# SUSTAINABLE DESIGN STRATEGIES IN ARCHITECTURAL CONSTRUCTION, FOCUSING ON BIOMATERIALS AND THEIR APPLICATIONS FOR THE GOALS OF THE 2030 AGENDA

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ABSTRACT

This paper is an attempt to raise awareness among the scientific community regarding biomaterials and innovative technologies that may contribute to the vision of sustainable cities of the future and the achievement of the goals of sustainable development of the United Nations (UN). It focuses on the 11th sustainable development goal, which urges us to create resilient and sustainable cities without poverty and exclusion. The methodology followed is both the secondary research of the problem through an analytical literature review and other elements, as well as the primary research through five case studies in Greece, which are consistent with the strategies proposed by the authors to achieve the UN's 11th sustainable development goal, which urges us to create resilient and sustainable cities, free from poverty and exclusion. Thus, five indicators were developed with sub-criteria covering various dimensions of the subject, such as: 1. Performance of biomaterials; 2. Architecture and design; 3. Circular economy; 4. Resilience to changing climatic conditions; and 5. Community participation in decision-making. At the same time, the authors interviewed eight Greek architects who have integrated biotechnology and digital construction into their projects. Each indicator was assessed against qualitative criteria and case studies were selected based on these indicators. The purpose of this thesis is to explore the connection between biomaterials and technology in architectural construction as a design philosophy that can lead to a more efficient design, which will reduce and deal with the dramatic effects of climate change. It aims to learn from the principles of the circular economy and incorporate this knowledge into the development of new structures and the transformation of existing ones to understand the importance and impact their application can have in achieving the 11th goal of the 2030 agenda.

*Keywords: biomaterials, low-carbon building materials, circular economy, modern construction technologies, passive energy systems, sustainable urban planning, biomimicry, UN sustainable development goals, 2030 agenda.*

## 1 INTRODUCTION

The building sector is accountable for 38% of all energy-related $CO_2$ emissions, including emissions from the building construction industry, according to the United Nations (UN)'s 2020 'Global Status Report for Buildings and Construction' [1]. Reducing the amount of $CO_2$ in the atmosphere significantly is necessary to limit global warming to a 1.5° rise. The substantial pledges made by politicians to cut greenhouse gas emissions associated with the built environment are essential to achieving the objectives of the Paris Agreement. The quantity of resources utilised during the building and operation stages, the materials chosen, and how those materials were extracted, produced, and consumed are some factors that affect the emissions linked to the construction industry. Humans suffer from the manufacture and use of energy-intensive mineral-based building materials, as well as from climate change.

The design and construction of intelligent, sustainable, and responsive environments are now possible thanks to developments in material science, computation, and digital technologies, as well as the re-examination of conventional building materials. A model of materially responsive architecture has emerged over the past 20 years because of research and applications of novel materials as well as digital technologies like digital manufacturing,

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ubiquitous computing, and artificial intelligence, among others. This model offers special opportunities for creating novel performances and behaviours in the architectural space. Our future cities will undoubtedly have a thick layer of dispersed sensors, actuators, and digital interfaces, but they will also have a top layer of new materials that are pliable and soft instead of hard and rigid, that can sense like sensors, actuate like motors, and be programmed like software. As a result, the city's physical area becomes the smooth blending of material and digital content, fostering a dynamic interaction between the built environment, ongoing human needs, and the environment [2].

According to the above, the buildings and construction sector is the largest emitter of greenhouse gases, accounting the 37% of global emissions. The production and use of materials like cement, and steel, have a significant carbon footprint. Historically, much of the sector's progress has centred around reducing the 'operational' carbon emissions of buildings, from heating, cooling, and lighting. Projections suggest that these operational emissions will decrease from 75% to 50% of the sector's total emissions in the coming decades. A report, 'Building Materials and the Climate: Constructing a New Future', developed by UNEP, Yale Center for Ecosystems and Architecture in the framework of the Global Alliance for Buildings and Construction, highlights the pressing need to establish innovative cooperation models to decarbonise building materials. These models are critical for achieving the world's ambitious target of net zero emissions from the built environment sector by mid-century. The report also pinpoints three overarching strategies that need to be implemented together to decarbonise building materials: (i) Avoid unnecessary extraction and production; (ii) Shift to regenerative materials; and (iii) Improve decarbonisation of conventional materials. By implementing these strategies jointly, we can pave the way for a greener, more sustainable built environment, aligning with our global climate objectives.

Chen et al. [3] states that using bioplastics, biocomposites, bio cement, geopolymers, mycelium- and cellulose-based materials in construction offers several benefits, such as increased sustainability, a reduced carbon footprint, and improved indoor air quality. However, there are obstacles to their general use, including as high production costs, conformity to industry standards, and strict regulatory compliance. These biomaterials have the potential to significantly reduce resource use, promote a circular economy, and encourage more environmentally friendly building techniques when incorporated into construction. More precisely, bioplastics – which are made from renewable materials like corn, sugarcane, and algae – provide an environmentally friendly substitute for plastics made from petroleum. Their biodegradability lessens their environmental impact while simultaneously reducing plastic waste, according to Oberti and Paciello [4]. Additionally, biocomposites are strong, lightweight materials that are ideal for interior finishes and structural parts. These materials are created by combining natural fibres like hemp, bamboo, flax, or kenaf with biopolymers. According to Ahmad et al., they are essential in preserving resources and reducing the need for traditional materials [5]. Furthermore, biocement reduces carbon emissions during manufacture by enhancing cement characteristics with biological additives or microorganisms. According to Gebru et al., geopolymers have a smaller carbon footprint and environmental impact than regular Portland cement since they bind using waste materials or industrial byproducts [6]. Furthermore, Alemu et al. state that mycelium-based materials are grown in moulds using the root-like structure of fungi to create biodegradable and lightweight structures. These structures can be used for packaging, furniture, and insulation panels, supporting the concepts of the circular economy [7]. Moreover, cellulose-based materials are utilised for acoustic panels, cladding, and insulation. They are generated from plant cell walls. According to Kausar et al., they lessen their negative effects on the environment while increasing energy efficiency and indoor air quality [8]. Additionally, Choi et al. discovered

 
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that using composite boards made from coffee waste in wood structures resulted in a 4%–9% decrease in heating energy consumption for the buildings [9]. Furthermore, after 28 days of curing, eggshell powder-added concrete samples had a water absorption rate of 1.62 ± 0.16%, which was 40% lower than the control group, according to Niyasom and Tangboriboon [10]. Furthermore, hydrangea stems are used as a building material for insulation. Therefore, lowering the need for polyurethane in buildings aids in lowering its production, preventing the production of wastewater and exhaust gases during the manufacturing process [11]. According to Menon et al. [12], the process of biologically and organically mediated mineralisation, which results in the precipitation of calcium carbonate, is induced by using fungi to heal concrete cracks.

In a more detailed study on the use of mycelium in construction, it was discovered that while mycelial composites can be made inert by heat treating them to kill the mycelium, living material has the potential to produce new active properties like self-healing, self-repairing, and partial self-organisation. Therefore, while there are many benefits to employing materials derived from fungi, it might not be essential to fully abandon conventional building materials. It is quite probable that building in the future will be an integrated process that enables architects to simultaneously utilise conventional and bio-based materials. By using mycelium-based building materials, new technical, aesthetically pleasing, and environmentally friendly building solutions are possible. These solutions, which create an alternative paradigm to the state-of-the-art ‘intelligent buildings’, which heavily rely on technical infrastructures, are made possible by biologically based functionalities like self-regulation, adaptation, autonomous growth, and self-repair. New design, planning, and construction techniques that consider the material’s characteristics throughout a building’s life cycle as well as fungi that have precisely controllable physical properties – like load-bearing capacity, diffusion properties, and fire resistance – are needed to introduce these materials into the construction industry [13]. Planning techniques have changed significantly because of the expansion of computerised design possibilities, which has bolstered advancements in the field of fungal architecture. Digital planning tools have expanded the diversity of architectural design language. New, material-efficient, or – for design reasons – free-form components are possible, particularly when working with volume materials like mushrooms, where the components are made in a ‘shaping’ formwork process rather than in a ‘material processing’ method.

The main research question of this paper is whether the use of biomaterials and biomimetic design strategies, assisted by modern innovative construction methods, can lead to constructions that will absorb carbon dioxide emissions to face the numerous challenges of climate change. According to the structure of this research, after the literature review, design strategies with innovative technologies that change the way we plan for the climate are presented, concerning the 11th goal of sustainable development of the UN, which urges us to design cities safe, durable and sustainable. Following is the methodology which is based on the qualitative analysis of primary material through interviews with distinguished architects and finally the conclusions of the research are listed.

## 2 DESIGN STRATEGIES AND BEST PRACTICES

The use of biomaterials to address climate change is recognised in the 11th sustainable development goal of the UN, which seeks to provide decent and affordable housing for all. In this context, the demand for green construction materials is becoming increasingly intense because of the worsening environmental impacts of current material production practices. If new urban areas could store carbon rather than emit it, they would be more effective at curbing climate change and reducing climate disasters like floods. Consequently, the best practices were selected, based on the strategies for achieving the 11th goal of sustainable development of the UN.

### 2.1 The biomimicry paradigm

According to the architect Pawlyn, studying the assembly of materials in biology has many advantages, such as low-energy production with locally available materials, the absence of persistent and bio-accumulative toxins, and closed-loop interconnections that permit everything to be reused. Thus, inventive carbon sequestration systems serve as examples of the biomimetic paradigm's dynamics. Biomimicry is a vast and largely unexplored source of ideas that can help us solve some of the most difficult problems facing humanity today. These ideas include how to rethink waste as a concept and find ways to save enormous amounts of water, energy, and materials while still creating beautiful solutions that have the potential to heal our relationship with other living things [14].

'Bioconcrete' is a new substance developed in response to the increasing global $CO_2$ emissions caused by concrete production. It is a type of self-healing concrete to which biocement, an environmentally friendly main ingredient, has been added. This substance is only active when water is present and can lie dormant for many years. Thus, in modern culture, bio concrete, produced through microbially induced calcite precipitation can be a good substitute for environmentally friendly building materials [15].

### 2.2 Sustainable 3D printing constructions from agricultural waste

In line with UN sustainable development goal 11.10, which calls for financial and technical support to less developed nations so they can construct long-lasting, sustainable structures out of local resources, this article recommends as best practice the use of biomaterials made from recycled agricultural waste.

Case study: GAEA Products S.A.: In Greece, some constructions use agricultural waste as raw materials. An example is the use of dried olive as a material for making furniture or decorative items. Also, some units exploit agricultural waste for energy production, such as through biomass or biogas. These initiatives combine sustainable waste management with the creation of products and energy, thus promoting the circular economy. An example of a company dealing with this way of recycling and using agricultural waste is the company 'GAEA Products S.A.', which produces and markets products such as furniture, lighting, and decorations from dried olives.

### 2.3 Solutions incorporating nature in urban environments

Target 11.7 of the UN's sustainable development goals calls for ensuring that everyone will have access to secure, inclusive, and accessible green and public places by 2030. Green wall solutions are essential to the search for more sustainable buildings made of long-lasting materials with lower environmental impact, better financial performance, and circularity. They also help to mitigate the heat island effect that occurs in large urban centres.

Case study: Gatsby Athens Hotel, Architectural office WOA*:* The structure of the building was preserved as is, with the only essential addition being the intense planting on the different levels of the facade. The vertical gardening installation manages to reduce $CO_2$ levels, increase oxygen production, and improve air quality. It works sound-absorbing and at the same time thermally insulating, improving the overall energy efficiency of the building volume. It has been estimated that for every square meter of greenery, at least 300 g of $CO_2$ is removed, which can remove up to 6 cubic feet of $CO_2$ gas per year [16].

### 2.4 3D-printed low-carbon concrete

By tying in the 11th sustainable development objective of the UN with the several ways to accomplish $CO_2$-free architecture, we selected strategies that support energy efficiency and reconstruction with new technology while also favourably impacting environmental sustainability. More specifically, the UN's sustainable development target 11.1 states that the objective is to guarantee everyone's access to appropriate, safe, affordable housing and the renovation of slums until 2030. Low-carbon concrete solutions combined with 3D printing technology offer a tremendous potential to decarbonise buildings and achieve speed and economy in construction, ensuring that everyone has access to secure and cheap housing. This kind of concrete can be used in circular construction because it is entirely recyclable and produced locally. They combine a low carbon footprint with circular benefits by incorporating recovered trash from construction and demolition projects. By using them, $CO_2$ emissions can be decreased from the market reference by at least 30%. Also, the use of expertise software, can measure and reduce embodied carbon from pre-design to practical completion, and enhance the sustainability of Architectural projects. Achieve sustainability goals, such as delivering net-zero projects or carbon reduction, delivering whole building life-cycle assessments, earning green certifications, meeting global and national regulations, or improving projects for circularity, life-cycle cost, and biodiversity [17].

Case study: The SPOT building, Greece, Lafarge +Pieris Architects, 2023: 'The SPOT' building aims for the minimum environmental footprint in its life cycle. Based on the circular economy principles, building materials with a low carbon footprint and high energy savings were used to construct the project. This is the first building in Greece where robotic 3D concrete printing technology was applied on a real scale [18].

### 2.5 Natural materials

Natural materials can be described as raw materials that only require minimum processing before their application and can be obtained from plant, animal, or mineral sources [19]. In addition to their availability and direct utilisation – like most woods – natural materials may exhibit some key properties for sustainability, such as having a renewable origin if properly managed.

Case study: Seliana, Greece: Re-Green is a permaculture centre located in Mount Corinthia, aiming to actively experience the power of green living. Re-Green means reusing and recycling materials, reducing waste, rethinking and re-modelling, and redesigning. It embodies sustainable living and energy saving. In this case study, the construction of Maloca, a circular hall of 101 $m^2$, with natural construction, was analysed. It was built by hand, with reusable, organic materials, mainly clay, sand, straw, stones, and wood. The frame was made of wood and straw, which were mixed with mud, stabilised with linseed oil, and waterproofed with beeswax. Different construction techniques have been used for each wall that serves different purposes depending on the orientation. One wall was built with straw bales, another with earthbags and clay with straw, as well as cordwood and brick. Glass bottles are inserted into the surface of the walls, which allow light to enter the structure. These are six examples of physical buildings in a 100 $m^2$ structure [20].

## 3 METHODOLOGY

According to Schwandt, a paradigm is a shared worldview that represents the beliefs and values in a discipline and that directs how problems are solved (Schwandt 2001, cited in Chilisa and Kawulich [21]). Choosing a research paradigm was the first step toward developing the methodology of the study [21]. The selected paradigm influenced the research's methodological approach and, in the end, determined the techniques for data collection that would best address the study's research questions [21].

### 3.1 Research design

The research aimed to reveal the strategic importance of biomaterial usage in architectural constructions to lead to the decarbonisation of future constructions for a circular economy, considering the opinion of Greek architects who live and work in Greece or abroad. Thus, the study was informed by the constructivist/interpretative paradigm. Constructivism and interpretivism are related concepts that address understanding the world as others experience it [21]. For this aim and the individual objectives of the study to be addressed, both primary and secondary research was used.

Primary research methods can be quantitative, qualitative, or mixed approaches; they deal with data that is collected initially and generated by an analysis done for a specific study [22]. A qualitative research strategy was taken in this study because, as Groat and Wang [22] point out, this kind of research is especially useful for gaining deep insights and comprehending the experiences, perspectives, and motivations of people working in a certain sector. In this essence, it was the best research methodology for this study since it allowed the researcher to better understand the attitudes and approaches of interviewed architects about the use of biomaterials and cutting-edge building methods. It made it possible for the researcher to record their perspectives, judgments, and experiences, giving rise to a more holistic comprehension of their methods and choices regarding the construction. Additionally, when delving deeply into a subject, qualitative methods yield richer data than quantitative methods since they address the 'reason why' that underlies decisions [23]. They use tools like interviews and focus groups intending to 'describe, understand or obtain meaning' [22].

The interviews were conducted with experienced architects to gain rich insights concerning the performance of biomaterials, architecture and design, circular economy, climatic endurance, and social acceptance, drawn from their own experience. The rich, narrative data generated were used to provide context, support the research findings, and reveal subjects that could be tested in future research. Also, the qualitative approach offered the flexibility to adapt the questions based on the insights gathered during the research. Given that the underpinning philosophy of the interpretative approach perceives truth as context-dependent and the nature of knowledge as subjective [21], the interviews conducted were addressed to eight architectural offices, to receive valuable input from different perspectives on the five key indicators of the study. Except for primary research, there was also secondary research conducted. Preliminary knowledge was attained through academic studies, that helped inform the overall findings. An extensive literature review outlined various secondary research theories and provided the theoretical framework to structure primary research questions. Having formed some preconceived themes, an inductive approach was followed with the expectation that the participants' perceptions and experiences would reflect and enrich them [23].

### 3.2 Data collection methods

For the primary research, the qualitative data were collected via semi-structured qualitative interviews. These in-depth interviews provided rich, descriptive data and allowed gathering potential insights on a particular topic from key interviewees [23]. They were carried out in person at the conference 'Down on Earth', which took place in Athens, Greece at the Concert

Hall on 22 May 2024, and by internet and consisted of open-ended, descriptive, and more theoretically oriented questions [24], obtaining data grounded in the experience and practice of the interviewees. This approach made sure that the subjects discussed in the interviews remained relevant to the topic and the objectives of the study, while at the same time giving some freedom to interviewees, enabling them to express themselves in their way and time. The researcher's questionnaire was built on two levels: the main questions, containing questions posed to all interviewees, and the additional questions level, which contained sub-questions linked to the main ones, that helped the researcher enrich the conversation when needed. This model was based on the 'grand tour' questions and 'sub-questions model' that is linked to the interpretative paradigm [21], where a grand tour question is posed as a general issue and the sub-questions are used to clarify the broad-based grand tour question [21], [24].

The interviews were carried out in Greek, which is both the interviewer's and interviewees' native language, as concern for the Greek architects who work in European cities, to facilitate an active discussion with the participants and make sure that there would not be any misunderstandings or difficulty in expressing a meaning. The selected population comprised eight individuals from different architectural offices, all operating in sustainable design construction and material science. The interviewees were all experienced, with a large academic experience, and were thus able to provide rich and valuable input on the subject. The basic meaning of the answers was written in a notice book and the next day answers were typed with more details.

As the data gathered from the interviews was dense, the need to group them to make the breadth and depth of information more manageable, discover emerging patterns or commonalities, and generally make sense of them was apparent. To do so, the process of thematic analysis was used, which involved the exploration of the collected data, and then the sorting of the data, once an initial understanding was obtained. Putting the data in a thematic order means that a topic was identified and applied to the data, rather than paying attention to the order in which the data was produced (recorded and transcribed). The interview questions followed the same structure as the strategies and case studies. Hence, the data produced by the interviews was to a high degree structured according to the main areas investigated in the research. The main practice was that each piece of data was assigned to one code. The codes were formed before the study, according to a structural code analysis [25], however by analysing the raw data new codes also emerged [26] that were grouped under each question or sub-theme investigated by putting distinctive colours to them [23], [27]. These codes were either specific words that the interviewees used, or concepts emerging from the literature studied [27]. Once the data was coded, the codes were analysed and transformed into categories or themes [27], to make some interpretive sense of the data, and build explanations and arguments, in line with the research aim and objectives.

### 3.3 Limitations

Numerous limitations related to the nature of qualitative research or the researcher's role were identified in the main research. Firstly, the sample size was small, thus it might not fully reflect the broader perspectives and approaches used by Greek architects. Additionally, semi-structured interviews may steer the discussion in a direction that is more in line with the researcher's viewpoint than the interviewees', even while they provide the flexibility of modifying questions by the conversation's natural flow [23].

Furthermore, bias can be intentionally or unintentionally introduced by researchers into the design, data collection, and result interpretation processes, which might compromise the research's impartiality and dependability. Since the interviewer and the interviewees were both native Greek speakers, all of the interviews in this study were conducted in Greek. Another limitation on data interpretation could have come from the researcher's professional expertise in architecture [28].

## 4 RESULTS

The results of the interviews regarding the five key indicators used in five case studies which present different strategies for achieving the 11th sustainable development goal, which however have a common point of reference in the use of biomaterials, showed the following:

A. In terms of the effectiveness of biomaterials, even though the use of sustainable materials in construction can reduce $CO_2$ emissions by up to 30% [29], in Greece their use is in its infancy. Technologies of biomaterials that could exploit the self-healing properties of materials so that they can autonomously adapt to environmental changes have not yet been implemented. Existing buildings can be treated as receptacles for a greener facility, aiming at biodiversity, such as the Gatsby Athens Hotel in Athens, but there are difficulties in terms of proper planning at the level of phyto technical, structural, and architectural design. How will trees survive at high altitudes, how will the risks associated with high winds be mitigated, how can maintenance be sustainable, and how can irrigation be reliable?
B. Regarding architectural construction with advanced technologies, all eight architects interviewed agreed that with artificial intelligence and 3D printing technology, we can have applications for circular construction with information, by a percentage of 87%. With the use of artificial intelligence, we can record the habits of the inhabitants and analyse the microclimate data to have lower energy consumption, optimised thermal comfort of the inhabitants, upgraded safety, and better waste management and infrastructure operations. It has been said that artificial intelligence helps because it uses large amounts of data to perform in a short time a process that would take a long time to process with just our minds.
C. As to the circularity of the construction, it was said that the materials should be from the construction area. Each building should constitute a material passport, which will describe its value after the end of its life and estimate the energy result, to calculate the integrated energy of the life cycle of the building. The view that forms follow environment has been said, as a paraphrase of 'form follows function'. Also, reference was made to the historical construction with clay, which is biodegradable and is located in the area where we are constructing the building, with an emphasis on the passive cooling that the clay does. There was mention of recent discoveries, such as the creation of a polymer with pulverised bricks from demolitions that can be applied to facades, as well as substances such as chitosan, which can be found in the shell of mussels, and filter pollutants. Finally, the use of $CO_2$ substances, such as biochar from pyrolysis of agricultural waste with recycled concrete, which is made from $CO_2$ instead of emitting $CO_2$, has been proposed.
D. In terms of climate resistance, the views of the architects were to review the existing typologies and to develop new models both for the public space and for the constructions, to use heavy materials for heat accumulation. Emphasis was placed on social and government actions as well as the renovation of existing buildings, arguing that it is an ecologically wiser choice compared to new construction due to the reduction of embodied carbon, which in existing buildings can achieve goals such as net zero. The opinion was also expressed to focus on the void and not on the buildings, to adopt the solution of floating architecture. Finally, the buildings can be changed according to

needs, while regarding the appropriate urban planning model, it was said to adopt the urban planning model of the ‘sponge city’.

E. In terms of community participation and political will, it was proposed to create a single open-access website, where all public participation procedures in environmental decision-making will be carried out. Also, establishing safeguards for the effective exercise of participation rights (e.g., discouraging abusive prosecutions), strengthening participation with an obligation to provide timely notification of upcoming consultations, the extension of public consultations to new acts (e.g., amendments, proposals for laws, and proposals for revision of the Constitution) and carrying out exploratory consultations, an institution that is the first step before the final consultation, when all the possibilities and the policy options are still open. The strengthening of the role of local communities with binding local referendums, the establishment of a new procedure concerning the ‘Citizens’ Initiative’ with a request to the competent administrative authorities for the issuance of a regulatory act provided for in an authorising provision of the law, and finally, strengthening the ability of every citizen to submit a request for control of any incident he considers to be adversely affecting the environment. Regarding the state’s role in the paradigm shift, there has been a convergence that holistic interventions are a matter of political will, concerning how we pre-qualify individual investors or what incentives we give to private individuals to take a more ecological path.

## 5 DISCUSSION

The primary research yielded fascinating insights gleaned from the experiences of the participants. As is evident, there is a great deal of opportunity for addressing environmental issues and advancing sustainable development in the construction sector using biomaterials. The financial feasibility of biomaterials, however, is a key barrier, according to the respondents [30]. This is because some biomaterials now require greater production costs than traditional materials, which makes them less competitive in the market. Making sure biomaterials satisfy industry criteria and performance standards is another crucial difficulty [31]. To earn the faith and confidence of building developers and construction experts, one must demonstrate consistency in performance, durability, and safety. To promote the smooth integration of biomaterials into construction projects and achieve broader acceptance of them, standardised testing techniques and material certifications are essential [3]. Keeping up with the complex regulatory environment presents another difficulty. The numerous environmental and safety regulations about biomaterials may be challenging for manufacturers and other industry participants to follow [32]. Preventing setbacks and ensuring the sustainable application of biomaterials requires an understanding of and adherence to regulatory regulations. Moreover, a hindrance is the ignorance and misinterpretation of biomaterials by clients and industry experts [33]. In conclusion, to meet the expanding demand for biomaterials, there must be an increase in manufacturing volume [34]. This calls for significant investments in R&D, production facilities, and infrastructure. Furthermore, to ensure a consistent and reliable supply of biomaterials, which will raise their accessibility and affordability for the building industry, it is imperative to increase the scale of production. The challenge for future constructions is to measure the total carbon from the time the building materials are extracted until they are demolished, so it needs to create such an industry standard. As we are forced to build more, we need to limit the use of natural resources and rethink the concept of resources and where these resources can be found. The bricks from demolitions which are 10,000,000 per year, if pulverised, can give a new material, polymer for facade application. Also, from the pyrolysis of agricultural waste and recycled concrete, we can get biochar, that is made of $CO_2$ instead of emitting $CO_2$. Biochar is a fertiliser for the soil and increases agricultural production. We need architecture that regenerates and improves the environment. Another example is chitosan found in mussel shells, which filter pollutants [35]. Clay is also a biodegradable material and can be found on the site where we constructed the building. Clay is also known as passively cool. With the help of innovative technologies, we can see buildings as material banks, digitise matter, automate material recording, and create digital libraries with robots for reconstruction. Inspection with aerial ground robots. To be classified based on new evaluation criteria. Each building should constitute a material passport that will describe its value, after the end of its life, so that we get information about the reuse rate of the building's materials and the condition in which they are. To have information on applications for circular construction and to create alternative economic models, as with Singapore and Helsinki. There must be a paradigm shift, to see our cities as vast material reserves.

## 6 CONCLUSIONS

The depletion of non-renewable mineral resources is the foundation for the manufacture of basic building materials. In addition to raw resources, the human population is dependent on global ecological systems for air pollution, which is frequently linked to the building and manufacturing of building materials. Bio-renewable materials, including agricultural byproducts, can sequester $CO_2$ throughout their existence and have low-carbon production techniques. Therefore, many biomaterials are carbon neutral or carbon negative when looking at life cycle analysis. Plant-based renewable biological resources, including waste food streams, are rich in useful components such as cellulose, carbohydrates, lignin, and proteins. In the case of Greece, furniture, tiles, benches, large surfaces, and useful objects have been created from the pit of the olive tree. Thus, the value was given to what could be called the 'bio-waste' of the oil-making process, extending the life cycle of the pomace and incorporating the values of sustainability with 'zero waste' [36]. Resurrecting bio-architecture as an alternative to other construction processes is the result of the present trend toward sustainable building construction and growing environmental awareness. Because biomaterials are renewable, their primary benefit is their little environmental impact. Biomaterials enable quick installation and prefabrication. As a result, biomaterials are now seen as a desirable substitute for many conventional building techniques, making them the building materials of the 21st century. Biomaterials mitigate emissions from other materials because they can efficiently sequester carbon. From the perspectives of the environment, society, and human health and well-being, biomaterials provide a comprehensive strategy with the ability to mitigate various effects at each stage of the building's life cycle. These ideas help us get closer to our plan for integrating nature into the built environment. By creating this nature-based strategy, we will contribute to creating a future that benefits both people and the environment.

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