

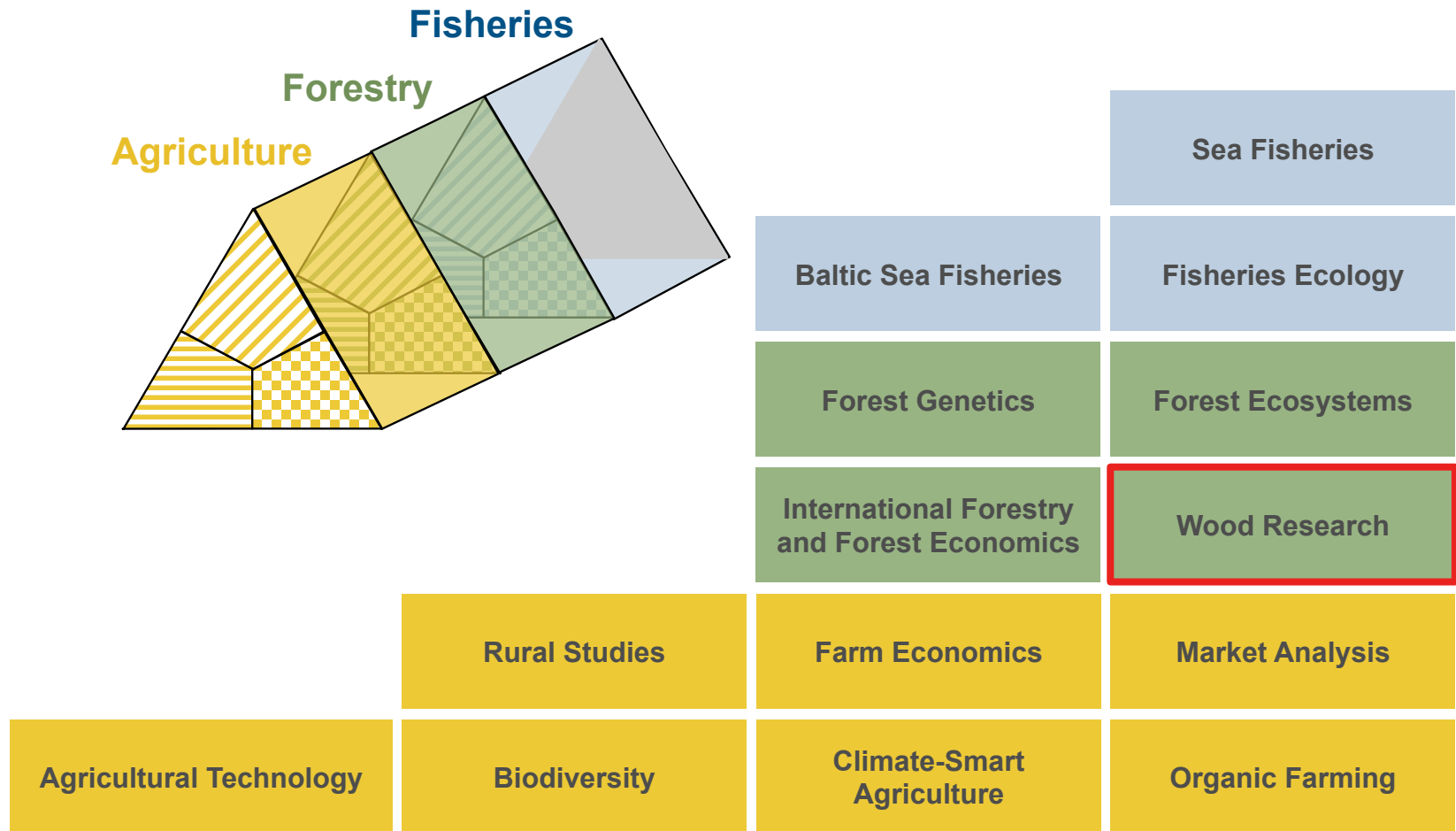
# Life cycle assessment of pre-fabricated timber houses according to the European state-of-the-art standards

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# Thünen Institute – Federal German Research Institute



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- **13 member companies of German Association of Pre-fabricated Houses (Bund Deutscher Fertigbau)**



# Aims of the study

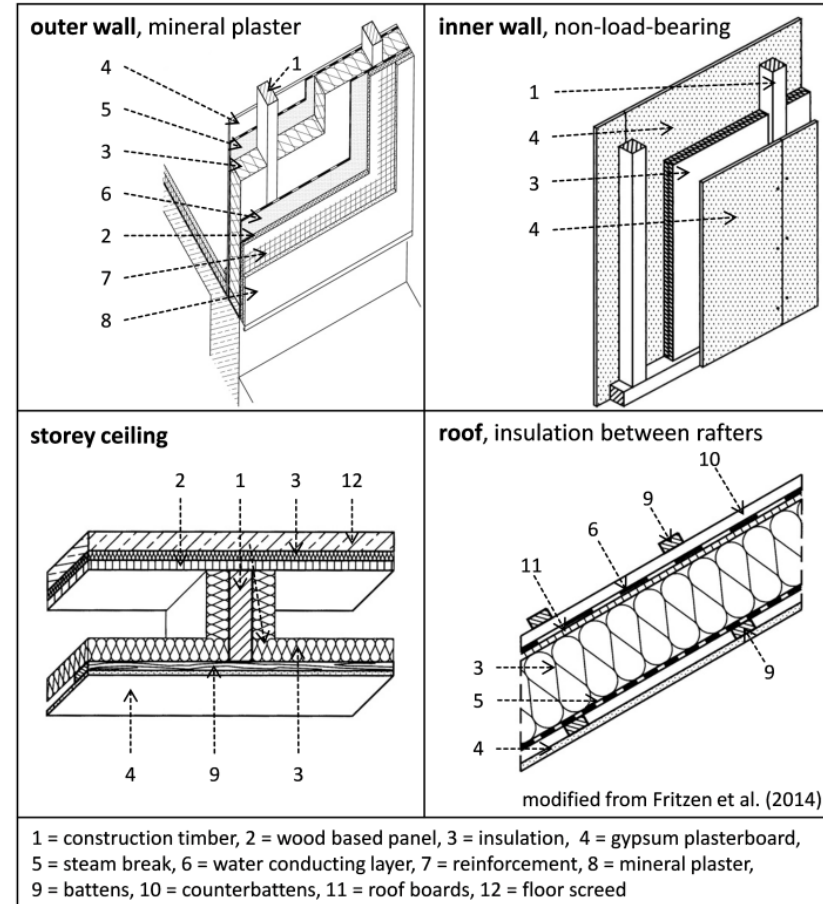
- **Provide average LCA data for the German sector**
- **Develop an LCA-model applicable to any company**

- **ISO 14040/44 (ISO 2006)**
- **EN 15804 (CEN 2013)**
- **EN 15978 (CEN 2012)**
- **EN 16485 (CEN 2014)**

# Functional units

- 1 m<sup>2</sup> outer wall
- 1 m<sup>2</sup> inner wall
- 1 m<sup>2</sup> roof element
- 1 m<sup>2</sup> ceiling element
- average house of project partners (141 m<sup>2</sup> net living area)

average  
of project  
partners



Achenbach et al. (in preparation)

- **Production data from project partners**
  - collected by a two step questionnaire-survey
  - yearly basis (required by EN 15804)
- **Plausibility check**

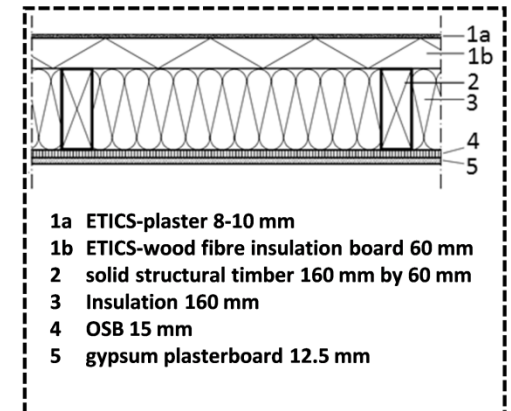
material input for house production 2009 (waste is to be deducted)		
construction materials	quantity	unit
construction timber	1967.5	m <sup>3</sup>
panels		
gypsum plasterboard	718.9	m <sup>3</sup>
oriented strand board (OSB)	1039	m <sup>3</sup>
insulation		
mineral wool	3590	m <sup>3</sup>
wood fibre insulation board	2167	m <sup>3</sup>

Result from primary data collection



**Production Output**  
produced surface area of prefabricated building units in 2009

Result from primary data collection



Design drawings from house manufacturers

## Wooden building products

**vTI**  
Johann Heinrich  
von Thünen-Institut  
**ARBEITSBERICHT**  
aus dem Institut für Holztechnologie und Holzbiologie  
Nr. 2012/1

### Solid wood and engineered wood - ÖKoHolzBaudat

- Rüter, S. & Diederichs 2012. Ökobilanz-Basisdaten für Bauprodukte aus Holz(ÖKoHolzBauDat) Abschlussbericht [LCA data for wooden building products. Final report]. Hamburg, Germany: Johann Heinrich von Thünen-Institut, Institut für Holztechnologie und Holzbiologie, in German.
- Diederichs, S. K. 2014a. 2010 status quo for life-cycle inventory and environmental impact assessment of wood-based panel products in Germany. Wood and Fiber Science 46(3): 1–16.
- Diederichs, S. K. 2014b. 2010 status quo for life-cycle inventory and environmental impact assessment of the core sawmill products in Germany. Wood and Fiber Science 46(1): 1–20.

Ökobilanz-Basisdaten  
für Bauprodukte aus Holz  
Sebastian Rüter, Stefan Diederichs

Zentrum Holzwirtschaft  
Universität Hamburg

### Wooden interior doors

- Wenker, J.L. , Achenbach, H., Diederichs, S., Rüter, S. 2015. Life cycle assessment of wooden interior doors in Germany - A sector representative approach for a complex wooden product according to EN 15804 methodology, DOI 10.1111/jiec.12296.

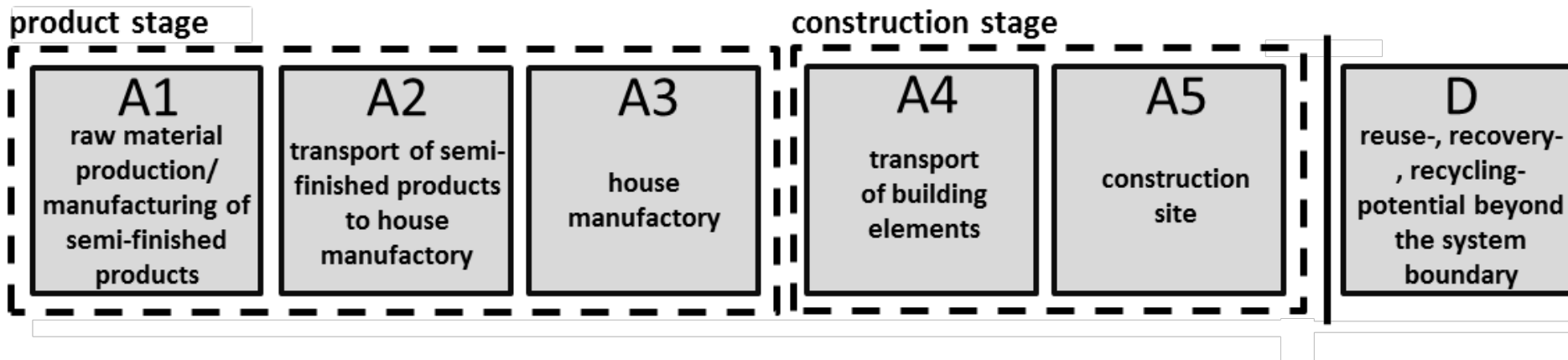


## Non-wood building products

- IBU EPD
- GaBi Professional
- ecoinvent

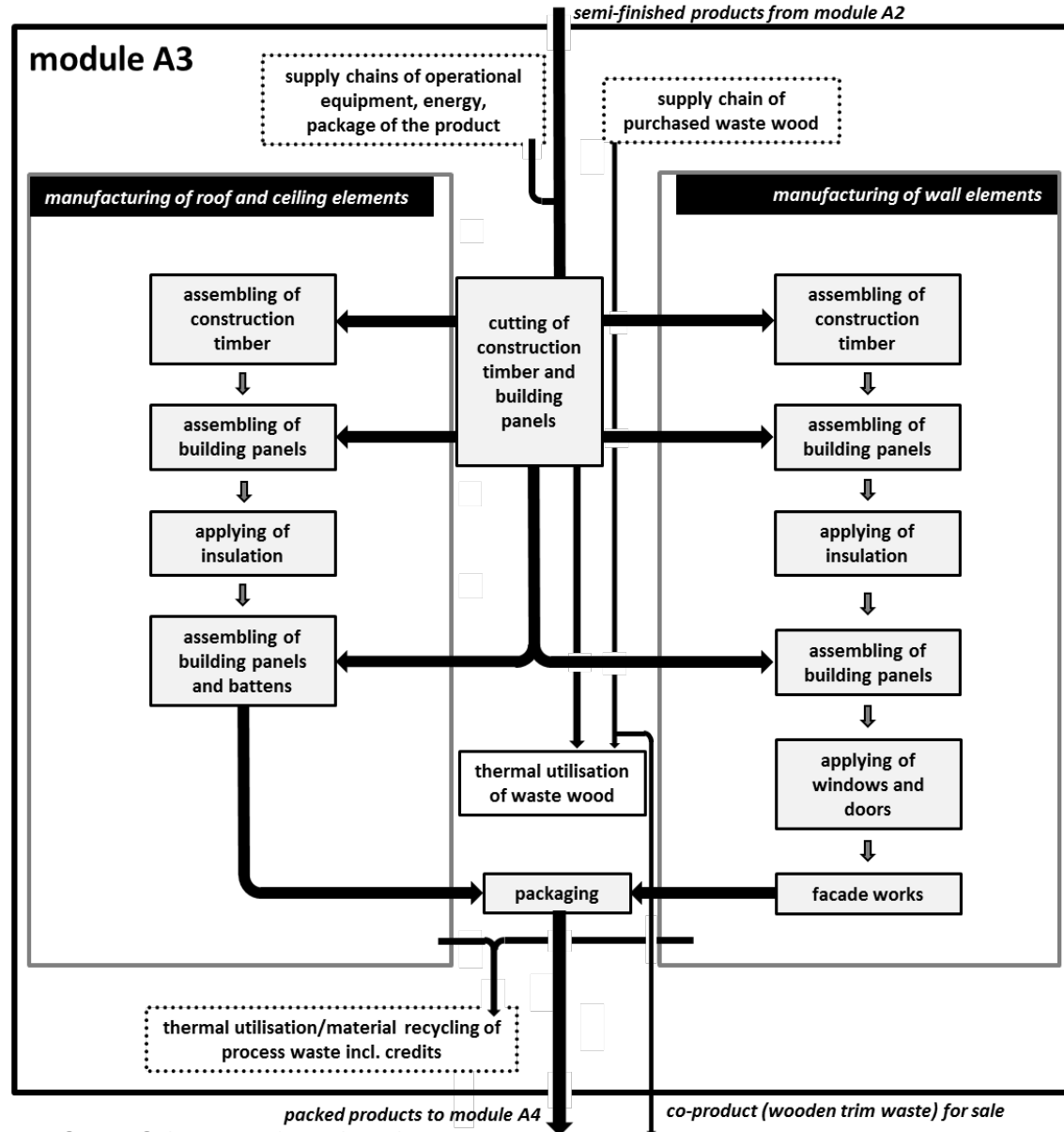
# System boundary

## Modules of product stage



# System boundary

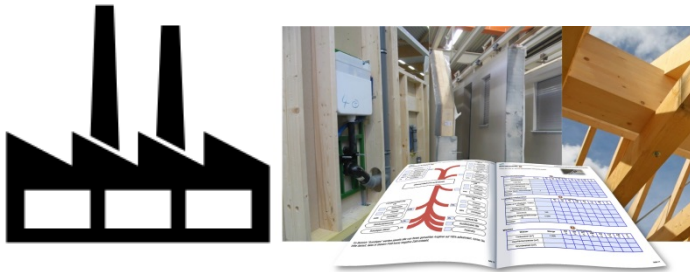
## Module A3



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# Allocation of material and energy

Data collected in house manufactory for a full year of production

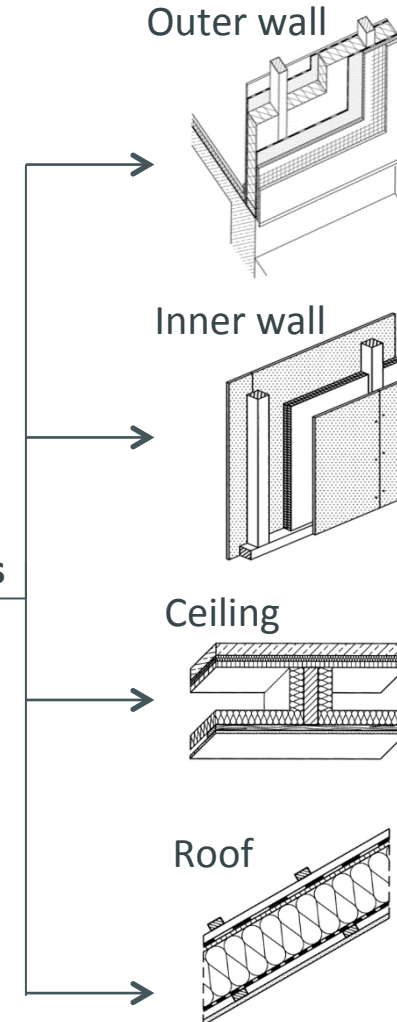


## Building materials

Solid wood, engineered wood, gypsum boards, etc.

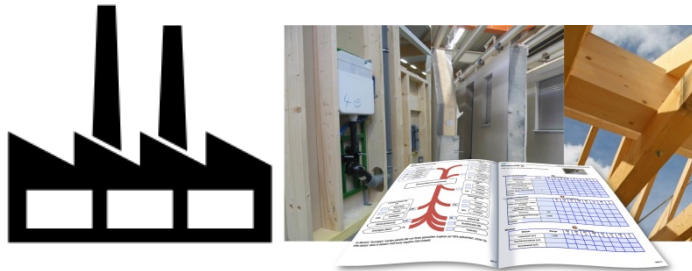
allocation done by house manufacturers

Production lines of building elements



# Allocation of material and energy

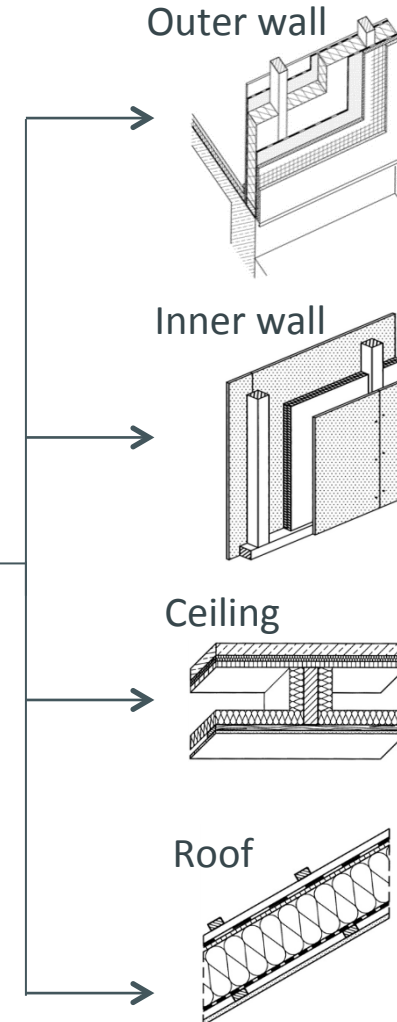
Data collected in house manufactory for a full year of production



**Electrical energy**

allocation done by  
production volume

Production lines of building elements



# Preliminary results

## Life Cycle Inventory of building elements Input

	Input				unit
	1 m <sup>2</sup> OW	1m <sup>2</sup> IW	1m <sup>2</sup> RE	1m <sup>2</sup> CE	
<b>Semi-finished building materials</b>					
Solid wood	22.15	11.42	20.80	19.98	kg
Engineered wood	13.65	15.90	1.81	15.89	kg
Gypsum boards	10.52	16.43	8.98	9.06	kg
Insulation materials	7.46	1.15	4.43	2.21	kg
Plaster	6.10	-	-	-	kg
Gas concrete	0.44	-	-	-	kg
Bricks and mortar	14.51	-	-	-	kg
Fastening materials	0.82	0.82	0.82	0.82	kg
Sealants	0.41	0.41	0.41	0.41	kg
Steam break / water conducting layer	0.26	-	0.47	-	kg
Laquer and paint	0.31	-	0.11	-	kg
<b>Energy demand</b>					
Electricity	27.42	27.42	27.42	27.42	MJ
From oil and gas	13.70	12.99	12.81	12.81	MJ
Wooden trim waste / purchased postconsumer waste wood for energy production	5.83	6.09	5.33	5.22	kg
Diesel for forklifts	0.07	0.07	0.07	0.07	kg
Diesel for crane on construction site (module A5)	0.17	0.17	0.17	0.17	kg
<b>Operational equipment</b>					
Oil, grease, cleaning supplies, sanding belts, etc.	0.01	0.01	0.01	0.01	kg
Fresh water	23.29	23.29	23.29	23.29	kg
Fresh water on construction site	1.26	1.26	1.26	1.26	kg
<b>Package of semi-finished products and operational equipment</b>					
PE foil	1.10	0.53	1.25	1.03	kg
Polystyrene	0.14	0.07	0.15	0.13	kg
Cardboard	0.25	0.12	0.28	0.23	kg
<b>Package for the transport of the building elements to construction site</b>					
PE foil	0.28	0.21	0.24	0.23	kg

# Preliminary results

## Life Cycle Inventory of building elements - *Output*

<b>Outputs</b>					
	<b>1m<sup>2</sup> OW</b>	<b>1m<sup>2</sup> IW</b>	<b>1m<sup>2</sup> RE</b>	<b>1m<sup>2</sup> CE</b>	<b>unit</b>
<b>Product</b>	<b>73.94</b>	<b>45.15</b>	<b>36.29</b>	<b>47.66</b>	<b>kg</b>
<b>Packaging</b>	<b>0.28</b>	<b>0.21</b>	<b>0.24</b>	<b>0.23</b>	
<b>Coproduct – wooden trim waste from pre-fabrication in house manufactory</b>	<b>0.61</b>	<b>0.47</b>	<b>0.39</b>	<b>0.61</b>	
<b>Emissions from thermal utilization of waste wood</b>	<b>calculated by background data</b>				
<b>Emissions from burning diesel, oil and natural gas</b>					
<b>Ashes from thermal utilization of waste wood</b>					
<b>Industrial waste</b>	<b>2.11</b>	<b>1.75</b>	<b>3.12</b>	<b>2.24</b>	

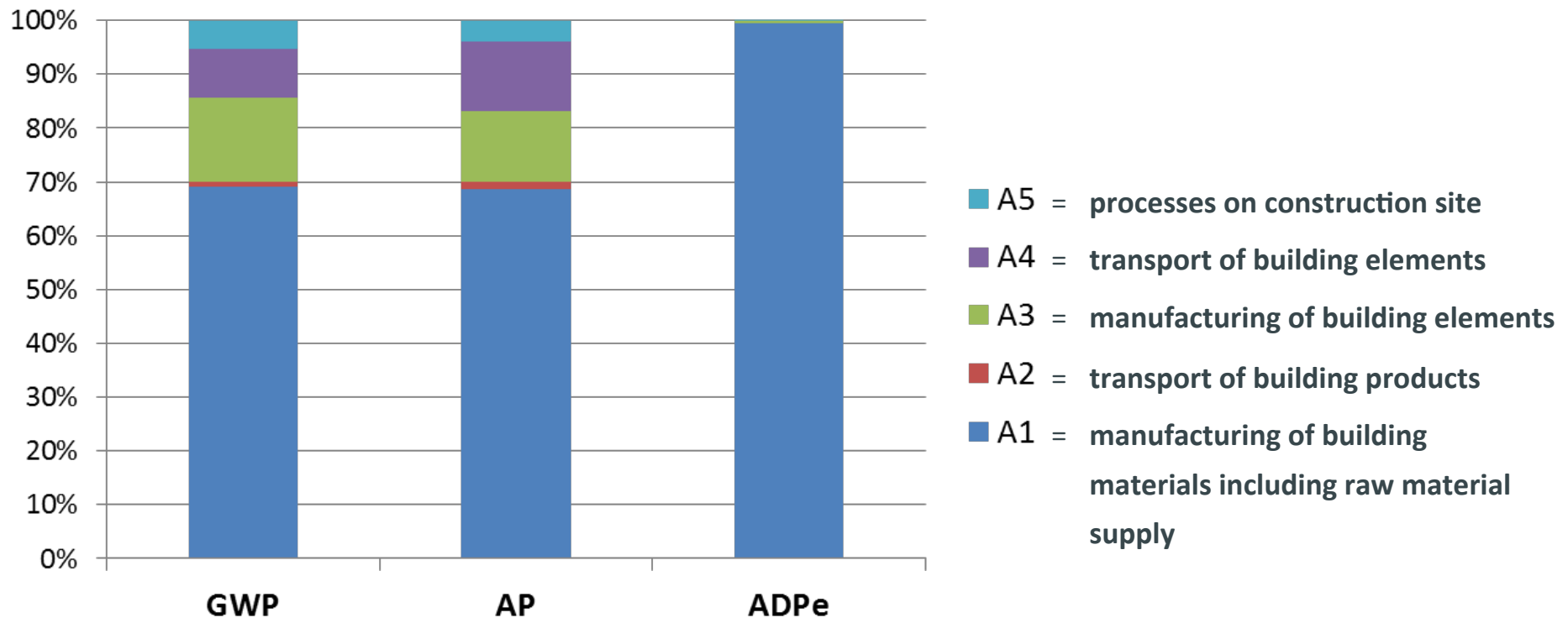
## Composition of the average house

Building element / product	quantity	unit
Outer Wall	181.32	m <sup>2</sup>
Inner Wall	115.09	m <sup>2</sup>
Roof	118.79	m <sup>2</sup>
Ceiling	137.83	m <sup>2</sup>
Floor screed	12.923	kg
Entry door	1	piece
Windows from plastic, wood and alumium	18	piece
Window boards from plastic, wood and alumium	257	kg
Interior doors from wood and wood panels	7	piece



# Preliminary results

## Dominance analysis of the average house (modular, GWP category without wood inherent carbon)



Achenbach et al. (in preparation)

## Transport distances

Transport distance	Share
Germany	89%
< 50 km	8%
50 - 200 km	19%
200 - 400 km	41%
> 400 km	21%
Europe	ca. 10%
others	ca. 1%

Achenbach et al. (in preparation)

**Average diesel demand for one building: 884 l**

# Preliminary results

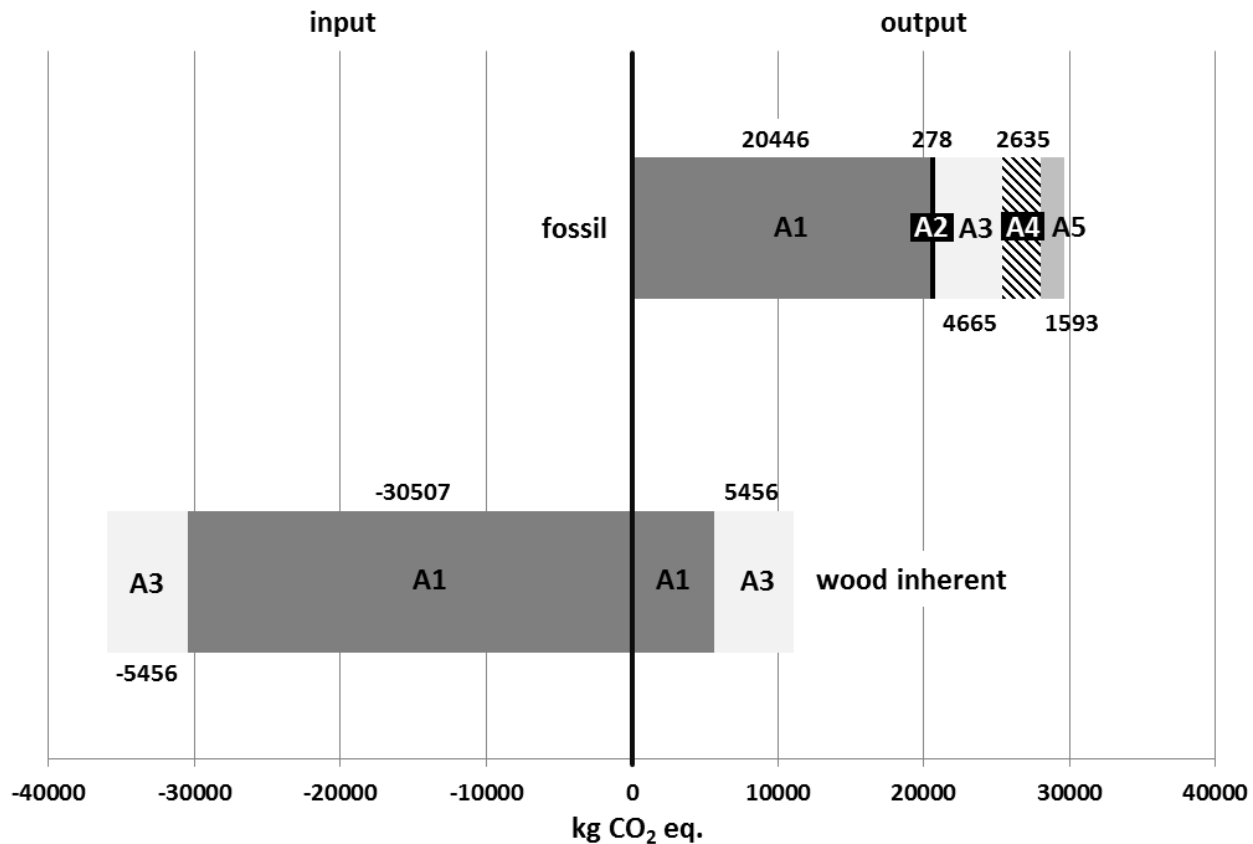
## Dominance analysis of the average house (modular, GWP category without wood inherent carbon)

<b>GWP</b> (kg CO <sub>2</sub> eq.)	<b>%</b>	<b>AP</b> (kg SO <sub>2</sub> eq.)	<b>%</b>	<b>ADPE</b> (kg Sb eq.)	<b>%</b>
Doors and windows (A1)	17.85	Doors and windows (A1)	22.19	Gypsum boards (A1)	33.21
Mortar and floor screed (A1)	9.84	Transport of building elements to construction site (A4)	12.97	Doors and windows (A1)	26.13
Insulation (A1)	8.97	Insulation (A1)	11.06	Fasteners (A1)	20.06
Wood based panels (A1)	8.97	Solid wood (A1)	10.63	Insulation (A1)	7.83
Transport of building elements to construction site (A4)	8.90	Burning wood in house manufactory (A3)	7.74	Mortar and floor screed (A1)	4.3
Electricity demand of pre-fabrication in house manufactory (A3)	7.90	Wood based panels (A1)	6.66	Plaster (A1)	3.97
Solid wood (A1)	6.18	Mortar and floor screed (A1)	4.45	others	4.50
Processes at construction site (A5)	5.38	Electricity demand of pre-fabrication in house manufactory (A3)	4.23	Achenbach et al. (in preparation)	
Polyurethane foam (A1)	4.48	Processes at construction site (A5)	3.93		
Gypsum boards (A1)	3.76	Fasteners (A1)	3.71		
Fasteners (A1)	3.61	others	12.43		
Production waste of house manufactory (A3)	3.6				
others	7.84				

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# Preliminary results

## Wood inherent carbon balance



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# System boundary

