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Sustainability performance of wood-based materials:

A systemic assessment of lightweight materials for the mobility sector

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COMET Competence Centers for Excellent Technologies
Bundesministerium für Digitalisierung und Wirtschaftsstandort
FFG Österreichische Forschungsförderungsgesellschaft
Das Land Steiermark → Wirtschaft und Innovation
SFG NEUES DENKEN. NEUES FÖRDERN.
tirol Unser Land
Tirol Standortagentur

AIM

- Overview on impact assessments of wood-based and conventional materials
- Sustainability performance profile

RESEARCH QUESTION

How is the sustainability performance of wood-based materials compared to other bio-based and conventional materials from a systemic perspective?

Source: http://www.spiegel.de/auto/aktuell/holz-im-autobau-zurueck-zu-den-wurzeln-a-1087249.html

Importance of the study

Bioeconomy

Transition away from fossil-based resources towards bio-based resources (EC 2012)

Automotive Industry

Reduce green-house gas emissions of their fleet and increase recyclability of its components (EC 2000, 2014)

Forest-Based Industry

Global change and economic pressure (Weiss 2011)

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(Wood – Computer Aided Research)

… to introduce Engineered Wood Products (EWP), Engineered Wood Components (EWC) and wood based materials to the mobility sector

… to make EWPs and EWCs predictable by means of computer simulation

Literature Review

1. **Existing studies on sustainability of lightweight materials**
    - **Mayyas et al. (2012): Sustainable lightweight vehicle design: a case study of eco-material selection for body-in-white**
        - Consideration of TBL;
        - Not included: natural fiber composites or wood-based materials
    - **Kim et al. (2013): Life-Cycle Energy and Greenhouse Gas Emission Benefits of Lightweighting in Automobiles**
        - GHG emissions and primary energy results from 33 studies were harmonized
        - Aluminum, glass-fiber reinforced plastic, and high strength steel decrease impacts compared to conventional steel
        - Not included: all TBL dimensions; natural fiber composites or wood-based materials
2. **Transition towards a bio-based economy:**
    - Wood or natural fiber composites already common in the European automotive industry (Carus et al., 2015)
3. **Wood as a technical material for automotive applications analyzed by Kohl et al. (2016, 2017), Leitgeb et al. (2016)**
    - No sustainability assessments of wood in automotive applications identified

METHOD

1. **Literature review**
2. **Qualitative and quantitative content analysis**
3. **Develop sustainability performance profile including all TBL dimensions**
4. **Complement profile with systemic assessment (in progress)**

Source: https://sustain.wisconsin.edu/sustainability/triple-bottom-line/

DATA COLLECTED

Secondary literature

- sustainability assessments of lightweight materials in the automotive industry
- sustainability assessments of wood-based products

Results I

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Nr.	Author	Year	Title
1	Akhshik et al.	2017	Life cycle assessment and cost analysis of hybrid fiber-reinforced engine beauty cover in comparison with glass fiber-reinforced counterpart
2	Alves et al.	2010	Ecodesign of automotive components making use of natural jute fiber composites
3	Boland et al.	2016	Life Cycle Impacts of Natural Fiber Composites for Automotive Applications: Effects of Renewable Energy Content and Lightweighting
4	Dubreuil et al.	2012	A Comparative Life Cycle Assessment of Magnesium Front End Autoparts
5	Duflou et al.	2009	Environmental impact analysis of composite use in car manufacturing
6	Hardwick et al.	2016	Vehicle lightweighting through the use of molybdenum-bearing advanced high-strength steels (AHSS)
7	Mayyas et al.	2012	Sustainable lightweight vehicle design: A case study of eco-material selection for body-in-white
8	Poulikidou et al.	2015	A material selection approach to evaluate material substitution for minimizing the life cycle environmental impact of vehicles
9	Puri et al.	2009	Life cycle assessment of Australian automotive door skins
10	Raugei et al.	2015	A coherent life cycle assessment of a range of lightweighting strategies for compact vehicles
11	Sun et al.	2017	Life cycle assessment-based selection of a sustainable lightweight automotive engine hood design
12	Witik et el.	2011	Assessing the life cycle costs and environmental performance of lightweight materials in automobile applications
13	Zah et al.	2007	Curauá fibers in the automobile industry – a sustainability assessment

Analysed studies for developing a sustainability performance profile

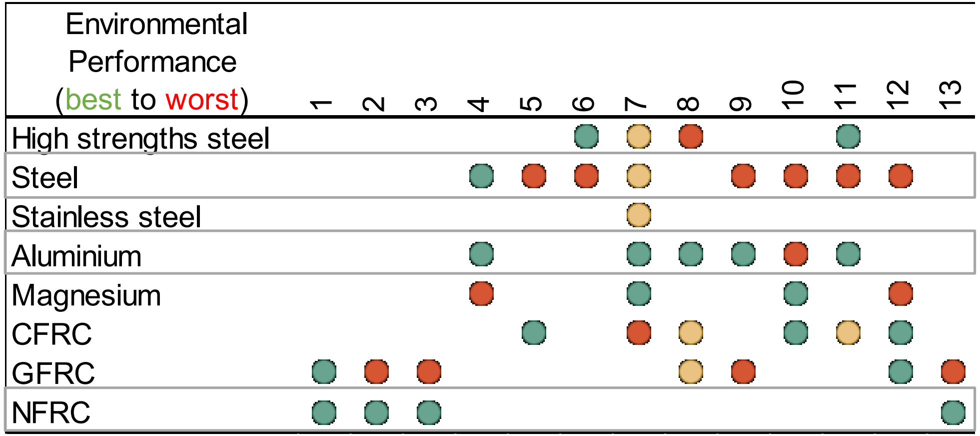
Results II

	Planet																	People							Profit
	CC	ED	EQ	R	NO	NMVOC	AC	OD	ET	PO	AP	EI 99	RMC	AC Air	WP	SW	WU	HH	HHC	HHNC	HTP	OH*	I*	IE*	C
Akhshik et al. 2017	x	x						x	x		x			x		x	x		x	x					x
Alves et al. 2010			x	x														x				x	x	x	x*
Boland et al. 2016	x	x																							
Dubreuil et al. 2012	x	x			x	x	x				x														
Duflou et al. 2009												x													
Hardwick et al. 2016	x	x				x			x					x											
Mayyas et al. 2012	x	x																							
Poulikidou et al. 2015	x	x																							
Puri et al. 2009	x	x					x	x		x			x		x	x									
Raugei et al. 2015	x	x					x														x				
Sun et al. 2017	x	x			x	x	x																		
Witik et el. 2011	x		x	x														x							x
Zah et al. 2007	x						x	x	x	x			x									x	x		x*

* indicators are not LCA results but from a qualitative content analysis of the literature

Planet	
CC	climate change
ED	energy demand / consumtption
EQ	ecosystem quality
R	resources
NO	nitrogen oxides
NMVOC	non-methane volatile organic compounds
AC	acidification / sulfur oxides
OD	ozone depletion / potential
ET	eutrophication / +potential / air / water
PO	photochemical oxidation / photo-oxidants creation potential
AP	air pollutants
EI 99	eco-indicator 99
RMC	raw material consumption
AC Air	acidification air
WP	water pollution
SW	solid waste
WU	Water use
People	
HH	human health
HHC	human health - cancer
HHNC	human health - non-cancer
HTP	human toxicity potential
OH	occupational health
I	income source local people
IE	industrial employment
Profit	
C	costs

Results III



Qualitative assessment of the environmental performance of materials considering all indicators chosen within a study

CFRC … Carbon fiber reinforced composite
GFRC … Glass fiber reinforced composite
NFRC … Natural fiber reinforced composite

Publication (Climate Change)

Material Assessed / Environmental Performance (best to worst)	1	3	4	6	7	8	9	10	11	12	13
High strengths steel				1	5	4			2		
Steel			2	2	4		3	3	4	3	
Stainless steel					2						
Aluminium			1		1	1	1	1	1		
Magnesium			3		3			4		4	
CFRC					6	2		2	3	2	
GFRC	2	2				3	2			1	2
NFRC	1	1									1

ranking of materials within studies

Publication (acidification)

Material Assessed / Environmental Performance (best to worst)	4	9	10	11	13
High strengths steel				1	
Steel	1	1	2	2	
Stainless steel					
Aluminium	2	2	1	3	
Magnesium	3		3		
CFRC			2	4	
GFRC		3			2
NFRC					1

Results IV

Material Assessed	Social Performance (best to worst)	1 (HHC)	1 (HHNC)	2 (HH	12 (HH)	10 (HTTP)	2 (OH)	13 (OH)	13 (I)	2 (I)	2 (IE)
		Publication (impact indicator)									
	High strengths steel										
	Stainless steel										
	Steel				2	2					
	Aluminium					3					
	Magnesium				4	1					
	CFRC				3						
	GFRC	1	2	2	1	2	2	2	2	2	1
	NFRC	2	1	1			1	1	1	1	2

ranking of materials within studies

Material Assessed	Economic Performance (best to worst)	1	12	13
		Publication		
	High strengths steel			
	Stainless steel			
	Steel		4	
	Aluminium			
	Magnesium		2	
	CFRC		3	
	GFRC	2	1	2
	NFRC	1		1

CFRC … Carbon fiber reinforced composite
GFRC … Glass fiber reinforced composite
NFRC … Natural fiber reinforced composite

Results V

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Sustainability performance of wood in comparison to steel and WPC (based on Petersen and Solberg, 2005)

Author	Year	Substitution	Object	CC	ED	EQ	R	NO	NMVOC	AC	OD	ET	PO	AP	EI 99	RMC	AC Air	WP	SW	WU	ES	HH	HHC	HHNC	HTP	OH*	I*	IE*	C
Morkved et al.	1990	Wood - Steel	frames, roof, walls		+																								
Engelbertsson	1997	Wood - Steel	beams																		+								
Kristensen	1999	Wood - Steel	warehouse frame	+						=		-	+												-				
Petersen et al.	2002bc	Glulam - Steel	beams	+																									
Bolin et al.	2011a	Wood - WPC	decking	+		+				+		+		+		+				+									
Bolin et al.	2011b	Wood - Steel	structural framing	+		+				+		+		+		+				+									
Bolin et al.	2011c	Wood - Steel	utility poles	+		+				+		+		-		+				+									

+ wood is better than the material it is compared with; - wood is worse than the material it is compared with; = wood is similar to the material it is compared with

DISCUSSION AND CONCLUSION

- **Lightweight materials are getting more important – High use phase impacts**
  - Steel performs worse than most compared materials (weight)
  - Aluminium has beneficial environmental performance
  - Social and economic aspects rarely considered
- **Natural fiber composites tend to perform better in all TBL dimensions**
- **No studies on the sustainability performance of wood within the automotive industry identified**

OUTLOOK

→ **Complement data on sustainability performance of wood-based materials/components**

- Interviews with experts from relevant industries
- Social impact analysis
- Life cycle assessment of wood-based components

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