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Evaluation of the Environmental Sustainability of Hemp as a Building Material, through Life Cycle Assessment

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***Abstract* – Environmental issues, especially those related to the over-exploitation of natural resources, are leading towards considering alternative solutions and new approaches, such as the circular economy. Currently, some key elements of the circular economy approach are sustainable procurement of raw materials, improvement of production processes and ecological design, adoption of more sustainable distribution and consumption models, development of secondary raw material markets. This work aims to analyse the use of hemp as a building material, replacing traditional construction materials, but respecting at the same time the thermal, insulating and acoustic characteristics required in the construction of a building. The methodology used was Life Cycle Assessment (LCA), which considered the hemp cultivation phase and the production phase of hemp-lime ("hempcrete") walls. The hempcrete product was compared with two different solutions: a hemp and lime block, and a traditional perforated brick block with external insulation in polystyrene. In particular, the differences among the products in terms of embodied energy and net CO_2 emissions were analysed. Results showed that the hempcrete wall had better environmental performances than the other two solutions.**

***Keywords* – Building sector; eco-sustainability; hempcrete; Life Cycle Assessment (LCA); natural materials**

1. INTRODUCTION

Environmental issues, especially those related to the over-exploitation of natural resources, are leading towards considering alternative solutions and new approaches, such as the circular economy [1]. Currently, some key elements of the circular economy approach are sustainable procurement of raw materials, improvement of production processes and ecological design, adoption of more sustainable distribution and consumption models, development of secondary raw material markets [2].

Construction is one of the most relevant sectors in terms of environmental impacts, due to the significant use of raw materials, fossil energy consumption and the consequent Greenhouse Gases emissions. The use of unconventional and environmentally-friendly materials and technologies is worldwide recognised as a key factor to allow the decrease of material and energy consumption in buildings [3]. Indeed, the traditional materials commonly

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used in construction come from production processes causing a significant consumption of energy and non-renewable resources; in addition, these materials have often end-of-life problems, as they are non-recyclable [4].

Hemp is a very interesting material among natural ones (alongside wood, clay, cork, raw soil, etc.), in a context in which constructing energy efficient buildings with almost zero energy consumption has become essential. In fact, hemp is among the sustainable building products that consume less "grey energy" and have less environmental impact in terms of CO_2 emissions [5], [6].

Global concerns about climate change have led to the development of building materials that use plant biomass, which has the added benefit of carbon sequestration, in addition to a low embodied energy. 'Vegetable concretes' consist of an organic or inorganic binder mixed with biomass from agro-forestry industries, such as rice husks, straw bales, hemp, kenaf, cork and so on. Currently, hemp-lime compounds are probably one of the most required materials, in the building sector [4]. They have a clear advantage over comparable conventional materials in terms of embodied energy, and also in terms of net CO_2 emissions, over the entire life cycle of a typical building [7]. However, LCA studies related to the environmental performances of the building products are still rare in this context.

The objective of this work is to evaluate the environmental performance of hemp woody core, a material deriving from hemp straw, dried in the field after harvesting hemp seeds or flowers, used in the building sector as an alternative to traditional materials. In particular, the Life Cycle Assessment of the 'hempcrete' product was performed; hempcrete consists in a mix of hemp woody core and hydrated lime, replacing the classic walls built with traditional materials, but guaranteeing the same thermal and acoustic performance.

Hempcrete was also compared with two alternative solutions: the first solution is the use of the hemp and lime blocks, while the second is the solution commonly used in building, consisting of a perforated brick block and external insulation in polystyrene. Environmental impacts, and specifically differences in terms of embodied energy and net CO_2 emissions were investigated.

1.1. Application of hemp in the building sector

There is a renewed interest in hemp, a forgotten crop, now re-evaluated for its great qualities. It is a versatile plant, adapting to different climatic and pedological conditions, growing quickly, regenerating the soil by purifying it of pollutants and removing carbon dioxide from the atmosphere. Its biomass can be used for a very wide range of industrial and artisanal uses, including the production of eco-sustainable building materials.

Until a few decades ago, Italy was the second largest producer of *Cannabis sativa* in the world [6]. This plant is the non-psycho-active type most suitable for domestic use, and represents a resource both in the textile sector and for people's daily lives. However, the difficulty of competing with the emerging Asian markets caused an almost total abandonment of this cultivation in the Italian territories [6]. Since the 1990s, thanks to some passionate farmers and scholars, interest in hemp and its industrial uses returned to grow, together with a reintroduction of the crop and use of its derivatives.

The current use of hemp woody core in the building sector is due to Charles Rasetti [6], a Breton bricklayer who experimented different mixes of hemp with various binders (e.g., limes, cements, gypsum, etc.), to be used in the restoration of ancient houses and subsequently in new buildings in the 1980s. Rasetti sets a construction system, which, in various ways, developed throughout the entire Breton region, and then expanded to Canada, France and other European countries. In France, the cultivation of hemp has never stopped, not even during the mid-twentieth century, when it had disappeared almost everywhere. Therefore, the

regional production chains remained active, carrying on the know-how on the cultivation and production of hemp byproducts, as well as the production of seeds, of which France is still the main producer in the world.

1.2. Different hemp-based products

Hemp in the building sector is used thanks to the union of the hemp woody core with lime. Lime acts as a binder between the hemp fragments, which vary their thickness (in mm) according to the processing and sieving typology. There are many reasons for which hemp is almost always associated with lime, including one in particular: the ecological qualities of lime in comparison to traditional materials (e.g., concrete) [8].

Different hemp-based materials can be realized for the building sector; the main ones are the following [8]:

Hempcrete: it is a mixture of hemp woody core and lime (1:2 ratio) that is directly put inside a formwork made on site, as for a normal concrete casting. The grain size of hemp varies between 6 and 15 mm. This material is used for the construction of non-load-bearing walls with thermo-acoustic insulation performance and high breathability. The lime that is used is a hydrated lime [6]. There is also a main structure in wood sustaining the wall.

Hemp Blocks: they are prefabricated materials consisting of lime and natural or mineralized hemp-based compound, with a grain size between 6 and 15 mm. They are used for the construction of walls. Hydraulic lime is used in this case, with the possible addition of secondary binders.

Conglomerate: it is a compound of hemp woody core and lime, used for insulation of vertical structures, with thermal and acoustic insulation performance and high breathability. The lime used is the hydrated or the aerial one, plus other natural additives.

Low/Medium Density Panels: insulating panels made of compressed hemp fibre mixed with binders (generally corn starch), in a variable percentage from 10 to 15 %, sometimes treated with flame inhibitors (ammonium salts).

High Density Panels: self-supporting insulating panels composed of hemp woody core mixed with natural binders or adhesives/resins (including sometimes raw soil), to be used for the realization of various types of internal and external artefacts (e.g., cavities or false ceilings).

Plasters: there are three different types of plasters, produced mixing hemp woody core and lime (hydrated or aerial), in which the hemp grain size respectively varies between 3 and 6 mm, between 1 and 3 mm, and under 1 mm. In the third type, marble dust, hemp oil or cellulose can be added.

1.3. State of the art: studies on hemp in the building sector

Several studies related to hemp-based products employed in the building sector were carried out during the last 15 years. In the United Kingdom, in 2008 the National Non-Food Crops Center promoted a study [9], funded by the Department for Environment, Food and Rural Affairs, focusing on the environmental and comfort aspects of hemp buildings. The results of the research showed the environmental advantages related to hemp cultivation and its use in construction for walls, in terms of CO_2 storing and energy consumption reduction; in particular, hemp proved to be an optimal material in terms of "energy efficiency" of buildings, by decreasing heat loss to the outside and consequently also decreasing emissions due to the use of heating and cooling systems. Moreover, the use of a renewable-reproducible material, instead of non-renewable, energy-intensive ones, completely went in the optic of circular economy.

Several studies have been carried out on hemp and its union with a binder in the construction sector. In most of them, the characteristics of hemp as an insulating material and the comparison with the classic plastic insulating materials [7] or other traditional materials (e.g., rockwool) [10] have been studied. Also, reviews of the factors affecting the properties and performance of hemp-based materials were performed [8], [11], [12]. The review of Ingrao *et al.* [13] highlighted the characteristics of hemp-based building materials, underlining their versatility and potential in terms of reducing environmental impacts in the construction sector.

However, up to date there is few sustainability studies based on the LCA methodology, and some of them are focused only on the agricultural phase of hemp cultivation. Scrucca *et al.* [3], for example, evaluated the carbon footprint of the hemp cultivation, through Life Cycle Assessment. The total carbon footprint resulted lower than the absorption of CO_2, due to the carbon captured and stored during the growth of hemp. The study showed that the greatest impact was due to the use of chemical fertilizers in the cultivation, while all the other production stages had no negative impacts on the environment.

Florentin *et al.* [7] went further the cultivation phase and evaluated the life cycle analysis of the hemp-lime bio-compound as a building material. Both energy consumption and carbon content were investigated. The physical properties and thermal performance of the hemp-lime building material were compared with those of conventional ones through laboratory tests, temperature measurements in test cells and thermal simulations. The results showed that the hemp-lime compound not only had a clear advantage over conventional materials in terms of embodied energy, but also in terms of net CO_2 emissions over the entire life cycle of a typical building. This was mainly due to the active carbon sequestration of hemp during its growth phase, and the gradual sequestration of the carbon emitted during the production of the lime. From the point of view of thermal properties, the behaviour of a hemp-lime insulation material was found practically identical to that of a commonly used lightweight concrete insulation material.

Jami *et al.* [8] presented a review of the state of the art of research on hemp concrete, in order to identify the gaps that could guide future research, for its implementation in the sector of sustainable construction. Indeed, there are several gaps in research regarding the hydraulicity of the binder, the strength, durability, fire resistance of hemp concrete. At the same time, hemp concrete presents a low degree of incorporated carbon and of embodied energy, as it requires few processing before being used, making it ideal for green building applications.

Finally, Arrigoni *et al.* [14] analysed through LCA the environmental performance of non-load-bearing walls made with hemp pre-fabricated blocks. The overall emission of CO_2 resulted to be negative, thanks to the biogenic absorption of CO_2 during the growth of hemp in the field and the absorption of CO_2 resulting from the carbonation of blocks after construction.

2. METHODS

This study was performed with the support of the LCA methodology, a standardized procedure able to assess the environmental impacts of the proposed product system [15], including its specific unit processes in a cradle-to-gate approach. The reference ISO 14040 and 14044:2006 Standards [16], [17] were considered for performing the study.

SimaPro 9.0 [18] software developed by *Pré Consultants* and *Ecoinvent* 3.0 [19] supported the data processing for the creation of the LCA model. Moreover, the thermal performance

of the different compared solutions was estimated using *Termus* software [20] from ACCA software, a national leader in the development of building programs.

Three different methods were used for the impact assessment phase. The overall environmental impacts were evaluated using Ecoindicator 99 method [21], quantifying damns to human health, ecosystems and resources consumption. The Cumulative Energy Demand method (CED, [22]) was used for focusing on the different types of energy consumption occurring in the life cycle. Finally, the IPPC method [23] was applied for measuring CO_2 emissions in terms of CO_2 eq.

2.1. Goal and Scope definition

2.1.1. Objective of the study

The present study is a comparative LCA, i.e., it aims to study the production process of a product, in order to compare its environmental impacts with those of an analogous product in terms of function, but different in composition [24]. In particular, the objective of the work was to evaluate the environmental impacts of a wall made with hempcrete (mixture of hemp woody core and lime in 1:2 ratio, directly put inside a formwork made on site), and to compare it with two alternative solutions: a wall made with hemp and lime blocks (pre-fabricated materials), and a traditional wall, consisting of a perforated brick block and external insulation in polystyrene.

2.1.2. Functional Unit

The functional unit considered in the study was one m^2 of wall. The three different solutions had the same thermal insulation performance.

The analysis of hempcrete wall was taken from a real case study, consisting in an extension (i.e., super elevation) of a building under construction in the north of Italy. The comparison with the other two solutions was carried out assuming that the elevation was made with hemp blocks in one case, and with conventional materials used in the traditional building technique, in the other.

2.1.3. System Boundaries and quality of data

To focus the analysis on the production phase, an LCA 'from cradle to gate' can be performed, from the production of initial inputs to the final product, omitting the phases of product distribution [25]. The overall investigated LCA system considered 3 mains unit processes (Fig. 1): the hemp cultivation and harvesting, the processing of hemp straw for obtaining hemp woody core and fibre, and the assembly of the hempcrete wall, mixing hemp woody core and lime. The "use phase" of the wall, where a process of carbon sequestration generally occurs, due to the CO_2 resulting from the carbonation of lime after construction [14], was not considered and could be object of future research.

In reference to hemp cultivation, main data were directly provided from the national hemp association (*AssoCanapa*), with particular regards to the area of north of Italy. The same association provided the necessary data for the second phase, that of hemp straw processing. The data for the final phase related to the wall assembly were taken from the super elevation case study before mentioned. For the comparison with the hemp and lime blocks wall, data were taken from literature [26], while for the comparison with the traditional wall in polystyrene data were taken from *Ecoinvent* database [19].

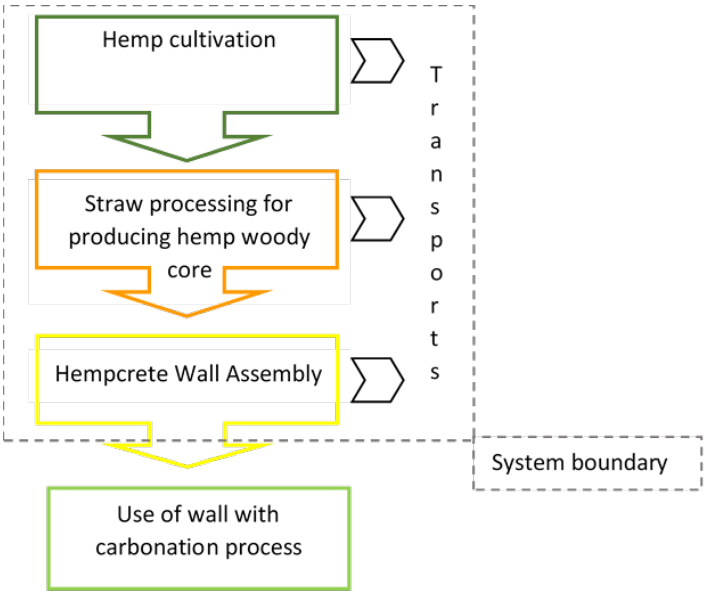

Fig. 1. System boundaries of 1 m^2 of hempcrete wall analysed.

2.2. Inventory Analysis

2.2.1. Data assumptions and Description of the inventory data for each stage

The first phase considered was hemp cultivation. The reference cultivation area was one hectare. According to *AssoCanapa* association, the yield of the crop generally consists in 6 ton/ha of seeds and 8 ton/ha of dried biomass (hemp straw). The main operations included were ploughing, harrowing, sowing, fertilizing, harvesting and baling. Fertilization and irrigation are not practiced in the cultivation area analysed, therefore emissions in air related to fertilizers are not present. Among the cultivation inputs, the seed was not considered because hemp is not present in the software database and the adaptation of other crops would have involved too complex calculations. The amount of CO_2 stored by hemp cultivation was equal to 13 ton/ha.

The second phase corresponded to processing of hemp straw for obtaining hemp woody core and fibre. This process generally consists in a simple mechanical separation of the two materials: the hemp woody core is the internal and hardest part of the hemp stem, while fibre is the external one. The main input deriving from the first phase is the hemp straw, which is first left in the field for a natural drying process (5–7 days) and, after reaching a humidity rate around 13 %, is transported to the *AssoCanapa* company, where it is processed. The transport is carried out by means of articulated lorries for a distance of maximum 50 km. The main outputs obtained from processing of straw are hemp woody core, which corresponds to 75 % of the total (6 ton) and fibre, which corresponds to the remaining 25 % (2 tonnes). The necessary amount of diesel for separating hemp woody core from fibre was accounted.

The third and final phase considered in the life cycle was the assembly of one m^2 of hempcrete wall. One of the necessary inputs in this phase, together with hemp woody core and lime, is fir wood (coming from another area in the north of Italy, transport distance of 245 km), which is used as support structure for the hemp and lime wall. The 20×20 cm wood

pillar was not considered in the LCA study. This because the pillars, being load-bearing, are placed at a distance of 3.5 m, and considering the pillar in one m^2 of wall would have meant overestimating its environmental load over the system. Differently, the wood strips, which generally are put between two pillars and have a size of 4×4 cm each one, were accounted into the process. One m^2 of wall includes 3 strips, for a total weight of 1.98 kg. For obtaining one m^2 of hempcrete wall, 45 kg of hemp woody core, 90 kg of hydrated lime (ratio 1:2) and 80 L of water for mixing the two materials are necessary. The hemp woody core and lime run across a distance respectively of 326 and 155 km by lorry. Also, the energy necessary for kneading hemp woody core, lime and water was accounted. An electric powered concrete mixer with a mixing capacity of 0.5 m^3 is used on site. The mixing time is always about 20 minutes, even if it is not fully loaded. We estimated the average consumption of a concrete mixer with these characteristics, which resulted in 5.59 kWh. The emissions connected to transport and to energy consumption, for all the phases of the life cycle, were already accounted by the database *Ecoinvent* in the related processes.

Finally, two other inputs, i.e. the main plaster (with a thickness between 1.5 and 2 cm) and the finishing plaster (with a thickness of 1 cm), that normally are put over the hempcrete cast to complete the wall, were accounted in the process. Each plaster is composed of hemp woody core, lime and water, in different proportions. Even in this case, the transport distances and electricity necessary for mixing hemp and lime were accounted in the process.

Annex shows the main inputs for the evaluation of the overall environmental impact in terms of natural resources, materials and energy divided in each single unit process.

2.2.2. Allocation procedure

In reference to the allocation procedure, there are two by-products obtained from the first phase of the life cycle analysed: seeds and straw, coming from the hemp cultivation phase. An allocation of 50 % and 50 %, based on economic criteria, was applied in this case, as both seeds and straw have an important market, especially after the recent "rebirth" of hemp for the textile and construction uses.

Then, in the second phase of the life cycle the two by-products coming from straw processing are hemp woody core and fibre. In this case, a mass allocation was applied, considering a yield of 75 % for hemp woody core and of 25 % for fibre.

2.2.3. Comparison scenarios

The comparison was made by choosing alternative solutions capable of guaranteeing equivalent thermal performance in winter conditions, i.e. capable of guaranteeing a thermal transmittance (reference performance parameter) of about 0.2 $W/(m^2K)$. The thermal performance of the solution hempcrete was derived from the technical relation of the case study project report, certifying compliance with the requirements for limiting the buildings energy consumption and the related heating systems.

The solution made in hemp and lime blocks was used as second term of comparison, taking the data from a study of Colombo *et al.* [26], and considering a wall of 30 cm for having the same thermal performance as the hempcrete wall.

The other construction technique used for comparison was a conventional solution typically used in residential construction (hereinafter referred to as 'common wall'), consisting of a perforated brick block (30 cm) with an external polystyrene coat, 12 cm thick. The thermal performance of this solution was estimated using the *Termus* software from ACCA software [20], a national leader in the development of building programs. As mentioned, data related to the common wall were directly taken from *Ecoinvent* database, considering the item 'clay

brick' as first approximation, since the data relating to the perforated blocks were not available in the software database. The impacts could therefore be different, since the type of processing considered is not known and this aspect should be subject of further investigation.

3. RESULTS AND DISCUSSION

Analysing the life cycle inventory of hempcrete, we found that the process having the major influence in the system is that of production of hydrated lime (67.3 % of incidence), followed by a 19.2 % of the incidence caused by electricity consumption and about 7 % caused by the use of the wood support structure. The hemp influences the life cycle of hempcrete only for 6.2 %. The agronomic phase of hemp appears to have a very low degree of incidence, due to the absence of the phases of irrigation, fertilization and parasitic treatments.

Life Cycle Impact Assessment (LCIA) is a mandatory LCA step where potential environmental impacts throughout the product or process life cycle quantify the effect of the collected LCI data as in- and out-flows [15]. As mentioned, three different methods were used for performing LCIA. Fig. 2 shows the impacts evaluation (Ecoindicator method) for the only hempcrete material, confirming the impacts of lime on the overall process, for several of the impact categories, except for Land Use, in which hemp cultivation has obviously the greatest impact. Also transports processes have a significant impact, especially on Fossil Fuels category.

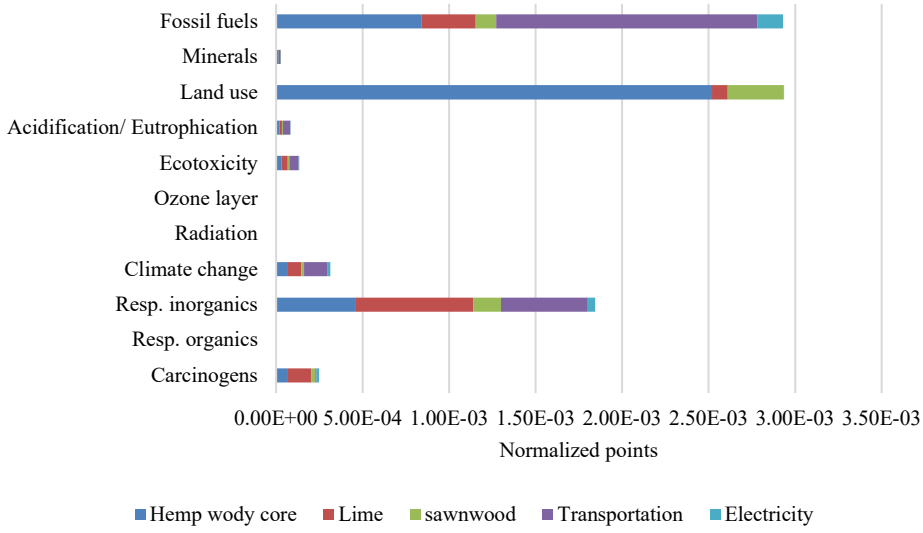

Fig. 2. Hempcrete wall evaluation (Ecoindicator method).

The results of the impact assessment phase for the three solutions investigated, through the Ecoindicator method, are reported in Fig. 3, showing the normalized results.

The common wall has a sensibly higher impact than the other two solutions for all the categories, except for Land use where it has the lowest normalized value. For Land use the greatest impact is given by the hempcrete wall and this is mainly due to the use of the soil during to the cultivation of hemp. In all the other categories, the hempcrete wall is the solution having the lowest impact, in comparison to the other two. The hemp block wall, despite the

use of hemp, appears to have a greater impact than hempcrete and this is due to the different type of processing connected with construction of blocks, and to the different type of lime (hydraulic one) used in the process. Some categories such as Respiratory inorganics, Respiratory organics and Ecotoxicity have almost equal values between the two solutions with hemp.

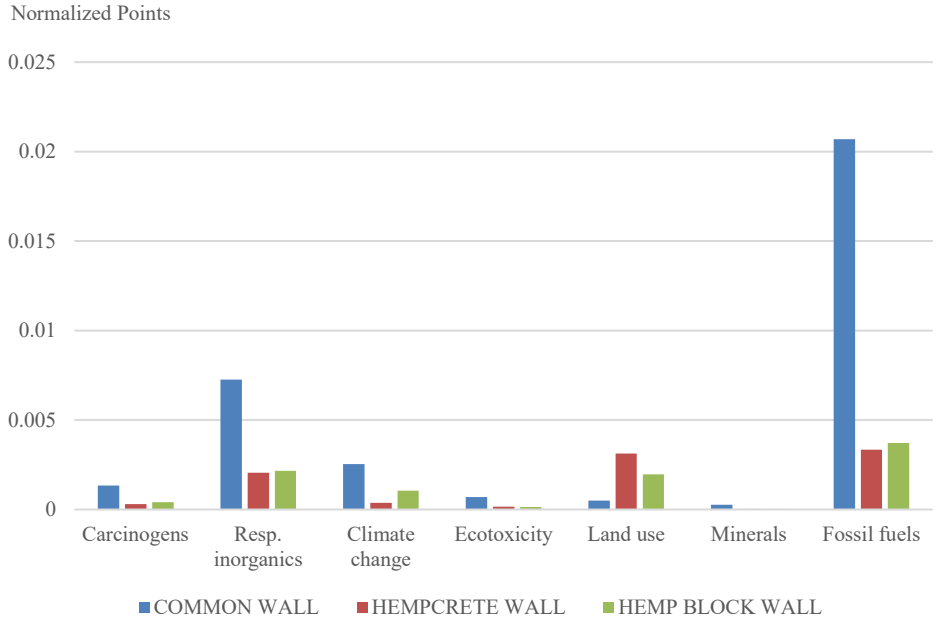

Fig. 3 Comparison among 1 m^2 of hempcrete wall, hemp blocks wall, common wall – Method Ecoindicator 99.

Fig. 4 shows the results of the comparison using the Cumulative Energy Demand (CED). In the Non-renewable fossil category, which is the most impacting one, the common wall is the worst solution. This is due to the presence of polystyrene as an insulating material: in fact, this material requires a large amount of non-renewable energy for the processing phases. The second solution most impacting for this category is the hempcrete wall, and this is probably due to the consumption of diesel in the straw processing phase and to the overall transport processes. In the Non-renewable, nuclear category the common wall has the highest impact, connected with the presence of uranium in some processing of the raw materials for making the final product. Finally, for the renewable biomass category, the hempcrete wall has the best result (135.70 MJ for m^2), with a significant renewable energy value connected to the considerable presence of hemp in the wall. The other two solutions have a much lower percentage of renewable biomass, for one m^2 of product.

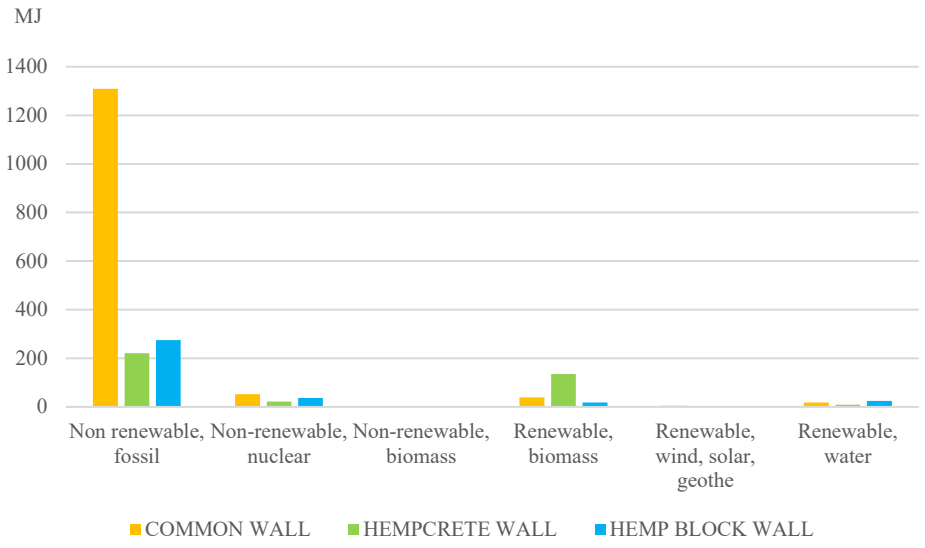

Fig. 4. Comparison among 1 m^2 of hempcrete wall, hemp blocks wall, common wall – Method CED (value in MJ).

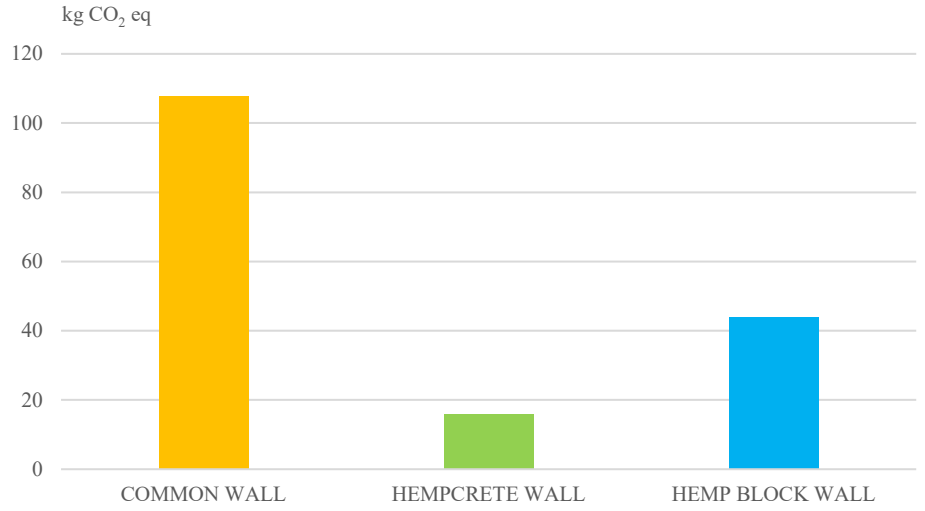

Fig. 5. Comparison among 1 m^2 of hempcrete wall, hemp blocks wall, common wall – (IPCC GWP 100a kg CO_2 eq).

Fig. 5 shows the results in terms of CO_2 emissions, using the IPPC method. The graph shows how the hempcrete wall produces a lower quantity of CO_2 eq (15.22 kg/m^2) than the other two solutions. This is due to the use of hemp, which in the field phase has a high absorption of CO_2 (about 13 t/ha), and also to the few amounts of processes that are carried out for arriving to the final product. The other two solutions, on the other hand, have higher values of CO_2 emissions, with the hemp block wall having a value greater of 2/3 than hempcrete (44 kg/m^2). This result is connected to the presence of hydraulic lime in the block

construction phase. Finally, with 107.88 kg of CO_2 eq, the common wall is clearly the most impactful, even if the data contained in the software database were used as first approximation for evaluating the impacts of this solution.

The results of our study are in line with the other studies performed in the field, showing that the hempcrete wall not only has a clear advantage over comparable conventional materials in terms of embodied energy, but also in terms of net CO_2 emissions, over the entire life cycle of a typical building. This is primarily due to the active carbon sequestration of hemp during its growing phase and to its rusticity, allowing a low amount of agronomic input [7]. Also, the few amounts of processes involved in the production of the wall (electricity for mixing hemp and lime is the only operation required) positively influenced the results. The gradual sequestration of carbon by lime carbonation after the construction would further improve the carbon balance, as demonstrated in other studies [14], and this is could be object of future research.

We found that hempcrete has a better performance also in comparison to hemp blocks, because all the operations necessary for constructing the prefabricated blocks are avoided. A certain amount of fossil energy consumption is still present, due in this case to the transports that occur during the life cycle. The elimination of some of the transport routes, shortening the chain, would further increase the environmental sustainability of the system.

4. CONCLUSION

This work tried to analyse the life cycle of a solution for unconventional building based on hemp and lime, in order to evaluate the impacts produced and make a comparison with two other construction techniques. To carry out this evaluation we used the LCA methodology, which allowed us to better evaluate all the impacts of the hempcrete solution and to make a comparison, from an environmental point of view, with hemp blocks and common blocks with outer coating in polystyrene.

The hempcrete wall resulted to be the least impactful solution in all the impact categories, except for Land use. The hemp block wall had slightly higher values in terms of impact while the so-called 'common wall' was the most impactful, even if as a first approximation for this solution the *Ecoinvent* software database was used.

From the analysis with the CED method, it can be seen that the hempcrete wall was still the most efficient among the three different solutions. Also, the evaluation in terms of CO_2 emissions found a clear separation between the hempcrete wall and the other two solutions. In fact, the CO_2 eq per one m^2 of wall resulted to be of 15.9 kg, while for the hemp block wall was 44 kg, and for the common wall was 108 kg.

Our analysis stopped at the stage of construction of the wall, therefore the CO_2 absorption due to the so-called carbonation process, that takes place in the years after construction, could be object of further analysis. A further decrease in kg CO_2 eq could be noted, with even negative values, as shown in some previous studies present in literature. A shortening of the supply chain and an additional development of the cultivation in a wider area could reduce the impacts connected with transports, decreasing as a consequence the still present consumption of fossil energy connected to them.

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ANNEX. LCI WITH REFERENCE TO ONE M^2 OF HEMPCRETE WALL

Hemp Cultivation Phase			
Input	**Unit**	**Amount**	**Data source/Comment**
Ploughing	ha	1	Data from National Hemp Association
Harrowing	ha	1	
Sowing	ha	1	
Harrowing	ha	1	
Baling	n.	27	
CO_2 hemp storing	ton	13	
Output	**Unit**	**Amount**	**Data source/Comment**
Seeds	ton	6	Allocation 50 %
Biomass (hemp straw)	ton	8	Allocation 50 %
Straw Processing			
Input	**Unit**	**Amount**	**Data source/comment**
Hemp straw	ton	8	Data from National Hemp Association
Diesel consumption	kg	51.42	
Transport of straw	tkm	400	
Output	**Unit**	**Amount**	**Data source/comment**
Hemp woody core	ton	6	Allocation 75 %
Fiber	ton	2	Allocation 25 %
Hempcrete Wall Assembly			
Input	**Unit**	**Amount**	**Data source/comment**
Hemp Woody Core	kg	45	Data from super elevation case study
Hydrated Lime	kg	90	
Fir Wood	kg	1.98	
Water	l	80	
Electricity	kWh	1.86	
Total Transports	tkm	32.11	
Main Plaster	m^2	1	
Finishing Plaster	m^2	1	
Output	**Unit**	**Amount**	**Data source/comment**
Hempcrete wall	m^2	1	
Main plaster			
Input	**Unit**	**Amount**	**Data source/comment**
Hemp Woody Core	kg	2	

Hydrated Lime	kg	8	Data from super elevation case study
Water	l	4	
Electricity	kWh	1.86	
Output	**Unit**	**Amount**	**Data source/comment**
Main plaster	m^2	1	
Finishing Plaster			
Input	**Unit**	**Amount**	**Data source/comment**
Hemp Woody Core	kg	1	Data from super elevation case study
Hydrated Lime	kg	5	
Water	l	2	
Electricity	kWh	1,86	
Output	**Unit**	**Amount**	
Finishing plaster	m^2	1	