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STRAWTEGI CO_2TTAGE: A ZERO NET CARBON STRAW PANEL PROTOTYPE

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ABSTRACT

This paper presents a case study of a zero net carbon footprint home and shares design details as open-source information. Currently under construction, the home is built using a modular wall panel system insulated with dense-packed chopped straw that is the first permitted structure of its kind in the US. Technical aspects of the project are reviewed including carbon calculations, code compliance, and R-values. Results of informal fire tests on building panels demonstrate the need for laboratory certified testing for fire and thermal performance to further validate mainstream use of chopped straw as a valuable, high-performance, carbon sequestering building material.

KEYWORDS

carbon sequestration; straw; chopped straw; hempwool; wood fiber sheathing; fly ash; net zero carbon footprint; climate action; modular

INTRODUCTION

Extreme weather conditions across the globe have brought the urgency of climate change action. "Every year, the built environment produces around 40% of global emissions" (Architecture's Carbon Problem, 2022). Common building materials like spray foam, XPS foam, and cement are extremely high in embodied carbon, and do more environmental damage than good, even before a building is occupied. The goals of Net Zero Energy and reducing operational emissions during a building's life cycle are no longer adequate; Zero Net Carbon is the now gold standard for sustainable construction (King, 2017). Reduction of upfront CO_2 emissions from building materials across the industry is an immediate priority to limit the worst impacts of climate change. Natural, carbon sequestering, and rapidly renewable bio-based materials like straw, hemp, and wood, can provide worthy, impactful, and immediate alternative solutions.

The Strawtegi CO_2ttage accessory dwelling unit is a demonstration project, in Salt Lake City, Utah, focused on achieving a zero net carbon footprint. The project uses natural materials such as lumber, wood fiber board, densely packed chopped straw, and hemp batting to sequester atmospheric carbon within the structure, safely locking it in for the life cycle of the building, which could be 100 years or more. This home will sequester net 5.5 tons more carbon equivalents than were emitted in the production and assembly of the building's shell from resource extraction to ready product. The result is a natural, beautiful, and comfortable home that meets and exceeds standards for health, safety, thermal comfort, durability, and environmental sustainability, demonstrating that adaptation of conventional building practices for positive climate change can yield immediate results. The prototype unit, using modular panels insulated with dense-packed chopped straw is the first permitted structure of its kind in the US. As a private developer responsible for the design and implementation of this project, my aim in this paper is to describe the unique materials and processes involved, and to share our outcomes and findings thus far as open-source information. With further testing, demonstration, and investment in scalability, these materials and methods could advance more rapidly toward mainstream application, adding to our toolkit of solutions for drawing carbon down out of our atmosphere and locking it into our built environment for decades to come.

THE NEED FOR REDUCTION OF UPFRONT CARBON EMISSIONS

According to the UNEP Emissions Gap report, to meet the 1.5C goal, global emissions need to be reduced by 50% by 2030 (GlobalABC/IEA/UNEP,2020). Embodied carbon encompasses all the carbon emitted before a building is occupied, including extracting, transporting, and manufacturing building materials. During the next 10 years, it is estimated that embodied carbon will represent up to 74% of all CO_2 emissions from new buildings constructed during that period. “Compared with operational carbon, this is a staggering number. The embodied carbon of concrete, steel, and aluminum alone accounts for 22.7% of global CO2 emissions, and most of it is from buildings and infrastructure construction” (Groundbreaking New Resource for Going Green, 2022). Achieving industry-wide decarbonization at a scale and pace necessary to meet global goals will require collaborative efforts across the building sector and presents business opportunities in emerging markets with an estimated value of approximately USD 24.7 trillion by 2030 (IFC, 2019).

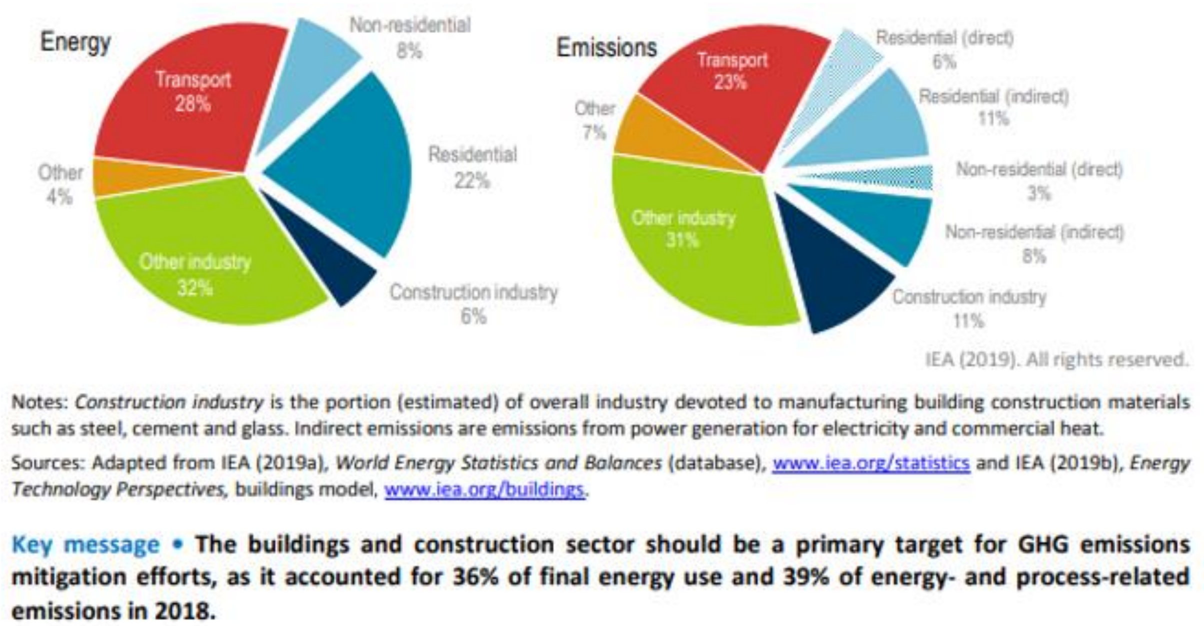


Figure 1: Energy and emissions in the building and construction sector
(GlobalABC,IEA/UNEP, 2019 *Global Status Report for Buildings and Construction*)

VISION FOR THE PROJECT

The vision for this project arose from deep dialog at the Natural Building Colloquium, sponsored by the non-profit Builders Without Borders in 2015. Participants expressed concern about the need to mainstream natural building practices. The Strawtegi CO_2ttage project was designed to demonstrate natural building solutions adapted for urban settings, with hope that these solutions would be more readily accepted, adopted, and scaled for application by local building officials, contractors, and developers. The modular panel system reduces the thick footprint of a typical straw bale wall and allows for streamlined installation on site. Open-source sharing of information and details across media platforms encourages replication by others, including owner-builders, and inspires further exploration toward mainstream adaptation of natural carbon sequestering building materials for climate action.

OVERALL DESIGN INTENT

The 650 sq. ft. Strawtegi CO$_2$ttage is designed to work in harmony with nature to sequester carbon, and significantly reduce the upfront and operational carbon footprint of the home while maintaining the luxuries, convenience, and comfort expected for modern urban lifestyles. As it is an accessory dwelling unit, the aesthetic design is consistent with the character of the main house and the charm of an older Salt Lake City neighborhood. Home ownership in such neighborhoods has become increasingly inaccessible due to high property values; this ADU provides affordable access to the anticipated quality of life for people of varying income levels.

Passive solar orientation supports year-round comfort. In the summer, when the sun is higher in the sky, the windows are completely shaded by overhangs and awnings, and still function to super insulate interior spaces from ambient temperatures outside. The high-performance building shell is designed for a long maintenance-free building life. Insulating chopped straw, encapsulated in wood fiber board structural sheathing, is key to the R-30 modular wall design proposed. The Strawtegi CO$_2$ttage uses 42 modular panels, efficiently assembled offsite in a climate-controlled shop. The panels are then delivered and rapidly assembled on site with the support of a lift or crane. The 4'x 8' modular wall panel system has little material waste and is friendly toward supervised, limited-skill sweat equity contributions during construction, which can greatly lower labor costs. The roof assembly is insulated with Hempitecture's hemp wool batting to meet R-49 code requirements and is finished with durable integrated solar roof tiles by Tesla. Engineered wood shake siding by LP Smart Side, provides a traditional look while drastically improving the performance and maintenance of exterior wood siding. Inside, the concrete slab is stained with natural pigments and polished for a highly durable and maintenance-free finish. The spacious two-story plan includes a full stair leading to an open bedroom loft with vaulted ceiling and overlook into the kitchen area below. Tongue and groove wood flooring upstairs provides a beautiful, low-maintenance, natural floor that will patina over time. Durable, healthy, non-toxic materials throughout are sourced from reputable local suppliers.

a) exterior view b) straw panel assembly

Figure 2: Exterior views and basic panel construction

Figure 3: Upper & lower floor plan and elevations illustrating modular panel layout

Figure 4: Interior views

CARBON SEQUESTERING MATERIALS

The Strawtegi CO_2ttage emphasizes rapidly renewable, biogenic, carbon sequestering materials that are readily available within our region. Many have proven valuable for application in building products such as insulation, composite and fiberboard, insulating block, flooring, and surface materials. Materials including straw, rice hulls, bamboo, hemp, corn husk, and others are harvested in annual cycles that produce waste materials available for a secondary market. (Magwood, 2016) Further testing and demonstration of the validity of these diverse materials is necessary to scale up their use and carbon draw-down impact on climate change as soon as possible.

Trees are one of our most valuable resources for drawing down atmospheric carbon. Trees breathe in CO_2 and exhale oxygen critical for life on earth. When we nurture and expand our forests, we can work in harmony with nature to cultivate and harvest what we need to survive on this planet: abundant oxygen, healthy ecosystems that support diverse species, and the raw stock for structural lumber necessary to provide shelter and other structures for community life. So long as our forest stocks are carefully cultivated, managed, and never depleted, sustainably harvested wood products are a fantastic way to build human environments in balance with nature while locking sequestered atmospheric carbon in our structures for decades. Details of carbon sequestering materials in the Strawtegi CO_2ttage follow:

Wood Framing

All new lumber used in the Strawtegi CO_2ttage is from FSC (Forest Stewardship Council) or equivalent certified sources. The modular panel system uses 2x8 wood structural members for each panel. Aged, weathered wood joists were salvaged from a local barn for the exposed interior perimeter bond beam and exposed floor joist system supporting the second floor.

Fiberboard Sheathing

The fiberboard sheathing panels specified are produced by MSL SONOclimat, ECO 4. The 1.5", 4'x 8' panels provide the modular panels with a highly breathable structural sheathing appropriate for use with straw insulation and negates thermal bridging at the panel edges.

> The SONOclimat ECO4 insulation panel is made entirely from recycled and recyclable wood fibres. The SONOclimat ECO4 panel provides a thermal resistance value of R4, an unparalleled permeability to water vapour of 25.9 perms, robust structural properties (5.84 kN/m) as well as impressive sound attenuation properties. The SONOclimat ECO4's high water vapor permeability enables moisture to exit the wall structure, thereby preventing the development of mold and decay. The SONOclimat ECO 4 panel can be used as insulation for exterior and interior walls and contributes to obtaining credits for eco-friendly construction programs (MSL, SONOclimate Eco4 Product, 2022).

Like many other sustainably harvested forestry products, these sheathing panels are produced in Canada. No equivalent product is currently made in the US, though GoLab plans to manufacture a similar product in Maine in 2023.

Chopped Straw

Dense packed chopped straw used on this project is locally sourced from a commercial supplier of premium, clean, sun-dried, chopped straw. Standlee Premium Western Forage Certified Chopped Straw comes cut to 4" length, compressed in 2 cu. ft. bags (56.6L compressed volume), weighing roughly 17.6 lbs per bag (Certified Chopped Straw Product, 2022). Our technique for hand filling the panels allows most of the straw to remain compressed. We are able to use 8 bags, or 16 cu ft of straw in a full 4'x 8' panel, overfilling and manually compressing the straw prior to attaching the fiberboard panel (see Figure 1b).

Hempwool
Hempitecture Hempwool provides excellent thermal values of R3.7 per inch for an efficient and vapor permeable high performance building envelope. The product is made from 90% industrial hemp fiber, sustainably grown in the US and offsetting 9.8 tons of CO_2 per acre, per year. That is the equivalent of taking 2.1 cars off the road, per year, per acre of Hemp farmed. It is also naturally hypo-allergenic, mold and pest resistant, and easy to install with simple tools and a pressure fit application (Hempwool Product, 2022).

Engineered Wood Siding
LP Smartside produces composite wood fiber siding from sustainably harvested renewable sources "with leading carbon lifecycle attributes;...products are durable and designed to offer solutions for energy efficiency, construction speed, and reduced construction waste" (Smartside, 2022). As an engineered wood product, LP Smartside provides a low-maintenance, highly durable, and readily available exterior finish solution with a 50-year warranty.

SUSTAINABLE ENHANCEMENTS TO NON-BIO-BASED MATERIALS

Due to the need for strength, durability, and resiliency, foundation and roofing materials are typically high in embodied carbon. Fortunately, that is changing as public demand for new products and solutions is increasing.

Cement
Cement production accounts for roughly 7% of total global CO_2 emissions. 80% of concrete's carbon footprint comes from cement. Fly ash is a coal combustion by-product created at coal power plants. It can be diverted from landfills and used in concrete production to reduce the amount of cement and water needed, while making concrete denser and more durable (Fly Ash, Headwaters). Concrete for foundation wall footings and slabs accounts, by far, for most of the greenhouse gas emissions on the Strawtegi CO_2ttage project, despite initial specification of 20-29% fly ash. However, by allowing a 56-day curing cycle for concrete, we were able to increase fly ash content to 40%, significantly improving the carbon footprint of the project's concrete while meeting the 3,000 psi structural specifications. Since Utah's power grid depends significantly on coal, making fly ash locally abundant, 2022 Utah legislation proposed support for inserting fly ash additives to concrete for all state funded projects. Although many low-carbon concrete technologies such as Carbon Cure, Carbon Built, and Blue Planet Systems, are now available, none are available in the Intermountain West. More consumer demand and political support is needed to increase awareness and adoption of new lower carbon concrete production.

Solar Roofing
Integrated solar roof tiles provide double duty service for their embodied carbon footprint, performing as both a waterproof weather shield and PV cells absorbing sunlight and generating electrical current to power household equipment. Durable Tesla roof tiles will provide a sleek and elegant look that is well suited to a small structure. The shingle system, including a power wall, is priced several thousand dollars less than the originally proposed standing seam metal roof with standard solar panels. The system comes with a 25-year power output warranty and is easily monitored through an online app.

Perlite
Locally mined, natural perlite will be used with a vapor barrier below grade to insulate the structure's thermal mass concrete floor. At R3.13 per inch, 7" bagged perlite, direct from the Hess factory, will provide roughly a R22 thermal value under slab.

> Perlite under slab insulation is a natural inorganic product that is dimensionally stable, does not rot, support combustion or provide habitat for rodents. Because of its natural pH, the product does not foster corrosion in piping and electrical wiring that may be in the underfloor area. (Underslab, 2022)

Lime Plaster
Wet areas in the Strawtegi CO_2ttage are glazed all around in beautiful, water-repellent tadelakt lime plaster locally produced by Limestrong. This traditional Moroccan finish is hand burnished with soap and wax to create a seamless, luxurious and low maintenance finish (Tadelact 2022). Tadelakt is free of toxins, is antibacterial, hypo-allergenic and regulates moisture. Lime plaster also slowly reabsorbs carbon dioxide from the air and is 100% recyclable.

Other
Healthy, natural, non-toxic material selections are emphasized throughout, including natural and reclaimed wood, butcher block counters, Eureka straw board (MDF) cabinetry and naturally stained and polished concrete slab. Beautiful and highly repairable natural clay and lime plaster walls by Limestrong and American Clay, will highlight the home's hand-crafted aesthetics.

EQUIPMENT SELECTIONS

High performance equipment, appliances, and solar panels come at a premium cost upfront but have short-term payback periods and greatly reduce water use, ongoing emissions and operational costs long term. Alpen's quadruple-glazed, high-performance, solar-gain windows are appropriately tuned to each elevation facade by AE Building Systems to optimize heat benefit in the winter while still achieving a super-high insulating value (U-Factor, as low as 0.10). Two energy efficient Fujitsu Halcyon mini-split systems will operate independently to heat and cool the upper and lower floors, 33.1 SEER. The Rheem ProTerra hybrid electric heat-pump water heater is 400% more efficient than standard electric water heaters. A Heat Recovery Ventilator system assures adequate fresh air, passive night-time cooling, and filtered cool air when windows cannot be opened due to poor air quality outdoors.

MODULAR PANEL DETAILING, ASSEMBLY, AND PERFORMANCE

This adaptation of typical straw bale construction allows for a 12" thick perimeter wall, which is far more applicable in urban settings than traditional baled straw walls at 16" to 18" thick. Each 4'x8' panel is packed with 16 cu ft (140lbs) chopped straw. Using an estimated R-value of 2.6 per inch, we estimate the straw insulation value within a 2"x8" lumber frame at R-20, with a total R-30 value for a sheathed and finished wall. Total weight of a full wall panel without cut outs for windows or doors is approximately 316 lbs, which can be maneuvered manually by several strong builders, but is more easily set with a lift or crane.

The modular panels are designed for one or two story residential construction and require physical connections between side by side panels. When stacked, panel to panel connections require interior and exterior perimeter bond beams. The panel system does not allow for plumbing or electrical wiring to be buried within the wall core. All chases through the exterior wall for utility services are designed into the panel layout prior to construction. Plumbing is planned with surface mounted pipes located in cabinets or the utility room. There is a continuous electrical chase designed into the base of each panel, allowing for electric wiring to be run on site after the walls are assembled. Shallow 1" electrical boxes are used throughout so no electrical wiring penetrates into the wall cavity. 1 ½" Thich fiberboard sheathing panels are easily routed vertically to allow electric boxes to be mounted at heights required by code.

Building authorities in Salt Lake City use the 2015 IRC (International Residential Code) which does not require a fire rating for interior or exterior walls in single family residential dwellings. This modular wall assembly was a non-issue for Salt Lake City code officials. In order to better understand the vulnerability of our panel design in a fire, we conducted our own informal fire test. The promising results will be shared in detail further in another section. To our knowledge, this is the first permitted structure using chopped straw insulation in the United States. We fully encourage others to replicate and improve upon the methods presented here, after clarifying requirements with local building officials and project engineers.

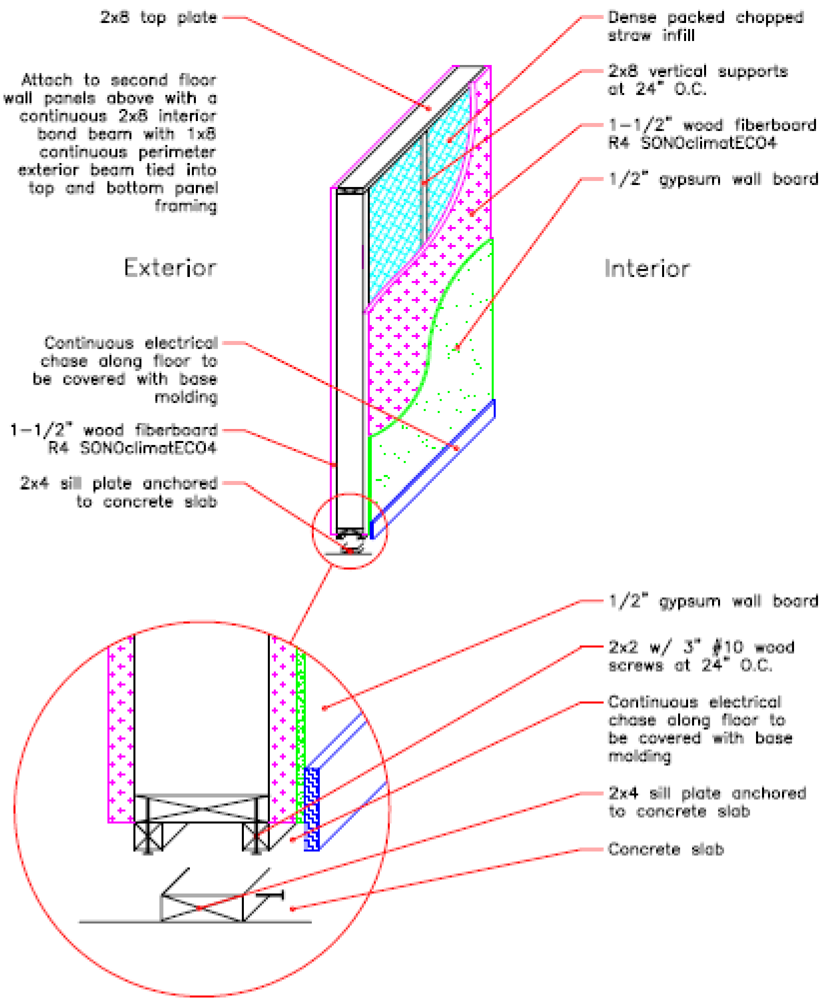


Figure 5: Panel isometric & detail

EMBODIED CARBON CALCULATIONS

Several tools have become available in recent years to help builders and planners analyze and compare carbon emissions related to various design decisions and alternate material selections. The Strawtegi CO_2ttage was used as a prototype model for the new BEAM calculator tool that will soon be available free online through Builders for Climate Action. For our purposes, embodied carbon was analyzed for the building envelope only.

> This report includes biogenic carbon storage credit for FSC certified forest products, framing lumber, engineered wood siding, wood sheathing, furring, straw, hemp and wood fiber insulations. This building stores over 15 tons of carbon dioxide equivalent within its biogenic materials, which is equivalent to taking 3.25 cars off the road for a year. The dwelling's net total embodied carbon is negative 5.5 tons of carbon dioxide equivalent, meaning its main materials stored more greenhouse gas than they emitted during life cycle phases A1-A3 (e.g. from resource extraction to ready products). This is an outstanding and exemplary performance (Strawtegi, *Builders for Climate Action, Carbon Footprint Results*, 2021).

BUILDERS FOR CLIMATE ACTION

BEAM

BUILDING EMISSIONS ACCOUNTING FOR MATERIALS

CARBON FOOTPRINT RESULTS

Client:	Susan Klinker
Project:	Strawgeti C02ttage ADU
Designer/Builder:	Love Schack
Evaluator Name:	Erik Bowden
Evaluation Date:	May 19, 2021

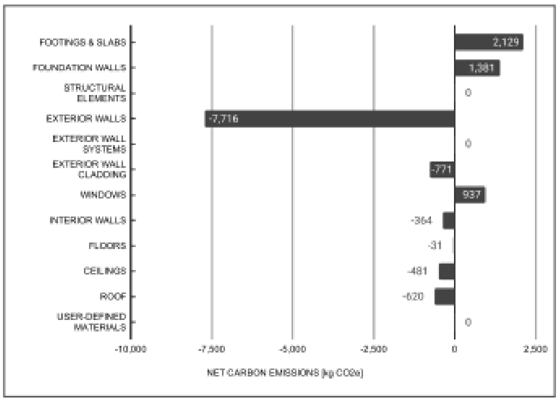
Project Description:
Additional dwelling unit with a focus on carbon reductions. Features include straw infill walls, hemp batt insulation, and high efficiency windows

Evaluation Notes:
This version includes biogenic carbon storage credit for forestry products that are FSC or equivalent.

SECTION SUBTOTALS

SECTION	NET CARBON EMISSIONS [kg CO2e]
FOOTINGS & SLABS	2,129
FOUNDATION WALLS	1,381
STRUCTURAL ELEMENTS	0
EXTERIOR WALLS	-7,716
EXTERIOR WALL SYSTEMS	0
EXTERIOR WALL CLADDING	-771
WINDOWS	937
INTERIOR WALLS	-364
FLOORS	-31
CEILINGS	-481
ROOF	-620
USER-DEFINED MATERIALS	0
NET TOTAL	-5,535
NET TOTAL PER SQ. METRE	-117

EMBODIED CARBON BY SECTION



TOP 10 HIGHEST IMPACT MATERIALS

SECTION	kg CO2e	MATERIAL
Foundation Walls	1,050	Concrete – 2501-3000 psi, 20-29% Fly Ash / NRMCA / US Avg /
Footings & Slabs	1,036	Concrete – 2501-3000 psi, 20-29% Fly Ash / NRMCA / US Avg /
Windows	937	Window - triple pane / Fiberglass frame / / USA & CAN
Footings & Slabs	900	Concrete – 2501-3000 psi, 20-29% Fly Ash / NRMCA / US Avg /
Floors	594	Hardwood flooring - AVERAGE
Roof	522	Steel Roofing Panels - AVERAGE
Foundation Walls	226	Rebar / Concrete Reinforcing Steel Institute / / 15M
Footings & Slabs	142	Rebar / Concrete Reinforcing Steel Institute / / 15M
Cladding	135	Drywall 1/2" Typical - AVERAGE
Int. Walls	89	Drywall 1/2" Typical - Interior Walls - AVERAGE

Figure 6
Builders for Climate Action, Materials Emissions Accounting for Strawtegi CO_2ttage

FIRE TESTING

In the absence of substantiated lab tests, our crew performed an ad hoc test to better understand how densely packed chopped straw in the wall panel cavity will react when exposed to fire. Our goal is to document and share results, contributing to the conversation and body of knowledge about best practices in emerging bio-based building technologies. This series includes two tests. The first establishes a baseline vulnerability when dense-packed chopped straw is exposed to flame; the second demonstrates what happens when the panel designed for the Strawtegi CO_2ttage project, using chopped straw as insulation in the wall cavity, is exposed to fire.

Test #1 Fire Test for dense packed chopped straw exposed to open air

This test demonstrates how loose chopped straw burns when it is dense-packed and exposed to open air on all sides. The dried chopped straw was densely packed into an 8" diameter wire cage and then weighted down with a fire brick to simulate density conditions inside a wall. The study included one sample treated with a cup of Borax as a fire retardant. A second sample was untreated. Both conditions are set aflame with a 500k BTU torch at 10 second intervals, three times, with the results timed and recorded on video.

Results

After three 10+ second episodes of exposure to intense flame, at 500k BTU, both samples extinguish. The untreated sample continues to smolder longer. When the wire cage is lifted, it is clear that the straw at the interior of both 8" columns is uncharred, however, there is much more uncharred material in the Borax treated column. This test demonstrated a baseline risk for what we may experience moving forward to test #2, as larger areas of chopped straw are exposed to flame and open air.

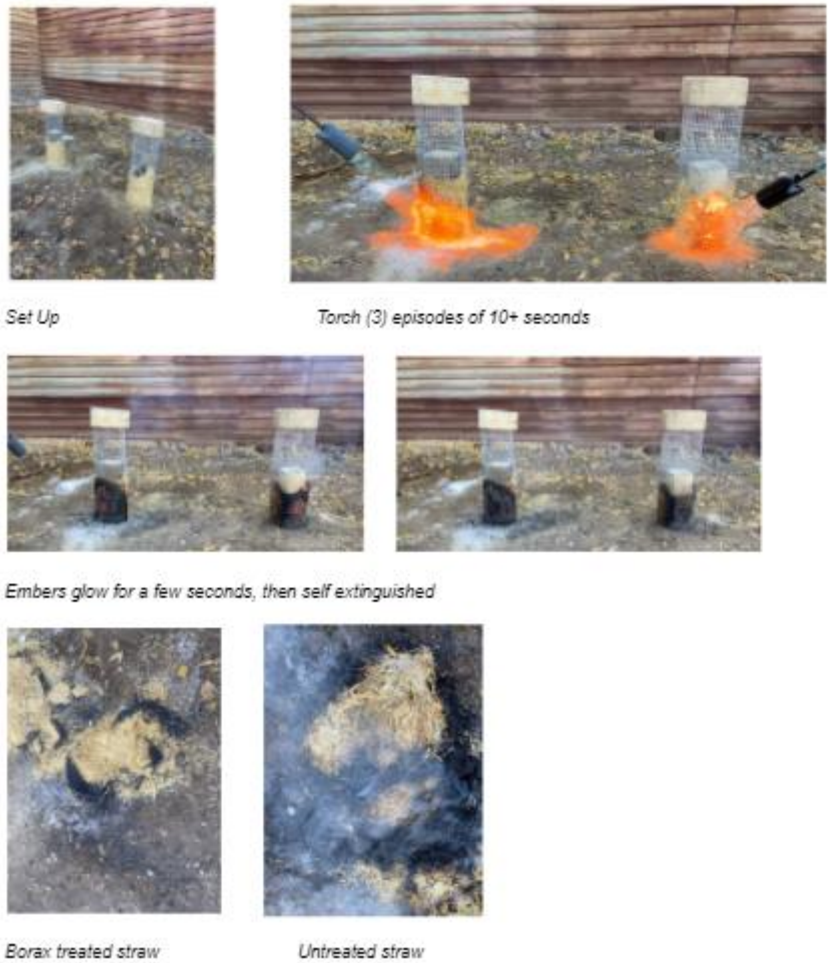


Figure 7: Fire test for densely packed chopped straw exposed to open air.

Test #2 Fire Test for modular wall panel configuration for Strawtegi CO_2ttage

This test simulates conditions for fire safety/risk in a home if fire penetrates the chopped straw insulation inside the wall cavity. The module to be tested is the 4'x8' basic modular wall panel sheathed with 1 ½" MSL Sonoclimat ECO 4 panel on both interior and exterior sides, plus ½" gypsum wall board (GWB) on the interior. Drywall should provide a 30-minute standard fire resistance rating for interior safety. On the left, the drywall has been cut away in an 8" circle to allow the fire to immediately contact the MSL wall panel and penetrate the wall cavity and straw insulation sooner. On the right, the fire must first burn through the drywall before advancing into the wall cavity. The torch flame is angled upward about 45 degrees on the interior, GWB side of the wall panel. Both torches are aimed at a point 2' ft above the ground, and 1' ft in from the side edge of the panel. Two hours of continuous flame was applied at a rate of 500k BTU from two separate torches, set 2' apart.

Results
On the left side, white smoke begins to seep out of the panel's side cracks almost immediately after being ignited. The fire penetrates the MSL board and advances to burn the straw in the wall cavity. The straw on the outermost inside edge of the panel is exposed as black charred surface straw. The hole at the center of the flame slowly increases in width and depth. The straw above the flame area does not fall as the hole increases; surrounding straw and MSL fiberboard remain surprisingly stable. The fire advances to fully to penetrate to the exterior side of the MSL board after approximately 30 minutes. The fire on the right side, somewhat restrained by ½" GWB, never fully penetrates the wall cavity to the exterior during the two-hour test. For two hours the fire continues to spread slowly, the materials never becoming engulfed in flame. Straw embers form a char-like crust and remain encapsulated within the wall cavity, generally self-extinguishing; they do not become airborne or uncontrollably engaged. After two hours the flame was eliminated, and the panels lightly hosed down from both sides and left to smolder for 30 more minutes. The panel was then lowered from its vertical position and the face of the panel was removed. Char areas inside the panel showed very limited spread, and no spread beyond a 24" radius around the flame point. There was no evidence of any chimney effect, or flame tending to rise vertically inside the wall. The 2x8 lumber at the side edges, just 12" from the flame's center point did catch fire and char but did not appear to lose its's structural integrity.

Cut away GWB on left. 2 hour sustained flame at 500k BTU Straw self extinguished after burning through

Scorched straw remains in place. Lowering the panel No chimney effect

No impact to straw above 4 ft ht

Figure 8: Informal fire test on Strawtegi prototype panel

Exposing interior wall cavity   Measure fire impact area

Figure 9: Informal fire test demonstrating limited flame spread inside the panel

Promising results from both tests confirm the level of fire-risk when using the straw panels as designed, and the need for laboratory certified testing for fire and thermal performance of chopped straw as a valid carbon sequestering building material. A full video record with infrared temperature readings and a detailed report of this informal fire test is available upon request through contact information on the website at www.strawtegi.org.

CONCLUSION

Throughout history, people have creatively used natural materials in their immediate surroundings to construct shelter, understanding that their survival requires equilibrium with the cycles of life around them. Imbalances eventually cause a crisis, demanding a reckoning of the scales, usually by population reduction (Klinker, 2004). Our global systems are out of balance, threatening people worldwide.

The building and construction sector is now responsible for almost 40% of CO2 emissions annually, and our global building stock is set to double by 2050. Maintaining current systems for new construction is simply not sustainable, leading to an increasingly uncomfortable and destructive future. Taking action to decarbonize the sector is the most important step we can take, as building professionals, to reduce the impacts of climate change. Working with nature-based solutions and urban ecosystems must be part of the path forward. When we build with rapidly renewable biogenic materials, we support the drawdown of atmospheric carbon through natural systems, and lock that sequestered carbon into the building for it’s lifetime.

The goal of the Strawtegi CO_2ttage project is to initiate a ripple effect, encouraging and inspiring others to use and expand the application of straw and other natural materials as viable, high-performance, rapidly-renewable, carbon-sequestering building materials that advance climate solutions. The panel system is easily adaptable to smaller dimension lumber, still sequestering carbon and offering strong thermal performance for more affordable applications. At the end of a long life, this building shell is fully recyclable and compostable, returning nutrients to the earth, to be recycled again.

Despite supply chain delays, our team looks forward to completing the Strawtegi CO_2ttage test build project in 2022. We are committed to open-source sharing of details, findings, field modifications, and ongoing performance monitoring, and encourage replication and further exploration by others. Contact information and updates on the building process will be shared online at www.strawtegi.org. Details will continue to be refined through additional Strawtegi projects. We seek support and partnerships to advance lab testing to better understand and validate the biogenic materials and configurations used so they can be more rapidly adopted and accepted by building officials.

Change is in the works. By understanding and working with natural systems, we can limit the impacts of climate change. Rapidly shifting toward carbon sequestration in our built environments is a top priority in the international dialog about climate change. Practical solutions proposed in the Strawtegi CO_2ttage project demonstrate and contribute to the conversation regarding appropriate solutions. With further testing, demonstration, and investment in scalability, these materials and methods could advance more rapidly toward mainstream application, adding to our toolkit of solutions for drawing carbon down out of our atmosphere and locking it into our built environment for decades. "It is well within the realm of possibility for the buildings and construction sector to deliver its full mitigation potential and help the world achieve its climate and sustainable development goals. Together, we can build for the future" (Global ABC/IE, 2019).

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CONFLICT OF INTEREST
The author declares that they have no conflicts of interest associated with the work presented in this paper.

DATA AVAILABILITY
Data on which this paper is based is available from the authors upon reasonable request.
Contact Strawtegi at www.strawtegi.org