Balticfloc

RĪGAS TEHNISKĀ UNIVERSITĀTE

Balticfloc

LIFE CYCLE ASSESSMENT OF PAPER-HEMP INSULATION MATERIAL

Riga (Latvia) June 2023

Balticfloc

RĪGAS TEHNISKĀ UNIVERSITĀTE

Content

1-GENERAL ASPECTS _____ 4

1.1. Commissioner of the LCA study, internal or external practitioner of the LCA study 4

1.2. Date of report, contact and deliverable tools _____ 4

1.3. Statement that the study has been conducted according to the requirements of this standard _____ 4

2. GOAL OF THE STUDY _____ 5

2.1. Reasons for carrying out the study and its intended application and audience, i.e., providing information and data for an EPD® for business-to-business and/or business-to-consumer communication _____ 5

3. SCOPE OF THE STUDY _____ 5

3.1. Product Characterization _____ 5

3.2. Declared unit _____ 6

3.2.1. Definition, including relevant technical specification(s) _____ 6

3.2.2. Reference Service Life (RSL) _____ 6

3.2.3. Product mass required for the declared unit: principal product, additional product for implementation and/or life in use and packaging _____ 7

3.3. System boundary according to the modular approach _____ 7

3.3.1. Overview and definition of the systems boundaries and lifecycle phases studied (processes or data needs) _____ 7

3.3.2. A1-A3 Product stage _____ 8

3.3.3. A4-A5 Construction process _____ 10

3.3.4. B1-B7 Use stage _____ 10

3.3.5. C1-C4 End-of-life _____ 10

3.3.6. Benefits and loads beyond the system boundary _____ 11

3.3.7. Omissions of life cycle stages _____ 11

3.4. Quantification of energy and material inputs and outputs, considering how plant-level data is allocated to the declared products _____ 11

3.4.1. Assumptions about relevant background data _____ 11

3.5. Cut-off criteria for initial inclusion of inputs and outputs. _____ 11

3.5.1. Description of the application of cut-off criteria and boundaries to other product life cycles 11

3.5.2. List of excluded processes _____ 12

4. LIFE CYCLE INVENTORY ANALYSIS _____ 13

4.1. Qualitative/quantitative description of unit processes necessary to model the life cycle stages of the declared unit, considering the provisions of EN ISO 14025 regarding data confidentiality _____ 13

4.1.1. A1-A3 Product stage _____ 13

4.2. Sources of generic data or literature used to conduct the LCA _____ 13

4.3. Validation of data, including: _____ 13

4.3.1. Data quality assessment _____ 13

4.3.2. Treatment of missing data _____ 14

4.4. Allocation principles and procedures, including _____ 15

4.4.1. Documentation and justification of allocation procedures _____ 15

4.4.2. Uniform application of allocation procedures 15

5. LIFE CYCLE IMPACT ASSESSMENT 15

5.1. LCIA procedures, calculations, and results of the study (reference to all characterization models, characterization factors and methods used, as defined in this European Standard) 15

5.1.1. Parameters describing the environmental impacts 15

5.1.2. Parameters describing the resource use and others 17

5.1.2.1. Parameters describing the waste categories and others output flows 18

5.1.2.2. Parameters describing the biogenic carbon content at factory gate 18

5.2. A statement that the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks 18

6. LIFE CYCLE RESULTS AND INTERPRETATION 19

6.1. Product comparison with similar products 30

7. CONCLUSIONS 33

8. BIBLIOGRAPHY 34

Annex 1 - LCI for Paper-hemp insulation material 35

1-GENERAL ASPECTS

1.1. Commissioner of the LCA study, internal or external practitioner of the LCA study

The analysis and report have been carried out by Riga Technical University and its Institute of Energy Systems and Environment for Balticfloc.

It has been prepared only for the use of Balticfloc and this is the only company that can distribute this report or disclose it to other parts.

We need to clarify that this study is only based on the current facts, circumstances and assumptions which are specified in the report. Should these facts, circumstances or assumptions would be different, our conclusions might be different.

Moreover, the results of the study should be considered in the aggregate regarding to the assumptions made and not taken individually. The intended target group is Business-to-Business.

1.2. Date of report, contact and deliverable tools

The present report has been issued in June 2023. Participants contact information is provided in the following table.

Company	Address	Participant	Contact
Institute of Energy Systems and Environment, RTU	Āzene street 12 – K1 (Riga, Latvia)	Maksims Feofilovs	Email: maksims.feofilovs@rtu.lv

The deliverables and tools for this project are:

- An LCA report for internal use only (this document).
- One EPD® (Environmental Product Declaration) developed for The International EPD System: Construction Products PCR 2019:14 (EN 15804:2012+A2:2019/ISO 21930).

1.3. Statement that the study has been conducted according to the requirements of this standard

This document is consistent with European Commissions established Product Environmental Footprint Category Rules Guidance (2018) and the international standards of construction products: ISO 14025 (2006), ISO 21930 (2007), EN 15804:2012+A2:2019, and PCR 2019:14 Construction Products version 1.11. Also, LCA standards have been followed: ISO 14040 (2006), ISO 14044 (2006).

2. GOAL OF THE STUDY

2.1. Reasons for carrying out the study and its intended application and audience, i.e., providing information and data for an EPD® for business-to-business and/or business-to-consumer communication

Balticfloc is interested in gathering more information on the environmental impact (CO_2 emission and use of natural resources) of their products and will make this information available using EPD® (Environmental Product Declaration), which will make transparent and traceable environmental impact results of the paper-hemp insulation panels. Also, to make product results comparison with similar products (mineral wool panels, pure paper cellulose-bico panels).

In addition of the publication of this EPD®, this study also has the aim to analyze the environmental impact of the Paper-hemp insulation material life cycle in order to evaluate the processes (i.e., materials, transportation or end of life treatment) with the biggest impact (i.e., environmental hotspots). These results can be used to improve their environmental performance in the future.

This document is the report of methods, results and complements for the Environmental Product Declaration (EPD®) in line with the requested level of detail defined by the standards. It therefore includes the description of the Declared Unit, the system studied (i.e., boundaries and model), the key values and parameters (e.g., transport distances). The LCA report and EPD® is developed by the Institute of Energy Systems and Environment of Riga Technical University for the only use of Balticfloc.

This report gathers the data and hypotheses established can be further validated during the Environment Product Declaration (EPD®) verification by a third party verifier and published in EPD platform.

The aim of this report is to measure carbon emission of paper-hemp bico panel production process in cradle to gate system boundaries. As well as the underlying contribution to the carbon emissions of the various components and compare the results with other alternative products in the insulation market.

3. SCOPE OF THE STUDY

The scope of the study comprises the Paper-hemp insulation material products. This report provides the data for further validation of Environmental Product Declaration (EPD®), as well as an interpretation of the results.

No grouping of products has been done during this study, and results are presented for one Declared Unit.

3.1. Product Characterization

Balticfloc Paper-hemp insulation material is thermal insulation materials for buildings which is made by mixing ground paper with specially treated hemp fiber. The thermal insulation material is made in sheets and it is easy to use for insulation of buildings as it will not require special machinery necessary for loose-fill ecowool. It is also very important that hemp is a material friendly to people and the environment, because during the processing of materials no CO_2 is emitted. Consumption of energy for production of hemp fiber is seven to eight times lower than for production of the same amount of synthetic fiber.

The most suitable hemp variety must be determined, from which to obtain fiber for production of ecowool. Hemp is a well known crop in Latvia. The specifics of harvesting must be taken into consideration so that it can be used for production of ecowool. As a result, a fine fiber is obtained, which is mixed with ground waste paper, heated in an oven and thermal insulation sheets are produced in a special technological process.

UN CPC code: 31449 Fibreboard of wood or other ligneous materials, Other fibreboard

Table 1. Main Characteristics of Balticfloc Paper-hemp insulation materials

Gross density	52.2 kg/m^3
Panel thickness	50/80/100 mm
Thermal resistance	1.0 m^{2}K/W

The content information of the final product is presented in the following table:

Table 2. Main content characteristics of Balticfloc Paper-hemp insulation materials

Product components	Weight, kg	Post-consumer material, weight-%	Renewable material, weight-%
Hemp fiber	1.22	0.0 %	100%
Paper waste	1.16	100%	85.7%
Bico Fibre	0.2	0.0 %	0%
Fire retardant	0.2	0.0 %	0%
TOTAL	2.78	41.7 %	79.6 %
Packaging materials	**Weight, kg**	**Weight-% (versus the product)**	
Metal wires	0.002	0.1 %	
PE bags	0.006	0.3 %	
TOTAL	0.008	0.4 %	

3.2. Declared unit

3.2.1. Definition, including relevant technical specification(s)

By considering the functions of this product, the declared unit can be described as follows: the raw materials and intermediate products acquisition, transportation to building site, manufacturing and installation, and end of life of 1 m^2 of Paper-hemp insulation material with a thickness of 50/80/100 mm, installed, and with a useful life of 50 years.

The Paper-hemp insulation material mats are designed to be easy-to-install, structurally sound and with thermal insulation properties comparable to those of mineral wool.

3.2.2. Reference Service Life (RSL)

The Reference Service Life (RSL) of Paper-hemp insulation material is 50 years.

3.2.3. Product mass required for the declared unit: principal product, additional product for implementation and/or life in use and packaging

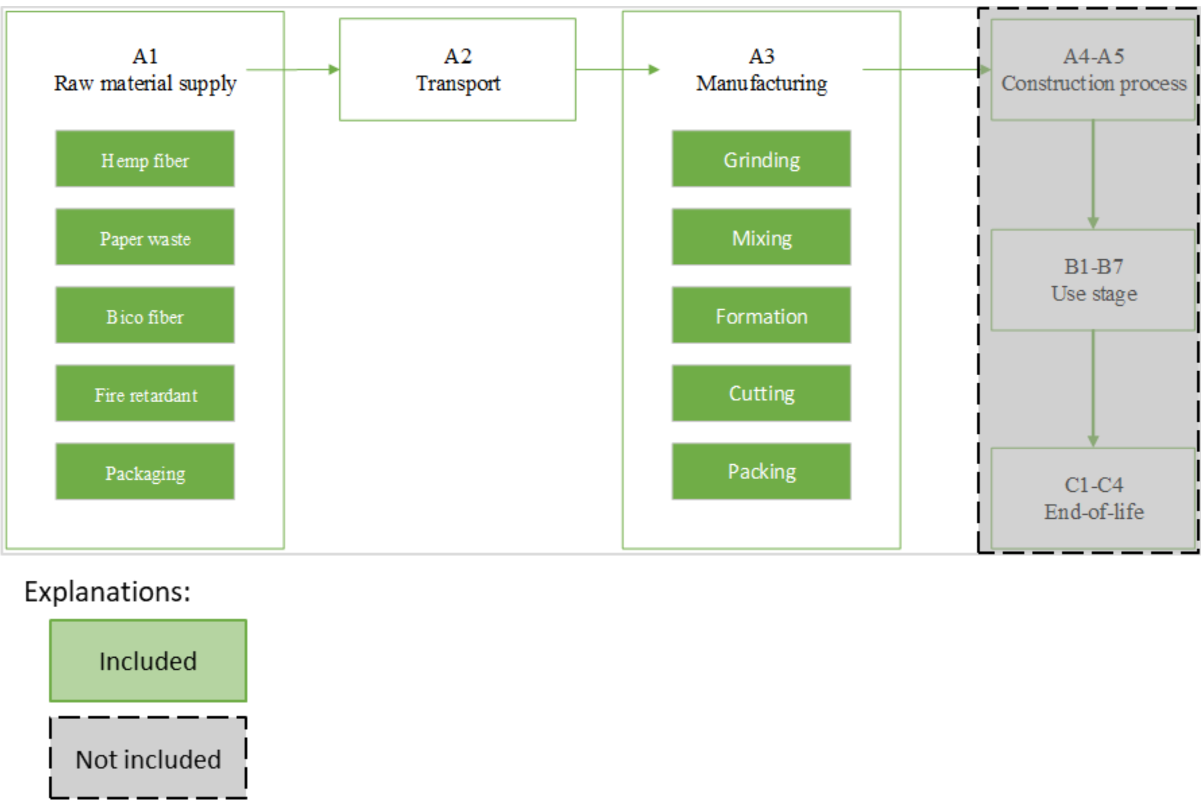
The masses and basic data for calculating the declared unit of Paper-hemp insulation material are described in the Table 4 to and in Annex I LCA Inventory.

3.3. System boundary according to the modular approach

3.3.1. Overview and definition of the systems boundaries and lifecycle phases studied (processes or data needs)

This EPD® is a "cradle to gate" and the diagram can be seen in Figure 1.

Figure 1. System boundaries for the cradle to gate for the Paper-hemp insulation material.



Baltic**floc**

RĪGAS TEHNISKĀ UNIVERSITĀTE 1862

Table 3: Modules declared within the EPD scope.

	Product stage			Construction process stage		Use stage							End of life stage				Resource recovery stage
	Raw material supply	Transport	Manufacturing	Transport	Construction installation	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
Module	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
Modules declared	X	X	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Geography	EUR	EUR	LV	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Specific data used	> 90%			-	-	-	-	-	-	-	-	-	-	-	-	-	-
Variation – products	NOT RELEVANT					-	-	-	-	-	-	-	-	-	-	-	-
Variation – sites	NOT RELEVANT					-	-	-	-	-	-	-	-	-	-	-	-

X: Module accounted for ND: Module Not Declared

3.3.2. A1-A3 Product stage

The product stage for Paper-hemp insulation material is subdivided into "Raw material acquisition", "Transport" and "Manufacturing" modules. The aggregation of the modules A1, A2 and A3 is a possibility considered by the EN 15804:2012+A2:2019 standard. This rule is applied in the associated EPD®. Referred to the interpretation of results, the components with the biggest impacts will be explained. In this report, the relative impact of energy and raw materials into the A1-A3 stages are evaluated independently from the transport activities as well as from the manufacturing process.

- **A1, Raw material supply**

This module considers the extraction and processing of all raw materials and energy which occur upstream of the studied manufacturing process (except for ancillary and packaging used in the product manufacturing process). The raw materials to produce one declared unit of Paper-hemp insulation material are shown in the following table:

Table 4: Input of materials for manufacturing 1 m^2 of Paper-hemp insulation material.

PARAMETER	VALUE (kg/m^2)
Hemp fiber	1.22
Paper waste	1.16
Bico fiber	0.2
Fire retardant	0.2
Metal wires	0.002
PE bags	0.006

- **A2, Transport to the manufacturer**

The raw materials required for the construction of the Paper-hemp insulation material are first transported to the manufacturing place located in Latvia with the exception of hemp and paper waste, which is gathered from local Latvian sources. This stage accounts for all raw materials transported to Balticfloc facilities, where they are processed for manufacturing of Paper-hemp insulation material. For calculations, transport distances of all raw materials were included depending on the vehicle technology (see Annex 1).

The modeling for transport was carried out according to EN 15804:2012+A2:2019 standards and the Product Category Rules for Construction Products PCR 2019:14, version 1.11. Transport is calculated based on a scenario with the parameters described in the following table:

Table 5. Transport parameters for Paper-hemp insulation material (by road)

PARAMETER	VALUE/DESCRIPTION
Fuel type and consumption of vehicle or vehicle type used for transport e.g., long-distance truck, boat, etc.	Average truck trailer EURO6 with a 16 - 32 t payload, with a diesel consumption of 38 liters for 100 km.
Distance	90 km for hemp fiber 100 km for paper waste 1911 km for Bico fiber 3600 km for fire retardant 405 km for PE bags
Capacity utilization (including empty returns)	45 % of the capacity in volume according to Ecoinvent v3.8 and Life Cycle Inventories of Road and Non-Road Transport Services
Volume capacity utilization factor	0.45

- **A3, Manufacturing**

This module includes all activities related to the manufacturing of the Paper-hemp insulation material. The manufacturing process includes the hemp, paper waste and Bico fiber grinding, mixing, forming and cutting into desired size for later packaging. The inventory for this stage was collected from the available date from Paper-hemp insulation material production in 2023 and then normalized to the Declared Unit.

3.3.3. A4-A5 Construction process

The construction process is divided into 2 modules: transport to the building site (A4) and installation (A5).

- A4, transport to the building site. **Not Declared**

This module includes transport from the production gate to the building site.

- A5, installation into the building. **Not Declared**

The installation of product without the use of any additional material or energy expenditure.

3.3.4. B1-B7 Use stage

This stage includes any emissions to the environment of the used product (module B1) and technical operations on the product: maintenance, repair, replacement, and refurbishment (respectively module B2 to B5).

- B1, use or application of the installed product. **Not Declared**

The product does not produce any emissions to the environment during its use. Pollutant emissions to the environment during its use have been considered not relevant.

- B2, maintenance; B3, repair; B4, replacement; B5, refurbishment. **Not Declared**

The declared product performances assume a product working life that equals or exceeds the building lifetime. Once installation is complete, no actions or technical operations are required during the use stage until the end-of-life stage. Therefore, the Paper-hemp insulation material has no impact (excluding potential energy savings due to insulation properties not included in the scope of this study) on these modules.

- B6, operational energy use; B7, operational water use. **Not Declared**

The product is not related to any electricity or water use during the operation of the building.

3.3.5. C1-C4 End-of-life

This stage includes the different modules of end-of-life C1 to C4 detailed below. During the life cycle of the product any hazardous substance listed in the "Candidate List of Substances of Very High Concern (SVHC) for authorization" has not been used in a percentage higher than 0,1% of the weight of the product.

- C1, de-construction, demolition. **Not Declared**

The de-construction and/or dismantling of the entire building. The environmental impact is assumed to be the one corresponding to emissions from wall dismantling and the fuel required for the machinery to perform the demolition tasks.

- C2, transport. **Not Declared**

Transport to waste disposal site: 50 km are assumed.

- C3, waste processing for reuse, recovery, and/or recycling. **Not Declared**

The product is landfilled without reuse, recovery, or recycling.

- C4, disposal. **Not Declared**

The product is assumed to be 100% landfilled.

3.3.6. Benefits and loads beyond the system boundary

In module D is declared the environmental benefits from reusable products, recyclable materials, or energy recovery.

3.3.7. Omissions of life cycle stages

This is a cradle-to-gate. Stages A1-A3 have been included. The following flows are not included in the system boundaries:

- The construction of plants is excluded since the related flows are assumed to be negligible compared to the production of the building product when compared at these systems' lifetime levels.
- Manufacture of equipment used in production, buildings or any other capital goods;
- Transportation of personnel to the plant;
- Transportation of personnel within the plant;
- Research and development activities.
- Long-term emissions.

3.4. Quantification of energy and material inputs and outputs, considering how plant-level data is allocated to the declared products

Quantifications for the life cycle inventory inputs and outputs of energy and materials come from the LCA results of all the products belonging to the Paper-hemp insulation material available in the Ecoinvent v3.8 database.

3.4.1. Assumptions about relevant background data

The data relating to background processes for raw materials, transport activities and energy expenditure in the production of Paper-hemp insulation material components are found or accordingly modified from the Ecoinvent unit processes and/or available EPDs.

3.5. Cut-off criteria for initial inclusion of inputs and outputs.

3.5.1. Description of the application of cut-off criteria and boundaries to other product life cycles

- All input and output flows in a unit process i.e., considering the value of all flows in the unit process and the corresponding LCI whenever available.
- Cut-off criterion of 1% on mass inputs and primary energy at the unit process level, and 5% at the information module level.
- No simplification of the LCI by additional exclusions of material flows.

All hazardous and toxic materials and substances are included in the inventory and the cut-off rules do not apply.

Following ISO 14025 standard[1], and the EN 15804:2012+A2:2019, the pollutant pays principle has been followed. Allocation of recycled material, also known as open loop recycling, is reported in the inventory as an input or output to the technosphere when such materials leave or enter the specific product system. Therefore, a system boundary between the product's systems in a material recycling cascade must be defined between individual sub-processes.

When a product is discarded, and its original function is lost, it can be processed further in a waste management system. Those parts of the initial product system that are utilized in a new product will be accounted for as material recycling in the LCI (as a flow to technosphere).

The exact boundary settings between the first and the next product systems are defined by the *willingness to pay* for the recycled material. This implies that from the moment the user of a secondary material pays for the material, this (secondary) product system will also be responsible for the environmental burden from that point on. This principle is referred to in the International EPD system as the *Polluter-Pay (PP) allocation method.*

Consequently, if there is an inflow of recycled material to the production system, the recycling process and the transportation from the recycling process to where the material is used shall be included. If there is an outflow of material to recycling, the transportation of the material to a sorting facility/recycling process shall be included. The material intended for recycling is then an outflow from the production system. This is achieved using the "Allocation at the Point of Substitution" system created by Ecoinvent for modeling the *Polluter-Pay (PP) allocation method.*

3.5.2. List of excluded processes

See chapter: "3.3.7 Omissions of life cycle stages"

[1] ISO 14025:2006 Environmental labels and declarations -- Type III environmental declarations -- Principles and procedures

4. LIFE CYCLE INVENTORY ANALYSIS

This chapter presents the sources of input data for Paper-hemp insulation materials product life cycle as well as the main hypothesis.

4.1. Qualitative/quantitative description of unit processes necessary to model the life cycle stages of the declared unit, considering the provisions of EN ISO 14025 regarding data confidentiality

4.1.1. A1-A3 Product stage

Background processes data A1 to A3 from all the materials belonging to Paper-hemp insulation material were collected from suppliers EPDs were existent. Where any EPD was not available, Ecoinvent v3.8 database has been used.

4.2. Sources of generic data or literature used to conduct the LCA

The environmental data related to the production of components of the Paper-hemp insulation material without EPD, the energy consumption, transportation and waste management have been taken from Ecoinvent v3.8 database (see Annex I for more details).

4.3. Validation of data, including:

4.3.1. Data quality assessment

Data quality is an important aspect to evaluate the validity of any environmental impact assessment. In this study, a data quality rating (DQR) has been developed going along with the following criteria:

- Geographical representativeness (GeR): the specific data used on the process of manufacturing, transport, and installation of the analyzed product have been provided, so they are representative of the geographical area covered. For the other processes as far as possible, generic data representative of Europe have been used.
- Time representativeness (TiR): the quantity of materials used and transport distance, refers to 2023. Referred to generic data the Ecoinvent v3.8 database has been updated in the last year.
- Technological representativeness (TeR): the specific data reflect the physical reality of the declared product since they are based on data from the manufacturer.
- Precision (P): The data was overall measured, calculated, and internally verified.

The data was checked according to EPDs on similar products and available data for raw materials from other manufacturers. The LCA model input data were based on technical information directly obtained from Balticfloc. The data quality was verified within the Balticfloc 2023 production data. Therefore, the data are checked twice, on-site and during the process of approval for the annual report.

A data quality score for each data quality criterion is given according to the rating scale presented as follows.

Table 6. Scoring scale for data quality rating (DQR)

Score for (TeR, GeR, TiR, P)	Data Quality Level
1	Excellent
2	Very good
3	Good
4	Fair
5	Poor

Based on the rating, a DQR for each inventory input is calculated as follows:

$$DQR = \frac{TeR+GeR+TiR+P}{4}$$

The DQR results are presented along with the life cycle inventory in Annex 1. Their overall evaluation for the data quality rating can be understood as:

Table 7. DQR rating

Overall data quality rating	Overall Data Quality Level
$DQR \leq 1.5$	Excellent quality
$1.5 < DQR \leq 2.0$	Very good quality
$2.0 < DQR \leq 3.0$	Good quality
$3.0 < DQR \leq 4.0$	Fair quality
$DQR > 4$	Poor quality

A data quality rating was performed with a rating system where 1 means excellent and 5 poor. An average for each criterion is presented as follows:

Table 8. Average DQR for this study LCI

Technological Representativeness, TER	Geographic representativeness, GER	Time Representativeness, TIR	Precision, P	Average DQR
1.55	1.8	2	1.25	1.65

4.3.2. Treatment of missing data

To the best of the EPD’s developers’ knowledge, no missing data is found during this study.

4.4. Allocation principles and procedures, including

4.4.1. Documentation and justification of allocation procedures

Allocation among co-products has been avoided as only one product results from the operations considered within the scope. However, energy and material flows have been allocated to the declared unit following physical criteria.

4.4.2. Uniform application of allocation procedures

Following the recommendations in the EN 15804:2012+A2:2019 and PCR 2019:14, allocation among products and co-products has been avoided. Material and energy flows have been allocated to the main product following physical/mass criteria.

5. LIFE CYCLE IMPACT ASSESSMENT

5.1. LCIA procedures, calculations, and results of the study (reference to all characterization models, characterization factors and methods used, as defined in this European Standard)

The impact assessment calculations are made in full accordance with EN 15804:2012+A2:2019 standard. This standard requires parameters describing the core environmental impact indicators, additional environmental impact indicators, parameters describing the use of resources, indicators describing waste categories, environmental information describing output flows, and information describing the biogenic carbon content at the factory gate if necessary.

5.1.1. Parameters describing the environmental impacts

The calculation of environmental impacts has been done with the impact characterization factors defined in the European Commissions established Product Environmental Footprint Category Rules Guidance (2018) and EN 15804+A2 V.1.0. These factors are already included in SimaPro 9.4 software which already incorporates the EF 3.0 and EN 15804:2012+A2:2019 as an impact assessment method. The impact categories and indicators to be included in this LCA are shown in **Tables 9 to 14.**

Table 9. Core environmental impact categories and indicators

Impact category	Indicator	Unit
Climate change - total	Global warming potential, (GWP-total)	kg CO_2-eq
Climate change - fossil	Global warming potential fossil fuels, (GWP-fossil)	kg CO_2-eq
Climate change - biogenic	Global warming potential biogenic, (GWP-biogenic)	kg CO_2-eq
Climate change – land use and land use change	Global warming potential land use and land use change, (GWP-luluc)	kg CO_2-eq
Climate Change	GWP100a	kg CO_2-eq
Ozone depletion	Depletion potential of the stratospheric ozone layer, (ODP)	kg CFC 11-eq
Acidification	Acidification potential, Accumulated exceedance (AP)	mol H^{and} -eq
Eutrophication aquatic freshwater*	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg PO_4 -eq.[2]
Eutrophication aquatic freshwater**	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg P -eq.[3]
Eutrophication aquatic marine	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg N-eq
Eutrophication terrestrial	Eutrophication potential, Accumulated exceedance (EP – terrestrial)	mol N-eq
Photochemical ozone formation	Formation potential of tropospheric ozone (POCP)	kg NMVOC-eq
Depletion of abiotic resources – minerals and metals	Abiotic depletion potential for non-fossil resources (ADP-minerals&metals)	kg Sb-eq
Depletion of abiotic resources – fossil fuels	Abiotic depletion potential for fossil resources (ADP-fossil)	MJ, net calorific value
Water use	Water (user) deprivation potential, deprivation-weighted water consumption	m^3 world eq. deprived

[2] The freshwater eutrophication impact category results have been calculated using the output data obtained from Simapro © software and then adjusted to the specified units as appear in the EN 15084 using the conversion factors reported in Baitz M. and Bos U. (2020).

[3] These reported results are presented as obtained directly from the LCA method EN 15084+A2 V1.00 / EF 3.0 available in Simapro.

The additional environmental impact indicators displayed in Table 10 are to be calculated and included in the LCA study, as recommended in the EN 15804:2012+A2:2019.

Table 10. Additional impact categories and indicators

Impact category	Indicator	Unit
Particulate matter emissions	Potential incidence of disease due to PM emissions (PM)	Disease incidence
Ionizing radiation, human health	Potential human exposure efficiency relative to U235 (IRP)	kBq U235 eq.
Eco-toxicity (freshwater)	Potential comparative toxic unit for ecosystems (ETP-fw)	CTUe
Human toxicity, cancer effects	Potential comparative toxic unit for humans (HTP-c)	CTUh
Human toxicity, non-cancer effects	Potential comparative toxic unit for humans (HTP-nc)	CTUh
Land use related impacts / soil quality	Potential soil quality index (SQP)	dimensionless

5.1.2. Parameters describing the resource use and others

To improve the transparency of the description of the environmental performance of the system, three other groups of indicators must be declared: Parameters describing resources, environmental information describing waste categories, and environmental information describing output flows. Additionally, information describing the biogenic carbon content at factory gate is also included.

Table 11. Parameters describing the resource use

Parameter	Parameter unit expressed per declared unit
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ, net calorific value
Use of renewable primary energy resources used as raw materials	MJ, net calorific value
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ, net calorific value
Use of non-renewable primary energy resources used as raw materials	MJ, net calorific value
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Use of secondary material	kg
Use of renewable secondary fuels	MJ, net calorific value
Use of non-renewable secondary fuels	MJ, net calorific value
Use of net fresh water	m^3

5.1.2.1. Parameters describing the waste categories and others output flows

Also, information regarding waste disposal and outputs for re-use, recycling and recovery, as well as any exported energy is to be calculated and presented for each module or life cycle stage.

Table 12. Parameters describing the waste categories

Parameter	**Parameter unit expressed per declared unit**
Hazardous waste disposed	kg
Non-hazardous waste disposed	kg
Radioactive waste disposed	kg

Table 13. Parameters describing the other output flows

Indicator	Parameter unit expressed per declared unit
Components for re-use	kg
Materials for recycling	kg
Materials for energy recovery	kg
Exported energy	MJ per energy carrier

5.1.2.2. Parameters describing the biogenic carbon content at factory gate

If the mass of biogenic carbon containing materials in the product is less than 5% of the mass of the product, the declaration of biogenic carbon may be omitted.

Table 14. Parameters describing the biogenic carbon content at the factory gate

Biogenic carbon content	**Parameter unit expressed per declared unit**
Carbon content in product	kg
Carbon content in accompanying packaging	kg

5.2. A statement that the LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks

According to the EN 15804:2012+A2:2019 standard, the LCIA results are relative expressions translating impacts into environmental themes such as climate change, ozone depletion (midpoint impact category). Thus, the LCIA results do not predict impacts on category endpoints such as impact on the extinction of species. In addition, the results do not provide information about the exceeding of thresholds, safety margins or risks.

6. LIFE CYCLE RESULTS AND INTERPRETATION

In this section the environmental performance results for the Paper-hemp insulation material are presented. In addition to the indicators, the GWP 100a indicator is displayed. This indicator includes all greenhouse gases included in GWP-total but excludes biogenic carbon dioxide uptake and emissions and biogenic carbon stored in the product. The impact on the environment of the life cycle of 1 m^2 of Paper-hemp insulation material is shown in Table 15, and in Figure 2.

Table 15. Impact on the environment of the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute value. Life cycle stages are grouped.

Impact category	Unit	Product Stage A1-A3
Climate change - Fossil	kg CO_2 eq	1.51E+00
Climate change - Biogenic	kg CO_2 eq	-2.00E+00
Climate change - Land use and LU change	kg CO_2 eq	1.16E-03
Climate change	kg CO_2 eq	-4.90E-01
Ozone depletion	kg CFC11 eq	3.34E-07
Acidification	mol H+ eq	8.20E-03
Eutrophication, freshwater	kg P eq	4.08E-04
Eutrophication, marine	kg N eq	1.52E-03
Eutrophication, terrestrial	mol N eq	1.64E-02
Photochemical ozone formation	kg NMVOC eq	5.11E-03
Resource use, minerals and metals	kg Sb eq	1.91E-05
Resource use, fossils	MJ	2.87E+01
Water use	m^3 depriv.	3.11E-01

Table 16. Global warming potential (GWP100a) additional indicator.

Impact category	Unit	Product Stage A1	Product Stage A2	Product Stage A3
Global warming (GWP100a)	kg CO2 eq	8.99E-01	2.15E-01	3.62E-01

Table 17. Impact on the environment of the life cycle of 1 m^2 of Paper-hemp insulation material. In percentage.

Impact category	Product Stage A1	Product Stage A2	Product Stage A3
Climate change - Fossil	61.1%	14.4%	24.5%
Climate change - Biogenic	-100.4%	0.0%	0.4%
Climate change - Land use and LU change	69.7%	7.5%	22.9%
Climate change	-221.1%	44.3%	76.9%

Ozone depletion	68.3%	15.0%	16.6%
Acidification	74.1%	7.5%	18.4%
Eutrophication, freshwater	87.5%	3.5%	9.0%
Eutrophication, marine	74.4%	8.2%	17.4%
Eutrophication, terrestrial	74.2%	8.3%	17.4%
Photochemical ozone formation	72.4%	10.2%	17.4%
Resource use, minerals and metals	93.7%	4.0%	2.3%
Resource use, fossils	68.1%	11.5%	20.4%
Water use	87.6%	3.2%	9.2%

The following figures 2, 3, 4, and 5 give an insight on the main contributors (hot-spots) within impact categories Climate change (fossil), Climate change, Ozone depletion and Resource use (fossils) and Resource use, minerals and metals, which are further used also in the comparison with other alternative producer products.

Figure 2. Tree network flow for Climate change with cut off 5% of the life cycle impacts of 1 m² of Paper-hemp insulation material.

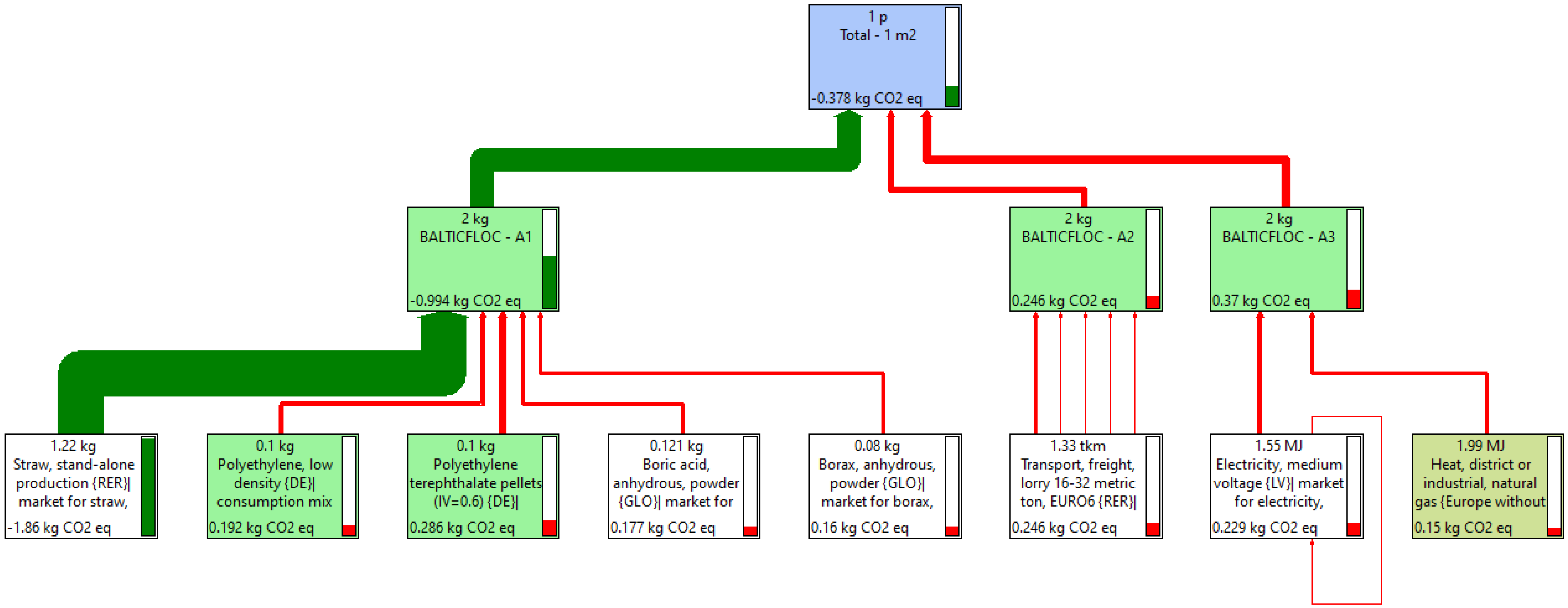


Figure 3. Tree network flow for Ozone depletion with cut off 1% of the life cycle impacts of 1 m^2 of Paper-hemp insulation material.

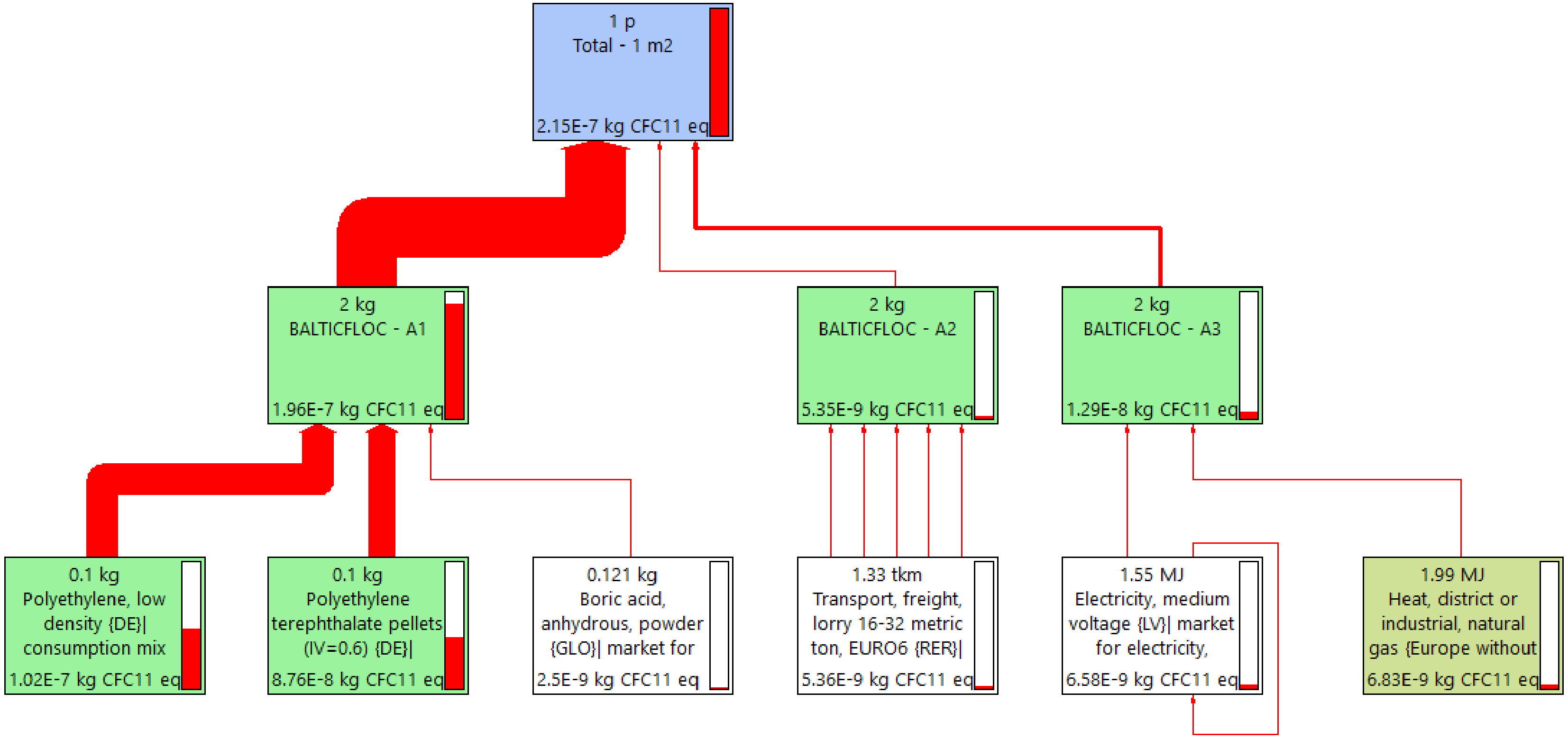


Figure 4. Tree network flow for Resource use, minerals and metals with cut off 1% of the life cycle impacts of 1 m^2 of Paper-hemp insulation material.

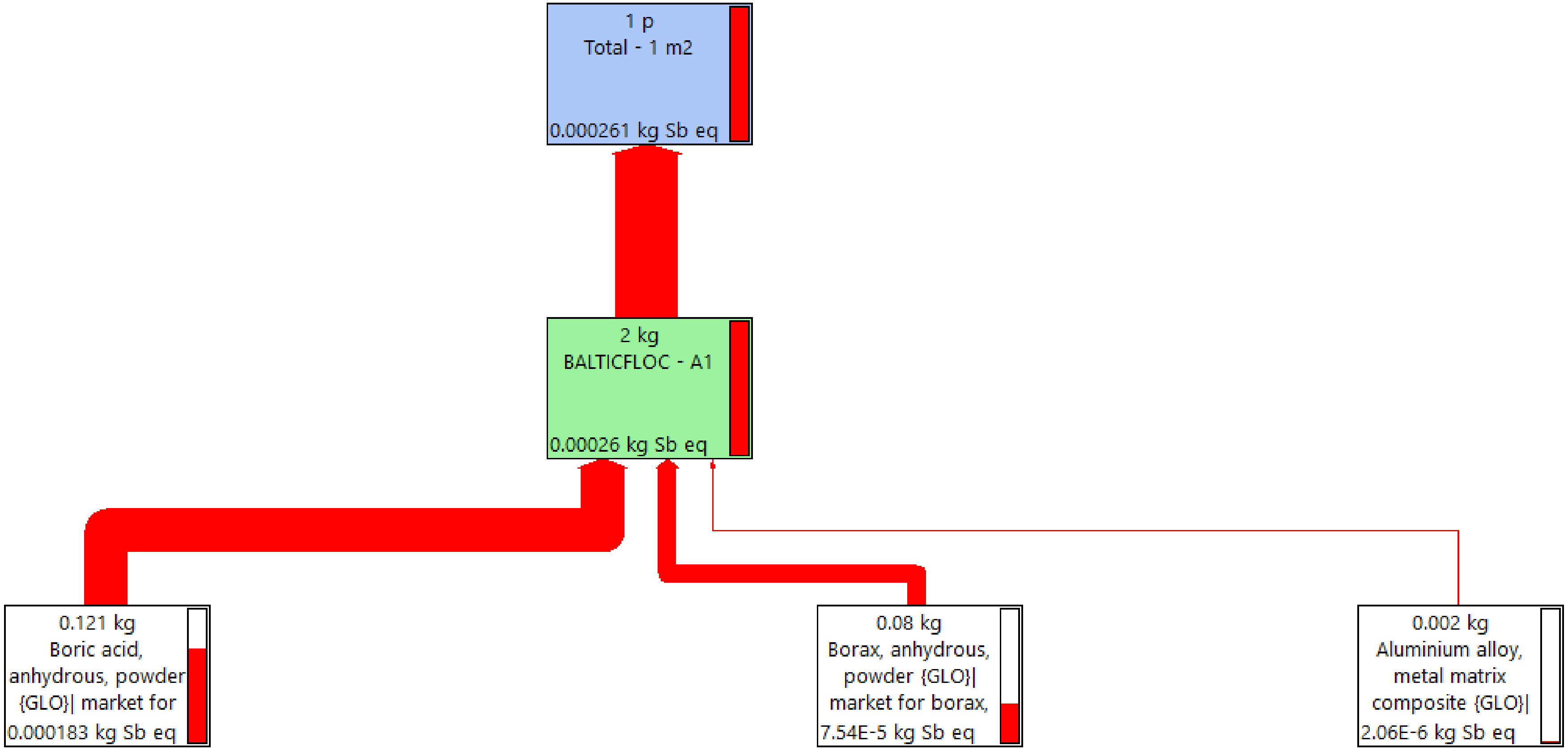


Figure 5. Tree network flow for Resource use, fossils with cut off 5% of the life cycle impacts of 1 m^2 of Paper-hemp insulation material.

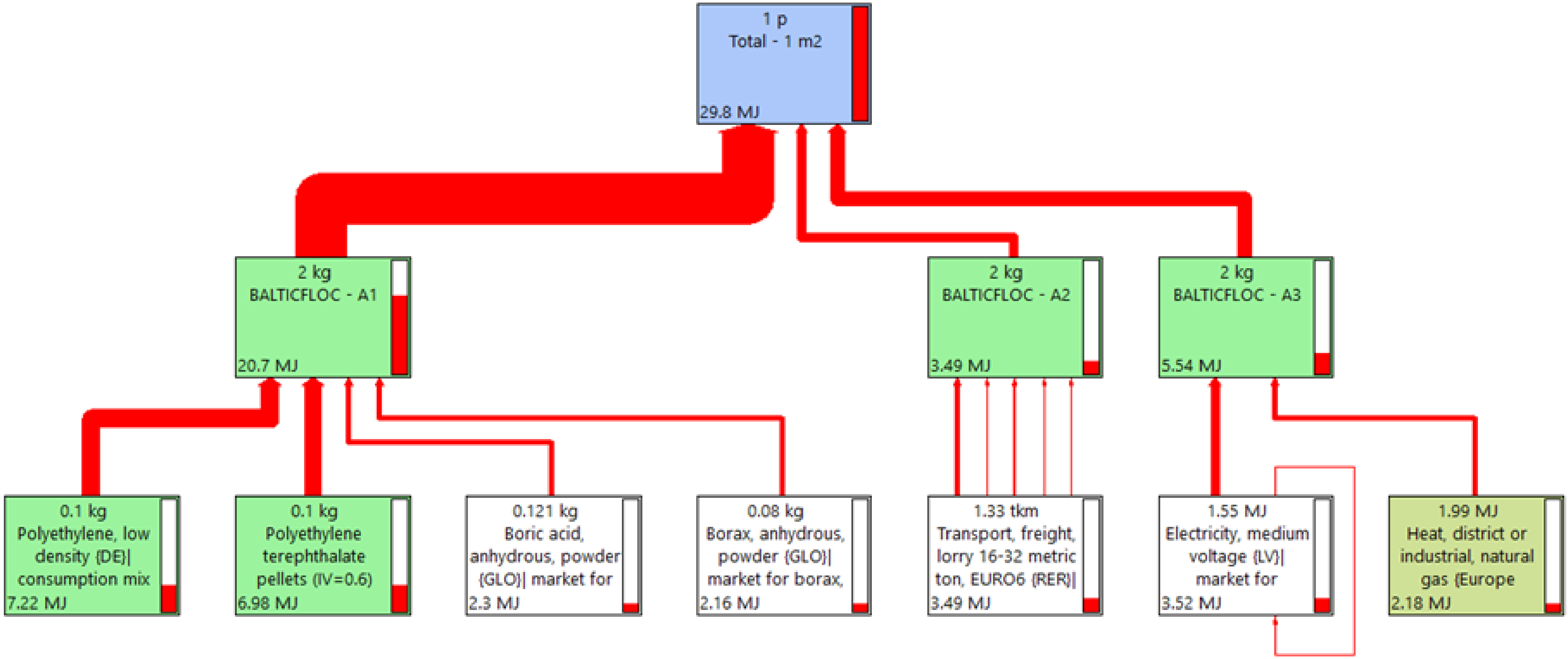


Table 18. Impact on the environment of the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute value. Life cycle stages are not grouped.

Impact category	Unit	Product stage A1	Product stage A2	Product stage A3
Climate change - Fossil	kg CO_2 eq	9.19E-01	2.17E-01	3.69E-01
Climate change - Biogenic	kg CO_2 eq	-2.00E+00	1.97E-04	7.19E-03
Climate change - Land use and LU change	kg CO2 eq	8.08E-04	8.66E-05	2.66E-04
Climate change	kg CO_2 eq	-1.08E+00	2.17E-01	3.77E-01
Ozone depletion	kg CFC11 eq	2.28E-07	5.02E-08	5.55E-08
Acidification	mol H+ eq	6.08E-03	6.16E-04	1.51E-03
Eutrophication, freshwater	kg P eq	3.57E-04	1.42E-05	3.67E-05
Eutrophication, marine	kg N eq	1.13E-03	1.25E-04	2.65E-04
Eutrophication, terrestrial	mol N eq	1.22E-02	1.36E-03	2.86E-03
Photochemical ozone formation	kg NMVOC eq	3.70E-03	5.24E-04	8.88E-04
Resource use, minerals and metals	kg Sb eq	1.79E-05	7.68E-07	4.32E-07
Resource use, fossils	MJ	1.95E+01	3.28E+00	5.86E+00
Water use	m^3 depriv.	2.73E-01	1.00E-02	2.87E-02

Table 19. Additional voluntary indicators for the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute values. Life cycle stages are not grouped.

Impact category	Unit	Product stage A1	Product stage A2	Product stage A3
Particulate matter	disease inc.	7.94E-08	1.75E-08	1.27E-08
Ionising radiation	kBq U-235 eq	1.09E-01	1.69E-02	3.06E-02
Ecotoxicity, freshwater	CTUe	2.06E+01	2.58E+00	2.36E+00
Human toxicity, cancer	CTUh	-3.77E-10	8.29E-11	2.08E-10
Human toxicity, non-cancer	CTUh	-9.85E-08	2.61E-09	1.42E-09
Land use	Pt	3.60E+02	2.29E+00	1.68E+00

Table 20. Additional voluntary indicators for the life cycle of 1 m^2 of Paper-hemp insulation material. In percentage. Life cycle stages are not grouped.

Impact category	Product stage A1	Product stage A2	Product stage A3
Particulate matter	72.5%	15.9%	11.6%
Ionising radiation	69.5%	10.8%	19.6%
Ecotoxicity, freshwater	80.6%	10.1%	9.3%
Human toxicity, cancer	-440.4%	96.9%	243.5%
Human toxicity, non-cancer	-104.3%	2.8%	1.5%
Land use	98.9%	0.6%	0.5%

Table 21. Use of resources of the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute values.

Impact category	Unit	Product stage A1	Product stage A2	Product stage A3
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ/Declared Unit	2.17E+01	1.17E-02	3.33E-01
Use of renewable primary energy used as raw materials	MJ/Declared Unit	4.52E-01	3.52E-02	5.32E-01
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ/Declared Unit	2.21E+01	4.70E-02	8.65E-01
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ/Declared Unit	1.86E+01	3.22E+00	5.51E+00
Use of non-renewable primary energy used as raw materials	MJ/Declared Unit	9.61E-01	6.94E-02	3.44E-01
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ/Declared Unit	1.95E+01	3.28E+00	5.86E+00
Use of secondary material	kg/ MJ/Declared Unit	0.00E+00	0.00E+00	0.00E+00
Use of renewable secondary fuels	MJ/Declared Unit	0.00E+00	0.00E+00	0.00E+00
Use of non-renewable secondary fuels	MJ/Declared Unit	0.00E+00	0.00E+00	0.00E+00
Use of net fresh water	m3/Declared Unit	0.00E+00	0.00E+00	0.00E+00

Table 22. Use of resources of the life cycle of 1 m^2 of Paper-hemp insulation material. In percentage.

Impact category	Product stage A1	Product stage A2	Product stage A3
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	98.4%	0.1%	1.5%
Use of renewable primary energy used as raw materials	44.4%	3.5%	52.2%
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	96.0%	0.2%	3.8%
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	68.0%	11.8%	20.2%
Use of non-renewable primary energy used as raw materials	69.9%	5.0%	25.0%
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	68.1%	11.5%	20.4%
Use of secondary material	0.0%	0.0%	0.0%
Use of renewable secondary fuels	0.0%	0.0%	0.0%
Use of non-renewable secondary fuels	0.0%	0.0%	0.0%
Use of net fresh water	0.0%	0.0%	0.0%

Table 23. Waste production of the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute values.

Indicator	Unit	Product stage A1	Product stage A2	Product stage A3
Hazardous waste disposed	kg/Declared Unit	9.58E-05	8.57E-06	6.27E-06
Non-hazardous waste disposed	kg/Declared Unit	9.21E-02	1.72E-01	1.38E-02
Radioactive waste disposed	kg/Declared Unit	1.02E-04	2.22E-05	1.60E-05

Table 24. Waste production of the life cycle of 1 m^2 of Paper-hemp insulation material. In Percentage.

Indicator	Product stage A1	Product stage A2	Product stage A3
Hazardous waste disposed	86.6%	7.8%	5.7%
Non-hazardous waste disposed	33.1%	61.9%	5.0%
Radioactive waste disposed	72.7%	15.9%	11.4%

Table 25. Outputs flows of the life cycle of 1 m^2 of Paper-hemp insulation material. In absolute values.

Indicator	Unit	Product stage A1	Product stage A2	Product stage A3
Components for re-use	kg/Declared Unit	0.0E+00	0.0E+00	0.0E+00
Material for recycling	kg/Declared Unit	0.0E+00	0.0E+00	3.40E-01
Materials for energy recovery	kg/Declared Unit	0.0E+00	0.0E+00	0.0E+00
Exported energy, electricity	kg/Declared Unit	0.0E+00	0.0E+00	0.0E+00

Table 26. Biogenic carbon content of 1 m^2 of Paper-hemp insulation material. In absolute values.

Indicator	Unit	Value
Carbon content in product	kg	1.40E+00
Carbon content in accompanying packaging	kg	0.0E+00

6.1. Product comparison with similar products

Paper-hemp insulation material results forma LCA is compared with 4 other insulation material alternatives. In Table 27 are main characteristics that represents alternatives.

Table 27. Alternative characteristics

	Product	Thermal conductivity, W/mK
Alternative 1	wood fiber thermal insulation	0.036
Alternative 2	wood fiber thermal insulation	0.038
Alternative 3	hemp fiber insulation	0.04
Alternative 4	stone wool thermal insulation	0.039

The comparison of results has been made with the FU 1m^2 and only for A1-A3 production stage - divided by production stages or as total value for production stages A1-A3. For all alternatives geographical scope is Europe. Figure 6. shows a comparison of the results for the impact categories.

Figure 6. Result comparison of Climate change for 1 m^2 of insulation material.

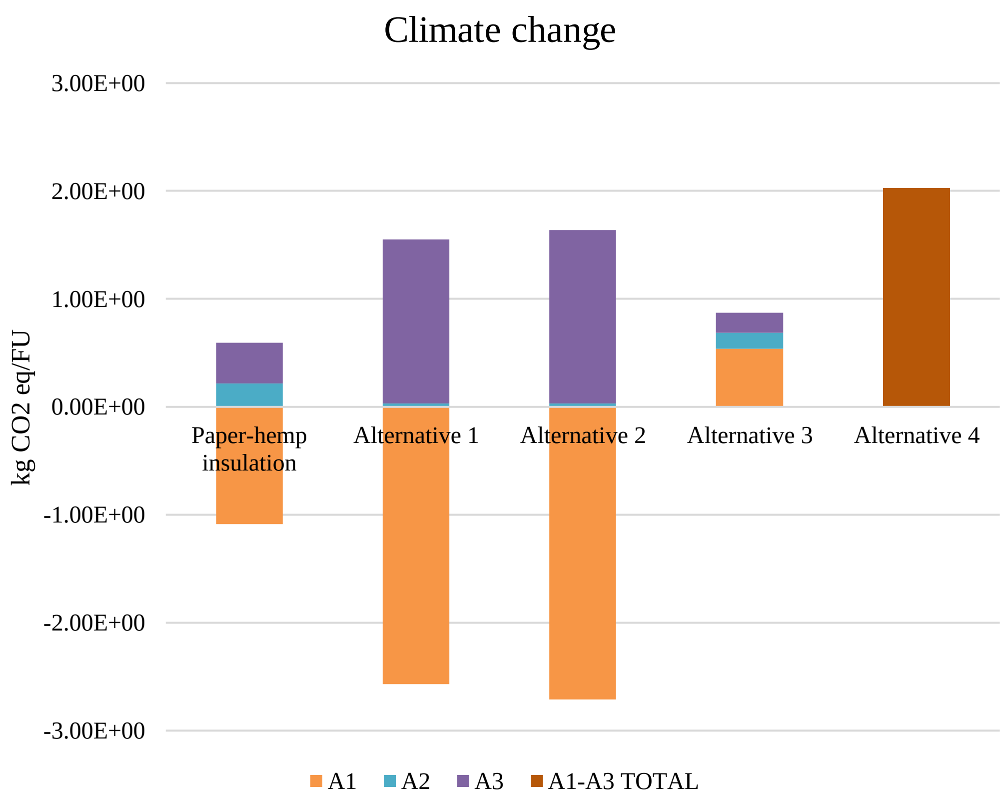


Figure 7. Result comparison of Ozone depletion, for 1 m^2 of insulation material.

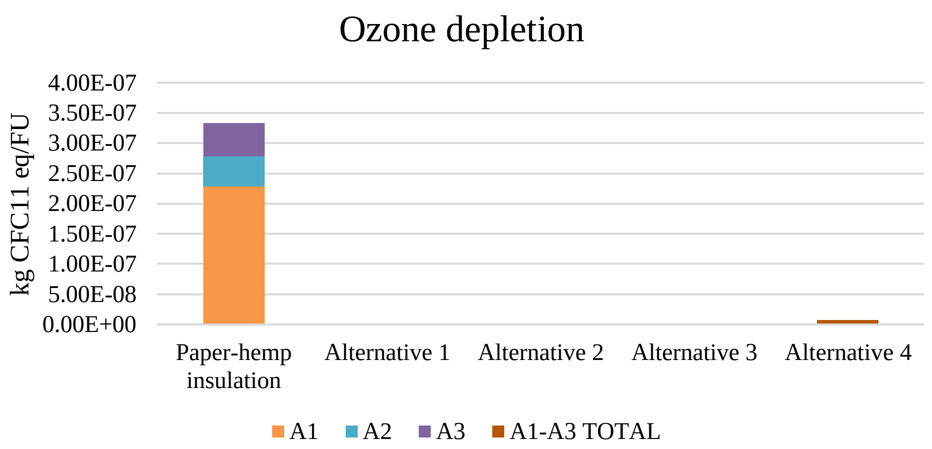


Figure 8. Result comparison of Resource use (minerals and metals) for 1 m^2 of insulation material.

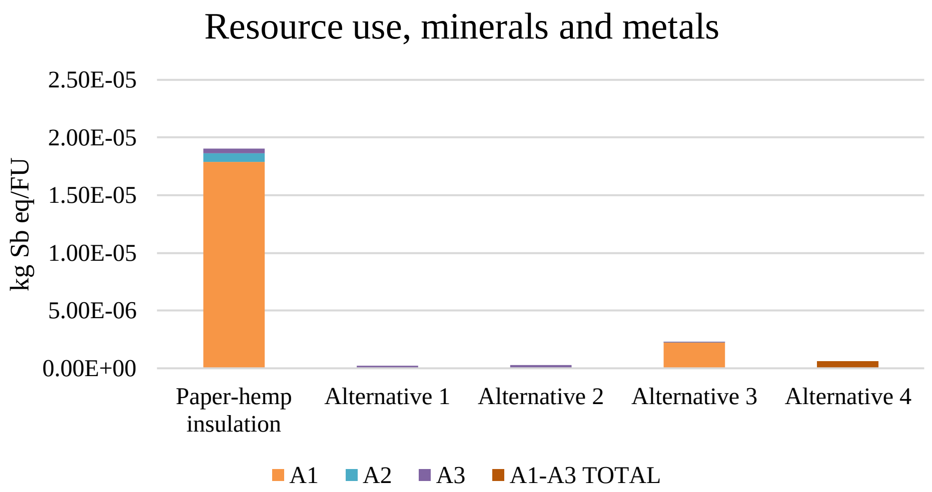
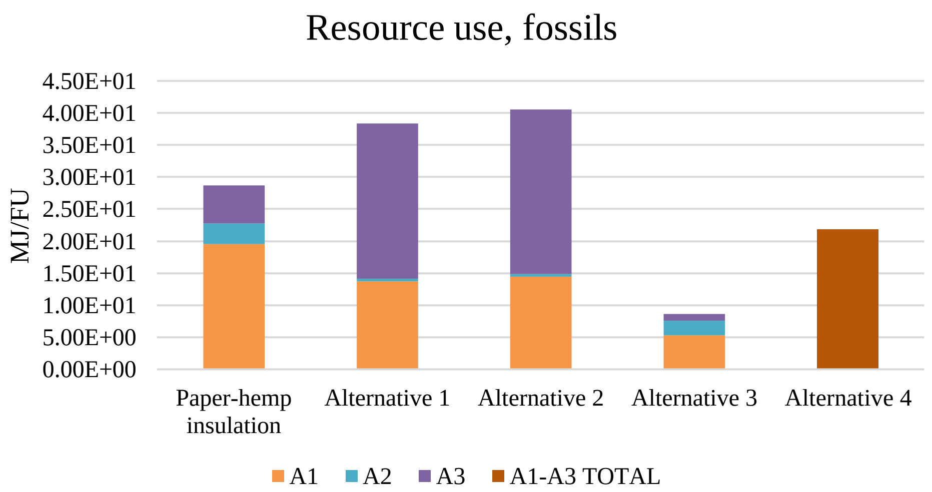


Figure 9. Result comparison of Resource use (fossils) for 1 m^2 of insulation material.



The results of the paper-hemp insulation material and the results of 4 other insulation material alternatives were expressed in eco-points (Pt) using the SimaPro software. 1 Pt represents one thousand of the annual environmental loads of an average European citizen. The comparison made by eco-points is in mPt and Figure represents paper-hemp insulation material and 3 alternatives, but Figure 4 represents paper-hemp insulation material and one alternative (stone wool thermal insulation material) due to the same impact categories.

Figure 10. Eco-point results for paper-hemp insulation material and insulation material alternatives for the impact category Climate change (total), Ozone depletion, Resource use (minerals and metals) and Resource use (fossils).

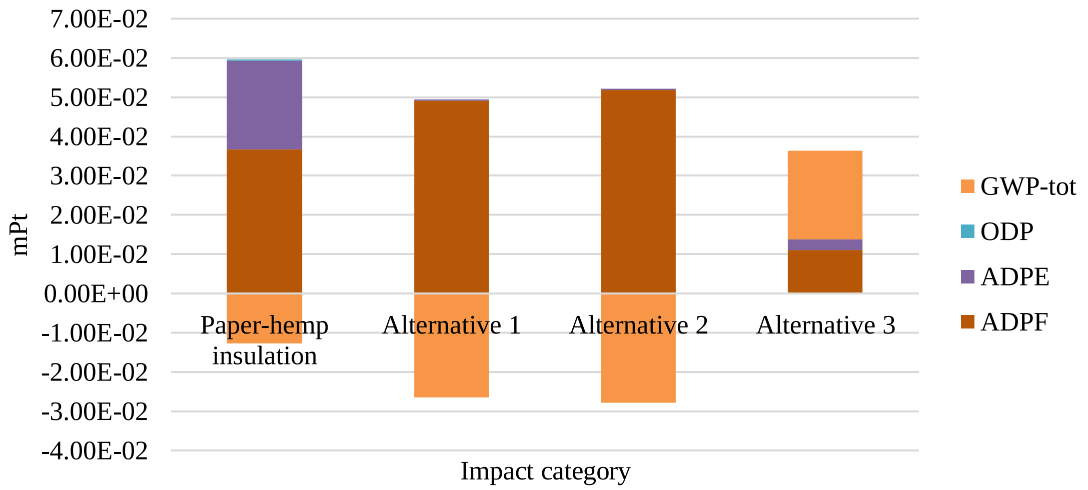
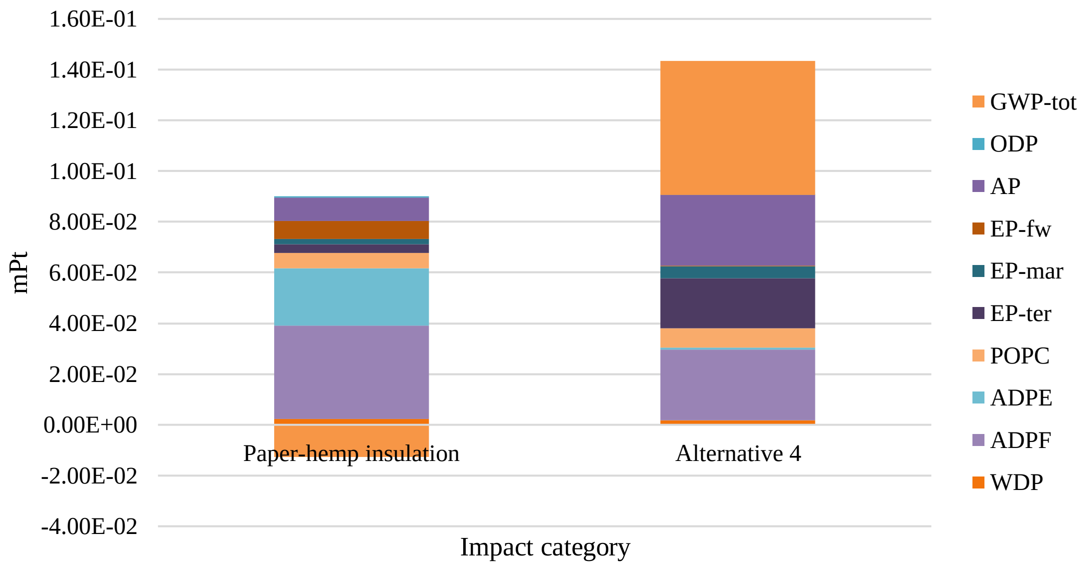


Figure 4. Eco-point results for paper-hemp insulation material and insulation material alternative for the impact category - Climate change (total), Ozone depletion, Acidification, Eutrophication (freshwater), Eutrophication (marine), Eutrophication (terrestrial), Photochemical ozone formation, Resource use (minerals and metals), Resource use (fossils) and Water use.

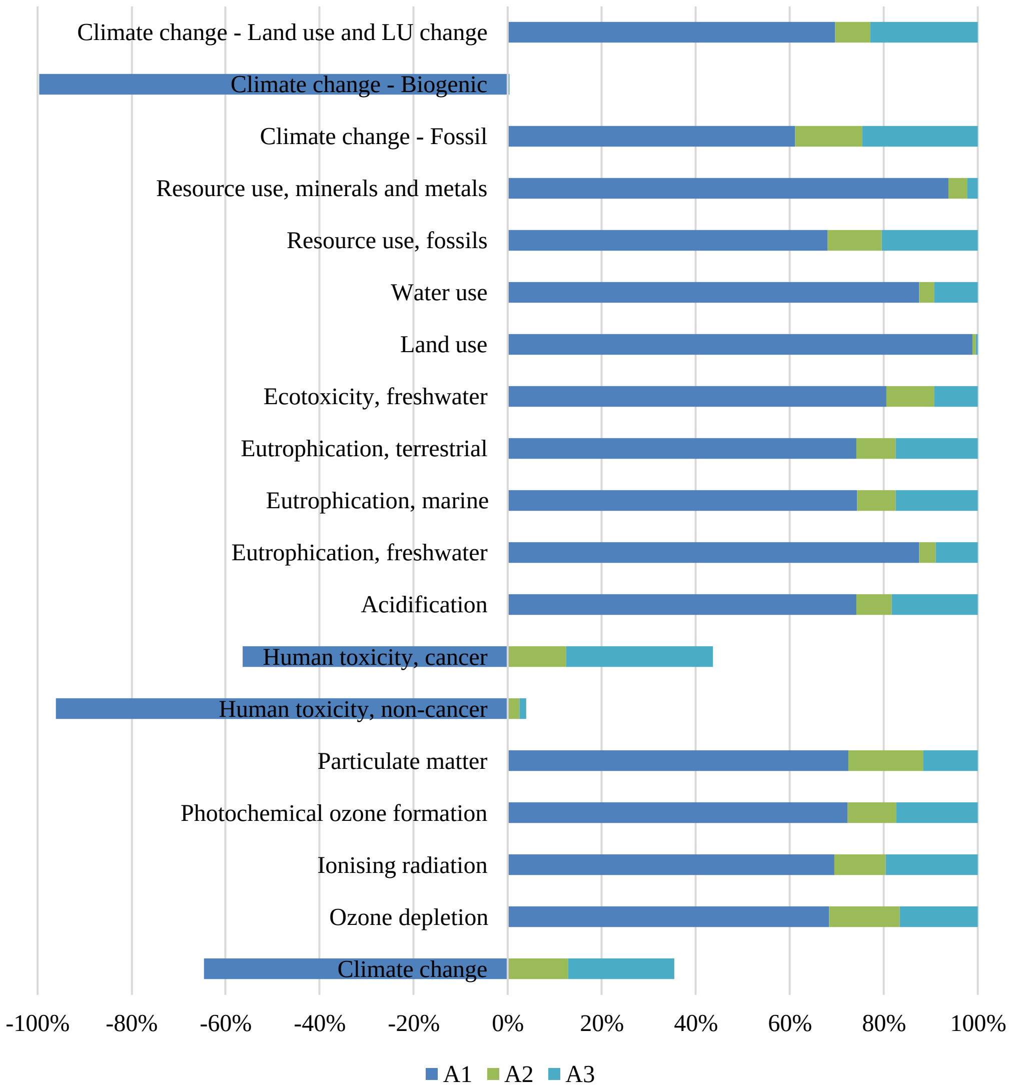


7. CONCLUSIONS

An LCA study has been carried out for the Paper-hemp insulation material of Balticfloc. The document presents the results for 1 m^2 of material (declared unit). Finally, an EPD® has been developed under The International EPD System, which in case necessary allows the further use of obtained results within green procurement.

The impact on the environment of the life cycle of 1m^2 of Balticfloc Paper-hemp insulation material version on Climate change is -4.90E-01 kg of CO_2-eq. As "cradle to gate" model largest environmental impact is from production stage A1 – raw material and largest impact comes from input - Bico fibre. Figure 5 shows the percentage distribution of each impact category by production stages. Use of hemp and paper waste materials makes positive impact to impact categories and results for those categories are negative and is as benefit to environment.

Figure 5. Impact categories share by module for Paper-hemp insulation material.



8. BIBLIOGRAPHY

- General Programme Instructions of the International EPD® System. Version 3.01.
- PCR 2019:14. Construction Products. Version 1.11
- SUB-PCR TO PCR 2012:01, 2020. Acoustical System Solutions (Construction Product)
- EN 15804:2012+A2:2019 Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products;
- ISO 14040:2006: Environmental Management-Life Cycle Assessment-Principles and framework.
- ISO 14044:2006/Amd 2:2020 Environmental management. Life Cycle Assessment. Requirements and guidelines
- ISO 14025:2010 Environmental labels and declarations. Type III environmental declarations. Principles and procedures.
- Ecoinvent v3.8 Database.
- Baitz M. and Bos U. (2020). Impact Methods, Data Collection and Data Requirements. Webinar: Environmental Footprint (EF) Transition Phase (2020).

Annex 1 - LCI for Paper-hemp insulation material

Table 28. Paper-hemp insulation material A1 – A3

Material/Process	Quantity per Declared unit	Unit	Comments	Item in database	DQR
A1					
Hemp fiber	1.22	kg		Straw, stand-alone production {RER}| market for straw, stand-alone production | Cut-off, U	1.75
Paper waste	1.16	kg		Paper waste	1.5
Bico fiber	0.1	kg		Polyethylene, low density {DE}| consumption mix	1.75
	0.1	kg		Polyethylene terephthalate pellets (IV=0.6) {DE}| consumption mix	1.75
Fire retardant	0.12	kg		Boric acid, anhydrous, powder {GLO}| market for | Cut-off, U	2
	0.08	kg		Borax, anhydrous, powder {GLO}| market for | Cut-off, U	2
Metal wires	0.002	kg		Aluminium alloy, metal matrix composite {GLO}| market for | Cut-off, U	2
PE bags	0.006	kg		Packaging film, low density polyethylene {RER}| production | Cut-off, U	1.5
A3					
Electricity	0.43	kWh		Electricity, medium voltage {LV}| market for | Cut-off, U	1.5
Gas for furnace	0.05	m^3	1.85 MJ	Heat, district or industrial, natural gas {Europe without Switzerland}| heat production, natural gas, at industrial furnace >100kW | Cut-off, U	1.75
Particulate matter (dust)	0.105	kg		Emission, unspecified	2
Cutbacks from product	0.235	kg		Cutbacks from product	2

Hemp hurd/ shives	0.44	kg		Low quality hemp	2
Metal wires	0.002	kg		Metal wires	1.75
PE bags	0.004	kg		Waste polypropylene {LV}| market for waste polypropylene | Cut-off, U	1.5

Table 29. Paper-hemp insulation material LCI A2

Material/Process from database	Material transported	Transported Distance (km)	Quantity per Declared unit (kgkm)	DQR
A2				
Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	Hemp fiber	90	110	1.25
Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	Paper waste	100	116	1.25
Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	Bico fiber	1911	382	1.25
Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	Fire retardant	3600	720	1.25
Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, U	PE bags	405	2.43	1.25