CUSTOMER REPORT

VTT-CR- 03665 -18 | 19.7.2018

Life cycle assessment for EcoCocon exterior wall panel

Authors: Sirje Vares

Confidentiality: Confidential

Report's title

Life cycle assessment for EcoCocon Exterior wall panel

Customer, contact person, address	**Order reference**
EcoCocon UAD Odminiu Str. 10-9, 01122 Vilnius, Lithuania Marius Tarvydas	VTT-CRM-158424-18
Project name	**Project number/Short name**
Life cycle assessment for EcoCocon exterior wall panel	119565, EcoCocon

Summary

The objectives of this work was to make a Life Cycle Assessment for an average EcoCocon exterior wall panel (made from straw bales). The assessment was based on LCA, which considers the entire life cycle of a product, from the raw material extraction and acquisition, through the energy and material production and manufacturing, to the use and the end of life treatment and the final disposal. Also benefits and loads beyond the system was considered.

This is a background report for the EcoCocon exterior wall panel assessment where all materials/energy flows are explained and data sources are given.

Espoo, 31.7.2018

Written by

Sirje Vares,
senior research scientist

Accepted by

Jari Shemeikka,
team leader

VTT's contact address

Vuorimiehentie 3, 02040 Espoo, Finland

Distribution

Customer, UAD EcoCocon, LT and
VTT Technical Research Centre of Finland Ltd

Contents

1 Objectives of the work

Life cycle assessment (LCA) is a method, which considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal.

The objectives of this work is make a Life Cycle Assessment for average EcoCocon exterior wall panel (made from straw bales). Life Cycle assessment is assessed according to the method described in SFS EN 15804 + A1. Functional unit in the assessment is 1 m^2 of average exterior wall system.

Assessment based on the Core rules for the assessment of construction product (SFS EN 15804 + A1).

The assessment covers next life cycle stages) (in brackets information modules according to the standard):

- Product stage (raw-material supply, raw material transport, panel manufacturing) (A1 - A3)
- Construction process (panel transportation and installation) (A4 - A5)
- Use stage (panel repair, maintenance, refurbishment, replacement during the long lasting building life) (B2 - B5)
- End of life stage (De-construction and demolition, transportation, waste processing and disposal) (C1 - C4).
- Life cycle beyond the system boundaries (benefits and loads after life cycle (D).

For compliance with the standard, only the product stage modules (A1-A3) is required for the product environmental declaration but other life cycle stages are optional. However, this proposal contains whole life cycle assessment with all process stages and information modules.

Table 1. Life cycle phases covered in this assessment (EN 15804 + A1).

Phase		**Description**	
Product Phase	A1	Provision of raw materials	X
	A2	Transport of raw materials	X
	A3	Production	X
Construction Phase	A4	Transport to the construction site	X
	A5	Installation	X
Use phase	B1-B7	*no relevant material and energy flows	X
End of Life Phase	C1	Dismantling	X
	C2	Transport for waste treatment	X

Phase		Description	
	C3	Waste management	X
	C4	Waste disposal	X
Information module	D	Benefits and loads beyond the system boundary	X

Note: X = included in life cycle assessment

The impact assessment phase of LCA is aiming at evaluating the significance of potential environmental impacts using the LCI results. LCA result considers parameters, which are describing environmental impacts, resource use, different waste categories and other environmental information like components for re-use, and recycling.

Life cycle assessment considers following impact categories:

- depletion of abiotic resources (fossil) (ADP fossils);
- depletion of abiotic resources (elements) (ADP elements);
- acidification of soil and water (AP);
- ozone depletion (ODP);
- global warming (GWP);
- eutrophication (EP);
- photochemical ozone creation (POCP).

Parameters which describing resource:

- Use of renewable primary energy excluding renewable primary energy resources used as raw materials (PERE)
- Use of renewable primary energy resources used as raw materials (PERM)
- Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials) (PERT)
- Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials (PENRE)
- Use of non-renewable primary energy resources used as raw materials (PENRM)
- Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) (PENRT)
- Use of secondary material (SM)
- Use of renewable secondary fuels RSF)
- Use of non-renewable secondary fuels (NRSF)

- Net use of fresh water (FW)

Other environmental information describing different waste categories and output flows:

- Hazardous, non-hazardous and radioactive waste disposed (HWD, NHWD, RWD)
- Components for re-use (CRU),
- Materials for recycling (MFR),
- Materials for energy recovery (MER)
- Exported electricity and heat (EEE, EEH).

2 Product

2.1 General product description

EcoCocon Straw Modules (Panels) are produced by EcoCocon UAD in Lithuania. The load-bearing, exterior wall panels are insulated with straw and used for modular construction. According to the producer, no additives have been added to straw or wood. Panels are Passivhaus and Cradle to Cradle certified.

2.2 Applications

The EcoCocon Straw Modules are used for small and medium sized buildings, for exterior, insulated and loadbearing wall segments. The walls are later covered on the inside with a clay plaster or gypsum based dry board and on the outside protected by a vapour permeable membrane and wood fibreboard. The final facade can be plastered or a ventilated facade can be installed.

In this EPD only the panels themselves are considered, without any other layers inside or outside

2.3 Panel types

The panels (modules) can individually be produced to demanded measures, depending on the project. Typically, there is a six panel size types (Table 2, Figure 1).

Table 2: Production of panel types during the year 2016-2017 in %.

Panel type	**% produced wall surface during 2016-2017**
Standard panels	52,5 %
Braced panels	17 %
Column Panels	4 %
Inclined panels	13 %

Sill panels	6 %
Lintel panels	7,5 %
	100 %

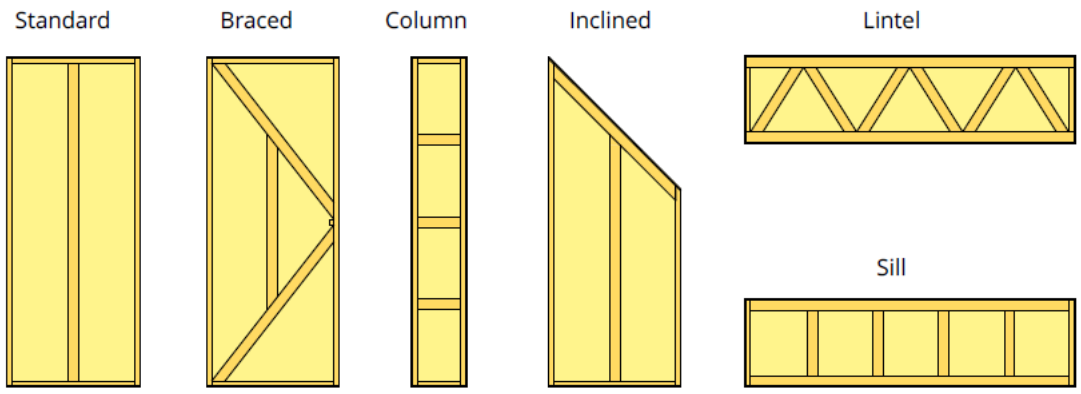

Figure 1. Wall panel types produced.

To be able to achieve an average value per m^2 for the different types of panel, two values have been taken into account:

- average % of panel types delivered during the last two years (Table 2)
- average use of materials in one type of panel (Table 3).

Table 3: Average use of materials per m^2 of panel.

	Volume %	**Weight, %**	**Weight, kg/m²**	**% Waste**	**Weight, kg/m² including waste**
Wood	9.6 %	27.18 %	17.26	10 %	19.0
Plywood	1.6 %	6.52 %	4.35	10 %	4.79
Wood fibreboard	0.2 %	0.38 %	0.23	5 %	0.24
Straw	88.6 %	64.77 %	40.62	5 %	42.65
Screws	-	1.16 %	0.74	-	0.74
Total	100 %	100 %	63.2		66.19

Material properties used for calculations based on values presented in Table 4.

Table 4. Material properties.

Material used	Value	Unit
Wood C24	350	kg/m^3
Wheat and Rye straw nominal density	110	kg/m^3
Straw nominal/max. humidity	15/20	%
Plywood (used)	640-700 (670)	kg/m^3
Wood fibreboard	270	kg/m^3
Screws	Carbon steel, martensitic stainless steel, nickel coated	

2.4 Technical data

Fire resistance tests have been made on a clay plastered (interior) and wood fibre covered (exterior) wall segment 3x3 m. The achieved values were REI120 from the interior and REIef120 from exterior side.

Panels have at all times be protected from direct contact with water.

Table 5. Technical data of the declared straw panel according to NTI-01-061:2013

Property	Value
Load-bearing capacity:	22-36 kN/m - see Technical Assessment for details
Class of reaction-to-fire performance:	B-s1,d0
Thermal resistance RD:	8.1 (m^{2}K)/W
Airborne sound insulation indicator RW (C; Ctr; C100-5000):	54 (-1;-3;0) dB
Useful life	50 year

2.5 Used materials

2.5.1 Wood

The wood is FSC certified C24 quality. The wood is purchased from SIA Baltic Wood Trading with production ready dimensions 95 mm x 45 mm and 45 mm x 45 mm. We estimate the transport

distances to be 196 km from local seller. In production, the wood is cut to correct length. We estimate that there is about 10% waste. The leftovers are used for heating during winter.

2.5.2 Straw

Straw is purchased in the form of round bales from local producers and stored in a non heated warehouse during the rest of the year. The round bales are wrapped on the round side with a thin Polypropylene lacing holding the straw together.

The straw is checked for moisture content during harvest, storing and production, and must not exceed 20% rel. moisture content. Nominal value is approx. 15%.

The straw is moved between storage and production onsite with a forklift. The remaining machinery for the production of the panels is electrical. In wall production, straw waste is 5 %, this is based on the estimation. The leftovers are used for heating during winter.

2.5.3 Plywood

The plywood is cut to dimensions from large boards on site. All tools are electrical. The Plywood is purchased from Trukme Latvia Finieris and transport is estimated to be up to 87 km from local seller. In wall production, plywood waste is 10 %, this is based on the estimation. The leftovers are used for heating during winter.

2.5.4 Wood fibreboard

Wood fibreboard is cut to size on site. Used tools are electrical. As very small amounts are used, the wood-fibre boards are taken from other deliveries to building sites. The transport is in that case negligible. We estimate that there is about 5 % waste. The leftovers are used for heating during winter.

2.5.5 Polypropylene lacing

There is 0.4 kg of Polypropylene used for one round bale (average weight 230 kg straw). That is approximately 0.0742 kg/kg straw (0.4 kg / 230 kg = 0.0742 kg). The polypropylene lacing of the round bales is returned for recycling.

It is assumed that polypropylene comes from Netherland (for Example SABIC Europe). The transportation distance to Lithuania is 1545 km.

2.5.6 Screws

The screws are delivered ready for use to the production site. The screws are delivered by Ottensten (194 km) in Lithuania but produced by Eurotec. However, the transportation distance is taking into account from manufacturing site Eurotec (Belgium, Venlo) and the distance to the Lithuania, wall manufacturing site (Kybartu) is 1484 km. Material for screws is a hot-dipp galvanized steel. There is no waste.

2.6 Production

The production facility is 100% electrical. Heating is supported by waste burning ovens in winter. For material lifting diesel and natural gas is used (Table 6).

Storage of raw materials, production of EcoCocon panels and their storage before delivery is limited to a local production site. No water is used at all for production. Some water is used for sanitary means for the workers but this is not included to the assessment.

Table 6. Use of energy in production per year and per panel-m^2 (for 3000 m^2 panels produced).

Designation	Values per year	Values per m^2	Unit
Electricity for machinery, lighting and IT	9200	3.054	kWh
Fuel for forklift (diesel)	50	0.017	litre
Fuel for forklift (natural gas)	80	0.027	litre
Biomass oven for heating	Only waste materials from production is burned		

2.6.1 Storage of finished products

Finished panels are stored until delivery in a non-heated warehouse. The transport of panels to and from the onsite storage is provided with a forklift and showed in Table 6.

2.6.2 Packaging

The panels are not separately packed - during loading on a transporter, wooden sticks are used to put the panels on. Approx. 0.4 m^3 of wood is used for 140 m^2 of panels in one lorry. That is approx. 1.3 kg low quality wood per m^2 of panel. These wooden sticks are used as well for the storage of panels on building site and it is assumed that also for the heating after end of use.

2.7 Transportation and installation

2.7.1 Transport

The EcoCocon panels are transported to the customer by the manufacturer, usually with large trailer. Panels are loaded with a forklift (2.5 h) in covered trucks (140 m2 panels fits to one truck) and delivered from production directly to the building site. As the building sites can be anywhere in Europe, the impact from transport can vary a great deal.

Here, it is estimated that the distance to the fictional building site is 100 km.

2.7.2 Unloading and installation on building site

The panels are unloaded with a Manitou forklift or crane. Panels can easily be moved by hand on the ground floor to their exact installation point. We calculate 2.5 hours for installation of panels from one truck (140 m^2).

2.8 Use phase

During the use phase, there are no material and energy flows that are relevant for this product group assessment. The stage replacement is synonymous with the product life. There are no other material and energy flows when removing the product. Stages B5 conversion / renewal, B6 energy use and B7 water use are not applicable at insulation level.

According to the EcoCocon service life catalogue, reference service life for exterior wall panel from straw is at least 50 years.

2.9 End of Life stage

Reuse or recycling does not take place under the current economic and technical conditions. In principle, incineration in a waste incineration or co-incineration plant or utilisation in biogas plants is possible.

As there are no harmful substances in the EcoCocon panels, landfill or incineration for co-generation of heat and electricity or the use in biogas plants is possible, depending on availability and legislation in the respective countries. Screws can be extracted by magnet after shredding or decomposition.

The use of straw in large-scale biomass power plants is becoming mainstream in the EU. The straw is either used directly in the form of bales, or densified into pellets, which allows for the feedstock to be transported over longer distances.

In this assessment, at the end of the use phase, the product is transported by truck to the thermal recycling plant. The mean transport distance was assumed to be 150 km.

For straw, no any densification process phase is used but other materials (wood, plywood, wood fibre board) will be processed for the incineration.

2.10 Reuse, recovery and recycling potential (Phase D)

The assumption is that the product is sent for the thermal utilisation at the end of its useful life and the credit, substituting Lithuanian electricity production, is declared in the information module D accordingly.

Material losses, in module A3, is utilized for energy, polypropylene lacing, metal screws are recycled. These credits are also assigned in module D.

Table 7 shows the result for material utilization for energy for the case when utilization efficiency is 75 %.

Table 7. Waste to Energy production, for substitution (Phase D).

	Material waste for energy utilization	Moisture content	Net Caloric value (MC 0%)	Energy	Energy, when plant efficiency is 75 %
	kg	%	MJ/kg	MJ/m^2 (kWh/m^2)	MJ/m^2 (kWh/m^2)
Wood	20.3	16 %	19	325	
Plywood	4.8	7 %	20.0	80	
Wood fibre-board	0.24	6%	19.3	4.4	
Straw	42.65		14.4 (MC 15%)	614	
Total				1023 (284)	768 (213)

MC - Moisture content

3 LCA assessment

3.1 System boundaries

LCA includes cradle to grave assessment: Production Phase (A1-A3), Construction Phase (A4-A5), Use Phase (B1-B7), Disposal Phase (C1-C4) and Credits and Loads (D).

Assessment does not include crop growth, construction of manufacturing site, human labour and employee commute, maintenance and operation of equipment.

All inputs and outputs of wall materials are recorded and included in the calculations. The background data represents company data for materials sold and produced in Europe.

3.2 Inventory data for the Production phase (A1-A3)

The cut-off criteria for the wall materials corresponding to the used data sets.

Transports in the upstream chains of separate producers are included in the generic data used.

Wall manufacturing data based on UAB EcoCocon 2016 - 2017 production year.

Generic data for the straw bale production based on the assessment from literature (Kirck 2008) (described in chapter below 3.2.1).

3.2.1 Unit data for provision of straw bales

It was assumed that there were no location-dependent differences in the cultivation and harvest of cereals within EU. In that regard values from Krick (2008) and from page 47, Table 5 can be used. As round bales are closer to large bales, it is estimated that the primary energy (PEI) for collecting, pressing and transporting (to the production site) in worst case scenario is 59.1 kWh/t and in an ideal scenario is 39.5 kWh/t. According to that, average energy consumption 50 kWh/t has been used.

The straw bales are transported from the field to the production site by tractor and then with a lorry (this is included to the straw bale production).

Straw is a by-product from the growing of Commercial crops. The raw materials needed for food production such as seeds, fertilisers and pesticides are not considered for the straw used in the product. Processes that are connected with food production are not been taken into account. Straw is used as a waste product. The reclamation of the agricultural area remains unconsidered, a possible later renaturation is outside the considered system.

The calorific value of the straw (15% moisture) at end of life through incinerating is 14.4 MJ/kg or 4032 kWh/t (Source: Teagasc).

Table 8. Inventory data for Production of Straw bales.

Input flow	Physic amount	Measure unit	Source/Comment
Straw	1	kg	
Electricity, LT, Ecoinvent, medium voltage, 2014	0,050	kWh	Amount including energy for collection, pressing and transportation of straw bales to the production site (Krick 2008)
Output flow			
Feedstock for straw	14.4	MJ	

3.2.2 Provision of raw- materials (A1)

In the following LCA calculation, only the panels themselves are included. Because the wall build up might vary for different buildings, other additional materials have to be calculated separately. Wall material (without inner and outer materials) and production wastes are included to the assessment (according to the Table 3). In addition, wooden sticks, used for transporting the panels, are taken into account.

As SIA Baltic Wood Trading has no EPD's published, environmental impacts caused from the use of wood, based on the Stora Enso Classic sawn production and EPD. It covers 90% of Stora Enso sawn timber production in Europe, among the others also some Baltic countries is included. It is assumed that this EPD (EPD Classic Sawn) represents also situation for Lithuania.

Plywood and wood fibre board are both used in a small amount. Those are the products, which produced all over Europe and in purchase process, whomever product could be obtained. In this assessment, Plywood represent MetsäWood and wood fibreboard Steico produced products.

The background data represents companies' data for materials sold and produced in Europe. Sources are presented in Table 9.

Table 9. Inventory data for the production of the raw materials used for the straw wall (Phase A1).

Input flows			
	Physic amount	Measure unit	Source/Comment
Wood	20.3 (19 + 1.3)	kg	Classic Sawn EPD (Manufacturer Stora Enso Wood Products Oy Ltd in Sweden, Austria, Finland, Latvia, Russia, Czech Respublic (verification by Vahanen Environment Oy). (Wood structure + wood sticks for wall transportation).
Plywood	4.8	kg	Plywood EPD, MetsäWood Spruce Plywood (verification by Inspecta)
Wood fibreboard	0.24	kg	EPD for Wood fibre insulation materials. STEICO SE. EPD from Institut Bauen und Umwelt e.V. (IBU) (verification by Independent verifier appointed by SVR)
Straw	42.65	kg	Estimated according to the literature (Kirck 2008)
Polypropylene lacing	0.0742	kg	Eco-profiles and EPD of the European Plastics Manufacturers Polypropylene (PP), PlasticsEurope
Screws	0.74	kg	EPD Hot-dip galvanised steel building products. Ruukki (verified by Ecobio Oy).

3.2.3 Raw material transportation (A2)

Transportation distances and amount transported based on UAB EcoCocon information. As wood fibreboards are taken from other deliveries, no transportation is accounted. Straw bale transportation is accounted to the straw bale production and thus this distance is not included here.

As the unit emission database for transport (VTT Lipasto) covers emission factors for operating vehicles, measured in mass units and allocated to each tonne of freight transported over one kilometre, the unit for transportation input is ton km (tkm)).

Table 10. Inventory data for the transportation (Phase A2).

Input flow	Physic amount	Measure unit	Source/Comment
Semi trailer combination, pay load capacity 25 tons, Highway driving	5.61	ton km*	VTT database Lipasto, road transport freight. (4.0 (structural wood and wooden sticks from package) + 0.42 (plywood) +0 (wood fibre board as wood fibre board used from other delivery) + 0 (straw, this was already included to the straw production) + 1.1 (screws) + 0.11 (polypropylene lacing) = 5.61 ton km)

* unit ton km = tonne of freight transported over one kilometre

3.2.4 Production (A3)

The primary data about the wall panel production and installation based on EcoCocon production values. Panel composition based on the production during 2016 - 2017 year, energy consumption to the year 2017. Electricity consumption during the wall panel production bases on the Lithuanian electricity production in 2014.

The energy use on production site is limited to the energy sources reported.

Production leftovers dealt here as production wastes for later utilization.

The construction and maintenance of factory building and related infrastructure have been excluded from the assessment.

Input and output flows for the process Phase A3 is given in Table 11.

Table 11. Inventory data for the Production (Phase A3).

Input flow	Physic amount	Measure unit	Source /Comment
Materials for panel production	67.49		Reported in Table 9
Electricity, market for electricity, medium voltage	3.054	kWh	Ecoinvent, Electricity LT, medium voltage transmission, 2014
Natural gas, burned in gas turbine	0.027	litre	EcoInvent data v2.0 Faist Emmenegger, M. Heck, T., Jungbluth, N. 2007. Erdgas. Sachbilanzen von Energiesystemen. Final report No. 6
Diesel used in wheel loaders	0.017	litre	VTT database Lipasto. Unit emissions for working machines, 2017.
Output flows			
Wall panel from straw	1	m2	
Wooden waste	1.73	kg	
Plywood waste	0.44	kg	
Wood fibreboard waste	0.011	kg	
Straw waste	2.03	kg	
Polypropylene lacing, waste	0.0742	kg	

3.3 Inventory data for the phase transportation to the construction site (A4-A5)

3.3.1 Transportation (A4)

Transport from the wall producer to the fictitious building site (100 km) is considered.

Table 12. Inventory data for the wall panel transportation (Phase A4).

Input flow	Physic amount	Measure unit	Comment
Semi trailer combination, pay load capacity 25 tons, Highway driving	6.45	ton km	VTT database Lipasto, road transport freight.

3.3.2 Installation (A5)

The primary data about the wall panel installation based on EcoCocon estimation of time needed unload and install panels from one truck.

Table 13. Inventory data for the phase wall installation (Phase A5).

Input flow	Physic amount	Measure unit	Comment
Wheel loaders (Diesel used in mobile crane)	0.232	litre	VTT database Lipasto. Unit emissions for working machines, 2017.
Output flow			
Wooden sticks, used in wall transportation	1.3	kg	For energy production

3.4 Inventory data for the wall use (B1 - B7)

During the use phase, there are no material and energy flows that are relevant for the LCA (see Chapter 2.7)

3.5 Inventory data for the end of life (C1 - C4)

Attribution of end-of-life processes of wood and wood-based products to modules C1 – C4 and D depending on whether a flow reaches the end-of-waste status and on the R1 value of the incineration facility (if applicable) (EN 16485).

Here it is estimated that R1 value for incineration is > 0.6, which resulting attribution of processes to information modules described below:

- C1 (dismantling) - deconstruction
- C2 (Transport for waste treatment)- transport to the incineration site
- C3 (waste management) - crushing, site operation and material combustion

3.5.1 De-construction (C1)

Building de-construction is calculated according to the Stora Enso EPD. The amount per 1 kg converted to the panel weight 63.3 kg.

Table 14. Inventory data for the phase building de-construction (Phase C1).

Input flow	Physic amount	Measure unit	Comment
De-construction	63.3	kg	Building de-construction calculated according to the EPD Classic Sawn and phase C1, de-construction.

			(Manufacturer Stora Enso Wood Products Oy Ltd in Sweden, Austria, Finland, Latvia, Russia, Czech Republic (verification by Vahanen Environment Oy)
Output flow			
Waste	63.3	kg	

3.5.2 Transport to the waste treatment (C2)

At the end of the use phase and deconstruction, the product, production wastes and wooden sticks, used in transportation, transported by truck (semi-trailer combination) to the incineration plant (Table 15).

Table 15. Inventory data for the transport to the waste treatment plant (Phase C2).

Input flow	Physic amount	Measure unit	Comment
Semi trailer combination, pay load capacity 25 tons, Highway driving	10.1	ton km	VTT database Lipasto, road transport freight.

3.5.3 Waste management (C3)

The scenario for panels at the end of use is the thermal utilisation in a waste incineration plant. Phase C3 takes into account waste preparing for the incineration and material combustion (Table 16). It is assumed that material preparing for the incineration is the same for sawn wood and plywood (including also production wastes and wooden sticks used during panel transportation.

Table 16. Inventory data for the phase waste treatment (Phase C3).

Input flow	Physic amount	Measure unit	Comment
Preparing for incineration (sawn wood and plywood)	25.1	kg	Classic Sawn EPD (Manufacturer Stora Enso Wood Products Oy Ltd in Sweden, Austria, Finland, Latvia, Russia, Czech Republic (verification by Vahanen Environment Oy), preparing for incineration
Preparing for incineration (wood fibreboard)	0.24	kg	EPD for Wood fibre insulation materials. STEICO SE. EPD from Institut Bauen und Umwelt e.V. (IBU)
Material to incineration	68.8	kg	Wood to incineration plant (efficiency 75 %) calculated according to the Classic Sawn EPD (Manufacturer Stora Enso Wood Products Oy Ltd in Sweden, Austria, Finland, Latvia, Russia, Czech

			Republic (verification by Vahanen Environment Oy).

3.5.4 Waste disposal (C4)

The sorting of residue (metals, burnt clay) and landfilling of the ashes after thermal utilisation is assumed to be extremely low and not accounted.

3.6 Inventory data for the phase D

The product will sent for the thermal utilization at the end of its useful life and declared as credit in the information module D accordingly. In addition, 5 %/10 % material loss in module A3 will used for energy. It is estimated that the energy from waste incineration plant will substitute average Lithuanian electricity production.

Caloric values is used for the estimation of energy amount for substitution. For the case when waste to energy plant efficiency is approximately 75 %.

Plastic lacing removed in module A3 will substitute primary PP production. Steel from screws returned as a scrap steel to the steelmaking process.

Table 17. Inventory data for the phase benefits and loads beyond the system boundary (Phase D)

Input flow	Physic amount	Measure unit	Comment
Energy for substitution	195	kWh	Substituting Lithuanian electricity production
PP lacing	0.0742	kg	Eco-profiles and EPD of the European Plastics Manufacturers Polypropylene (PP), PlasticsEurope Substituting primary material production
Screws	0.7	kg	EPD Hot-dip galvanised steel building products. Ruukki. Issued: 1 December 2014. Valid until: 1 December 2019

Environmental performance

The EPD of Straw wall Panel includes the information about potential environmental impacts, use of resources, waste categories and other information like materials for re-use, -recycling, -energy.

The declared environmental performance unit is 1 m^2- of average straw wall without inner and outer covering materials. The construction and maintenance of factory building and related infrastructure have been excluded from the assessment.

Product phase (A1-A3) and construction phase (A4-A5)

Table 10. Parameters describing environmental impacts (Product stage and construction stage).

Para-meter	Units in equiv.	A1	A2	A3	A1 -A3	A4	A5	A4 - A5
ADPE	kg Sb	3.78E-03	0	5.20E-03	8.99E-03	0	0	0
ADPF	MJ	99.2	3.25	37.6	140	3.82	1.31	5.1
AP	kg SO_2	0.351	5.95E-04	8.94E-03	0.361	6.99E-04	1.86E-03	2.56E-03
ODP	kg CFC 11	4.13E-05	0	2.53E-07	4.15E-05	0	0	0
GWP*	kg CO_2	-91.2	0.216	2.26	-88.7	2.53E-01	0.620	0.874
EP	kg$(PO_4)^{3-}$	0.0964	1.56E-04	1.95E-03	0.099	1.83E-04	4.86E-04	6.69E-04
POCP	kg C2H4	0.0293	3.33E-05	3.83E-04	0.0297	3.91E-05	1.85E-04	2.25E-04

Notes: ADPE = Depletion of abiotic resources-elements, ADPF = Depletion of abiotic resources-fossil fuels, AP = Acidification for soil and water, ODP = Ozone Depletion, GWP = Global Warming, EP = Eutrophication, POCP = Photochemical ozone creation.
* Wood materials storing CO_2 during the growth: wood 1.59 kg/kg, Plywood 1.69 kg/kg, straw 1.34 kg/kg and wood fibreboard 1.4 kg/kg. In total stored CO_2 is-97.6 kg

Table 11. Parameters describing resource use.

Para-meter	Unit	A1	A2	A3	A1 -A3	A4	A5	A4 - A5
PERE	MJ	117	0	4.40	122	0	0	0
PERM	MJ	1033	0	0	448	0	0	0
PERT	MJ	537	0	4.40	541	0	0	0
PENRE	MJ	95	3.25	40.5	139	3.82	6.48	10.3
PENRM	MJ	12.7	0	1.48	14.2	0	0	0
PENRT	MJ	108	3.25	42.0	153	3.82	6.48	10.3
SM	kg	0	0	0	0	0	0	0
RSF	MJ	0	0	3.20E-05	3.20E-05	0	0	0
NRSF	MJ	0	0	5.33E-04	5.33E-04	0	0	0
FW	m^3	6.04	0	8.55	14.6	0	0	0

Notes: PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials, PERM = Use of renewable primary energy resources used as raw materials, PERT = Total use of renewable primary energy resources, PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials, PENRM = Use of non-renewable primary energy resources used as raw materials, PENRT = Total use of non-renewable primary energy resources, SM = Use of secondary material, RSF = Use of renewable secondary fuels, NRSF = Use of non-renewable secondary fuels, FW = Net use of fresh water.

Table 12. Other environmental information describing waste categories.

Para-meter	Unit	A1	A2	A3	A1 -A3	A4	A5	A4 - A5
HWD	kg	9.13E-02	0	0	9.13E-02	0	0	0
NHWD	kg	4.41E-02	0	0	4.41E-02	0	0	0
RWD	kg	7.34E-03	0	0	7.34E-03	0	0	0

Notes: HWD = Hazardous waste disposed, NHWD = Non-hazardous waste disposed, RWD = Radioactive waste disposed

Table 13. Other environmental information describing output flows.

Para-meter	Unit	A1	A2	A3	A1 -A3	A4	A5	A4 - A5
CRU	kg	0	0	0.0742	0.0742	0	0	0
MFR	kg	5.12E-02	0	4.20	4.25	0	0	0
MER	kg	2.59E-02	0	1.04E-03	2.69E-02	0	0	0
EEE	MJ	2.90E-02	0	0	2.90E-02	0	0	0
EET	MJ	0	0	0	0	0	0	0

Notes: CRU = Components for re-use, MFR = Materials for recycling, MER = Materials for energy recovery, EEE = Exported energy, electricity, EEH = Exported energy, heat

Use phase (B1-B7) and End of Life phase (C1-C4) and phase D

Table 14. Parameters describing environmental impacts.

Para-meter	Units in equiv.	B1-B7	C1	C2	C3	C4	C1-C4	D
ADPE	kg Sb	0	3.43E-08	0	4.24E-06		4.27E-06	-3.64E-01
ADPF	MJ	0	6.18	5.98	16.4		28.51	-2503
AP	kg SO_2	0	7.29E-04	1.09E-03	0.0697		7.16E-02	-1.59
ODP	kg CFC 11	0	8.06E-08	0	2.83E-07		3.64E-07	-4.58E-04
GWP	kg CO_2	0	7.58E-02	0.397	98.6		99.09	-151
EP	kg$(PO_4)^{3-}$	0	1.14E-04	2.87E-04	0.0375		0.038	-0.417
POCP	kg C_2H_4	0	1.87E-05	6.12E-05	5.02E-03		5.10E-03	-0.115

Notes: ADPE = Depletion of abiotic resources-elements. ADPF = Depletion of abiotic resources-fossil fuels. AP = Acidification for soil and water. ODP = Ozone Depletion. GWP = Global Warming. EP = Eutrophication. POCP = Photochemical ozone creation.

Table 15. Parameters describing resource use.

Para-meter	Units	B1-B7	C1	C2	C3	C4	C1-C4	D
PERE	MJ	0	2.34E-02	0	6.28		6.30	-308
PERM	MJ	0	0	0	-1032		-1032	0.00
PERT	MJ	0	2.34E-02	0	-1026		-1.03E+03	-308
PENRE	MJ	0	6.18	5.98	38.1		50.2	-2790
PENRM	MJ	0	0.00	0.00	-0.271		-0.27	-20.1
PENRT	MJ	0	6.18	5.98	37.8		49.9	-2810
SM	kg	0	0	0	0		0	0
RSF	MJ	0	0	0	0		0	0
NRSF	MJ	0	0	0	0		0	0
FW	m3	0	4.72E-04	0	0.0409		4.14E-02	-599

Notes: PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials. PERM = Use of renewable primary energy resources used as raw materials. PERT = Total use of renewable primary energy resources. PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials. PENRM = Use of non-renewable primary energy resources used as raw materials. PENRT = Total use of non-renewable primary energy resources. SM = Use of secondary material. RSF = Use of renewable secondary fuels. NRSF = Use of non-renewable secondary fuels. FW = Net use of fresh water.

Table 16. Other environmental information describing waste categories

Para-meter	Units	B1-B7	C1	C2	C3	C4	C1-C4	D
HWD	kg	0	0	3.80E-05		3.80E-05	1.69E-02	0
NHWD	kg	0	0	1.48		1.48	2.71E-02	0
RWD	kg	0	0	3.26E-04		3.26E-04	3.30E-04	0

Notes: HWD = Hazardous waste disposed. NHWD = Non-hazardous waste disposed. RWD = Radioactive waste disposed

Table 17. Other environmental information describing output flows.

Para-meter	Units	B1-B7	C1	C2	C3	C4	C1-C4	D
CRU	kg	0	0	0	0	0	0	0
MFR	kg	0	0	0	0.82	0	0.819	-0.819
MER	kg	0	0	0	68.0	0	68.0	-68.0
EEE	MJ	0	0	0	0	0	0	760
EET	MJ	0	0	0	0	0	0	0

Notes: CRU = Components for re-use. MFR = Materials for recycling. MER = Materials for energy recovery. EEE = Exported energy, electricity. EEH = Exported energy, heat

References

Standards:

EN 15804:12 + A1:2013 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products

EN 16449:2014 Wood and wood-based products - Calculation of the biogenic carbon content of wood and conversion to carbon dioxide

EN 16485:2014 Round and sawn timber - Environmental Product Declarations - Product category rules for wood and wood-based products for use in construction

ISO 14025:2010 Environmental labels and declarations - Type III environmental declarations - Principles and procedures

ISO 14040:2006 Environmental management - Life Cycle Assessment.

ISO 14044:2006 Environmental management - Life Cycle Assessment - Requirements and guidelines

EPDs

EPD Hot-dip galvanised steel building products. Ruukki. Issued: 1 December 2014. Valid until: 1 December 2019

EPD Sawn timber - Environmental Product Declaration. Classic Sawn by Stora Enso. Approved date: 2018-06-01, Valid until: 2023-05-31, Reference year: 2014

EPD Plywood - Environmental Product Declaration. Metsä Wood Spruce Plywood. Uncoated. Published May 2014. Validity: until January 2019. Reference year: 2012

EPD Wood fibre insulation materials. Declaration number EPD-STE-20150327-IBD1-EN. Owner: STEICO SE. Institut Bauen und Umwelt e.V. (IBU) Issue date 05/02/2016. Valid to 04/02/2021

Eco-profiles and Environmental Product Declarations of the European Plastics Manufacturers Polypropylene (PP) PlasticsEurope. April 2014. December 2016: update water balance.

KRICK 2008 Dissertation von Benjamin Krick: Untersuchung von Strohballen und Strohballenkonstruktionen hinsichtlich ihrer Anwendung für ein energiesparendes Bauen unter besonderer Berücksichtigung der lasttragenden Bauweise, Universität Kassel, 2008

Teagasc: Fact sheet. Tillage No. 12

Ecoinvent 2010 Database ecoinvent data v2.2. The Life Cycle Inventory. Swiss Centre for Life Cycle Inventories, St. Gallen, 2010. http://www.ecoinvent.org/

Lipasto - a calculation system for traffic exhaust emissions and energy use in Finland. VTT Technical Research Centre of Finland Ltd. http://lipasto.vtt.fi/en/index.htm

http://www.ecococon.lt/english/straw-panels/