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REPORT ON INFRASTRUCTURE FOR PRODUCTION OF CONSTRUCTION MATERIALS IN N-W AFRICA & EU

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Executive summary

This report investigates the infrastructure for production of construction materials in N-W Africa and EU in the aim of analysing the needs and potentialities in the building sector. First of all, a brief overview of ecological and green materials is presented. These materials can be classified according to their origin of obtainment into three classes. The following table summarizes the processed ones:

Materials from geological origins	Materials from vegetal origins	Materials from animal origins
Adobe (Mudbrick) Earth plaster Rammed earth Compressed earth block Natural Stone/Rock Cob	Straw Bamboo Hempcrete Papercrete	Wool

The principal properties of these materials have been introduced. In fact, the insulation properties, in particular thermal conductivity, relative to straw construction, wool, hempcrete is low enough to maintain the natural thermal comfort inside building. While the based-earth materials are serving better as structural elements of construction. In order to combine and enhance both excellent thermal and mechanical properties, many scientific surveys are carried out. as a matter of fact, natural additives are applied on earth bricks (straw, typha, olive wastes, cork sawdust…).

The second section of this report, focuses on reviewing the size and typology of ecological and bioclimatic construction companies in Africa and EU.

The activities of production of ecological construction materials are presented as:

- A non-exhaustive list of manufacturers found in Africa.
- A non-exhaustive list of manufacturers found in EU.

Provided information include:

- Contact;
- Exact type of activity, products and services;
- Some of their achievements.

In the end, very important variety of materials adapted to any climate's conditions are potentially used in promoting the bioclimatic and ecological building sector. However, most of activities in Africa are traditional, and many of them are not legally registered. In general, limited activities of companies found; the infrastructure is too weak to support the global transformation.

Abbreviations

Term	Name
AVN	Association la Voûte Nubienne
CEB	Compressed Earth Blocks
ONG – NGO	Non-Governmental Organisation
NV	Nubian Vault
NW	North West

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1. Introduction

The main goal of bioclimatic construction approach is to achieve naturally comfortable living conditions (temperatures, humidity, luminosity, ventilation etc.), by using materials and designs adapted to the climate and natural resources of the geographical location of the construction project.

Despite the great potential of bioclimatic constructions in terms of human and natural resources both in EU and Africa, the preparation of the appropriate infrastructure of the implementation of innovative, eco-friendly materials that researchers have developed during last years have faced many challenges. Therefore, the production activities of bioclimatic materials and constructions in Africa remain traditional or artisanal. The main goal of this report is to identify and map the existing manufacturing activities and businesses active in the field of bioclimatic materials and constructions.

This report exposes a review of:

- Bioclimatic materials and their characteristics, in the aim of assimilating the language and the technical interpretations.
- The mapped activities in EU and Africa of bioclimatic materials production, mainly manufacturers and types of material that are being used in buildings' construction.

2. Overview of climatic materials for construction

Following the vision of this project, bioclimatic ecological materials and processes can be defined as products whose raw materials are of origin from earth, plant, or animals. These constructions are known for their reduced consumption of energy compared to conventional construction, make use of recycling, and finally take into consideration local conditions to offer comfort for its users [1], [2]. The bioclimatic materials can be used in the construction or renovation of buildings and it cover a wide range of construction products.

There are many techniques of production of earth-based construction and based on the process of their fabrication, they can be grouped into three main families:

- Moulded earth, shaped during its plastic state such as adobe, cob, earthen plaster…
- Compacted earth in a wet state, not saturated with water such as rammed earth, compressed earth block…
- Earth-bag construction which consists of filling soil and others additives in degradable/normal bags.

The use of bio-based materials generally decreases the emission of GHG gases and has lower carbon foot print and contribute on the preservation of natural resources [3]. This is why it is encouraged by the public authorities during the construction or renovation of buildings.

However, bio-based materials are not necessarily 100% natural and we can't claim that they have no impact on the environment. They can sometimes be processed, contain chemical additives in varying proportions or have been transported long distances. In a sustainable construction approach, it is therefore preferable to use local bio-based materials and the least processed possible, provided that they meet the characteristics for which they are used.

2.1 Types of ecological construction materials in Africa and in the EU

2.1.1 Local materials from geological origins

Adobe

One of the oldest building techniques, mud bricks, are unfired earth made from a mixture of mud, sand and water mixed with a binding material mostly straw. Traditionally, it is formed by hand in a wooden mold. The bricks are then dried in the open air.

Figure 1: Adobe blocks
Photo credit: Salem Al Qudwa. Source : https://www.pinterest.com/pin/562246334703579392/

Earth Plaster

Earth plaster is essentially sand and clay (with chopped straw, if desired) mixed together in the proper proportions to prevent cracking. When mixed and applied properly, this wall covering will be hard, durable, and visually attractive. In many regions, earth plaster can even be used on the exterior walls of the building. It may easily last for seven to ten years or more, depending on use condition, without any maintenance

Figure 2: Plastering a wall
Photo credit: Travis Toon. Source: https://www.dancingrabbit.org/about-dancing-rabbit-ecovillage/eco-living/building/natural-building/earthen-plaster/

Rammed earth

Rammed earth technique consists of compacting layers of soil between temporary formworks up to the desired level, creating walls with a thickness ranging between 30cm to 60 cm. The earth mixture is compacted into layers of about 7.5cm to 15 cm by the use of a rammer, adding a new formwork above when one is filled, until achieving the required height; then the formworks can be removed [4].

Today, metal formwork and pneumatic compaction tools are used. In some case, it's required to stabilize the earth with additives, such as cement or lime, to ensure strength. The main manufacturing process adopted for rammed earth constructions is as follow [5]:

Preparing the site.
Laying the foundation.
Analysing the soil.
Framing the walls.
Tamping the soil.
Finishing the walls

Figure 3: Rammed earth house - La maison Gueffier à La Roche-sur-Yon

Source: https://www.ot-roche-sur-yon.fr/decouvrir/visites/sites-et-monuments-historiques/3152-maison-gueffier.html

Compressed earth block

A compressed earth block is a building material made primarily from wet soil compressed at high pressure in molds using a small pestle or a press.

Compressed earth blocks are one of the most widespread earthen building techniques. The compaction of earth improves the quality and the mechanical performance of the blocks [6].

Figure 4: Compressed earth blocks (CEBs) come in dozens of shapes

Source: http://www.naturalbuildingblog.com/more-info-on-compressed-earth-blocks-cebs/

Cob

The cob is a construction technique that consists of shaping clay balls that are stacked directly by hand and compacted to form a solid wall without the assistance of formwork. A sharp tool is then used to smooth the wall. Today, buildings made of cob can be restored, but the technique is no longer widely used

Figure 5: Cob building - KEPPEL GATE

Source: www.buildsomethingbeautiful.co.uk/blog/project/keppel-gate

Natural Stone/Rock

Natural stone or rock is an inexhaustible material and is widely used in partitioning for its incombustibility. Its extraction and processing do not require a lot of energy [7]. Stone construction can be restored or transformed while still ensuring comfort. The stone captures calories to release it slowly, hence its very good inertia. However, depending on the nature of the rock, Magmatic, Sedimentary or Metamorphic, its thermal insulation properties are not much interesting [8].

Figure 6: Stone building during construction

Photo credit: ANDY GOLDSWORTHY. Source: https://hangingstones.org/houses/

2.1.2 Local materials from vegetal origins

Straw Construction

When a grain of cereals such as wheat, rye, barley, etc. excluding oats, is removed after the harvesting process, the leftover dried and dead stems are known as Straw. Straw is used in construction as compressed wheat straw. It is considered to be a good thermal insulator [9]. Regarding the implementation, the straw bales are implemented by a filling process, within a matrix of wood structure, or may be used as load-bearing elements. On the other hand, straw may be used as additive in unfired clay bricks and in plasters.

Figure 7: Straw-bale house

Source: https://www.smarterhomes.org.nz/smart-guides/construction-and-materials/other-types-of-construction/

Bamboo

Bamboo is an extremely strong and resistant material. It is used for partitions and floors. Bamboo is easily adaptable to all climates, hence can be harvested and used on almost all continents. This material is suitable for construction for its lightness in addition to its resistance which is 8 times more efficient than that of wood with a maximum pressure of 40kg / mm and 5 kg / mm respectively [10].

Figure 8: A bamboo construction.

Source: https://images.adsttc.com/media/images/5bbe/79bf/f197/ccec/bc00/008c/slideshow/Comedor_3.jpg?1539209658

Hempcrete

Hemp is mixed with lime sand, or pozzolans, then used as a material for construction and insulation. Transformed to prefabricated blocks, hempcrete provides high vapor permeability. It is considered as a carbon negative material thanks to its capacity of absorption of CO_2 from the atmosphere while growing. The exterior of a hempcrete based construction requires a protection against water using plaster.

Figure 9: Hempcrete blocks

Source : https://www.hempbuildmag.com/

Paper

Paper may be recycled and used as a construction material. The material is made from a mixture of shredded paper and a sodium silicate gluing agent, a protector against flame and moisture [11]. The mixture is compressed under high pressure. The new composite offers two main advantages: quick to be manufactured and can be moulded into various shapes. It may also be used also as a "Paper Crete" by adding Portland cement [12].

Figure 10: Papercrete block.

Source: https://civilengi.com/papercrete-the-building-substance/

2.1.3 Local materials animal origins

Wool

Wool is a very safe, effective thermal and acoustic insulator [13], sheep wool insulation is a relatively well developed marked in Western Europe and is starting to rise in popularity. It comes in rolls of batts or ropes with various sizes depending on the manufacturer. In general, wool batts are of 50 mm to 150mm thick according to market. It can be used in all elements of a building but it costs more comparing to the conventional fiberglass insulation [14].

Figure 11: Sheep wool rolls

Source : MaterialDistrict

2.1.4 Physical and mechanical properties

- **Density**

The density or dry density (ρ) of a material is the ratio between its mass and its volume measured in its dry state. This property depends on several parameters, the most important ones being the particle size distribution, the proportion and nature of the binder phase, the water content at application, and the application energy (compaction, vibrating, etc.). Using Straw in a clay brick the density gets less and becomes 1830 Kg/m3 to 1500 Kg/m3 depending on the composition [15], while the length of the straw blocks can vary between 80cm and 120cm and the density must be between 80 and 120 Kg/ m3 to be able to use the straw blocs as a building material [16].

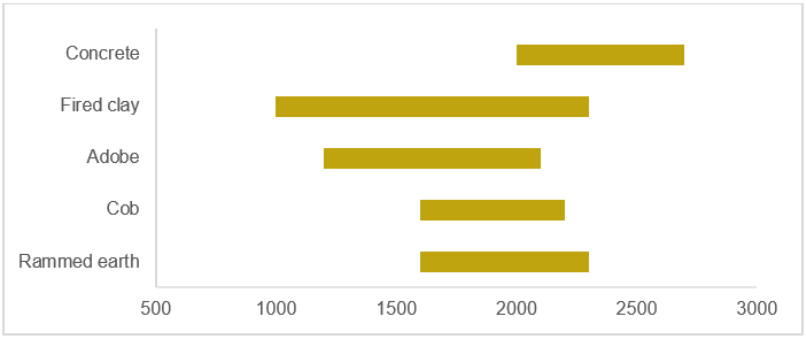
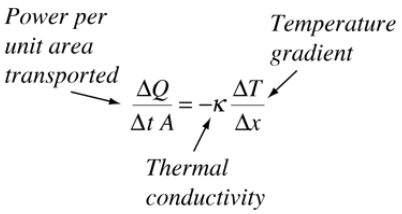


Figure 12: Density of different earth construction (in Kg/m3) [17].

The Figure represents the density of different earth construction materials and compared to conventional construction materials like fired clay bricks and concrete. We can observe that, depending on the construction procedure, the density of earth materials can be close to those conventional construction materials. Bamboo has a density of 580-700 kg/m3. The higher the density, the stronger the material, while wool used as insulator is 1310 kg/m3 dense.

- **Thermal Conductivity**

The thermal conductivity (k) indicates the quantity of heat (in W) that passes through per m2 of surface area 1 meter thickness of this material for 1 K temperature difference (ΔT) between the outer surface and the inner surface. It is expressed in W/m.K.



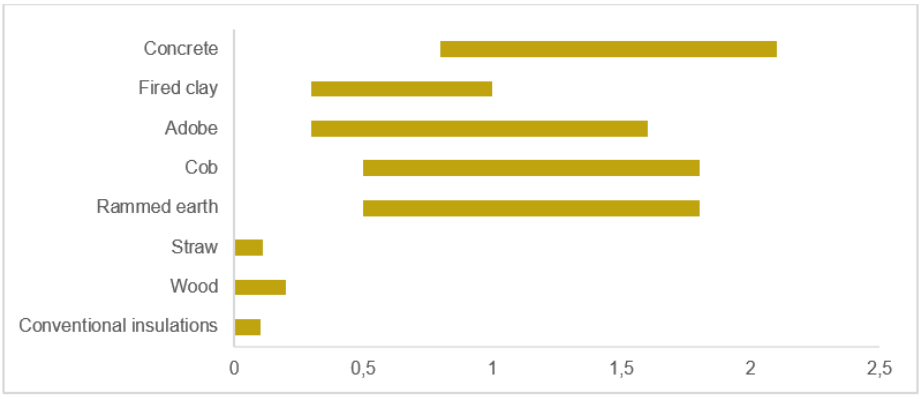


Figure 13: Thermal conductivity of different earth construction (in W/m.K) [17], [18], [19].

The material is considered good insulator when the value of K is low. Therefore, materials with a conductivity of less than 0.065 W/m.K are considered as insulating materials. The figure 2-2 presents the thermal conductivity of some climatic materials compared to the conventional ones.

The conductivity of an earth depends first on its density and porosity. It is of the order of 1.3 W/m.K for rammed earth and can go down to 0.10 W/m.K for earth-straw mixes with 500 kg/m3 of density. Straw is an excellent thermal insulator. With a thermal conductivity of 0.052 W/m.K,

straw is among the best insulators and above all, it occupies the first place (by far) in the performance / price ratio. A straw wall has a thermal resistance of more than 7 m2. K / W [20]. Unfortunately, nowadays in Europe conventional bales are quite rare and straw is generally packed in round bales that are not usable in building construction.

Bamboo has an estimated longitudinal thermal conductivity of 0.55–0.59 W/m K. It is a good thermal conductor in construction, which represents an advantage for its use on underfloor heating [21].

Sheep wool insulation has a thermal conductivity of between 0.035 – 0.04 W/mK which is very low values [22].

- **Compressive strength**

The parameters that contribute to a high compressive strength of an earth are:

- ☑ high density,
- ☑ low water content,
- ☑ high content of clays and silts,
- ☑ the presence of swelling clays,
- ☑ good homogeneity,
- ☑ small grains.

Many other parameters come into play in the earth's cohesion mechanisms that determine its resistance. The Figure 2.3 represents the compressive strength of bioclimatic earth materials and conventional materials and it shows that this property is the main problem that earth constructions are facing. In the literature, several researches are conducted to enhance this property by adding additives and stabilizers. The section 2.2 presents a state of the art of theses research activities.

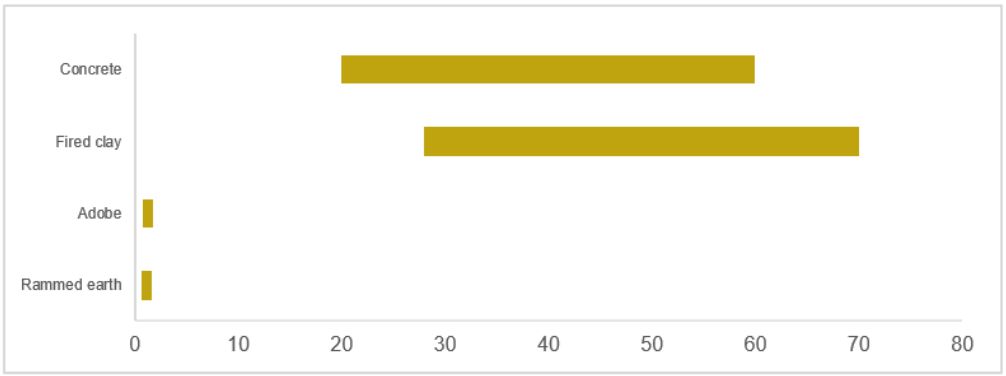


Figure 14: Compressive strength of different earth construction (in MPa) [17].

Regarding the MOR (Modulus at Rupture) of bamboo in tension is of the order of 200 MPa and in compression it is 70 MPa. The flexural MOE (modulus of elasticity) is 13,500 MPa (experimental values). As a rule, the physical and morphological properties are strongly correlated with the diameter of the stem.

Straw has a very low pseudo-elastic modulus (from 0.05 to 0.9 MPa), depending on the density but also other factors or parameters that are to be taken into consideration, such as the type of straw, the method of manufacture of the straw bale, and the content of water [9].

- **Acoustic Properties:**

Straw has good acoustic properties. Given the heterogeneity of a straw bale, it can absorb a wide range of frequencies and wavelengths. The density as well as the airtightness of a pressed straw bloc gives the necessary and right sound attenuation. In addition, since straw is not a rigid material, it can therefore act as “an acoustic spring” providing acoustic disconnection, which can provide a sound insulation that reaches up to 55 dB [9].

In a recent study [23], sound insulation of 150mm × 150mm × 150mm earth bricks and for fiber reinforced mud brick walls have been examined. Table 2-1 shows the results:

Table 1: Sound frequency-dB of selected materials

Material	Fired Brick	Concrete Brick	Clay + polystyrene fabric	Clay + straw	Clay + plastic fibre
Sound frequency-dB	59	58	53	52	51

Rammed earth has acceptable sound absorbing properties which reduces noise transfer. Tests indicate a sound transmission rating of over 58 decibels for a density of 2000 Kg/m^3. Whereas, wood and its derivatives are light materials, so as such their sound insulation performance is a conductor of sound and not particularly good [24].

2.2 Earth bricks with natural additives

The production process of conventional building materials consumes a high amount of energy which has a negative impact on the environment. The use of locally available materials and upgradation of traditional techniques can be a good option for sustainable development [25]. Consequently, earth has attracted the attention of the researchers as a building construction material for its availability and lower environmental impact [26]–[30]. However, we can see from the Figure 2–3, that the compressive strength of the bioclimatic materials is much lower than of the conventional construction materials, this lead to the intensive research in this field and several natural additives where proposed to enhance the mechanical properties of these materials [15], [31]–[33].

On the other hand, waste disposal from the agricultural and industrial sectors raises another serious concern [34], [35]. Therefore, the reuse of waste in construction materials production might be an environment friendly way to manage them. In some cases, it even implies an enhancement of the bricks properties as well as an advantage for brick producers [25].

Several recent studies widely considered the use of several waste materials for the development of unfired earth blocks construction and concluded that waste materials can help to develop renewable and environmentally friendly building products.

Different test methods and standards have been performed on the obtained material, but the most widely mentioned are density, thermal conductivity, compressive strength and water absorption. The tables below review the state-of-the-art of research on the effects of these various wastes (organic and non-organic) in the production of earthen construction materials [25].

Numerous papers are presented in Table 2-2. The tables also specify the types of additives, sources, the objective of the work and location of research.

Table 2: Overview of research works on using different additives for production of unfired earth blocks

Additive	Works ref	location	Content (wt%,vol%) and fibre length (mm)	Soil, sand and clay type	Idea	Results
Straw	[36]	**Spain**	25, 33.3 vol % 50–100 mm	Local soil	Authors evaluated the impact of straw fiber incorporation on the engineering properties of unfired earth bricks.	From the experiments conducted by Binici et al. [37] average water absorption value was found 36.80% and the lowest thermal conductivity value was recorded for wheat straw at 0.30 W/mK (3% fibre), barley straw at 0.31 W/mK (3% fibre). Other two studies presented the lowest thermal conductivity value of 0.25 W/mK (2.5% fibre) [26] and 0.26 W/mK (5%fibre) [15]. Vega et al. [36] showed that maximum compressive strength (3.99 MPa for 33.3 vol% fibre) was achieved with the highest amount of straw while maximum flexural strength (0.82 MPa for 25 vol% fibre) was acquired with the lowest fibre content. Wang et al. used cement (10, 15 and 20%) with straw and reported that addition of cement prolonged the curing time [15], and increased the compressive strength (11.70 MPa for 20% cement and 5% fibre). Other studies found optimum compressive strength as 5.80 MPa [37], 0.46 MPa [38], 4.58 MPa [26], 1.86 MPa. Parisi et al. [38] measured peak tensile strength as 0.56 MPa (0.64% fibre). The density of the specimens ranged between 1544.98 kg/m3- 1827.58 kg/m3 [15], 1400 kg/m3-1470 kg/m3 [26], 1628.70 kg/m3-1766.2 kg/m3 [37], 1357.70 kg/m3-1575.60 kg/m3 (wheat straw) and 1139.90–1542.50 kg/m3 (barley straw) [38]. Macgwood et al. [39] also evaluated the use of straw bales as a construction material. Authors suggested multiple design considerations to be adopted such as passive solar design as well as the builndig's window's shape and orientation to maximize solar radiation intake. The study also tackled the impact of the foundation and roofing type on the built house. Some examples of roofing or foundations roofs to be used are concrete stem structures, pier foundations, sandbags etc.
	[37]	**Turkey**	2.5%	Clay, bentonite		
	[15]	**Morocco**	2, 3, 4, 5%, 20 mm	Local Clay		
	[38]	**Italy**	0.64% <10 mm	Clayey/silty sand		
	[26]	**Turkey**	1 mass%, 20 mm	Cohesive soil		
	[39]	**Gabriola Island**				
Olive waste fibre	[29]	**Morocco**	10, 20, 30 vol%	Commercial clay sand	Lamrani et al. assessed the thermal efficiency of unfired clay masonry bricks combining 10, 20, 30 vol% of olive waste fibre [OW], date palm fibre [DPF] and straw [S].	It reported that the addition of S and DPF improved the thermal performance of the samples while OW began to degrade the performance. The density of the samples ranged between 1398.30 kg/m3-1642.59 kg/m3 (OW), 1218.74 kg/m3-1572.19 kg/m3 (DPF) and 1221.43 kg/m3-1554.35 kg/m3 (S). In the case of thermal conductivity, straw fibre reinforced samples performed the best (0.26 W/mK), followed by DPF (0.28 W/mK) and OW (0.40 W/mK) samples.
	[40]	**Spain**	5, 10, 15%	Commercial clay sand	Serrano et al. studied the feasibility of different byproducts wastes as additives in the manufacture of adobe blocks. The additives were categorised into two	The mechanical test results indicated that in the case of fibre admixed samples the best flexural strength behaviour was achieved by fescue admixed samples (0.33 MPa-0.60 MPa) followed by corn plant (0.25 MPa-0.39 MPa) and straw (0.15 MPa- 0.29 MPa) while the highest compressive strength was obtained by corn plant (1.98 MPa-3.25 MPa) followed

Additive	Works ref	location	Content (wt%,vol%) and fibre length (mm)	Soil, sand and clay type	Idea	Results
					groups namely fibre (corn plant, fescue and straw of 1–3 wt%) and pellet (olive stones of 5– 15 wt%).	by straw (2.04 MPa–2.90 MPa) and fescue (1.93 MPa–2.88 MPa). On the other hand, pellet adobe samples exhibited compressive and flexural strength varied from 0.98 MPa to 1.61 MPa and 0.07 MPa to 0.16 MPa respectively.
Sawdust	[35]	**Turkey**	2.5, 5, 10%	Raw brick clay	Demir conducted experiments to develop unfired clay bricks using grass, sawdust and tobacco residues (2.5, 5 and 10 wt%	Based on the test results it can be concluded that the compressive strength of the unfired brick samples improved from 3.35 MPa to 5.10 MPa, 3.10 MPa to 4.75 MPa and 3.40 MPa to 5.15 MPa for sawdust, tobacco residue and grass addition respectively
Wool sheep	[30]	**United Kingdom**	0.25,0.5% 10 mm	Soil from brick manufacturer	examined the utilisation of sheep wool to reinforce unfired earth blocks	The results reported that density increased with the increasing amount of wool fibre and ranged from 1790 kg/m3 (19.5% alginate and 0.25% wool) to 1800 kg/m3 (19.5% alginate 0.50% wool). The compressive strength reached its peak at 4.44 MPa.
Corn cob	[41]	**France**	3, 6% 15 mm	Quarry fine	Laborel-Préneron, A. et al. utilised 3 and 6 wt% of barley straw and corn cob to produce unfired earth blocks and investigated the mechanical and hygrothermal properties.	The test results showed that bulk density decreased from 1878 kg/m3-1754 kg/m3, 1603 kg/m3-1221 kg/m3, 1519 kg/m3-1315 kg/m3 and thermal conductivity reduced from 0.26 W/mK- 0.35 W/mK, 0.20 W/mK-0.30 W/mK, 0.14 W/mK-0.28 W/mK with the addition of corn cob, hemp shiv and straw fibre respectively. Moreover, compressive and flexural strength also reduced with a higher amount of waste addition except for the straw fibre blended samples where maximum compressive strength (3.80 MPa) was found at 6% of fibre addition. Optimum compressive strength of corn cob samples were recorded as 3.20 MPa for 3% of fibre content.
Wood aggregate / Wood fibre	[42]	**Burkina Faso**	10–40%	Clayey soil	P. Nshimiyimana et al. investigated the compressive strength of compressed earth blocks utilising calcium carbide residue (CCR) and rice husk ash (RHA).	The results showed that due to the pozzolanic interaction between earth particles and the CCR the compressive strength nearly doubled (3.40 MPa) for 8% CCR content in comparison to the control sample (1.90 MPa). However, more than 8% of CCR addition decreased compressive strength. Therefore, in the second phase, the compressive strength of the samples with more than 8 CCR was further enhanced by the partial replacement of CCR by RHA (10 to 40%). It was observed that in the case of 10% and 15% CCR the optimum RHA replacement was 20% and 30% respectively. The compressive strength was found 5.30 MPa for 20%RHA and 6.60 MPa for 30%RHA substitution which was respectively twice and three times higher than the only 10% (2.50 MPa) and 15% CCR (2.20 MPa) sample.
	[43]	**United Kingdom**	undefined	Conventional Clay	Heath et al. investigated the incorporation of wood fibre/ aggregate in the development of unfired earth blocks.	Heath et al. found that adding wood fibre to unfired brick resulted in a dry density reduction (1597 kg/m3) of up to 12% than the control sample (1793 kg/m3) and compressive strength was noted as 10.50 MPa.
	[28]	**Zimbabwe**	1.5, 3%	Clayey soil	Masuka et al. investigated the	Masuka et al. initially prepared four samples of the various ratio of lime (L), coal fly ash (F) and wood aggregate (W)

Additive	Works ref	location	Content (wt%,vol%) and fibre length (mm)	Soil, sand and clay type	Idea	Results
					incorporation of wood fibre/ aggregate in the development of unfired earth blocks.	(L: 4–8%, F: 10–16%, W: 1.5–3%). Among all the samples, L-10%, F-10% and W1.5% sample showed a significantly higher compressive strength value of 8.30 MPa. Later the study used cement (4% and 10%) with this mixture to further investigate its impact on the physical and mechanical properties of the samples. The study concluded that the sample prepared with 10% lime, 10% fly ash and 4% cement was the most cost-effective composition (based on the cost of raw materials lime and cement) which also fulfilled the engineering specifications as stated in the British standards BS EN772.
Sisal fibre	[44]	**Kenya**	0.25, 0.5, 0.75, 1.0, 1.25% 3–10 mm	Bautzen clay	Namango investigated the different properties of sisal fibre (0.25, 0.5, 0.75, 1.0, 1.25 wt% and 10 mm) and cassava powder (1.5, 2.5, 4, 5 ,7, 10, 15, 20 wt%) stabilised compressed earth blocks	The test results revealed that for sisal fibre-reinforced blocks optimum flexural (1.63 MPa) and compressive strength (9.14 MPa) were achieved for 0.75% of sisal which corresponded to a 64.30% and 90.50% improvement in strength compared to the fibre-free block. The density of the sisal reinforced blocks increased to 1895 kg/m3 for 0.75% fibre and subsequently dropped at 1.25% of fibre addition (1738 kg/m3). On the other hand, the samples with cassava powder had compressive strength between 7.36 MPa (1.5% cassava) and 4.29 MPa (7% cassava). The trend of flexural strength values was similar to that of the compressive strength and ranged between 0.94 MPa and 1.71 MPa.
Fescue	[40]	**Spain**	1, 2, 3%	Commercial clay sand	Serrano et al. studied the feasibility of different byproducts wastes as additives in the manufacture of adobe blocks. The additives were categorised into two groups namely fibre (corn plant, fescue and straw of 1–3 wt%) and pellet (olive stones of 5– 15 wt%).	The mechanical test results indicated that in the case of fibre admixed samples the best flexural strength behaviour was achieved by fescue admixed samples (0.33 MPa-0.60 MPa) followed by corn plant (0.25 MPa-0.39 MPa) and straw (0.15 MPa- 0.29 MPa) while the highest compressive strength was obtained by corn plant (1.98 MPa-3.25 MPa) followed by straw (2.04 MPa– 2.90 MPa) and fescue (1.93 MPa–2.88 MPa). On the other hand, pellet adobe samples exhibited compressive and flexural strength varied from 0.98 MPa to 1.61 MPa and 0.07 MPa to 0.16 MPa respectively
Date palm fibre	[45]	**Algeria**	0.05, 0.10, 0.15, 0.2% 35, 120 mm	Local soil, crushed sand	Taallah et al. Taallah and Guettala studied the utilisation of date palm fibre on compressed earth blocks production. Various percentages of cement (5, 6.5 and 8%) and fibre (0.05, 0.10, 0.15, 0.2 wt% and 20 mm, 35 mm) were incorporated to conduct the tests.	The results of the experiments exhibited that the better outcome of the dry compressive (12.50 MPa) and tensile strength (1.50 MPa) were achieved by samples with 0.05% of fibre and 8% cement content. The lowest water absorption (9.50%) and swelling value (0.18%) was also attained with this percentage. However, higher fibre content decreased the thermal conductively (0.80–0.76 W/mK) and bulk density (1910–1892 kg/m3) of the specimens.
Palm	[46]					
Seaweed	[47]	**Italy**	10%, 10 mm	Raw brick clay	Achenza and Fenu, and Dove incorporated seaweed fibre additives for unfired clay bricks	According to the test results densityof the samples varied from 1690 kg/m3 to 2250kgm/m3 and 1720 kg/m3 to 1810 kg/m3 . It was observed that the compressive strength improved (about

Additive	Works ref	location	Content (wt%,vol%) and fibre length (mm)	Soil, sand and clay type	Idea	Results
					production. Achenza and Fenu used 10 mm long and 10 wt% seaweed fibre and natural polymer (beetroots and tomato residues) with soil. Dove utilised 0.1% Scottish seaweeds (Laminaria hyperborean) with silt loam to prepare the blocks	75%) with natural polymers addition in the sample and the highest compressive strength was observed as 4.40 MPa. The test results also presented a water absorption value of around 2.10gm/cm2. On the other hand, Dove presented maximum compressive and flexural strength of 1.64 MPa and 0.95 MPa respectively
	[27]	**UK**	0.1%	Silt loam		
Eggshell	[48]	**Ghana**	10, 20, 30, 40%	Laterite soil	Adogla et al. utilised eggshell powder (10, 20, 30 and 40 wt%) to examine their potentiality to substitute soil partially in the production of lateralised unfired compressed bricks	From the density tests, it was noticed that the dry density of the samples increased gradually (2101 kg/m3 to 2044 kg/m3) as the amount of waste increased. On the other hand, compressive strength test findings showed that there was an upward trend in the values of compressive strength of the samples as the amount of ash percentage increased to maximum 30% and after that compressive strength showed a decrease in value. The optimum compressive value was found at 3.05 MPa after 6 days of curing

3. Review of infrastructure for production of construction materials and sustainable activities in Africa and EU

Governments, companies, associations and all organizations must now get involved in this movement towards the promotion of bioclimatic construction materials. Not only ethically, but also in terms of accumulating efforts and building networks for the exchange of expertise. And that's especially in Africa where most of green manufacturing/implementation activities are traditional, low impact and low production. For this reason, the mapping of all rising start-ups and SMEs active in the field is very crucial to the development of this field.

This section focuses on reviewing the size and typology of construction companies in Africa and EU. However, we believe that the presentation of the list of the political and societal actors in the different countries is very important since it represents and gathers those manufacturing activities. We are presenting also examples of successful projects that have used local resources and have ensured the concept of bioclimatic buildings.

3.1 In Africa

3.1.1 Active organizations in the context

We have been able to map a non-exhaustive list of different actors, most of them are federations, associations and government agencies. The list is presented in Table 3-1 These organizations will offer us the necessary support for future actions.

Table 3: A non-exhaustive list of African organization acting in the green bioclimatic buildings and materials

Country	Name	Contact	Relevant Activities/Missions
Senegal	Agence Nationale des Éco Villages	2082 Sicap Liberte 3 x Avenue Bourguiba Dakar - Sénégal (+221) 338 24 33 66	The National Agency for Ecovillages is a state structure whose objective is to create ecovillages throughout Senegal.
	Association le Partenariat	https://www.lepartenariat.org/lassociation/ +221 33 961 46 51	An International Solidarity Organization. Support the local, sustainable and united economic development of the territories. Improve the living conditions of the populations, in particular through access to basic social services. Implement a strategy to combat global warming by disseminating innovations in the field of the environment and sustainable development.
	Syndicat Professionnel des Entrepreneurs du Bâtiments Travaux Publics du Sénégal	S/c GTO 7, rue Mermoz BP 1520 Dakar - Sénégal (+221) 338 23 25 08	Representation of the economic sector and collaborate with state entities and services, through active participation in social and technical development; The study and analysis of all issues relating to the workforce;
	Agence de Promotion des Investissements et des Grands Travaux	https://investinsenegal.com/ (+221) 33 849 05 55	National agency in charge of investment promotion. Its mission is the development of partnerships between public and private and the promotion of investment in Senegal. APIX supervises the execution of major state projects.

Country	Name	Contact	Relevant Activities/Missions
Morocco	Fédération des Industries des Matériaux de Construction	https://fmc.org.ma/ 212 522 39 54 51/53	Representation of the sector; Promotion of the quality of construction products; Preparation of SMEs / SMIs for upgrading actions; Carrying out sectoral studies on the construction materials industries; Promotion of technological development and environmental protection.
	Cluster Efficacité Energétique des Matériaux de Construction	https://clusteremc.org/ 212 522 402 634	•Bring together players in the construction sector and sustainable development sector around collaborative projects with strong innovative content. •Support cluster companies to become more competitive. •Increase the innovation capacity of members by promoting collaboration between industry, researchers and training organizations. •Promote the creation and development of R&D and innovation projects and the emergence of innovative start-ups.
	Centre Des Techniques Et Matériaux De Construction	https://cetemco.org/ (+212) 522 321 078	Interprofessional Association responsible for: •development of quality, enhancement of productivity and promotion of safety and environmental protection; •research and development activities relating to construction materials.
	l'Association Professionnels des Briquetiers	5, rue Chajarat Addor -ex Forain, c/o Drapor 20100 Casablanca (+212)5 22 95 91 29	•Ensure the representation of members to various national and international partners; •Contribute to the development of the building materials sector; •Ensure the adaptation of standards to product developments; •Promote the efforts made in terms of technological upgrading.
	Fédération Nationale du Bâtiment et Travaux Publics	432, Rue Mostafa El Maâni 20 000 +212 522 20 02 69 +212 522 27 43 49	•Organization, defense and representation of companies in the sector; •Promotion of groupings and partnerships between companies in Morocco and abroad.
	Morocco Green Building Council	No Data found	No Data found
Mauritania	l'Établissement pour l'Exécution des Travaux Réalisés en Matériaux Locaux	https://etr-ml.com/ +222 45 25 92 39	•The management and the exploitation of artisanal or industrial quarries for the production of local construction materials; •The execution of project using local materials, in particular stone and clay, as well as the marketing of these materials; •The organization and implementation of training actions in the field of local building materials or related activities; •Expertise, quality control and monitoring of work carried out in stone and clay; •Contribute to the emergence of industrial and artisanal production units.
	l'ONG mauritanienne ECODEV	http://www.ecodev.mr/index.php/en/ (00 222) 45 29 30 54	Eco-development (Ecodev) is an association governed by Mauritanian law committed to the development of its country. To this end, it is involved in any initiative aimed at improving the living conditions of the population. The

Country	Name	Contact	Relevant Activities/Missions
		se@ecodev.mr	association also contributes to the protection of natural resources and the environment.
	Club des professionnels de la construction en terre crue	No Data found	No Data found
	Fédération Nationale des Bâtiments et Travaux publics	No Data found	No Data found
Burkina Faso Ghana Nigeria	L'Association pour Le Développement d'une Architecture Et d'un Urbanisme Africain	BP. 648 - OUAGADOUGOU - BURKINA FASO Ouagadougou Kadiogo Burkina Faso (226) 50 30 73 52	ADAUA (Association for the Development of Traditional African Urbanism and Architecture) is an organisation of people from a number of different countries, headquartered in Ouagadougou, Burkina Faso. Established in 1975, ADAUA aims to revive and promote indigenous African architecture and to train local inhabitants in appropriate technologies. (Source: AKTC)
	La Fabrique	https://www.lafabrique-bf.com/ (+226) 55 03 33 33 contact@lafabrique-bf.com	Identify project leaders and co-build with them long-lasting companies with a high impact on society and / or the environment.
Algeria	Association Environnement et Développement Durable	OMAR BAALI aeddi2013@gmail.com +(213)662364185	• Generate public interest and awareness for the environment and the protection of natural resources. • Encourage the transition to a green economy and take advantage of renewable energies. • The implementation of environmental projects to meet the needs of civil society. AEDDI promotes exchange between associations working in the fields of ecology, nature, the environment and sustainable development.
Tunisia	Association Méditerranéenne des Materiaux et de l'Environnement A2ME	a2me.sfax@gmail.com +216 20 412 517	•Promote and develop all studies and research relating to biodegradable materials and environmental protection. •To organize seminars and meetings and all kinds of scientific events concerning the use of materials and the protection of the environment. •Supervise researchers and work in monitoring all research activities in the field of materials and environmental protection.
	Tunisian Confederation of Industry, Trade and Handicrafts (Union tunisienne de l'industrie, du commerce et de l'artisanat)	http://www.utica.org.tn/Fr/ contact@utica.org.tn +216 71 142 000	•Encourage investment, innovation and value creation. •Support businesses by providing them with support, advice and information. •In 2018, the union has organized "Les 10èmes journées de l'éco-construction et l'innovation", an event treating the the eco-construction.
	l'Agence Foncière d'Habitation	http://www.afh.nat.tn/index.php?id=4	The A.F.H is a public company, with legal personality and financial autonomy. Its main missions are: •Provide the housing and urban planning sectors with the developed land they need to meet public and

Country	Name	Contact	Relevant Activities/Missions
			private demand, paying particular attention to reducing production costs; •Support the efforts of municipalities in carrying out their urban projects; •Participate in the national effort to maintain populations in their area of origin by carrying out decentralized projects at the lowest cost;
Ghana	Giving life nature volunteer (GILINAVO)	https://www.facebook.com/gilinavoghana.org/ http://www.gilinavoghana.org/ +233 30 298 0897 gilinavoghana2000@gmail.com	An NGO that encourages the volunteerism of students, institutions, and basically everyone wishing to protect natural sources and the environment in Ghana.
Nigeria	The health of Mother Earth Foundation (HOMEF)	+234 817 370 6095 home@homef.org https://homef.org/	Organize forums and publish articles that enhance the public awareness about the current environmental and biodiversity issues alongside the need to adopt sustainability of mother earth.

3.1.2 Active manufacturers in production of construction materials

The main types of ecological constructions in Africa are: Stone, Mud-Bricks, Compressed Earth Bricks (CEB) and Typha Bricks. Other materials are historically widely common in African architecture such as straw alone, wood alone (bamboo), typha alone.

An example of a good use of Mud-Bricks is the Nubian Vault which is renewable, fast to manufacture, does not require a qualified manpower, good acoustic and thermal properties and available on site. This technique is described in details in Task T3.3. The most active actor in The Nubian Vault construction in Africa is L'Association Voute Nubienne (AVN). The use of CEB and Typha Bricks is very common in West Africa as well. ElemenTerre is a pioneer company in CEB production and use. With five mechanical presses the production capacity reaches up to 1,000 bricks per day. The construction methods remain traditional.

We have been able to map a non-exhaustive list of manufacturers of these materials and presented the results in Table 3-3. The following table 3-4 reviews, besides, other types of green, bioclimatic construction manufacturers (green roofs, green walls, bricks with plastic additives, stones, plasters, insulations …). During the investigation process, we concluded that:

- Lack of coordination between companies for the creation of collaborative networks specific to bioclimatic building materials.
- Absence of advertising and communication strategies with potential customers.
- The companies are still small which means that the production will not meet the total needs of the market.
- The manufacturing methods are traditional and are not methods based on scientific research.
- There are no procedures or certifications for quality, environment and safety at the production level.
- Although these constructions are bioclimatic, much more researches are needed to ensure their relevance especially for safety (eg natural disasters) and lifespan.

- Green building in sub-Saharan Africa is more extensive than in North Africa. This can be explained by the fact that the rural population in sub-Saharan Africa is dominant as shown in Table 3-2 (Source: World Bank).

Table 4: Percentage of rural population in some African countries in 2019

North Africa			Sub-Sahara		
Morocco	**Algeria**	**Tunisia**	**Burkina Faso**	**Guinee**	**Mali**
37%	**27%**	**31%**	**70%**	**64%**	**57%**

Table 5: A non-exhaustive list of manufacturers of earthen bioclimatic construction (Nubian Vault, Compressed Earth Bricks and Typha bricks) in Africa

Country	Company	Information/Contact	year of Creation	Activity	Examples of projects achieved
Senegal	ElemenTerre	http://www.elementerre-sarl.com/	2010	Design and supervision of Bioclimatic Buildings, particularly using earth and typha Use of Compressed Earth Blocks (BTC).	Realisation of the extension of the Djoloff hotel in Fann-Hock Building located in Saint Louis (Senegal), infill with mud bricks
	Association la Voûte Nubienne	https://www.lavoutenubienne.org/ avn-mali@lavoutenubienne.org +33 (0) 4.67.81.21.05	2000	The Nubian Vault (NV) technical concept architectural technique that requires only available earth (adobe) bricks and mortar.	Construction of 2 buildings for a medical centre using (NV) in Burkina Faso. First village built entirely with the Nubian Vault technique in Mauritania.
	Le collectif Worofila Architecture Terre	worofila@gmail.com	—	The Worofila Collective is specialized in the design and supervision of bioclimatic buildings in Senegal, particularly using earth and typha.	L'écopavillon terre-typha de Diamniadio
	Eiffage	https://www.eiffage.sn/ eiffage.senegal@eiffage.com (+221) 33 839 73 39	—	stone and brick masonry, terracotta and other work,	Regional Express Train. Highway of l'Avenir Dakar-Diamniadio.
	GIE Presse Ta Terre	https://didierhubert.wixsite.com/briquedeterre/au-senegal didier.hubert@hotmail.fr	—	Production and sale of Compressed Earth Bricks (CEB).	
	Association TypHAS	—	—	Typha bricks.	Made the typha roofing of the first building of the Afrika Mandela Ranch of l'Ecole des Métiers
	TyCCOA	https://www.tyccao-typha.org/ (+222 41 956 932)	2018	Earth-typha building materials. Rigid insulating panels. Fiber-reinforced earth panels. Bulk insulation (crushed typha). Thatched roofs.	—

Country	Company	Information/Contact	year of Creation	Activity	Examples of projects achieved
				Vegetable concrete: blocks, plasters, prefabricated concrete and solutions made from laterite.	
Morocco	DHIBA Construction BTP	N°35 NOUVEAU MARCHE BENSERGAOU, Agadir (+212) 528 84 21 93	2015	Building construction and constructions with adobe.	—
	Argilex	http://www.argilex.ma/ info.argilex@gmail.com argilex@argilex.ma (+212) 620000061	2004	Construction of sustainable and comfortable ecological buildings. Restoration of old buildings respecting traditions. Sale of materials for ecological construction and restoration of buildings. Advice and technical assistance in the fields of ecological design and construction, as well as the restoration of built heritage.	Dar al oumouma, anzi, Tafraout. (batiment en pierre de la region)
Mauritania	HABIDEM	habidemauritanie@gmail.com (+222) 45291249	2015	Project management and the execution of ecological construction projects. Promoting traditional Mauritanian construction techniques and local materials, with the aim of contributing to the improvement of local living conditions and to access to sustainable habitat.	The construction of a bioclimatic habitat with clay and typha materials (educational and research building for a university)
	IPC.sarl	Teyarett, Nouachott, Mauritania (+222) 36307134	2011	works with BTC Hydraform. Lubricants: Anti-Rust Lubricants, Lubricating Greases, Lubricating Oils.	Gas stations in the city of Nouakchott
	Rex Rural Express	info-rex@bavcorp-international.com https://bavcorp-international.com/rex.php (+222) 20 12 82 89	—	Production and sale of Compressed Earth Bricks (CEB). building and public works	
	TyCCOA	https://www.tyccao-typha.org/ (+222 41 956 932)	2018	Earth-typha building materials. Rigid insulating panels. Fiber-reinforced earth panels. Bulk insulation (crushed typha).	—

Country	Company	Information/Contact	year of Creation	Activity	Examples of projects achieved
				Thatched roofs. Vegetable concrete: blocks, plasters, prefabricated concrete and solutions made from laterite.	
Burkina Faso	Zi Matériaux	http://zi-materiaux.com/ (+226) 25 43 31 75	1992	Production of all types of earth bricks. Design work.	
	Nouvelle Technologie de Construction (NTC)	01 BP 1444 OUAGA 01, OUAGADOUGOU, BURKINA FASO (+226) 25 43 51 62	1997	Production and sale of Compressed Earth Bricks (CEB) and tiles.	
	Nice SARL	http://nicesarl.com/ info@nicesarl.com (+226) 79043940	2013	Production and sale of Compressed Earth Bricks (CEB). Housing construction using local materials.	
Algeria	Eco-Labina	Hai el yassamine hlm 132 lsp bt f etage 04 lot 12 (+213) 773156952	2012	Production of all types of earth bricks, rammed earth blocks.	Built a pilot house type F4 in Timimoune, the south of Algeria.
	BRIQUETERIE TIDJELABINE	Zone Industrielle (Marché des Véhicules) 35490 Tidjelabine http://www.briqueterie-tidjelabine.com	2007	refractory bricks and blocks and insulating refractory bricks	—
Tunisia	SD-FABCO	https://sdfabco.tn/ contact@sdfabco.tn	2018	Production and sale of Compressed Earth Bricks (CEB).	—
	ECONOVA	RDC Imm Melika Rue Lac Windermere Les Berges du Lac 1053 Tunis	2015	Production and sale of Compressed Earth Bricks (CEB).	—
Ghana	Hive Earth	https://www.hiveearth.com/ info@hiveearth.com	2016	Eco construction company uses locally sourced materials such as laterite, clay, stone, granite and lime to make durable and affordable structures.	Building individual houses.

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Table 3-6: A non-exhaustive list of other green and bioclimatic construction manufacturers in Africa

Country	Company	Contact	Date of Creation	Activity	Examples of projects achieved
Senegal	SOPREMA	https://www.soprema.com/	1908	Insulation. WaterProofing. Photovoltaic. Green roof, Roofing. Civil engineering (CivilRock).	—
Morocco	Cooperative Adrar-Nouh	+212 610369829	2017	Cannabric materials Hemp concrete, vegetable waste from hemp staks.	SunImplant
	Eco-Dôme Maroc	http://ecodomemaroc.ma/ ecodome.maroc@gmail.com	2016	Green, economical and eco-friendly construction of Dome-shaped houses with heat and insulation propeties, using basic raw aterials: rammed earth and Superadobe technique	A house in Sidi Allal EL Bahraoui (Maroc) fittig a family of 5. a 250m² cultural center for students in the Agouim region (Morocco)
	POP-UP HOUSE	https://www.popup-house.com/ 00212 06 59664846	2015	Manufacture of frames and other joinery. Construction of green houses	
	Menara Ponce	contact@menaraponce.com 212 (0) 524 49 99 0	2013	Blocks made from pumice stone, a volcanic stone known for its insulating properties, its extreme lightness and its resistance.	Production of PonceBloc.
	CMPE	http://www.cmpe.ma/ (+212) 522 40 22 72	1994	Producer and exporter of plaster and gypsum	—

Country	Company	Contact	Date of Creation	Activity	Examples of projects achieved
	EXCELOGE	Dr Al Caid Harbil - Marrakech-Médina (AR)	2016	Designer. Builder in Morocco of bioclimatic metal frame houses.	
Burkina Faso	teco2	0 BP 3887 Ouagadougou 01 Ouagadougou - Burkina Faso http://tecocarre.com/ info@tecocarre.com (+226) 79 07 13 80	1996	Production of roofing composed of low-cost recycled plastic matertials that keep temperatures within the home comfortable.	School benches made from plastic waste and other locally sourced input materials.
	ECOCO	claudetayo1@gmail.com (+226) 57 10 18 31	—	Modular construction site forms made from a mixture of recycled plastic and sand.	—
Egypte	Schaduf	https://schaduf.com/landscape-design/ sara.kamal@schaduf.com (+20)-100-637-0838	2011	Construction of green walls.	—
	Green Build Egypt	https://www.greenbuildegypt.com/home info@greenbuildegypt.com	—	Innovative materials, that meet and solve problems in the Construction Industry.	Al Guezira Plaza. Ki Wellness 1 Spa.
Nigeria	Teku International Farm	Ibrahim Salisu	—	Construction of buildings using bamboo stems	Started the construction of the first building with bamboo, in the area of Unguwan Sarki at the center of Kaduna.
Tunisia	SICAP	http://www.sicap.com.tn/ Conulting@sicap.com.tn (+216) 71510224	2001	Landscaping. Green roofs and walls. Maintenance. Pruning, Pollarding, Slaughter. Landscape masonry. Swing.	Phenicia Hotel
Morocco, Algeria, Tunisia	ISOVER Saint-Gobain	https://www.isover-maghreb.com/ 00212 522 66 57 31/32	1993	Innovating Solutions for High Energy efficiency. Manufacturing of Isolating Materials.	—
	PAREXLANKO	https://www.parexlanko.com/ 0 826 08 20 20	—	PARNATUR hemp plaster body. Bio-based two-component solution for exterior and Thermal insulation.	—

3.1.3 Green projects in Africa

In this paragraph, we are discussing concrete successful projects achieved in Africa. Unfortunately, we cannot cover all the projects. Yet, these picked ones offer an example where the bioclimatic construction concept is well respected.

La Maison des Yvelines / Yvelines House - Senegal

Rewarded in COP23, Yvelines House is an achievement by the L'Association Voute Nubienne (AVN), the non-governmental organization Le Partenariat and the company Habitat Moderne, in Ourossogui.

Figure 15: Yvelines House

The construction has been made by the Nubian Vault (NV) technical concept which; an ancient architectural technique that uses local sourced raw materials (mud bricks) and simple tools. It does not require a high qualified technical competence. It provides a solution for affordable and well-adapted buildings suitable for private and community use, in both rural and urban settings. Thus, the building make it fully meets sustainability practices.

Details of this construction practice are shown in D3.3. The image below shows a construction site for the Nubian Vault.

Figure 16: NV Building site of the Artisanal Production Unit in Niéna (Mali) / Source: AVN

Villa Janna Ecolodge - Morocco

Africa's largest eco-friendly complex that is built using rammed earth and mud bricks. The building uses renewable energies by integrating water treatment, solar energy, waste recycling. The construction has been achieved in 2015 and it is located in Marrakech.

Figure 17: Villa Janna Ecolodge

Let's build my school

An initiative launched by a group of architects who aims to build schools in underprivileged areas. They use local materials as soil, sand and clay to ensure a low-cost construction and a good environment for students and teachers. They are trying to come with innovative methods of constructions. Figure 18 shows a site in NGEKHOKH in 2016.

Figure 18: Building a school in Ngekhokh / source: https://www.letsbuildmyschool.org/

3.2 In EU

3.2.1 Companies active in production of construction materials

A non-exhaustive list of these existing manufacturers and actors in bioclimatic constructions and material in EU is presented in Table 3-5.

Same as Africa, EU is facing the same difficulties; the construction with bioclimatic materials and their manufacturing are too weak to support the global transformation, coordination between companies is absent, communication is not enough.

The particularity in EU is that:

- companies are more organized, and we can find much more techniques of manufacturing and construction which all based on previous scientific works.
- We also notice that there is a growing market for sustainable buildings because of the awareness raising in European community. We also found that there is some companies of consulting in the field of green construction, this is an important step, because the existence of trained professionals in the field will encourage constructors to build bioclimatic building.
- The lack of regulations represents a real limitation of this type of constructions
- Training and new programs in bioclimatic construction will certainly develop the field and give it a real boost.

Table 7: A non-exhaustive list of green and bioclimatic construction manufacturers in EU

Country	Company	Contact	Activity	Examples of projects achieved
Spain	MALPESA	https://www.malpesa.es/en/empresa.jsp malpesa@malpesa.es +34 953 67 07 11	Ecological bricks construction.	Gallery of projects: https://www.malpesa.es/pdf/publicaciones/Catalogo-Malpesa-2020-Edicion-digital.pdf
	SH Construcciones	http://www.sh-construcciones.com/ info@sh-construcciones.com +34 617 466 295	Ecological construction.	WEBER PRAL ECO CLIMA A dry mix pre-coloured lime-based mortar. Benefits include water resistance, low contraction and no painting low maintenance. RENDERLATH A purpose made three-layer mesh system consisting of a backing plastic sheet with slow moisture release paper layer behind the mesh wires
	Grupo Diaz Redondo	http://www.grupodiazredondo.com/en/index.html hdr@hdr.es +34 925 55 11 09	Ceramic products. Ecological tiles and bricks constructions.	Gallery of projects: http://www.grupodiazredondo.com/en/proyectos/
	Palaualpicat	http://www.palaualpicat.com/esp/gamas.html info@palaualpicat.com +34 973 73 60 00	Manufacturer/ Producer, which operates in the Bricks industry (Ecological).	Gallery of projects: http://www.palaualpicat.com/descargas/CATALOGO_PALAU.pdf
Portugal	valegandara	http://www.valegandara.com/contactos valegandara@valegandara.com +351 231 927 300	Clay Paver. Garden Paver.	—
	CERAMICA TORREENSE DE MIGUEL PEREIRA,SUCESSORES,LDA.	Rua Fábrica, Nr. 1 2565-601 Outeiro Da Cabeça	Ecological Roofing materials.	—
France	AKTA BVP	http://www.akta-bvp.com/ AKTA – BVP 22 rue de Kerentre, 56150 BAUD – FRANCE +33 (0)2 97 39 70 44	Projected Vegetable Concrete Half-timbering, wood frame, straw construction. internal/ external thermal insulation systems.	Single-family timber frame house - Sloveni, House in Straw Bales and insulating jacket in Projected Vegetable Concrete® Brec'h (56),
	Baumer Chanvre	https://baumer-ereasy.business.site/ 13 rue de l'Industrie, 25410 Saint-Vit	Hemp, Lime, Natural Cement Promp. Masonry and Renovation. Research and development of solutions for the application of hemp concrete in construction.	—
	VICAT	https://www.vicat.com/ +33 4 74 27 59 00	Biosourced Biosys.	—

Country	Company	Contact	Activity	Examples of projects achieved
		4 Rue Aristide Bergès, Les Trois Vallons 38080 L'Isle-d'Abeau, France /	Cement plants, aggregates, quarries, concrete plants, finishing products factories Hemp concrete.	
	NEOLITHE	https://neolithe.fr/ 5 rue des Ateliers, 49290 Chalonnes-sur-Loire, France	Aggregate with negative carbon impact that can be used in concrete made from non-recyclable household waste.	—
	MATERR'UP	https://materrup.com/ (+33) 5 58 55 59 57	It develops and produces structural and cooling concretes from a patented clay cement. The purpose of these "green concretes" is to decarbonize construction.	Construction of its first pilot plant in 2021 with its clay concretes.
	AGILCARE	https://www.agilcare.co/ (+33) 6 95 29 06 49	Buildings built with Nano, pre-fabricated, wooden and eco-friendly elements that can be assembled and disassembled and do not generate waste.	Construction of the largest 3D printed bridge in the world.
	XtreeE	https://xtreee.com/en/ (+33) 6 80 45 54 12	Develops construction systems in clay and concrete 3D printing. 3D printing makes it possible to reduce the consumption of cement in construction by up to 70%, as fabrication of cement generates 8% of global CO2 emissions.	—
	Karibati	http://www.karibati.fr/ (+33) 6 12 33 11 65	Provides Bio-based materials for construction.	—
	RC BOIS CONCEPT	1129 RTE DE NALLETIERE 38470 COGNIN-LES-GORGES France	Frames, roofs, the installation of your Velux roof windows and a whole range of extensions. Ecological thermal and sound insulation	—
	ALFI TECHNOLOGIES	https://www.alfi-technologies.com/en/	Building materials production (Heavy clay, insulation, concrete, boards).	—
Belgium	Chanvreco SA	chanvreco.be Tinlot, Walloon Region, Belgium +320477600325	Hemp aggregates (cultivated in Belgium) for construction (lime-	—

Country	Company	Contact	Activity	Examples of projects achieved
			hemp mixture) and intended for the insulation of buildings.	
	LEBAILLY	pierre.flament@lebailly.eu +32 (0) 65 620 052	Mud-Brick products, clay coatings; Hautrage Stoneware and the Factory Slabs using local clay and fireclay. Alumino-silicate refractory products: BAUXIC 60 product with a silicon carbide additive. The addition of silicon carbide to a refractory alumina notably improves its resistance to corrosion and its mechanical resistance to abrasion	—
	ECOBATI	https://www.ecobati.com/en +32 4 246 32 49	thermal insulation and sound insulation and in the field of ecological decoration (paints, oils, stains, floors and marmoleum, clay and lime plasters ...).	—
	BIOCONSTRUCT	https://www.bioconstruct.com/ info@bioconstruct.de +49 5226 / 5932 – 0	Passive houses and low-energy wood-frame houses that respect the environment.	Gallery of projects: https://www.bioconstruct.com/biogas-examples-overview/
	ECO-LOGIS	https://www.eco-logis.com/?lang=en +32 81 43 58 65 rue du Warichet 2 5081 Meux	Organic paints and thermal insulation materials and phonic natural.	—
	PU Europe	https://www.pu-europe.eu/ secretariat@pu-europe.eu + 32 2 786 35 54	Sustainable construction with highly thermal efficient and extremely durable construction materials, promoting buildings' green renovation.	—
	LA MAISON DE DEMAIN	https://lamaisondedemain.be/ +32 61 53 39 62	Buildings with a low ecological footprint. The use of sustainable materials such as wood and the KLH panel construction technique (laminated solid wood panels) make them so-called ecological constructions.	Gallery of projects: https://lamaisondedemain.be/inspirations/

Country	Company	Contact	Activity	Examples of projects achieved
Italy	Schönthaler OHG	https://www.hanfstein.eu/home-english/ info@schoenthaler.com +39 0473 739 937	HEMP-LIME-PLASTER. Hempcrete.	—
	Nordtex	https://www.nordtex.it/ info@nordtex.it +39 0472 84 71 10	Clay blocks filled with wood fiber. Clay blocks filled with mineral granulate. Clay blocks filled with rock wool. Normal clay blocks. Sheep's wool. Straw, husk and rice husk. Hemp panels.	—
	DIASEN Green Building Future	https://www.diasen.com/ diasen@diasen.com +39 0732 971818	Thermal and acoustic insulation: Use of cork, clay and diatomaceous earth for their thermal and acoustic insulation properties and hygroscopic characteristics, with the addition of natural hydraulic lime, waterproofings, and coating.	—
	MOGU	https://mogu.bio/ enquire@mogu.bio	Flooring: floor tiles consist of a mycelium composite core coated with a bio-based resin of 90% bio-based products such as corn crops, rice straws, spent coffee groungs, discarded seaweed and clam shells.	Flooring: floor tiles consist of a mycelium composite core coated with a bio-based resin of 90% bio-based products such as corn crops, rice straws, spent coffee groungs, discarded seaweed and clam shells.
	MALVIN s.r.l	https://www.malvinsrl.com/en-gb/home amministrazione@malvinsrl.com +39 0818132780	Thermoisolating, Bioplastar (Natural Hydraulic Lime and Sugar Grain Base). Eco-compatible, bio-mortar products: natural lime and biopozzolan base and NHL base. Anti-fire insulation, Anti-fire protection, Soundproofing Roof ceiling Slabs.	—
	Naturalia BAU	https://naturalia-bau.it/it/prodotti/argille/ Tel: +39 0473 499 050 Fax: +39 0473 499 060 info@naturalia-bau.it	The manufacturing of the company clay brand Naturaclay board and	—

Country	Company	Contact	Activity	Examples of projects achieved
			stones. In addition to clay panels of D/15, D/20 and D/25.	
	La Banca della Calce srl	https://www.bancadellacalce.it/bdc/ info@bancadellacalce.it + 39 051 4842426	Full set of products and solutions for the construction: thermal-plasters, blocks, interspaces, external insulations, roofs, foundations, finishing and pastel color washable paints, based on hemp.	—
	Equilibrium Srl	https://www.equilibrium-bioedilizia.it/it info@equilibrium-bioedilizia.com + 39 800 172553	Green construction. Hempcrete, Natural Beton, Natural Lime Plaster, Natural Breathable Stabilization, Natural Dolomite Binder.	Capriate san Gervasio (BG) - Coat with Natural Beton® 200 of hemp and lime.
	Senini srl	https://www.senini.it/en/ Senini@senini.it + 39 030 9665711	Lime-Hemp construction system for green building.	—
	Edilcanapa srl	https://www.edilcanapasrl.it/ info@edilcanapasrl.it +39 085 8421848	Hemp based materials: Bio mortar, Thermal plaster, Finishing plaster, Blocks and Insulating screed.	—
	MANIFATTURA MAIANO spa	http://www.maiano.it/ maiano@maiano.it +39 055 894071	Hemp fiber panel.	—
	NAFCO Napoli (NA)	Via Emanuele Gianturco, 23 80146 - NAPOLI +39 081 5636417	Hemp fiber panel.	—
	MGN srl	www.mgnintonaci.it info@mgnintonaci.it +39.0445.576402	Plasters	Gallery of projects: https://www.mgnintonaci.it/realizzazione/
Netherlands	Fiction Factory	https://www.fictionfactory.nl/en/who/company/ (+33) 0 20 635 24 24	Sustainable and circular projects.	In 2016, the company launched Wikkelhouse a modular building system made of cardboard components, which comprises a series of interlocking cardboard segments that each weight 500 kg and can be assembled in just one day.
	Space&Matter	http://www.spaceandmatter.nl/	Design of places that people love to call home and that improve the health of the planet.	Schoonschip: A sustainable floating neighbourhood in the North of Amsterdam.

Country	Company	Contact	Activity	Examples of projects achieved
Slovenia	RIHTER D.O.O.	https://www.rihter.eu/ info@rihter.si +386 3 839 04 30	Construction of buildings using ecological materials, including wood which is the basic construction material. Custom-made houses and buildings.	—
Slovakia	ECOCOCON	https://ecococon.eu/ info@ecococon.eu	Buildings that are made of renewable materials, and would last decades before being returned safely to nature after use. Buildings that would contain healthy, locally sourced materials and leave a minimal ecological footprint.	Gallery of projects: https://ecococon.eu/projects
Germany	GLAPOR WERK MITTERTEICH GMBH	https://www.glapor.de/en/ +49 9633 4007690	Foam glass slabs and foam glass gravel from our own manufacturing plants. The combination: GLAPOR perimeter insulation formwork and foam glass gravel.	Gallery of projects: https://www.glapor.de/en/referenzen/
	ClayTec	https://www.claytec.de/en# service@claytec.com +49 2153 918-0	Clay plasters, clay drybuilding, heavy clay products, and internal insulation.	Gallery of projects: https://www.claytec.de/en/references?
Norway	Kebony	http://www.kebony.com/ info@kebony.com	Transformation of sustainable wood species such as pine into finished products with characteristics comparable—and in some cases better-performing—to those of precious tropical hardwoods.	The Forestale: Luxury Ecolodge made using Kebony wood - ACQUALAGNA, ITALY
Czech Republic	ERC-TECH	https://www.erc-tech.eu/ info@erc-tech.eu (+420) 603 201 285 (+420) 777 755 123	ERC-TECH “Effective Recycling Concrete Technology”. Turning up to 100% of waste into raw materials and first-class products with a wide range of product applications in construction industry with a major environmental benefit.	Developed know-how patent. It consists of concrete a dry mix for the preparation of concrete, and a method for preparing this concrete from 100% recycled aggregates lower cement content in basic design, further in combination cement with GGBS, Fly Ash and others alternative binders.
Austria	Binder+Co	https://www.binder-co.com/ office@binder-co.at (+43) 3112 800-0	Treatment and recycling of valuable primary and secondary raw materials. The company offers	The latest innovation is the so-called BUBLON plant for the production of “perlite popcorn”. This new material is used in the construction industry thanks to its outstanding insulation properties.

Country	Company	Contact	Activity	Examples of projects achieved
			crushing – screening – wet processing – thermal processing – sorting – bagging and palletizing.	
Spain and France	Terreal	https://terreal.es/ support.technique@terreal.com +34972488700	Ecological tiles Bricks constructions.	Gallery of projects: https://terreal.es/fileadmin/MediaPIM/Documents/Guide%20produit/Couverture/TERREAL-Guide-Produits-Canal-Grands-Moules-Du-Sud.pdf
Poland - Belgium- Denmark- Germany- Nederland	IRBIS Thatcher	http://thatching.pl/ irbis@thatching.pl +48 501 517 490	-Thatch, rethatching. -Provides addictional thermal insulation to the roof surface. -Analysis ofwooden construction to meet required parameters for the reed roof. -Service of thach: fire protection, moss cleaning, reed compaction, ridge replacement, wind-up repairs, roof remodeling, chimney repairs.	Thatch Renovation in KARPACZ in 2016 Poland- Thatch in POLFIBRA system in 2012 Poland- Thatch with Home Modernization in AALSRODE in 2005 demark
Spain, Italy and France	Hemp Eco System	https://www.hempecosystems.org/	Wall insulating mix. Thermal insulation. Plaster.	—

3.2.2 Active organizations in bioclimatic constructions and materials

We have been able to list some of the main NGO's, consulting firms, and not-for-profit organizations acting in bioclimatic constructions and materials in EU. The list is presented in Table 3-6.

Table 3-6: A list of NGOs working in bioclimatic constructions and materials in EU

Country	Company	Contact	Activity
Belgium	MODERN BUILDING ALLIANCE	Phone: +32 (0)2 792 30 39 info@modernbuildingalliance.eu https://www.modernbuildingalliance.eu/contact/ https://twitter.com/ModernBuildEU?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor	Supporting the EU in ensuring safe and sustainable construction for people across Europe mainly about the plastic industry in the construction sector.
	CPEA (Climate Positive Europe Alliance)	nfo@cpea.eu +49 711 722322-28 https://www.cpea.eu	Accelerate the market transformation towards more sustainable market practices by facilizing the flow of dialogue between the interested associations and providing insights and solutions for challenges faced by the construction and real estate owners' community.
	The concrete Initiative	communications@cembureau.eu https://www.theconcreteinitiative.eu/about-us/contact-us	A project that examines the economic, social, and environmental implications of sustainable construction and the need for a balances approach. It mainly shows that including concrete in sustainable constructions can help solving Europe's challenges.
Germany	DGNB (German sustainable building council)	+49 711 722322-0 Fax +49 711 722322-99 info@dgnb.de https://www.dgnb.de/en/council/association/ https://twitter.com/dgnb_ev https://www.linkedin.com/company/dgnb-german-sustainable-building-council/	Promote sustainability in construction and real estate industry and inspire awareness of buildings sustainability in a wider range of population).
	REM ASSETS	+49 (0) 711/203 796 22 https://www.rem-assets.de/leistungen/ https://www.linkedin.com/company/rem-assets-unternehmensimmobilien-ag/?originalSubdomain=de	A company that provides real estate consulting services related to the environment to property owners and builders through the entire life cycle of the property.
Austria	ÖGNI(Austrian Sustainable Building Council)	office@ogni.at +43 664 15 63 507 https://www.ogni.at/ https://www.linkedin.com/company/%C3%B6gni-%C3%B6sterreichische-gesellschaft-f%C3%BCr-nachhaltige-immobilienwirtschaft/	An NGO that aims to show the added value of creating an environmentally and resource-saving buildings to reach higher economic and social efficiency.
	REEEP (Energy and Energy	+43-1-26026-3425 See map: Google Maps info@reeep.org	International organisation that advances markets for renewable energy and energy

	Efficiency Partnership)	https://twitter.com/REEEP	efficiency with a particular emphasis on the emerging markets and developing countries.
Spain	GBCe (Green Building Council España)	+34 91 411 98 55 info@gbce.es https://gbce.es/	An NGO that gathers representatives from the entire industry to enhance the collaborations in the sector through promoting events, providing education, studies, and breaking news concerning sustainability.
Netherlands	Natural home project	**email:** house@naturalhomes.org **https://twitter.com/naturalhomes** **skype:** naturalhomes	A not-for-profit organization that consults its audience about using natural materials for living a healthy lifestyle.
		Talking natura homes https://www.facebook.com/groups/naturalhomes/	where they discuss natural buildings materials, methods, and architecture,
		Kitchen Table https://www.facebook.com/groups/naturalhomes kitchen/	exchange knowledge and experiences about natural living
		Permahome https://www.facebook.com/groups/perma home/	discuss the design, techniques, land, and social issues related to sustainable living and lifestyle.
EU	McKinsey Sustainability	https://www.mckinsey.com/business-functions/sustainability/ https://twitter.com/mcksustainable	A consulting company working with ESG advisors to lead its clients towards a wave of innovation and economic growth that advances sustainability and safe the environment.

4. Final conclusion

During the preparation of this report, deep investigations on infrastructure, for bioclimatic construction and production of bio and geo-sourced materials in N-W Africa and EU, are carried out within the help of our partners in different countries. The access to this kind of information is very difficult since the sources of data are absent. The added value of this work is that it offers the possibility to the public to have an easy access to the gathered and structured information.

As conclusion, this field is very promising and can offer affordable and comfortable houses, creates new jobs, and protects the environment. However, several crucial constraints limit its development. The main limitation is a lack of communication and advertising strategies for this type of constructions and materials. In addition, we observed that there is a need of developing new technologies that can optimize the time of production and manufacturing process of bioclimatic construction and materials. Furthermore, there is an increasing need to develop a solid supply chain specific to this field.

Historically, most of constructions in rural regions in Africa were traditionally eco-bioclimatic structures. Nowadays, most rural regions inhabitants choose to switch to concrete-based construction since they consider them more modern as well as presenting alternative solutions for the weaknesses of their traditional bioclimatic constructions. To solve this problem and convince the inhabitant to continue using their traditional constructions, more eco-bioclimatic model constructions should be developed, that should demonstrate that it is possible to build modern and affordable bioclimatic constructions using local materials able to withstand harsh outdoor environmental conditions.

Another limitation worth mentioning is that most of companies in Africa are specialized only in construction activity and most materials are produced locally in site. Thus, the knowledge remains limited at the company level and the time of construction is too long. On the other hand, we have observed the existence of specialized companies in the production of bioclimatic materials in EU, consequently decreasing the energy and time devoted to construction.

The database showed limited number of companies found in Africa as most of active companies in the construction field are not legally registered, making the informal sector a very dominant one in Africa. In addition, depending on the outdoor environment in each specific region of Africa, stone construction or earth construction are the most common.

We believe that academic support via the creation of programs related to bioclimatic construction and material is very crucial to promote collaborations and provide the bridge between the academic and industrial sector. This will result in the creation of new start-ups as consulting and production companies to find solutions and alternatives for identified constraints and limitations and promote a growth and development in the construction sector in Africa.

The sequel of this work is Report D3.7, which will emphasize more on bio-climatic and construction materials in EU and Africa, including their technical and financial aspect.

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