EUROPEAN UNION

Interreg

EUROPEAN UNION

France (Channel Manche) England

BIO-CIRC Project

European Regional Development Fund

BIO-CIRC Project

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

Economic Analysis

30 June 2022 – Final Version

EUROPEAN UNION
European Regional Development Fund
NOMADEIS A WAVESTONE COMPANY
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.

Nomadéis Le Havre
120, boulevard Amiral Mouchez • 76600 Le Havre • France
Phone: +33 (0)1 45 24 31 44
www.nomadeis.com

The Alliance for Sustainable Building Products
The Foundry, 5 Baldwin Terrace • London N1 7RU • United Kingdom
Phone: +44 (0) 20 7704 3501
https://asbp.org.uk

Eden Renewable Innovations Limited
Soulands Gate, Soulby, Penrith • Cumbria, CA11 0JF • United Kingdom
Phone: +44 (0) 1768 486285
https://www.thermafleece.com

Back To Earth Limited
22 Tuns Lane, Silverton • Exeter, EX5 4HY • United Kingdom
Phone: +44 (0) 1392 861763
https://www.backtoearth.co.uk/

Copyrights

Table of contents

Introduction

As part of the BIO-CIRC project, the technical, environmental and economic characteristics of the three prototypes, made of polyester from bedding waste (duvets and pillows), recycled polyester and wool, were assessed in order to gain a comprehensive and multi-dimensional understanding of their strengths and weaknesses.

Many innovative products that are developed in research centres never reach the market because they are simply not competitive compared to existing products. The economic assessment aims to determine whether the three waste-based insulation materials that were developed during this project would be competitive relative to conventional insulation materials. The objective of this study is therefore to estimate the selling price of these insulations and to identify the factors that have a significant impact on production costs. These results will form an indispensable basis for any manufacturer wishing to produce and massively distribute these insulating products on the market.

As the BIO-CIRC project developed 3 prototypes that could be produced in 2 countries (France and the UK), **this study presents the results of 6 different scenarios**. Each model translates the economic estimations for every prototype in each country.

Note: Throughout this document, the term "*unit*" refers to a product with a surface area of 1 m^2 and a thermal resistance of R = 5 m^2.K/W. The term "*final product*" refers to a roll of insulation ready for sale with a thermal resistance of R = 5 m^2.K/W but whose size and thickness will vary according to the prototype.

Methodology and data

The economic assessment of these insulation materials for construction is essentially a simulation exercise because they are not yet produced on a large scale given that they are still at the prototype stage. For the purposes of this study, several models were developed to compute the costs of fictitious companies that would manufacture the polyester insulation material either in France or in the UK. The different steps of the manufacturing – and the related costs - will differ depending on scenarios but in any case, the modelled company receive the bedding waste (duvets and pillows), transform them into insulation materials and ship them to the final insulating retailer.

The modelling methodology for these polyester-based insulation materials is specific, because the price of collected and sorted waste duvets and pillows - the main raw material - is unknown. In France and in the UK, the furnishing items waste stream is not properly organised yet. Contracts between local authorities (who collect and store the waste), waste management operators, and companies specialised in recycling and reusing waste products do not exist. Therefore, the market for the collection, treatment and reuse of waste bedding does not exist yet, and therefore the price of treated waste duvets and pillows is not disclosed. This is problematic since all major costs must be measured to compute unit production costs.

Thus, due to the absence of satisfactory methods for estimating the price of waste bedding, unit production costs cannot be calculated with the usual 'bottom-up' approach, where all costs are identified and quantified. Therefore, a top-down approach was developed, which consists of (i) determining a "target" selling price, comparable to the prices of other insulation products on the market; (ii) quantifying all costs related to the production of a unit, except for the purchase cost of the duvets and pillows, and (iii) subtracting the unit production costs from the target price in order to determine the potential purchase cost of waste bedding.

More precisely, the following steps were undertaken:

1. The **production chain** for the bedding-based insulation materials was broken down into its main steps (see Production chain). The following slightly differ depending on whether the scenario is French or British.
2. The strongest assumption was that the plant processes **500 tonnes of polyester per year**. This assumption helped to estimate the pace, the number of machines, the quantity of raw materials required to run the plant. Overall the amount of inputs needed at each step was estimated in terms of machinery, consumables, utilities, labour, shipment, etc.
3. **All variable and fixed costs associated with each step** of the production process were identified and measured in a detailed and comprehensive way. However, as explained earlier, **the cost of duvets and pillows was ignored because no data exists on the price of waste bedding**. Thus, total annual production costs **net of bedding purchase costs** were quantified.
4. Knowing that the factory processes 500 tonnes of polyester per year and the different proportion of other raw materials (see prototype description), it is possible to estimate the **total insulating production of 1 m² with R = 5 m².K/W**.
5. To determine the potential turnover and enable the reverse analysis, **three “target” distributor selling prices were defined**. These prices are based on the market analysis conducted during the BIO-CIRC project. They reflect the average prices of insulating products for attics and were converted to correspond to the prices for 1 m² of attic cover, with a thermal performance of R = 5 m².K/W:
    a. 12€: similarly to glass wool and rock wool;
    b. 22€: similarly to expanded polystyrene, wood fibre, sheep’s wool, linen or recycled textiles;
    c. 31€: similarly to polyurethane, cellulose wadding, hemp or extruded polystyrene.
6. Multiplying the number of units produced by one of the target prices and adding the manufacturer's margin give the **manufacturer's potential turnover**. This helps to **estimate the company taxes**.
7. Summing up all the costs related to the operation of the factory, adding the manufacturer's margin (20%) and taxes, dividing this total by the number of units produced gives the **manufacturer's unit selling price** (net of waste bedding costs).
8. The potential **purchase cost of duvets and pillows** was computed, for each of the three target prices, and for a given prototype with 1 m² of mural cover and a thermal performance of R = 5 m².K/W, as: *bedding purchase cost = target distributor selling price – distributor margin (25%) - manufacturer’s unit selling price (net of bedding costs)*.
9. A **negative result** indicates that the fictitious company will **need to be subsidised** to be profitable. A **positive result** will give the maximum price at which the fictitious company could buy the waste bedding to be economically viable (i.e. with a minimum 20% margin on the sale of its products).
10. As this result will give the purchase cost of duvets and pillows of **a unit** (1 m^2 with R=5 m².K/W). It has to be divided by the mass of a unit and multiply by a thousand to get the **purchase cost for a tonne of bedding waste**.

It should be noted that this analysis is a simulation exercise that relies on certain assumptions and on the data available. Thus, results should not be taken at face value. However, they give a good idea of the magnitude and distribution of production costs.

Prototype description

Eden Renewable Innovations, mainly assisted by Back to Earth, developed the three bedding-based insulation prototypes. The rationale is that used bedding is part of a waste stream that is under-exploited in the circular economy, since most duvets and pillows in France and in the UK are currently not re-used or recycled. They are either sent to landfills or used as an energy source as part of waste-to-energy schemes. Unfortunately, these two solutions generate pollution. Therefore, the idea developed as part of the BIO-CIRC project is to exploit the interesting thermal properties of the duvets by re-using them as an insulation material for the construction industry.

In order to improve the performance and quality of the insulating materials, polyester extracted from bedding waste was mixed with other raw materials. To limit the carbon and environmental footprint of the product, recycled or natural materials were selected: recycled polyester and wool.

Here is the composition of each prototype:

- BIO-CIRC Prototype 1: 65% Polyester duvet, 25% rPET, 10% Bi-Co PET Binder;
- BIO-CIRC Prototype 2: 25% Polyester duvet, 65% Wool, 10% Bi-Co PET Binder;
- BIO-CIRC Prototype 3: 39% Polyester duvet, 51% Wool, 10% Bi-Co PET Binder;

And Table 1 reports the characteristics of each prototype.

Characteristics	Prototype 1	Prototype 2	Prototype 3	Unit
length	4,5	5	5	m
width	0,37	0,37	0,37	m
thickness	0,1	0,1	0,1	m
area	1,67	1,85	1,85	m²
volume	0,167	0,185	0,185	m^3
density	16	18	18	kg/m^3
mass	2,7	3,7	3,7	kg
thermal conductivity	0,044	0,042	0,042	W/mK
thermal performance (R)	2,27	2,38	2,38	m².K/W
thickness for R = 5 m².K/W	0,22	0,21	0,21	m
% PET from duvets & pillows	65%	25%	39%	%
% rPET	25%	0%	0%	%
% Wool	0%	65%	51%	%
% Bi-Co PET binder	10%	10%	10%	%

Table 1 - Characteristics of each prototype

It is also interesting to know the average characteristics of the inputs (duvets and pillows). Table 2 reports the dimensions and thermal properties of the waste bedding-based insulation product. The dimensions are those of a typical, large duvet.

Characteristics	Standard polyester duvet		Standard polyester pillow	
	value	**unit**	**value**	**unit**
length	2	m	1	m
width	2	m	1	m
thickness	0,04	m	0,09	m
area	4	m²	0	m²
volume	0,16	m^3	0,03	m^3
density	19,5	kg/m^3	40,0	kg/m^3
mass	3,12	kg	1,30	kg
thermal conductivity	0,043	W/mK	0,043	W/mK
thermal performance (R)	0,93	m².K/W	2,09	m².K/W
thickness for R = 5 m².K/W	0,22	m	0,22	m

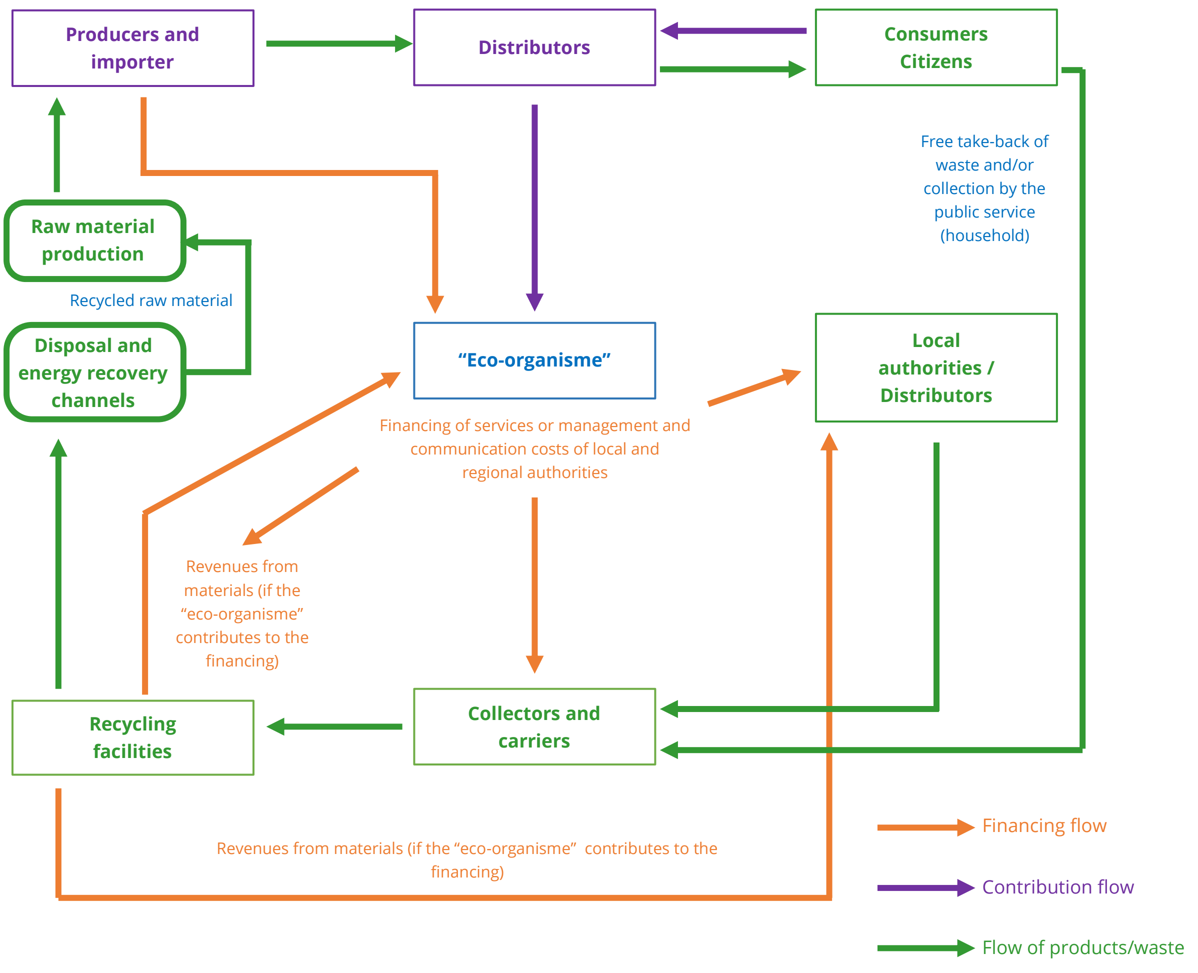
Table 2 – Characteristics of standard polyester duvets and pillows

Context of used bedding supply

French regulatory context

In Europe, extended producer responsibility (EPR) – *Responsabilité Elargie du Producteur* (REP) in French – schemes are extensively used to reduce the environmental impacts associated with a product's entire lifecycle. Under this policy approach, producers of consumer goods are financially and/or physically responsible for the collection, transport, treatment, re-use, recycling or final disposal of goods that are disposed of by consumers. The objective is, by making producers accountable for the negative environmental and social impacts associated with the waste flows they generate, to prevent excessive waste production, promote more environmentally compatible product design and foster the collection, re-use and recycling of products at their end-of-life.

In order to fulfil their obligations under the EPR principle, the producers can either develop i) individual schemes or ii) collective schemes through the creation of an entity call "eco-organism". In that latter case, the eco-organism is in charge for the collection of funds from the producers and the management of the proper end-of-life of the products, through financial support to the municipalities and/or direct contracts with waste operators. The Figure below shows the typical organisation of an EPR with an eco-organism.



Source: *ADEME, Les filières à responsabilité élargie du producteur – Panorama – Edition 2017*

In France, since 2011, the law has required issuers on the market of furniture components to take charge of the collection, sorting, reuse and disposal of these products (called "waste furniture components" - WEEE) in the form of an ERP channel. Two eco-organizations, Éco-mobilier (focusing on household furniture and bedding) and Valdelia (focusing on professional furniture), were accredited by the State at the end of 2012. Since 1 October 2018, upholstered seating or sleeping products (PRAC), to which duvets and pillows belong, have been brought within the scope of the ERO DEA. The first call for tenders for the collection and management of used sleeping bags was recently launched by Éco-mobilier and the companies' bids are currently being evaluated. The emerging ERP sector for the management of this waste is therefore in the process of being structured.

Structure of the bedding waste-to-insulation industry in France

Taking into account this regulatory context, the following figure shows the structure that would be in place in France if a dedicated recycling stream for used duvets and pillows were set up.

The orange section corresponds to the role of the manufacturer modelled in this study.

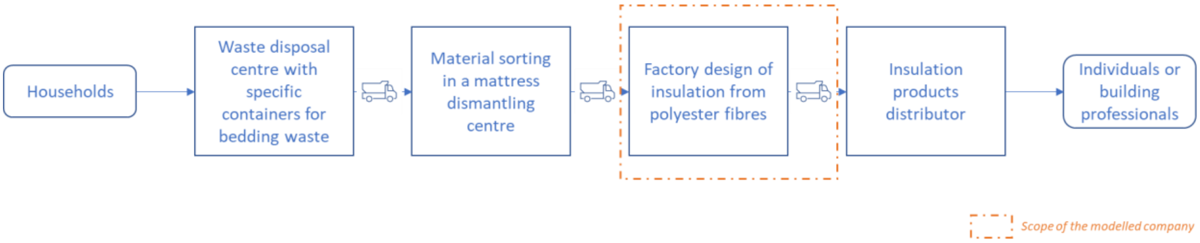


Figure 1 – Structure of the bedding waste-to-insulation industry (France)

British context

In the UK, waste management is slightly different. The polluter pays principle and extended producer responsibility is also a driver of waste management, but there is no eco-organism dealing with bedding waste. Currently, non-clothing household textiles are not collected due to their low or non-existent market value. Bedding is neither targeted in collections for reuse/recycling since it is considered low grade in quality with a very limited end market. Thus, textile banks, charities and other textile collectors usually ask the public not to give them duvets and pillows. But they receive duvets and pillows anyway and often dispose of them at a loss. In the context of the BIO-CIRC project, it was decided to **rely on the Salvation Army to supply duvets and pillows**.

The **T1.1 work package of the project gives more details** about the structure of the waste bedding management sector in France and the UK.

Structure of the bedding waste-to-insulation industry in the UK

Taking into account this regulatory context, the following figure shows the structure that would be in place in UK if a dedicated recycling stream for used duvets and pillows were set up with the help of the Salvation Army.

The orange section corresponds to the role of the manufacturer modelled in this study.

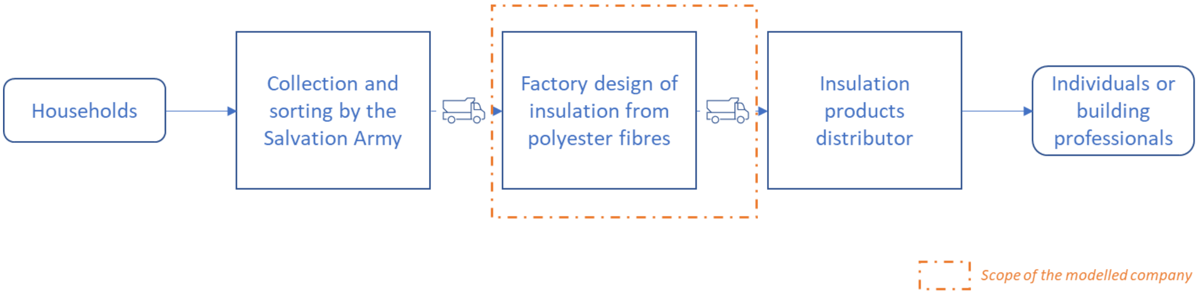


Figure 2 - Structure of the bedding waste-to-insulation industry (UK)

Production chain

In both countries, the production chain is almost the same. **The only difference is an additional washing and drying step in the French case**. This additional step is justified by the different supply conditions. As bedding waste is collected in France from waste disposal centres, the **risk of contamination is much higher**. In order to produce good quality insulation and avoid degradation of the final product, this decontamination step had to be integrated. The deliverable of work package T1.2 enabled to determine the most practical, economical and least carbon intensive method. In this economic modelling, it was assumed that pillows and duvets were washing 65 °C during 20 minutes and drying during 40 minutes.

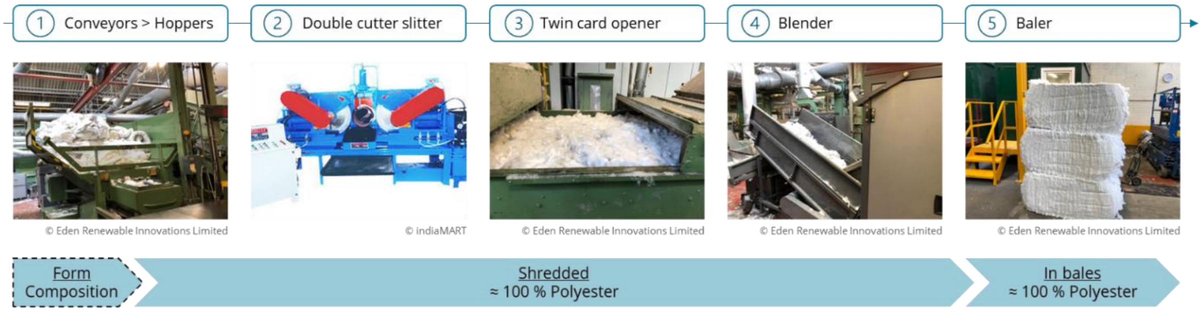
Production scenario

The fictitious company modelled in this deliverable operates from the collection of bedding waste to the sale of an insulation product to building material distributors. The only difference between the French and UK scenarios is a preliminary washing and drying step, but in both scenarios, once the bedding waste is collected (and washed and dried for the French scenario), it is processed into insulation after passing through two production lines:

1) **Duvets and pillows refiberisation**: The purpose of this first line is to unravel / unweave the polyester fibres to obtain bales made of 100% polyester fibres.
2) **Insulation manufacturing**: The second line aims at mixing the different components (polyester, rPET, wool, etc.), heating, cutting and packaging the insulation. After this stage, they are ready for transport.

Production line 1: Duvets and pillows refiberisation

Figure 3 shows the different steps of the first production line:



© Eden Renewable Innovations Limited © indiaMART © Eden Renewable Innovations Limited © Eden Renewable Innovations Limited © Eden Renewable Innovations Limited

Figure 3 – Production line n°1: Duvets and pillows refiberisation

1) **Conveyors > Hoppers**: This first machine collects the incoming duvets and pillows in one place and places the raw material on the conveyor belt;
2) **Double cutter slitter**: Duvets and pillows are cut and opened to release the polyester fibres trapped in the covers;
3) **Twin card opener:** The polyester fibres are untangled with cards. This step allows the fibres to be untangled and to be sorted more precisely in the case where foreign elements (e.g. buttons, etc.) have not been spotted so far;

4) **Blender:** All the collected polyester fibres are then blended into a homogeneous mixture (which contains at least 95% polyester);
5) **Baler:** The polyester fibres are then baled to simplify their transport and to better match the next production line.

Production line 2: Insulation manufacturing

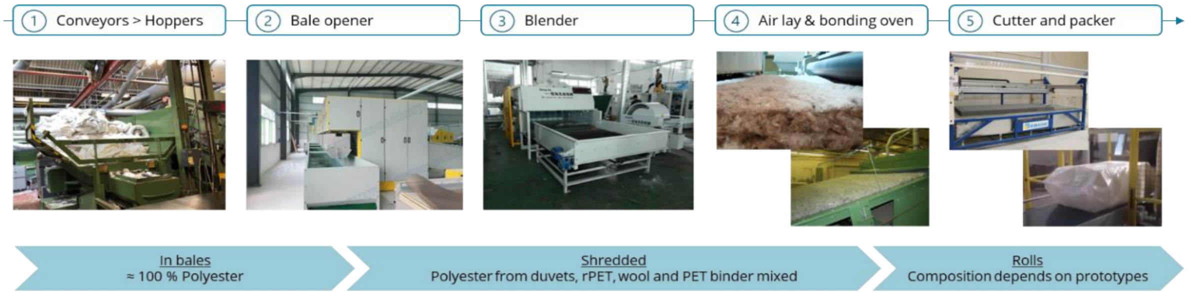


Figure 4 - Production line 2: Insulation manufacturing

1) **Conveyors > Hoppers**: After being transported from one production line to another using a forklift truck, the bales are positioned on production line 2;
2) **Bale opener**: The polyester bales are opened to be mixed with other raw materials for future insulation products;
3) **Blender:** Polyester from used duvets and pillows is mixed with other raw materials such as rPET and sheep's wool as well as a polyester-based binder. The final mix depends on the composition of the chosen and produced prototype;
4) **Air lay & bonding oven:** The final mixture is then heated and flattened to form a sort of large mattress;
5) **Cutter and packer:** This mattress is then cut at regular intervals to match the desired length of the final insulating material and almost immediately packed in its plastic packaging.

Cost breakdown

Production and operating assumptions

Plant assumptions

In both scenarios, the plant was supposed to operate 252 days per year, 7 hours per day, equivalent to 1764 hours per year. The strongest assumption is that the modelled plant processes 500 tonnes of duvets and pillows per year. Thus the **plant processes 283 kilograms of polyester every hour**. Given the number of machines required to carry out this activity and the need for storage space, **a factory of 8,000 m2 was modelled**.

Input assumptions

Based on the amount of polyester processed each year and the composition of the prototypes, raw material quantities (input assumptions) can be computed and the results are presented in the following table:

	P1		P2		P3	
	%	**t**	**%**	**t**	**%**	**t**
PET from duvets & pillows	65%	500	25%	500	39%	500
rPET	25%	192	0%	0	0%	0
Wool	0%	0	65%	1300	51%	654
Bi-Co PET Binder	10%	77	10%	200	10%	128
Total raw materials	***100%***	***769***	***100%***	***2 000***	***100%***	***1 282***

Table 1 – Input assumptions

The quantity of raw materials will strongly influence the pace and the number of machine required (see machines assumptions).

Output assumptions

As the composition differs from one prototype to another, the quantity of insulation produced each year differs between prototypes. Following table reports the estimated production depending on the prototype chosen.

	P1	P2	P3
Total raw materials (t)	769	2 000	1 282
Final products (rolls)	40 469	97 982	62 809
Units (1 m2 ; R = 5)	218 531	529 101	339 167

Table 2 – Estimated output production

Machines assumptions

Once the inputs (recovered polyester and other raw materials) and outputs (final production) were determined, it was possible to estimate the number of machines required for each stage by calculating the flow rate needed per hour. Given the high load capacity (see Appendix 1) of the different machines, it is not necessary to duplicate the number of machines at every stage to avoid bottlenecks. However, for prototypes 2 and 3, the lower proportion of polyester (25% and 39%) results in a higher quantity of raw materials (2000 tonnes and 1282 tonnes) than prototype 1 (769 tonnes).

These input quantities therefore increase the production and the production rate (given that the factory still processes 500 tonnes per year), which exceeds the maximum rate of some machines. It was therefore decided to double the number of these machines to enable the factory to keep the same output regardless of the prototype produced and to avoid bottlenecks. Thus, the number of machines depends on the prototype produced and serves as a basic assumption for the evaluation of the costs at each stage of the industrial process.

Labour assumptions

Some basic assumptions were made to estimate the manpower required. In particular, it is supposed that each employee works 7 hours a day, 209 days per year, taking into account time off and an absenteeism rate of 5%.

More machinery also suggests more staff. The labour assumptions therefore also vary depending on the prototypes. The table in Appendix 1 details the manpower required to operate each production line. For example, in the case of prototype 1, it was estimated that 11 people were needed to run the plant. For prototype 1, there are 9 positions to manage but as the factory operates 252 days a year and each employee works 209 days a year, two extra people have been considered in this model to bridge this gap.

Transport assumptions

This model takes into account the transport of the insulation to the partner distributors. For this purpose, it was assumed that the average distance covered by each truck for a delivery is 400 km and that it is always running at a full capacity.

French specificity

The production and operating assumptions are the same for the French and English scenarios, except for an preliminary washing and drying step for the French case. Therefore, this additional step has repercussions on the machines (washers and dryers) and labour (people required to run these steps) assumptions.

Cost estimations

Machines-related costs

The majority of the machine related assumptions are based on information provided by Eden Renewables Innovation Limited in Appendix 1. For each machine, four elements were taken into account in order to estimate the costs:

1. The **purchase cost** has been included in the model taking into account its depreciation period. In other words, for a €1 million machine with a 20-year lifespan, we counted

€50,000 of expenditure per year. Calculating all the purchase costs gives the initial investment required (if all the machines are purchased at once in the first year). The initial investment was estimated in the following section.

2. The **consumable costs** were calculated from the production figures and/or the running time of the machines. For example, for step 5 "Cutter and packer" of the 2nd production line, bags are required to impermeably pack the insulation. According to Eden Renewables Innovation Limited, each bag costs £1.85 (see Appendix 1). Thus, multiplying the cost by the number of bags required (equal to the number of insulations produced) gives the consumable costs for this step.
3. The only **utilities** needed in this industrial process are **electricity and water** (in the French case only which requires water to wash duvets and pillows). Multiplying the consumption of each machine (see Appendix 1) by the price per kWh or per litre of water gives the utilities costs. Note that these costs differ between the French and British scenarios: the price per kWh has been estimated at €0.35 in the British case and €0.15 in the French case.
4. The **annual maintenance cost** was calculated for each machine by multiplying the average maintenance frequency by the average cost of a repair. For example, for the twin card opener machine (see Appendix 1), the mean time before failures (MTBF) – which corresponds to the mean time between two repairs – is 100 hours and the average price of a repair is £300 (or €351). The twin card opener machine works 1764 hours per year and the annual maintenance cost is equal to 1764/100*351 = €6 192.

	Forklift truck	Coveyor > Hopper	Double cutter slitter	Twin card opener	Blender	Baler	
Unit	2	1	1	1	1	1	unit
Capacity	500	500	500	500	500	500	kg/hour
Purchase cost / machine	46 800 €	234 000 €	468 000 €	1 755 000 €	58 500 €	117 000 €	€/unit
Depreciation period	10	25	25	25	25	25	years
Consumables unit/year	0	0	24	4	0	2500	unit/year
Consumables €/unit	0,0 €	0,0 €	234,0 €	1 170,0 €	0,0 €	2,3 €	€/unit
Utilities = Electricity	2	10	15	30	2	3	kWh/hour
Mean Time Between Failures (MTBF)	300	200	150	100	400	400	hour
Mean cost to repair	87,75 €	175,50 €	263,25 €	351,00 €	87,75 €	175,50 €	€

	Forklift truck	Coveyor > Hopper	Double cutter slitter	Twin card opener	Blender	Baler	
Machine	4 680 €	9 360 €	18 720 €	70 200 €	2 340 €	4 680 €	
Consumables	0 €	0 €	5 616 €	4 680 €	0 €	5 850 €	
Utilities	529 €	2 646 €	3 969 €	7 938 €	529 €	794 €	
Maintenance	516 €	1 548 €	3 096 €	6 192 €	387 €	774 €	**TOTAL**
Total	**11 450 €**	**13 554 €**	**31 401 €**	**89 010 €**	**3 256 €**	**12 098 €**	**160 769 €**

Table 2 – Example of machine costs (production line n°1) for prototype 1 in France

Plant costs

The costs of running and renting the plant are highly dependent on where the plant is located. Necessarily these costs are different between the plant modelled in France and the UK. There is a significant differential between the French and UK scenarios due to the cost of rent being almost 5 times higher in South East London.

French scenario

The rental costs of an 8,000 m2 factory were estimated after an online benchmark of equivalent sized factories near Rennes. This cost estimation remains the same for all the three prototypes produced in France.

Size of the plant	8000	m2
Rental cost per m2 per year	40,75 €	€/m2/year
Rental cost per m2 per month	3,40 €	€/m2/month
Rental cost per year	326 000,00 €	€/year
Charges per m2 per year	14,00 €	€/m2/year
Rental fees	30%	
Total rental cost per year	**535 800 €**	**€/year**

Table 3 – Plant costs estimation in France

British scenario

The rental costs of an 8,000 m2 factory were estimated after an online benchmark of equivalent sized factories in South East London. This cost estimation remains the same for all the three prototypes produced in the UK.

Size of the plant	8000	m2
Rental cost per m2 per year	188,91 €	€/m2/year
Rental cost per m2 per month	15,74 €	€/m2/month
Rental cost per year	1 511 251,56 €	€/year
Charges per m2 per year	16,38 €	€/m2/year
Rental fees	25%	
Total rental cost per year	**2 020 104 €**	**€/year**

Table 4 – Plant costs estimation in the UK

Labour costs

Labour costs also show a **strong difference between the French and UK scenarios**. Although charges are lower in the UK, wages are on average higher and cost the employer comparatively more overall. However, four people are needed for the washing and drying steps required in the French case. This means that overall, labour costs are higher in France.

Furthermore, the economic weight of labour is **also different depending on the prototype chosen** since prototypes 2 and 3 require more machines and therefore more labour (see Labour assumptions).

French scenario

Number of employee	15
Number of months in a year	12
Monthly wage/employee	1 600 €
Employer contributions/employee	672 €
Total cost/employee	2 272 €
TOTAL labour costs	**408 960 €**

Table 5 – Estimated labour costs for prototype 1 in France

British scenario

Number of employee	11
Number of months in a year	12
Monthly wage/employee	2 157 €
Employer contributions/employee	230 €
Total cost/employee	2 388 €
TOTAL labour costs	**315 168 €**

Table 6 - Estimated labour costs for prototype 1 in the UK

Raw materials costs

Cost of purchase rPET (£ excluding VAT / t)	2 106 €	2 000 €
Cost of purchase wool (£ excluding VAT / t)	3 510 €	3 000 €
Cost of purchase PET binder (£ excluding VAT / t)	2 925 €	2 925 €

	P1			**P2**			**P3**		
	t	**€ (UK)**	**€ (FR)**	**t**	**€ (UK)**	**€ (FR)**	**t**	**€ (UK)**	**€ (FR)**
PET from duvets & pillows	500	?	?	500	?	?	500	?	?
rPET	192	405 000 €	384 615 €	0	0 €	0 €	0	0 €	0 €
Wool	0	0 €	0 €	1300	4 563 000 €	3 900 000 €	654	2 295 000 €	1 961 538 €
Bi-Co PET Binder	77	225 000 €	225 000 €	200	585 000 €	585 000 €	128	375 000 €	375 000 €
Total raw materials	***769***	***630 000 €***	***609 615 €***	***2 000***	***5 148 000 €***	***4 485 000 €***	***1 282***	***2 670 000 €***	***2 336 538 €***

Shipment costs

As mentioned in the "transport assumptions" section, it is assumed that the trucks drive full and cover an average of 400 km for each delivery. Furthermore, it is assumed that each truck is capable of carrying 80 m3 of goods (the useful capacity of a semi-trailer is 90 m^3 but a margin has been retained, about 10 %, to take into account the impossibility of optimising this space to the maximum).

By dividing the volume produced each year by the volume available per truck, we obtain the number of trips made each year. Given that 48 077 tonnes of insulation are produced each year, this means that 601 trips are required every year. The cost of the 240,400 km travelled each year for the transport of these products is therefore estimated in the following table:

	Assumptions	Units
Cost per km per ton	1,38 €	€/t/km
length available per truck	13,1	m
width available per truck	2,4	m
height available per truck	2,6	m
Volume per truck	80	m3
Final products per truck	67	units
Mass per truck	1280,7	kg
Number of truck rides per year	601,0	rides
Average distance of a truck rid	400	km
Total distance per year	240400	km
Total cost of transport per year	**331 515,20 €**	**€/year**

Tax estimation

To estimate coporate taxes, the potential turnover of the company had to be anticipated. For this purpose, the production costs were calculated without taking into account the possible purchase of duvets and pillows to which a manufacturer margin of 20% was added.

For the French scenario, this tax was then calculated by applying a rate of 25% to the benefits made during the year. Two other taxes were also estimated: the *Cotisation foncière des entreprises maximale (CFE)* and the *Cotisation sur la valeur ajoutée des entreprises (CVAE)*.

Corporate tax	
Manufacturer projected turnover	3 074 523 €
Total costs	2 562 102 €
Benefits	512 420 €
Tax to be paid	128 105 €

Cotisation foncière des entreprises maximale (CFE)	**6 559 €**

Cotisation sur la valeur ajoutée des entreprises (CVAE)	**20 000 €**

Initial investments

In this economic analysis, all costs related to fixed assets (machinery, buildings, etc.) have been allocated over time on a straight-line basis according to their life span. The main objective is to get an idea of the economic profitability of the activity: if all purchase costs are fully integrated from the first year, the model is necessarily loss-making (some machines cost several million euros). This method of accounting remains fairly close to reality because these fixed assets are not always purchased at once and/or are backed by a bank loan.

However, it is useful and interesting to have an idea of the initial investment needed to launch such a business, taking the strongest assumption: all fixed assets are purchased at once and in the first year. This initial investment, which corresponds to capital expenditures (CAPEX), is presented in the following tables according to the scenario chosen.

The operational expenditures (OPEX) give an idea of the annual expenses borne by the company for the needs of its activity. They provide an order of magnitude of the expenses to be paid each year to operate the company, once the fixed assets have been acquired.

Capital & Operational Expenditures

Scenario 1: Prototype 1 in France

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	1	3 510 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	3 510 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	1	877 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	877 500 €
Blender	526 500 €	25	1	526 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	526 500 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	4	187 200 €	0	0 €	4	187 200 €	0	0 €	4	187 200 €	0	0 €	561 600 €
Dryer	3 000 €	3	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	324 000 €
Washing machine	3 500 €	3	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	231 000 €
Total investment				8 645 200 €		92 500 €		279 700 €		92 500 €		279 700 €		92 500 €	9 482 100 €

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	609 615 €	408 960 €	153 590 €	535 800 €	53 978 €	103 741 €	21 439 €	310 039 €	2 197 163 €

Scenario 2: Prototype 1 in the UK

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	1	3 510 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	3 510 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	1	877 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	877 500 €
Blender	526 500 €	25	1	526 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	526 500 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	4	187 200 €	0	0 €	4	187 200 €	0	0 €	4	187 200 €	0	0 €	561 600 €
Total investment				8 552 700 €		0 €		187 200 €		0 €		187 200 €		0 €	8 927 100 €

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	630 000 €	315 168 €	160 235 €	2 020 104 €	126 309 €	103 741 €	21 439 €	578 704 €	3 955 700 €

Scenario 3: Prototype 2 in France

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	2	7 020 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	7 020 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	2	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Blender	526 500 €	25	2	1 053 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 053 000 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	6	280 800 €	0	0 €	6	280 800 €	0	0 €	6	280 800 €	0	0 €	842 400 €
Dryer	3 000 €	3	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	324 000 €
Washing machine	3 500 €	3	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	231 000 €
Total investment				13 652 800 €		92 500 €		373 300 €		92 500 €		373 300 €		92 500 €	14 676 900 €

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	4 485 000 €	518 016 €	401 980 €	535 800 €	53 978 €	213 487 €	28 765 €	716 535 €	6 953 562 €

Scenario 4: Prototype 2 in the UK

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	2	7 020 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	7 020 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	2	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Blender	526 500 €	25	1	526 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	526 500 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	6	280 800 €	0	0 €	6	280 800 €	0	0 €	6	280 800 €	0	0 €	842 400 €
Total investment				**13 033 800 €**		**0 €**		**280 800 €**		**0 €**		**280 800 €**		**0 €**	**13 595 400 €**

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	5 148 000 €	429 775 €	363 230 €	2 020 104 €	126 309 €	152 484 €	21 439 €	859 788 €	**9 121 130 €**

Scenario 5: Prototype 3 in France

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	2	7 020 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	7 020 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	2	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Blender	526 500 €	25	2	1 053 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 053 000 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	6	280 800 €	0	0 €	6	280 800 €	0	0 €	6	280 800 €	0	0 €	842 400 €
Dryer	3 000 €	3	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	18	54 000 €	324 000 €
Washing machine	3 500 €	3	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	11	38 500 €	231 000 €
Total investment				**13 652 800 €**		**92 500 €**		**373 300 €**		**92 500 €**		**373 300 €**		**92 500 €**	**14 676 900 €**

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	2 336 538 €	518 016 €	274 083 €	535 800 €	53 978 €	137 356 €	28 765 €	459 317 €	**4 343 854 €**

Scenario 6: Prototype 3 in the UK

			Year 1		Year 5		Year 10		Year 15		Year 20		Year 25		
	Cost/unit	Lifespan	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Unit	Costs	Cumulative total for 25 years
Air lay & bonding oven	3 510 000 €	25	2	7 020 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	7 020 000 €
Twin card opener	1 755 000 €	25	1	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Cutter and packer	877 500 €	25	2	1 755 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	1 755 000 €
Blender	526 500 €	25	1	526 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	526 500 €
Double cutter slitter	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale opener	468 000 €	25	1	468 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	468 000 €
Bale coveyor > Hopper	351 000 €	25	1	351 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	351 000 €
Coveyor > Hopper	234 000 €	25	1	234 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	234 000 €
Baler	117 000 €	25	1	117 000 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	117 000 €
Blender	58 500 €	25	1	58 500 €	0	0 €	0	0 €	0	0 €	0	0 €	0	0 €	58 500 €
Forklift truck	46 800 €	10	6	280 800 €	0	0 €	6	280 800 €	0	0 €	6	280 800 €	0	0 €	842 400 €
Total investment				**13 033 800 €**		**0 €**		**280 800 €**		**0 €**		**280 800 €**		**0 €**	**13 595 400 €**

	Raw materials	Human resources	Taxes	Rental	Utilities	Consumables	Maintenance	Transport	Total
Operational expenditures	2 670 000 €	429 775 €	268 944 €	2 020 104 €	126 309 €	152 095 €	21 439 €	857 339 €	**6 546 005 €**

Results

The global results of the economic analysis for the production and sell of each of the 3 prototypes, both in France and in the UK, are presented in the 2 summary tables below.

As explained above, given that waste polyester duvets and pillows are currently not priced, a retro-analysis was performed, starting from a distributor selling target price (either 12 €, 22 € or 31€ per mural m^2 of insulant for a thermal resistance (R-value) of 5 m^2.K.W^{-1}) and successively removing intermediate costs (distributor commercial margin estimated at 25%; product manufacturer gross margin of 20% and production costs) in order to assess the cost of waste polyester duvets and pillows required to be economically viable.

In the tables below, two cases can be encountered:

- The duvets cost is negative (below 0) and red highlighted: **a subsidy would be required** in order to make the production of the product economically viable and to sell it at a standard price on the market;
- The duvets cost is positive (above 0) and green highlighted: **the product manufacturer could potentially afford to buy** the waste polyester duvets and pillows up to a certain price, and still be economically viable and sell it at a standard price on the market.

Global results for France

	Prototype 1			Prototype 2			Prototype 3		
Target distributor price	12 €	22 €	31 €	12 €	22 €	31 €	12 €	22 €	31 €
- Distributor Margin (25%)	3,0 €	5,5 €	7,8 €	3,0 €	5,5 €	7,8 €	3,0 €	5,5 €	7,8 €
Manufacturer's target unit selling price	9,0 €	16,5 €	23,3 €	9,0 €	16,5 €	23,3 €	9,0 €	16,5 €	23,3 €
Manufacturer's unit selling price net of duvets	12,4 €	12,4 €	12,4 €	15,0 €	15,0 €	15,0 €	15,5 €	15,5 €	15,5 €
Estimated duvet price for 1m2 of insulating	- 3,4 €	4,1 €	10,8 €	- 6,0 €	1,5 €	8,2 €	- 6,5 €	1,0 €	7,7 €
Estimated duvet price (in €/kg)	- 1,5 €	1,8 €	4,7 €	- 6,4 €	1,5 €	8,7 €	- 4,4 €	0,7 €	5,3 €
Estimated duvet price (in €/t)	- 1 500,0 €	1 778,0 €	4 728,2 €	- 6 401,2 €	1 535,3 €	8 678,1 €	- 4 410,5 €	677,0 €	5 255,8 €

Global results for the UK

	Prototype 1			Prototype 2			Prototype 3		
Target distributor price	12 €	22 €	31 €	12 €	22 €	31 €	12 €	22 €	31 €
- Distributor Margin (25%)	3,0 €	5,5 €	7,8 €	3,0 €	5,5 €	7,8 €	3,0 €	5,5 €	7,8 €
Manufacturer's target unit selling price	9,0 €	16,5 €	23,3 €	9,0 €	16,5 €	23,3 €	9,0 €	16,5 €	23,3 €
Manufacturer's unit selling price net of duvets	20,2 €	20,2 €	20,2 €	29,4 €	29,4 €	29,4 €	21,8 €	21,8 €	21,8 €
Estimated duvet price for 1m2 of insulating	- 11,2 €	- 3,7 €	3,0 €	- 20,4 €	- 12,9 €	- 6,1 €	- 12,8 €	- 5,3 €	1,4 €
Estimated duvet price (in €/kg)	- 4,9 €	- 1,6 €	1,3 €	- 13,8 €	- 8,7 €	- 4,2 €	- 8,7 €	- 3,6 €	1,0 €
Estimated duvet price (in €/t)	- 4 901,5 €	- 1 623,5 €	1 326,6 €	- 13 845,2 €	- 8 743,2 €	- 4 151,3 €	- 8 710,3 €	- 3 622,8 €	955,9 €

It appears that in France, none of the 3 prototypes could compete with glass wool and rock wool (mean sell price at 12€/m^2) without receiving a subsidy (which would perhaps be possible given the Extended Producer Responsibility Scheme in France), but all of the 3 should be able to compete with expanded polystyrene, wood fibre, sheep's wool, linen or recycled textiles (22€/m^2) and with polyurethane, cellulose wadding, hemp or extruded polystyrene (31€/m^2), without subsidies and also paying for the raw materials (or decreasing the final selling price). In the UK, subsidies would be required for all prototypes and target selling prices, except for prototypes 1 and 3 at 31€/m^2, where the economic model would be viable without subsidies.

Commercialisation and marketability strategy

Product image and sale arguments

Sale arguments

The principal sale arguments for the prototypes are as follows:

- The prototypes generats **reduction in CO_2 emissions** compared to conventional equivalent materials such as glass and mineral wools (see LCA report). The prototypes thus appear as **climate friendly**;
- The recycling of waste duvets and pillows lies within the **circular economy** and, as such, makes a fair use of materials and spares fossil and mineral resources jeopardized by over-exploitation, while reducing the quantity of waste produced;
- Thanks to its thermal and hygrometric properties, the prototype increases the **indoor well-being**;
- Given the potential for the prototypes to lie in the social economy, it may appear as a **socially responsible product**.

Adverstising

Adverstisement could be performed based on the abovementionned sale arguments and should target the following audiences:

- **Local authorities**, who would notably be interested to support this production given its potential for creating employment in the social economy;
- **Public owners with large construction and retrofitting operations**, such as public housing operators, hospitals, universities, schools, etc.;
- **Property developers**;
- **Architects**, through national and regional associations;
- **Large construction compagnies** (such as Bouygues, Vinci, Eiffage, etc.) as well as **artisan federations;**
- **Associations promoting sustainable building;**
- **Construction product distributors.**

Distribution channels

Given that the panels can i) be massively produced in a factory but ii) will assembled as a prefabricated unit, the most appropriate distribution channels appear to be either i) **specialized gross construction material distributors** or ii) **direct sale** to construction professionals through the producer's own network.

SWOT analysis

As a conclusion, a SWOT analysis (Strenghs, Weaknesses, Opportunities and Threats) has been performed.

Strenghs ➢ **Thermal performance** ➢ **Low carbon footprint** ➢ **Indoor well-being** ➢ **Support of social economy** ➢ **Circular economy scheme and materials use efficiency**	**Weaknesses** ➢ Current business model needs to receive **subsidies** to sale the product at a competititve price
Opportunities ➢ **Low carbon footprint** to be more valued in a context of climate emergency ➢ **Extended Producer Responsability** recently enlarged to waste duvets: **sustainable outlets required for that waste stream**	**Threats** ➢ **Economic simulation** is by nature uncertain ➢ **Further research** tests should be undertaken to refine the prototype design

Limits of the modelling

The results presented in this report should be treated with caution, as they are estimates derived from a simple modelling exercise. Cost and price estimates are inaccurate because some of the data used and some of the assumptions and calculations made are imprecise. These issues are inherent to any modelling or forecasting work. One should bear in mind that the polyester-based insulation module remains at the prototype-stage, as it is not yet produced or commercialised. The goal of this economic assessment was simply to produce a first approximation of production costs, and hence of the selling price, to compare it with competing insulation materials, and to explore cost-reduction strategies.

Production costs may be underestimated:

- Due to time, resource and data constraints, the modelling exercise is not perfectly exhaustive. Some cost categories and components may be missing (e.g. some tools, equipment etc.). However, the most significant and relevant ones have been accounted for.
- Taxes were excluded from the analysis, as they are proportional to the company's profits, which themselves depend on costs, prices, quantities and turnover. Indeed, the estimation of taxes with a reverse model reaches a complexity level beyond the scope of the present study.
- The modelling did not take into account the potential heterogeneity of the size of the duvets. To address this heterogeneity in an industrial plant could increase costs.
- Transport costs for the shipment of wool (prototypes No 2 and 3) was not modelized, and this may weight on the production costs, especially in France.

Exploring strategies for cost optimisation

Industrial process

Some cost optimisation items are presented below:

- Unit input costs might be reduced if raw materials, packages, machinery etc. are bought in large quantities to earn discounts.

- The washing and drying processes may be further optimised or simplified (lower costs). These processes have been modelized using a typical launderette. Using equipment of industrial size would minimize costs.

- Some machines / equipment are currently under-used in the current modelling (in particular at the start of the process stream, as well as at the end of the stream for prototypes 2 and 3 (which include wool in the composition)). Although it is not always feasible to proceed as lean manufacturing (some dead times cannot be avoided for logistical reasons, for instance), the use of some machines / equipment could be increased with complementary productions.

- In addition to the previous item above, the plant was supposed to operate 252 days per year, 7 hours per day, equivalent to 1764 hours per year. Working in 2, 3, 4 or 5 shifts would increase the use of the machines / equipment and therefore decrease their economic weight on the production costs. However, it should be noted that night labour may require additional salary costs and other expenses related to health and safety procedures.

Social economy

French scheme

In the French regulation, the structures of integration through economic activity – *Structure d'Insertion par l'Activité Economique (SIAE) in French* - can constitute a solution to increase the social utility of one's company while slightly reducing its operating costs. Four main types of structures coexist:

- Workshops and integration sites – *Ateliers et chantiers d'insertion (ACI);*
- Integration Enterprises – *Entreprises d'insertion (EI);*
- Intermediate Associations – *Associations Intermédiaires (AI);*
- Temporary Integration Work Enterprises – *Entreprises de travail temporaire d'insertion (ETTI);*

Within the framework of the BIO-CIRC project, the only possible status is "Integration Enterprise", as it is the only one compatible with a lucrative market activity.

An integration enterprise is a company operating in the commercial sector, but whose aim is above all social. The objective is to offer people facing difficulties a productive activity while supporting them to overcome their difficulties (re-education to work rhythms, training, social support, etc.). The ultimate goal is to enable these people to reintegrate sustainably into the professional world.

There is no issue of status since no legal form is imposed on the integration enterprise, which produces goods or services like any other enterprise.

In order to become an integration enterprise, it is necessary to sign an agreement with the State. This agreement is for a maximum of 3 years (renewable) and specifies in particular:

- The number of full-time equivalent positions filled by people approved by *Pôle Emploi*, giving them the right to State aid;
- The rules governing the remuneration of people in work integration
- The human resources used to supervise the employees on integration;
- The evaluation and monitoring of people on integration (assessments, etc.);
- The procedures for submitting job offers to *Pôle emploi*.

This agreement gives the right, within the limit of the number of integration posts fixed by the latter, to a financial aid (aid to the integration post). This aid consists of a fixed amount and a variable amount. The variable amount is set each year by a joint order of the Minister for Employment and the Minister for the Budget and takes into account changes in the minimum wage. The amount of the variable part is expressed as a percentage of the basic amount, between 0% and 10%. It is determined by taking into account:

- The characteristics of the people hired, and where applicable, the prisoners who have signed a commitment form (in the case of integration companies located in a prison);
- The actions and means of integration implemented;
- The results observed on leaving the structure.

An integration enterprise therefore hires people with social and professional difficulties under a fixed-term integration contract – *Contrat à Durée Déterminée d'Insertion* in French - that cannot exceed 24 months.

In the case of a manufacturer producing one of the BIO-CIRC prototypes, being an 'integration enterprise' may have several economic advantages such as:

- State subsidies (fixed and variable part);
- Lower labour costs (due to lower salaries).

In addition, from a marketing and communication perspective, being a social economy player may give a very positive image of the company and tend to increase both visibility and sales.

However, being an 'integration enterprise' may also have drawbacks such as:

- Higher management required to frame the employees under re-insertion;
- Risks of damage or theft of equipment;

- Renewal of the staff every 2 years, which means a recurring initial training effort and a certain loss of productivity.

A careful risk/benefit qualitative and quantitative assessment should be performed on a real case before a company engage on that trail. Such assessment goes far beyond the scope of the present study.

Carbon regulations and market

Principles for the operation of carbon markets

Carbon markets aim to limit greenhouse gas (GHG) emissions by allocating allowances, i.e. a right to emit tonnes of CO2 into the atmosphere. These allowances can be bought. Emitting companies are required to have a number of allowances equivalent to their CO2 emissions at the end of each year. Companies that emit more GHGs than the allowances allocated to them are therefore obliged to buy back allowances, generating an additional cost. The price of allowances must be high enough to act as a disincentive for companies to reduce their emissions at source. Allowance trading can therefore take place either in an organised market or over the counter.

These markets were developed following the Kyoto agreements to limit GHG emissions. They were accompanied by a **carbon credit** system that is not binding but which allows companies developing projects that make it possible to save GHGs (renewable energy, insulation, reforestation, etc.) to sell credits to the largest emitters so that they can be included in their quota. There are organisations that certify these credits, and their price is extremely variable (from a few euros to several hundred euros). For a credit to be validated, it must meet 4 conditions:

- **Additionality**: for a carbon credit to be awarded, it must be demonstrated that the project could not succeed without the money. For example, for a forest conservation project, the project must show that without the money from the sale of carbon credits, the forest would be cut down;

- **Measurability:** it is necessary to be able to calculate the amount of CO2 avoided or sequestered with a recognised methodology;

- **Verifiability**: it must be possible to calculate the amount of CO2 avoided or sequestered and to account it for every year. Therefore, to be able to verify the uniqueness of carbon credits;

- **Permanence**: carbon avoidance or sequestration must be long term. Overall, the minimum duration is 7 years.

About 12% of global emissions were covered by carbon pricing in 2015. The Carbon Pricing Leadership Coalition predicts that this will rise to 30% by 2030. The first market-based systems were introduced in the United States in the 1990s. Today, more than 40 countries have specific regulations on the subject (tax, carbon market, etc.). China has set up a national carbon market in 2021. Regional and sectoral disparities, however, make it impossible to establish a universal carbon price.

The carbon market mechanism is often compared to the carbon tax mechanism. Their principle is the same: to reduce GHG emissions, but the principles differ. The carbon tax puts a price on carbon, whereas the market decides on a maximum volume of emissions that cannot be exceeded without additional costs.

Focus on Europe

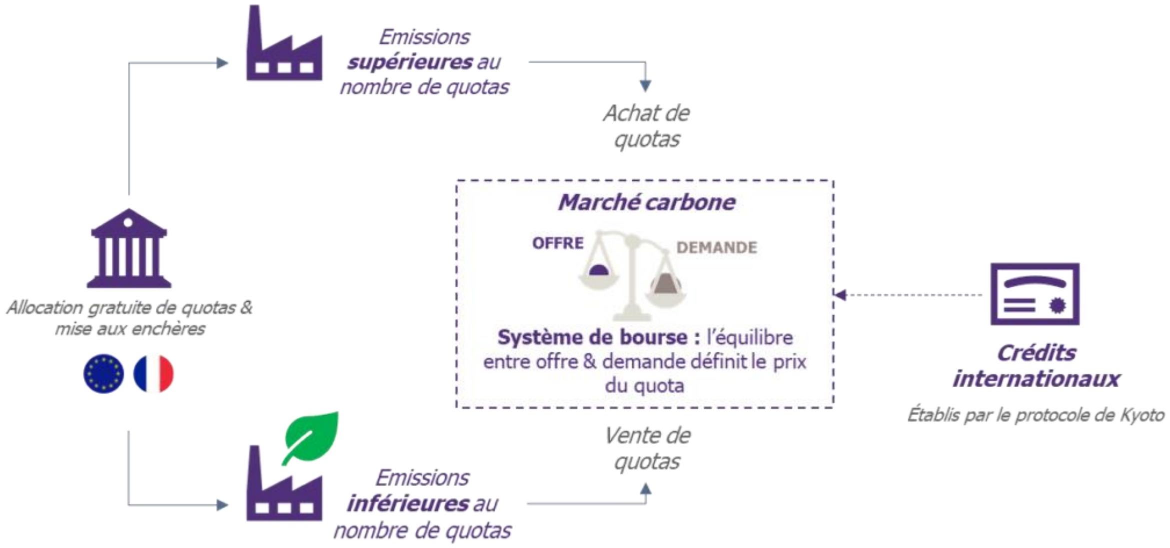
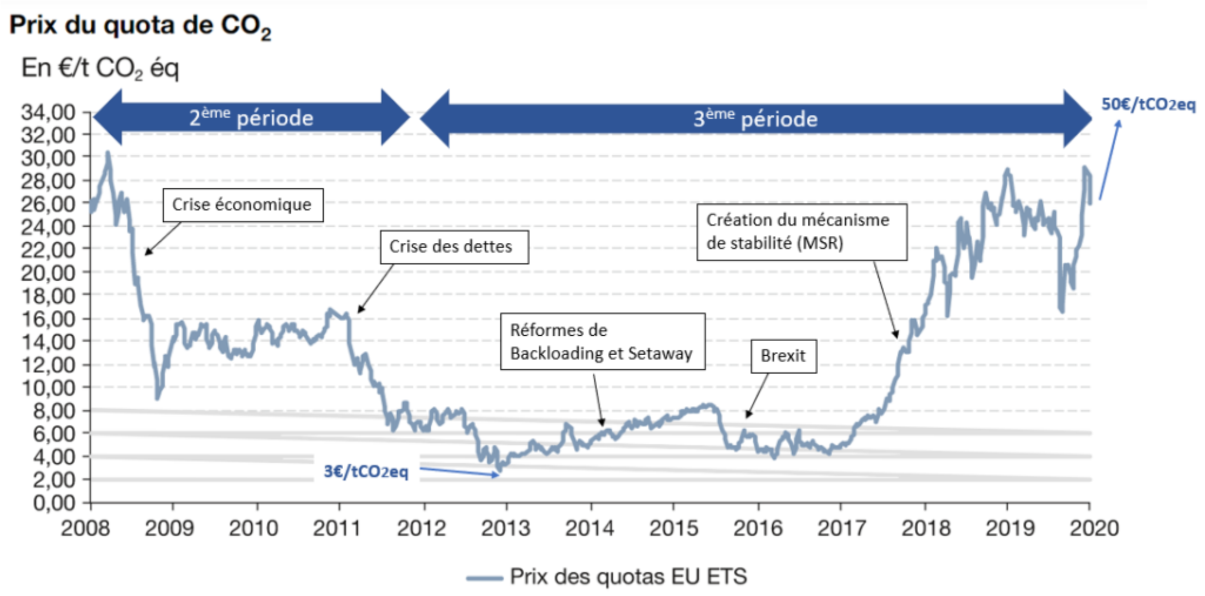


Figure from Nomadéis-Wavestone

The European Union's carbon market (or EU ETS, for Emissions Trading Scheme) is the largest in the world. It was created on 1 January 2005 to meet the commitments made when the Kyoto Protocol was signed. It concerns more than 11,000 power plants and industrial installations, which account for about 45% of European emissions of CO2, NO2 and PFCs (the three types of GHGs counted).

In the early years, too many free allowances were issued and a drop in industrial activity due to the 2008 crisis greatly reduced the impact of the carbon market: companies had no incentive to reduce their emissions. The market was reformed in 2017 and the price has since risen from just under €10 per tonne to over €45 in 2021. This logic will be reinforced with the end of free allowances from 2027.



Graphic from Nomadéis-Wavestone. ETS = Emission Trading System

The EU ETS is based on three pillars that ensure its stability and compliance with its targets:

- An accounting register where the emissions and compliance of each installation is recorded;
- A robust emissions measurement, reporting and verification system to ensure that emissions data is accurate;
- A penalty system to ensure that the rules, and therefore the environmental integrity of the market mechanism, are followed.

Some financial market mechanisms such as borrowing or saving allowances also exist. They allow companies to anticipate a possible growth in their activities and therefore in their emissions, or to keep part of their allowances if their production in a given year has proved to be more constrained than expected.

Prospects for the evolution of the carbon market

The European Green Pact aims to reduce the EU's emissions by 55% by 2030. This objective will be achieved in part through a reform of the carbon market, including a reduction in free allowances for certain sectors. The principle is to increase the price of carbon through market mechanisms, and to impose a carbon contribution at the borders to avoid environmental dumping.

Discussions are ongoing on the construction of the next version of the ETS. The European Parliament detailed its position on the subject in June 2022 and announced the launch of an ETS II from 2026 which will take into account building and road transport. The inclusion of transport and construction in the ETS should lead to an increase in the price of allowances, which is in line with the policy sought by the European Commission. However, it is not yet clear how these two sectors will be included (as a separate new market or as part of the existing one). Private individuals should be excluded until at least 2029. These points are currently being debated and will probably be clarified by the end of 2022 and during 2023 for gradual entry into force from 2024.

However, there is a clear trend towards an increase in the price of carbon quotas, and in the building sector, when it is integrated into the carbon market, bio-sourced materials will certainly make it possible to reduce the bill for developers or lessors by limiting energy consumption during construction and operation. It is difficult to give orders of magnitude at this stage until the Commission's work is completed.

Refurbishment sector

In France, the building sector accounts for about a quarter of GHG emissions, and 60% of these emissions are related to heating. The energy renovation of buildings is therefore a priority to achieve carbon neutrality.

Several mechanisms have been implemented. The CEE, *Certificats d'Economies d'Energies*, is a French scheme that aims to encourage economic actors and individuals to reduce their energy consumption. These schemes are in their 5th normative period. The current period runs from 2022-2025 and is still being defined. Since the Pact law of 2019, this scheme also applies to the 1300 sites concerned by the European carbon market on a national scale. According to the Ministry of Ecological Transition (MTE – *Ministère de la Transition Ecologique*), since 2011 in the residential sector, this scheme has notably encouraged the installation of:

- 1 million individual boilers and the replacement of collective boilers for 400,000 flats;
- 480,000 wood-burning appliances;
- 116,000 heat pumps;
- 260,000 m² of solar water heaters in the DOM (about 50,000 homes);
- 45 million m² of insulation (about 300,000 dwellings with attic or roof insulation and 125,000 with wall insulation);
- More than 3 million windows with insulating glass;
- 6 million A+ class LED lamps.

Over the same period, in the service sector, the MTE estimates that the measures have encouraged the installation of:

- 20 million m² of roof insulation;

- 100 kilometres of heating network insulation.

However, France's shortcomings in terms of energy renovation are regularly pointed out by various environmental movements and the government seems to want to develop this system.

The building sector is directly involved in obtaining these certificates by improving the energy performance of buildings. **There is therefore an opportunity for materials with good energy performance to be used in the construction process to obtain these certificates.** Under schemes such as *Ma Prime Renov'*, for example, individuals are helped to renovate their buildings. This is another opportunity for biobased materials whose skills meet the requirements to make their case and benefit from public aid to develop beyond new construction.

Another tool: carbon offset

Carbon offsetting does not reduce GHG emissions, but it does offset them by sequestering carbon. This tool has been heavily criticised because it is easier to implement than a systemic reduction of GHG emissions, but it will not be possible in the current state of technology to offset all emissions. It is therefore a tool that is advocated to offset the irreducible part of our emissions once reduction programmes are implemented. There are international reference standards, such as the Gold Standard developed by the WWF or the Verified Carbon Standard, which is widely used in Europe.

Biobased materials capture CO2 during their growth and can therefore become carbon sinks, provided that their exploitation generates more biomass than is extracted each year. This storage can be assessed by an LCA. The production of bio-sourced materials and their use in construction or renovation projects can therefore be used to obtain carbon credits that can then be used financially to reduce the costs of a real estate operation.

Conclusions on carbon markets and regulations

In the context of carbon markets, bio-based materials will certainly provide interesting economic benefits for the construction sector:

- By limiting the energy costs related to the production of materials in the construction phase;

- By improving the energy performance of buildings;

- By allowing these gains to be valued on the carbon markets.

On this last point, regulatory developments in Europe, with the increase in the price of quotas and the integration of the building sector into the ETS, should be highly favourable to bio-based materials and thus strengthen their competitiveness. However, these developments are not yet set in stone and the regulations are still being developed. At present, the emission of carbon credits, which are based on non-binding adhesion mechanisms, is the only way to value the energy gains of the sector through compensation.

Appendices

Appendix 1: Production chain assumptions

Phase		Timeframe		Machine			
No	**Name of the phase**	**Nature of the phase (Occasional or continuous)**	**1/ if occasional : duration (hours) + Frequency (per day, week, month or year) 2/ if continuous: duration per day (hours)**	**Name of required machine(s)**	**Capacity of the machine(s)**	**Purchase cost (excluding VAT) of each machine**	**Lifetime of each machine (hours, days, weeks, months or years)**
Phase 1	Duvet Segregation & Sorting	Continuous	8 hours / day	Conveyor	500kg per hour	£2k-£5k	25 years
				Sorting Table	500kg per hour	£20k-£40k	25 years
				Forklift Truck		£20k-£40k	10 years
Phase 2	Duvert Refiberisation	Continuous	8 hours / day	Conveyors & Hoppers	500kg per hour	£100k-£200k	25 years
				Doutle Cutter Slitter	500kg per hour	£250k-£400k	25 years
				Twin card opener	500kg per hour	£1m-£1.5m	25 years
				Blender	500kg per hour	£50k	25 years
				Bailer	500kg per hour	£60k-£100k	25 years
Phase	Insulation Manufacture	Continuous	8 hours / day	Bale Hopper & Conveyor	500 kg per hour	£150k-£300k	25 years
				Bale opener	500 kg per hour	£200k-£400k	25 years
				Blender	500 kg per hour	£300k -£450k	25 years
				Air lay & bonding Oven	500 kg per hour	£2m-£3m	25 years
				Cutter & Packer	500 kg per hour	£500k-£750k	25 years
				Fortlift Truck			10 years

Phase		Consumables & utilities				Labour	Maintenance		
No	**Name of the phase**	**Consumables required**	**Purchase cost (excluding VAT) of each consumable**	**Utilities required**	**Purchase cost (excluding VAT) of utilities**	**Labour required / machine (number of employees required to run a process ; Full Time Equivalent)**	**Mean Time Between Failures (MTBF)**	**Mean Time to Repair (MTTR)**	**Mean cost to repair**
Phase 1	Duvet Segregation & Sorting	None	£0	None	£0.30 per kWh	2	0	0	£0
		None	£0	Conveyor 2.5 kWh per hour.	£0.30 per kWh	2	200	4	£300,00
				2 kWh per hour	£0.30 per kWh	1	300		
Phase 2	Duvert Refiberisation	None		10 kWh per hour	£0.30 per kWh	3	200	2	£150,00
		Blades	£200 per 6 months x 12	15 kWh per hour	£0.30 per kWh		150	3	£225,00
		Drum pins	£1,000 per drum x 4 per year	30 kWh per hour	£0.30 per kWh		100	4	£300,00
		None		2 kWh per hour	£0.30 per kWh		400	1	£75,00
		Bale wire	£2 per 200kg bail	3 kWh per hour	£0.30 per kWh		400	2	£150,00
Phase	Insulation Manufacture			15 kWh per hour	£0.30 per kWh	6	400	2	£150,00
				15 kWh per hour	£0.30 per kWh		250	3	£225,00
				20 kWh per hour	£0.30 per kWh		300	2	£150,00
				80 kWh per hour	£0.30 per kWh		250	6	£450,00
		Bags & wrap	£1.85 per pack	10 kWh per hour	£0.30 per kWh		300	2	£150,00
				2 kWh per hour	£0.30 per kWh		300	1	£75,00

EUROPEAN UNION

Interreg
EUROPEAN UNION
France (Channel Manche) England

BIO-CIRC Project

European Regional Development Fund

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