



## SB&WRC Project

# Final report

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*June 2019*

### **Abstract of the project**

The SB&WRC (*Sustainable Bio&Waste Resources for Construction*) project, an undertaking of more than two years, aims to conceive, produce and test three innovative, low-carbon, thermal insulation materials from agricultural co-products and recycled waste. The project is supported by the development program Interreg VA France (Channel) England and its budget, estimated to be 1.8M€, is co-financed by the ERDF (European Regional Development Fund) for 69% (1.26M€ contribution).

This project, led by Nomadéis, is carried out by a cross-channel partnership which gathers academic research laboratories, private research and consulting companies, manufacturers and professional non-profit organisation of the building sector:

- Nomadéis;
- Veolia Propreté Nord Normandie;
- University of Bath;
- Ecole Supérieure d'Ingénieurs des Travaux de la Construction de Caen (ESITC Caen);
- Construction21;
- UniLaSalle;
- University of Brighton;
- Alliance for Sustainable Building Products.





**Nomadéis**

120, boulevard Amiral Mouchez • 76600 Le Havre

4, rue Francisque Sarcey • 75116 Paris

Phone: +33 (0)1 45 24 31 44

[www.nomadeis.com](http://www.nomadeis.com)

**Project team:**

Nicolas DUTREIX, Associate Director

Cédric BAECHER, Associate Director

Guillaume LAULAN, Project Manager

Adrien DUCHADEUIL, Analyst

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## 1. Overview of the project

### 1.1 *Background and objectives*

On the one hand, the **construction sector** represents a significant part of the **energy consumption** and of the **CO<sub>2</sub> emissions** worldwide. On the other hand, large amounts of agronomic and waste resources, which remain to be valorised in a **circular economy** logic, are present in France and England.

Therefore, the ***Sustainable Bio&Waste Resources for Construction (SB&WRC) project***, supported by the **INTERREG VA France (Channel) England programme**<sup>1</sup> as part of its Priority 2<sup>2</sup> and Specific Objective 2.1<sup>3</sup>, aimed at creating, developing and testing three innovative, low-carbon, insulation material for construction from bio- and waste resources that are currently under-valorised or which use is not yet optimised.

In order to foster the uptake of these prototypes by manufacturers and interested stakeholders as well as raise the awareness of building professionals towards bioresources and waste-based products for construction, the project partners aimed to produce economic and environmental assessments for each of the developed prototypes. These assessments, alongside awareness-raising actions, formed the dissemination component of the project.

The SB&WRC project ran for more than two years intending to go from potential waste and agricultural resources to functional prototypes of insulation material for which a certain amount of data was produced in order to interest manufacturers. Figure 1 thereafter summarises the main activities and their respective timeline undertaken by the partners.

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<sup>1</sup> The INTERREG VA France (Channel) England programme is a Cross Border European Territorial Cooperation (ETC) Programme which aim to support the development of the France (Channel) England area, in line with the goals of the 2020 Europe strategy to create jobs and stir smart, sustainable and inclusive growth.

<sup>2</sup> Support the transition towards a low-carbon economy in the France (Channel) England area.

<sup>3</sup> Increase the development and uptake of existing or new low-carbon technologies in sectors that have the highest potential for a reduction in greenhouse gas emissions.

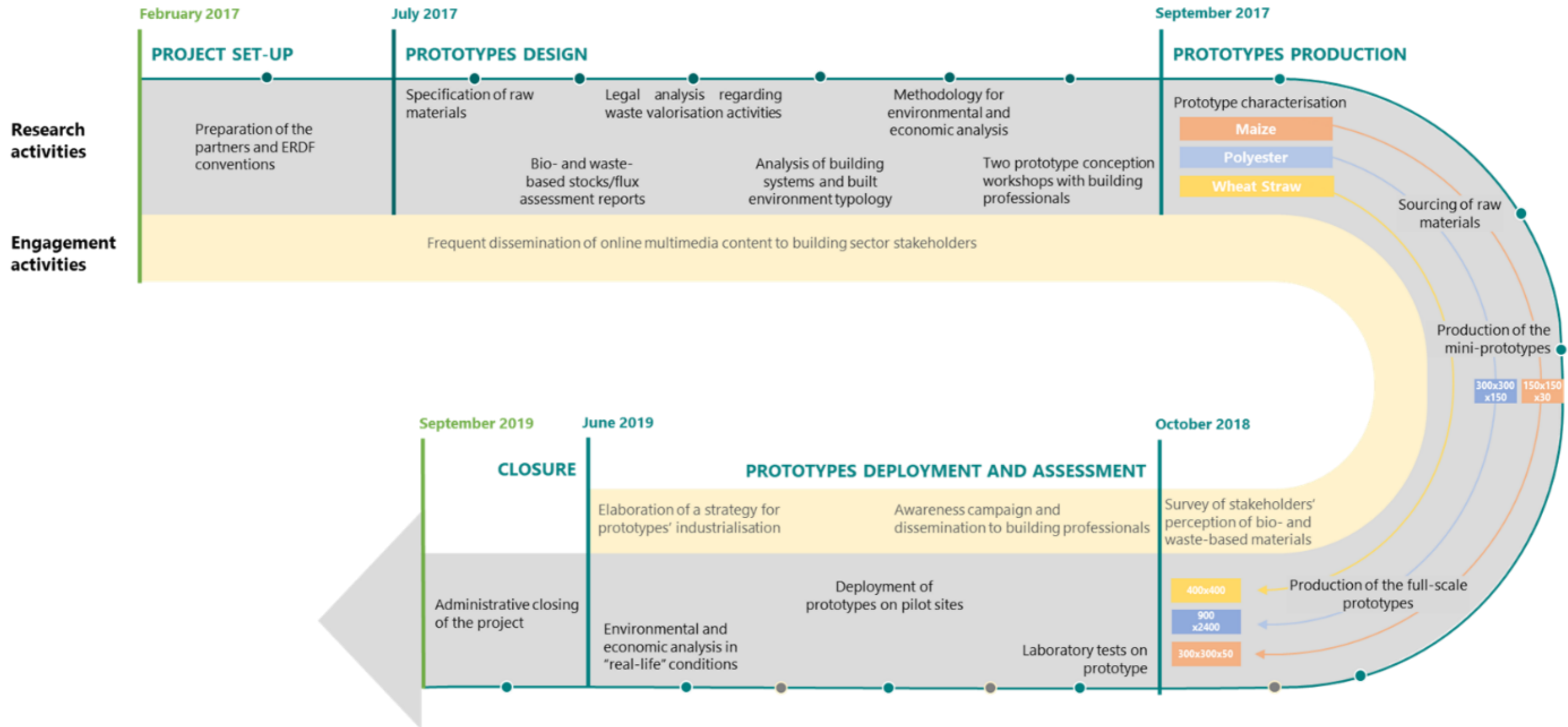


Figure 1 : Schematic summarising the SB&WRC project's activities and timeline

## 1.2 Initial phase of the project

During the initial phase of the SB&WRC project, which started in July 2017, the partners narrowed down their choice of 20 pre-selected resources down to a handful. The latter **were studied in terms of their availability in the FMA region, their constructability potential, their physical properties** and, specifically for waste resources, the **legal framework** around their reuse or recycling. From there, the project partners opted for the following 3 resources:

- **Maize pith;**
- **Polyester from waste duvets;**
- **Wheat straw.**

Subsequently, the partners undertook several laboratory tests to characterise the selected resources that were considered and understand their core properties. In parallel, a series of **workshops**, which involved external construction stakeholders, were held to define the constructive systems (what type of insulation product in the case of SB&WRC) that would be prototyped for each chosen resource.

This phase thus finished when partners had set which resources they would use, and whether it had good potential as an insulant and had an idea of the constructive form they were aiming for.

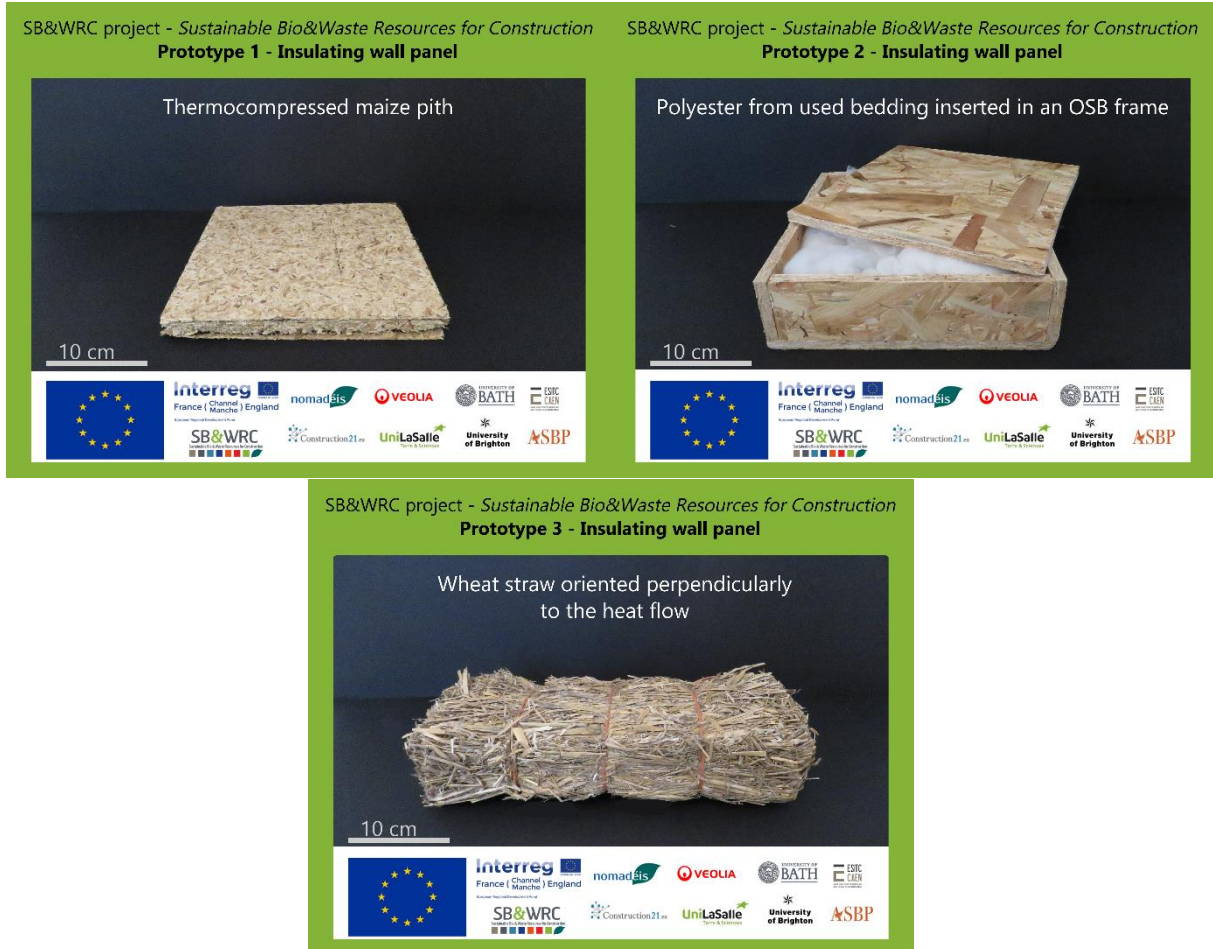
## 1.3 Prototype development phase of the project

Project partners then went into the prototype production phase, where research work on each resource involved characterising different material configuration, testing out and optimising production methods, creating **mini then full-scale prototypes**. In parallel, the transformed resources were subjected to a series of **physical, chemical and thermal characterisation** tests that would enable partners to better understand the material they had chosen and how it would be best used within the functional prototypes.

This phase also involved **cooperation between partners** whereby material or resources collected by one partner were sent over to another partner which had the capacity to test or complement the research. For example: Veolia managed to supply both partner ESITC Caen and partner University of Brighton with waste duvets or all partners furnished their transformed base materials to partner UniLaSalle in order for the latter to perform small flame flammability tests.

During this phase, partners also started their outreach and dissemination work. Indeed, while the scientific experiments above mentioned were taking place, project partners also attended **conferences and industry events** to present the project's goals, methodologies and results as well as to raise awareness on the use of bio- and waste-based construction material: UK Construction Week / Timber Expo in London, Delivering Healthy Buildings in Bristol and Woodbuild Wales (ASBP), COP23 in November 2017 in Bonn (Nomadéis), Fibra Innovation on 3<sup>rd</sup>-4<sup>th</sup> October 2018 in Paris (Nomadéis and Construction21), London Build Expo on 27-28<sup>th</sup> of November 2018 in London (UK partners and Nomadéis), ISO-BIO final conference on 29<sup>th</sup> January in Brussels (Nomadéis), ASBP Healthy Buildings Conference on 28<sup>th</sup> February 2019 in London (with the University of Bath).

This work notably involved creating posters in order to maximise information distribution. In addition, each mini-prototypes also circulated to each partner to serve as material props when members of the project were presenting. This resulted in supporting hands-on material to attract stakeholders and better explain the research that was undertaken. Figure 2 thereafter shows the mini-prototypes developed for both testing and dissemination activities.



*Figure 2: Pictures of the three mini-prototypes that were conceived by the project partners and used during conferences and congresses as material example of the research*



## 1.4 Prototype deployment phase

In the last technical phase, prototypes were produced in their final, full-scale, forms (as shown in Figure 3). **prototypes were deployed** either in climatic chamber or on pilot sites (the Large Environmental Chamber of the University of Bath, the Waste House of the University of Brighton, and the Hot Box apparatus of the ESITC Caen) to be tested for their **core commercial properties of interest: thermal conductivity** (“lambda”) and **thermal transmittance** (“U-value”). Figure 3 thereafter presents the 3 full-scale prototypes deployed for testing at the large Environmental Chamber of partner University of Bath.

In parallel, a **survey of attitudes** towards such materials as well as of perception of the developed SB&WRC prototypes was launched and circulated on partners Construction21 and ASBP’s respective platforms and newsletters in order to reach their subscribers. Flyers with a QR code leading to this online survey were also created and distributed by the partners, both at their premises and during the various events they attended. Further assessments of the prototypes included a **Life Cycle Assessment** which measured a prototype’s environmental impact (CO<sub>2</sub> consumption, land eutrophication, ozone depletion, etc.). An **economic assessment and a massification strategy** were also undertaken to evaluate costs of the production and transportation chains as they were and imagine scenarios to transform these prototypes into marketable, and profitable, products. These studies could form the base of a business model for interested investors.

Partners continued their **dissemination activities** which notably involved:

- A dedicated section of the “Waste Zone” of the Future Build conference curated by partner University of Brighton on 5-7<sup>th</sup> March 2019 in London, demonstrating the resources and their transformation. This exhibition was completed by ASBP’s activities which comprised an exhibition stand held in the Knowledge Forum and a popular seminar in the Materials Zone;
- An exposition in partner ESTIC Caen’s campus during the open gates day J’NOV on 8-9<sup>th</sup> March 2019;
- The holding of an exhibition stand and of a conference by the French partners during the Passi’Bat fair on 16-17<sup>th</sup> April 2019 in Paris;
- An evening seminar at ASBP offices in London on 23<sup>rd</sup> May 2019;
- A closing event held on 18<sup>th</sup> June at Veolia’s headquarters in Aubervilliers, near Paris;
- A demonstration deployment on partner UniLaSalle’s campus near Rouen on 21<sup>st</sup> June 2019, through a pedagogical exhibition performed in their experimental greenhouses and a conference;
- Presentation of a scientific paper related to the project research activities by partner University of Bath at the International Conference on Bio-Based Building Materials in Belfast on 26<sup>th</sup>–28<sup>th</sup> June 2019.

In addition to the posters and mini-prototypes, flyers were made and distributed by members of the project at each event. These summarised the project’s goals and results and encouraged stakeholders to participate in the perception survey. Four videos and a teaser presenting the project were designed, produced and published on the internet. A total of eight newsletters were written, compiling contributions from each partner on its research and dissemination activities, and published on the online communities hosted by Construction21.



*Figure 3: Picture of the three full-scale prototypes as deployed at the partner University of Bath's large Environmental Chamber.*

## 1.5 Deliverables produced

Numerous deliverables have been produced and translated both in French and English by the project partners. The main ones are summarised in the table below.

Preliminary studies
Specification of raw materials
Assessment of resources and flows in the Programme zone
Legal analysis regarding waste upcycling activities
Analysis of building systems, built environment typology and proposition of innovative designs
Technical documentation for each prototype
Design Fact Sheet
R&D Protocol
Technical Fact Sheet
Environmental analysis (LCA)
Economic analysis
Transversal technical documentation
Pilot Site Presentation Sheet – ESITC Caen’s Hot Box
Pilot Site Presentation Sheet – Building Research Park, University of Bath
Pilot Site Presentation Sheet – Waste House, University of Brighton
Pilot Site Presentation Sheet – Campus of UniLaSalle
Installation report – ESITC Caen’s Hot Box
Installation report – Building Research Park, University of Bath
Installation report – Waste House, University of Brighton
Analyses reports for dissemination
Massification strategy of the prototypes
Survey report: Perception of French and British stakeholders on bio- and waste-based materials

## 2. Assessment of the program and project goals

### 2.1 Summary of program and project outputs

Table 1: Summary of the outputs					
Work package	Program output indicator	Project output	Project output	Status	Achievements
3	2.1 Number of new or enhanced low carbon products, services, processes or systems designed	3.1	Design of prototype 1	✓	Three prototypes made from bio- and waste resources (maize, waste duvets and wheat straw) were designed, each with their own mechanical and thermal specifications
		3.2	Design of prototype 2	✓	
		3.3	Design of prototype 3	✓	
4	2.2 Number of new or enhanced low carbon products, services, processes or systems produced	4.1	Production of prototype 1	✓	Prototype 1 made from maize pith (an unused agricultural co-product) was produced. It was subjected to laboratory tests and deployed. A life cycle analysis confirmed that it has a carbon footprint much lower than standard insulants
5	2.2 Number of new or enhanced low carbon products, services, processes or systems produced	5.1	Production of prototype 2	✓	Prototype 2 made from polyester (sourced from used bedding, an otherwise unused waste resource) was produced. It was subjected to laboratory tests and deployed. A life cycle analysis confirmed that it has a carbon footprint much lower than standard insulants
6	2.2 Number of new or enhanced low carbon products, services, processes or systems produced	6.1	Production of prototype 3	✓	Prototype 3 made from wheat straw (a very common agricultural co-product) was produced. It was subjected to laboratory tests and deployed. A life cycle analysis confirmed that it has a carbon footprint much lower than standard insulants
7	2.4 Nb of part. In awareness raising or training events for take up and development of LCT	7.1	Awareness raising of French and English construction professionals on biobased/recycled materials	✓	A very large number of professionals were targeted: an estimated 19,000 people. This was done through an online presence, the perception survey, the newsletters diffusion, distribution of flyers, deployment and exhibitions events, etc.
	2.4 Nb of part. In awareness raising or training events for take up and development of LCT	7.2	Conferences aimed at disseminating the findings of the project among construction professionals	✓	More than 1,500 people were estimated to have been engaged directly by SB&WRC project partners through conferences, posters, stands etc.
	2.3 Number of supported LCT multisectoral networks	7.3	Creation of a dedicated open and permanent online community on Construction21's platform	✓	Two online communities were created (a French and an English one) and frequently posted on with newsletters, articles of interests, etc.

## 2.2 Summary of program and project targets

Table 2: Summary of the targets			
Target Groups	Target value	Target Groups Reached	Status
Enterprise, excluding SME	3,550	6,921	✓
SME	15,350	19,565	✓
Higher education and research	15	4,616	✓

## 2.3 Assessment of the fulfilment of program and project objectives

The SB&WRC project has reached all of its initial objectives and exceeded some: three functional prototypes of insulation materials made from different resources, each of them with a carbon footprint at least 25% lower than conventional insulation product (this number excludes the carbon sequestration that agricultural co-products would have done). Outreach work is estimated to have impacted thousands of professionals and academic actors, and large amount of data and deliverables were produced in the course of the project.

**As such, the project is considered a success.**

The Programme Interreg V FMA's Specific Objective which is to "Increase the development and uptake of existing or new low-carbon technologies in the sectors that have the highest potential for a reduction in greenhouse gas emissions" has therefore been fulfilled by developing low-carbon, energy saving, products for the construction sector.

## 2.4 Principal results and discussion of the project's activities

### 2.4.1 Prototype 1: maize pith

From a technical standpoint, the maize pith prototype is a real success. Indeed, as a resource, maize pith is an ideal candidate as a novel construction material. The canes of grain maize are currently under or not valued and they are relatively abundant even after any potential current usage is deducted from total yearly production in the FMA zone. The separation of maize pith from the bark is facilitated thanks to a patented machine that automates it. At the moment, maize pith produced in this fashion is an unused waste from an agricultural co-product.

The base material possesses astounding thermal potential thanks to its native alveolar structure. The maize pith insulation prototype performed well from a thermal conductivity point of view, reaching a  $\lambda$  of  $0.042 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ . As it stands, the full-scale prototype is easy to handle having two denser outer layers that acts as a backbones of sorts and a less dense inner layer which acts as a good insulant. As partners have developed it, the overall wall panel (the chosen constructive system) is light, it resists well to inflammation but cannot bear load (low compression resistance).

However, the economic study made on the fabrication of the prototype as it is currently built highlighted that the thermocompression process was driving economic costs high, even in comparison with other high end bioresources such as expanded cork. Costs minimizing strategies were identified and comprised mainly the improvement of machine productivity and the production of thick panels.

Therefore, the maize pith prototype is very promising as the base material possesses great thermal conductivity properties. However, the current production process needs refining (changing the thermal press for example) or a different constructive system may need to be found that would improve economic costs.

### 2.4.2 Prototype 2: reused polyester

Using polyester from waste duvets is a formidable value proposition. Waste beddings are only very marginally reused in the UK and France: most of the time they are either buried in landfill sites or, at best, used for energy recovery by buying burnt. Its two main outlets are not making use of a material, which despite being of petrochemical origin, was designed as an insulating product for human use.

The prototype developed consists in a reused duvet which has been collected, sorted and cleaned, and then hung and stapled into a wooden frame. The deployment tests revealed a performant intrinsic thermal conductivity in the order of  $0.043 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$  in the tests performed by partners ESITC Caen and University of Bath, although the results done at the Waste House by the University of Brighton led to a lower performance of  $0.069 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ , potentially related to either a different density or to the experimental set up used.

The LCA fares well, most notably in terms of carbon emission compared to conventional products, mostly because its process does not involve heat treatment (which could degrade the structure). Its economic valuation, however, was particularly complicated as the waste bedding collection and management sector is currently emerging part of the data required for the modelling could not be accessed. Therefore, a reversed modelling was performed and indicated that in order to sell the prototype at prices similar to existing bio-based and conventional insulating materials, a subvention should be received by a producer. This scenario appears realistic in the French context, where the duvet producers have recently got the regulatory obligation to ensure the management of the end-of-life of their products. The current effort to structure the collection and management of waste duvets in France appears as a particularly good opportunity for the prototype



developed, in line with circular economy schemes. Finally, it appeared that an optimised production set up would likely be based on a prefabrication process.

Further development research may be beneficial, notably to i) determine an optimal density and ii) consider social economy perspectives in the business model.

### 2.4.3 Prototype 3: wheat straw

Wheat straw is an emerging resource in construction and is very interesting owing to the fact that it is abundantly grown in France and England. Once its current uses are taken into account (soil fertilisation, cattle feed, etc.), a few million tonnes of material are still available for other uses such as construction. Current wheat straw products require larger amounts and width compared to conventional insulants to be thermally interesting when used in buildings, there is thus an incentive to optimise these products in order for them to be thermally optimised, therefore costing less per m<sup>2</sup> and requiring less resources. In this context, the research on the straw intended to optimise straw stalks orientation and increase density which aimed at reducing (that is, improving) the thermal conductivity of the prototype.

Despite successful development of a process that enabled project partners to reorient and compress straw bales, and of a satisfying proof of concept on mini-prototypes (thermal conductivity of 0.044 W.m<sup>-1</sup>.K<sup>-1</sup>, in the order of magnitude of the target), the full-scale prototypes did not show the desired thermal improvements compared to existing wheat straw products.

If the LCA shows good results with regards to its carbon footprint (without accounting for carbon sequestration obtained by growing wheat plants which would drive the footprint even lower), further improvements of the prototype would be necessary in order to make it economically viable compared to existing construction bales. In the end, for the purpose of this project prototype 3 has been shown to be capable to innovate but its execution is yet hampered by mechanical limitations. Further work should focus on improving the transformation process, with the final purpose to develop a baler machine which would automatically orient the straws in their optimal configuration for construction.

### 2.4.4 Communication aspects

With regards to the communication, dissemination and outreach aspects, one main point must be noted. The survey which was posted online on a professional hosting website was diffused to the network of partners ASBP and Construction21 (which represents an estimated potential respondents pool of 18 000 people). Thereafter, all communication (online newsletters, printed posters and flyers) prompted construction stakeholders to participate in the survey. The level of 100 participants on each side of the Channel proved difficult to fulfil. It took several months and continuous solicitations from the communication and lead partners to finally reach this level of engagement. This may indicate a lack of interest of stakeholders to engage with the community or to participate to the development of novel products. Further, only a few professions are well represented within the sample (example: architects) whereas insurance professionals or building workers are nearly absent. This may indicate that only certain categories of construction professionals feel concerned about sustainable innovation in the building sector. This mirrors observations made by lead partner Nomadéis whereby certain socio-economic professions are harder to engage with and mobilise.

To reach out to specific categories of construction professionals such as building workers in the context of a perception survey, it is recommended that funding be dedicated to more direct approaches. It may be longer stays at professional conferences and expositions in order to receive face-to-face feedback or a telephone inquiry campaign which generally increase response rates.

Otherwise, all other communication aspects (engagement with professionals, attendance to SB&WRC conferences, etc.) were successful and exceed the project's objectives. As seen in Table 1, thousands of people were engaged in one way or another through the various dissemination and communication activities undertaken by project partners.



### **3. Recommendations**

#### ***3.1 Resources***

1. Other resources may be worth studying such as oyster shells, terracotta and other brick waste and rapeseed pith (the latter which may have properties close to that of maize pith).

#### ***3.2 Maize pith prototype***

2. The future development of prototype 1 needs to resolve the challenges posed by thermocompression either by :
  - a. changing constructive system, for instance, the pith could be glued using an organic binder or used as a bulk product destined to be blown; or
  - b. by addressing the economic burden that thermocompression represents, through a deepened technical and economic study mobilising process experts, for instance.

#### ***3.3 Reused polyester prototypes***

3. Further research is needed to systematically test how the polyester from waste duvets may be implemented (level of compression, type of external cladding, removal or not of the external quilt, sowing for ease of handling, etc.) and how such disposition affect the thermal performance, how much resources it uses and how convenient it is to implement. Ideally, laboratory tests to determine the optimal density would be required. Complementary tests at the Waste House may be required to confirm the thermal performance of the prototype.
4. Given that the prototype lies within a circular economy paradigm, the reuse of wooden frames in the case of a prefabricated production process could be considered and documented, focusing on local actors in the FMA area.
5. Diversify the construction systems that may be derived from this material (pipe insulation, polyester wool (bulk product, etc.) would be interesting in order to open new market opportunities.

#### ***3.4 Extend life cycle and economic analyses***

6. Further work is needed to include the end of life of each products (may it be biodegradation, recycling, incineration,...) within the LCAs, most notably in relation with foreseeable regulatory and market expectations.
7. Economic analyses should also include other possible scenarios such as the ones made possible in by the social and solidarity economy, future carbon taxes or evolution of carbon taxes, evolution of European or national building regulations which would favour natural products or reused waste.

### ***3.5 Further technical analyses***

8. Given that the impact of bio- and waste-based resources on air quality (moulding, emission of volatile organic compound, etc.) is a recurring worry expressed by various stakeholders, further studies on the proposed prototype should include literature reviews and adequate tests to measure the impact of the prototypes on indoor air quality. Such study could also address the matter of ease of deployment during the construction phase, which is a recurring concern for construction workers. More generally, the identification of the complementary tests corresponding i) to the official requirements for construction materials or ii) to market expectations (such as for instance fire, duration, compaction (dimensional stability), and acoustic), and then the performance of all or part of these tests, are deemed interesting in order to ease the uptake of the prototypes by industrials.
9. More generally, a more comprehensive understanding of the French and UK biobased insulation market is deemed necessary to help the dissemination of the prototypes developed. Also, the impact assessment of the integration of the prototypes within the local economy (with a focus on local employment) would be particularly relevant, notably as a market argument for private entities, but also to grant local support from public authorities.





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