HESTIA—Harnessing Emissions into Structures Taking Inputs from the Atmosphere

PROJECT DESCRIPTIONS

National Renewable Energy Laboratory – Golden, CO

High-Performing Carbon-Negative Concrete Using Low Value Byproducts from Biofuels Production - $1,749,935

The National Renewable Energy Laboratory (NREL) and partners will develop a carbon-negative, thermally insulating concrete that uses bio-based supplementary cementitious materials and concrete additives generated from low-value byproducts created during sustainable aviation fuel production. The NREL team will demonstrate that activated carbon, aerogels, and ash produced from biomass processing, as well as additional CO_2 calcination of these materials, can replace a large portion of ordinary portland cement in common “ready-mix” concrete. Such plant derived intermediates can permanently sequester atmospheric CO_2 in concrete in the form of solid carbon using this approach. This material can be ground and recycled at end of life for use as road base or aggregate with no risk of organic matter decomposition and CO_2 secondary release.

Texas A&M University – College Station, TX

Hempcrete 3D Printed Buildings for Sustainability and Resilience - $3,742,496

Texas A&M will develop resilient net-carbon-negative building designs for residential and commercial applications via large-scale 3D printing with hempcrete, a lightweight material made of the hemp plant’s woody core mixed with a lime-based binder. Construction 3D printing can significantly lower production costs, construction times, and environmental impacts from reduced construction waste. Hempcrete can provide structures that are more resilient to natural hazards compared with commonly used, light-weight, wood-framing construction. Unlike conventional construction materials, hempcrete is a net-carbon-negative material, which can augment net-carbon-negative building designs.

University of Colorado Boulder – Boulder, CO

A Photosynthetic Route to Carbon-Negative Portland Limestone Cement Production - $3,193,063

The University of Colorado Boulder will manufacture and commercialize a net-CO_2-storing portland limestone cement using biogenic limestone ($CaCO_3$) produced from calcifying microalgae. Heating $CaCO_3$ to produce calcium oxide (quicklime) in the process of making cement releases CO_2. This technology aims to produce biogenic $CaCO_3$ using coccolithophores, calcareous microalgae that sequester and store CO_2 in mineral form through biological direct air capture via photosynthesis and calcification. Using this $CaCO_3$ in biogenic cement production leads to a net carbon neutral carbon cycle. The team will blend biogenic $CaCO_3$ with the biogenic portland cement to produce net-CO_2-storing portland limestone cements.

University at Buffalo – Buffalo, NY

Modular Design and Additive Manufacturing of Interlocking Superinsulation Panel from Bio-based Feedstock for Autonomous Construction - $2,179,852

The University at Buffalo will design and additively manufacture modular interlocking superinsulation panel materials using a patented combination of biogenic cellulose (or straw) and superinsulation silica aerogel. Unlike sourcing raw biogenic material, the scalable cellulose/straw/silica aerogel material can enable high-throughput continuous manufacturing of panels at ambient conditions. The panels will provide high thermal insulation, structural durability, moisture and fire resistance, soundproofing, and easy installation at a low cost. The panels will meet embodied and operational carbon-negative emission requirements and provide recycling/repurposing capabilities.

University of Pennsylvania – Philadelphia, PA

High-Performance Building Structure with 3D-Printed Carbon Absorbing Funicular Systems –$2,407,390

The University of Pennsylvania will design a carbon-negative medium-size building structure by (1) developing a high-performance, prefabricated, funicular floor structural system with minimized mass and maximized surface area for carbon absorption; (2) using a novel carbon-absorbing concrete mixture as building material; (3) 3D printing the parts with a novel concrete mixture and additional bio-based carbon-storing materials. This technology complements mass-timber-based approaches via carbon-negative building design and 3D printing. It will address increasing global construction demand without straining existing forest resources.

National Renewable Energy Laboratory – Fairbanks, AK

Celium: Cellulose-Mycelium Composites for Carbon Negative Buildings/Construction- $2,476,145

The National Renewable Energy Laboratory (NREL) will develop cost-effective, bio-based insulation by fabricating net CO_2-negative cellulose-mycelium composites. The NREL team will combine foamed cellulose with mycelium, the root network of fungi, to create a new class of high-performing, carbon-capturing and storing foams and composites. The team will develop thermally and acoustically insulating mycelium-cellulose composites that (a) capture and store carbon, (b) are locally manufactured, (c) are cost-competitive with carbon-positive synthetic and mineral materials, (d) are antimicrobial, and (e) are targeted toward building energy retrofits. The team’s technology leverages abundant cellulose from beetle-killed conifers and small-dimensional woody biomass.

Pacific Northwest National Laboratory – Richland, WA

The Circular Home: Development and Demonstration of a Net-Negative-Carbon, Reusable Residence - $2,627,466

Pacific Northwest National Laboratory will develop an innovative design process and modular single-family “Circular Home” that is carbon-negative cradle-to-grave. The team will design the Circular Home primarily of biogenic materials, which will create zero operational carbon, and design it for easy disassembly and reassembly for reuse and minimal waste generation. Major components remain in use for three times longer time than the expected 50-year lifespan of a conventionally constructed single-family dwelling, ensuring the initial design will compound carbon sequestration benefits. Compared with current code-built homes, the proposed design’s greenhouse gas emissions will equate to 71% avoided carbon in the second building iteration and 52% in the third.

Oregon State University – Corvallis, OR

Cellulose Cement Composite (C3) for Residential and Commercial Construction - $2,500,000

Oregon State University will develop C3, a cellulose cement composite, for use in residential and light commercial construction as an alternative to dimensional lumber and sheet products. The team will create C3 from small-diameter logs unsuitable for lumber production. Their removal from the forest as a potential fuel source can help lessen wildfires. The C3 material is net-carbon-negative and absorbs additional atmospheric CO_2. C3 materials resist rot and fungal growth, fire, and heat transfer. They can be deployed quickly due to compatibility with current construction processes and lend themselves to large-scale commercial adoption.

Oak Ridge National Laboratory – Oak Ridge, TN

Renewable, Carbon-negative Adhesives for OSB and Other Engineered Woods - $1,098,000

Oak Ridge National Laboratory will develop a renewable, carbon-negative adhesive for oriented strand board (OSB) engineered wood that matches the performance and approximate cost as the incumbent adhesive but does not contain isocyanate, which can irritate the eyes, nose, throat, and skin. The team will use the latest developments in sustainable bioresources and biobased polymer chemistry and select biomass feedstocks based on availability, chemical functionality, energy required for chemical synthesis, carbon negativity, and guidance from a techno-economic analysis. The new adhesive will require zero or minimal modifications to existing OSB manufacturing plants to facilitate industry adoption.

University of Wisconsin-Madison – Madison, WI

Carbon-Negative Ready-Mix Concrete Building Components Through Direct Air Capture - $2,256,250

The University of Wisconsin-Madison will develop a carbon-negative replacement for portland cement, a component of concrete. Concrete is ubiquitous in buildings because it is inexpensive, strong, rigid, and resistant to fire, fatigue, and creep. It can also be cast in place, which enables flexibility in building design. Ordinary portland cement is highly carbon intensive, with its production responsible for about 3 billion metric tons of CO_2 per year, or 8% of total anthropogenic CO_2 emissions. This project will utilize direct air capture and convert industrial mineral wastes into a recyclable cementitious replacement for portland cement with superior durability. The process will store captured CO_2 permanently as a strong, multi-purpose building material resulting in a net reduction in this greenhouse gas.

Northeastern University – Boston, MA

4C2B: Century-scale Carbon-sequestration in Cross-laminated Timber Composite Bolted-steel Buildings - $3,150,000

Northeastern University will lead a multi-institutional team to demonstrate the potential widespread deployment of carbon-negative multi-story buildings through the construction of steel-framed buildings with cross-laminated timber (CLT) floor and wall diaphragms. Diaphragms are structural elements that transmit lateral loads to the vertical resisting elements. The project will encompass the proper design for deconstruction and reuse of these structural elements. CLT diaphragms can store up to 50% of their weight in biogenic carbon. Reusing the CLT will store this carbon for 100+ years to reverse global warming potentials, which the typical 40–50-year lifespan of building materials is unable to accomplish.

Purdue University – West Lafayette, IN

Strong and CO_2 Consuming Living Wood for Buildings - $958,245

Purdue University develop a transformational “living” wood with the strength of steel, a self-healing capability, and combined carbon-sequestering benefits from wood and microbes. The living wood captures CO_2 during its growth, manufacturing, and use. By leveraging microbe activities, the manufacturing of living wood largely eliminates the use of harsh chemicals commonly used to treat and modify it. The right microbes fill the wood pores while capturing CO_2 into strong biomaterials, significantly strengthening the wood scaffold and promoting self-healing. Manufacturing living wood is inherently scalable and will promote healthy forest management and a national bioeconomy.

University of Tennessee-Knoxville – Knoxville, TN

Lignin-derived Carbon Storing Foams for High Performance Insulation - $2,557,383

The University of Tennessee-Knoxville has demonstrated that high-quality polyurethane (PU) insulating foams are readily prepared from lignin extracted from biomass, facilitating cellulosic biorefinery processing and improving the foam's economic and environmental performance. The team will develop higher performance, carbon-negative, and eco-friendly lignin-PU foams using a non-isocyanate method as a building insulation material. To this end, the team will (1) investigate and select the optimal biomass feedstock and lignin processing method for high-performance and low-cost lignin-PU synthesis, (2) develop lignin-PU foam forming method with and without using isocyanate, and (3) specify the characteristics of lignin-PU foam and its technical functioning as a high-performance insulation material.

Clemson University – Clemson, SC

An Entirely Wood Floor System Designed for Carbon Negativity, Future Adaptability, and End of Life De/re/Construction - $1,042,934

Clemson University will develop a 100% wood mass timber floor system for buildings. Mass timber products are comprised of thick, compressed layers of wood and used to create strong, structural load-bearing elements. Carbon stored in the timber floor (and taken out of the atmosphere) will offset carbon emitted during production and construction of other building materials. Team members will build and test full-scale components and specimens to evaluate structural safety and performance, acoustic performance, and viability of de/re/construction (d/r/c). U.S. buildings are often subject to demolition even when they are still functional. By designing for d/r/c, the proposed system will allow building components to have a second life instead of demolition and disposal.

Aspen Products Group – Marlborough, MA

High Performance, Carbon Negative Building Insulation - $1,152,476

Aspen Products Group will develop a sustainable, high-performance, thermal insulation that incorporates atmospheric CO_2 into the insulation's structure. The team will combine cellulosic raw material sourcing and processing, insulation chemistry optimization, manufacturing process development, insulation product testing, and process and life cycle analysis modeling to demonstrate an insulation product that meets construction technical performance requirements and provides cost-effective manufacturing. This project will improve building energy efficiency and reduce greenhouse gas emissions.

BamCore – Ocala, FL

Maximizing Carbon Negativity in Next Generation Bamboo Framing Materials - $2,230,060

BamCore aims to transition its bamboo/wood hybrid (40%/60%) dual panel hollow wall system to 90+% bamboo content to develop a prefabricated, building code-compliant vertical framing wall system for constructing carbon-negative low- and mid-rise buildings. Bamboo produces structural fiber five-to-six times faster than wood. The team will also develop stand-alone biogenic insulation and fire-retardant layers to replace fiberglass and gypsum board as well as end-of-life (EOL) strategies for deconstruction to preserve panel integrity and/or alternative use. The result is a substantially more carbon-negative building material than wood with superior performance, lower overall cost, and high EOL value.

SkyNano – Knoxville, TN

CO_2mposite: Recycling of CO_2, Carbon Fiber Waste, and Biomaterials into Composite Panels for Lower Embodied Carbon Building Materials - $2,000,000

SkyNano will develop a composite panel that contains CO_2-derived carbon nanotubes (CNTs), recycled carbon fiber waste, and bio-derived natural fibers that exhibits excellent mechanical and functional properties while maintaining a carbon-negative footprint on a cradle-to-grave basis. Panel applications include interior wall coverings, non-load bearing interior walls, exterior facades, and ceiling panels. The technology will increase mechanical and functional performance of materials used in built environment, introduce new materials to an industry that has used essentially the same ones for decades, and enable interior building surfaces to be CO_2 negative.

Biomason – Durham, NC

Soteria - Carbon Negative Bioconcrete Unit Production Concept - $1,812,118

Biomason will retool bioconcrete production processes and material combinations to generate carbon-negative cementitious building materials. Biocementation, or microbial induced calcite precipitation is a viable technology for manufacturing concrete materials with significantly reduced energy, carbon, and logistical footprints. Biomason aims to (1) eliminate synthetic urea as biocement carbon source, (2) incorporate carbon-loaded, biomass, and/or recycled base aggregate materials, and (3) tune biocement speciation for enhanced carbon inclusion. These strategies will yield a carbon-negative cementitious building material production strategy that can potentially replace most products now served by carbon-intensive traditional cement.