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GROW2BUILD - LOCAL CULTIVATED HEMP AND FLAX AS RESOURCE FOR BIOBASED BUILDING MATERIALS

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Abstract

The use of local cultivated hemp and flax in building materials contributes to the transformation to the biobased economy in North West Europe. Here the growing conditions for hemp and flax are favorable and cultivation and processing expertise is available. Despite the market potential isolated initiatives were not able to overcome the numerous challenges. Currently, only a small number of stakeholders remain with hemp and flax for use in technical applications other than in textiles. The Interreg IVb-project Grow2Build enhances the efficiency and competitiveness in the production and uses of hemp and flax based materials in building and construction. Main topics of Grow2Build: 1) facilitating the interregional and transnational product chain development through informing of and collaboration with relevant stakeholders; 2) optimization of resources quality through optimization of cultivation and processing techniques; 3) improvement of the performance of biobased building materials through product innovation;4) development of the demand through information, awareness and guidance. Besides the optimization of cultivation and processing techniques and improvement of hemp and flax biobased building materials, spreading knowledge and bringing together stakeholders will increase the demand for biobased building materials. Various communication tools are developed in the project including a Centre of Excellence and a mobile exhibition. During workshops and innovation network events various stakeholders discussed the chances and challenges for the use of hemp and flax biobased products, linking demand and supply. By sharing knowledge the following bottlenecks were identified: 1) biobased building and CO_2 sustainable building may conflict with traditional building practice, thinking and culture; 2) Performance of (new) biobased building materials should be distinctive and science based; 3) main stream architectural design should be aware of the possibilities of biobased materials 4) national building regulations needs harmonization with surrounding regions for promotion and exchange of innovative biobased building products; 5) lack of investors.

Keywords:

Hemp, Flax, Building material, Biobased material, Fire resistance, Hempcrete, Hemp concrete, Market development, market demands, stakeholders

1 INTRODUCTION

Biobased economy is gaining increasing interest in the North West European (UK, NL, DE, BE, FR) economy. The use of local sustainably cultivated hemp and flax in building materials may contribute to the transformation to this new economy. Hemp and flax are multipurpose crops that yield strong and long bast fibers, short woody core fibers and seeds that are rich in oil. Each crop part finds its use as building product from insulation material, fiber boards and panels to coatings and paints (Table 1).

Despite the long tradition of their use in building applications, the flax and hemp products are currently largely displaced in the European building industries by fossil derived synthetic products. Therefore, reintroduction of innovative building products based on flax and hemp is of interest that meet the modern quality demands. At the moment there are a number of bottlenecks encountered throughout the whole production and supply chain of hemp and flax building materials, as well as in the marketing of those products. These bottlenecks are of different nature from legislation issues to fiber feedstock availability and raw material quality aspects. Moreover, the solutions to overcome the bottlenecks can be different amongst EU member states. The focus of the Interreg IVb-project Grow2Build (G2B) is to enhance the efficiency and competitiveness in the production and uses of hemp and flax based materials in building and construction.

Tab. 1. Flax and Hemp derived building and construction products

Crop	Plant part	Product	By-product	Use in building and construction
Flax/Hemp	Seed	Oil		Linoleum
				Paints & coatings
				Putty
			Press cake	-
	Stem	Fiber (bast)		Fabric: curtains, wall coverings, batten, bags & canvas
				Twine: Ropes & twine, lines.
				Non-woven: Insulation mats
				Paper: Sheets, Foam, fluff
				Cellulose: Polymer and mineral composites.
			Shiv (hurds)	Particle boards, mineral composites

In North West Europe the growing conditions for hemp and flax are favorable and the traditional expertise is available on cultivation and processing of these crops. Significant efforts have been made to establish sustainable supply chains for these crops to provide high quality products to building markets. The challenges to succeed are numerous, including aspects of technical, logistical, qualitative and commercial nature. The failure of isolated local initiatives, not only leave behind disappointing financial consequences, but also create a negative image of hemp and flax building materials. Currently, only a relative small number of stakeholders are engaged with hemp and flax processing for use in technical applications other than textiles. To make flax and hemp based building materials successful and profitable it is necessary that stakeholders work together, as well as have a transnational cooperation to stimulate the biobased building materials market in a more efficient way. This will stimulate innovation networks and strengthen the synergy between primary production, primary / secondary transformation, manufacturing and end-use of hemp and flax fibers in technical building products.

The main topics within the project are 1) facilitating the interregional and transnational product chain development concerning hemp and flax based biomaterials through informing of and collaboration with all relevant stakeholders; 2) optimization of the quality of the resources through optimization of cultivation and processing techniques; 3) improvement of the performance of hemp and flax biobased building materials through product innovation and 4) development of the demand through information, awareness and guidance. The focus area of the project is UK, NL, DE, BE and FR.

The project is now entering the phase of delivering its results. Besides the optimization of dedicated cultivation and processing techniques and improvement of performance of hemp and flax biobased building materials, spreading knowledge and bringing together stakeholders will increase the demand for biobased building materials. Various communication tools have been developed in the project, such as flyers, brochures, websites. A physical Centre of Excellence has been established at the Brunel University near London and a mobile exhibition is constructed to show the various hemp and flax biobased building products on events.

At several workshops / innovation network events, various stakeholders from the production and supply chain, including architects, building contractors and policy makers, discussed the challenges in the use of hemp and flax biobased products. In this way demand and supply can be linked to each other and knowledge is shared. At the same time, when technical specifications of end-users is available, the bottlenecks for supply of performing products will become clear.

The main bottle necks that were identified:

1) Biobased building and CO_2 sustainable building may conflict with traditional building practice, thinking and culture; 2) performance of (new) biobased building materials should be distinctive and science based. Also non-standard characteristics such as moisture control and health should be taken into account; 3) main stream architectural design should be aware of the possibilities of biobased materials. More knowledge will increase the use of biobased building materials; 4) national building regulations needs harmonization with surrounding regions for promotion and exchange of innovative biobased building products. At the same time SME’s should be guided to meet the various regulations; 5) lack of investors. SME’s often have the ideas but not the money to make a new product a success.

In this paper the bottlenecks in the chain are presented by following the example of the live cycle from cultivation to its final use of an innovative building product based on hemp shiv: the hemp based building material in block or wall form [Sassoni, 2014]. The blocks of hemp consist of 100% shiv (or hurds) that are mixed with hydraulic lime and water. This composition makes ‘hempcrete’ building materials a mixture of entirely natural organic and mineral ingredients [2]. Mixed with the mineral lime binder, hemp shiv can make mortars and cementious products with specific characteristics and good performance in building materials. These hemp-lime mortars and cements benefit, in particular, from an open porosity, which result in good thermal and energy performance often beyond the expectations required for construction and renovation.[Samri, 2013]

2 CULTIVATION & MARKET SUPPLY

Within the limits of climate and soil fertility, structure and health, an arable farmer can choose between various crops. Whether or not to cultivate hemp depends on the complexity of the cultivation, (contract)prices of competing crops and future perspectives of markets. As long as competing crops such as wheat or energy crops give higher prices to the farmer than hemp, it is not expected that the acreage of hemp will increase significantly in Western Europe in the coming years [Ronde, 2013]. The acreage of hemp in Europe was estimated in 2014 at 15.000 hectares. France is the leader in the production of fibre hemp, with a constant production, dedicated to the production of fibres for specialty papers, followed by smaller and annually changing acreages in England and The Netherlands. These fluctuations are indicative of the poor established markets for hemp fibres and still experimental cultivation.

Various projects conducted in the EU in the past decades on hemp and flax cultivation and product development have shown that technically no obstacles exists for high yielding and high performing fibre crop production and conversion to marketable products. The relatively labour intensive technologies to manufacture textiles, paper, non-wovens, and ropes from flax and hemp fibre have been moving from Western Europe to China and other low-wage countries [Van Dam, 2014a,b]. Developing markets for composites and building materials now often rely on supplies of fibres mostly from Eastern Europe. Transportation costs of bulky fibre over large distances is not economic and considered less sustainable. Therefore, supplies of fibre to local market demand is the most ecologically option, when the infrastructure for conversion to profitable building products is available.

If the industrial quality specifications on fibre raw material performance are established farmers can influence to a certain extend the final characteristics of hemp or flax fibre products by cultivation measures such as fertilization and density and harvesting methods [Ronde, 2013]. It is important for a profitable fibre crop, apart from high yields of the strong bast fibre, also to find an additional outlet for the by-products that are released from the fibre extraction process. In the hemp fibre extraction hemp the woody core parts are separated that are known as shiv or hurds. These light weight woody particles have good absorbing properties and are therefore used as a high-quality bedding material [Carus, 2013]. Currently this application is the largest market for hemp shiv (Fig. 1). The hemp shiv can also be used as bulk insulation or as aggregate in construction blocks, prefab panels (light and insulating) or wall plastering [Hirst, 2010].

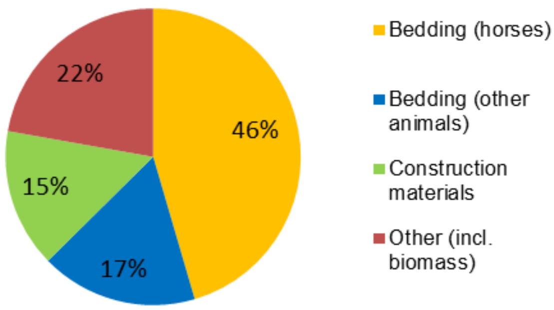

Fig. 1: Applications for European hemp shives [Carus, 2013]

3 PRODUCTION OF HEMPCRETE BLOCK

Based upon hemp shiv a concrete-like product can be manufactured with interesting properties. The prefabrication of wall elements (blocks or prefabricated walls) can be done mechanized on (semi)-industrial scale, or locally on site manually for the construction or renovation of floors, interior and exterior walls, insulation of roofing and plaster coatings on existing walls

The manufacture of the so-called 'hempcrete block' is carried out according a very specific method of cold-moulding, followed by drying in the open air. A mixture is made of hemp shiv and inorganic hydrated caustic lime[3] (sometimes with added portland cement or other mineral binders). The mixture is poured into the mould and left to set at environmental conditions. The time of complete drying to obtain hempcrete blocks is depending on the thickness, but at around 2 months full strength is attained. A block of hempcrete, with equal thermal resistance, requires less energy in its production than terracotta bricks and aerated concrete blocks.

Technical data of hempcrete block:

Ratio of ingredients[4]:

100 - 125 kg of hemp shiv; 165 - 180 kg of hydraulic binder; 150 - 180 L of water

Sequence of mixing:

Hydraulic binder is added to water and mixed to obtain a "slurry" consistence. Hemp shiv are then added until they are well coated.

Size of mould:

For fire test performed hempcrete were manufactured in 600x300x200mm blocks which were assembled to build one 1500x1000x200mm wall and one 1500x500x200mm wall. Curing time: demoulding after 2 days drying; full strength obtained at 2 months curing in the air; 10% water is retained in de block at ambient conditions; Age at test: November 2013 at CREPIM. Technical data: compression strength 0.10 MPa [Cérézo, 2005] [Nguyen et al., 2010] [Chamoin 2010] / density (300 kg/m^3)

[2] http://cdn2.hubspot.net/hub/367735/file-562656995-pdf/documents/Frequently_asked_questio

[3] http://www.hemp-technologies.com/nz/resources/Simple-Hempcrete-Binder-Recipe.pdf

[4] Personal communication: Philippe Auvergne, CHANVRIBLOC - ZI des Marais - 38350 LA MURE - France

4 EUROPEAN FIRE REACTION CLASSIFICATION.

As hempcrete block is a construction element, one of the tests it is subjected to is the European fire reaction tests: EUROCLASSES system. This EU classification system for the fire reaction properties of building construction products[5] consists of two sub systems, one for construction products excluding floorings, e.g. wall and ceiling surface linings, insulating materials, and another similar systems for floorings. Both sub systems have 7 classes A to F of which classes A1 and A2 are non-combustible, or low combustible products. This system is replacing the national classification systems.

A hempcrete block, according the earlier mentioned technical data, has the following level of classification: B, s1- d0. This fire test was carried out by CREPIM and this level classification was reached by results of tests performed on blocks of 20 cm of thickness and with a density of 300 kg/m^3, shown in Fig.2.). The class B means that the FIGRA value assessed during SBI test is lower than 120 W/s. The complementary classification in relation to smoke production is s1. This means that the hempcrete block releases a very little quantity of smoke during its combustion. The complementary classification in relation to fall of flaming droplets/particles is d0, the hempcrete block doesn't produce flaming droplets during its combustion.

The main objective of hempcrete producing companies is to obtain the level A2, s1- d0 to be competitive with established building materials. This A2-ranking means the material is practically incombustable. To reach this level of performance, the value of the Gross heat of combustion of hempcrete block must to be lower than 3 MJ/kg according to the EN ISO 1716 test method. This test determines the potential maximum total heat release by a product when complete combustion occurs, regardless of its end use. The specimen in the form of a pellet or powder is placed in crucible in the bomb which is then filled with pure oxygen (Fig. 3). The bomb is pressurised and exploded; using firing wire connected to electrodes. The calorific value is calculated by measuring the temperature change resulting from the reaction within the bomb.

Preliminary tests were performed by CREPIM in 2014. The block of hempcrete described previously (density=300 kg/m^3 / thickness=20cm) has a gross heat of combustion of around 3.5 MJ/kg. This value is just above of the limit accepted to reach the A2 level. For this kind of material, the flame retardant is the inorganic binder. Therefore, the quantity of inorganic binder must be increased in the formulation of hempcrete blocks in order to reach a value of PCS (EN1716) lower than 3,0 MJ/kg.

The level A2 of fire reaction ranking for hempcrete blocks can open the doors of public and private construction markets. For the public sector, to respect the regional building regulation, and for the private sector, to prove that this material can offer the optimal comfort for your house.

[5] introduced in Europe by COMMISSION DECISION (2000/147/EC) of 8 February 2000, implementing Council Directive 89/106/EEC (Ref. OJ L 50, 23.2.2000)

Fig.2: Demonstration of fire reaction test on hempcrete blocks at CREPIM

Fig. 3: Calorimetric bomb for the Gross Heating Value GHV determination – CREPIM device

For small and medium companies certification of new products like the hempcrete building blocks is complex and relative expensive. In general, the established test methods have been developed for standard commercial building materials. Innovative products may not comply with the norms, but still have a good performance in the application. On one hand governmental support for small companies to certify new products would be of help to enter the market and on the other hand new evaluation protocols should be developed or current tests should be adapted in order to incorporate the deviant and specific characteristics of biobased building materials.

5 ENVIRONMENTAL PERFORMANCE LCA

Life Cycle Analysis (LCA) show that bio-based building materials have a better score than conventional building materials [Valkhoff, 2010]. Looking more in detail to bio-based concrete the major part of the environmental impact is coming from the inorganic binder [Dupre, 2013]. The impact of the cultivation and processing of the plant source is limited compared to the inorganic binder. The LCA can be improved by the introduction of other hydraulic binders and/or changing the formulation without changing the properties of the final product.Due to the low use in fertilizers and pesticides and low fuel use during cultivation the environmental footprint of hemp is in general lower than other plant sources. The environmental performance improvements that are obtained by applying formulations of lightweight bio-based concretes is expected to have more favourable consequences. In particular, a cost reduction because of the hydraulic binder is the most present component of the point of view of weight and ecological footprint.

6 EXAMPLE OF PRACTICAL RESEARCH & KNOWLEDGE DEVELOPMENT

A monitoring campaign was performed from February to October 2012 in a house build with hempcrete spraying technology to assess the hygrothermal indoor climate fluctuations when this kind of material is used in real conditions. This study was conducted by the CETE Sud Ouest on a newly build house in Périgueux in France. The results of this study have been presented in the frame of ECOBAT 2013 fair in Paris [SAMRI, 2013].

Fig.4: Hempcrete spray application [DB Chanvre photographs]

Previous investigations assess the physical properties of the product on lab scale. These results are insufficient to accurately predict the indoor climate and comfort of a home as a result of the hygrothermal performance of the building material [Collet et al., 2012]. Thermography conducted by CETE Sud Ouest shows a homogenous temperature distribution across the various walls of the house and demonstrates the insulation quality of the wall material (hemp shotcrete) with a thickness of 30 cm. The measurement of air permeability shows some leaks, these may occur at peripheral walls between the different connections, due to shrinking phenomena of drying posts. Such defects need to be treated to maintain a good level of air-tightness of the casing. The level of thermal comfort in the house is satisfying with homogeneous air temperatures between rooms. They vary, depending on the environmental weather conditions and heating regimes, in the range 20 to 24°C in winter and between 21 and 28°C in summer.

Foregoing is an example of knowledge development that needs to be build up together with sharing experience and exchange of practice. The frequently claimed relationship between ecological building materials and effects on human well-being needs objective recording of relevant data. Comparison is needed of relevant characteristics of traditional buildings and similar innovative alternative constructions. Recording of data such as moisture and temperature fluctuations in relation to outdoor climate and the effects of materials choice upon proliferation of agents that may affect human health (fungi, allergens, VOS, radiation, etc.). A lot of experience with biobased building materials is available but practical information is very fragmented and dispersed [Spiegel, 2010; Berge, 2009; Gustavsson 2006; Puettmann 2005; Lippke 2004;]. In the centre of excellence of Grow2Build a start is made with gathering the fragmented knowledge.

7 MARKET DEMAND AND STAKEHOLDERS AWARENESS

During workshops/innovation network events organized by G2B with different stakeholders in the building and construction chain, it was noted that players positioned towards the end of the chain of biobased building materials (e.g. the architects, contractors, and constructors, fig 5) are rather conservative and unaware of alternative building practices and know only traditional building materials. Using biobased building materials in design and construction is different and requires adaptation of common industrial building practice. For example when hemp building blocks are used a foundation should be laid of a certain height from the ground level or it should be based on a water repellent bed to avoid capillary water and the need a loadbearing wooden or reinforced concrete framework, when the bearing wall needs to support the weight of floors, roof/ceiling. Besides that local traditional methods and building materials use are well preserved, as can be noted when surpassing a national border, it was found that most stakeholders in the building and construction process are largely unaware of the potential of alternative methods of construction. From the commissioner to the constructor, all need to change and adapt to the concept of using a different method. Unknown materials and experimental methods ask more creative skill and mutual confidence of a building team to overcome the unforeseen hurdles and to share the risks. At the moment, the main stream building contractors in EU are driven by cost reduction and process efficiency and have limited interest in sustainability or experience with biobased building materials other than timber. As architects and building contractors are driven by price and demand in the market, they will start working with biobased building materials only if a demand exists and the profit is good. During the last years more and more architects and building contractors see the opportunities in the biobased building sector.

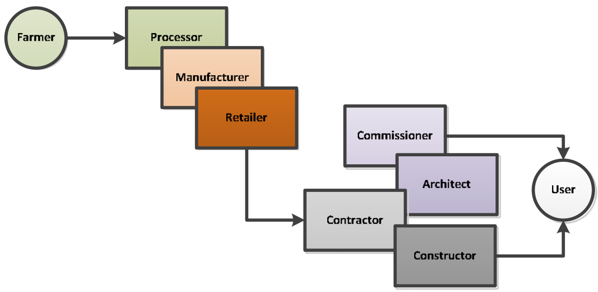

Fig. 5: Bio-based building chain

The question is, is it possible to increase demand with awareness? Will the chain work if (small) demand increases? Would it work to stimulate revenue models where small innovative companies work together with bigger building contractors where the small company brings in the innovation and the bigger company money and market? What are the limits of success? When all new constructions need hemp shiv what is the consequence for the farmer? Globally 4 billion tons of cement[6] are consumed annually of which EU is contributing only 6% or ca. 240 million ton. If only 1% of hemp shiv is added 2.4

[6] http://www.cembureau.be/about-cement/key-facts-figures

million tons of hemp shiv are required. This is 55x the current hemp shiv market in EU (43.000 tons, EIHA 2012) [Carus, 2013] and that would require an hemp acreage increase to approximately 0.9 million ha arable land. It is therefore expected that for the near future the market introduction of such biobased innovation as hempcrete will remain an interesting niche market, where architects and builders that seek to distinguish themselves find an inspiration.

Grow2build facilitates the interregional and transnational product chain development concerning hemp and flax based biomaterials through informing of and collaboration with all relevant stakeholders. Through cultivation trials the quality of the resources is optimised together with the processing techniques by carrying out a ringtest. In product innovation pilots various hemp and flax based initiatives have been supported by Grow2Build partners:

- MATERIANOVIA is working on the improvement of the retting of hemp and flax by controlled enzymatic reactions.
- CREPIM supports hempcrete block manufacturers to improve the fire reaction of this kind of material
- SAXION is working on wood-oil biofilm for wood preservation and on the production of flax-based thermoplastics for construction.
- Brunel is working on improvement of mechanical properties of hemp and flax composites with biobased matrix.

The innovative pilots is in the final stage.

By setting up a centre of excellence and via various events the project contributes to the demand through information, awareness and guidance. More information can be found on www.grow2build.eu.

8 CONCLUSIONS

There is a market potential for biobased building materials. An increasing number of initiatives and examples can be found throughout Europe and worldwide. At the same time numerous challenges hinders introduction into mainstream building practice and the chain of biobased building materials to mature. Better specification of the added value of biobased building materials based on scientific studies will help to distinguish traditional and biobased building material and lead to a healthy chain. Building and construction industries, as important stakeholders in the chain need to be made aware of the potential that is offered by biobased building materials. Public institutes can stimulate the use of biobased building materials by initiation of pilots and prescription in procurement policy. At the same time building regulation needs to be harmonized for innovative biobased building products.

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10 REFERENCES

Berge, B.; The ecology of building materials. Routledge, 2009.

Carus, M.; Korst, S.; Kauffmann, A.; Hobson, J. et. Al.; The European hemp industry: Cultivation, processing and applications of fibres, shivs and seeds. European Industrial Hemp Association (EIHA), Hürth (Germany), 2013.

Cérézo, V. Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales: approche expérimentale et modélisation théorique. Diss. Ecole Nationale des Travaux Publics de l'Etat, 2005.

Chamoin J, Collet F, Pretot S. Perméabilité à l'humidité de matériaux à base de chaux et de chanvre. XXVIIIèmes rencontres universitaires de Génie Civil. La Bourboulle; 2010.

Collet, F.; Pretot, S. "Experimental investigation of moisture buffering capacity of sprayed hemp concrete." Construction and Building Materials 36 (2012): 58-65.

Dam, J.E.G. van; Markets for fibre crops in EU and China (FIBRA D2.2, May 2014) FBR-WUR 1482; ISBN 978-94-6257-061-0; Jan E.G. van Dam – "Market analysis for bast fibre crops in EU and China", 19th NAROSSA, Poznan PL 16-18 06 2014.

Dupre, B.. Agros-Betons et Analyse de Cycle de Vie (ACV) : le poids de la formulation en fonction des types de granulats utilisés, Codem Picardie, Ecobat Sciences & Techniques, 2013.

Gustavsson, L.; Sathre R.; "Variability in energy and carbon dioxide balances of wood and concrete building materials." Building and Environment 41.7 (2006): 940-951.

Hirst, E.A.J.; Walker, P.; Paine, K.A.; Yates, T.; Characterisation of Low Density Hemp-Lime Composite Building Materials under Compression Loading. In Zachar, J. ed. Second International Conference on Sustainable Construction Materials and Technologies, June 28 – June 30, 2010, Univertità Politecnica delle Marche, Ancona, Italy. ISBN 978-1-4507-1490-7.

Lippke, B. et al.; "CORRIM: Life-cycle environmental performance of renewable building materials." Forest Products Journal 54.6 (2004): 8-19.

Nguyen, T. T.; Picandet, V.; Carre, P.; Lecompte, T., et al. "Effect of compaction on mechanical and thermal properties of hemp concrete." European Journal of Environmental and Civil Engineering 14.5 (2010): 545-560.

Puettmann, M. E.; Wilson, J.B.; "Life-cycle analysis of wood products: cradle-to-gate LCI of residential wood building materials." Wood and Fiber Science 37 (2005): 18-29.

Samri, D.; Etude du comportement thermique d'une maison en béton de chanvre, CETE du Sud-Ouest, Ecobat Sciences & Techniques, 2013.

Sassoni, E.; Manzani, S.; Motori, A.; Montecchi, M.; Canto, M.;´Novel sustainable hemp-based composites for application in the building industry: Physical, thermal and mechanical characterization`, Energy and Buildings, 77, pp. 219-228. 2014.

Spiegel, R; Meadows, D.; Green building materials: a guide to product selection and specification. John Wiley & Sons, 2010.