IsoHemp hempcrete blocks

Life Cycle Assessment
EN 15804+A1 (2014)
Project report

For:

IsoHemp S.A.
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B-5380 Fernelmont
www.isohemp.be

By

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Abbreviations and acronyms

AP	Acidification potential
BE	Belgium
CH	Switzerland
CNP	Natural cement
ELCD	European reference Life Cycle Database
EP	Eutrophication potential
EPD	Environmental Product Declaration
EuLA	European Lime Association
FR	France
FU	Functional unit
GWP100	Global Warming Potential – 100 years
I_{env}	Environmental indicator(LENOZ)
LCA	Life cycle assessment
LCI	Live cycle inventory
LENOZ	Lëtzebuerger Nohaltegkeets-Zertifizéierung fir Wunngebaier (Luxemburg sustainability certification for residential buildings)
NHL	Natural hydraulic lime
ODP	Ozone depletion potential
PE	Polyethylene
PEPs	Products, Environment, and Processes
POCP	Photochemical ozone creation potential
PP	Polypropylene
SME	Small and medium entreprise
ULiège	Université de Liège
wt	weight

1 Introduction

This report presents the life cycle assessment (LCA) if IsoHemp hempcrete blocks.

This study is realised in order to get the agreement to add the product in the Okabaudat database (Luxemburg) and get the LENOZ certification.

2 General information

1) Name and address of the manufacturer:

IsoHemp S.A.
18 Rue du Grand Champ
B-5380 Fernelmont
www.isohemp.be

2) Date of the report: April 2018

3) LCA is made in compliance with NBN 1s5804+A1 (2014).

3 Goal of the study

The goal is the realisation of the life cycle assessment of IsoHemp hempcrete blocks. The company wants to communicate on its product in accordance with the rules and standards of the European countries. It also wants to comply with Luxemburg rules. To that end, IsoHemp has to obtain a LENOZ certification [1] (Lëtzebuerger Nohaltegkeets Zertifizéierung fir Wunngebaier or Luxemburg sustainability certification for residential buildings).

The Luxemburg Act of December 23th 2016 is the introduction of a certification of the sustainability of the housing and changes the amended Act of 25 February 1979 on aid for housing, as part of the "Climate Bank and Sustainable Housing Package'. The purpose is to promote the sustainability of housing in Luxembourg by the introduction of the certificate LENOZ. This certification, announced in the Government's program aims to increase awareness about the sustainability of the housing and the transparency of the real estate market.

This certificate requires the calculation of an environmental indicator involving impact factors determined by a life cycle analysis of in accordance with the EN 15804 standard.

This study will also emphasize the environmental qualities of the product in a scientific way. It will also serve to consolidate the communication on objective basis using quantitative data.

4 Scope of the study

4.1 Description of the product

IsoHemp hempcrete blocks are great for glued, non-load-bearing masonry for building healthy, natural insulation and partition walls. It is very versatile and recommended by professionals for both new builds and renovations, whether they are single-family projects, community buildings and commercial buildings[2] (Figure 1). The technical datasheet and the specifications are in Annex 1.

They are made by mixing hemp shives and limes.

[1] http://logement.public.lu/fr/lenoz.html

[2] https://www.isohemp.com/en/hempcrete-blocks-naturally-efficient-masonrys

Figure 1: IsoHemp Hempcrete blocks

Hempcrete blocks are the answer to a number of technical challenges.

The IsoHemp hempcrete blocks are particularly suitable for residential constructions, for adding a second wall to existing walls on the inside or from the outside, as well as industrial partitioning and for apartments.

It allows you to achieve low-energy, very low-energy and passive house standards.

They are technically recognised and have all necessary certifications as per the current European regulations.

The five major hempcrete block features are[2]:

- thermal regulation;
- humidity regulation;
- acoustic insulation;
- protection and fire resistance;
- health and environmental qualities.

4.2 Definition of the functional unit

The functional unit (FU) is defined as 1 m^3 of IsoHemp hempcrete blocks palletized, packed for shipping.

It has the following characteristics:

- 1 pallet = 1.296 m^3 of blocks (1.2 m large and 1.4 m high). The blocks exist in several thicknessses – the volume of a pallet does not change but the number of blocks is adapted.
- Dimension of the blocks:
    - Thickness: 6, 9, 12, 15, 20 and 30 cm
    - Length: 60 cm
    - Height: 30 cm
- 1 complete pallet wheighs: **390 kg of dry blocks**[3] + 25 kg for the pallet + 1.5 kg for the "accessories" (plastic hat + plastic ligatures + cardboards corners), that is 416.5 kg. The total weight corresponding to 1 m^3 palletized and packed blocks is then 321.4 kg.
- Blocks tolerance is ± 1 mm on thickness
- Thermal conductivity of one IsoHemp hempcret block: λ_{UI} = 0,076 W/m.K

[3] Manufacturer data – that is 301 kg for 1 m^3 of dry blocks

- It takes 5.5 blocks per square meter of insulation (except for blocks of 30 cm thick: 8.33 blocks/m²).

There is only one manufacturing plant for the IsoHemp hempcrete blocks. All primary data are directely collected on the site.

4.3 System boundaries

4.3.1 Description

The system boundaries, for cradle-to-grave, covers all the modules defined by the standard EN 15804. EN 15804 provides core product category rules (PCR) for Type III environmental product declarations (EPD) for any construction product and construction service.

Production stage	A1 – Raw meterials	Raw materials for the blocks and packaging
	A2 – Transport	Transport to the manufacturer
	A3 – Manufacturing	Production of the blocks, storage and palletization
Construction stage	A4 – Transport	Transport to the building site
	A5 – Installation	Installation of the blocks in the building, adhesive mortar
Use stage	B1 – Use	
	B2 - Maintenance	
	B3 – Repair	
	B4 – Replacement	
	B5 - Refurbishment	
End-of-life stage	C1 – Demolition	
	C2 – Transport	Transport of the blocks to waste processing
	C3 – Reuse/Recovery/Recycling	
	C4 - Disposal	Inert landfill
Benefits	Benefits/Recycling	
	Benefits/Energy recovery	

4.3.2 Omission of certain stages

- Use stage B1-B7: no technical operation is necessary during the phase going from use up to the end-of-life
- End-of-life phase: Demolition C1 is neglected because it is integrated in the comprehensive demolition of a building (see inventory); C3: no treatment is necessary
- Benefits: no waste recovery

Excluded of the frontiers of the system:

- buildings and infrastructure;
- ground storage space;
- household waste (usual waste linked to the human presence: food packaging, etc.);

– packaging waste at IsoHemp customer that uses blocks for its building (hat, ligatures, corners,paper bags of adhesive mortar);
– pallets: they are wood pallets purchased in second-hand, and which are reused many times (recovery from the customer of the guaranteed pallets), their impact is negligible;
– wastewater: insignificant (15 m^3/year, i.e. 0.0025 m^3/UF).

4.3.3 Electricity production

Electricity is Luminux mix as sold to IsoHemp and is detailed in Annex 2. The input includes the production of the electricity, its transport and the transformations from high to medium to low tension. The composition of the Luminus mix as sold to IsoHemp is different from the average Belgian mix and has been added to Ecoinvent. It is detailed in Annex 2 (energy sources: 44.33% natural gas ad 55.67% nuclear power).

This specific mix is simply called "Electricity BE" in the inventory description.

5 Life cycle inventory

This paragraph details the inventory of the IsoHemp hempcret blocks[4].

Data on the process itself (quantities of raw materials, energy consumption, etc.) are primary data supplied by IsoHemp. They have been collected during the years 2014/2015 to be representative and they correspond to a whole year of production, because the operation of the production unit is discontinuous and distributed over several months a year.

5.1 A1-A3, Production stage

The production stage includes:

– A1: Raw material extraction and processing;
– A2: Transport to the manufacturer;
– A3: Manufacturing.

Production: 6000 pallets per year

For the production stage, the boundaries of the system stop at the factory gate, which corresponds to a "cradle-to-gate" LCA.

The process involves the following, in terms of raw materials and production steps (Figure 2):

– Hemp shives + hydrated lime + hydraulic lime (natural cement) + water
– Mixing, pressing, storage 24 hours in an area with natural ventilation (⇒ carbonation of limes), commissioning pallets and storage 2 months in the yard of the factory (finalization of carbonation).
– "Failed blocks" from pressing (i.e. uncomplete or broken blocks) are juste removed from the line and crushed by hand with a shovel, and then directly put back into the mixing tank. Therefore, there is no waste of raw matter due to imperfect pressing of the blocks.

Electricity mix is described in paragraph 4.3.3 and in Annex 2 (Luminus mix as sold to IsoHemp).

[4] http://isohemp.be/wp-content/uploads/2014/01/Isohemp-Cahier-des-charges.pdf

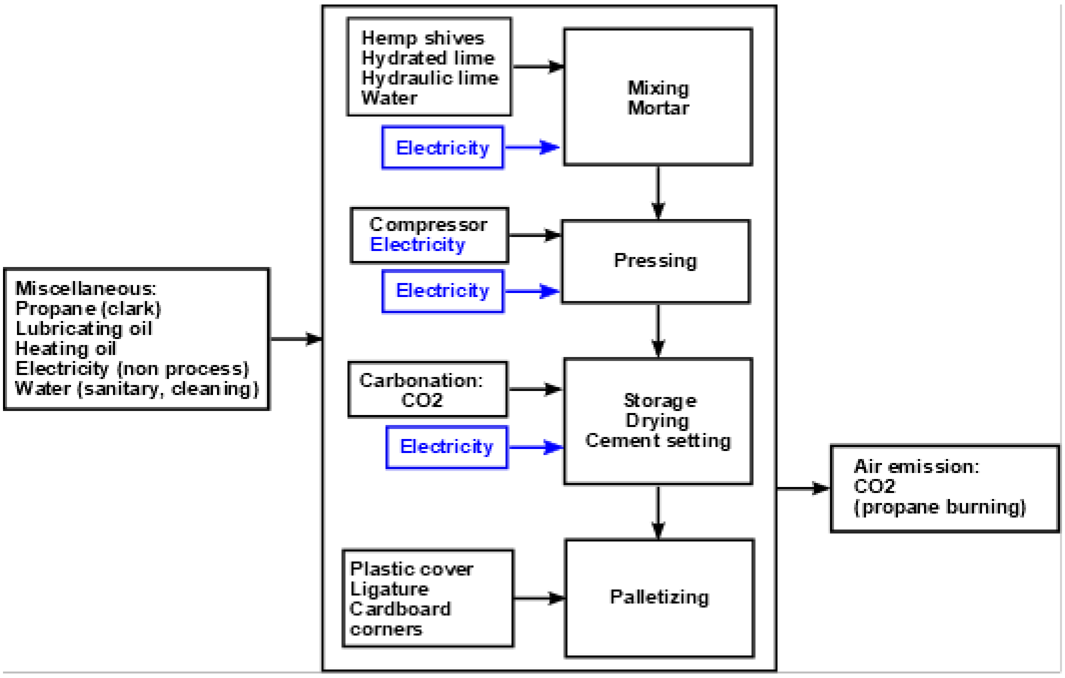

Figure 2 : Flowsheet of the production of IsoHemp hempcret blocks

5.1.1 Inventory

Note: the inventory data are indicated without taking into account the lifetime of the blocks. For calculations of the impacts, the inventory entries can also be divided by its value, which is 50 years, in order to take it into account.

5.1.1.1 Raw materials

The only "raw material" inputs for the production of IsoHemp hempcret blocks are hemp (as hemp shives), hydrated lime, hydraulic lime, and water (tap water) (Table 1).

They are mixed in the following proportions:

Table 1: Inventory of raw materials for the production of 1 m^3 (= 1 FU) of hempcrete blocks

Raw matter	kg/m^3 of hempcrete blocks
Hemp shives	**100**
Hydrated lime	**75**
Hydraulic lime	**115**
Water	**250**

5.1.1.2 Hemp shives

The hemp shives used by IsoHemp are produced in France by the society "Les Chanvrières de l'Aube"[5], located in Bar-sur-Aube. Only the shives are used for the production of hempcrete blocks. The hemp appellation is however preferred by society in the name of the product for greater clarity for the consumer. Indeed, the name

[5] http://www.chanvre.oxatis.com/Default.asp

hemp is known to the public, while the term shives is rarely understood and therefore asked for an explanation at every mention.

An alternative Belgian provider could be ChanvrEco (Prohemp range), but at present their method provides only straw, not shive. According to tests conducted by IsoHemp, this product is not suitable for their process.

Bar-sur-Aube is located 400 km far from Fernelmont. Transport is made using a 25-ton truck (EURO5[6]).

The inventory data for hemp are based on a French study carried out by INRA and a broad Steering Committee (Boutin et al., 2006). It was complemented by a critical review and, and although dating back to 2006, is a reference in the field. The inventory data and the calculations of impact are consistent with other studies ((González-García et al., 2010), (van der Werf and Turunen, 2008), (Van der Werf, 2004)).

Hemp is a crop used as head rotation in cropping systems. It provides two types of product: cortical fibre (external) and the shives. The cortical fibre once used for textile is today mainly used in paper-making industry. Coming from the marrow of the stem of hemp, shives is today mainly used in the manufacture of animal litter because of its absorption capacity. Properties of low density and high insulating power earned him to be increasingly used in the composition of some building materials (Boutin et al., 2006).

The agricultural phase of the culture of hemp has the phase of agricultural production, named technical route, and the production of fibres and shives, named primary processing phase. The values in the inventory are reported per kg of material (either straw, fibres of shives).

The studied system does not take into account production of seeds (for seeding the plant), production of hempseeds at the end of the cultivation stage, and inputs whose mass does not exceed 2% of the total mass of the inputs. The dust due to the primary transformation is considered as a waste (Boutin et al., 2006). Seeding operations and storage are also neglected. Figure 3 schematically illustrates the steps considered in the inventory of the production of shives, from the culture of hemp to primary processing.

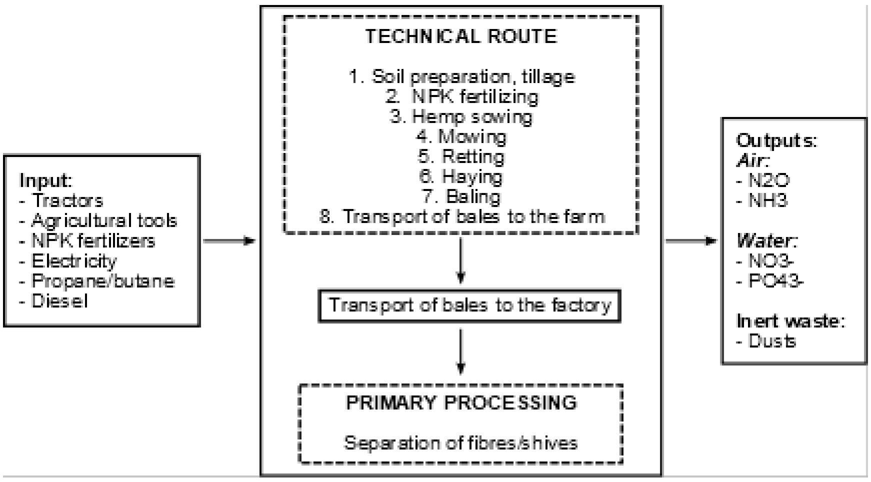

Figure 3 : Boundaries and steps for the production of hemp and the transformation in fibres and shives

The type of allocation of the inventory relative to the hemp straw production between the two products that are fibres and shives, as well as the allocation of the associated potential environmental impacts may be either a mass allocation or an economic allocation. Both cases are examinated in the reference study by Boutin et al. (2006).

[6] EURO5: 01/10/2009

In the present work, we use the economic allocation to share the impacts of the hemp. This choice is justified by the fact that the production of fibres is the main motivation for the hemp cultivation, and that large different exist between the price of the fibres and the shives (González-García et al., 2010). This choice is compliant with EN 15804 standard. Table 2 summarizes the production and the distribution between the various co-products.

The environmental impacts associated with the emission of dust during the process are not taken into account, because the data are not available. Their transport as waste is however recognised (see below, Table 5). The values for the mass and economic allocation in Table 2 are the ones that have been validated by the steering committee who revised the INRA study (Boutin et al. 2006). For the mass allocation, the value used in the study was rounded up to 60% for the shives and to 40% for the fibres. For the economic allocation, the value is rounded up to 32% for the shives and 68% for the fibres. Repartition of the entries in the inventory for the production and the transformation of hemp have been distributed between fibre and shives as described in the reference study of Boutin et al. (2006) in agreement with the recommandations of the steering committee and with its validation.

Table 2 : Relative production for the straw, fibre and shives (and dust), mass and economic allocation between the fibres and the shives (Boutin et al. 2006)

Matter	Production (kg/ha)	Relative production (kg/kg straw)	Mass allocation	Economic allocation
Straw	**7750**	1		
Fibres	2712.5	0.35	40%	68%
Shives	3720	**0.48**	60%	**32%**
(Dust)		(0.19)	(0)	(0)

– <u>Agricultural phase</u>

Cultivation

For the stages of work related to agriculture, the life cycle inventory of the hemp is reported in hour per hectare (h/ha) (Boutin et al., 2006). However, the Ecoinvent database only proposes data reported per hectare. Data are reported to shives by taking into account the productivity per hectare for the straw and the ratio between the straw and the shives.

Considered steps are (seeds being neglected):

- Tillage – spring tine harrow (CRA-W et al., n.d.)
- Fertilization (by broadcaster processing)
- Sowing
- Mowing by motor mower
- Haying by rotary tedder
- Baling
- Transport vers ferme (hyp. 1 route/ha, 10 km)

Fertilizing

The dosages of inputs are those indicated by the French study (Boutin et al., 2006). Potassium and phosphorus are not leached, so all refunds made by crop residues were taken into account. The doses of fertilizers are included in Table 3.

Table 3: Inputs for hemp cultivation (Boutin et al., 2006)

Fertilizing	Inputs (kg/ha)	Input-Restitution (kg/ha)	Quantities considered in LCA (kg/ha)	LCI (kg/kg straw)	LIC (kg/kg shives – economic allocation)
Nitrogen –N (kg/ha)	105	36	69	8.90E-03	**5.94E-03**
Phosphorus - P_2O_5 (kg/ha)	55	6	49	6.32E-03	**4.22E-03**
Potassium – K_2O (kg/ha)	81	60	21	2.71E-03	**1.81E-03**

Emissions of nitrates and phosphates in the water, as well as nitrous nitrogen and ammonia in the air are also taken into account. The method of calculation is that recommanded by Boutin et al. (2006). The results are:

Table 4: Emission to air and water due to the cultivation of hemp(Boutin et al., 2006)

	LCI (kg/kg straw)	LCI (kg/kg shives – economic allocation)
Emissions to water		
NO_3^-	3.87E-03	2.58E-03
PO_4^{3-}	9.61E-05	6.41E-05
Emissions to air		
N_2O	1.11E-04	7.42E-05
NH_3 (Urea + NH_4NO_3)	4.29E-05	2.86E-05

The storage of carbon in the soil is overlooked (especially because of the uncertainties of farming practices) (Boutin et al., 2006).

However the carbon storage in the product through the atmospheric capture necessary for photosynthesis is counted. According to Boutin et al. (2006), it should be 1.6 kg of CO_2 for 1 kg of dry matter. This amount of CO_2 captured by the plant must be removed from the carbon footprint of the hemp industry. Without any other indication, we consider that the CO_2 is stored evenly in the plant, and therefore it takes 1.6 kg of CO_2 to produce 1 kg of shives.

We can assume that the carbon is stored permanently, in "fossilized" form. The way hemp is wrapped in the lime concrete makes it unlikely that a combustion ora decomposition could release the CO_2.

The embodied renewable energy stored in hemp shives is assimilated to "wood", and its value is 15 MJ/kg. This value is taken into account for the calculation of renewable primary energy resource consumption (in particular the part used as raw material).

– **Primary transformation**

The fibres-shives separation is made in electrical installations. Diesel fuel and propane are also used to transport hemp straw, hemp fibres and the shives on the site of primary processing (Boutin et al., 2006).

– **Transport of the straw and of the dust produced during the transformation of hemp**

According to the NF P01-010 (copmpliant with EN 15804), the potential environmental impact of the transport is assessed by the amount of diesel consumed during the journey. These products transport distances have been calculated using the data provided by manufacturers. For dust, it is transported between the primary processing plant and the spreading place of dust. Other destinations of dust were not retained, as in the reference study (Boutin et al., 2006), the dust is considered as a waste.

The distances and real transported loads are, respectively:

- for hemp straw: 100 km and 17 t by 24 t trucks (EURO5)
- for sdust: 11.7 km and 17 t by 24 t trucks (EURO5).

Table 5 includes the inputs and outputs, associated with the transformation of 1 kg of hemp straw.

Table 5: Inputs and outputs, associated with the transformation of 1 kg of hemp straw. (Boutin et al., 2006)

Inputs			Outputs	
	For 1 kg of straw	For 1 kg of shives		For 1 kg of straw
Diesel primary transformation (kg/kg)	7.60E-04	5.07E-04	Dust (kg/kg)	0.19
Diesel transport (kg/kg))	3.32E-03	2.21E-03	Fibres (kg/kg)	0.35
Electricity (kJ/kg)	2.84E-02	1.90E+01	Shives (kg/kg straw)	0.48
Propane/butane (kg/kg)	3.00E-04	2.00E-04		

– <u>Transport of shives to IsoHemp facilities</u>

The Chanvrerie de l'Aube is 400 km from Fernelmont. The transport is by 25 t trucks (EURO5).

5.1.1.3 Hydrated lime

Hydrated lime is supplied by Carmeuse (BE), as $Ca(OH)_2$. It is producet at the Seilles quarry (BE).

A LCA has been transmitted by Carmeuse to IsoHemp. It corresponds to a study that has established the cradle-to-gate LCA of hydrated lime. This study has been validated by the European Lime Association (EuLA), and the corresponding inventory is integrated in the (free) database "European reference Life Cycle Database"[7] (ELCD) under the name *Hydrated lime; production at plant – RER (2007)*. This inventory is representative of the production of hydrated lime in Europe.

Hydrated lime carbonates naturally in air, and the capture of CO_2 is taken into account in the study (Figure 4). The carbonation is considered as complete because of the low thickness of material in which the CO_2 diffuses, and it takes place during the dry-storage (after a start in the phase of preparation of mortar when adding water) (Nozahic, 2012, Pretot 2014).

[7] http://eplca.jrc.ec.europa.eu/?page_id=126

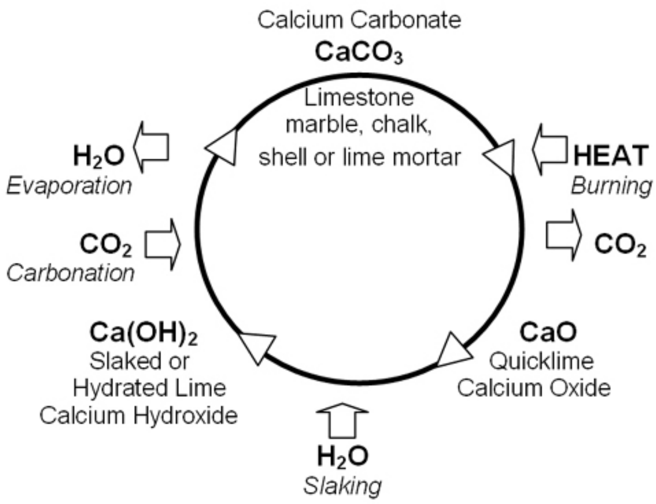

Figure 4: The lime cycle[8]

Carbonation of lime is stoechiometric:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

There is a sequestration of **0.594 kg of CO_2 per kg of $Ca(OH)_2$** used.

The inventory of hydrated lime correspond to the lime itself and the transport to IsoHemp facilities by truck (13.5 km, 13 t/course) (EURO5). Note that the quarry is very close to IsoHemp factory.

5.1.1.4 Hydraulic lime – natural cement

The natural hydraulic lime is obtained from limestone containing 15 to 20% of clay which, during the calcination, gives the silicates and aluminates of calcium capable of setting by hydration, according to the same reactions as the setting of a cement in presence of water. The natural hydraulic lime (NHL) used by the building sector (Boehm, Calcia, white lime lime white Lafarge, plane, St-Astier, Socli, Wasselonne...) are generally hydraulic and eminently hydraulic.

Pure limestones are rare. They are often mixed with marls and clays rich in chemical elements such as iron, aluminum, and especially silica. Between 800 and 1,500 ° C, calcium from the limestone combines with these elements and form silicates of calcium, but also the aluminates and ferro-aluminates of calcium. By contact with the water, these components will form insoluble carbohydrates, which give the binder an hydraulic character. The proportions of alumina and iron are very low (in white binders, iron levels are less than 0.1 or 0.2%). The phenomenon of hydraulically setting is essentially due to the reaction between CaO and silicates.

Thereafter, in contact with moist air, the lime and the formed hydrates will be carbonated (with the carbon dioxide of the air) to restore calcium carbonate and silica of origin.

For reasons of confidentiality, the exact nature of this raw material is kept secret. It comes from a deposit in France whose composition gives special properties to this natural cement. It is almost unique in the world (there are two or three deposits of this type).

The producer has provided the module of environmental information of the production of this natural cement (called "CNP" according to the provider-specific name and whose identity is confidential). The data cover only production. Transport, the implementation and the end of life of the product are not counted. Natural cement

[8] http://www.oldbuilders.com/what%20is%20lime/whatislime.htm

meets the standards NF P15-314 and NF P15-317. These specific data are used for the calculation of the impact (instead of the results that would be provided by a generic data in a database) (Table 6 and Table 7).

Table 6: Contribution of natural cement (CNP) to the flows included in NF EN 15804+A1 (n.c. non concerned ; n.d. non determinated)

Indicateurs de flux sortants	Unité	1 tonne de CNP
Utilisation de l'énergie primaire renouvelable, à l'exclusion des ressources d'énergie primaire renouvelables utilisées comme matières premières	MJ	n.d.
Utilisation des ressources d'énergie primaire renouvelables utilisées en tant que matières premières	MJ	n.d.
Utilisation totale des ressources d'énergie primaire renouvelables (énergie primaire et ressources d'énergie primaire utilisées comme matières premières)	MJ	98,6
Utilisation de l'énergie primaire non renouvelable, à l'exclusion des ressources d'énergie primaire non renouvelables utilisées comme matières premières	MJ	3455,5
Utilisation des ressources d'énergie primaire non renouvelables utilisées en tant que matières premières	MJ	n.d.
Utilisation totale des ressources d'énergie primaire non renouvelables (énergie primaire et ressources d'énergie primaire utilisées comme matières premières)	MJ	n.d.
Utilisation de matière secondaire	kg	n.c.
Utilisation de combustibles secondaires renouvelables	MJ	n.c.
Utilisation de combustibles secondaires non renouvelables	MJ	n.c.
Utilisation nette d'eau douce	m^3	11,3
Déchets dangereux éliminés	kg	$1{,}4.10^{-3}$
Déchets non dangereux éliminés	kg	9,9
Déchets radioactifs éliminés	kg	$2{,}4.10^{-2}$
Composants destinés à la réutilisation	kg	n.c.
Matériaux destinés au recyclage	kg	n.c.
Matériaux destinés à la récupération d'énergie	kg	n.c.
Énergie fournie à l'extérieur	MJ	n.c.

Table 7: Contribution to impact categories

Indicateurs d'impact	Unité	1 tonne de CNP
Réchauffement climatique	kg CO_2 équivalent	571
Appauvrissement de la couche d'ozone	kg CFC^{-11} équivalent	$2{,}0.10^{-5}$
Acidification des sols et de l'eau	kg SO_2 équivalent	0,46
Eutrophisation	kg PO_4^{3-} équivalent	0,1
Formation d'ozone photochimique	kg éthène équivalent	$2{,}1.10^{-2}$
Épuisement des ressources abiotiques (éléments)	kg Sb équivalent	$2{,}7.10^{-4}$
Épuisement des ressources abiotiques (combustibles fossiles)	MJ, pouvoir calorifique inférieur	2692

The "non determined" items in Table 6 are in fact not relevant in the production of the CNP[9], so their absence is not problematic for the use of theses data in the calculation of the environmental impacts of the IsoHemp hempcret blocks.

According to the producer, the rate of carbonation of its natural cement is close to 75%. Without precise information on its composition, we assume that the carbonation is 75% of what it would be if it was composed only of hydrated lime, or 0.75 x 0.594 = 0.4455 kg CO_2/kg natural cement. A previous study had considered 0.459

[9] Personnal communication from the producer

kg CO_2/kg natural cement, without precision on the method of calculation other than a communication of the producer. As for hydrated lime, the carbonation is considered as complete, because of the long service life of the material (Arrigoni 2017, Nozahic 2012, Pretot 2014).

The inventory of the hydraulic lime includes the natural cement and the transport to IsoHemp facilities by 40 t trucks (750 km, 25 t/course) (EURO5).

5.1.1.5 Process water

The water added to the mix of hemp shives and limes is tap water, at a rate of 250 kg per m^3 (or per FU).

5.1.2 Production line

In addition to the inputs described previously (hemp, limes, water), the IsoHemp hempcret blocks production line includes the following steps, as described in the flowsheet (Figure 2).

Palletization (packaging): the dryied blocks are put on the wood pallets (omitted – see Goal and Scope). Blocks are protected of the rain by a hat in polypropylene (PP) (0.5 kg) and held in place by ligatures in polyethylene (PE) (0.5 kg). Two cardboard corners (210 g each) prevent the ligature from cutting or damaging the blocks. As a reminder, a pallet represents 1.296 m^3 of blocks.

The cardboard corners are partly made with recycled paper. For 1 kg of cardboard, 0.763 kg of waste paper are used[10]. With two corners per pallet, it means that 0.247 kg of recycled paper is used per FU. This is counted in the "Use of secondary material" resource use category.

The embodied non-renewable energy stored in the hat and the ligatures is respectely 44 MJ/kg for PP and 43 MJ/kg for PE, and these amounts are considered for the calculation of the use of non-renewable primary energy resources used as raw material.

Power consumption of the different steps of mixing and pressing, as well as for the internal transport of raw materials on belt transporters, are provided by IsoHemp, by direct measurement on facilities (primary data).

Information about CO_2 sequestration by limes has been developped in paragraphs 5.1.1.3 and 5.1.1.4. They are considered as "negative emissions" of CO_2 in the evaluation of the impacts (capture). The elements "CO_2 cature – lime" are processes implemented in Simapro and they correspond to the carbon sequestration by the limes on the basis of 1 kg of lime (repectively hydrated or hydraulic).

[10] Ecoinvent database 3.4 – Core board production / cut-off

Table 8: LCI relative to the production process of IsoHemp hempcret blocks in IsoHemp facilities (for 1 m³ - 1FU)

Inventory data	Quantity	Units	Comments
Preparation of mortar			
Electricity	0.246	kWh	hydrtated lime, in situ conveying
Electricity	0.693	kWh	hemp shives, in situ conveying
Electricity	0.337	kWh	hydraulic lime, in situ conveying
Electricity	2.12	kWh	mixing
Pressing of the blocks			
Electricity	0.965	kWh	pressing
Electricity	0.957	kWh	compressor
Storage			
Electricity	0.684	kWh	conveying of the blocks
Capture CO_2 hydrated limee	75	kg	carbonation (75*-0.594= -44.55 kg CO_2)
Capture CO_2 hydraulic lime	115	kg	carbonation (115*-0.4455= -51.23 kg CO_2)
Palletization			
Hat PP	0.386	kg	0.5 kg per pallet
Ligatures PE (HD)	0.386	kg	0.5 kg per pallet
Cardboard corners 210 g	0.324	kg	2 corners per pallet
Electricity	1.804	kWh	
Transport of the hat	170*0.386	kgkm	Truck 25t, Waregem (BE)
Transport of the ligatures	980*0.386	kgkm	Truck 25t, Isère (FR)
Transport of the corners	1109*0.324	kgkm	Truck 25t, Chalabre (FR)
Miscellaneous			
Propane	0.111	kg	
Lubricating oil	0.0386	kg	
Heating gasoil	0.648	kg	heating of the office
CO_2 combustion of propane	0.111*2.994	kg	emissions to air
Tap water	1.93 10^{-3}	kg	non process water ("human use")
Electricity	0.9	kWh	Conveying belt in situ

5.1.3 Emissions

As reported previously (see paragraph 5.1), failed blocks from pressing are fully delivered in the manufacturing chain. There is no waste or sewage.

The only emission taken into account is the CO_2 due to the combustion of propane for the forklift.

5.1.4 Hazardous substances

No hazardous substance is used or issued by the process.

5.2 A4-A5, Contruction process stage

The construction process stage includes:

- A4: Transport to the building site;
- A5: Installation into the building.

The installation of the IsoHemp hempcrete block walls require the use of a mortar glue.

It is also produced on the site of IsoHemp.

The adhesive mortar consists of a mixture of natural plaster 20%, lime 22% and sand 58% (%wt). The seals have a thickness of 3 mm.

- Natural plaster (hemihydrate form): Parisian quarry (FR), transported in tanker of 25t in bulk, 330 km (EURO5).
- Hydrated lime: Carmeuse quarry(Seilles, BE), 25t truck, 13.5 km (EURO5)
- Silica sand: Paris region, 25t, 330 km truck (EURO5)

It need two bags of 25 kg of adhesive mortal per pallet of blocks.

The components of the adhesive mortar are mixed and put into cardboard bags. The energy spent by the action of mixture is very low (mixer engine of maximum 11kW) and runs 15 minutes every hour. We neglect this energy consumption (too imprecise data, and small amount).

The cardboard bags come from Oudenaarde. A bag weighs 90 gram. The bags are excluded from the frontiers of inventory of raw materials and waste (low weight and reduced transport distance).

It needs 7 litres per 1 bag of 25 kg of adhesive mortarl. The (tap) water is taken at installation location and it is counted in the inventory of the IsoHemp hempcrete blocks installation.

Table 9: Inventory of adhesive mortal for the placing of hempcrete blocks (1 m^3)

Materials	Per pallet – 2x25 kg de colle	per FU (1 m^3)
Natural plaster	50*0.2 = 10 kg	7.72 kg
Hydrated lime	50*0.22 = 11 kg	8.49 kg
Silica sand	50*0.58 = 29 kg	22.38 kg
Cardboard bag	2*0.090 = 0.180 kg	0.14 kg
Total		**38.73**
Water	**2*7 = 14 litres**	**10.80 litres**

A whole pallet weighs about 416.5 kg. The weight corresponding to 1 m^3(1 FU) is then 321.4 kg.

As a result, the weigh of the charge to be transported to the client is 360 kg for 1 FU, including adhesive mortal.

All the packaging waste at client (PP hat, PE ligatures, carcboard corners and bags, pallets) are not included in the boundaries of the system.

The average distance to the client is about 100 to 150 km according to IsoHemp. The value actually used is 125 km (truck, EURO5).

5.3 B1-B7, Use stage (fabric and operation of the building)

The stage use is divided in seven modules.

- B1: Use or application of the installed product;

- B2: Maintenance;
- B3: Repair;
- B4: Replacement;
- B5: Refurbishment;
- B6: Operational energy use;
- B7: Operational water use.

Description of the scenarios and additional technical information:

No technical operation is necessary during the phase of use up to the end of life. Thus, the IsoHemp hempcrete blocks have no impact during this stage.

5.4 C1-C4, End-of- life stage

The end-of-life stage includes:

- C1: De-construction, demolition;
- C2: Transport to waste processing;
- C3: Waste processing to reuse, recovery and/or recycling;
- C4: Disposal.

According to the manufacturer, the lifespan of the IsoHemp hempcrete blocks is about 100 to 150 years. According to the LENOZ procedure, a lifespan of 50 years is however envisaged in the present case.

No assumption about de-construction or demolition of the buildings where IsoHemp hempcrete blocks are installed is made, and consequently, this stage is not counted. Indeed, the perspective is long-term, and today it is impossible to predict what will be the methods of de-construction and recycling which will be implemented at such a distant horizon.

C1. De-construction, demolition

The de-construction or demolition of the insulation products is part of the demolition of a whole building. In the present case, the environmental impact due to the dismantling of the hempcrete blocksis supposed to be very low and then can be neglected.

C2. Transport to waste processing

The hypothesis is that the construction and demolition waste sorting centre is 25 km from the building[11].

For 1 m^3 of blocks, you have to add the weight of the blocks and the one of the adhesive mortar that is assembling them, i.e. 301 + 39 = 340 kg.

Waste are not recycled, reused or valued energetically. They were supposed to be landfilled as inert and non-hazardous waste without specific preparation.

The impacts, according to the database Ecoinvent 3.4, are identical for landfill of "generic" inert waste and of limestone residues.

C3. Waste processing to reuse, recovery and/or recycling

The product is considered to be put in landfill without reuse, recover and/or recycling.

[11] FDES Isoconfort - https://www.isover.fr/sites/isover.fr/files/assets/documents/FDES_2015_ISOCONFORT_32_60mm.pdf

C4. Disposal

The hempcrete blocks are supposed to be landfilled as inert and non-hazardous waste (Pretot 2014). Hemp shives are supposed to be inerted by limes, and do not release the sequestered CO_2.

5.5 D, Benefits and loads beyond the product system boundary

There is no waste valorization.

6 Life cycle assessment

6.1 Method for assessment

Life cycle assessment (LCA) is a method that is assess the potential environmental impacts of a product throughout its life cycle, in a "cradle-to-grave" perspective, according to ISO standards 14040:2016 (ISO, 2006a) and 14044:2016 (ISO, 2006b).

For such a study, it is necessary to quantify the input and output of the perimeter defined in the study, namely raw material and energy flows, as well as emissions of pollutants in air, water and soil. Thus, these flows can be translated in terms of potential impacts on the environment. The characterization of impacts is carried out according to the standard EN 15804+A1 (2014), which provides core product category rules (PCR) for Type III environmental product declarations (EPD) for any construction product and construction service.

Impact assessment are evaluated with Simapro 8.5.0 software (2018) (Pré-Consultant, CH).

The databases used for the modeling are Ecoinvent 3.4 (November 2017)[12] (Wernet et al. 2016) and ELCD 3.2 (November 2017). ELCD is used only for the hydrated lime, with the data transmitted by Carmeuse and which are included in this database. The data are described as good quality data. Data collected on site is representative of the plants. Completeness, plausibility and consistency have been checked by EESAC expect, with a further review by EuLA experts, and an external review by Fraunhofer IBP, carried out in accordance with ISO 14040 series[13].

Impact assessment are estimated in compliance with EN 15804+A1 (2014). According to Annex C, the characterisation factors should be taken from CML-IA version 4.1, dated October 2012. The CML-IA version implemented in Simapro 8.5 is the version 4.2 (April 2013). In order to use the "right" characterisation factors, we have used the MMG LCIA Method 2017. This method is validated to establish the Belgian EPD and it includes the indicators calculation with the CML-IA version 4.1, October 2012. The official document published by the "Service Public Fédéral – Santé publique, sécurité de la chaîne alimentaire et environnement" is in Annex 3.

Resource use (primary energy use and water) and waste are evaluated with the method SBK Bepalingsmethode, 20 oktober 2017 (NMD 2.1). This is the official Dutch calculation method for the assessment of the environmental performance of construction and civil engineering works (GWW) over their entire service life, based on EN 15804. Substance names and characterisation factor are adapted based on CML spreadsheet "CML-IA_april_2015.xls" and PRé "CML-IA baseline 3.03" with respect to EN15804. The characterisation factors listed in the following tables are taken from CML –IA version 4.1, dated October 2012. Details on the method can be found on the website https://www.milieudatabase.nl/. All documents (in English) are available at the page https://www.milieudatabase.nl/index.php?q=english-documents, in particular the guide describing the Assessment Method Environmental Performance Construction and Civil Engineering Works (GWW)[14].

The inventory as modeled in Simapro with all database entries is listed in Annex 4.

6.2 Life cycle assessment results

The value are indicated without any lifespan included. Usual lifespan for LENOZ characterisation is 50 years.

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[12] https://www.ecoinvent.org

[13] Fazio, Simone; Pennington, David (2007): Hydrated Lime EU 2007; Production at plant (Location: RER). European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-eplca-956fc38e-f90b-4cea-ae6a-06f090976d4e

[14] http://www.milieudatabase.nl/imgcms/SBK_Assessment_method_version_2_0_TIC_versie.pdf

Table 10 and Table 11 detail the results.

Resource use

- Use of primary energy as raw materials:
  - renewable: hempshives and cardboard corners (see 5.1.1, hemp shives)
  - non-renewable: PP hat and PE ligatures (see 5.1.2)
- Use of primary energy excluding primary energy used as raw material: the EN 15804 includes this note, “In order to identify the input part of renewable/non renewable primary energy used as an energy carrier and not used as raw materials, the parameter “use of renewable/non renewable primary energy excluding renewable/non renewable primary energy resources used as raw materials” is considered and can be calculated as the difference between the total input of primary energy and the input of energy resources used as raw materials.” (7.2.4, Note).

Use of secondary materials

- Recycled paper in cardboard corners (see 5.1.2).

Table 10: Impact assessemnt of 1 FU of IsoHemp hempcrete blocks (1 m³) – without lifespan

Impact assessment	Producation stage	Construction stage		Use stage							End-of-life stage				D Benefits and loads boeyond the product system boundary
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Usa	B2 Maintenance	B3 Repair	B4 Remplacement	B5 Refurbishment	B6Operational energy use	B7 Operational water use	C1 De-construction,	C2 Transport	C3 Waste processing	C4 Disposal	
Acidification [kg SO_2 eq]	2.12E-01	2.32E-02	1.44E-02	0	0	0	0	0	0	0	0	4.38E-03	0	1.43E-02	0
Eutrophication [kg PO_4^{3-} eq]	7.18E-02	3.85E-03	1.99E-03		0	0	0	0	0	0	0	7.27E-04	0	2.42E-03	0
Global warming(GWP100a) [kg CO2 eq]	-9.63E+01	7.36E+00	9.78E+00	0	0	0	0	0	0	0	0	1.39E+00	0	2.44E+00	0
Photochemical ozone creation [kg C_2H_4 eq]	1.85E-02	1.18E-03	1.59E-03	0	0	0	0	0	0	0	0	2.22E-04	0	5.28E-04	0
Ozone depletion [kg CFC-11 eq]	7.68E-06	1.36E-06	4.60E-07	0	0	0	0	0	0	0	0	2.58E-07	0	7.23E-07	0
Depletion of abiotic resources (elements) kg Sb eq]	1.28E-04	2.03E-05	5.35E-06	0	0	0	0	0	0	0	0	3.83E-06	0	2.60E-06	0
Depletion of abiotic resources (fossil) [MJ]	1.08E+03	1.10E+02	6.82E+01	0	0	0	0	0	0	0	0	2.09E+01	0	6.05E+01	0

Resource use	Producation stage	Construction stage		Use stage							End-of-life stage				D Benefits and loads boeyond the product system boundary
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Usa	B2 Maintenance	B3 Repair	B4 Remplacemen	B5 Refurbishment	B6Operational energy use	B7 Operational	C1 De-construction,	C2 Transport	C3 Waste processing	C4 Disposal	
Use of renewable primary energy excluding renewable primary energy resources used as raw material [MJ]	2.31E+01	1.67E+00	1.24E+00	0	0	0	0	0	0	0	0	3.15E-01	0	4.99E-01	0
Use of renewable primary energy resources used as raw material [MJ]	1.5E+03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materail) [MJ]	1.53E+03	1.67E+00	1.24E+00	0	0	0	0	0	0	0	0	3.15E-01	0	4.99E-01	0
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material [MJ]	1.27e+03	1.20E+02	7.54E+01									2.26E+01	0	6.73E+01	0
Use of non-renewable primary energy resources used as raw material [MJ]	3.36E+01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materail) [MJ]	1.30E+03	1.20E+02	7.54E+01									2.26E+01	0	6.73E+01	0
Use of secondary material [kg]	0.247	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use of renewable secondary fuels [MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Use of non-renewable secondary fuels [MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Net use of fresh water [m^3]	1.72E+00	1.93E-02	5.38E-02	0	0	0	0	0	0	0	0	3.65E-03	0	5.82E-02	0

Waste	Producation stage	Construction stage		Use stage							End-of-life stage				D Benefits and loads boeyond the product system boundary
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Usa	B2 Maintenanc	B3 Repair	B4 Remplacem	B5 Refurbishme nt	B6Operation al energy	B7 Operational	C1 De-construction	C2 Transport	C3 Waste processing	C4 Disposal	
Hazardous waste disposal [kg]	4.65E-04	6.33E-05	2.27E-05	0	0	0	0	0	0	0	0	1.2E-05	0	2.47E-05	0
Non hazardous waste disposal [kg]	2.53E+01	5.37E+00	2.01E+00	0	0	0	0	0	0	0	0	1.01E+00	0	3.4+E02	0
Radioactive waste disposal [kg]	5.98E-03	7.76E-04	2.25E-04	0	0	0	0	0	0	0	0	1.47E-04	0	3.06E-05	

Other output flows	Producation stage	Construction stage		Use stage							End-of-life stage				D Benefits and loads boeyond the product system boundary
	A1 / A2 / A3	A4 Transport	A5 Installation	B1 Usa	B2 Maintenan	B3 Repair	B4 Remplace	B5 Refurbishm ent	B6Operatio nal energy	B7 Operationa	C1 De-constructio	C2 Transport	C3 Waste processing	C4 Disposal	
Components for re-use [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials for recycling[kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials for energy recovery [kg]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exported energy [MJ]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Synthesis

Table 11: Synthesis of impact assessment of 1 UF of IsoHemp hempcrete blocks (1 m^3) – without lifespan

IMPACT ASSESSMENT Agregation of modules					
Impact [units]	**Production stage A1-A3**	**Construction stage A4-A5**	**Use stage B1-B7**	**End-of-life stage C1-C4**	**Total life cycle**
Acidification [kg SO_2 eq]	2.12E-01	3.76E-02	0	1.87E-02	**2.68E-01**
Eutrophication [kg PO_4^{3-} eq]	7.18E-02	5.84E-03	0	3.72E-03	**8.13E-02**
Global warming(GWP100a) [kg CO2 eq]	-9.63E+01	1.71E+01	0	3.81E+00	**-7.54E+01**
Photochemical ozone creation [kg C_2H_4 eq]	1.85E-02	2.77E-03	0	7.50E-04	**2.21E-02**
Ozone depletion [kg CFC-11 eq]	7.68E-06	1.82E-06	0	9.81E-07	**1.05E-05**
Depletion of abiotic resources (elements) kg Sb eq]	1.28E-04	2.56E-05	0	6.43E-06	**1.60E-04**
Depletion of abiotic resources (fossil) [MJ]	1.08E+03	1.79E+02	0	8.14E+01	**1.34E+03**

IMPACT ASSESSMENT Agregation of modules					
Resource use	**Production stage A1-A3**	**Construction stage A4-A5**	**Use stage B1-B7**	**End)of-life stage C1-C4**	**Total life cycle**
Use of renewable primary energy excluding renewable primary energy resources used as raw material [MJ]	2.31E+01	02.9E+00	0	8.13E-01	**2.68E+01**
Use of renewable primary energy resources used as raw material [MJ]	1.5E+03	0	0	0	**1.5E+03**
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materail) [MJ]	1.53E+03	2.9E+00	0	8.13E-01	**1.53E+03**
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material [MJ]	1.27E+03	1.96E+02	0	8.99E+01	**1.55E+03**
Use of non-renewable primary energy resources used as raw material [MJ]	3.36E+01	0	0	0	**3.36E+01**
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materail) [MJ]	1.30E+03	1.96E+02	0	8.99E+01	**1.59E+03**
Use of secondary material [kg]	0.25E+00				**0.25E+00**
Use of renewable secondary fuels [MJ]	0	0	0	0	**0**
Use of non-renewable secondary fuels [MJ]	0	0	0	0	**0**
Net use of fresh water [m^3]	1.72E+00	7.32E-02	0	6.18E-02	**1.86E+00**

IMPACT ASSESSMENT Agregation of modules					
Waste	**Production stage A1-A3**	**Construction stage A4-A5**	**Use stage B1-B7**	**End-of-life stage C1-C4**	**Total life cycle**
Hazardous waste disposal [kg]	4.65E-04	8.60E-05	0	3.67E-05	**5.88E-04**
Non hazardous waste disposal [kg]	2.53E+01	7.37E+00	0	3.41E+2	**3.73E+02**
Radioactive waste disposal [kg]	5.98E-03	1.00E-03	0	1.77E-04	**7.15E-03**

IMPACT ASSESSMENT Agregation of modules					
Other output flows	**Production stage A1-A3**	**Construction stage A4-A5**	**Use stage B1-B7**	**End-of-life stage C1-C4**	**Total life cycle**
Components for re-use [kg]	0	0	0	0	**0**
Materials for recycling[kg]	0	0	0	0	**0**
Materials for energy recovery [kg]	0	0	0	0	**0**
Exported energy [MJ]	0	0	0	0	**0**

Figure 5 shows the impacts of the different stages of the life cycle of the IsoHemp hempcrete blocks. Production stage (A1-A3) induces most of the impacts.

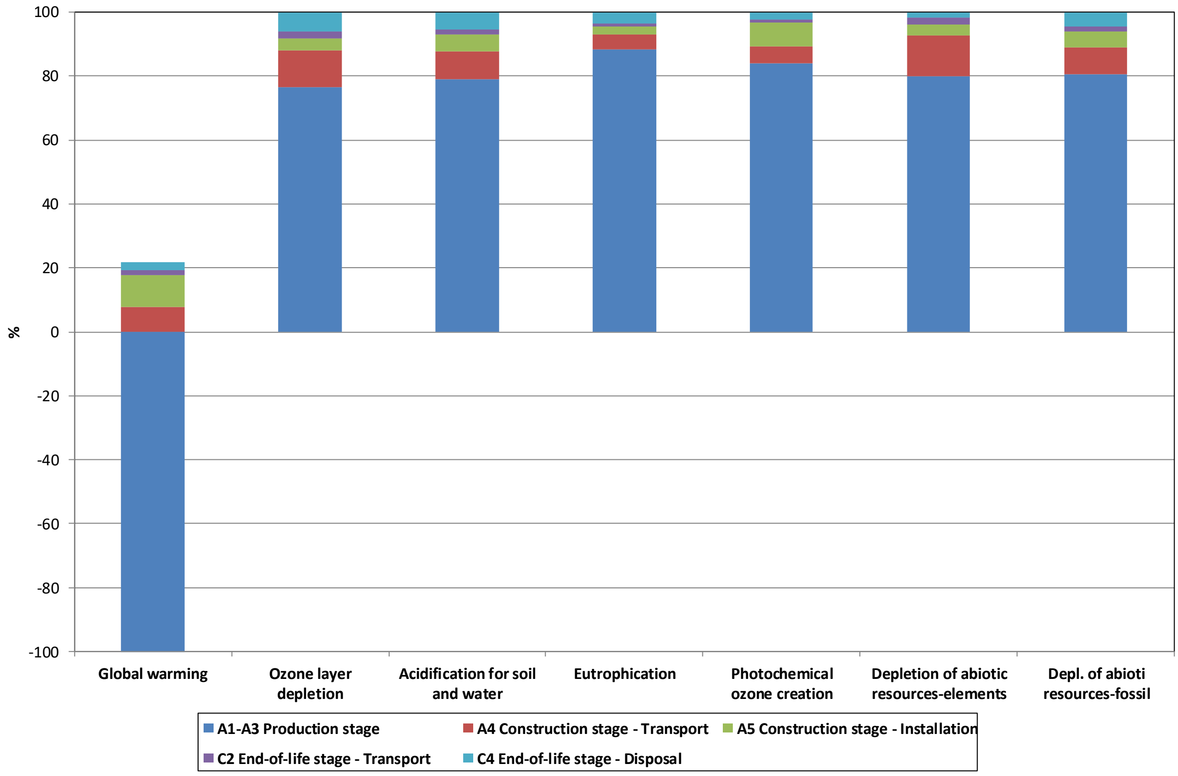

Figure 5 : Environmental impact of 1 UF of IsoHemp hempcrete blocks – characterization CML-IA (ver. 4.1)

Figure 6 shows in details the impacts of the production stage (A1-A3). Raw materials are clearly the most impacting elements.

Hemp shives (in dark blue) and carbonation of limes (in light blue, storage) induce a long-term carbon capture, having a "negative" impact in the GWP category. Due to the long lifespan of the IsoHemp hempcrete blocks, this carbon storage is considered as definitive and complete. So the hempcrete blocks can be seen as efficient carbon sinks (Arrigoni 2017). The disposal (landfill) does not induces CO_2 release (Nozahic 2012, Pretot 2014).

Besides hemp shives, limes are the most impacting elements, especially hydraulic lime (but it needs once and a half time more of it than of hydrated lime). This element is very specific due to its particular composition and can not be replaced.

Table 12 shows the impacts of the differents elements involved in the production stage of the hempcrete blocks.

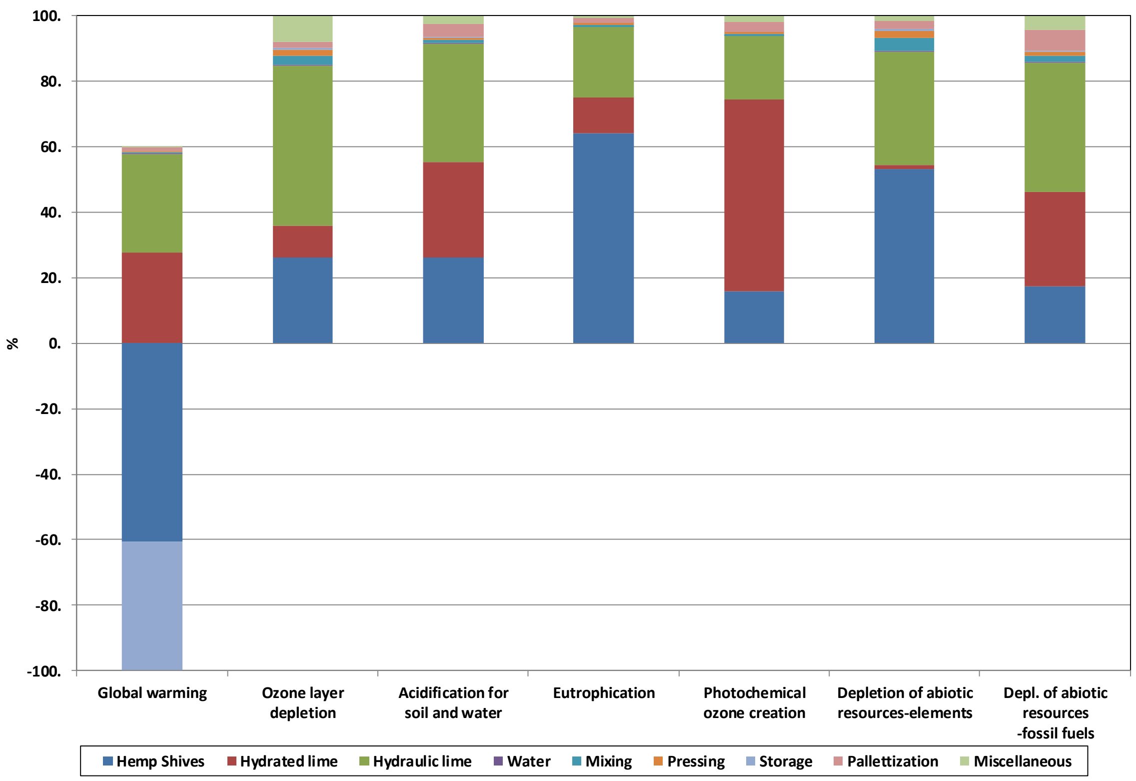

Figure 6 : Impact assessments – details for the Production stage (A1-A3) of IsoHemp hempcrete blocks – characterization with CML-IA (4.1) (no lifespan)

Table 12: Impact assessments – details for the Production stage (A1-A3) of IsoHemp hempcrete blocks – characterization with CML-IA (4.1) (no lifespan)

Impact assessment	Total	Hemps shives	Hydrated lime	Hydraulic lime	Water	Mixing	Pressing	Storage	Palletti zation	Miscela neous
Global warming (GWP100a) [kg CO2 eq]	**-9.63E+01**	-1.47E+02	6.70E+01	7.32E+01	9.40E-02	1.23E+00	6.95E-01	-9.55E+01	2.51E+00	1.12E+00
Ozone depletion [kg CFC-11 eq]	**7.68E-06**	2.01E-06	7.38E-07	3.77E-06	8.70E-09	2.23E-07	1.26E-07	4.50E-08	1.50E-07	6.05E-07
Acidification [kg SO_2 eq]	**2.12E-01**	5.53E-02	6.21E-02	7.68E-02	4.47E-04	2.15E-03	1.22E-03	4.33E-04	8.49E-03	5.23E-03
Eutrophication [kg PO_4^{3-} eq]	**7.17E-02**	4.60E-02	7.80E-03	1.55E-02	5.43E-05	4.37E-04	2.47E-04	8.81E-05	1.02E-03	5.50E-04
Photochemical ozone creation [kg C_2H_4 eq]	**1.85E-02**	2.93E-03	1.09E-02	3.59E-03	2.73E-05	1.29E-04	7.29E-05	2.60E-05	5.85E-04	3.22E-04
Depletion of abiotic resources (elements) kg Sb eq]	**1.28E-04**	6.85E-05	1.39E-06	4.45E-05	3.45E-07	4.83E-06	2.74E-06	9.74E-07	3.17E-06	1.93E-06
Depletion of abiotic resources (fossil) [MJ]	**1.08E+03**	1.89E+02	3.09E+02	4.26E+02	1.32E+00	2.08E+01	1.18E+01	4.20E+00	6.80E+01	4.77E+01

7 Evaluation of environmental performance for LENOZ certification

This approach aims at the use of building materials with a low environmental impact.

Building materials are evaluated according to their global warming potential, ozone depletion potential, photochemical ozone creation potential, adicification and eutrophication potential[1].

7.1 *Evaluation of the environmental indicator I_{env}:*

The evaluation of the environmental indicator l I_{env} is based on the values of the impact assessment indicators with a lifespan of 50 years[1].

The equation used to the calculation of the indicator I_{env} is defined by:

$$I_{env} = 10^3 \cdot \left(\frac{0{,}54 \cdot GWP_{mat}}{11\,209} + \frac{0{,}09 \cdot ODP_{mat}}{0{,}0146} + \frac{0{,}12 \cdot POCP_{mat}}{60} + \frac{0{,}09 \cdot AP_{mat}}{51} + \frac{0{,}16 \cdot EP_{mat}}{0{,}75} \right)$$

avec GWP_{mat}, ODP_{mat}, $POCP_{mat}$, AP_{mat} et EP_{mat} les critères des matériaux de construction issues du fichier « *Ökobau.dat* » [m^3].

Tableau 5: Facteurs de normalisation pour le calcul de l'indicateur environnemental [11]

Incidence environnementale	Emission moyenne par européen (EU-25+3) en 2010	
Potentiel de réchauffement global (GWP)	11 209	kg CO_2- éq. / tête
Potentiel de déplétion ozonique (ODP)	0,0146	kg R11- éq. / tête
Potentiel de création d'ozone photochimique (POCP)	60	kg C_2H_4 - éq. / tête
Potentiel d'acidification (AP)	51	kg SO_2- éq. / tête
Potentiel d'eutrophisation (EP)	0,75	kg PO_4-éq. / tête

Impact assessment	Value for the total life cycle	Value including 50 years lifespan
GWP [kg CO_2 eq]	-7.54E+01	-1.51E+00
ODP [kg CFC-11 eq]	1.05E-05	2.10E-07
POCP [kg C_2H_4 eq]	2.21E-02	4.41E-04
AP [kg SO_2 eq]	2.68E-01	5.37E-03
EP [kg PO_4^{3-} eq]	8.13E-02	1.63E-03

I_{env} = 1000 x (0.54 . (-1.51)/11209 + 0.09 . 2.10 10^{-7}/0.0146 + 0.12 . 4.41 10^{-4}/60 + 0.09 . 5.37 10^{-3}/51 + 0.16 . 1.63 10^{-3}/0.75)

I_{env} (IsoHemp hempcrete blocks) = 0.2859

8 Conclusions

The environmental impact of the IsoHemp hempcrete blocks is mainly in the categories of GLobal warming potential (GWP100) and the Depletion of abiototic resources (fossil). The production stage of the blocks, especially because of the raw materials contribution, is the most important one, and this in all categories.

The impact in the Global warming potential category has a negative value of -75.4 kg CO_2 eq for 1 m of blocks for its all life cycle (cradle-to-grave), without taking in account its lifespan(50 years).

This negative value indicates a long term CO_2 storage, beneficial for the environment. Sequestration is related both to the use of CO_2 for growth of hemp (photosynthesis) and carbonation of limes (hydraulic and hydrated), and can be taken into account in the analysis of the life cycle because of the longevity of this type of material. These findings are consistant with those of other studies (Arrigoni 2017, Boutin 2003, Bruijn 2008, Ip 2012, Nozahic 2012, Pretot 2014).

The Depletion of abiotic resources is mainly affected by the extraction of hydraulic lime. This product has specific properties that do not allow its replacement by alternative material, which could pose a lesser impact.

The product and the process had initially been an ecodesigned, and were therefore already optimized from an environmental point of view.

In conclusion, IsoHemp hempcrete blocks, made of hemps shives and limes, have very interesting environmental performance due to the nature of their components and the simplicity of their manufacturing process. They are of great interest especially in what concerns global warming by storing CO_2 (negative impact), due to its capture during the growth of hemp but also by the carbonation of limes.

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10 Annex 1 - IsoHemp hempcrete blocks – Technical datasheet and specification

http://isohemp.be/wp-content/uploads/2014/01/Isohemp-Cahier-des-charges.pdf

ISOHEMP
L'ISOLATION NATURELLE ET PERFORMANTE

Cahier de charges 2014

Bloc de chanvre IsoHemp Fiche technique - Cahier des charges

Définition générale du matériau

Les blocs isolants en béton de chanvre de fabrication belge. Les produits sont obtenus par un mélange de granulat de chanvre, d'un mélange de chaux et d'eau sans additifs supplémentaires. Le produit est moulé, pressé, durcit et séché à l'air libre sans nécessiter un apport de chaleur.

Applications

Nouvelle construction, isolation extérieure, isolation intérieure, isolation de sol et maçonnerie intérieure.

Les blocs de chanvre permettent la réalisation d'enveloppe de bâtiments ou le remplissage d'ossatures quelconques.

Caractéristique physique

Masse volumique apparente à l'état sec : $300 < \rho < 370$ [kg/m³]
Valeur de conductivité thermique : $\lambda_{UI} = 0{,}076$ [W/mK]

Caractéristiques du produit

Les blocs sont de couleur allant de beige à blanc cassé avec une surface poreuse entre les brins des végétaux permettant une accroche aisée de la couche de finition.

Les blocs sont de dimensions :

- Epaisseurs : 120, 155, 200, 300 mm
- Longueur : 60 cm
- Hauteur : 30 cm (20 cm pour les blocs de 30 cm d'épaisseur)

La tolérance des blocs est de ± 1 mm sur l'épaisseur

Conditionnement

Palettes de dimension 1000 X 1200 mm pour une hauteur de 1,40 m.

IsoHemp S.A. - rue du Grand Champ, 18 (Z.I. Noville-les-Bois) – 5380 Fernelmont
Tel. : +32 (0) 81/39 00 13 – Fax : +32 (0) 81/39 00 14 – Email : info@isohemp.be.

Cahier de charges 2014

Mise en œuvre

Maçonnerie isolante de remplissage ou de couverture associée à une maçonnerie portante ou une structure poteau-poutres en bois, béton ou acier.

Il s'agit d'une maçonnerie autoportante.

Mortier composé de chaux, sable et liant hydraulique ou d'un mortier de type « prêt à l'emploi » renseigné par le fabricant.

Les blocs sont collés en joint mince de 3mm. La première ligne est posée sur un support imperméable empêchant les remontées capillaires.

Interposition d'une membrane d'étanchéité au départ de l'élévation sur maçonnerie de fondation.

Les lignes suivantes seront posées avec un mortier-colle appliqué à l'aide d'une truelle crantée ou non, d'un peigne à colle ou de tout autre outil permettant de coller rapidement les blocs.

Les blocs sont fixés mécaniquement aux différents supports de structure : poteaux, maçonneries au moyen de pattes métalliques galvanisées.

Selon les différentes applications, les dessus de portes et de fenêtres nécessiteront la pose de linteaux en béton, terre cuite, en bois ou en utilisant des profilés type « cornières » ou « équerres » métalliques.

L'ensemble des prescriptions du fabricant sont d'application.

Caractéristiques techniques des blocs de chanvre

Epaisseur [mm]	120	155	200	300
Dimension [mm]	600X300	600 X 300	600 X 300	600 X 200
Blocs par m² [-]	5.55	5.55	5.55	8.33
Densité [kg/m³]	360	360	360	360
Résistance thermique [m²K/W]	1.6	2	2.6	4
Déphasage [h] (ISO 13786)	6.25	9.33	12.5	18.75
Indice d'affaiblissement acoustique Rw [dB]	37	39	42	45
Coefficient d'absorption acoustique α [-]	0.8	0.8	0.8	0.8
Réaction au feu (NF EN 13501-1)	d0 - M1	d0 – M1	d0 –M1	d0 – M1

d0 : petites gouttes et débris enflammés
M1 : Incombustible à petite flamme

IsoHemp S.A. - rue du Grand Champ, 18 (Z.I. Noville-les-Bois) – 5380 Fernelmont
Tel. : +32 (0) 81/39 00 13 – Fax : +32 (0) 81/39 00 14 – Email : info@isohemp.be.

11 Annex 2 – Electricity mix by Luminus

This is the official document sent by Luminus to IsoHemp about the electricity they pay for.

Informations concernant votre prix

Que payez-vous et pour qui?

Electricité

39%	Luminus
43%	Gestionnaire de réseau
1%	Gouvernement
17%	TVA

D'où provient votre électricité?

Votre tarif

Votre tarif		Total d'énergie fournie par Luminus
0,00%	sources d'énergie renouvelables	35,46%
0,00%	cogénération non renouvelable	0,00%
44,33%	gaz naturel	28,61%
0,00%	autres combustibles fossiles	0,00%
55,67%	nucléaire	35,93%
0,00%	divers	0,00%

Total d'énergie fournie par Luminus

Pour plus d' informations sur l'impact sur l'environnement des émissions de CO2 et des déchêts radioactifs de la production d'électricité en fonction des différentes sources d'énergie: www.climat.be et www.ondraf.be

12 Annex 3 – Belgian EPD Programme

EPD stands for 'environmental product declaration' and is a written declaration containing quantified information about a given set of environmental impacts based on a life-cycle analysis.

The Royal Decree on Environmental Messages provides for the creation of a federal EPD database and lays down various rules that are characteristic of EPD programmes. The EPD programme applies the requirements of the Royal Decree on Environmental Messages. The FPS of Health relies on the NBN EN ISO 14025 standard, thus acting as programme operator. The programme of the FPS of Health is named 'Belgian EPD Programme' or B-EPD in short.

The principal aim of the Belgian EPD programme is to provide interested organisations with a framework for developing and making available EPDs in accordance with the Royal Decree on EPDs. The B-EPD programme is applicable to building products that are placed or made available on the market in Belgium or that can be used in buildings on the Belgian territory.

The programme started on 7 December 2016.

Impact caterogries and modules for B-EPD are described in details on the following document;
https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/b-epd_indicators_v1_1.pdf (last accessed 09.04.2018)

service public fédéral
SANTE PUBLIQUE,
SECURITE DE LA CHAINE ALIMENTAIRE
ET ENVIRONNEMENT

federale overheidsdienst
VOLKSGEZONDHEID,
VEILIGHEID VAN DE VOEDSELKETEN
EN LEEFMILIEU

1

B-EPD

IMPACT CATEGORIES AND MODULES FOR B-EPD

v. 1.0 _ 12.10.2017
epd@environment.belgium.be

2

1 IMPACT CATEGORIES

Following impact categories and models are mandatory for EPDs according to the Belgian EPD Program:

CEN indicators	Global Warming Potential	As in EN 15804 (IPCC 2007, 100y) / CML-IA version 4.1, october 2012 *(IPCC 2013 also accepted)*
	Acidification Potential	As in EN 15804 (Huijbregts, (RAINS) 1999 - CML) / CML-IA version 4.1, october 2012
	Eutrophication Potential	As in EN 15804 (Heijungs, Guinée, et al, 1992: environmental life cycle – CML) / CML-IA version 4.1, October 2012
	Ozone Depletion potential	As in EN 15804 (World Meteorological Organization, 2003, steady state) / CML-IA version 4.1, October 2012 *(updated CF published by JRC also allowed)*
	Photochemical ozone creation potential	As in EN 15804 (Jenkin, 1999 + Derwent, 1998 – CML) / CML-IA version 4.1, october 2012
	Abiotic depletion potential (fossil)	As in EN 15804
	Abiotic depletion potential (elements)	
Toxicity	Eco toxicity (freshwater)	Usetox *(We recommend to use version 2)*
	Human toxicity (cancer effects)	Usetox *(we recommend to use version 2)*
	Human toxicity (non-cancer effects)	Usetox *(We recommend to use version 2)*
Particulate matter	PM2,5	Riskpoll with Humbert update (2009) *(We also accept the more recent update of 2011)*
Water scarcity	Water scarcity	Swiss ecoscarcity model by Frischknecht (2008)
Ionizing radiation	Human Health effects	Frischknecht based on Dreicer (2000)
Land use related impacts	Soil organic matter (SOM) - transformation	Mila I canals (2007)
	Soil organic matter (SOM) - occupation	Mila I canals (2007)
	Biodiversity due to land occupation	Kölner (2000) as used in eco-indicator 99
	Biodiversity due to land transformation	Kölner (2000) as used in eco-indicator 99

An EPD compliant to the Belgian EPD program shall report the **GWP due to biogenic carbon** separately. This is laid down in the horizontal PCR document: NBN/DTD B 08-001, which can be purchased here:

https://www.nbn.be/nl/catalogue/standard/nbndtd-b-08-001?fulltext=DTD+15804#direct

3

For the time being the building tool of the regional authorities also needs following three flows for use in their building calculator. If you want your EPD to be used in the building calculator, then we recommend to also include them. These indicators can also be entered in the database.

Land use related impact	Biodiversity due to land occupation • Urban, industry • agricultural • forest Biodiversity due to land transformation • Tropical forrest	Based on Kölner (2000) as used in eco-indicator 99, but with characterization factors set to 1.

Secondary data

For the time being we accept both EPDs made with eco-invent background data and EPDs with Gabi background data.

Simapro

The regional authorities provided us with an excel file and a **.csv file** with indicators and CF to make it easy to create the set of indicators in Simapro. You can download them from our website. We however did not verify it hence do not take responsibility for it. For others tools they do not yet have .csv file.

2 MODULES AND LINK WITH THE BUILDING CALCULATOR OF THE REGIONAL AUTHORITIES

Following modules are mandatory to be declared: A123, A4, C2, C3, C4 and D. More details can be found in the NBN/DTD B 08-001.

This has consequences for the use of the building calculator of the regional authorities which calculates also modules A5, B2, B4, B6 and C1. For transparency reasons we inform you in the paragraph how this building calculator very likely will deal with missing or non-representative modules. This way manufacturers can decide by themselves whether or not they declare additional modules.

- The building calculator does not calculate B1, B3, B5, B7 and D for the time being.
- Every module declared in the B-EPD will be used within the building calculator.
- If module B2 is declared in the B-EPD, the B-EPD is recommended to declare 3 scenarios: B2_1 cleaning, B2_2 small maintenance, B2_3 major maintenance. For all three the frequency should be declared.
- If A5, B2, B6 and C1 are not declared in the B-EPD than the impact will be copied from a generic similar product in the building calculator.
- If B4 is not declared in the B-EPD it will be calculated by the building calculator based on the RSL. No distinction between esthetical and required maintenance.
- The impact of ancillary materials has to be included

4

In the database also other EPDs are possible (cfr. general program instructions). The minimum requirements for these to be used in the building calculator are as follows.

The EPD

- Shall conform to EN 15804, and
- Shall be verified by a 3rd party in the frame of a program operator (MRPI, HQE FDES, BRE EPD, AENOR, IBU, EPD International, Eco-platform EPDs), and
- Shall have declared the additional impact categories, and
- The scenarios shall be representative for Europe

Only if all the requirements above are met, than following rules will apply:

- In case modules are **declared** but when they are not representative for Belgium:

    - A4: the declared impact + penalty of x% (for manufacturing sites outside Europe, A4 is mandatory to be declared for the transport towards EU).
    - A5: the declared impact + penalty of x%
    - B2: the declared impact + penalty of x%
    - B3: will not be used as the tool does not calculate this module
    - B4: the declared impact + penalty of x%
    - B5: will not be used as the tool does not calculate this module
    - B6: the declared impact + penalty of x%
    - B7: will not be used as the tool does not calculate this module
    - C1: the declared impact + penalty of x%
    - C2: impact from a generic similar product in the tool representative for BE
    - C3: impact from a generic similar product in the tool representative for BE
    - C4 Disposal: impact from a generic similar product in the tool representative for BE
    - D: will not be used in MMG as MMG does not calculate this module

- In case modules are **not declared** the impact is copied from a generic product representative for BE in the calculation tool. A penalty is added of y %.

In reality this means that a manufacturer will always have to calculate the additional indicators (which shall also be part of the verification) IF he wants his EPD to be used by the building calculator of the regional authorities.

Note: the percentage x and y are to be determined by the owners of the building calculator.

f you have any comments or questions to this document, please contact us via epd@environment.Belgium.Be

13 Annex 4 – Inventory and Simapro modeling

13.1 A1-A3, Production stage – main assembly

Products		
A1-A3 Bloc Béton Chanvre-epd	**1**	**p**
Materials/assemblies		
chènevotte-culture et transformation- 1 kg epd	100	p
chaux aérienne 1 kg-epd	75	p
chaux hydraulique 1 kg-EPD	115	p
Tap water {Europe without Switzerland}| market for | Alloc Def, U	250	kg
mix mortier- élec pour 1 UF-epd	1	p
02 Pressage-epd	1	p
03 Stockage-epd	1	p
04 Paletisation-carton - epd	1	p
05 Divers-epd	1	p

13.1.1 Hemp shives

Products			
chènevotte-culture et transformation- 1 kg epd	**1**	**p**	
Materials/assemblies			
Urea, as N {RER}| production | Alloc Def, U	0.00595	kg	N
Phosphate fertiliser, as P2O5 {RER}| triple superphosphate production | Alloc Def, U	0.00422	kg	P2O5
Potassium chloride, as K2O {RER}| potassium chloride production | Alloc Def, U	0.00181	kg	K2O
Chènevotte - émissions	1	kg	émissions liées à 1 kg chènevotte
Diesel, at regional storage/RER U	0.000507	kg	diesel - transfo primaire
Diesel, at regional storage/RER U	0.00221	kg	diesel - transport
Propane/ butane, at refinery/RER U	0.0002	kg	transport interne (transpalette)
Processes			
Tillage, harrowing, by spring tine harrow {CH}| processing | Alloc Def, U	0.000086	ha	travail du sol - herse canadienne
Fertilising, by broadcaster {CH}| processing | Alloc Def, U	0.000086	ha	fertilisation
Sowing {CH}| processing | Alloc Def, U	0.000086	ha	semis du chanvre
Mowing, by motor mower {CH}| processing | Alloc Def, U	0.000086	ha	fauchage
Haying, by rotary tedder {CH}| processing | Alloc Def, U	0.000086	ha	fanage
Baling {CH}| processing | Alloc Def, U	0.000086	p	mise en balles
Transport, tractor and trailer, agricultural {CH}| processing | Alloc Def, U	10*0.32/0.48	kgkm	transport balles vers la ferme-hyp 10 km
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	40*0.32/0.48	kgkm	transport balles vers transfo primaire-hyp. 40 km
Electricity, low voltage, production FR, at grid/FR U	18.96	kJ	électricité process
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	400	kgkm	transport depuis l'Aube, camion 25t, 400 km

Products				
Chènevotte - émissions avec energy	**1**	**kg**		
Resources				
Energy, gross calorific value, in biomass		15	MJ	
Emissions to air				
Dinitrogen monoxide	high. pop.	7.42E-05	kg	N2O
Ammonia	high. pop.	2.86E-05	kg	NH3
Carbon dioxide	high. pop.	-1.6	kg	stockage carbone
Emissions to water				
Nitrate	groundwater	0.00258	kg	NO3-
Phosphate	groundwater	6.41E-05	kg	PO4---

13.1.2 Hydrated lime

Products			
chaux aérienne 1 kg-epd	**1**	**p**	
Materials/assemblies			
Hydrated Lime EU 2007, production at plant RER S	1	kg	data EuLA
Processes			
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	13.5	kgkm	transport-13.5 km camion 25 t

13.1.3 Hydraulic lime

Products			
chaux hydraulique 1 kg-EPD	**1**	**p**	
Materials/assemblies			
Lime, hydraulic {RoW}| production | Alloc Def, U	1	kg	SANS rectif pour data fournisseur EPD
Processes			
Transport, freight, lorry >32 metric ton, EURO5 {RER}| transport, freight, lorry >32 metric ton, EURO5 | Alloc Def, U	750	kgkm	transport-750 km camion 40 t

13.1.4 Adhesive mortar preparation

Products			
mix mortier- élec pour 1 UF-epd	**1**	**p**	**Isohemp\epd**
Materials/assemblies			
Processes			
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	0.319/1.296	kWh	chaux aérienne, transport in situ
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	0.898/1.296	kWh	chanvre, transport in situ
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	0.437/1.296	kWh	chaux hydraulique, transport in situ
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	2.744/1.296	kWh	mélanger mortier

13.1.5 Pressaging

Products			
02 Pressage-epd	**1**	**p**	**Isohemp\epd**
Materials/assemblies			
Processes			
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	1.250/1.296	kWh	presse, pour 1 UF
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	1.24/1.296	kWh	compresseur, pour 1 UF

13.1.6 Storage

Products			
03 Stockage-epd	**1**	**p**	**Isohemp\epd**
Materials/assemblies			
capture CO2 chaux aérienne	97.2/1.296	kg	carbonatation pour 1 UF
capture CO2 chaux hydraulique	149/1.296	kg	carbonatation pour 1 UF
Processes			
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	0.887/1.296	kWh	transport des blocs pour 1 UF

Products			
capture CO2 chaux aérienne	1	kg	
Emissions to air			
Carbon dioxide	-0.594	kg	Undefined

Products		
capture CO2 chaux hydraulique	**1**	**kg**
Emissions to air		
Carbon dioxide	-0.594*0.75	kg

13.1.7 Palletization

Products			
04 Paletisation-carton - epd	**1**	**p**	
Materials/assemblies			
Polypropylene, granulate {GLO}| market for | Alloc Def, U	0.5/1.296	kg	chapeau en PP
Polyethylene, high density, granulate {GLO}| market for | Alloc Def, U	0.5/1.296	kg	ligatures PE (HD)
Core board {RER}| production | Alloc Rec, U	2*0.21/1.296	kg	2 cornières en carton 210g, cut off
Processes			
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	1.804/1.296	kWh	élec pour 1 UF
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	0.386*170	kgkm	transport chapeau-Waregem170 km
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	0.386*980	kgkm	transport ligature- Isère 980 km
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	1109*0.324	kgkm	transport cornieres carton - 1109 km

13.1.8 Miscellaneous

Products			
05 Divers-epd	**1**	**p**	
Materials/assemblies			
Liquefied petroleum gas {RoW}| market for | Alloc Def, U	0.144/1.296	kg	Propane pour le clark - pour 1 UF
Lubricating oil {RER}| production | Alloc Def, U	0.05/1.296	kg	Huile lubrifiante pour 1 UF
Light fuel oil {Europe without Switzerland}| market for | Alloc Def, U	0.84/1.296	kg	Mazout chaffage pour 1 UF
combustion 1 kg propane	0.144/1.296	kg	Emissions CO2 et H20 combustion propane
Tap water {Europe without Switzerland}| market for | Alloc Def, U	2.5E-3/1.296	kg	nettoyage et sanitaires
Processes			
Electricity, low voltage, production BE, at grid/BE U - luminus isohemp	1.167/1.296	kWh	électricité hors procédé

Products			
combustion 1 kg propane	**1**	**kg**	
Emissions to air			
Carbon dioxide		2.994	kg

13.2 Electric mix by Luminus – IsoHemp mix

Principe: Production ⇒ high voltage ⇒ medium voltage ⇒ low voltage

Products		
Electricity, production mix BE/BE U - luminus isohemp	**1**	**kWh**
Materials/fuels		
Electricity, high voltage {BE}| electricity production, hard coal | Alloc De	0	kWh
Electricity, high voltage {BE}| electricity production, oil | Alloc Def, U	0	kWh
Electricity, high voltage {BE}| electricity production, natural gas, conver	0.4433	kWh
Electricity, industrial gas, at power plant/BE U	0	kWh
Electricity, hydropower, at power plant/BE U	0	kWh
Electricity, high voltage {BE}| electricity production, hydro, pumped sto	0	kWh
Electricity, nuclear, at power plant/UCTE U	0.5567	kWh
Electricity, at wind power plant/RER U	0	kWh
Electricity, at cogen ORC 1400kWth, wood, allocation exergy/CH U	0	kWh
Electricity, at cogen with biogas engine, allocation exergy/CH U	0	kWh

Products		
Electricity, high voltage, production BE, at grid/BE U - luminus iso	**1**	**kWh**
Materials/fuels		
Electricity, production mix BE/BE U - luminus isohemp	1.0082	kWh
Transmission network, long-distance {UCTE}| construction | Alloc Def,	3.17E-10	km
Transmission network, electricity, high voltage {CH}| construction | Alloc	8.44E-09	km
Electricity/heat		
Emissions to air		
Heat, waste	0.028041	MJ
Ozone	0.0000045	kg
Dinitrogen monoxide	0.000005	kg
Emissions to water		
Emissions to soil		
Heat, waste	0.0014759	MJ

Products		
Electricity, medium voltage, production BE, at grid/BE U - luminus	**1**	**kWh**
Materials/fuels		
Electricity, high voltage, production BE, at grid/BE U - luminus isohemp	1.0066	kWh
Sulfur hexafluoride, liquid {RER}| production | Alloc Def, U	7.825E-08	kg
Transmission network, electricity, medium voltage {CH}| construction | A	3.24E-08	km
Electricity/heat		
Emissions to air		
Heat, waste	0.013096	MJ
Sulfur hexafluoride	7.825E-08	kg
Emissions to water		
Emissions to soil		
Heat, waste	0.010715	MJ

Products		
Electricity, low voltage, production BE, at grid/BE U - luminus isol	**1**	**kWh**
Materials/fuels		
Electricity, medium voltage, production BE, at grid/BE U - luminus isohe	1.0676	kWh
Sulfur hexafluoride, liquid {RER}| production | Alloc Def, U	4.5893E-09	kg
Distribution network, electricity, low voltage {CH}| construction | Alloc D	2.94E-07	km
Electricity/heat		
Emissions to air		
Heat, waste	0.060879	MJ
Sulfur hexafluoride	4.5893E-09	kg
Emissions to water		
Emissions to soil		
Heat, waste	0.18264	MJ

13.3 A4 – Construction – Transport

Products			
A4 Construction -Transport	**1**	**p**	**Isohemp\epd**
Materials/assemblies			
Processes			
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	360*125	kgkm	transport blocs sur palette + colle

13.4 A5 – Construction - Installation

Products			
A5 Construction - Installation	1	p	**Isohemp\epd**
Materials/assemblies			
Stucco {FR}| production | Alloc Def, U - isohemp	7.72	kg	plâtre naturel - 20%
Hydrated Lime EU 2007, production at plant RER S	8.49	kg	chaux aérienne - 22%
Sand {CH}| gravel and quarry operation | Alloc Def, U	22.38	kg	sable siliceux - 58 % (FR donc CH)
Tap water {Europe without Switzerland}| market for | Alloc Def, U	10.81	kg	eau
Processes			
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	7.72*330	kgkm	plâtre naturel - région parisionne 330 km
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	8.49*13	kgkm	chaux Carmeuse - 13 km
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	22.38*330	kgkm	sable - région parisienne

13.5 C2 – End-of-life – Transport of waste

Products			
C2 fin de vie-transport des déchets	1	p	**Isohemp\epd**
Materials/assemblies			
Processes			
Transport, freight, lorry 16-32 metric ton, EURO5 {RER}| transport, freight, lorry 16-32 metric ton, EURO5 | Alloc Def, U	25*340	kgkm	transport blocs + mortier vers centre de tri

13.6 C4 – End-of-life - Disposal

Products		
C4 fin de vie - élimination	1	p
Materials/assemblies		
Disposal, inert waste, 5% water, to inert material landfill/CH U-isohemp	340	kg