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Complementary life cycle inventories for wood products

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1 Goal and scope

This report documents life cycle inventories for several wood product that update or complement the wood products contained in the UVEK datapool with the aim to include these datasets in the "KBOB-list" on life cycle data on construction products in Switzerland (KBOB 2016a).

The report covers the following life cycle inventories:

- cross-laminted timber, average glue mix, at plant/RER
- glued laminated timber, average glue mix, at plant/RER
- glued laminated timber, average glue mix, at plant/CH
- glued laminated timber, MUF adhesive, at plant/CH
- glued laminated timber, PUR adhesive, at plant/CH
- glued solid timber, average glue mix, at plant/RER
- glued solid timber, average glue mix, at plant/CH
- glued solid timber, MUF adhesive, at plant/CH
- glued solid timber, PUR adhesive, at plant/CH
- plywood, hardwood veneer, UF-bonded, at plant/RER
- structural timber, average glue mix, at plant/RER
- three- and five-layered board, at plant/RER
- tubular particleboard, at plant/RER
- gluing mill/CH I

The life cycle inventories are set up in line with the methodological requirements defined in KBOB (2015); the indicators declared include:

- eco-points according to the method of ecological scarcity (Bafu, 2013),
- greenhouse gas emissions (IPCC, 2013),
- cumulated energy demand, renewable(Frischknecht et al. 2007b),
- cumulated energy demand, non-renewable (Frischknecht et al. 2007b),
- cumulated energy demand, total (Frischknecht et al. 2007b).

Long-term emissions (> 100 years) have been included for the assessment according to the method of ecological scarcity.

2 Cross-laminated timber production/RER

2.1 Description of the product

Cross-laminated timber (CLT) is a wood panel product made from gluing layers of solid-sawn timber together. Each layer of boards is oriented perpendicular to adjacent layers and glued on the wide faces of each board, usually in a symmetric way so that the outer layers have the same orientation. An odd number of layers is most common, but there are configurations with even numbers as well (which are then arranged to give a symmetric configuration).

Regular timber is an anisotropic material, meaning that the physical properties change depending on the direction at which the force is applied. By gluing layers of wood at perpendicular angles, the panel is able to achieve better structural rigidity in both directions. It is similar to plywood but with distinctively thicker laminations.

CLT is distinct to glued laminated timber, a product with all laminations orientated in the same way.

The composition of the inventoried cross-laminated timber is displayed in Table 2-1.

Table 2-1: Composition of the inventoried cross-laminated timber

Composition	kg/m³	%
Wood [1)]	395.6	89.36%
of which carbon	*173.9*	*43.97%*
Water [1)]	39.6	8.94%
Melamine urea formaldehyde adhesive	3.983	0.90%
1 component PUR adhesive	3.382	0.764%
Polymer isocyanate emulsion adhesive	0.189	0.04%
Total	**442.7**	**100%**

[1)] wood and water content has been recalculated as the density of 490 kg/m³ reported in Rüter & Diederichs (2012) is considered to be too high for cross-laminated timber made from current softwood species such as spruce and fir (see Sell 1997) and given the usually grading strength C16/C24. For the recalculation of the wood and water content, an average oven-dry density of converted with a basic wood density of 430 kg dry/m3 wet kg/m³ and a moisture content of u = 10 % is assumed (whereas in practice, wood is kiln dried to u = 12 %). Considering the resulting shrinkage in volume of about 8 %, this leads to a re-calculated basic wood density (kg oven-dry matter/m³ wet volume) of 396 kg/m³.

Synonyms, German name: Brettsperrholz

2.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German cross-laminated timber production covering about 84.9% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF-, MUF or PF-adhesive and 0.05 kg of acetone emissions/kg of PUR-adhesive.

2.3 Description of the unit process

Table 2-2 lists the inputs and outputs as a gate-to-gate inventory for the production of cross-laminated timber. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies:

a) a different level of processing of the woody raw material per production site
b) different adhesives per production site

Table 2-2: Life cycle inventory (gate-to-gate) for the production of cross-laminated timber/RER

Inputs	Quantity	Unit
Wooden raw materials		
Softwood, under bark	0.633	m³
Sawn timber, kiln dried	0.955	m³
Electricity	101.8	kWh
Fuels		
others (also vegetable oils)	1.167	MJ
Residual wood, internal sources	811.3	MJ
Bark, internal sources	33.5	MJ
Ancillary materials		
Diesel	1.809	kg
	77.4	*MJ*
Lubricants, machines	0.333	kg
Cutting materials	0.017	kg
Cleaning agents	0.016	kg
Tyres	0.061	kg
Drinking water	88.99	kg
Surface water	25.5	kg
Lubricants, motors	0.025	kg
Adhesives		
Melamine urea formaldehyde	3.983	kg
Polyurethane	3.382	kg
Emulsion polymer isocyanate	0.189	kg
Outputs	**Quantity**	**Unit**
Products		
Cross-laminated timber	1	m³
Co-products (shavings and wood chips)	0.588	m³
Bark from roundwood input (12 %)	0.0863	m³
Airborne emissions		
Formaldehyde from adhesive	0.0059745	kg
Acetone from adhesive	0.1691	kg
Others		
Wastes	0.435	kg
Waste water/partly as emissions into air	114.5	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 2-3: Input/0utput table of woody resources for the production of cross-laminated timber/RER

INPUTS		
Softwood, under bark	0.633	m³
Sawn timber, kiln dried	0.955	m³
OUTPUTS		
Cross-laminated timber	1	m³
	395.6	*kg*
Co-products (shavings, wood chips and bark)	282.3	kg
of which used energetically	*44.0*	*kg*
of which sold externally	*238.3*	*kg*
USE AS WOOD FUEL		
Residual wood, internal sources	811.3	MJ
converted with 19.217 MJ/kg LHV	*42.2*	*kg*
Bark, internal sources	33.6	MJ
converted with 19.217 MJ/kg LHV	*1.7*	*kg*
Sum: fuel wood from external sources	*0.0*	*MJ*
	0.0	*kg*
Sum: fuel wood from internal sources	*844.9*	*MJ*
	44.0	*kg*

Table 2-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of cross-laminated timber.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infra-structure.

2.4 Modelling of the unit process

The dataset is modelled as follows (Table 2-4:

Table 2-4: Modelling of the production process of cross-laminated timber, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Cross-laminted timber, average glue mix, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	25.5*allocation_factor	23.5	kg	
Materials/fuels				
sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	0.633*allocation_factor	0.583	m^3	
sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	0.955*allocation_factor	0.88	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	101.8*allocation_factor	93.8	kWh	
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	(811+33.5+1.167)*allocation_factor	779	MJ	
diesel, burned in building machine, with particle filter/CH	77.4*allocation_factor	71.3	MJ	
Lubricating oil, at plant/RER	(0.333+0.025)*allocation_factor	0.33	kg	
Steel, low-alloyed, at plant/RER	0.017*allocation_factor	0.0157	kg	
Steel product manufacturing, average metal working/RER	0.017*allocation_factor	0.0157	kg	
Soap, at plant/RER	0.016*allocation_factor	0.0147	kg	
Synthetic rubber, at plant/RER	0.061*allocation_factor	0.0562	kg	
tap water, at user/kg/RER	89.0*allocation_factor	82	kg	
Melamine, at plant/RER	MUF*0.235*allocation_factor	0.862	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	0.738	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	1.23	kg	33.4% of MUF system according to Rüter & Diederichs
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0156	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & D.
Polyurethane, rigid foam, at plant/RER	PUR*allocation_factor	3.12	kg	
Methylene diphenyl diisocyanate, at plant/RER	EPI*0.85*allocation_factor	0.148	kg	
Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER	EPI*0.15*allocation_factor	0.0261	kg	

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Transport, lorry >16t, fleet average/RER	(0.633*800*1.12*100+0.017*100+(0.333+0.025+0.016+0.061+MUF*1.02+PUR+EPI)*100)/1000*allocation_factor	53	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, freight, rail/RER	(0.633*800*1.12*0+0.017*200+(0.333+0.025+0.016+0.061+MUF*1.02+PUR+EPI)*600)/1000*allocation_factor	4.46	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.435+0.061+0.333)*10/1000*allocation_factor	0.00764	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for GLULAM
Emissions to air				
Formaldehyde	0.00597*allocation_factor	0.00555	kg	based on Rüter & Diederichs (2012)
Acetone	0.1691*allocation_factor	0.156	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	0.435*allocation_factor	0.401	kg	
Recycling steel and iron/RER	0.017*allocation_factor	0.0157	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.061*allocation_factor	0.0562	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	(0.333+0.025)/(1-0.1)*allocation_factor	0.366	kg	
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.114*allocation_factor	0.105	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		238.3	kg oven-dry	
p_chips		0.107	Euro2005	
MUF		3.983	kg/m^3	
PUR		3.382	kg/m^3	
EPI		0.189	kg/m^3	
Calculated parameters				
allocation_factor	(v_main_product*p_main_product)/(v_main_product* p_main_product+m_chips*p_chips)	0.921		

2.5 Results

In Tables 2-5 to 2-7 the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 2-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Cross-laminted timber, average glue mix, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**2881**	**6.50**
	kWh	**800**	**1.81**
CED renewable	**MJ**	**14548**	**32.8**
	kWh	**4041**	**9.12**
CED total	**MJ**	**17428**	**39.3**
	kWh	**4841**	**10.9**
Weight			*443*

Table 2-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Cross-laminted timber, average glue mix, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	221	0.50
Energy resources	25851	58.35
Mineral resources	4802	10.84
Land use	102819	232.10
Global warming	70905	160.06
Ozone layer depletion	86	0.20
Main air pollutants and PM	68238	154.04
Carcinogenic substances into air	9239	20.85
Heavy metals into air	10619	23.97
Water pollutants	6187	13.97
POP into water	1523	3.44
Heavy metals into water	8975	20.26
Pesticides into soil	217	0.49
Heavy metals into soil	1827	4.12
Radioactive substances into air	0	0
Radioactive substances into water	650	1.47
Noise	5048	11.40
Non radioactive waste to deposit	284	0.64
Radioactive waste to deposit	20460	46.18
Sum	**337951**	**762.9**
Weight		*443*

Table 2-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Cross-laminted timber, average glue mix, at plant/RER	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**155**	**0.350**
Weight		*443*

2.6 Interpretation

Table 2-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 2-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	sawnwood, board, soft-wood, dried (u=10%), planed, at sawmill/m3/RER	electricity, me-dium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in fur-nace 300kW/CH ohne Holzin-put	diesel, burned in building ma-chine, with particle fil-ter/CH	Polyurethane, rigid foam, at plant/RER	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	1.8%	4.0%	0.9%	0.0%	0.1%	0.3%	0.1%	0.3%
Mineral resources	0.2%	0.9%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Land use	8.1%	22.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Global warming	0.8%	8.2%	6.3%	0.2%	1.0%	1.8%	0.9%	1.8%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.7%	10.9%	2.1%	2.5%	0.5%	1.0%	0.9%	1.7%
Carcinogenic substances into air	0.0%	1.4%	0.2%	0.8%	0.0%	0.0%	0.1%	0.2%
Heavy metals into air	0.1%	1.5%	0.3%	0.6%	0.0%	0.1%	0.1%	0.4%
Water pollutants	0.2%	0.8%	0.1%	0.0%	0.1%	0.3%	0.2%	0.2%
POP into water	0.0%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%
Heavy metals into water	0.1%	1.0%	0.2%	0.0%	0.1%	0.7%	0.2%	0.3%
Pesticides into soil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Noise	0.0%	0.6%	0.0%	0.0%	0.4%	0.0%	0.4%	0.1%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	0.0%	2.2%	3.3%	0.2%	0.0%	0.1%	0.0%	0.1%
Sum	**12.2%**	**54.4%**	**13.7%**	**4.7%**	**2.4%**	**4.3%**	**3.0%**	**5.4%**

3 Glued laminated timber production, average glue mix/Europe without Switzerland

3.1 Description of the product

Glued laminated timber, also called glulam, is a type of structural engineered wood product comprising a number of layers of dimensional sawn timber bonded together with durable, moisture-resistant structural adhesives.

Glued laminated timber (glulam) according to EN 14080 is manufactured from bonded lamellae with parallel fibre orientation. There are at least two lamellae with thicknesses from 6 to 45 mm. The timber is planed and classified into strength classes by visual or machine grading. The adhesive used to bond the lamellae has to fulfil the requirements for loadbearing structural timber components. The suitability of the wood species in glulam construction has to concur with EN 14080. Spruce, fin, pine and larch are most commonly used. One can distinguish between homogenous (all lamellae across a beam's cross-section belong to one strength class) and combined (outer and inner lamellae belong to different strength classes) glued laminated timber. For each of these two configurations EN 14080 defines seven different types of strength classes.

Glued laminated timber is particularly suited for components bearing high stresses or spanning large distances that have to satisfy stringent requirements with respect to dimensional stability and appearance. Straight as well as curved beams can be manufactured.

By laminating a number of smaller pieces of sawn timber, a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns or horizontal beams (standard forms), as well as curved, arched shapes (special forms). Glulam is readily produced in curved shapes and is available in a range of species and appearance characteristics to meet varied end-use requirements. Connections are usually made with bolts or plain steel dowels and steel plates.

Glulam optimizes the structural values of wood, which is a renewable resource. Because of their composition, large glulam members can be manufactured from a variety of smaller trees harvested from second-growth forests and plantations. Glulam provides the strength and versatility of large wood members without relying on the old growth-dependent solid-sawn timbers. As with other engineered wood products, it reduces the overall amount of wood used when compared to solid sawn timbers by diminishing the negative impact of knots and other small defects in each component board.

The high strength and stiffness of laminated timbers enable glulam beams and arches to span large distances without intermediate columns, allowing more design flexibility than with traditional timber construction. The size is limited only by transportation and handling constraints.

The CE-certification of this product according to the harmonized standard EN 14080 has been compulsory for the European market since 08.08.2015.

The composition of the inventoried glued laminated timber production, average glue mix/Europe without Switzerland is displayed in Table 3-1.

Table 3-1: Composition of the inventoried glued laminated timber production, average glue mix/Europe without Switzerland

Composition	kg/m³	%
Wood [1)]	395.6	89.11%
of which carbon	*173.5*	*43.87%*
Water [1)]	39.6	9%
Melamine urea formaldehyde adhesive	8.22	1.85%
Phenol resorcinol adhesive	0.29	0.07%
1 component PUR adhesive	0.29	0.07%
Polymer isocyanate emulsion adhesive	0.001	0.00%
Total	**444.0**	**100%**

[1)] wood and water content has been recalculated as the density of 507 kg/m³ reported in Rüter & Diederichs (2012) is considered to be too high for glued laminated timber made from current softwood species such as spruce and fir (see Sell 1997) and given the usually grading strength C16/C24. For the recalculation of the wood and water content, an average oven-dry density of converted with a basic wood density of 430 kg dry/m3 wet kg/m³ and a moisture content of u = 10 % is assumed (whereas in practice, wood is kiln dried to u = 12 %). Considering the resulting shrinkage in volume of about 8 %, this leads to a re-calculated basic wood density (kg oven-dry matter/m³ wet volume) of 396 kg/m³.

Synonyms, German name: Brettschichtholz (Standardträger)

3.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German glued laminated timber production, standard forms, average glue mix production, covering about 89.6% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF-, MUF or PF-adhesive and 0.05 kg of acetone emissions/kg of PUR-adhesive.

3.3 Description of the unit process

Table 3-2 lists the inputs and outputs as a gate-to-gate inventory for the production of glued laminated timber, standard forms. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies:

a) a different level of processing of the woody raw material per production site
b) different adhesives per production site

Table 3-2: Life cycle inventory (gate-to-gate) for the production of glued laminated timber, standard forms/Europe without Switzerland

Inputs	Quantity	Unit
Wooden raw materials		
Softwood, under bark	0.306	m³
Sawn timber, undried	0.659	m³
Sawn timber, kiln dried	0.438	m³
Electricity	88.6	kWh
Fuels		
Natural gas	6.663	MJ
Light fuel oil	19.4	MJ
others (also vegetable oils)	95.0	MJ
Post-consumer wood	19.8	MJ
Residual wood, external sources	58.2	MJ
Residual wood, internal sources	1178.1	MJ
Bark, internal sources	50.4	MJ
Ancillary materials		
Diesel	1.105	kg
	47.3	*MJ*
Lubricants, machines	0.069	kg
Cutting materials (metals)	0.018	kg
Cleaning agents	0.027	kg
Tyres	0.134	kg
Drinking water	0.024	kg
Surface water	34.567	kg
Lubricants, motors	0.033	kg
Adhesives		
Melamine urea formaldehyde	8.722	kg
Phenol resorcinol formaldehyde	0.325	kg
Polyurethane	0.415	kg
Emulsion polymer isocyanate	0.001	kg
Outputs	**Quantity**	**Unit**
Products		
Glued laminated timber, average glue mix, standard forms	1	m³
Co-products (shavings and wood chips)	0.403	m³
Bark from roundwood input (12 %)	0.0417	m³
Airborne emissions		
Formaldehyde from adhesive	0.0131	kg
Acetone from adhesive	0.0208	kg
Others		
Wastes	0.28	kg
Waste water/partly as emissions into air	34.6	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 3-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of glued laminated timber, standard forms.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infra-structure.

Table 3-3: Input/0utput table of woody resources for the production of glued laminated timber, standard forms/Europe without Switzerland

INPUTS		
Softwood, under bark	0.306	m^3
Sawn timber, undried	0.659	m^3
Sawn timber, kiln dried	0.438	m^3
OUTPUTS		
Glued laminated timber, average glue mix, standard forms	1	m^3
	395.6	*kg*
Co-products (shavings, wood chips and bark)	181.4	kg
of which used energetically	*63.9*	*kg*
of which sold externally	*117.5*	*kg*
USE AS WOOD FUEL		
Post-consumer wood	19.8	MJ
converted with 19.217 MJ/kg LHV	*1.03*	*kg*
Residual wood, external sources	58.2	MJ
converted with 19.217 MJ/kg LHV	*3.0*	*kg*
Residual wood, internal sources	1178.1	MJ
converted with 19.217 MJ/kg LHV	*61.3*	*kg*
Bark, internal sources	50.4	MJ
converted with 19.217 MJ/kg LHV	*2.6*	*kg*
Sum: fuel wood from external sources	*78.0*	*MJ*
	4.1	*kg*
Sum: fuel wood from internal sources	*1228.5*	*MJ*
	63.9	*kg*

3.4 Modelling of the unit process

The dataset is modelled as follows (Table 3-4):

Table 3-4: Modelling of the production process of glued laminated timber, average glue mix, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, average glue mix, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	34.6*allocation_factor	33.2	kg	
Materials/fuels				
sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	0.306*allocation_factor	0.294	m^3	
sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	0.659*allocation_factor	0.632	m^3	
sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	0.438*allocation_factor	0.42	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	88.6*allocation_factor	85	kWh	
Natural gas, burned in boiler condensing modulating >100kW/RER	6.663*allocation_factor	6.39	MJ	
Light fuel oil, burned in industrial furnace 1MW, non-modulating/RER	19.4*allocation_factor	18.6	MJ	
Wood chips, post-consumer wood, burned in furnace 1000kW/CH	(19.8+95.0)*allocation_factor	110	MJ	inkl. "others (also vegetable oils)"
Wood chips, from industry, softwood, burned in furnace 300kW/CH	58.2*allocation_factor	55.8	MJ	
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	(1178.1+50.4)*allocation_factor	1180	MJ	
diesel, burned in building machine, with particle filter/CH	47.3*allocation_factor	45.4	MJ	
Lubricating oil, at plant/RER	(0.069+0.033)*allocation_factor	0.0979	kg	
Steel, low-alloyed, at plant/RER	0.018*allocation_factor	0.0173	kg	
Steel product manufacturing, average metal working/RER	0.018*allocation_factor	0.0173	kg	
Soap, at plant/RER	0.027*allocation_factor	0.0259	kg	
Synthetic rubber, at plant/RER	0.0134*allocation_factor	0.0129	kg	
tap water, at user/kg/RER	0.024*allocation_factor	0.023	kg	
Melamine, at plant/RER	MUF*0.235*allocation_factor	1.97	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	1.68	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	2.8	kg	33.4% of MUF system; according to Rüter & Diederichs
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0355	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Phenol, at plant/RER	PRF*0.536*allocation_factor	0.167	kg	
Benzene, at plant/RER	PRF*0.157*allocation_factor	0.049	kg	Proxy for resorcinol, i.e. dihydroxy-benzene
Formaldehyde, production mix, at plant/RER	PRF*0.308*allocation_factor	0.096	kg	
Polyurethane, rigid foam, at plant/RER	PUR*allocation_factor	0.398	kg	
Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER	EPI*0.85*allocation_factor	0.000816	kg	2-Komponentenklebstoffe, bei denen SBR-Klebstoffe (i.e. Kunstkautschuk, StyrolButadien-Rubber), PVAc-Kleber (Polyvinyacetat) und EVA-Klebstoffe (Ethylenvinylacetat): Proxy als worst case für SBR for 85%
Methylene diphenyl diisocyanate, at plant/RER	EPI*0.15*allocation_factor	0.000144	kg	Isocyanyde hardener as 15%
Transport, lorry >16t, fleet average/RER	(0.306*800*1.12*100+(19.8+95.0)/19.4*100+0.018*100+(0.069+0.033+0.027+0.0134+MUF*1.02+PUR+EPI+PRF)*100)/1000*allocation_factor	27.8	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, freight, rail/RER	(0.306*800*1.12*0+(19.8+95.0)/19.4*0+0.018*200+(0.069+0.033+0.027+0.0134+MUF*1.02+PUR+EPI+PRF)*600)/1000*allocation_factor	5.63	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.28+0.134+0.069+0.033)*10/1000*allocation_factor	0.00495	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for GLULAM
Emissions to air				
Formaldehyde	0.0131*allocation_factor	0.0126	kg	based on Rüter & Diederichs (2012)
Acetone	0.0208*allocation_factor	0.02	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	0.280*allocation_factor	0.269	kg	
Recycling steel and iron/RER	0.018*allocation_factor	0.0173	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.134*allocation_factor	0.129	kg	

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	(0.069+0.033)/(1-0.1)*allocation_factor	0.109	kg	
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.0346*allocation_factor	0.0332	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		117.5	kg oven-dry	
p_chips		0.107	Euro2005	
MUF		8.722	kg/m^3	
PRF		0.325	kg/m^3	
PUR		0.415	kg/m^3	
EPI		0.001	kg/m^3	
Calculated parameters				
allocation_factor	(v_main_product*p_main_product)/(v_main_product*p_main_product+m_chips*p_chips)	0.960		

3.5 Results

In Tables 3-5 to 3-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 3-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued laminated timber, average glue mix, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**2515**	**5.66**
	kWh	**699**	**1.57**
CED renewable	**MJ**	**12677**	**28.6**
	kWh	**3521**	**7.93**
CED total	**MJ**	**15191**	**34.2**
	kWh	**4220**	**9.50**
Weight			*444*

Table 3-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued laminated timber, average glue mix, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	162	0.36
Energy resources	22537	50.76
Mineral resources	4306	9.70
Land use	96772	217.96
Global warming	61589	138.71
Ozone layer depletion	49	0.11
Main air pollutants and PM	57769	130.11
Carcinogenic substances into air	9293	20.93
Heavy metals into air	10794	24.31
Water pollutants	5222	11.76
POP into water	1401	3.16
Heavy metals into water	6349	14.30
Pesticides into soil	214	0.48
Heavy metals into soil	2537	5.71
Radioactive substances into air	0	0
Radioactive substances into water	564	1.27
Noise	4104	9.24
Non radioactive waste to deposit	210	0.47
Radioactive waste to deposit	17851	40.21
Sum	**301723**	**679.6**
Weight		*444*

Table 3-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Glued laminated timber, average glue mix, at plant/RER	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**135**	**0.303**
Weight		*444*

3.6 Interpretation

Table 3-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 3-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	Melamine, at plant/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	1.0%	2.4%	2.1%	1.0%	0.1%	0.2%	0.6%
Mineral resources	0.1%	0.5%	0.5%	0.0%	0.0%	0.0%	0.2%
Land use	4.6%	15.5%	11.9%	0.0%	0.0%	0.0%	0.1%
Global warming	0.4%	3.6%	4.4%	6.4%	0.3%	1.5%	3.9%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.4%	2.8%	5.8%	2.1%	4.2%	0.8%	2.9%
Carcinogenic substances into air	0.0%	0.2%	0.8%	0.2%	1.3%	0.0%	0.5%
Heavy metals into air	0.0%	0.3%	0.8%	0.3%	1.1%	0.3%	0.7%
Water pollutants	0.1%	0.5%	0.4%	0.1%	0.0%	0.1%	0.4%
POP into water	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%
Heavy metals into water	0.1%	0.5%	0.5%	0.2%	0.0%	0.1%	0.6%
Pesticides into soil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.1%	0.1%	0.0%	0.6%	0.0%	0.1%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Noise	0.0%	0.4%	0.3%	0.0%	0.0%	0.0%	0.6%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	0.0%	0.6%	1.2%	3.4%	0.3%	0.1%	0.3%
Sum	**6.9%**	**27.6%**	**29.1%**	**13.9%**	**8.0%**	**3.4%**	**11.1%**

4 Glued laminated timber production, MUF-glue/CH

4.1 Description of the product

Glued laminated timber, also called glulam, is a type of structural engineered wood product comprising a number of layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives, in this case melamine urea formaldehyde adhesive.

By laminating a number of smaller pieces of sawn timber, a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns or horizontal beams, as well as curved, arched shapes. Glulam is readily produced in curved shapes and is available in a range of species and appearance characteristics to meet varied end-use requirements. Connections are usually made with bolts or plain steel dowels and steel plates.

Glulam optimizes the structural values of wood, which is a renewable resource. Because of their composition, large glulam members can be manufactured from a variety of smaller trees harvested from second-growth forests and plantations. Glulam provides the strength and versatility of large wood members without relying on the old growth-dependent solid-sawn timbers. As with other engineered wood products, it reduces the overall amount of wood used when compared to solid sawn timbers by diminishing the negative impact of knots and other small defects in each component board.

The high strength and stiffness of laminated timbers enable glulam beams and arches to span large distances without intermediate columns, allowing more design flexibility than with traditional timber construction. The size is limited only by transportation and handling constraints.

The composition of the inventoried glued laminated timber production, MUF-glue/CH is displayed in Table 4-1.

Table 4-1: Composition of the inventoried glued laminated timber production, MUF-glue/CH

Composition	kg/m^3	%
Wood [1)]	395.6	89.25%
of which carbon	*173.5*	*39.14%*
Water [1)]	39.6	8.93%
Melamine urea formaldehyde adhesive	8.08	1.82%
Total	**443.2**	**100%**

Synonyms, German name: Glulam, Brettschichtholz

4.2 Sampling and representativeness

Data on the production process was compiled by Holzindustrie Schweiz[1] and covers the data of 4 Glulam producers using MDF adhesive in Switzerland with production volumes between 1'700 m^3 and 19'000 m^3 in 2017, with a median value of 7'500 m^3.

The system boundary of the unit process starts at the entry of planed and dried sawn timber into the gluing plant and ends with the final Glulam at the factory gate. The unit process includes the following process steps:

1. Pre-sorting of lamellas
2. Finger-jointing
3. Plaining of lamellas
4. Gluing
5. Planing of final product

As for the sawmilling and plaining processes inventoried in ecoinvent 3, the chipping of the cuttings from finger-jointing and its transport to the chips bunker as well as the suction of the shavings to the shavings bunker are allocated to the wood chips and the shavings at the bunker.

Acetone emissions are estimated based on Rüter & Diederichs, assuming 0.0015 kg formaldehyde/kg MUF used.

4.3 Description of the unit process

Table 4-2 describes the unallocated unit process for the production of Glulam with melamine-urea-formaldehyde adhesive in Switzerland.

The production volume of Glulam with MUF adhesive is taken from the ecoinvent 3 dataset for "glued laminated timber production, indoor use/CH". The production volumes of the by-products are calculated from the amount of the by-product/m^3 of reference product times the production volume of the reference product.

4.4 Modelling of the unit process

The dataset is modelled as follows (Table 4-3):

[1] Urs Luginbühl/HIS, personal electronic communication, 29.1.2020

Table 4-2: Unit process for the production of glued laminated timber with MUF adhesive in Switzerland (source: sampling by Holzindustrie Schweiz, personal communication, 3.2.2019)

Compartment	Unit process	Unit	Amount	Comment
Reference Product	glued laminated timber, average glue mix	m^3	1	
By-product	residual wood, dry	m^3	0.105	cuttings, etc. ; sent to internal chipping
By-product	shavings, softwood, loose, measured as dry mass	kg	88.5	shavings from the 2 planing steps
From technosphere	sawnwood, board, softwood, raw, dried (u=10%)	m^3	1.310	Raw material input
From technosphere	melamine formaldehyde resin	kg	8.09	Average glue input
From technosphere	electricity, medium voltage	kWh	24.8	plant data, including 2 planing steps, gluing
From technosphere	diesel, burned in building machine	MJ	10.6	Diesel consumption for internal transport
From technosphere	gluing plant	unit	1.70E-06	Estimate for infrastructure
To Environment	Formaldehyde	kg	0.0121	Formaldehyde emissions from MUF glues: 0.0015 kg/kg MUF (Rüter & Diederichs 2012)
From technosphere	lubricating oil	kg	0.102	value taken from Rüter & Diederichs 2012)
By-product	waste mineral oil	kg	0.102	value taken from Rüter & Diederichs 2012)

Table 4-3: Modelling of the production process of glued laminated timber, MUF adhesive, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, MUF adhesive, at plant/CH		1	m^3	
Materials/fuels				
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/CH	1.310*0.8*allocation_factor	1.01	m^3	
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/RER	1.310*(1-0.8)*allocation_factor	0.256	m^3	20% of imported lamellas (according to HIS, personal information)
Melamine, at plant/RER	MUF*0.235*allocation_factor	1.84	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	1.58	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	2.62	kg	33.4% of MUF system; according to Rüter & Diederichs
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0333	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
electricity, medium voltage, at grid/kWh/CH	24.8*allocation_factor	24	kWh	
diesel, burned in building machine, with particle filter/CH	10.6*allocation_factor	10.3	MJ	
Gluing mill/CH	1.7E-6*allocation_factor	1.65E-6	p	
Transport, lorry >28t, fleet average/CH	MUF*1.02*50/1000*allocation_factor	0.4	tkm	
Transport, freight, rail/CH	MUF*1.02*600/1000*allocation_factor	4.8	tkm	
Transport, lorry >16t, fleet average/RER	1.310*465*(1-0.8)*200/1000* allocation_factor	23.9	tkm	transport weight 465 kg/m^3; assumed import distance: 200 km
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput		659	MJ	
Lubricating oil, at plant/RER	0.0121*allocation_factor	0.0989	kg	
Emissions to air				
Formaldehyde	0.0121*allocation_factor	0.0117	kg	
Waste to treatment				
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH		0.110	kg	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		88.5	kg oven-dry	
p_chips		0.107	Euro2005	
m_residual_wood		0.105	kg/m^3	
p_residual_wood		0.06	kg/m^3	26.9 Euro per m^3 at 430 kg/m^3
MUF		8.09	kg/m^3	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_residual_wood *p_residual_wood+m_chips*p_chips)	0.969		

4.5 Results

In Tables 4-4 to 4-6 the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 4-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued laminated timber, MUF adhesive, at plant/CH**	
		per m^3	per kg
CED non-renewable	**MJ**	**1934**	**4.36**
	kWh	**537**	**1.21**
CED renewable	**MJ**	**12191**	**27.5**
	kWh	**3387**	**7.64**
CED total	**MJ**	**14125**	**31.9**
	kWh	**3924**	**8.86**
Weight			*443*

Table 4-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued laminated timber, MUF adhesive, at plant/CH**	
	UBP/m^3	UBP/kg
Water resources	103	0.23
Energy resources	20032	45.22
Mineral resources	5049	11.40
Land use	101031	228.06
Global warming	39227	88.55
Ozone layer depletion	53	0.12
Main air pollutants and PM	63796	144.01
Carcinogenic substances into air	8792	19.85
Heavy metals into air	10244	23.12
Water pollutants	5800	13.09
POP into water	1464	3.31
Heavy metals into water	5775	13.04
Pesticides into soil	460	1.04
Heavy metals into soil	1900	4.29
Radioactive substances into air	0	0
Radioactive substances into water	438	0.99
Noise	4658	10.52
Non radioactive waste to deposit	163	0.37
Radioactive waste to deposit	16248	36.68
Sum	**285232**	**643.9**
Weight		*443*

Table 4-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Glued laminated timber, MUF adhesive, at plant/CH**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**86**	**0.193**
Weight		*443*

4.6 Interpretation

Table 4-7 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 4-7: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/CH	sawnwood, board, softwood, raw, dried (u=10%), at sawmill/m3/RER	Melamine, at plant/RER U	electricity, medium voltage, at grid/kWh/CH U	Gluing mill/CH	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	4.8%	1.3%	0.2%	0.3%	0.1%	0.0%	0.4%
Mineral resources	1.1%	0.2%	0.0%	0.0%	0.2%	0.0%	0.1%
Land use	28.3%	7.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Global warming	6.8%	2.1%	1.5%	0.4%	0.7%	0.2%	2.1%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	13.7%	3.2%	0.8%	0.2%	0.8%	2.5%	1.2%
Carcinogenic substances into air	1.5%	0.4%	0.0%	0.0%	0.3%	0.8%	0.1%
Heavy metals into air	1.5%	0.4%	0.3%	0.1%	0.4%	0.6%	0.3%
Water pollutants	1.4%	0.3%	0.1%	0.0%	0.0%	0.0%	0.2%
POP into water	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
Heavy metals into water	1.0%	0.2%	0.1%	0.0%	0.3%	0.0%	0.3%
Pesticides into soil	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.3%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Noise	1.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.3%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	3.0%	0.5%	0.1%	1.6%	0.1%	0.2%	0.1%
Sum	**65.2%**	**15.9%**	**3.4%**	**2.6%**	**3.1%**	**4.7%**	**5.1%**

5 Glued laminated timber production, PUR-glue/CH

5.1 Description of the product

Glued laminated timber, also called glulam, is a type of structural engineered wood product comprising a number of layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives, in this case polyurethane adhesive.

By laminating a number of smaller pieces of sawn timber a single large, strong, structural member is manufactured from smaller pieces. These structural members are used as vertical columns or horizontal beams, as well as curved, arched shapes. Glulam is readily produced in curved shapes and is available in a range of species and appearance characteristics to meet varied end-use requirements. Connections are usually made with bolts or plain steel dowels and steel plates.

Glulam optimizes the structural values of wood, which is a renewable resource. Because of their composition, large glulam members can be manufactured from a variety of smaller trees harvested from second-growth forests and plantations. Glulam provides the strength and versatility of large wood members without relying on the old growth-dependent solid-sawn timbers. As with other engineered wood products, it reduces the overall amount of wood used when compared to solid sawn timbers by diminishing the negative impact of knots and other small defects in each component board.

The high strength and stiffness of laminated timbers enable glulam beams and arches to span large distances without intermediate columns, allowing more design flexibility than with traditional timber construction. The size is limited only by transportation and handling constraints.

The composition of the inventoried glued laminated timber production, PUR-glue/CH is displayed in Table 5-1.

Table 5-1: Composition of the inventoried glued laminated timber production, PUR-glue/CH

Composition	kg/m^3	%
Wood [1)]	395.6	90.10%
of which carbon	*173.5*	*39.52%*
Water [1)]	39.6	9.01%
Polymer isocyanate emulsion adhesive	3.90	0.89%
Total	**439.06**	**100%**

Synonyms, German name: Glulam, Brettschichtholz

Data on the production process was compiled by Holzindustrie Schweiz[2] and covers the data of 9 glulam producers using PUR adhesive in Switzerland with production volumes between 740 m^3 and 19'000 m^3 in 2017, with a median value of 7'500 m^3.

[2] Urs Luginbühl/HIS, personal electronic communication, 29.1.2020

The system boundary of the unit process starts at the entry of planed and dried sawn timber into the gluing plant and ends with the final Glulam at the factory gate. The unit process includes the following process steps:

1. Pre-sorting of lamellas
2. Finger-jointing
3. Plaining of lamellas
4. Gluing
5. Planing of final product

As for the sawmilling and plaining processes inventoried in ecoinvent 3, the chipping of the cuttings from finger-jointing and its transport to the chips bunker as well as the suction of the shavings to the shavings bunker are allocated to the wood chips and the shavings at the bunker.

Acetone emissions are estimated based on Rüter & Diederichs, assuming 0.05 kg acetone/kg PUR used.

5.2 Description of the unit process

Table 5-2 describes the unallocated unit process for the production of Glulam with PUR adhesive in Switzerland.

Table 5-2: Unit process for the production of glued laminated timber with PUR adhesive in Switzerland (source: sampling by Holzindustrie Schweiz, personal communication, 3.2.2019)

Compartment	Unit process	Unit	Amount	Comment
Reference product	glued laminated timber, average glue mix	m^3	1	
By-product	residual wood, dry	m^3	0.105	cuttings, etc. ; sent to internal chipping
By-product	shavings, softwood, loose, measured as dry mass	kg	88.5	shavings from the 2 planing steps
From technosphere	sawnwood, board, softwood, raw, dried (u=10%)	m^3	1.310	Raw material input
From technosphere	methylene diphenyl isocyanate	kg	3.90	Average glue input
From technosphere	electricity, medium voltage	kWh	24.8	plant data, including 2 planing steps, gluing
From technosphere	diesel, burned in building machine	MJ	10.6	Diesel consumption for internal transport
From technosphere	gluing plant	unit	1.70E-06	Estimate for infrastructure
To environment	Acetone	kg	0.195	Acetone emissions from PUR glues; 0.05 kg/kg PUR (Rüter & Diederichs 2012)
From technosphere	lubricating oil	kg	0.102	value taken from Rüter & Diederichs 2012)
By-product	waste mineral oil	kg	0.102	value taken from Rüter & Diederichs 2012)

The production volume of Glulam with PUR adhesive is taken from the ecoinvent 3 dataset for “glued laminated timber production, outdoor use/CH”. The production volumes of the by-products are calculated from the amount of the by-product/m^3 of reference product times the production volume of the reference product.

5.3 Modelling of the unit process

The dataset is modelled as follows (Table 5-3):

Table 5-3: Modelling of the production process of glued laminated timber, PUR adhesive, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, PUR adhesive, at plant/CH		1	m^3	
Materials/fuels				
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/CH	1.310*0.8*allocation_factor	1.02	m^3	
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/RER	1.310*(1-0.8)*allocation_factor	0.254	m^3	20% of imported lamellas (according to HIS, personal information)
Methylene diphenyl diisocyanate, at plant/RER	3.9*allocation_factor	3.78	kg	
electricity, medium voltage, at grid/kWh/CH	24.8*allocation_factor	24	kWh	
diesel, burned in building machine, with particle filter/CH	10.6*allocation_factor	10.3	MJ	
Gluing mill/CH	1.7E-6*allocation_factor	0.00000165	p	
Transport, lorry >28t, fleet average/CH	3.9*50/1000*allocation_factor	0.189	tkm	
Transport, freight, rail/CH	3.9*600/1000*allocation_factor	2.27	tkm	
Transport, lorry >16t, fleet average/RER	1.310*465*(1-0.8)*200/1000* allocation_factor	23.6	tkm	transport weight 465 kg/m^3; assumed import distance: 200 km
Lubricating oil, at plant/RER	0.0121*allocation_factor	659	kg	
Emissions to air				
Acetone	0.195*allocation_factor	0.189	kg	
Waste to treatment				
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH		0.110	kg	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		88.5	kg oven-dry	
p_chips		0.107	Euro2005	
m_residual_wood		0.105	m^3/m^3	
p_residual_wood		0.06	Euro2005	26.9 Euro per m^3 at 430 kg/m^3
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_pro-	0.969		

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
	duct*p_main_product+m_resi-dual_wood *p_resi-dual_wood+m_chips*p_chips)			

5.4 Results

In Tables 5-4 to 5-6 the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 5-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued laminated timber, PUR adhesive, at plant/CH**	
		per m^3	per kg
CED non-renewable	**MJ**	**1877**	**4.28**
	kWh	**521**	**1.19**
CED renewable	**MJ**	**12187**	**27.8**
	kWh	**3385**	**7.71**
CED total	**MJ**	**14064**	**32.0**
	kWh	**3907**	**8.90**
Weight			*439*

Table 5-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued laminated timber, PUR adhesive, at plant/CH**	
	UBP/m^3	UBP/kg
Water resources	141	0.32
Energy resources	19840	45.19
Mineral resources	4876	11.11
Land use	101004	230.08
Global warming	38246	87.12
Ozone layer depletion	89	0.20
Main air pollutants and PM	65304	148.76
Carcinogenic substances into air	8589	19.57
Heavy metals into air	8899	20.27
Water pollutants	5419	12.34
POP into water	1342	3.06
Heavy metals into water	8840	20.14
Pesticides into soil	460	1.05
Heavy metals into soil	1887	4.30
Radioactive substances into air	0	0.00
Radioactive substances into water	418	0.95
Noise	4395	10.01
Non radioactive waste to deposit	194	0.44
Radioactive waste to deposit	15631	35.61
Sum	**285574**	**650.5**
Weight		*439*

Table 5-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Glued laminated timber, PUR adhesive, at plant/CH	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**84**	**0.191**
Weight		*439*

5.5 Interpretation

Table 5-7 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 5-7: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawnwood, board, soft-wood, raw, kiln dried (u=10%), at sawmill/m3/CH	sawnwood, board, soft-wood, raw, dried (u=10%), at sawmill/m3/RER	Methylene diphe-nyl diisocyanate, at plant/RER U	electricity, medium voltage, at grid/kWh/CH U	Gluing mill/CH	Wood chips, from industry, softwood, burned in fur-nace 300kW/CH ohne Holzinput	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	4.8%	1.3%	0.4%	0.3%	0.1%	0.0%	0.1%
Mineral resources	1.1%	0.2%	0.0%	0.0%	0.2%	0.0%	0.1%
Land use	28.3%	7.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Global warming	6.8%	2.1%	2.5%	0.4%	0.7%	0.2%	0.7%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	13.7%	3.2%	1.0%	0.2%	0.8%	2.5%	1.5%
Carcinogenic substances into air	1.5%	0.4%	0.0%	0.0%	0.3%	0.8%	0.0%
Heavy metals into air	1.5%	0.4%	0.1%	0.1%	0.4%	0.6%	0.1%
Water pollutants	1.4%	0.3%	0.1%	0.0%	0.0%	0.0%	0.1%
POP into water	0.3%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into water	1.0%	0.2%	1.3%	0.0%	0.3%	0.0%	0.1%
Pesticides into soil	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.3%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Noise	1.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.3%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	3.0%	0.5%	0.0%	1.6%	0.1%	0.2%	0.0%
Sum	**65.2%**	**15.9%**	**5.5%**	**2.6%**	**3.1%**	**4.7%**	3.1%

6 Glued laminated timber production, average glue mix/CH

According to HIS, about 90% of glued laminated timber production uses PUR adhesive, 10% uses MUF-adhesive. This results in the following modelling of average production of glued laminated timber in Switzerland (Table 6.1):

Table 6-1: Modelling of the production process of glued laminated timber, average glue mix, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Value	Unit	Comment
Products			
Glued laminated timber, average glue mix, at plant/CH	1	m^3	
Materials/fuels			
Glued laminated timber, MUF adhesive, at plant/CH	0.1	m^3	
Glued laminated timber, PUR adhesive, at plant/CH	0.9	m^3	

In Tables 6-2 to 6-4 the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 6-2: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	Unit	Glued laminated timber, average glue mix, at plant CH	
		per m^3	per kg
CED non-renewable	**MJ**	**1883**	**4.28**
	kWh	**523**	**1.19**
CED renewable	**MJ**	**12187**	**27.7**
	kWh	**3385**	**7.69**
CED total	**MJ**	**14070**	**32.0**
	kWh	**3908**	**8.88**
Weight			*440*

Table 6-3: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Glued laminated timber, average glue mix, at plant CH	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**84.0**	**0.191**
Weight		*440*

Table 6-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued laminated timber, average glue mix, at plant CH**	
	UBP/m^3	UBP/kg
Water resources	137	0.31
Energy resources	19859	45.13
Mineral resources	4893	11.12
Land use	101007	229.56
Global warming	38344	87.15
Ozone layer depletion	85	0.19
Main air pollutants and PM	65153	148.08
Carcinogenic substances into air	8609	19.57
Heavy metals into air	9033	20.53
Water pollutants	5457	12.40
POP into water	1354	3.08
Heavy metals into water	8533	19.39
Pesticides into soil	460	1.05
Heavy metals into soil	1888	4.29
Radioactive substances into air	0	0
Radioactive substances into water	420	0.96
Noise	4422	10.05
Non radioactive waste to deposit	191	0.43
Radioactive waste to deposit	15693	35.66
Sum	**285540**	**649.0**
Weight		*440*

7 Glued solid timber production/RER

7.1 Description of the product

Glued solid timber consists of lamellae of the same strength class or manufacturer-specific strength class which are bonded together. According to EN 14080 glued solid timber comprise up to five lamellae with thicknesses from 45 to 85 mm. The total cross-section of the beam shall not exceed 280 x 280 mm. Glued solid timber is predominantly bending stressed (upright position of the square wood). The lamellae of glued solid timber are classified into strength classes by visual (e.g. according to DIN 4074-1) or machine grading and categorized (e.g. in C-classes according to EN 338). Strength and stiffness properties can be taken from EN 338. In the harmonized standard EN 14080 glued solid timber is standardized for the first time. The CE-certification of this product has been compulsory since 08.08.2015 for the EU market.

The composition of the inventoried glued solid timber/RER is displayed in Table 7-1.

Table 7-1: Composition of the inventoried glued solid timber/RER

Composition	kg/m³	%
Wood [1)]	395.6	89.88%
of which carbon	*174.8*	*44.20%*
Water [1)]	39.6	8.91%
Melamine urea formaldehyde adhesive	3.279	0.74%
Phenol resorcinol adhesive	0.154	0.03%
1 component PUR adhesive	1.547	0.35%
Polymer isocyanate emulsion adhesive	0.026	0.01%
Total	**440.2**	**100%**

[1)] wood and water content has been recalculated as the density of 500 kg/m³ reported in Rüter & Diederichs (2012) is considered to be too high for glued solid timber made from current softwood species such as spruce and fir (see Sell 1997) and given the usually grading strength C16/C24. For the recalculation of the wood and water content, an average oven-dry density of converted with a basic wood density of 430 kg dry/m³ wet kg/m³ and a moisture content of u = 10 % is assumed (whereas in practice, wood is kiln dried to u = 12 %). Considering the resulting shrinkage in volume of about 8 %, this leads to a recalculated basic wood density (kg oven-dry matter/m³ wet volume) of 396 kg/m³.

Synonyms, German name: Balkenschichtholz

7.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German glued solid timber production covering about 61.6% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF-, MUF or PF-adhesive and 0.05 kg of acetone emissions/kg of PUR-adhesive.

7.3 Description of the unit process

Table 7-2 lists the inputs and outputs as a gate-to-gate inventory for the production of glued solid timber. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies:

a) a different level of processing of the woody raw material per production site
b) different adhesives per production site

Table 7-2: Life cycle inventory (gate-to-gate) for the production of glued solid timber/RER

Inputs	Quantity	Unit
Wooden raw materials		
Softwood, under bark	0.389	m³
Sawn timber, undried	0.438	m³
Sawn timber, kiln dried	0.72	m³
Electricity	97.7	kWh
Fuels		
Natural gas	65.6	MJ
Light fuel oil	10.61	MJ
others (also vegetable oils)	49.8	MJ
Post-consumer wood	97.8	MJ
Residual wood, internal sources	911.6	MJ
Bark, internal sources	116.2	MJ
Ancillary materials		
Diesel	1.22	kg
	52.1	*MJ*
Lubricants, machines	0.101	kg
Cutting materials	0.019	kg
Cleaning agents	0.019	kg
Tyres	0.123	kg
Drinking water	0.0200	kg
Surface water	29.96	kg
Lubricants, motors	0.013	kg
Adhesives		
Melamine urea formaldehyde	3.28	kg
Phenol resorcinol formaldehyde	0.154	kg
Polyurethane	1.55	kg
Emulsion polymer isocyanate	0.026	kg
Outputs	**Quantity**	**Unit**
Products		
Glued solid timber	1	m³
Co-products (shavings and wood chips)	0.547	m³
Bark from roundwood input (12 %)	0.053	m³
Airborne emissions		
Formaldehyde from adhesive	0.00492	kg
Acetone from adhesive	0.0774	kg
Others		
Wastes	0.275	kg
Waste water/partly as emissions into air	29.97	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 7-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of glued solid timber.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infrastructure.

Table 7-3: Input/0utput table of woody resources for the production of glued solid timber/RER

INPUTS		
Softwood, under bark	0.389	m³
Sawn timber, undried	0.438	m³
Sawn timber, kiln dried	0.72	m³
OUTPUTS		
Glued solid timber	1	m³
	395.6	*kg*
Co-products (shavings, wood chips and bark)	251.3	kg
of which used energetically	*53.5*	*kg*
of which sold externally	*197.8*	*kg*
USE AS WOOD FUEL		
Post-consumer wood	97.8	MJ
converted with 19.217 MJ/kg LHV	*5.09*	*kg*
Residual wood, internal sources	911.6	MJ
converted with 19.217 MJ/kg LHV	*47.4*	
Bark, internal sources	116.2	MJ
converted with 19.217 MJ/kg LHV	*6.0*	
Sum: fuel wood from external sources	*97.8*	*MJ*
	5.1	*kg*
Sum: fuel wood from internal sources	*1027.8*	*MJ*
	53.5	*kg*

7.4 Modelling of the unit process

The dataset is modelled as follows (Table 7-4):

Table 7-4: Modelling of the production process of glued solid timber, average glue mix, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued solid timber, average glue mix, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	29.96*allocation_factor	27.6	kg	
Materials/fuels				
sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	0.389*allocation_factor	0.359	m^3	
sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	0.438*allocation_factor	0.404	m^3	
sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	0.720*allocation_factor	0.664	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	97.7*allocation_factor	90.1	kWh	
Natural gas, burned in boiler condensing modulating >100kW/RER	65.6*allocation_factor	60.5	MJ	
Light fuel oil, burned in industrial furnace 1MW, non-modulating/RER	10.6*allocation_factor	9.77	MJ	
Wood chips, post-consumer wood, burned in furnace 1000kW/CH	(97.8+49.8)*allocation_factor	136	MJ	inkl. "others (also vegetable oils)"
Wood chips, from industry, softwood, burned in furnace 300kW/CH	58.2*allocation_factor	53.7	MJ	
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	(911.6+116.2)*allocation_factor	948	MJ	
diesel, burned in building machine, with particle filter/CH	52.1*allocation_factor	48	MJ	
Lubricating oil, at plant/RER	(0.101+0.013)*allocation_factor	0.105	kg	
Steel, low-alloyed, at plant/RER	0.019*allocation_factor	0.0175	kg	
Steel product manufacturing, average metal working/RER	0.019*allocation_factor	0.0175	kg	
Soap, at plant/RER	0.019*allocation_factor	0.0175	kg	
Synthetic rubber, at plant/RER	0.123*allocation_factor	0.113	kg	
tap water, at user/kg/RER	0.02*allocation_factor	0.0184	kg	
Melamine, at plant/RER	MUF*0.235*allocation_factor	0.711	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	0.608	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	1.01	kg	33.4% of MUF system; according to Rüter & Diederichs

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0128	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs
Phenol, at plant/RER	PRF*0.536*allocation_factor	0.0761	kg	
Benzene, at plant/RER	PRF*0.157*allocation_factor	0.0223	kg	Proxy for resorcinol, i.e. dihydroxybenzene
Formaldehyde, production mix, at plant/RER	PRF*0.308*allocation_factor	0.0437	kg	
Polyurethane, rigid foam, at plant/RER	PUR*allocation_factor	1.43	kg	
Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER	EPI*0.85*allocation_factor	0.0204	kg	2-Komponentenklebstoffe, bei denen SBR-Klebstoffe (i.e. Kunstkautschuk, StyrolButadien-Rubber), PVAc-Kleber (Polyvinyacetat) und EVA-Klebstoffe (Ethylenvinylacetat): Proxy als worst case für SBR for 85%
Methylene diphenyl diisocyanate, at plant/RER	EPI*0.15*allocation_factor	0.0036	kg	Isocyanyde hardener as 15%
Transport, lorry >16t, fleet average/RER	(0.389*800*1.12*100+(49.8+97.8)/19.4*100+0.019*100+(0.101+0.019+0.123+0.013+MUF*1.02+PUR+EPI)*100)/1000*allocation_factor	33.3	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m3
Transport, freight, rail/RER	(0.389*800*1.12*0+(49.8+97.8)/19.4*0+0.019*200+(0.101+0.019+0.123+0.013+MUF*1.02+PUR+EPI)*600)/1000*allocation_factor	2.95	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m3
Transport, lorry 20-28t, fleet average/CH	(0.275+0.123+0.101+0.03)*10/1000*allocation_factor	0.00488	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for GLULAM
Emissions to air				
Formaldehyde	0.00492*allocation_factor	0.00454	kg	based on Rüter & Diederichs (2012)
Acetone	0.0774*allocation_factor	0.0714	kg	based on Rüter & Diederichs (2012)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	0.275*allocation_factor	0.254	kg	
Recycling steel and iron/RER	0.019*allocation_factor	0.0175	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.123*allocation_factor	0.113	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	(0.101+0.013)/(1-0.1)*allocation_factor	0.117	kg	
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.030*allocation_factor	0.0277	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		250	Euro2005	
m_chips		197.8	kg oven-dry	
p_chips		0.107	Euro2005	
MUF		3.28	kg/m^3	
PRF		0.154	kg/m^3	
PUR		1.55	kg/m^3	
EPI		0.026	kg/m^3	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_chips*p_chips)	0.922		

7.5 Results

In Tables 7-5 to 7-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 7-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued solid timber, average glue mix, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**2610**	**5.93**
	kWh	**725**	**1.65**
CED renewable	**MJ**	**13802**	**31.4**
	kWh	**3834**	**8.71**
CED total	**MJ**	**16411**	**37.3**
	kWh	**4559**	**10.4**
Weight			*440*

Table 7-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued solid timber, average glue mix, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	185	0.42
Energy resources	24101	54.77
Mineral resources	4575	10.40
Land use	103680	235.64
Global warming	64940	147.59
Ozone layer depletion	62	0.14
Main air pollutants and PM	62787	142.70
Carcinogenic substances into air	9521	21.64
Heavy metals into air	10482	23.82
Water pollutants	5409	12.29
POP into water	1414	3.21
Heavy metals into water	7228	16.43
Pesticides into soil	224	0.51
Heavy metals into soil	2297	5.22
Radioactive substances into air	0	0
Radioactive substances into water	614	1.40
Noise	4265	9.69
Non radioactive waste to deposit	231	0.52
Radioactive waste to deposit	19393	44.07
Sum	**321409**	**730.5**
Weight		*440*

Table 7-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Glued solid timber, average glue mix, at plant/RER	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**142**	**0.323**
Weight		*440*

7.6 Interpretation

Table 7-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 7-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	sawnwood, board, soft-wood, raw, air dried (u=20%), at sawmill/m3/RER	sawnwood, board, soft-wood, dried (u=10%), planed, at sawmill/m3/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in fur-nace 300kW/CH ohne Holzinput	Polyure-thane, rigid foam, at plant/RER	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	1.2%	1.5%	3.2%	1.0%	0.0%	0.2%	0.1%	0.4%
Mineral resources	0.1%	0.3%	0.7%	0.0%	0.0%	0.0%	0.1%	0.2%
Land use	5.3%	9.3%	17.6%	0.0%	0.0%	0.0%	0.0%	0.1%
Global warming	0.5%	2.1%	6.5%	6.3%	0.2%	0.9%	0.6%	3.0%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.4%	1.7%	8.7%	2.1%	3.2%	0.5%	0.6%	2.3%
Carcinogenic substances into air	0.0%	0.1%	1.1%	0.2%	1.0%	0.0%	0.0%	0.5%
Heavy metals into air	0.0%	0.2%	1.2%	0.3%	0.8%	0.0%	0.1%	0.6%
Water pollutants	0.1%	0.3%	0.7%	0.1%	0.0%	0.1%	0.1%	0.2%
POP into water	0.0%	0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.1%
Heavy metals into water	0.1%	0.3%	0.8%	0.2%	0.0%	0.3%	0.1%	0.4%
Pesticides into soil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.0%	0.1%	0.0%	0.4%	0.0%	0.0%	0.1%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Noise	0.0%	0.2%	0.5%	0.0%	0.0%	0.0%	0.2%	0.4%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	0.0%	0.4%	1.8%	3.3%	0.3%	0.0%	0.0%	0.2%
Sum	**7.9%**	**16.6%**	**43.1%**	**13.8%**	**6.0%**	**2.1%**	**2.0%**	**8.5%**

8 Glued solid timber production, MUF-glue/CH

Glued laminated timber and glued solid timber are produced according to the same product standard. During data collection, it was not possible to distinguish between the two groups of products. As the production process is identical and the products comparable, the data for glued laminated timber can be taken as a proxy for glued solid timber. The only difference is the difference in the import share of boards used for the production of the two.

The composition of the product can be found in Table 4-1.

8.1 Modelling of the unit process

The dataset is modelled as follows (Table 8-1):

Table 8-1: Modelling of the production process of glued solid timber, MUF adhesive, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, MUF adhesive, at plant/CH		1	m^3	
Materials/fuels				
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/CH	1.310*0.95*allocation_factor	1.21	m^3	
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/RER	1.310*(1-0.95)*allocation_factor	0.0635	m^3	5% of imported lamellas (according to HIS, personal information)
Melamine, at plant/RER	MUF*0.235*allocation_factor	1.84	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	1.58	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	2.62	kg	33.4% of MUF system; according to Rüter & Diederichs
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0333	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs
electricity, medium voltage, at grid/kWh/CH	24.8*allocation_factor	24	kWh	
diesel, burned in building machine, with particle filter/CH	10.6*allocation_factor	10.3	MJ	
Gluing mill/CH	1.7E-6*allocation_factor	1.65E-6	p	
Transport, lorry >28t, fleet average/CH	MUF*1.02*50/1000*allocation_factor	0.4	tkm	
Transport, freight, rail/CH	MUF*1.02*600/1000*allocation_factor	4.8	tkm	
Transport, lorry >16t, fleet average/RER	1.310*465*(1-0.95)*200/1000* allocation_factor	5.9	tkm	transport weight 465 kg/m^3; assumed import distance: 200 km
Emissions to air				
Formaldehyde	0.0121*allocation_factor	0.0117	kg	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		88.5	kg oven-dry	
p_chips		0.107	Euro2005	
m_residual_wood		0.105	kg/m^3	
p_residual_wood		0.06	kg/m^3	26.9 Euro per m^3 at 430 kg/m^3

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
MUF		8.09	kg/m^3	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_residual_wood *p_residual_wood+m_chips*p_chips)	0.969		

In Tables 8-2 to 8-4, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 8-2: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued solid timber, MUF adhesive, at plant/CH**	
		per m^3	per kg
CED non-renewable	**MJ**	1875	4.23
	kWh	**521**	**1.18**
CED renewable	**MJ**	**12049**	**27.2**
	kWh	**3347**	**7.56**
CED total	**MJ**	**13924**	**31.4**
	kWh	**3868**	**8.73**
Weight			*443*

Table 8-3: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued solid timber, MUF adhesive, at plant/CH**	
	UBP/m^3	UBP/kg
Water resources	98	0.22
Energy resources	19675	44.41
Mineral resources	4980	11.24
Land use	101181	228.40
Global warming	36801	83.07
Ozone layer depletion	54	0.12
Main air pollutants and PM	56144	126.74
Carcinogenic substances into air	6502	14.68
Heavy metals into air	8300	18.74
Water pollutants	5817	13.13
POP into water	1428	3.22
Heavy metals into water	5549	12.53
Pesticides into soil	497	1.12
Heavy metals into soil	995	2.25
Radioactive substances into air	0	0
Radioactive substances into water	430	0.97
Noise	4439	10.02
Non radioactive waste to deposit	148	0.33
Radioactive waste to deposit	16173	36.51
Sum	**269212**	**607.7**
Weight		*443*

Table 8-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Glued solid timber, MUF adhesive, at plant/CH**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**80.0**	**0.182**
Weight		*443*

9 Glued solid timber production, PUR-glue/CH

Glued laminated timber and glued solid timber are produced according to the same product standard. During data collection, it was not possible to distinguish between the two groups of products. As the production process is identical and the products comparable, the data for glued laminated timber can be taken as a proxy for glued solid timber. The only difference is the difference in the import share of boards used for the production of the two.

The composition of the product can be found in Table 5-1.

9.1 Modelling of the unit process

The dataset is modelled as follows (Table 9-1):

Table 9-1: Modelling of the production process of glued solid timber, PUR adhesive, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, PUR adhesive, at plant/CH		1	m^3	
Materials/fuels				
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/CH	1.310*0.95*allocation_factor	1.21	m^3	
sawnwood, board, softwood, raw, kiln dried (u=10%), at sawmill/m3/RER	1.310*(1-0.95)*allocation_factor	0.0635	m^3	5% of imported lamellas (according to HIS, personal information)
Methylene diphenyl diisocyanate, at plant/RER	3.9*allocation_factor	3.78	kg	
electricity, medium voltage, at grid/kWh/CH	24.8*allocation_factor	24	kWh	
diesel, burned in building machine, with particle filter/CH	10.6*allocation_factor	10.3	MJ	
Gluing mill/CH	1.7E-6*allocation_factor	1.65E-6	p	
Transport, lorry >28t, fleet average/CH	3.9*50/1000*allocation_factor	0.189	tkm	
Transport, freight, rail/CH	3.9*600/1000*allocation_factor	2.27	tkm	
Transport, lorry >16t, fleet average/RER	1.310*465*(1-0.95)*200/1000* allocation_factor	5.9	tkm	transport weight 465 kg/m^3; assumed import distance: 200 km
Emissions to air				
Acetone	0.195*allocation_factor	0.189	kg	
Input parameters				
v_main_product		1	m^3	
p_main_product		298	Euro2005	
m_chips		88.5	kg oven-dry	
p_chips		0.107	Euro2005	
m_residual_wood		0.105	m^3/m^3	
p_residual_wood		0.06	Euro2005	26.9 Euro per m^3 at 430 kg/m^3
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_residual_wood *p_residual_wood+m_chips*p_chips)	0.969		

In Tables 9-2 to 9-4, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 9-2: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Glued solid timber, PUR adhesive, at plant/CH**	
		per m^3	per kg
CED non-renewable	**MJ**	**1819**	**4.14**
	kWh	**505**	**1.15**
CED renewable	**MJ**	**12044**	**27.4**
	kWh	**3346**	**7.62**
CED total	**MJ**	**13863**	**31.6**
	kWh	**3851**	**8.77**
Weight			*439*

Table 9-3: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued solid timber, PUR adhesive, at plant/CH**	
	UBP/m^3	UBP/kg
Water resources	137	0.31
Energy resources	19484	44.38
Mineral resources	4807	10.95
Land use	101154	230.42
Global warming	35820	81.60
Ozone layer depletion	89	0.20
Main air pollutants and PM	57652	131.33
Carcinogenic substances into air	6299	14.35
Heavy metals into air	6954	15.84
Water pollutants	5436	12.38
POP into water	1306	2.97
Heavy metals into water	8614	19.62
Pesticides into soil	497	1.13
Heavy metals into soil	982	2.24
Radioactive substances into air	0	0
Radioactive substances into water	410	0.93
Noise	4176	9.51
Non radioactive waste to deposit	179	0.41
Radioactive waste to deposit	15556	35.44
Sum	**269555**	**614.0**
Weight		*439*

Table 9-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Glued solid timber, PUR adhesive, at plant/CH**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**79**	**0.179**
Weight		*439*

10 Glued solid timber production, average glue mix/CH

According to HIS, about 90% of glued solid timber production uses PUR adhesive, 10% uses MUF-adhesive. This results in the following modelling of average production of glued solid timber in Switzerland (Table 10-1):

Table 10-1: Modelling of the production process of glued solid timber, average glue mix, at plant/CH in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Value	Unit	Comment
Products			
Glued solid timber, average glue mix, at plant/CH	1	m^3	
Materials/fuels			
Glued solid timber, MUF adhesive, at plant/CH	0.1	m^3	
Glued solid timber, PUR adhesive, at plant/CH	0.9	m^3	

In Tables 10-2 to 10-4, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 10-2: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	Unit	Glued solid timber, average glue mix, at plant CH	
		per m^3	per kg
CED non-renewable	MJ	**1824**	**4.15**
	kWh	**507**	**1.15**
CED renewable	MJ	**12045**	**27.4**
	kWh	**3346**	**7.60**
CED total	MJ	**13869**	**31.5**
	kWh	**3853**	**8.76**
Weight			*440*

Table 10-3: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Glued solid timber, average glue mix, at plant CH	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**79**	**0.179**
Weight		*440*

Table 10-4: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Glued solid timber, average glue mix, at plant CH**	
	UBP/m^3	UBP/kg
Water resources	133	0.30
Energy resources	19503	44.32
Mineral resources	4824	10.96
Land use	101157	229.90
Global warming	35918	81.63
Ozone layer depletion	86	0.19
Main air pollutants and PM	57501	130.69
Carcinogenic substances into air	6320	14.36
Heavy metals into air	7089	16.11
Water pollutants	5474	12.44
POP into water	1318	3.00
Heavy metals into water	8308	18.88
Pesticides into soil	497	1.13
Heavy metals into soil	984	2.24
Radioactive substances into air	0	0
Radioactive substances into water	412	0.94
Noise	4202	9.55
Non radioactive waste to deposit	176	0.40
Radioactive waste to deposit	15618	35.50
Sum	**269520**	**612.6**
Weight		*440*

11 Gluing plant/RER

11.1 Description of the plant

The gluing of solid timber products is done in a gluing plant (*German*: Leimwerk), which is usually located adjacent to the sawmill and the planning mill. As the processing of sawn timber in the gluing plant contains – apart from the gluing steps such as finger-jointing and the gluing of sawn timber to boards and beams - several planing steps, the gluing plant is approximated with the data for a planning mill. Based on the data used for the approximation, the dataset represents a medium sized gluing plant, located with a sawmill.

11.2 Description of the unit process

The data for the unit process is derived from the dataset for the construction of a planning mill in Europe as available in ecoinvent 3. The data is scaled based on the average size of a gluing mill as inventoried for the Swiss production (5775 m^2) as compared to the size of the inventoried planning mill in ecoinvent 3 (11700 m^2).

Table 11-1: Unit process for the construction and disposal of a gluing plant/RER (source: own calculations based on ecoinvent 3 data for a planing mill)

Compartment	Unit process	Unit	Amount	Comment
Reference product	Gluing mill	unit	1	
By-product	waste reinforced concrete	kg	1395558	calculated from input at 2400 kg/m^3
By-product	waste bulk iron	kg	384035	calculated from input
From environment	Occupation, industrial area	m^2*year	288767	calculated from sampled surface over 50 years
From environment	Transformation, from unspecified	m^2	5775	sampled surface
From environment	Transformation, to industrial area	m^2	5775	sampled surface
From technosphere	building, hall	m^2	5775	sampled surface
From technosphere	concrete, sole plate and foundation	m^3	563	scaled via surface of building
From technosphere	reinforcement steel	kg	45018	80 kg/m^3
From technosphere	steel, low-alloyed, hot rolled	kg	384035	scaled via surface of building
From technosphere	sheet rolling, steel	kg	384035	calculated from input

11.3 Modelling of the unit process

The dataset is modelled as follows (Table 11-2):

Table 11-2: Modelling of the construction/deconstruction of a gluing mill/CH I in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Gluing mill/CH I		1	p	
Resources				
Occupation, industrial area	50*5775	2.89E5	m^2a	
Transformation, from unspecified, used		5775	m^2	
Transformation, to industrial area		5775	m^2	
Materials/fuels				
Building, hall/CH/I U		5775	m^2	
Concrete, sole plate and foundation, at plant/CH		563	m^3	
Reinforcing steel, at plant/RER		45018	kg	
Steel, low-alloyed, at plant/RER		384035	kg	
Hot rolling, steel/RER		384035	kg	
Sheet rolling, steel/RER		384035	kg	
Transport, lorry >28t, fleet average/CH	((384035+45018)*50+563*2300*20)/1000	4.74E4	tkm	Standard transport according to Frischknecht et al. 2007
Transport, freight, rail/CH	((384035+45018)*600/1000	0	tkm	Standard transport according to Frischknecht et al. 2007
Waste to treatment				
Disposal, building, reinforced concrete, to sorting plant/CH	0.9*563*2300	1.17E6	kg	
Disposal, building, reinforced concrete, to final disposal/CH	0.1*563*2300	1.29E5	kg	
Recycling steel and iron/RER	384035+0.1*45018	3.89E5	kg	
Disposal, building, reinforcement steel, to sorting plant/CH	0.9*45018	4.05E4	kg	

12 Plywood production, UF adhesive/Europe without Switzerland

12.1 Description of the product

Plywood is made out of glued veneers. Veneers are thin sheets of wood obtained by sawing, cutting, or peeling. They are among the longest-known wood-based construction materials. Veneers are produced from cordwood or from specially divided blocks by using peeling and cutting machines or, less commonly, by sawing. The coated veneers are stacked either manually or by machine. To make transportation easier and reduce stack height, coated veneer stacks are frequently pre-compressed in an unheated one-daylight press. Hot pressing occurs in one- or multi-daylight presses but usually with a smaller size. Pressing conditions (temperature, time, and pressure) depend on the type of wood, the strength of the plywood, and the type of adhesive. Pressures of 0.6 2.5 N/mm^2 and temperatures of 80 140 °C are usually applied. After gluing and sometimes climatisation, veneer plywood is sanded, cut to standard or ordered measurements, and graded according to quality.

Different types of plywood are available depending on the number and height of the layers; the type is not specified in this dataset. The most important adhesives for gluing wood are urea-formaldehyde resins. The use of UF resins to glue plywood was first described in 1929. Production of these wood adhesives has since developed enormously. Urea-formaldehyde resins are used for adhesion of wood materials used in the interior and have limited resistance to moisture. They can be readily adapted to operational requirements through the nature and dosage of curing aids and additives. Ammonium salts (e.g. NH_4Cl) are generally used as curing aids. They lower the pH by reacting with formaldehyde. The rate of curing increases with increasing temperature and decreasing pH. The viscosity of the adhesive liquor is adapted to processing conditions by the addition of water, depending on the content of extenders and fillers. The pressing temperature is 80 120 °C.

The composition of the inventoried plywood/RER is displayed in Table 12-1.

Table 12-1: Composition of the inventoried plywood/Europe without Switzerland

Composition	kg/m^3	%
Wood	680	82.53%
of which carbon	*340*	*41.27%*
Water	54.4	6.60%
Urea formaldehyde adhesive	89.53	10.87%
Total	**823.0**	**100%**

Synonyms, German name: Furniersperrholz

12.1 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German veneer plywood production covering about 100% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF-adhesive.

12.2 Description of the unit process

Table 12-2 lists the inputs and outputs as a gate-to-gate inventory for the production of veneer plywood.

Table 12-2: Life cycle inventory (gate-to-gate) for the production of veneer plywood/Europe without Switzerland

Inputs	Quantity	Unit
Wooden raw materials		
Hardwood, under bark	2.27	m^3
Electricity	534	kWh
Fuels		
Light fuel oil	73.0	MJ
Residual wood, internal sources	11573	MJ
Ancillary materials		
Diesel	0.084	kg
	3.60	*MJ*
Lubricants	0.242	kg
Metals	0.116	kg
Sanding belts	0.274	kg
Tyres	0.022	kg
Drinking water	124.1	kg
Surface water	10630.2	kg
Adhesives		
Urea formaldehyde	89.53	kg
Outputs	**Quantity**	**Unit**
Products		
Veneer plywood	1	m^3
Co-products (shavings and wood chips)	1.26	m^3
Bark from roundwood input (10 %)	0.252	m^3
Airborne emissions		
Formaldehyde from adhesive	0.134	kg
Others		
Wastes	0.495	kg
Waste water/partly as emissions into air	88.3	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 12-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of veneer plywood.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infrastructure.

Table 12-3: Input/0utput table of woody resources for the production of veneer plywood/Europe without Switzerland

INPUTS		
Hardwood, under bark	2.268	m³
OUTPUTS		
Veneer plywood	1	m³
	680	*kg*
Co-products (shavings, wood chips and bark)	706.0	kg
of which used energetically	*602.2*	*kg*
of which sold externally	*78.6*	*kg*
USE AS WOOD FUEL		
Residual wood, internal sources	11573	MJ
converted with 19.217 MJ/kg LHV	*602.2*	
Sum: fuel wood from external sources	*0.0*	*MJ*
	0.0	*kg*
Sum: fuel wood from internal sources	*11573*	*MJ*
	602.2	*kg*

12.3 Modelling of the unit process

The dataset is modelled as follows (Table 12-4):

Table 12-4: Modelling of the production process of plywood, hardwood veneer, UF-bonded, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Plywood, hardwood veneer, UF-bonded, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	1063.2*allocation_factor	10400	kg	
Materials/fuels				
sawlog and veneer log, hardwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	2.27*allocation_factor	2.22	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	534*allocation_factor	523	kWh	
Light fuel oil, burned in industrial furnace 1MW, non-modulating/RER	73.0*allocation_factor	71.5	MJ	
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	11573*allocation_factor	11300	MJ	
diesel, burned in building machine, with particle filter/CH	3.6*allocation_factor	3.53	MJ	
Lubricating oil, at plant/RER	0.242*allocation_factor	0.237	kg	
Steel, low-alloyed, at plant/RER	0.116*allocation_factor	0.114	kg	
Steel product manufacturing, average metal working/RER	0.116*allocation_factor	0.114	kg	
sanding belt	0.274*allocation_factor	0.268	kg	
Synthetic rubber, at plant/RER	0.022*allocation_factor	0.0215	kg	
tap water, at user/kg/RER	124*allocation_factor	121	kg	
Melamine formaldehyde resin, at plant/RER	89.53*allocation_factor	87.7	kg	
Ammonium sulphate, as N, at regional storehouse/RER	89.53*(2*14/132)*0.02*allocation_factor	0.372	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs
Transport, lorry >16t, fleet average/RER	(2.27*1000*1.1*100+0.116*100+(0.242+0.274+0.022+89.53*1.02)*100)/1000*allocation_factor	254	tkm	distances according to Frischknecht et al. 2007; transport weight of hardwood; 1000 kg/m^3
Transport, freight, rail/RER	(2.27*1000*1.1*0+0.116*200+(0.242+0.274+0.022+89.53*1.02)*600)/1000*allocation_factor	54	tkm	distances according to Frischknecht et al. 2007; transport weight of hardwood; 1000 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.495+0.274+0.242+0.022)*10/1000*allocation_factor	0.0101	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for plywood production

Emissions to air				
Formaldehyde	0.134*allocation_factor	0.131	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	(0.495+0.274)*allocation_factor	0.753	kg	
Recycling steel and iron/RER	0.116*allocation_factor	0.114	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.134*allocation_factor	0.131	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	0.242/(1-0.1)*allocation_factor	0.263	kg	
Treatment, plywood production effluent, to wastewater treatment, class 3/CH	0.0883*allocation_factor	0.0865	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		400	Euro2005	
m_chips		78.6	kg oven-dry	
p_chips		0.107	Euro2005	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_chips*p_chips)	0.979		

12.4 Results

In Tables 12-5 to 12-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 12-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Plywood, hardwood veneer, UF-bonded, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**14854**	**18.1**
	kWh	**4126**	**5.01**
CED renewable	**MJ**	**27639**	**33.6**
	kWh	**7678**	**9.33**
CED total	**MJ**	**42493**	**51.6**
	kWh	**11804**	**14.3**
Weight			*823*

Table 12-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Plywood, hardwood veneer, UF-bonded, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	1364	1.66
Energy resources	81007	98.43
Mineral resources	14434	17.54
Land use	104075	126.46
Global warming	342827	416.56
Ozone layer depletion	302	0.37
Main air pollutants and PM	287748	349.63
Carcinogenic substances into air	48598	59.05
Heavy metals into air	78314	95.16
Water pollutants	21911	26.62
POP into water	5283	6.42
Heavy metals into water	28150	34.20
Pesticides into soil	421	0.51
Heavy metals into soil	17903	21.75
Radioactive substances into air	0	0
Radioactive substances into water	2781	3.38
Noise	14193	17.24
Non radioactive waste to deposit	1069	1.30
Radioactive waste to deposit	88683	107.76
Sum	**1139063**	**1384**
Weight		*823*

Table 12-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Plywood, hardwood veneer, UF-bonded, at plant/RER**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**750**	**0.911**
Weight		*823*

12.5 Interpretation

Table 12-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 12-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawlog and veneer log, hardwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	Melamine formaldehyde resin, at plant/RER	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Energy resources	2.7%	1.6%	0.1%	2.5%	0.2%	0.1%
Mineral resources	0.4%	0.1%	0.1%	0.6%	0.1%	0.0%
Land use	9.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Global warming	0.9%	10.3%	0.8%	16.1%	1.3%	0.6%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.9%	3.4%	10.8%	8.5%	1.3%	0.4%
Carcinogenic substances into air	0.0%	0.3%	3.3%	0.5%	0.1%	0.1%
Heavy metals into air	0.1%	0.5%	2.8%	3.3%	0.1%	0.1%
Water pollutants	0.2%	0.2%	0.0%	1.2%	0.2%	0.1%
POP into water	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%
Heavy metals into water	0.1%	0.4%	0.1%	1.6%	0.3%	0.1%
Pesticides into soil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.1%	1.4%	0.0%	0.0%	0.0%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%
Noise	0.0%	0.0%	0.0%	0.6%	0.5%	0.1%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Radioactive waste to deposit	0.1%	5.5%	0.9%	1.3%	0.1%	0.1%
Sum	**14.5%**	**22.6%**	**20.3%**	**36.5%**	**4.3%**	**1.8%**

13 Structural timber production/RER

13.1 Description of the product

Structural timber is a building material with precisely defined product characteristics, which was developed specially to meet the high requirements of modern timber construction. Structural timber is a kiln-dried, strength-graded, and in most cases finger-jointed timber product made of solid softwood. Thanks to the method of cutting used and the low moisture content of the material it has little propensity for cracking, is dimensionally stable and, subject to due observance of the rules relating to the structural protection of wood, can also be used without wood preservatives. Structural timber is available in a wide range of preferred dimensions and wood types (spruce, fir, pine, larch or Douglas fir) with precisely defined surface finishes.

The composition of the inventoried structural timber/RER is displayed in Table 13-1.

Table 13-1: Composition of the inventoried structural timber/RER

Composition	kg/m³	%
Wood [1)]	395.6	90.80%
of which carbon	*176.4*	*44.60%*
Water [1)]	39.6	9.08%
Melamine urea formaldehyde adhesive	0.21	0.05%
Phenol resorcinol adhesive	0.01	0.002%
1 component PUR adhesive	0.29	0.07%
Total	**435.7**	**100.0%**

[1)] wood and water content has been recalculated as the density of 493 kg/m³ reported in Rüter & Diederichs (2012) is considered to be too high for structural timber made from current softwood species such as spruce and fir (see Sell 1997) and given the usually grading strength C16/C24. For the recalculation of the wood and water content, an average oven-dry density of converted with a basic wood density of 430 kg dry/m³ wet kg/m³ and a moisture content of u = 10 % is assumed (whereas in practice, wood is kiln dried to u = 12 %). Considering the resulting shrinkage in volume of about 8 %, this leads to a recalculated basic wood density (kg oven-dry matter/m³ wet volume) of 396 kg/m³.

Synonyms, German name: Konstruktionsvollholz

13.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German structural timber production covering about 61.6% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF-, MUF or PF-adhesive and 0.05 kg of acetone emissions/kg of PUR-adhesive.

13.3 Description of the unit process

Table 13-2 lists the inputs and outputs as a gate-to-gate inventory for the production of structural timber. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies:

a) a different level of processing of the woody raw material per production site
b) different adhesives per production site

Table 13-2: Life cycle inventory (gate-to-gate) for the production of structural timber/RER

Inputs	Quantity	Unit
Wooden raw materials		
Softwood, under bark	0.529	m³
Sawn timber, undried	0.379	m³
Sawn timber, kiln dried	0.549	m³
Electricity	58.7	kWh
Fuels		
Natural gas	6.23	MJ
Light fuel oil	2.265	MJ
others (also vegetable oils)	39.27	MJ
Post-consumer wood	116.0	MJ
Residual wood, internal sources	962.6	MJ
Bark, internal sources	223.7	MJ
Ancillary materials		
Diesel	1.18	kg
	50.5	*MJ*
Lubricants, machines	0.082	kg
Cutting materials	0.016	kg
Cleaning agents	0.009	kg
Tyres	0.11	kg
Drinking water	0.017	kg
Surface water	23.6	kg
Lubricants, motors	0.013	kg
Adhesives		
Melamine urea formaldehyde	0.212	kg
Phenol resorcinol formaldehyde	0.012	kg
Polyurethane	0.291	kg
Outputs	**Quantity**	**Unit**
Products		
Structural timber	1	m³
Co-products (shavings and wood chips)	0.456	m³
Bark from roundwood input (12 %)	0.0721	m³
Airborne emissions		
Formaldehyde from adhesive	0.000318	kg
Acetone from adhesive	0.0146	kg
Others		
Wastes	0.231	kg
Waste water/partly as emissions into air	23.2	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 13-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of structural timber.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infrastructure.

Table 13-3: Input/0utput table of woody resources for the production of structural timber/RER

INPUTS		
Softwood, under bark	0.529	m³
Sawn timber, undried	0.379	m³
Sawn timber, kiln dried	0.549	m³
OUTPUTS		
Structural timber	1	m³
	395.6	kg
Co-products (shavings, wood chips and bark)	219.5	kg
of which used energetically	*61.7*	*kg*
of which sold externally	*157.8*	*kg*
USE AS WOOD FUEL		
Post-consumer wood	116.0	MJ
converted with 19.217 MJ/kg LHV	*6.03*	*kg*
Residual wood, internal sources	962.6	MJ
converted with 19.217 MJ/kg LHV	*50.1*	
Bark, internal sources	223.7	MJ
converted with 19.217 MJ/kg LHV	*11.6*	
Sum: fuel wood from external sources	*116.0*	*MJ*
	6.0	*kg*
Sum: fuel wood from internal sources	*1186.3*	*MJ*
	61.7	*kg*

13.4 Modelling of the unit process

The dataset is modelled as follows (Table 13-4):

Table 13-4: Modelling of the production process of structural timber, average glue mix, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Structural timber, average glue mix, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	23.2*allocation_factor	21.7	kg	
Materials/fuels				
sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	0.529*allocation_factor	0.496	m^3	
sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	0.379*allocation_factor	0.355	m^3	
sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	0.549*allocation_factor	0.514	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	58.7*allocation_factor	55	kWh	
Natural gas, burned in boiler condensing modulating >100kW/RER	6.23*allocation_factor	5.84	MJ	
Light fuel oil, burned in industrial furnace 1MW, non-modulating/RER	2.265*allocation_factor	2.12	MJ	
Wood chips, post-consumer wood, burned in furnace 1000kW/CH	(116+39.2)*allocation_factor	145	MJ	inkl. "others (also vegetable oils)"
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	(962.6+223.7)*allocation_factor	1110	MJ	
diesel, burned in building machine, with particle filter/CH	50.5*allocation_factor	47.3	MJ	
Lubricating oil, at plant/RER	(0.082+0.013)*allocation_factor	0.089	kg	
Steel, low-alloyed, at plant/RER	0.016*allocation_factor	0.015	kg	
Steel product manufacturing, average metal working/RER	0.016*allocation_factor	0.015	kg	
Soap, at plant/RER	0.009*allocation_factor	0.00843	kg	
Synthetic rubber, at plant/RER	0.110*allocation_factor	0.103	kg	
tap water, at user/kg/RER	0.017*allocation_factor	0.0159	kg	
Melamine, at plant/RER	MUF*0.235*allocation_factor	0.0467	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	0.0399	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	0.0663	kg	33.4% of MUF system; according to Rüter & Diederichs

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.000842	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs
Phenol, at plant/RER	PRF*0.536*allocation_factor	0.00603	kg	
Benzene, at plant/RER	PRF*0.157*allocation_factor	0.00176	kg	Proxy for resorcinol, i.e. dihydroxy-benzene
Formaldehyde, production mix, at plant/RER	PRF*0.308*allocation_factor	0.00346	kg	
Polyurethane, rigid foam, at plant/RER	PUR*allocation_factor	0.273	kg	
Transport, lorry >16t, fleet average/RER	(0.529*800*1.12*100+(116+39.2)/19.4*100+0.016*100+(0.082+0.013+0.009+0.110+MUF*1.02+PUR+PRF)*100)/1000*allocation_factor	45.2	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, freight, rail/RER	(0.529*800*1.12*0+(116+39.2)/19.4*0+0.016*200+(0.082+0.013+0.009+0.110+MUF*1.02+PUR+PRF)*600)/1000*allocation_factor	0.415	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.232+0.110+0.082+0.013)*10/1000*allocation_factor	0.00409	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for GLULAM
Emissions to air				
Formaldehyde	0.000318*allocation_factor	0.000298	kg	based on Rüter & Diederichs (2012)
Acetone	0.0146*allocation_factor	0.0137	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	0.232*allocation_factor	0.217	kg	
Recycling steel and iron/RER	0.016*allocation_factor	0.015	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.110*allocation_factor	0.103	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	(0.082+0.013)/(1-0.1)*allocation_factor	0.0989	kg	

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.0232*allocation_factor	0.0217	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		250	Euro2005	
m_chips		157.8	kg oven-dry	
p_chips		0.107	Euro2005	
MUF		0.212	kg/m^3	
PRF		0.012	kg/m^3	
PUR		0.291	kg/m^3	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_chips*p_chips)	0.937		

13.5 Results

In Tables 13-5 to 13-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 13-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Structural timber, average glue mix, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**1782**	**4.09**
	kWh	**495**	**1.14**
CED renewable	**MJ**	**12764**	**29.3**
	kWh	**3546**	**8.13**
CED total	**MJ**	**14546**	**33.4**
	kWh	**4041**	**9.27**
Weight			*436*

Table 13-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Structural timber, average glue mix, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	122	0.28
Energy resources	20141	46.19
Mineral resources	4168	9.56
Land use	94043	215.69
Global warming	45028	103.28
Ozone layer depletion	36	0.08
Main air pollutants and PM	53140	121.88
Carcinogenic substances into air	8585	19.69
Heavy metals into air	8841	20.28
Water pollutants	4637	10.63
POP into water	1273	2.92
Heavy metals into water	5207	11.94
Pesticides into soil	288	0.66
Heavy metals into soil	2489	5.71
Radioactive substances into air	0	0
Radioactive substances into water	435	1.00
Noise	4268	9.79
Non radioactive waste to deposit	167	0.38
Radioactive waste to deposit	14065	32.26
Sum	**266931**	**612.2**
Weight		*436*

Table 13-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Structural timber, average glue mix, at plant/RER**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**98.0**	**0.225**
Weight		*436*

13.6 Interpretation

Table 13-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 13-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/CH	sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	2.0%	1.5%	3.0%	0.7%	0.1%	0.1%	0.2%
Mineral resources	0.2%	0.4%	0.7%	0.0%	0.0%	0.1%	0.2%
Land use	8.8%	9.9%	16.4%	0.0%	0.0%	0.0%	0.1%
Global warming	0.9%	2.1%	6.1%	4.6%	0.3%	1.0%	1.8%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.7%	2.3%	8.1%	1.5%	4.5%	1.0%	1.8%
Carcinogenic substances into air	0.0%	0.1%	1.1%	0.1%	1.4%	0.1%	0.4%
Heavy metals into air	0.1%	0.2%	1.1%	0.2%	1.2%	0.1%	0.5%
Water pollutants	0.2%	0.5%	0.6%	0.1%	0.0%	0.2%	0.2%
POP into water	0.0%	0.1%	0.2%	0.0%	0.0%	0.1%	0.1%
Heavy metals into water	0.1%	0.3%	0.7%	0.2%	0.0%	0.2%	0.4%
Pesticides into soil	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.1%	0.1%	0.0%	0.6%	0.0%	0.1%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Noise	0.0%	0.3%	0.4%	0.0%	0.0%	0.4%	0.4%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	0.0%	0.6%	1.7%	2.5%	0.4%	0.1%	0.1%
Sum	**13.1%**	**18.5%**	**40.2%**	**10.2%**	**8.5%**	**3.3%**	**6.2%**

14 Three and five layered board production/RER

14.1 Description of the product

Three and five layered boards is a wood panel product made from gluing layers of solid-sawn timber together. Each layer of boards is oriented perpendicular to adjacent layers and glued on the wide faces of each board, usually in a symmetric way so that the outer layers have the same orientation. An odd number of layers is most common, but there are configurations with even numbers as well (which are then arranged to give a symmetric configuration). Regular timber is an anisotropic material, meaning that the physical properties change depending on the direction at which the force is applied. By gluing layers of wood at perpendicular angles, the panel is able to achieve better structural rigidity in both directions. It is similar to plywood but with distinctively thicker laminations.

3- and 5- layered boards are comparable to cross-laminated timber (CLT) but the resulting boards are thinner and exclusively used in non-structural applications.

The composition of the inventoried three and five layered board/RER is displayed in Table 14-1.

Table 14-1: Composition of the inventoried three and five layered board/RER

Composition	kg/m³	%
Wood [1)]	395.6	87.34%
of which carbon	*170.4*	*43.09%*
Water [1)]	39.6	8.73%
Melamine urea formaldehyde adhesive	17.8	3.93%
Total	**453.0**	**100%**

[1)] wood and water content has been recalculated as the density of 453 kg/m³ reported in Rüter & Diederichs (2012) is considered to be too high for three and five layered board made from current softwood species such as spruce and fir (see Sell 1997) and given the usually grading strength C16/C24. For the recalculation of the wood and water content, an average oven-dry density of converted with a basic wood density of 430 kg dry/m³ wet kg/m³ and a moisture content of u = 10 % is assumed (whereas in practice, wood is kiln dried to u = 12 %). Considering the resulting shrinkage in volume of about 8 %, this leads to a re-calculated basic wood density (kg oven-dry matter/m³ wet volume) of 396 kg/m³.

Synonyms, German name: 3-Schicht-/5-Schicht Massivholzplatte

14.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German 3- and 5-layered board production covering about 100% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of MUF -adhesive.

14.3 Description of the unit process

Table 14-2 lists the inputs and outputs as a gate-to-gate inventory for the production of 3- and 5-layered board. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies a different level of processing of the woody raw material per production site.

Table 14-2: Life cycle inventory (gate-to-gate) for the production of three and five layered boards/RER

Inputs	Quantity	Unit
Wooden raw materials		
Softwood, under bark	2.492	m³
Sawn timber, undried	0.078	m³
Sawn timber, kiln dried	0.133	m³
Electricity	179.4	kWh
Fuels		
Post-consumer wood	256.0	MJ
Residual wood, internal sources	1444.8	MJ
Ancillary materials		
Diesel	0.919	kg
	39.3	*MJ*
Lubricants, machines	0.26	kg
Cutting materials	0.028	kg
Cleaning agents	0.019	kg
Tyres	0.155	kg
Drinking water	48.1	kg
Surface water	40.2	kg
Lubricants, motors	0.034	kg
Adhesives		
Melamine urea formaldehyde	17.793	kg
Outputs	**Quantity**	**Unit**
Products		
Three and five layered board	1	m³
Co-products (shavings and wood chips)	1.70	m³
Bark from roundwood input (12 %)	0.340	m³
Airborne emissions		
Formaldehyde from adhesive	0.0267	kg
Others		
Wastes	0.495	kg
Waste water/partly as emissions into air	88.3	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 14-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of - and 5-layered board.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infra-structure.

Table 14-3: Input/0utput table of woody resources for the production of three and five layered boards/RER

INPUTS		
Softwood, under bark	2.492	m^3
Sawn timber, undried	0.078	m^3
Sawn timber, kiln dried	0.133	m^3
OUTPUTS		
Three and five layered board	1	m^3
	395.6	*kg*
Co-products (shavings, wood chips and bark)	800.0	kg
of which used energetically	*75.2*	*kg*
of which sold externally	*724.8*	*kg*
USE AS WOOD FUEL		
Post-consumer wood	256.0	MJ
converted with 19.217 MJ/kg LHV	*13.3*	*kg*
Residual wood, internal sources	1444.8	MJ
converted with 19.217 MJ/kg LHV	*75.2*	
Sum: fuel wood from external sources	*256.0*	*MJ*
	13.3	*kg*
Sum: fuel wood from internal sources	*1444.8*	*MJ*
	75.2	*kg*

14.4 Modelling of the unit process

The dataset is modelled as follows (Table 14-4):

Table 14-4: Modelling of the production process of three- and five-layered board, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Three- and five-layered board, at plant/RER		1	m^3	
Resources				
Water, process, unspecified natural origin/kg	40.2*allocation_factor	34.7	kg	
Materials/fuels				
sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	2.492*allocation_factor	2.15	m^3	
sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	0.078*allocation_factor	0.0672	m^3	
sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	0.133*allocation_factor	0.115	m^3	
electricity, medium voltage, production RER, at grid/kWh/RER	179.4*allocation_factor	155	kWh	
Wood chips, post-consumer wood, burned in furnace 1000kW/CH	(256+0)*allocation_factor	221	MJ	inkl. "others (also vegetable oils)"
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	(1444.9+0)*allocation_factor	1250	MJ	
diesel, burned in building machine, with particle filter/CH	39.3*allocation_factor	33.9	MJ	
Lubricating oil, at plant/RER	(0.26+0.034)*allocation_factor	0.253	kg	
Steel, low-alloyed, at plant/RER	0.028*allocation_factor	0.0241	kg	
Steel product manufacturing, average metal working/RER	0.028*allocation_factor	0.0241	kg	
Soap, at plant/RER	0.019*allocation_factor	0.0164	kg	
Synthetic rubber, at plant/RER	0.155*allocation_factor	0.134	kg	
tap water, at user/kg/RER	48.1*allocation_factor	41.5	kg	
Melamine, at plant/RER	MUF*0.235*allocation_factor	3.6	kg	23.5% of MUF system; according to Rüter & Diederichs
Urea, as N, at regional storehouse/RER	MUF*(2*14/60)*0.431*allocation_factor	3.08	kg	43.1% of MUF system; according to Rüter & Diederichs
Formaldehyde, production mix, at plant/RER	MUF*0.334*allocation_factor	5.12	kg	33.4% of MUF system; according to Rüter & Diederichs
Ammonium sulphate, as N, at regional storehouse/RER	MUF*(2*14/132)*0.02*allocation_factor	0.0651	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Transport, lorry >16t, fleet average/RER	(2.492*800*1.12*100+(256+0)/19.4*100+0.028*100+(0.26+0.034+0.019+0.155+MUF*1.02+PUR+EPI+PRF)*100)/1000*allocation_factor	195	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, freight, rail/RER	(2.492*800*1.12*0+(256+0)/19.4*0+0.028*200+(0.26+0.034+0.019+0.155+MUF*1.02+PUR+EPI+PRF)*600)/1000*allocation_factor	9.63	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.495+0.155+0.26+0.034)*10/1000*allocation_factor	0.00814	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-08	p	according to ecoinvent 2.2 DS for GLULAM
Emissions to air				
Formaldehyde	0.0267*allocation_factor	0.0230	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	0.495*allocation_factor	0.427	kg	
Recycling steel and iron/RER	0.028*allocation_factor	0.0241	kg	
disposal, rubber, unspecified, 0% water, to municipal incineration/kg/CH	0.155*allocation_factor	0.134	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	(0.26+0.034)/(1-0.1)*allocation_factor	0.282	kg	
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.0883*allocation_factor	0.0761	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		485	Euro2005	
m_chips		724.8	kg oven-dry	
p_chips		0.107	Euro2005	
MUF		17.79	kg/m^3	
Calculated parameters				

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_chips*p_chips)	0.862		

14.5 Results

In Tables 14-5 to 14-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 14-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Three- and five-layered board, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**3396**	**7.50**
	kWh	**943**	**2.08**
CED renewable	**MJ**	**21803**	**48.1**
	kWh	**6056**	**13.4**
CED total	**MJ**	**25199**	**55.6**
	kWh	**7000**	**15.5**
Weight			*453*

Table 14-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Three- and five-layered board, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	190	0.42
Energy resources	35585	78.55
Mineral resources	5288	11.67
Land use	116662	257.53
Global warming	81755	180.47
Ozone layer depletion	58	0.13
Main air pollutants and PM	63501	140.18
Carcinogenic substances into air	8705	19.22
Heavy metals into air	11977	26.44
Water pollutants	6893	15.22
POP into water	1917	4.23
Heavy metals into water	7660	16.91
Pesticides into soil	255	0.56
Heavy metals into soil	3046	6.72
Radioactive substances into air	0	0
Radioactive substances into water	743	1.64
Noise	6694	14.78
Non radioactive waste to deposit	245	0.54
Radioactive waste to deposit	23504	51.89
Sum	**374680**	**827.1**
Weight		*453*

Table 14-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	**Three- and five-layered board, at plant/RER**	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**179**	**0.394**
Weight		*453*

14.6 Interpretation

Table 14-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 14-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

mpact category	sawlog and veneer log, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	sawnwood, board, softwood, raw, air dried (u=20%), at sawmill/m3/RER	sawnwood, board, softwood, dried (u=10%), planed, at sawmill/m3/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	Melamine, at plant/RER	Urea, as N, at regional storehouse/RER	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	6.1%	0.2%	0.5%	1.4%	0.0%	0.3%	0.2%	0.4%	0.3%
Mineral resources	0.6%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.3%	0.1%
Land use	27.1%	1.3%	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
Global warming	2.6%	0.3%	1.0%	9.3%	0.3%	2.2%	1.2%	3.1%	1.8%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	2.3%	0.2%	1.3%	3.1%	3.6%	1.2%	0.6%	3.0%	1.6%
Carcinogenic substances into air	0.1%	0.0%	0.2%	0.2%	1.1%	0.1%	0.0%	0.2%	0.4%
Heavy metals into air	0.2%	0.0%	0.2%	0.5%	0.9%	0.5%	0.3%	0.3%	0.4%
Water pollutants	0.6%	0.0%	0.1%	0.2%	0.0%	0.2%	0.1%	0.5%	0.2%
POP into water	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%
Heavy metals into water	0.3%	0.0%	0.1%	0.3%	0.0%	0.2%	0.1%	0.6%	0.3%
Pesticides into soil	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.1%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.1%	0.1%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
Noise	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.0%	1.2%	0.3%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive waste to deposit	0.1%	0.1%	0.3%	4.9%	0.3%	0.2%	0.1%	0.2%	0.2%
Sum	**40.5%**	**2.4%**	**6.4%**	**20.4%**	**6.8%**	**5.0%**	**2.7%**	**10.1%**	**5.9%**

15 Tubular particleboard production/RER

15.1 Description of the product

Particleboard – also known as particle board, and chipboard – is an engineered wood product manufactured from wood chips, sawmill shavings, or even sawdust, and a synthetic resin or other suitable binder, which is pressed and extruded.

Like a bridge construction, tubular particleboard provides an ideal combination of light weight and stability. Compared to solid boards, the weight of tubular particleboard is reduced by up to 60%.

The composition of the inventoried tubular particleboard/RER is displayed in Table 15-1.

Table 15-1: Composition of the inventoried tubular particleboard/RER

Composition	kg/m³	%
Wood	235.2	86.47%
of which carbon	*117.6*	*43.24%*
Water	16.32	6.00%
Urea formaldehyde adhesive	20.14	7.41%
Paraffin (hydrophobing)	0.34	0.13%
Total	**272**	**100%**

Tubular particleboards are used for door cores, isolation boards, furniture, packing, and decoration.

Synonyms, German name: Röhrenspanplatte

15.2 Sampling and representativeness

The life cycle inventory has been taken from the study by Rüter & Diederichs (2012). It represents the technology of a sample of German tubular particleboard production covering about 84.9% of the total production volume.

Emissions from the use of glue have been taken from Rüter & Diederichs (2012) assuming an emission of 0.0015 kg of formaldehyde per kg of UF adhesive.

15.3 Description of the unit process

Table 15-2 lists the inputs and outputs as a gate-to-gate inventory for the production of tubular particleboard. It should be noted that this inventory represents an average gate-to-gate inventory of all the production sites included in the sample, which implies a different level of processing of the woody raw material per production site.

Table 15-2: Life cycle inventory (gate-to-gate) for the production of tubular particleboard/RER

Inputs	Quantity	Unit
Wooden raw materials		
Pulp logs	0.008	t (oven-dry)
Wood chips	0.227	t (oven-dry)
Electricity	35.81	kWh
Fuels		
Natural gas	3.928	MJ
Light fuel oil	55.498	MJ
Heavy fuel oil	426.879	MJ
Residual wood, internal sources	891.142	MJ
Ancillary materials		
Diesel	0.3	kg
	12.84	*MJ*
Lubricants	0.015	kg
Metals	0.27	kg
Sanding belts	0.06	kg
Drinking water	36.8	kg
Adhesives		
Urea formaldehyde	20.1	kg
Additives		
Hydrophobing	0.339	kg
Outputs	**Quantity**	**Unit**
Products		
Tubular particle board	1	m^3
Co-products (shavings and wood chips)	0.0500	t (oven-dry)
Bark from roundwood input (12 %)	0.00096	t (oven-dry)
Airborne emissions		
Formaldehyde from adhesive	0.0302	kg
Others		
Wastes	0.345	kg
Waste water/partly as emissions into air	36.8	kg

The inputs of ancillary materials (excluding diesel, lubricants, cleaning agents and water) are also inventoried as wastes.

In addition, 3.33E-08 units of the dataset “wooden board factory, organic bonded boards” is inventoried as infrastructure; the value is taken from ecoinvent 2.2 for the production of organically bonded wood-based boards.

Table 15-3 provides a mass balance of the woody resources as an input/output table for the life cycle inventory of tubular particleboard.

The total sum of wood from internal and external sources used for energy purposes is used as an input for the quantification of the associated airborne emissions, wood ash for disposal and required infra-structure.

Table 15-3: Input/0utput table of woody resources for the production of tubular particleboard/RER

INPUTS		
Pulp logs	0.008	t (oven-dry)
corrected value according to mass balance	*9.59*	*kg*
Wood chips	0.227	t (oven-dry)
corrected value according to mass balance	*272.0*	*kg*
OUTPUTS		
Tubular particle board	1	m^3
	235.2	*kg*
Co-products (shavings, wood chips and bark)	46.4	kg
of which used energetically	*46.4*	*kg*
of which sold externally	*0.0*	*kg*
USE AS WOOD FUEL		
Residual wood, internal sources	891.1	MJ
converted with 19.217 MJ/kg LHV	*46.4*	*kg*
Sum: fuel wood from external sources	*0.0*	*MJ*
	0.0	*kg*
Sum: fuel wood from internal sources	*891.1*	*MJ*
	46.4	*kg*

15.4 Modelling of the unit process

The dataset is modelled as follows (Table 15-4):

Table 15-4: Modelling of the production process of tubular particleboard, at plant/RER in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Tubular particleboard, at plant/RER		1	m^3	
Materials/fuels				
pulpwood, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	80/387*allocation_factor	0.207	m^3	basic wood density: 387 kg/m^3
Wood chips, softwood, from industry, u=40%, at plant/RER	227/169*allocation_factor	1.34	m^3	bulk density: 169 kg/m^3
electricity, medium voltage, production RER, at grid/kWh/RER	53.4*allocation_factor	53.4	kWh	
Natural gas, burned in boiler modulating >100kW/RER	3.928*allocation_factor	3.93	MJ	
Light fuel oil, burned in industrial furnace 1MW, non-modulating/RER	55.5*allocation_factor	55.5	MJ	
Heavy fuel oil, burned in industrial furnace 1MW, non-modulating/RER	426.9*allocation_factor	427	MJ	
Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	891*allocation_factor	891	MJ	
diesel, burned in building machine, with particle filter/CH	12.84*allocation_factor	12.8	MJ	
Lubricating oil, at plant/RER	0.015*allocation_factor	0.015	kg	
Steel, low-alloyed, at plant/RER	0.27*allocation_factor	0.27	kg	
Steel product manufacturing, average metal working/RER	0.27*allocation_factor	0.27	kg	
sanding belt	0.06*allocation_factor	0.06	kg	
tap water, at user/kg/RER	36.8*allocation_factor	36.8	kg	
Melamine formaldehyde resin, at plant/RER	20.1*allocation_factor	20.1	kg	
Ammonium sulphate, as N, at regional storehouse/RER	20.1*(2*14/132)*0.02*allocation_factor	0.0853	kg	2% hardener based on solid mass of MUF-glue; according to Rüter & Diederichs
Paraffin, at plant/RER		0.339	kg	
Transport, lorry >16t, fleet average/RER	(80/387*800*1.12*100+227*1.4*100+0.27*100+(0.015+0.06+20.1*1.02+0.339)*100)/1000*allocation_factor	52.4	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, freight, rail/RER	(80/387*800*1.12*0+227*1.4*100+0.27*200+(0.015+0.06+20.1*1.02+0.339)*600)/1000*allocation_factor	44.4	tkm	distances according to Frischknecht et al. 2007; transport weight of softwood; 800 kg/m^3
Transport, lorry 20-28t, fleet average/CH	(0.345+0.015+0.06)*10/1000*allocation_factor	0.0042	tkm	Transport to waste disposal; distances according to Frischknecht et al. 2007

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Wooden board manufacturing plant, organic bonded boards/RER/I		3.33E-8	p	according to ecoinvent 2.2 DS for particleboard production
Emissions to air				
Formaldehyde	0.0302*allocation_factor	0.0302	kg	based on Rüter & Diederichs (2012)
Waste to treatment				
disposal, municipal solid waste, 22.9% water, to municipal incineration/kg/CH	(0.345+0.06)*allocation_factor	0.405	kg	
Recycling steel and iron/RER	0.270*allocation_factor	0.27	kg	
Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH	0.015/(1-0.1)*allocation_factor	0.0167	kg	
Treatment, particle board production effluent, to wastewater treatment, class 3/CH	0.0368*allocation_factor	0.0368	m^3	
Input parameters				
v_main_product		1	m^3	
p_main_product		162.75	Euro2005	
m_chips		0	kg oven-dry	
p_chips		0.107	Euro2005	
Calculated parameters				
allocation_factor	v_main_product*p_main_product/(v_main_product*p_main_product+m_chips*p_chips)	1		

15.5 Results

In Tables 15-5 to 15-7, the results of the life cycle assessment are documented per kg in line with the requirements for insulation materials of the KBOB recommendation.

Table 15-5: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: cumulated primary energy demand (CED)

Impact category	**Unit**	**Tubular particleboard, at plant/RER**	
		per m^3	per kg
CED non-renewable	**MJ**	**3406**	**12.5**
	kWh	**946**	**3.48**
CED renewable	**MJ**	**6679**	**24.6**
	kWh	**1855**	**6.82**
CED total	**MJ**	**10085**	**37.1**
	kWh	**2801**	**10.3**
Weight			*272*

Table 15-6: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: eco-scarcity points UBP 2013

Impact category	**Tubular particleboard, at plant/RER**	
	UBP/m^3	UBP/kg
Water resources	140	0.51
Energy resources	19011	69.89
Mineral resources	3036	11.16
Land use	12558	46.17
Global warming	83923	308.54
Ozone layer depletion	63	0.23
Main air pollutants and PM	53801	197.80
Carcinogenic substances into air	5869	21.58
Heavy metals into air	20811	76.51
Water pollutants	8137	29.91
POP into water	2287	8.41
Heavy metals into water	7900	29.05
Pesticides into soil	36	0.13
Heavy metals into soil	1561	5.74
Radioactive substances into air	0	0
Radioactive substances into water	382	1.40
Noise	3842	14.13
Non radioactive waste to deposit	229	0.84
Radioactive waste to deposit	12087	44.44
Sum	**235672**	**866.4**
Weight		*272*

Table 15-7: Results of the life cycle assessment according to the requirements of the KBOB recommendation 2016: greenhouse gas emissions GWP100

Impact category	Tubular particleboard, at plant/RER	
	kg CO_2 eq/m^3	kg CO_2 eq/kg
IPCC GWP 100a	**184**	**0.675**
Weight		*272*

15.6 Interpretation

Table 15-8 identifies the processes of the production process contributing more than 2% to the sub-categories of UPB 2013 as compared to the total UBP 2013 for the production process.

Table 15-8: Contributions of the most relevant processes of the production process to the sub-categories of UPB 2013 (red: processes contributing more than 2% to the total UBP 2013 of the production

Impact category	pulpwood, softwood, sustainable forest management, measured as solid wood under bark, at forest road/m3/RER	Wood chips, softwood, from industry, u=40%, at plant/RER	electricity, medium voltage, production RER, at grid/kWh/RER	Heavy fuel oil, burned in industrial furnace 1MW, non-modulating/RER	Wood chips, from industry, softwood, burned in furnace 300kW/CH ohne Holzinput	Melamine formaldehyde resin, at plant/RER	Transport, lorry >16t, fleet average/RER	others
Water resources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Energy resources	0.9%	2.3%	0.8%	0.8%	0.1%	2.7%	0.2%	0.3%
Mineral resources	0.1%	0.1%	0.0%	0.1%	0.0%	0.6%	0.1%	0.2%
Land use	4.2%	0.9%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
Global warming	0.4%	0.7%	5.1%	7.5%	0.3%	17.9%	1.3%	2.4%
Ozone layer depletion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Main air pollutants and PM	0.4%	0.5%	1.7%	4.1%	4.1%	9.4%	1.3%	1.4%
Carcinogenic substances into air	0.0%	0.0%	0.1%	0.1%	1.3%	0.6%	0.1%	0.3%
Heavy metals into air	0.0%	0.1%	0.3%	3.1%	1.0%	3.7%	0.1%	0.5%
Water pollutants	0.1%	0.1%	0.1%	1.4%	0.0%	1.3%	0.2%	0.3%
POP into water	0.0%	0.0%	0.0%	0.5%	0.0%	0.3%	0.1%	0.1%
Heavy metals into water	0.0%	0.1%	0.2%	0.6%	0.0%	1.7%	0.3%	0.5%
Pesticides into soil	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Heavy metals into soil	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%
Radioactive substances into air	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Radioactive substances into water	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Noise	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.5%	0.4%
Non radioactive waste to deposit	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Radioactive waste to deposit	0.0%	0.3%	2.7%	0.1%	0.3%	1.4%	0.1%	0.2%
Sum	**6.3%**	**5.0%**	**11.2%**	**18.2%**	**7.7%**	**40.5%**	**4.3%**	**6.8%**

16 Marktdatensätze “at regional storage”

Fortheir integration into the “KBOB-list”, a representative market mix of imported and domestically produced products is required, including an import scenario for the imported share plus a transport scenario to a regional storage for domestically produced products (if applicable).

16.1 Cross-laminated timber, average glue mix, at regional storage/CH

Cross-laminated timber production has started only recently in Switzerland; consequently a 100%-Import scenario is calculated.

An import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007).

The resulting modelling is documented in Table 16-1.

Table 16-1: Modelling of cross-laminated timber, average glue mix, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Cross-laminated timber, average glue mix, at regional storage/CH		1	m^3	
Materials/fuels				
Cross-laminated timber, average glue mix, at plant/RER		1	m^3	427.7kg/m^3
Transport, freight, rail/RER U	427.7*200/1000	88.5	tkm	
Transport, lorry >28t, fleet average/CH U	427.7*50/1000	22.1	tkm	

16.2 Glued laminated timber, average glue mix, at regional storage/CH

Data on the import share of imported glued laminated timber of total consumption is Switzerland is not available. Holzindustrie Schweiz estimates that about 2/3 of Glulam are imported[3].

For the impored share, an import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed; domestically produced Glulam is usually transported directly from the producer to the production site.

The resulting modelling is documented in Table 16-2.

[3] Urs Luginbühl/HIS, personal electronic communication, 26.2.2020

Table 16-2: Modelling of glued laminated timber, average glue mix, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued laminated timber, average glue mix, at regional storage/CH		1	m^3	
Materials/fuels				
Glued laminated timber, average glue mix, at plant/RER		0.666	m^3	444 kg/m^3
Glued laminated timber, average glue mix, at plant CH		0.333	m^3	440 kg/m^3
Transport, freight, rail/RER U	0,666*444*200/1000	59.1	tkm	
Transport, lorry >28t, fleet average/CH U	0,666*444*50/1000	14.8	tkm	

16.3 Glued solid timber, average glue mix, at regional storage/CH

Data on the import share of imported glued solid timber of total consumption is Switzerland is not available. Holzindustrie Schweiz estimates that about 2/3 of glued solid timber are imported[4].

For the impored share, an import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007); domestically produced glued solid timber is usually transported directly from the producer to the production site.

The resulting modelling is documented in Table 16-3.

Table 16-3: Modelling of glued laminated timber, average glue mix, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Glued solid timber, average glue mix, at regional storage/CH		1	m^3	
Materials/fuels				
Glued solid timber, average glue mix, at plant/RER		0.666	m^3	444 kg/m^3
Glued laminated timber, average glue mix, at plant CH		0.333	m^3	440 kg/m^3
Transport, freight, rail/RER U	0.666*444*200/1000	59.1	tkm	
Transport, lorry >28t, fleet average/CH U	0.666*444*50/1000	14.8	tkm	

16.4 Plywood, hardwood veeneer, UF-bonded, at regional storage/CH

Plywood from hardwood veneer is produced in minor quantities and manily for speciality applications outside the construction sector only. Thus, a 100% import scenario is calculated.

An import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007).

The resulting modelling is documented in Table 16-4.

[4] Urs Luginbühl/HIS, personal electronic communication, 26.2.2020

Table 16-4: Modelling of plywood, hardwood veeneer, UF-bonded, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Plywood, hardwood veeneer, UF-bonded, at regional storage/CH		1	m^3	
Materials/fuels				
Plywood, hardwood veeneer, UF-bonded, at plant/RER		1	m^3	823 kg/m^3
Transport, freight, rail/RER U	823*200/1000	165	tkm	
Transport, lorry >28t, fleet average/CH U	823*50/1000	41.2	tkm	

16.5 Structural timber production, at regional storage/CH

Structural timber is not produced in Switzerland. Thus, a 100% import scenario is calculated.

An import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007).

The resulting modelling is documented in Table 16-5.

Table 16-5: Modelling of structural timber production, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Structural timber, average glue mix, at regional storage/CH		1	m^3	
Materials/fuels				
Structural timber, average glue mix, at plant/RER		1	m^3	437.7 kg/m^3
Transport, freight, rail/RER U	437.7*200/1000	87.1	tkm	
Transport, lorry >28t, fleet average/CH U	437.7 *50/1000	21.8	tkm	

16.6 Three and five layered board production, at regional storage/CH

Three and five layered boards are not produced in Switzerland. Thus, a 100% import scenario is calculated.

An import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007).

The resulting modelling is documented in Table 16-6.

Table 16-6: Modelling of structural timber production, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Three and five layered board production, at regional storage/CH		1	m^3	
Materials/fuels				
Three and five layered board production, at plant/RER		1	m^3	453 kg/m^3
Transport, freight, rail/RER U	453*200/1000	90.6	tkm	
Transport, lorry >28t, fleet average/CH U	453*50/1000	22.7	tkm	

16.7 Tubular particleboard production, at regional storage/CH

Tubular particleboard is no produced in Switzerland. Thus, a 100% import scenario is calculated.

An import scenario of 200 km by train and 50 km by lorry for a transport to Berne is assumed (see also Frischknecht et al. 2007).

The resulting modelling is documented in Table 16-7.

Table 16-7: Modelling of tubular particleboad production, at regional storage in the KBOB:2016 data environment (KBOB 2016b)

Name of input/output (KBOB 2016)	Equation	Value	Unit	Comment
Products				
Tubular particleboard production, at regional storage/CH		1	m^3	
Materials/fuels				
Tubular particleboard production, at plant/RER		1	m^3	272 kg/m^3
Transport, freight, rail/RER U	272 *200/1000	54.4	tkm	
Transport, lorry >28t, fleet average/CH U	272 *50/1000	13.6	tkm	

16.8 Results „at regional storage/CH“

In Table 16-8, the results “at regional storage/CH are compiled.

Table 16-8: Results "at regional storage" in the KBOB:2016 data environment (KBOB 2016b)

Wirkungskategorie	Einheit	Cross-laminated timber, average glue mix, at regional storage/CH	Glued laminated timber, average glue mix, at regional storage/CH	Glued solid timber, average glue mix, at regional storage/CH	Plywood, hardwood veeneer, UF-bonded, at regional storage/CH	Structural timber production, at regional storage/CH	Three and five layered board production, at regional storage/CH	Tubular particleboard production, at regional storage/CH
UPB	UBP/m^3	**3.48E+05**	**3.03E+05**	**3.11E+05**	**1.16E+06**	**2.77E+05**	**3.85E+05**	**2.42E+05**
	UBP/kg	**786**	**685**	**702**	**1407**	**635**	**850**	**889**
IPCC GWP 100a	kg CO_2 eq/m^3	**162**	**122**	**125**	**762**	**105**	**185**	**187**
	kg CO_2 eq/kg	**0.365**	**0.276**	**0.283**	**0.925**	**0.240**	**0.409**	**0.689**
CED renewable	MJ/m^3	**14553**	**12505**	**13206**	**27649**	**12769**	**21808**	**6682**
	MJ/kg	**32.9**	**28.3**	**29.9**	**33.6**	**29.3**	**48.1**	**24.6**
	kWh/kg	**9.13**	**7.85**	**8.30**	**9.33**	**8.14**	**13.37**	**6.82**
CED non-renewable	MJ/m^3	**2991**	**2375**	**2419**	**15058**	**1890**	**3509**	**3473**
	MJ/kg	**6.76**	**5.37**	**5.47**	**18.30**	**4.34**	**7.75**	**12.77**
	kWh/kg	**1.88**	**1.49**	**1.52**	**5.08**	**1.21**	**2.15**	**3.55**
CED total	MJ/m^3	**17544**	**14880**	**15626**	**42708**	**14660**	**25317**	**10156**
	MJ/kg	**39.6**	**33.6**	**35.3**	**51.9**	**33.6**	**55.9**	**37.3**
	kWh/kg	**11.0**	**9.35**	**9.82**	**14.4**	**9.35**	**15.5**	**10.4**

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Annex 1: Detailed wood balances

Table A3-1 contains the wood balances of the inventoried datasets:

Table A3-1: Detailed wood balances of the different datasets:

	Sawlog under bark					Sawnwood raw			Sawnwood (u=10%)			other	Total input	Use			Total output
	m3	% bark	with bark	bark	basic w.d.	kg input	m3	basic w.d.	kg input	m3	basic w.d.	kg input	kg	kg	product	energet-ically	co-product	
cross-laminated timber	0.633	12%	0.719	0.0863	387.2	278.5	0	387.2	0.0	0.955	418.18	399.4	0	677.9	395.6	44.0	238.3	677.9
GLULAM RER	0.306	12%	0.348	0.0417	387.2	134.6	0.659	387.2	255.2	0.438	418.18	183.2	4.03	577.0	395.6	63.9	117.5	577.0
GLULAM CH	0					0.0	0		0.0	1.31	418.18	547.8	0	547.8	395.6	35.4	116.8	547.8
glued solid timber	0.389	12%	0.442	0.0530	387.2	171.2	0.438	387.2	169.6	0.72	418.18	301.1	5.1	646.9	395.6	53.5	197.8	646.9
plywood	2.268	10%	2.520	0.2520	540	1360.8	0		0.0	0		0.0	0	1360.8	680.0	602.2	78.6	1360.8
structural timber	0.529	12%	0.601	0.0721	387.2	232.8	0.379	387.2	146.7	0.549	418.18	229.6	6.03	615.1	395.6	61.7	157.8	615.1
3/5 layered board	2.492	12%	2.832	0.3398	387.2	1096.5	0.078	387.2	30.2	0.133	418.18	55.6	13.3	1195.6	395.6	75.2	724.8	1195.6
tubular particleboard	0.0240	12%	0.027	0.0033	387.2	10.5	0		0.0	0		0.0	272	282.5	235.2	46.4	0.942	282.5