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France (Channel Manche) England

BIO-CIRC Project

European Regional Development Fund

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Bio(and)**C**ircular **I**nsulation for **R**esourceful **C**onstruction

Environmental Assessment Report

Life Cycle Analysis of BIO-CIRC prototypes for UK & French contexts

30th June 2022 – Final Version

EUROPEAN UNION
European Regional Development Fund

nomadéis ASBP The Alliance for Sustainable Building Products thermafleece Nature's finest insulation backtoearth

Abstract of the project

The BIO-CIRC Project, Bio(and)Circular Insulation for Resourceful Construction, intends to tackle the building sector's high carbon, energy and resources dependencies while taking advantage of an unused waste resource: polyester from waste bedding.

The project aims to conceive, develop and deploy 3 prototypes of innovative low-carbon thermal insulation material made from polyester and combined with natural fibres. It intends to promote the emergence of a bespoke waste polyester valorisation industry and the use of virtuous Natural and Recycled Fibre Insulation products.

This project is carried out by a cross-channel partnership of 4 key and complementary links in the building sector's value chain:

- Nomadéis (lead partner)
- Alliance for Sustainable Building Products
- Eden Renewable Innovations
- Back to Earth

Planned over 2 years, the BIO-CIRC project receives funding from the European Regional Development Fund (ERDF). The ERDF's contribution amounts to €399,600 for a total budget of €499,500.

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Executive summary

ASBP worked with Renuables Ltd to carry out a Life Cycle Analysis (LCA) of the three prototypes manufactured during the project. The three prototypes were made of varying amounts of:

1) Re-fiberised polyester from waste bedding (referred to as rcPET).
2) Recycled polyester (rPET).
3) Sheep's wool.
4) Bi-component polyester (bi-co).

This report summarises the LCA results and provides a comparison with conventional insulation materials – glass wool and stone wool.

The results show that all prototypes (with manufacturing scenarios in both the UK and France) could provide a significant reduction in their environmental impact with an average reduction of 82.6% vs glass wool and 86.9% vs stone wool.

1 Datasets

The datasets used for the life cycle assessment modelling of the three prototypes are based on information provided by Renuables Ltd and readily available Environmental Product Declaration (EPD) data. An additional dataset was created for the fibres extracted from waste bedding (referred to as rcPET) using data and assumptions provided by the prototype manufacturer.

1.1 rcPET

The re-fiberised polyester from waste bedding (rcPET) data was provided by ERI based on manufacturing information.

It was assumed that the amount of energy to mix the fibres together to create 1 kg or 1 m^2 of prototype was 0.06 kWh more than the amount of energy required for manufacturing equivalent products. This assumption was based on personal communication with the manufacturer stating that the ragging process utilised a card puller which required 60kWh per tonne of material throughout.

In France, additional energy has been accounted for the additional requirement to clean the fibres at 65°C. An additional 0.68 kWh/kg was therefore added to the processing energy for the prototypes – FR1, FR2 and FR3.

1.2 Recycled polyester and sheep's wool

Data from the following EPD were used for the recycled polyester (rPET) and sheep's wool content - EPD S-P-04468[1] and S-P-04469[2].

[1] Data (environdec.com)
[2] Data (environdec.com)

The datasets were adapted to include French grid electricity mix data for the prototypes made in France to take into consideration the difference in electricity generation methods for the UK and France.

1.3 Bi-component

Bi-component (bi-co) is a high melting point PET fibre with a coating of a softer quicker melting PET fibre. The dataset was modelled by A. Norton in 2008.

2 Prototype composition

The innovative prototypes studied were made out of a combination of:

1) Re-fiberised polyester from waste bedding (referred to as rcPET).
2) Recycled polyester (rPET).
3) Sheep's wool.
4) Bi-component polyester (bi-co).

Analysis was conducted for the 3 prototypes manufactured and distributed in UK, and manufactured and distributed in France. Table 1 provides an overview of the prototypes that were evaluated:

Prototype	Composition	Manufact-ured in	Transport (A2)	Transport to site (A4)	Energy (A3)
UK1	65% rcPET 25% rPET 10% bi-Co	UK	50 km	300 km	UK grid electricity mix
UK2	25% rcPET 65% wool 10% bi-Co	UK	50 km	300 km	
UK3	39% rcPET 51% wool 10% bi-Co	UK	50 km	300 km	
FR1	65% rcPET 25% rPET 10% bi-Co	France	150 km	300 km	France grid electricity mix + 0.68 kWh to account for additional washing at 65°C
FR2	25% rcPET 65% wool 10% bi-Co	France	150 km	300 km	
FR3	39% rcPET 51% wool 10% bi-Co	France	150 km		

Table 1: Description of the 3 prototypes modelled each in France and in UK

3 Methodology

3.1 Scope

The results were modelled following ISO14040, ISO14044, ISO14025 and EN 15804+A2:2019 standards. The scope of the study cover modules A1 to A3, A4 – see Figure 1 below:

Product			Construction		Use stage (fabric)					End of life				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D
Raw materials supply	Transport to factory	Manufacturing	Transport to site	Construction – installation	Use	Maintenance	Repair	Replacement	Refurbishment	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse, recovery, recycling potential
X	X	X	X	-	-	-	-	-	-	-	-	-	-	-

Figure 1 – Modules covered by the study in accordance with EN 15804+A2:2019[3]

3.2 Declared unit and reference service life

The results are expressed both for:

- 1 kg of product.
- 1 m^2 of insulation product with an R = 1 m^{2}K/W plus packaging.

The prototypes are assumed to have the same service life as the building in which they are installed. This follows recommendations from EPD S-P-04468[4] and S-P-04469[5].

3.3 System boundary

Modules A1 to A3 include the impact of the raw materials. The data for the raw materials were sourced by Renuables from EPD previously carried out for those products:

1) Recycled polyester (rPET) - EPD reference S-P-04469 verified by EPD international.
2) Sheep's wool – EPD reference S-P-04468 verified by EPD international.

[3] PN514-BRE-EN-15804-PCR.pdf (greenbooklive.com)
[4] Data (environdec.com)
[5] Data (environdec.com)

Module A4: The values for A4 were based on assumptions created by the BIO-CIRC team and it was assumed that the distances travelled in France would be twice as long as in the UK due to the larger size of the country.

Module C1 to C4: the values assumed for those modules are the same as those used for EPD S-P-04468 and S-P-04469.

3.4 Data sources, quality and allocation

Data for rPET and sheep's wool were taken from EPD S-P-04468 and S-P-04469. LCA data was calculated using Ecoinvent 3.7 background data and the characterization factors stated in EN 15804+A2:2019. Medium voltage Ecoinvent entries for standard GB and FR grid energy mix were used to deal with transmission losses.

Bi-co was modelled using Norton AJ, 2008, The Life Cycle Assessment and Moisture Sorption Characteristics of Natural Fibre Thermal Insulation Materials, PhD Bangor University.

4 Results

This section provides results for the 3 prototypes modelled in two different countries expressed against the climate change indicators as stated in EN15804+A2:2019 for modules A1 to A3. Section 1.3.1 shows results for the prototypes made in UK and section 1.3.2 shows results for the prototypes made in France.

4.1 Results for products manufactured in the UK

Results in Table 2 below have been expressed in kgCO_2eq for 1 kg of product:

		Prototype		
Impact category - Climate Change	**Unit**	**UK1**	**UK2**	**UK3**
Fossil	kg CO_2 eq	1.03E+00	1.05E+00	9.72E-01
Biogenic	kg CO_2 eq	7.57E-02	-1.09E+00	-8.51E-01
Land use and LU change	kg CO_2 eq	1.30E-03	6.47E-03	5.25E-03
Total	**kg CO_2 eq**	**1.08E+00**	**-3.63E-02**	**1.09E-01**

Table 2 – Results for 1 kg of prototypes manufactured in the UK

Figure 2 below shows the results of table 2 in a graphical representation.

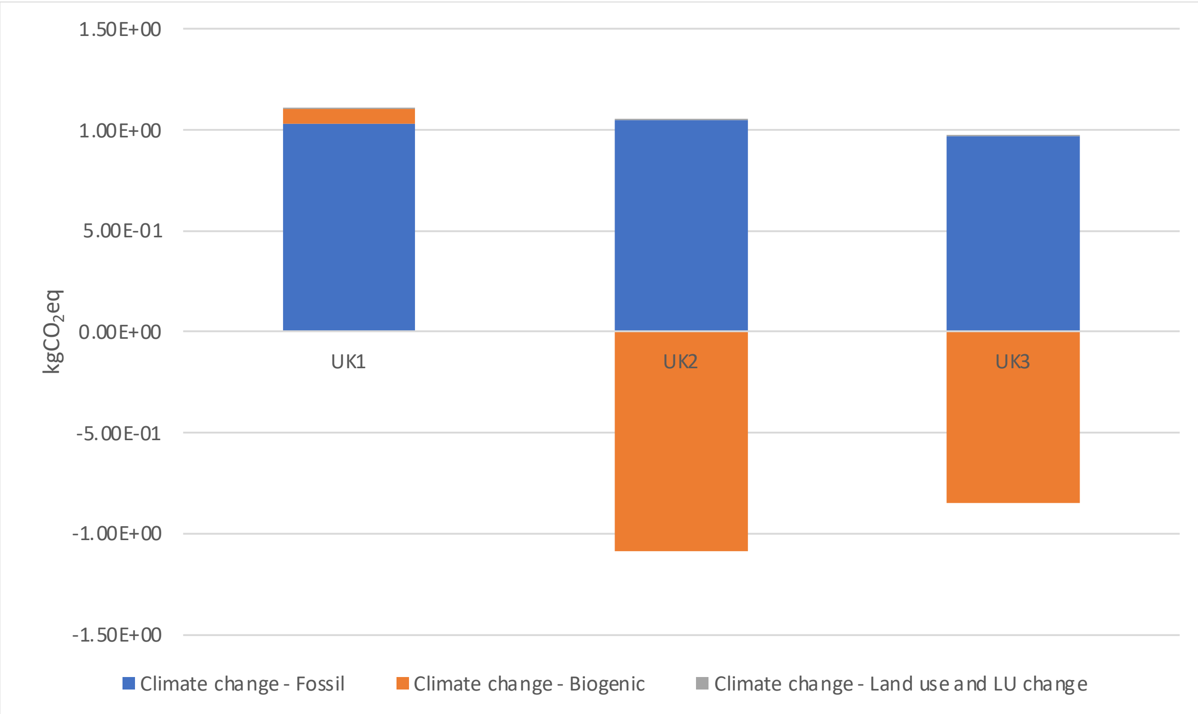

Figure 2 - Results for 1 kg of prototypes expressed in kgCO_2eq manufactured in the UK

Results in Table 3 below have been expressed in $kgCO_2eq$ for 1 m^2 of product with an R = 1 m^2K/W.

		Prototype		
Impact category - Climate Change	**Unit**	**UK1**	**UK2**	**UK3**
Fossil	kg CO_2 eq	6.64E-01	8.46E-01	7.84E-01
Biogenic	kg CO_2 eq	4.84E-02	-8.71E-01	-6.81E-01
Land use and LU change	kg CO_2 eq	8.36E-04	5.19E-03	4.21E-03
Total	**kg CO_2 eq**	**6.96E-01**	**-2.82E-02**	**9.34E-02**

Table 3 – Results for 1 m^2 of product with an R = 1 m^2K/W manufactured in the UK

Figure 3 below shows the results of table 3 in a graphical representation. Note: the biogenic carbon presented is directly linked to the quantity of wool used.

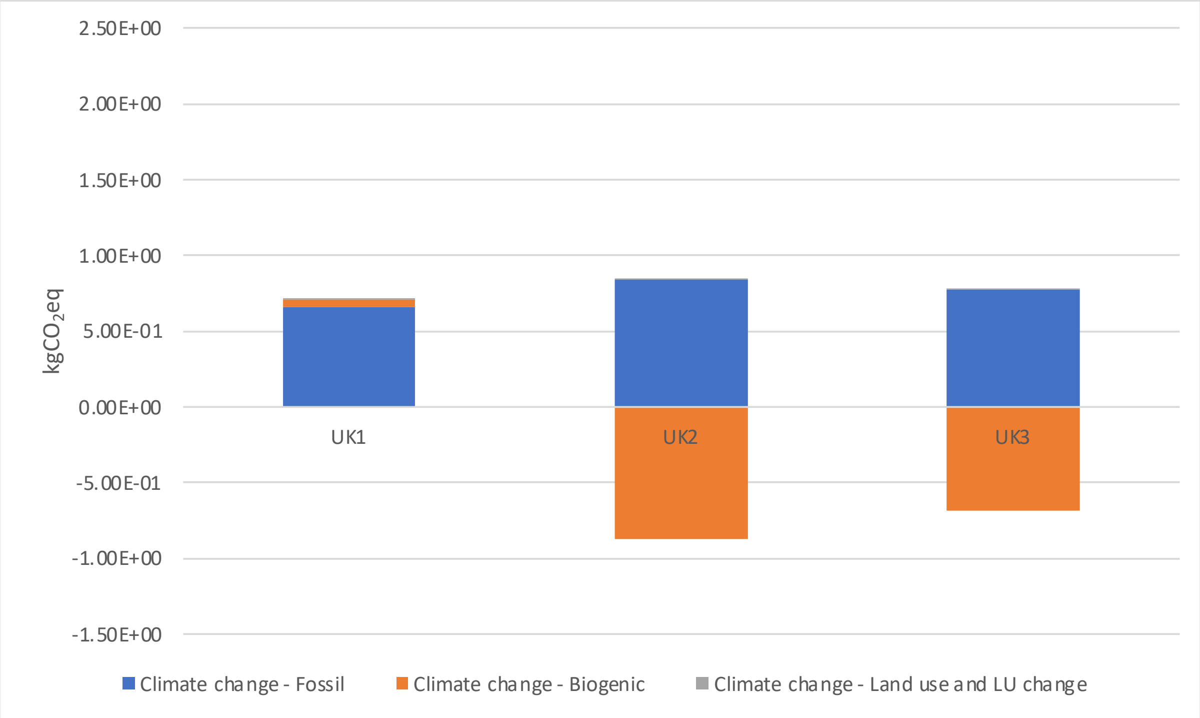

Figure 3 - Results for 1 m^2 of product with an R = 1 m^2K/W expressed in $kgCO_2eq$ manufactured in the UK

4.2 Results for products manufactured in France

Results in Table 4 below have been expressed in $kgCO_2eq$ for 1 kg of product:

		Prototype (including duvet cleaning)		
Impact category Climate Change	**Unit**	**FR1**	**FR2**	**FR3**
Fossil	kg CO_2 eq	9.61E-01	9.87E-01	7.27E-01
Biogenic	kg CO_2 eq	7.71E-02	-1.09E+00	-6.80E-01
Land use and LU change	kg CO_2 eq	1.16E-03	6.36E-03	4.11E-03
Total	**kg CO_2 eq**	**1.01E+00**	**-1.05E-01**	**3.83E-02**

Table 4 – Results for 1 kg of prototypes manufactured in France

Figure 4 below shows the results of table 4 in a graphical representation. Note: the biogenic carbon presented is directly linked to the quantity of wool used.

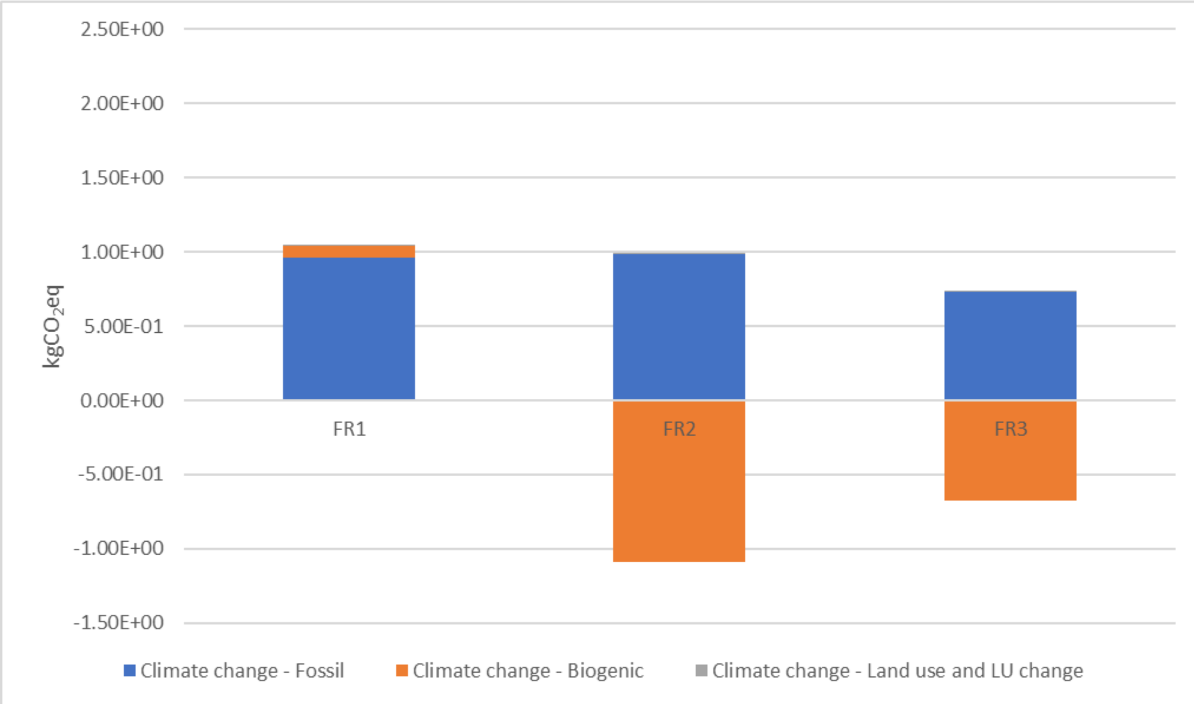

Figure 4 - Results for 1 kg of prototypes expressed in kgCO_2eq manufactured in France

Results in Table 5 below have been expressed in kgCO_2eq for 1 m^2 of product with an R = 1 m^{2}K/W.

		Prototype (including duvet cleaning)		
Impact category Climate Change	**Unit**	**FR1**	**FR2**	**FR3**
Fossil	kg CO_2 eq	6.15E-01	7.90E-01	7.27E-01
Biogenic	kg CO_2 eq	4.94E-02	-8.70E-01	-6.80E-01
Land use and LU change	kg CO_2 eq	7.46E-04	5.08E-03	4.11E-03
Total	**kg CO_2 eq**	**6.47E-01**	**-8.38E-02**	**3.83E-02**

Table 5 – Results for 1 m^2 of product with an R = 1 m^{2}K/W manufactured in France

Figure 5 below shows the results of table 5 in a graphical representation. Note: the biogenic carbon presented is directly linked to the quantity of wool used.

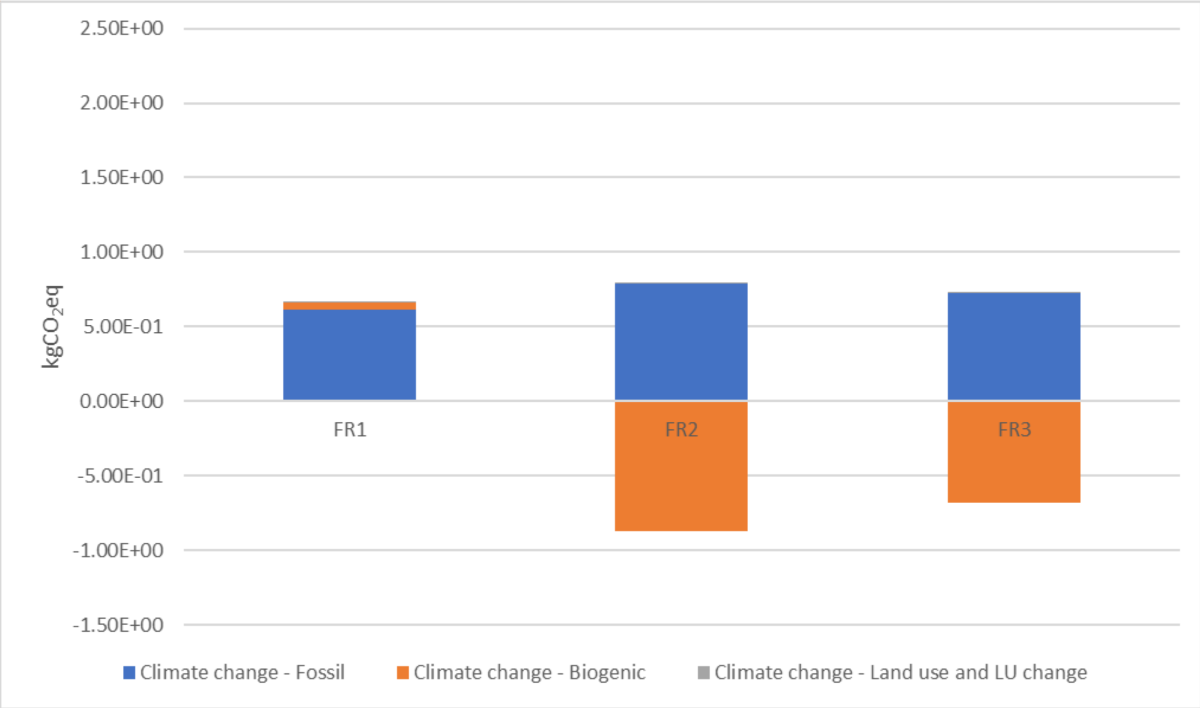

Figure 5 - Results for 1 m² of product with an R = 1 m²K/W expressed in kgCO_2eq manufactured in France

5 Comparison with conventional products

The environmental impacts of the prototypes have been compared against conventional insulation materials - glass wool and stone wool.

The functional unit for comparison is 1 m^2 of product with an R = 1 m^2K/W, expressed in kg CO_2 eq for the impact category – Climate Change/Global Warming Potential (GWP).

LCA data for the conventional products has been taken from EPD data available on EcoPlatform – ref no. ECO-00000015 and ref no. ECO-00000250.

	Prototypes manufactured in the UK			**Prototypes manufactured in France**			**Conventional products**	
	UK1	**UK2**	**UK3**	**FR1**	**FR2**	**FR3**	**Glass wool**	**Stone wool**
Total GWP kg CO2 eq	6.96E-01	-2.82E-02	9.34E-02	6.47E-01	-8.38E-02	3.83E-02	1.30E+00	1.73+00
Reduction vs glass wool	46.5%	102.7%	92.8%	50.2%	106.4%	97.1%	N/A	N/A
Reduction vs stone wool	59.8%	101.6%	94.6%	62.6%	104.8%	97.8%	N/A	N/A

Table 6 - Percentage reduction in environmental impact of prototypes versus conventional materials

The results (see Table 6/Figure 6) show that all of the prototypes (with manufacturing scenarios in both the UK and France) could provide a significant reduction in their environmental impact with an average reduction of 82.6% vs glass wool and 86.9% vs stone wool.

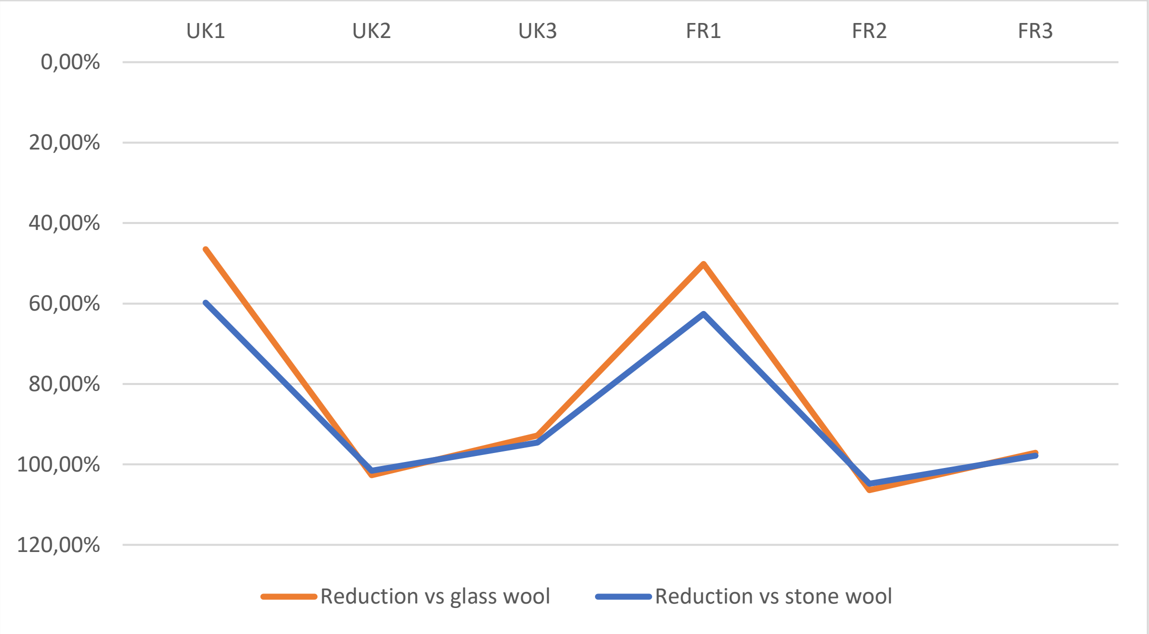

Figure 6 - Percentage reduction in environmental impact of prototypes versus conventional materials

Conclusion

The results show that all of the prototypes (with manufacturing scenarios in both the UK and France) could provide a significant reduction in their environmental impact with an average reduction of 82.6% vs glass wool and 86.9% vs stone wool.

The environmental impact of the BIO-CIRC prototypes compares well to the 3 prototypes (maize, wheat straw, duvet) developed during the precursor SBWRC project, which showed a similar reduction (35-95%, average of 63%) in environmental impact compared to conventional materials.

In the French model the inclusion of duvet cleaning adds a considerable amount of additional electricity consumption of 0.68kWh per kg of duvet fibre (twice that used in the processing). However, this only represents a limited increase in impact due to the high proportion of nuclear energy in the French grid mix. In fact, a small (1-5%) further reduction in prototype impacts is still revealed with the model for a French production with the assumption that all other aspects of production are the same.

It should be noted that this LCA study is part of a research project and the results presented are based on a prototyping scenario. Assumptions that have been made in the study are referenced within this report. Further life cycle analysis is required if the prototypes are to be manufactured at scale.

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The BIO-CIRC project is part of the cross-border European Territorial Cooperation (ETC) Programme Interreg VA France (Channel) England and benefits from financial support from the European Regional Development Fund