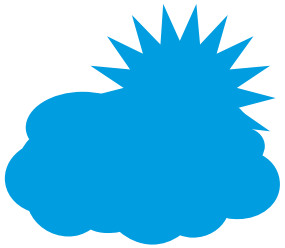
Definition of natural resources

Categorisation according to Dewulf et al. 2007

Water

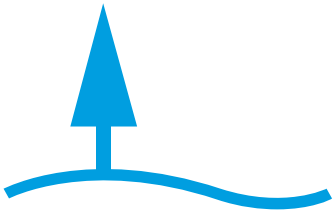


Fossil fuels
Nuclear Resources

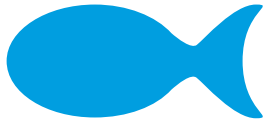


Abiotic renewable resources
Atmospheric resources

Metal ores
Minerals

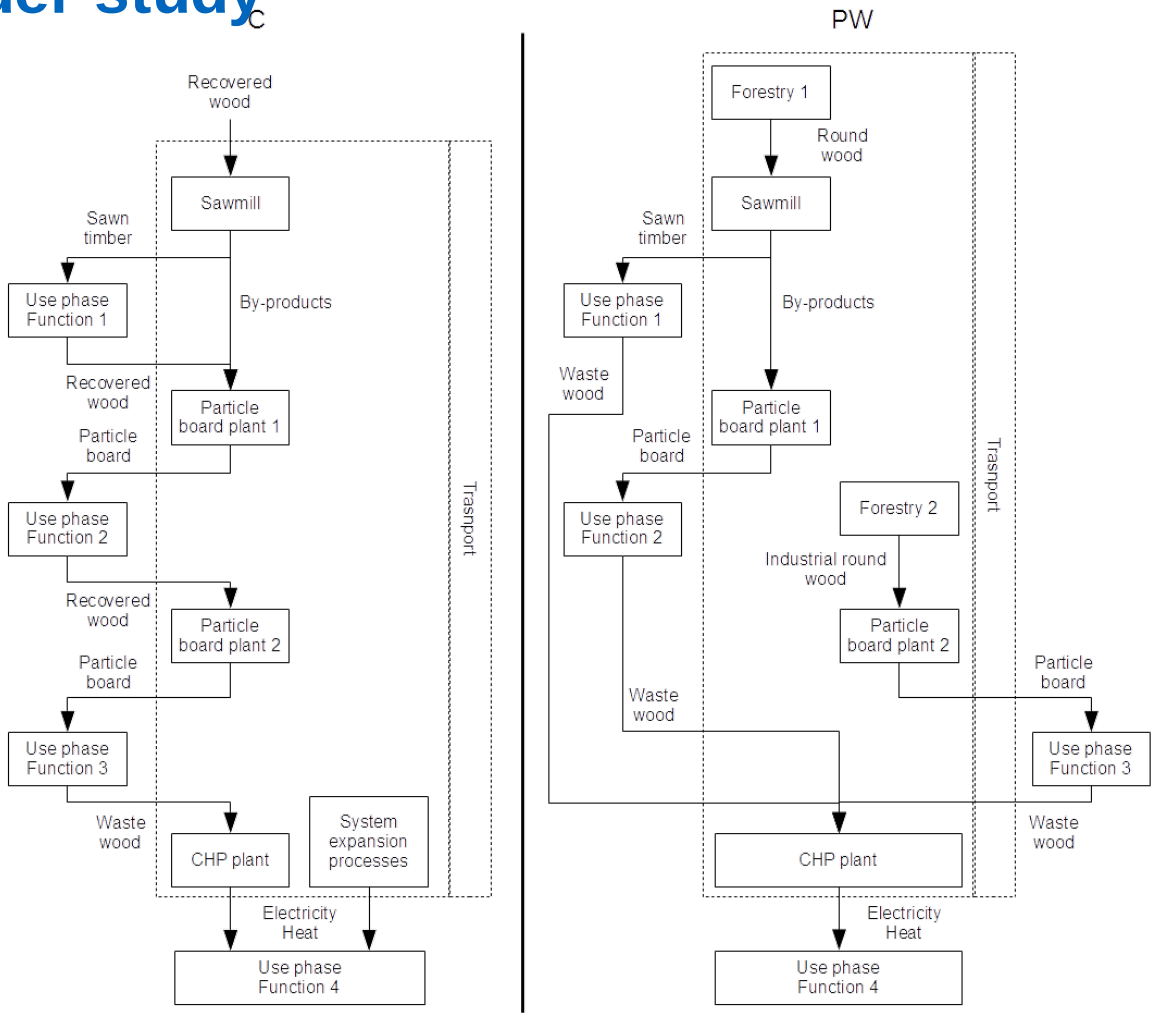


Land resources



Biotic resources

Systems under study



Risse et al 2016, submitted

Functional unit

System expansion: grid, primary wood, waste wood

System	Sawn timber in m³	Particle board in m³	Electricity in MJ	Heat in MJ	System expansion	
					Electricity in MJ	Heat in MJ
C	0.846	2.082	1,398	4,194	2,854	8,563
PW	0.846	2.082	4,252	12,757		

Characteristics of (bio-based) cascading systems

Multi-functionality → Cascade system provides several functions along the LC

Internal recycling processes

Bio-based system → Land area considered as relevant resource category

→ Exergy analysis

- → Aggregation of materials and resources in single score
- → Accounts for internal recycling flows
- → Calculation of efficiency is straightforward (without weighting)
- → LCIA indicators account for land area as such

→ Proved to be a viable method for resource use accounting and analysis of resource use efficiency to determine hotspots of exergy dissipation and improve efficiency

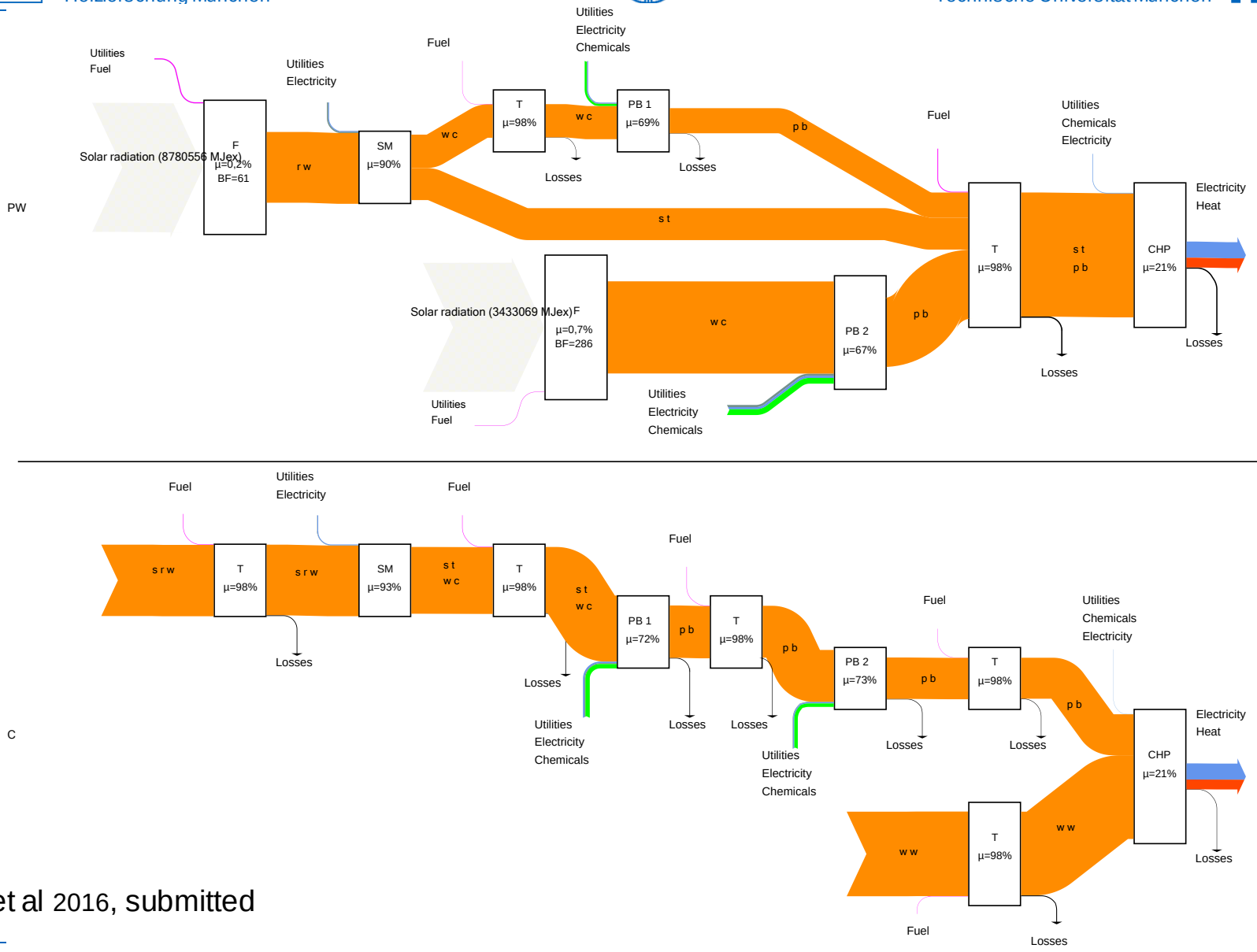
Exergy analysis

Exergy = The maximum of potential work that can be obtained from a resource or material when bringing it into equilibrium through reversible processes with the natural environment

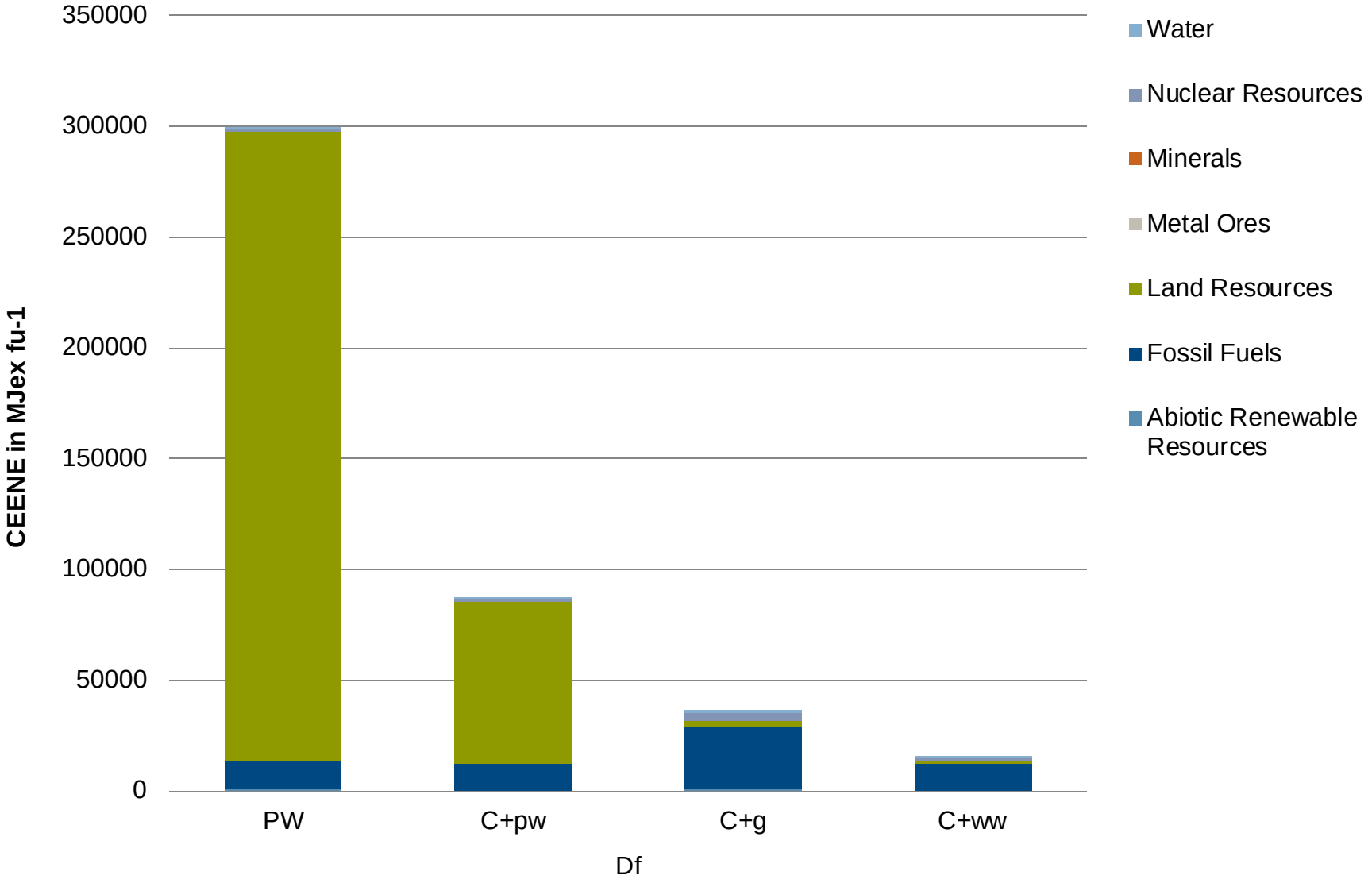
LCIA indicator: CEENE (Cumulative Exergy Extraction from the Natural Environment) (Dewulf et al. 2007)

Resource efficiency according to Szargut 1988

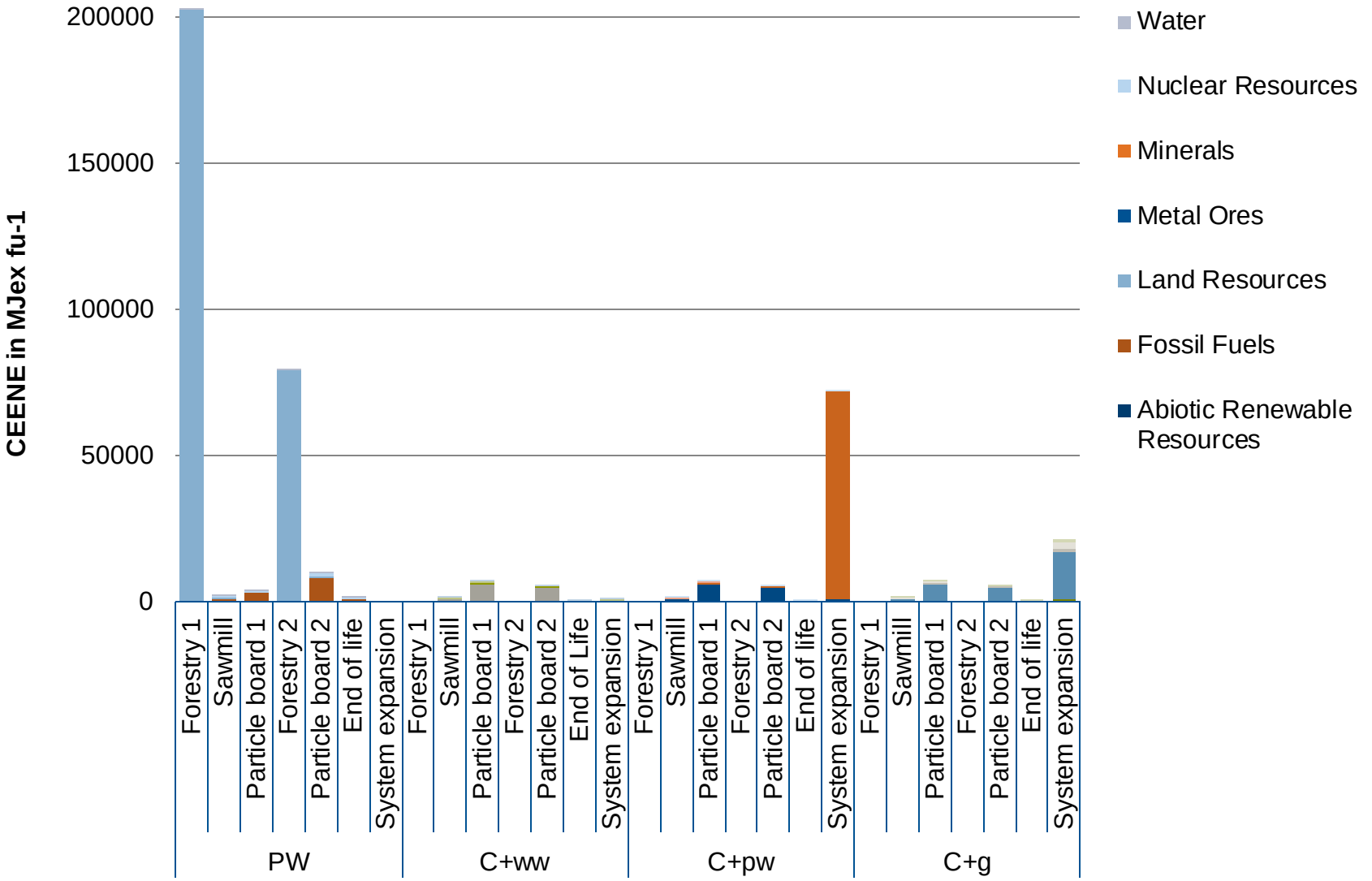
$$CDP_{mfs} = \frac{\sum(Useful\ Output_{Ex})}{\sum(Recovered\ Material_{Ex} + Recycled\ Material_{Ex} + CEENE\ of\ Supply\ Chain_{Ex})}$$



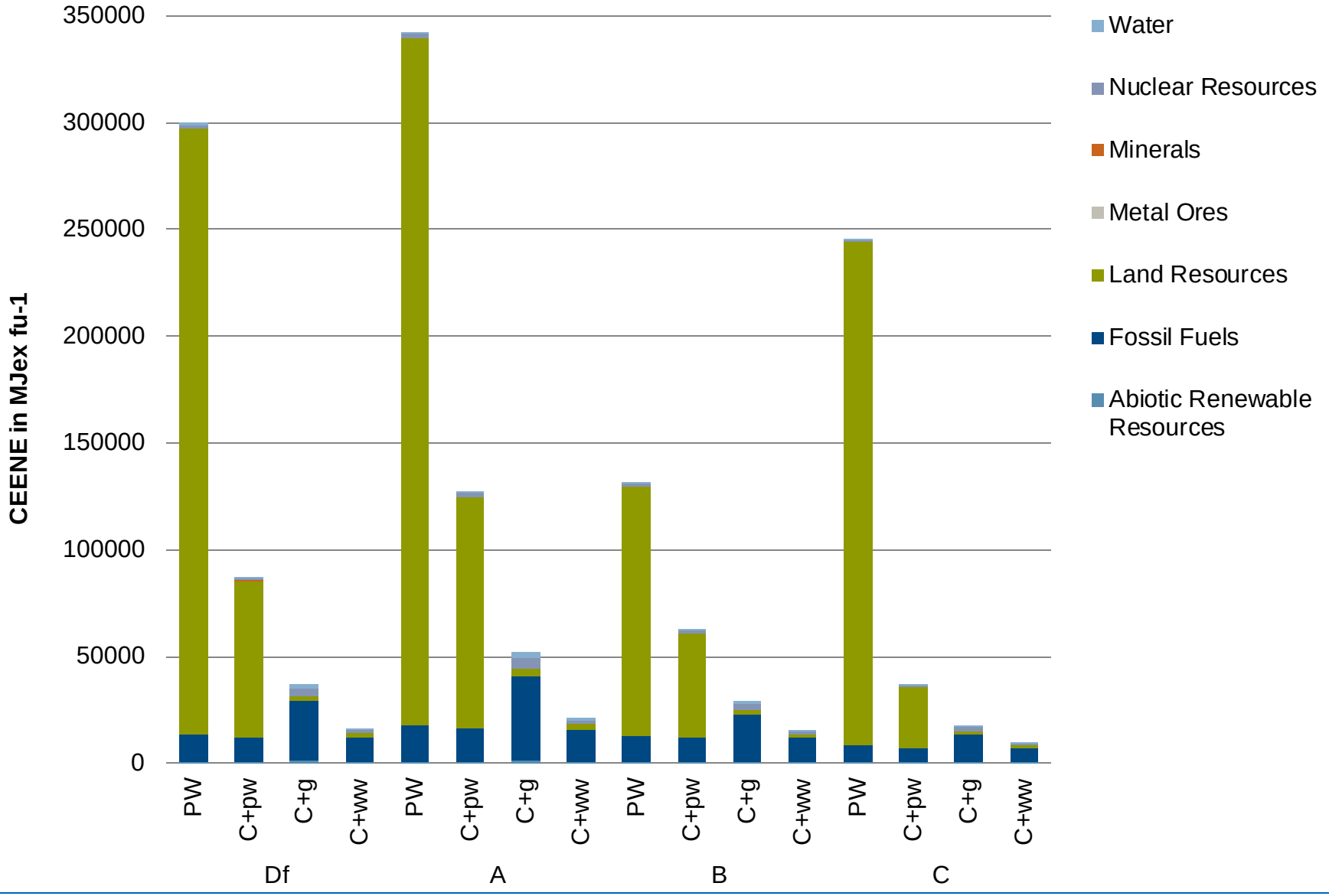
Risse et al 2016, submitted



Risse et al 2016, submitted



Risse et al 2016, submitted


CEENE in MJex fu-1
350000
300000
250000
200000
150000
100000
50000
0
PW
C+pw
C+g
C+ww
Df
A
B
C
Water
Nuclear Resources
Minerals
Metal Ores
Land Resources
Fossil Fuels
Abiotic Renewable Resources

Shortcomings of methodology

Land use accounting

Characterization factor calculated by the annual solar radiation per area and the maximum photosynthetic efficiency of converting solar radiation into aboveground biomass (2.3 %)

As biomass is the single useful output of forestry systems in the inventory data, forestry systems are described as very inefficient systems
For sure: land occupation is mandatory and tree growth demands time

But:
Additional functions provided from biomass growth, i. e. the establishment of an ecosystem, are disregarded, such as ecosystem services
Thus forest ecosystems are downgraded to one single function, but burdened with the full occupation of land use

Conclusions and Outlook

1) Cascading can reduce the resource consumption

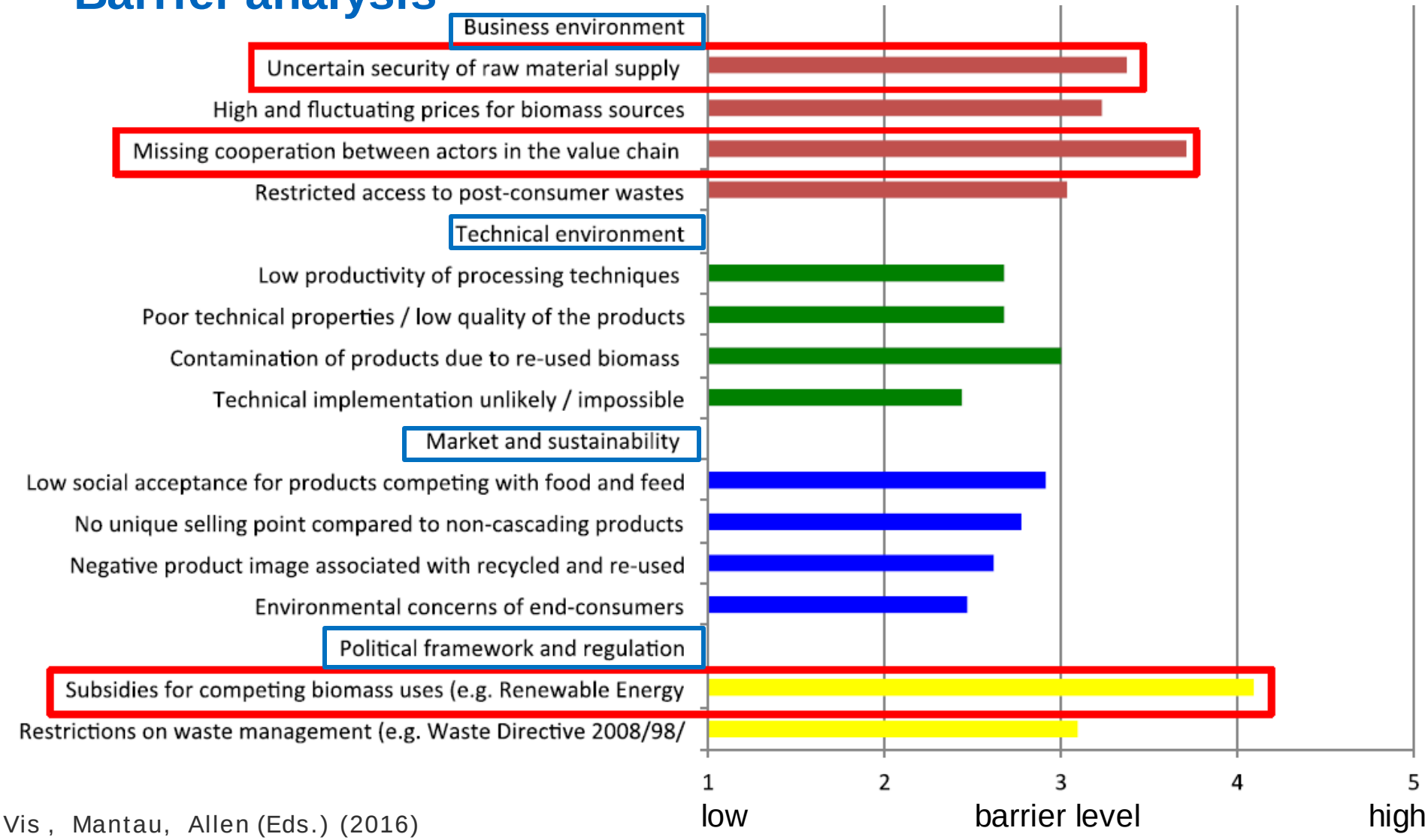
2) Cascading has a higher resource efficiency producing the same functional unit as a reference scenario

3) Exergy analysis proved to be a viable method to analyze resource efficiency of multi-functional systems

4) Further research is required to integrate ecosystem services in forest processes

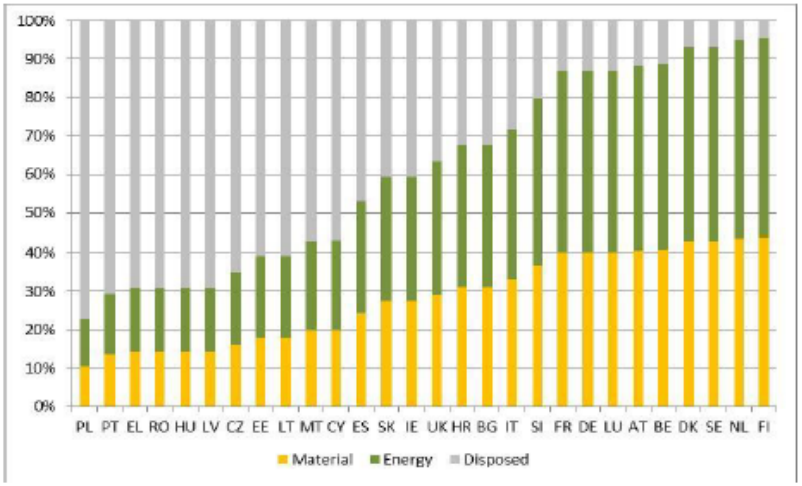
5) Extend resource definition and include socio-economic aspects into indicator

Barrier analysis

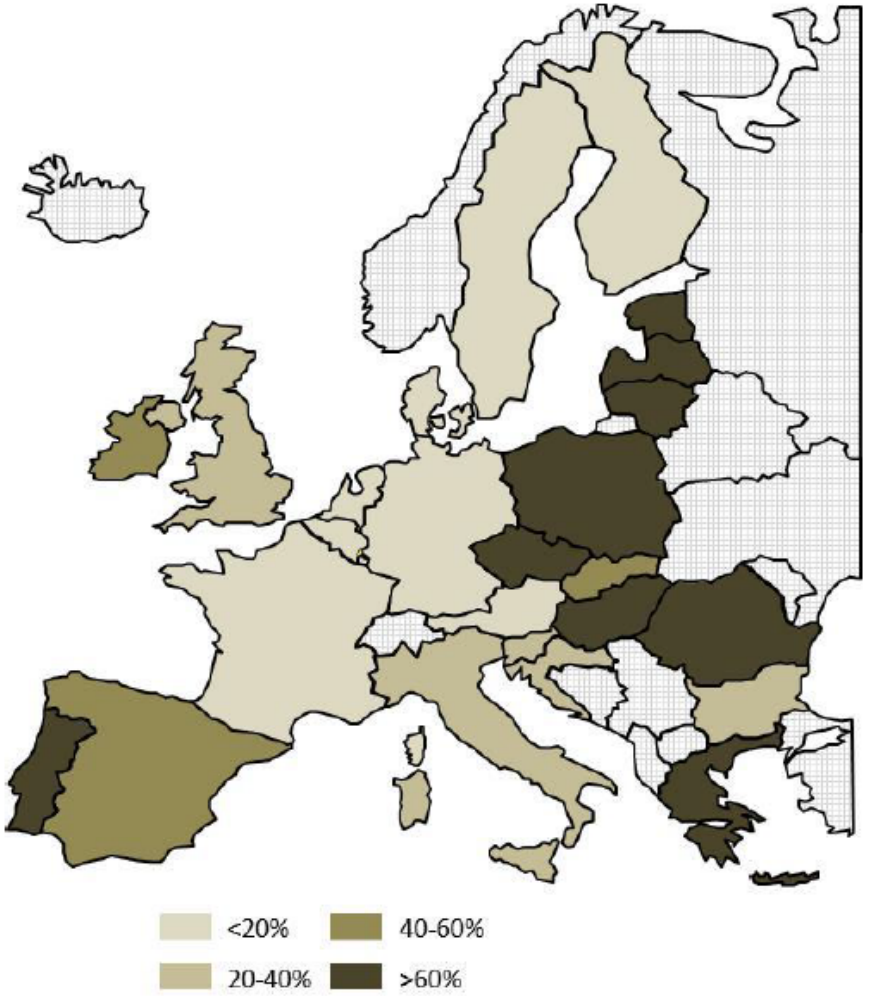


Vis , Mantau, Allen (Eds.) (2016)

Barriers to the provision of residues and used wood



- 16,8 M m^3 for material
- 19,5 M m^3 for energy
- 16,0 M m^3 disposed



Vis , Mantau, Allen (Eds.) (2016)

Source: Based on Mantau, U. EUwood - Final report.

Waste wood quality requirements

Application	Requirements to the quality of the recovered wood		
	Wood dimensions intact	Only clean wood (low level of impurities, paint removed)	No preservatives
Furniture	Y	Y	Y
Sawn wood in construction	Y	Y	Y
Particle board	N	N[a)]	Y
MDF	N	Y	Y
Wood plastic composites	N	Y	Y
Energy (household)	N	Y	Y
Energy (large scale)	N	N	Y/N[b)]
OSB	OSB currently requires fresh wood		
Plywood	Plywood requires fresh wood		
Paper	Paper requires fresh wood and residues or recovered paper		

Notes: [a)] Particle board producers can accept painted wood, but requires further cleaning onsite. [b)] Many energy plants are not designed to use wood with preservatives, especially if treated with copper, chrome and arsenic.

Vis , Mantau, Allen (Eds.) (2016)

Barriers to waste wood quality

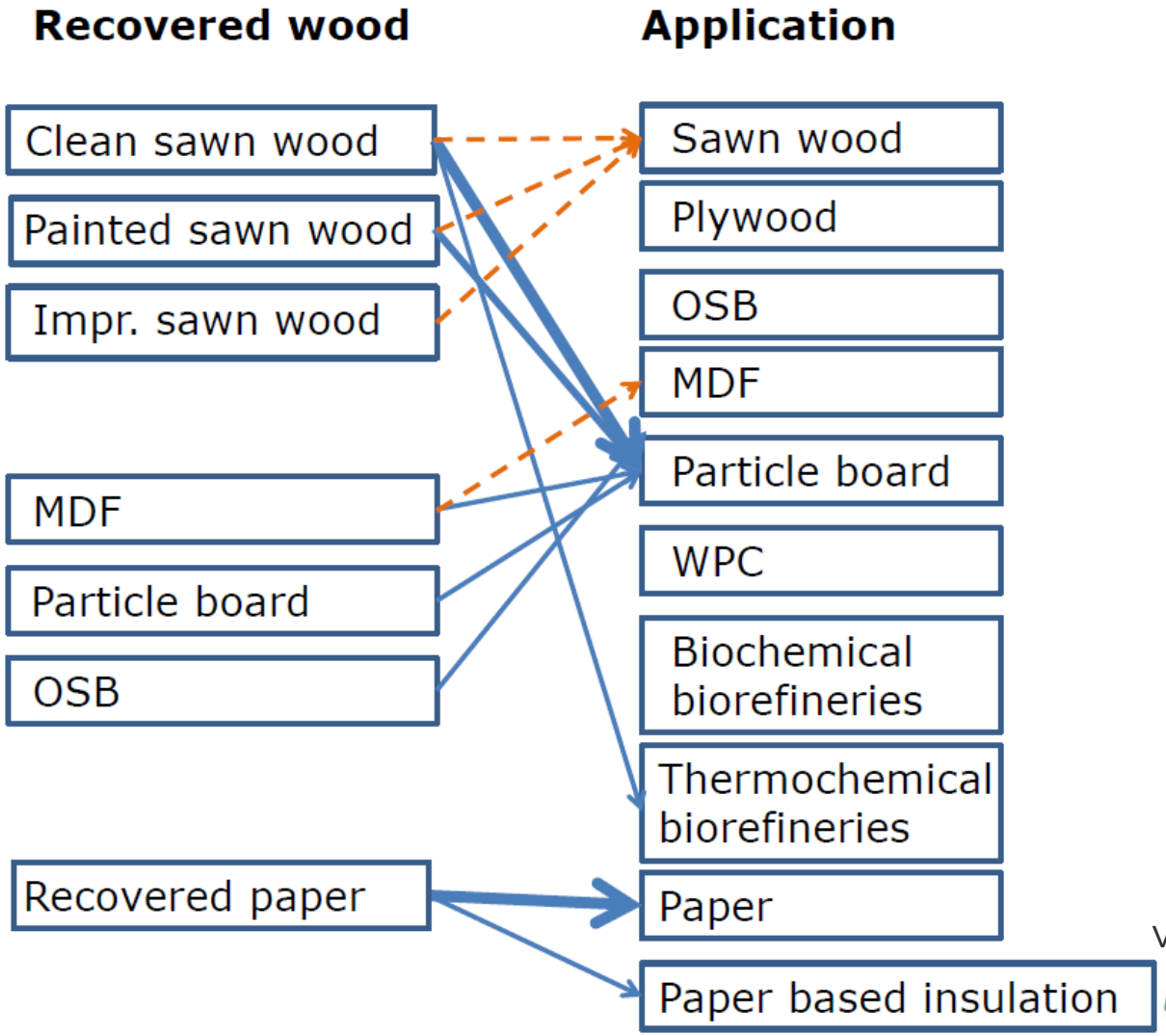
- Level of pollutant materials (historically) available in waste wood
- Lack of separate collection *at the source*
- Lack of cost effective methods to detect, sort and clean mixed waste wood fractions

Construction wood waste from a controlled demolition process
Picture by INTECUS

Destructive and non-destructive collection practices for bulky (furniture) waste items
Source: Harald Heinritz, abfallbild.de / Borough Council, UK

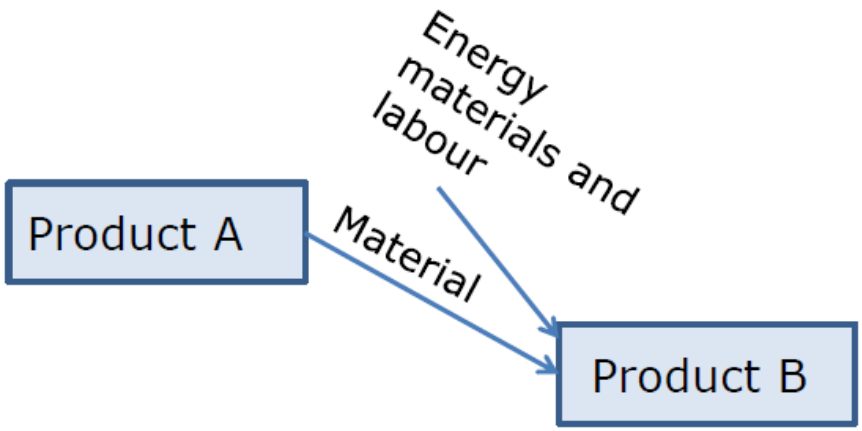
Vis , Mantau, Allen (Eds.) (2016)

Technical possibilities for cascading



Vis , Mantau, Allen (Eds.) (2016)

Market barriers to cascading use



- General
  - Producer A does not participate in the benefits of Producer B
  - Producer B has no influence on the activities of producer A
  - Cascading is easier if materials can be separated
- Wood specific
  - Fresh wood is available at reasonable costs with limited energy expenditure.

Governance barriers

- Lack of integrated approach towards energy and material application of biomass
- Lack of recovery targets for waste wood
- Limited attention for source separation of waste wood in Europe
- Strict regulations governing the level of contaminants in particleboard
- Waste status of recovered wood
- Lack of recognition of carbon emission reduction impacts of wooden products

Vis , Mantau, Allen (Eds.) (2016)

Specific EU actions recommended

- Development of an EU standard for the classification of wood waste assortments to provide harmonisation between Member State approaches, improve understanding or potential uses and trade

- Make explicit reference to wood under the definition of organic and biodegradable wastes in relation to the Circular Economy package

- Develop a platform through which to share best practice on the cascading use of wood, particularly where existing barriers have been overcome in specific situations

Specific EU actions recommended

- Improve the data around wood/wood waste use and flows through improved reporting and traceability of wood assortments
- Ensure that the material and resource efficient use of wood is a central element in the potential development of the Bioeconomy strategy as foreseen to be revised in relation to the Circular Economy package
- Harmonise energy and material policy. Addressing this issue should be the focus of efforts when developing the post 2020 energy and climate initiatives, and when considering the potential changes to the Bioeconomy strategy in relation to the recent Circular Economy package.

Wood specific actions recommended

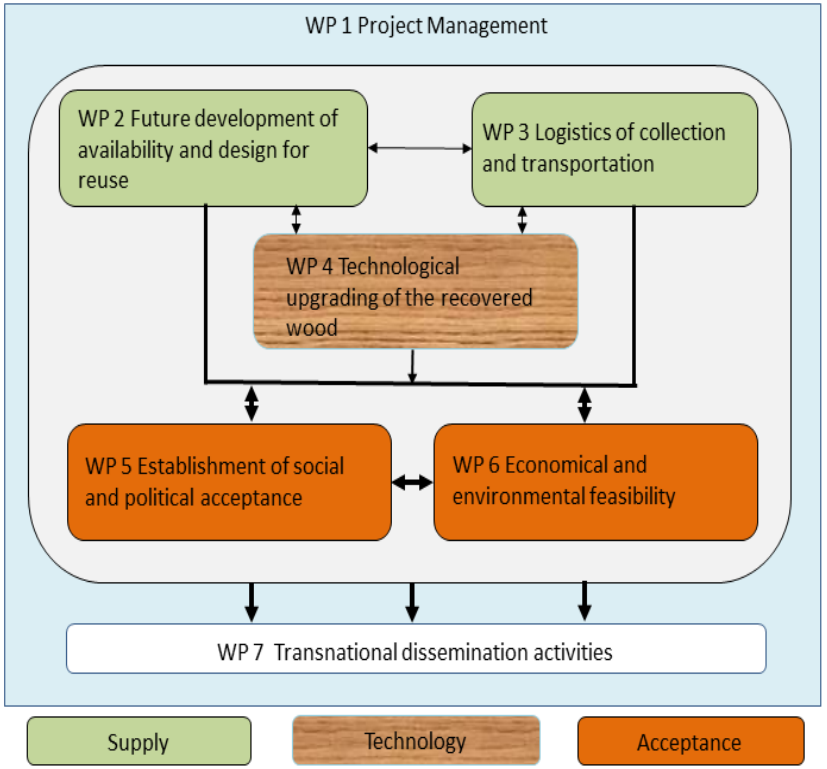
- An efficient waste wood collection and sorting is essential as it preserves the potential for energy conversion at the end-of-life
- Incentives for a future increased (solid) wood cascading
  - Design for reuse
  - On-site waste category classification and sorting
  - Increase of recovery rates
  - Development and application of in situ sensor, grading and separation techniques
  - Supply chain development between disparate actors;
  - Technological developments in utilising hardwood streams more effectively
- Improve quality of statistical data (waste wood and recycling data on post-consumer wood, monitor of cascading use)

Actual practice
building demolition

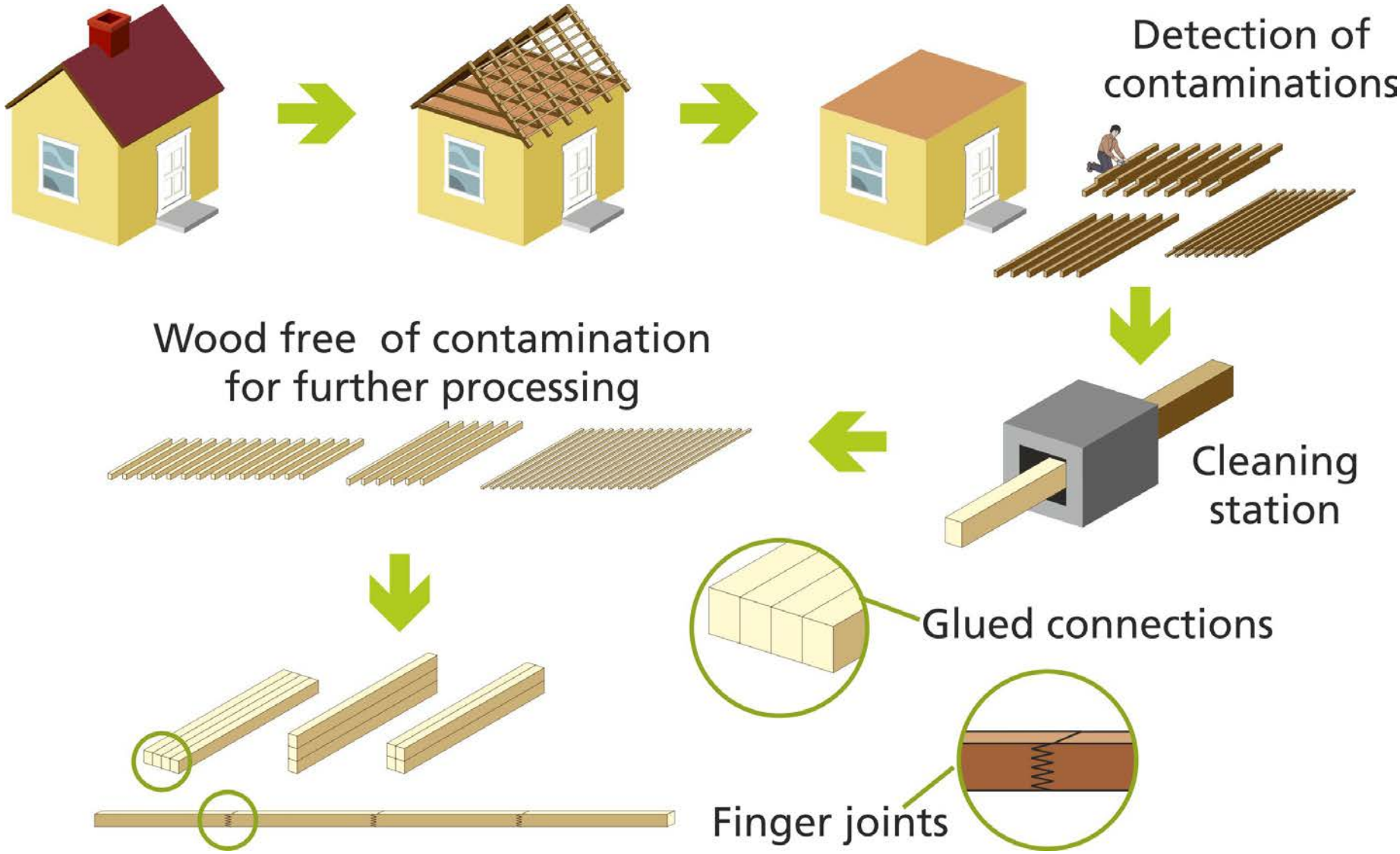
Selected dismantling of construction wood

Wood Wisdom Era Net+ "Cascading Recovered Wood "CaReWood" 2014-2017

- forecasts of volumes/qualities of RW (post consumer/industry)
- guidelines to facilitate future reuse
- software to support reverse logistic models for recovery of wood
- feasibility of up-grading solid RW technologies
- certification and labelling criteria to cascaded wood;
- evaluate environmental impacts and socio-economic viability



- ➢ business opportunities
- ➢ Mitigation of climate change (longer carbon storage)
- ➢ Safeguarding of resources in the biosphere
- ➢ Higher societal acceptance and valorisation of wood produc


Detection of contaminations
Cleaning station
Wood free of contamination for further processing
Glued connections
Finger joints

Cascade use of wood – illusion or silver bullet for sustainability ?




Acknowlegdement

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Michael Risse, Karin Höglmeier, Gabriele Weber-Blaschke

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FNR
Fachagentur Nachwachsende Rohstoffe e.V.

WoodWisdom-Net

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Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages

Cascades	Year	Origin of Biomass			cascading principle				product quality			rational sc	EoL	level		Sector	
		all kinds of biomass allowed as starting point	only main product allowed as starting point	only by-product allowed as starting point	single-stage cascading allowed	only multi-stage cascading	single- and multi-stage cascading allowed	direct energy use included in special cases	closed loop	down-cycling	up-cycling	Quantification possible	energy use	Strategic scope	Operational scope	importance of the concept for Wood Sector	importance of the concept for Biorefineries
Sirkin, Houten	1994	✓	✗	✗	✗	n.a.	n.a.	✗	✓	✓	✓	✗	n.a.	✗	✓	↑	↓
Fraanje	1997	n.a.	n.a.	n.a.	✗	✓	✗	✗	✗	✓	✗	✗	✗	✗	✓	↑	↓
Haberl, Geissler	2000	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓	✗	↑	↓
Dornburg	2004	✓	✗	✗	n.a.	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓	↑	↓
EPEA	2009	✓	✗	✗	✓	✗	✓	✗	n.a.	✓	✗	✗	✗	✗	✓	↑	↑
Arnold et al.	2009	✗	✓	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓	↑	↓
Frühwald	2010	✓	✗	✗	✗	✓	✗	✗	✓	✓	✓	✗	✓	✗	✓	↑	↓
UBA	2012	✓	✗	✗	✓	✗	✓	✗	n.a.	✓	✗	✗	✓	✓	✗	↑	↓
European Commission	2012	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓	✗	✓	✗	✓	↑	↑
Keegan et al.	2012	✓	✗	✗	✗	✓	✗	✗	✓	✓	✓	✗	✓	✓	✓	↑	↑
Odegard et al	2012	✓	✗	✗	✓	✗	✓	✗	✓	n.a.	n.a.	✗	n.a.	✓	✓	↑	↑
Bos-Brouwers	2012	✓	✗	✗	✓	✗	✓	✓	n.a.	n.a.	n.a.	✗	✓	✓	✓	↓	↑
Blue Economy	2012	✓	✗	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓	→	↑
Mantau (cascade factor)	2012	✓	✗	✗	✓	✗	✓	✗	✓	✓	✓	✓	✓	✗	✓	↑	↓
Indufor	2013	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓	↑	↓
European Commission	2013a	✓	✗	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓	✓	→	↑
European Commission	2013b	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✗	✓	✓	n.a.	✗	✓	✓	✓	↑	↓
Ellen Mac Arthur	2013	✓	✗	✗	✓	✗	✓	n.a.	✓	✓	✗	✗	n.a.	✓	✓	↑	↑
Gärtner et al	2013	✓	✗	✗	✗	✓	✗	n.a.	✗	✓	✗	✗	✓	✗	✓	↑	↓
EP	2013	✓	✗	✗	n.a.	n.a.	n.a.	✗	n.a.	n.a.	n.a.	✗	✓	✓	✓	↑	↑
SCAR	2014	✓	✗	✗	✓	✗	✓	✓	✓	n.a.	n.a.	✗	✓	✓	✓	↑	→
Malins et al	2014	✓	✗	✗	✓	✗	✓	✗	✓	n.a.	n.a.	✗	✓	✗	✓	→	↑
nova-Institute	2014	✓	✗	✗	✓	✗	✓	✗	✓	✓	✓	✗	✓	✗	✓	↑	↑
Thünen Institut	2015	✓	✗	✗	✓	✗	✓	n.a.	✓	n.a.	n.a.	✗	✓	✓	✓	↑	n.a.
Höglmeier	2015	✓	✗	✗	✓	✗	✓	✓	✓	✓	n.a.	✗	✓	✗	✓	↑	↓
Morris	2015	✗	✗	✓	✓	n.a.	n.a.	✗	✗	n.a.	n.a.	✗	✓	✗	✓	↑	↑
nova-Institute (BUF)	2015	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓	↑	↑
Mantau	2015	✓	✗	✗	✓	✗	✓	✗	✓	✓	✓	✓	n.a.	✗	✓	↑	↑
Project definition	2015	✓	✗	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	↑	↑

✓ = included
✗ = not included
n.a. = not applicable or not defined

↑ = important
→ = questionable

Source: nova-Institute, 2015

	Roundwood	Industrial	Reycling
Germany	20	46	34
France	41	37	22
Italy	0	5	95
Poland	38	47	15
Spain	31	41	28
Austria	20	45	35
UK	18	31	53

Input material (%) in Particleboard production (EPF, 2010)

German Regulation on Waste Wood Categories (WWC):

A I: natural wood, just mechanical treated
e.g. wood from packaging, pallets, cable drums, mouldings

A II: processed wood without PVC compounds
e.g. wood based panels, plywood, coated, painted or glued solid wood, laminated wood from interior fittings without PVC

A III: processed wood with PVC compounds
e.g. wood with PVC-coatings, pallets with plastic composites

AIV: wood containing hazardous substances
chemically preserved wood, wood from outdoor application, wood containing hazardous substances, e.g. railway ties, telegraph poles, wooden windows, construction timber, roof beams, timber from demolition,…

material use (panels)
energy use

Demonstrators of cascaded solid wood products developed

www.CaReWood.org

The wood sector and the potential to influence cascading are diverse. Research topics in order to improve understanding further and develop new initiatives. These areas should include:
in situ sorting and separation techniques;
supply chain development between disparate actors;
technological developments in utilising hardwood streams more effectively;
scanning and separation technologies;
product labelling and tracing

knowledge base of wood use in end-user markets is very poor. End-user markets consist of a broad variety of products and material mixtures, which makes this research more complex. The quantification of end-user markets should be promoted as well as the material proportion of such products is needed to.

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quality of statistical data is poor (waste wood and recycling data on post-consumer wood)

knowledge base of wood use in end-user markets is very poor. End-user markets consist of a broad variety of products and material mixtures, which makes this research more complex. The quantification of end-user markets should be promoted as well as the material proportion of such products is needed to monitor cascading use.

improve the understanding of wood flows in Europe. For instance, according to wood flow analysis just over one quarter of the inflow material is potentially available as waste wood. Therefore, it would be important to analyse the destination of the other two thirds and whether this is used or sequestered in products. Such information could also be valuable for research on carbon sequestration in harvested wood products.

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