Attainable and Sustainable Home Building Solutions

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Sustainability has fortunately been a recent concern in the construction industry as climate change continues to impose potentially insurmountable threats to the global environment. Although many new methods have been adopted in efforts to lessen the adverse environmental effects of construction-related activities, as a society, we still have much room for growth as the built environment accounts for almost 50% of global emissions. Many changes and standards must be adopted to make these solutions efficiently beneficial. To set industry standards, we must start with the most basic form of construction—residential building. This report covers two attainable framing solutions for environmentally conscious home building: hempcrete blocks, and a reusable, maneuverable framing system called XFrame™. This paper weighs their advantages and disadvantages in terms of cost, materials, practicality, and sustainability. Utilizing research and interviews with professionals in both of these methods, this paper covers the rationale behind choosing sustainable methods. This project also explores new knowledge that may invalidate the costly stigmas surrounding sustainable construction. Research was also conducted about how as an industry we can collectively lower the prices of green materials if the demand rises through the usage of methods like these.

Keywords: Sustainability, Reusability, Modular Framing, Hempcrete, Circular Economy

Introduction

Studies conducted in the last decade have revealed that we must eliminate built environment CO2 emissions entirely by 2040 to halt irreversible climate change. The built environment has recently been calculated to be almost 50% of global CO2 emissions annually. Out of these emissions, 27% have been from building operations and materials, and building materials are responsible for 20% percent (Architecture 2030). To alter the trajectory of these impending threats, we must start at the foundation of the industry—residential construction. An immeasurable amount of homes are demolished around the world on a daily basis increasing the toxicity of air quality in our environment, waste into our water sources, and particulate matter into our air. The construction of residential framing systems alone has detrimental impacts from the necessary transportation of materials, project waste, and building processes that produce toxic emissions. To instill change throughout the industry, residential construction must set the standard. Building materials have been created that are reusable, sustainably sourced, more efficient, and more beneficial to the homeowner. The only predicament is that environmentally conscious materials and construction can be associated with a premium price tag for homeowners and home builders. The goal of this paper is to introduce and propose two methods of
sustainable home framing methods- hempcrete building and reusable framing systems - that are not only attainable but provide a healthier internal environment.

**Research Methodology**

The methodology for the research is qualitative. All relevant information was gathered through scholarly articles, publications, and databases. To assess the innovations and developments of these two methods of construction, interviews were conducted with industry professionals for each. As these are two specific methods of residential building solutions, specialized interview questions were sent to XFrame™ representatives and a hempcrete builder.

**Literature Review**

The U.S. Green Building Council (USGBC) created the LEED or Leadership in Energy and Environmental Design Standards to encourage designers and builders to utilize sustainable design and development practices. These standards measure how sustainable the site is, the water efficiency, indoor air quality, sustainable innovations, sustainable energy practices, and how integrative and high-performing the building processes operate. These categories comprise the LEED scorecard [Figure 1] which scores how sustainable a building is based on its materials, methods, and processes ranging within these standards. Commercial and residential construction both have the potential to receive a LEED Certification if projects are built to certain environmental standards. Homes, however, are not often built with the intention of acquiring certain LEED certifications yet commercial spaces are pushed to obtain them by clients to uphold corporate social responsibilities. Obtaining a LEED certification for a home is costly and most homeowners would not find it necessary to utilize it. Home renovations and projects can be costly enough but corporations have already incorporated it into their budget as a standard cost. These certifications could help home builders and homeowners best utilize sustainable practices with certain guidelines and target achievements, but the cost and time of having to go through the LEED process outweigh the benefit to many. In 2014 a study conducted at UC Berkeley concluded that through utilizing LEED standards, “buildings contributed 50% fewer greenhouse gases [GHGs] than conventionally constructed buildings due to water consumption [and] 48% fewer GHGs due to solid waste and 5% fewer GHGs due to transportation” (USGBC, 2022).

However, these statistics are for commercial construction and there is little to no evidence that residential LEED standards are abundant enough to even make nearly the impact. As a result, it is paramount that homeowners and home builders use environmentally conscious building practices as a standard since there is not much opportunity for sustainable regulation.
Programs like LEED and high-end green technology can be expensive and have generated the stigma that sustainable construction can be pricey. However, this perception is misleading. The LEED Concepts Guide expresses that “if sustainability is viewed as an expensive add-on to a building, we would mistake efforts to reduce energy costs or improve indoor environmental quality as comparable to specifying a better grade of countertop or a more impressive front door” (LEED, 2014). Any enhancement above a minimally code-compliant baseline appears to be an added expense under this approach. If we consider energy improvement an integral part of the entire process, these costs are dramatically outweighed by long-term savings (LEED, 2014). By installing more energy-efficient appliances and materials for a one-time cost, the cost of maintaining and utilities is dramatically outweighed. The energy costs of inefficient building practices are reflected throughout the longevity of the building or home through pricey water, gas, and electric bills. By investing in highly efficient materials and equipment, a one-time purchase seems minimal when the maintenance of the final product is incredibly diminished.

While using more energy-efficient appliances and materials is especially important and has shown a great reduction in energy consumption, this does not solve the major issues at large. The LEED Core Concepts Guide also expresses that “as the concept of sustainability was applied to the built environment, it has become clear that doing less damage is not enough” (LEED, 2014). Leaders in the industry are finding that the need for fully integrative processes that are regenerative and beyond sustainable is necessary. New building systems must evolve with our living systems (plants, animals, and humans) and must “contribute to the long-term renewal of resources and life” instead of stunting their longevity on this planet. In doing so, we can ensure the harmonious coevolution of “humans and all life in that place” (LEED, 2014). In this effort, structural engineers and specialized craftsmen and
women have created building methods that have the ability to transform the entire process of traditional home construction.

Traditional framing methods that we currently utilize face many potential threats and utilize many toxic, unsustainable materials. Some of these threats include fire-resistant and durability issues with typical wood framing, shrinkage, unwanted sound, thermal insulation, and keeping the wood healthy. Not only is wood susceptible to damage easily, but the wall systems put in place such as an EIFS system contain a multitude of toxic materials. These include metal fasteners, air/water resistant barrier coatings, fiberglass insulation, reinforcing mesh, sheathing, and multiple base and finish coats. All of these include harmful toxins either found in drywall, paint, sealants, and metals and do not have any reusable qualities.

In replacement of these harmful materials, two proposed methods offer comprehensive and complete solutions: hempcrete home building and reusable modular framing systems. These two methods exhibit the level of comprehensive environmental knowledge that LEED defines as regenerative and beyond sustainable. Hempcrete is non-toxic, waterproof, and offers an internal, natural insulation system that can be easily accessible due to the abundant rate that hemp grows. It is formed in block formation and can replace an entire wall or framing system of a home. The reusable modular framing system, XFrame™, comes in large separate pieces that essentially “snap” into one another. These pieces are able to be reconfigured to eliminate all waste in renovations or demolition and allow these processes to be very easily executed.

**Hempcrete Building**

Hempcrete is a bio-composite comprised of the inner woody core of the hemp plant and a lime-based binder. The hemp core, often known as "Shiv," has a high silica content, allowing it to bind well with lime. Among all-natural fibers, hemp has this quality. The end product is a lightweight cementitious insulating material that weighs roughly one-seventh or one-eighth of the weight of concrete (American Lime Technology, 2019). Hemp grows very quickly and easily and “has the potential to be a very low-cost source of material. Nearly every part of the hemp plant can be used for something, and many hemp products—besides being highly durable and having a long lifespan—can, at end-of-life, be easily recycled, composted, or incinerated to produce biomass energy” (Wilson, 2017). The most widely utilized components of the hemp plant in construction materials are the outer bark, used to manufacture hemp fiber, and the core, used to make wood-like chips or "hurds." These hurds are dried and compacted with lime to create a block formation that is used to build the exterior framing and facade as well as the interior facade. The formation of multiple hempcrete blocks creates a natural framing and insulation system that naturally filters outside elements, humidity, scents, and temperatures. The fibers in hemp can be used to “make natural insulation material with a high thermal resistance (about R-3.5 per inch) and optimal moisture regulation (water vapor resistance factor of 1-2 µ) that can be substituted for fiberglass products. These properties are due to the structure of the hemp fiber, its many longitudinal splits, and cavities increasing absorption and permeability” (Wilson, 2017).
The most comprehensive reusable framing system on the market, XFrame™, was created by a Ph.D. Candidate at the Victoria University of Wellington, Ged Finch. I found Finch’s comprehensive approach to this sustainable method while stumbling upon his TedTalk. They shared his project while exploring how a circular economy model can fundamentally disrupt the way they build in New Zealand where they reside. By creating this method, Finch encourages “why we need to rethink how we build homes” (Finch, 2019). A circular economy construction model “replace[s] existing take-make-waste systems that extract resources for use in current industrial models with a circular system that designs out waste and pollution, keeps products and materials in use and regenerates natural systems” (Pasquale, 2019). This reusable framing system is also recoverable for the next generation of environmentally friendly construction. The XFrame™ system contains twelve standardized components that were created and patented after 4,500 hours of prototyping. This “braced structural matrix” is formed from multiple CNC (computer numerical control) milled-engineered plywood components. Without the need for any nails, glues, or screws, the components are then assembled into structural panels (XFrame™, 2022). The framing system consists of Fasmount hidden pressure clasps (that are used for reusable panels), parts made of 1200mm x 2400mm sheets of 12mm structural pine plywood using CNC mill, and are easily flat packed. Every part of the XFrame™ system consists of precision-milled, engineered radiata pine plywood and together these pieces form a unique geometric, diagonal grid system. The triangulated panels in the system are laterally resilient and the stable design “allows linings, glazing systems as well as claddings to be joint using precise and reversible fixing systems” (XFrame™, 2022). The plywood paneling is made of Wanhua Strawboard and does not release any formaldehyde and has a negative carbon footprint. This product is made from agricultural fibers that have been leftover from harvest and typically burned as waste, but the XFrame™ creators solidified their negative carbon footprint approach by using the non-toxic and recycled material versus using a potentially toxic manufactured board with a positive carbon footprint.
The Chief Technology Officer of XFrame™, Ged Finch, proposed the concept as their PhD project during their TedTalk at the University of Wellington. Their TedTalk “Why we need to rethink how we build homes” epitomizes the entire overarching concept of his innovation. The creator had set the intention of the concept to transition the “building industry from a linear economy to a circular economy” (XFrame™, 2022). The creators are in an ongoing process that makes XFrame™ a “platform technology” that allows supplementary systems and technology to be developed to “leverage the XFrame system and consequently advance the uptake of circularity” (XFrame™, 2022). The framing system allows for every adjoining wall layer to be reversibly linked in a way that preserves its fundamental value. The entire system is intended to facilitate the “recovery and reuse of almost all building layers.” The lock and snap system on this product ensures the designer, contractor, and building owner that it can reconfigure the walls in whatever way they please. The modular aspect allows not only an easy reconfiguration but also a very simple installation that requires minimal training. XFrame™ provides builders with detailed project-specific assembly instructions that are suited for a cohesive modular construction framing solution, and most recently, commercial fit-out solutions.

![Figure 3: XFrame™ modular framing system](image)

**Analysis of the Results**

**XFrame™**

As for XFrame™, it has emerged as a revolutionary system for framing homes, offering potential benefits such as design freedom, customization options, cost-efficiency, and environmental sustainability. Its Chief Technology Officer Ged Finch provided great insight as to how the company predicts how its evolution will precede its initial models.
When asked about the extent of design freedom provided by XFrame™, Finch acknowledged that designing a traditional family home with steep sloped roofs would require many custom XF parts. The shape of the building plays a significant role in determining the number of standard parts that can be utilized. While the response offered some insights into the challenges posed by specific architectural designs, it did not elaborate on the overall range of design options available with XFrame™.

Regarding customization, the CTO confirmed that contractors can paint, sand, or stain the XFrame™ system. They also mentioned that any lining half an inch or thicker can be used, with prefinished linings offering cost advantages. These answers provided confidence in the system’s ability to accommodate contractor-led customization, allowing for various aesthetic preferences to be met.

In terms of long-term cost benefits, Finch stated that cost advantages can be observed through reuse. Although the XFrame™ system is approximately 10% more expensive than traditional wood framing methods, its long-term benefits exceed the initial costs. It was also noted that the decreased overall assembly time partially offsets this cost difference. Finch revealed that XFrame™ utilizes softwood untreated structural pine plywood with lignin-based adhesives as of 2023. Additionally, Finch expresses that the utilization of XFrame™ maximizes time and cost efficiency through the use of standard parts. The pre-assembly of wall panels, availability of stocked standard parts, and the arrival of prefabricated panels ready for lining installation contribute to streamlined construction processes. The absence of wet trades and the pre-drilled, pre-marked, and standardized connections further enhance efficiency.

Regarding the commercial viability of XFrame™, the CTO reported excellent uptake of the system in commercial interiors and that they are gaining traction in the reusable modular room dividers in office spaces. In discussing the future evolution of XFrame™, Finch emphasized that improved materials would enhance circularity and that advancements in timber part manufacturing technology, including improved part milling and robotic-assisted assembly, would drive down costs.

**Hempcrete Builder**

Speaking with a local Hempcrete builder, Hemp Building Company, a representative offered great insight into the efficiency and health standards that building with hemp upholds. Its entire initial purpose had been committed to minimizing the carbon footprint of their homes. Hempcrete or hemplime, an insulating material derived from the hemp stalk’s core fiber and limestone, is a sustainable replacement for traditional construction methods offered by Hemp Building Co. In 2017, they started collaborating with Hemplime to create installation strategies that were affordable.

Primarily asking why hemp should be used in building, they were fully prepared with very logical reasons. Building with hempcrete is non-toxic for both people and the environment. When used as a building material, it has a built-in resistance to mold and mildew. During cultivation, hemp is a bioremediator that sequesters carbon. They confirm that hempcrete is regarded as a material that is both fireproof and non-combustible. The company has seen an uptick in its building method as communities have become increasingly concerned about toxic chemicals, materials, and airborne toxins penetrating their homes in areas that are closeby to urban areas. Utilizing hempcrete in a home
can not only improve the air quality but also improve the acoustics of the space while reducing exposure to risky volatile organic compounds.

In terms of efficiency, the representative stated that its efficiency is non-comparable as it is a natural resource with built-in insulation. Hempcrete is a versatile alternative insulating material that provides thermal bulk in addition to having an R-value of about 2.4/inch. Hempcrete is a porous substance with built-in temperature and moisture control. With this being said, it accounts for all portions of a wall system as it creates a rigid structure when formed, dry, and treated as an alternative to fiberglass insulation which is very toxic for the environment.

The Hemp Building Co prides itself on not only the efficiency but the sustainability of the product. I was told that during the course of its growing cycle, hemp can absorb about 18,000 lbs of carbon per acre as it is an extremely carbon-friendly substance. It produces a non-toxic, long-lasting, recyclable material with a variety of uses when combined with a lime binder. The representative commented on the importance of how toxic residential building materials can be let alone commercial materials. They continue to explain that while the process of building with hempcrete can be lengthy it is the only wall system that needs to be erected in the building process which results in a similar time frame to the traditional home erection if a full crew of highly-trained professional hempcrete builders are working simultaneously. When asked about the cost-benefit analysis of the system at large, their response also related to the circular economy. The idea that minimal additional materials are necessary (besides plumbing and electrical), the strength of the hempcrete outweighs the direct costs of typical wood framing construction. All of their clients have been extremely pleased with the lack of maintenance necessary for the system besides minimal touch-ups over the course of a few years.

**Conclusion**

The construction industry is increasingly recognizing the importance of sustainability in the face of climate change. While efforts have been made to mitigate the environmental impacts of construction, there is still a long way to go, as the built environment accounts for nearly 50% of global emissions. To set industry standards, it is crucial to focus on residential construction, which plays a significant role in the overall impact. This paper has explored two sustainable framing solutions for homes: hempcrete blocks and the XFrame™ reusable modular framing system. By weighing their advantages and disadvantages in terms of cost, materials, practicality, and sustainability, this research highlights the potential of these methods to contribute to environmentally conscious home building. The study also acknowledges the challenges associated with sustainable construction, including the perception that it is expensive. However, it argues that the long-term benefits of sustainable materials and practices, such as energy efficiency and reduced maintenance costs, outweigh the initial investment. The paper emphasizes the need for a shift towards regenerative and circular economy models in construction, where materials and resources are reused, waste is minimized, and natural systems are regenerated.

Through qualitative research and interviews with industry professionals, this paper provides insights into the feasibility and potential of hempcrete and the XFrame™ system. Hempcrete offers a non-
toxic, lightweight, and insulating material that can be sourced sustainably from the fast-growing hemp plant. On the other hand, the XFrame™ system presents a comprehensive and reusable framing solution that promotes a circular economy by minimizing waste and allowing for easy reconfiguration. Sustainable construction methods like hempcrete and the XFrame™ system offer promising alternatives to traditional framing systems. By embracing these innovations and addressing the cost barriers associated with sustainable construction, the industry can pave the way for a more sustainable future. Collectively, we have the opportunity to reduce the environmental impact of residential construction and create healthier, more energy-efficient homes. With increased demand and adoption of sustainable practices, there is the potential to lower the prices of green materials and make them more accessible to homeowners and builders. By embracing sustainable construction as a standard, we can make significant progress towards mitigating the environmental challenges posed by the construction industry and contribute to a more sustainable and resilient built environment.

References


