U.S. Department of Energy
Advanced Research Projects Agency – Energy (ARPA-E)

Request for Information (RFI)
DE-FOA-0002506
On Manufacturing Carbon Negative Materials to Reduce Embodied Emissions in Buildings

Introduction

The purpose of this RFI is to solicit input for a potential future ARPA-E research program focused on technologies that could enable buildings to be transformed into carbon sinks to reduce their embodied emissions while also providing a pathway for expanding carbon utilization approaches. This vision entails manufacturing novel materials derived from feedstocks including forestry and other purpose-grown raw materials, agricultural residues, as well as direct use of greenhouse gases (e.g., carbon dioxide, methane). The aim is to use these materials in place of existing building construction materials wherever possible, as well as to enable more efficient building designs.

Attaining this vision requires a radical departure from the use of modern building materials, and likely from the conventional manufacturing methods for building materials. At the same time, operational energy performance and the structural and fireproof code requirements of the buildings themselves must not be sacrificed. Comprehensive and robust life-cycle analyses and carbon accounting, along with permanency of storage and end-of-life design, will also be necessary. For these reasons, ARPA-E is especially interested in perspectives from both inside and outside the buildings sector community.

Many of today's buildings consist of steel, concrete, stone, brick and masonry materials. Their continued use is challenged by the energy intensive nature of their processing and manufacture. These manufacturing approaches can be particularly difficult to decarbonize. Wood, another common construction material, has seen a resurgence in interest with engineered woods and mass timber opening new possibilities due, in part, to their ability to store carbon. Land usage, transportation, and environmental impacts of adhesives used in engineered wood and mass timber production must be considered, however, for widespread adoption and to offset associated emissions. Additional pathways for increasing carbon storage content of the building stock, as well as exploring alternative materials with additional drawdown capabilities using greenhouse gas-based feedstocks will require advancements in materials and processing-to-scale. The nascency of these alternative materials pose an additional challenge for implementation in the risk-averse construction industry.

Background

Commercial and residential building operations (e.g., heating, cooling, lighting, and plug loads) in the U.S. accounted for over 800 million metric tons of carbon dioxide equivalents, or 12% of total greenhouse gas (GHG) emissions in 2018. These direct emissions (i.e. Scope 1), combined with indirect emissions (i.e. Scope 2) from electricity consumed by buildings, but produced off-site, resulted in over 2 billion metric tons of carbon dioxide equivalents or 30% of total annual GHG emissions.[1] The U.S. Mid-Century Strategy has set a target of at least 80% reduction in overall GHG emissions by 2050 relative to 2005 levels based on recommendations from the Intergovernmental Panel on Climate Change (IPCC).[2,3] Efforts underway to contribute to these targets include increases in renewable electricity supply along with aggressive energy efficiency measures and electrification (e.g., envelope, controls, and heat pumps) for buildings.[4]

As these decarbonization strategies are further pursued with respect to building operations, embodied emissions (i.e. Scope 3) resulting from the energy consumed in producing materials used in the design of buildings, along with the construction process itself, have come into increasing prominence.[5] Released during material sourcing (i.e. mining, harvesting, processing, manufacturing, transportation, and installation), construction, and disposal, these emissions are becoming a growing fraction for two main reasons. First, operational improvements continue to be made through adoption of more energy efficient codes, lowering their overall contribution. Second, increases in total embodied emissions can arise from the production of higher performance materials (e.g., insulation) to meet reductions in operational energy usage.[6,7,8] Approximately 10% of additional annual emissions in the US can be attributed to embodied emissions from buildings.[9] Globally, the trends are similar, with 28% of annual emissions resulting from building operations and another 11% due to the emissions from manufacturing building materials, transporting to construction sites, and the actual construction process.[10] Approaches for reducing embodied footprints include reducing the amount of material necessary, as well as

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[1] US Environmental Protection Agency, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#commercial-and-residential.

[2] U.S. Mid-Century Strategy for Deep Decarbonization, November 2016, https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf.

[3] IPCC, Summary for Policymakers. Global warming of 1.5ºC: An IPCC Special Report on the impacts of 1.5ºC above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2018, ISBN 978-92-9169-151-7.

[4] Langevin, J.; Harris, C.B.; Reyna, J.L., "Assessing the Potential to Reduce U.S. Building CO2 Emissions 80% by 2050," *Joule* 2403-2424 (2019), https://doi.org/10.1016/j.joule.2019.07.013.

[5] International Energy Agency (IEA), Material Efficiency in Clean Energy Transitions, March 2019, www.iea.org/publications/reports/MaterialEfficiencyinCleanEnergyTransitions/.

[6] IEA, Evaluation of Embodied Energy and CO_{2eq} for Building Construction (Annex 57) Overview of Annex 57 Results, September 2016, http://www.annex57.org/wp/wp-content/uploads/2017/05/Overview-Report.pdf.

[7] Rock, M.; Ruschi Mendes Saade, M.; Balouktsi, M; Nygaard Rasmussen, F.; Birgisdottir, H.; Frischknecht; Habert, G.; Lutzkendorf, T.; Passer, A., "Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation," *Applied Energy* V. 258, 114107 (2020).

[8] Embodied emissions are also sometimes referred to as embodied carbon due to the bulk consisting of carbon dioxide and methane.

[9] EIA Annual Energy Outlook 2021 with Projections to 2050, EIA. https://www.eia.gov/outlooks/aeo/

[10] Global Alliance for Buildings and Construction 2018 Global Status Report: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector. IEA (International Energy Agency) and UNEP (United Nation Environment Programme). https://www.worldgbc.org/sites/default/files/2018%20GlobalABC%20Global%20Status%20Report.pdf .

extending the service life of the material or structure by avoiding demolition through renovation, remodeling, and recycling strategies. The avoidance of new construction through the reuse of an existing building can result in significantly fewer emissions.[11] New construction, however, will continue to be necessary for buildings that cannot be successfully upgraded and to meet additional demand resulting from population growth. Between 2020 and 2050, residential housing units in the US are projected to increase by 22%, or a compound annual growth rate of 0.7%. Total square footage in the US commercial sector is projected to increase by almost 33% with a 1.1% compound annual growth rate of new additions.[12] As such, complementary strategies for reducing embodied emissions will include continued exploration of alternative materials alongside more efficient design processes and material salvaging.

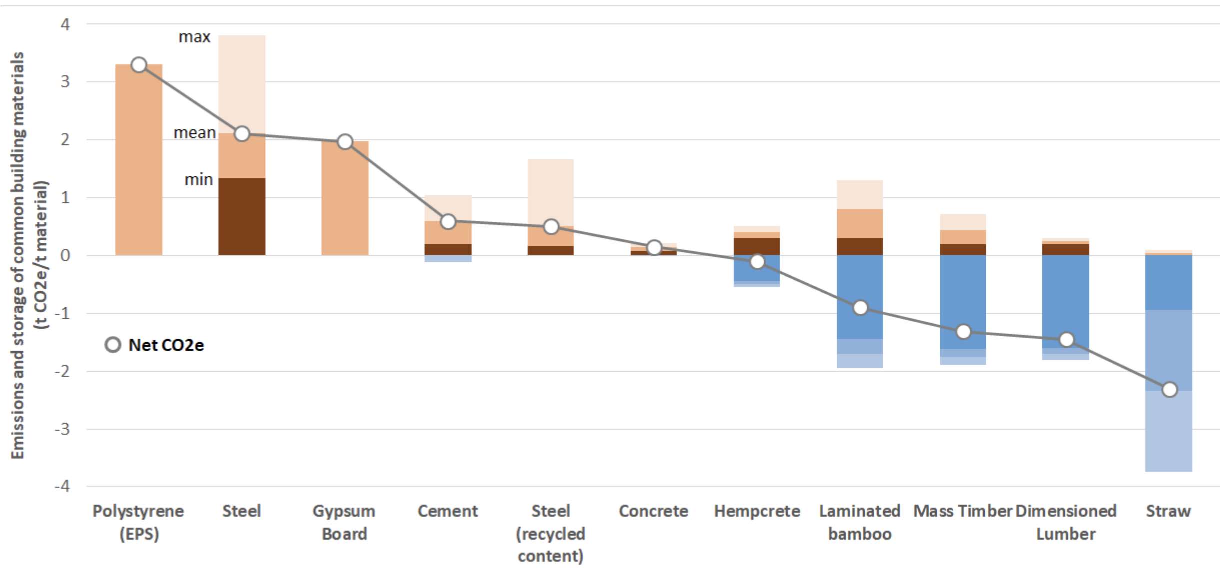

Figure 1. CO_2 emissions and CO_2 storage capacity of building materials where the net CO_2e is the difference between the mean emissions estimate and the mean storage estimate. Data from ref [13] and [14] evaluated on a life cycle assessment system boundary of A1-A3 (see Figure 2, below).

In particular, manufacturing and production of building materials that store GHG emissions in the final product could not only lower emissions, but also turn both newly constructed and renovated buildings into carbon sinks that contribute to carbon utilization targets for negative emission technologies.[15] As

[11] Malmqvist, T., et al., "Design and Construction Strategies for Reducing Embodied Impacts from Buildings – Case Study Analysis," *Energy & Buildings*, V. 166, 35-47, May 2018.
[12] US Annual Energy Outlook 2021, U.S. Energy Information Agency, https://www.eia.gov/outlooks/archive/aeo21/.
[13] Pomponi, F. and Moncaster, A. "Scrutinising Enbodied Carbon in Buildings: The Next Performance Gap Made Manifest," *Renewable and Sustainable Energy Reviews*, V. 81(P2), 2431-2442, 2018, DOI: 10.1016/j.rser.2017.06.049.
[14] Ruuska, "Carbon Footprint for building products," 2013, https://cris.vtt.fi/en/publications/carbon-footprint-for-building-products-eco2-data-for-materials-an.
[15] National Academy of Sciences, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, 2019.

shown for a representative set of typical and emerging structural and insulating building materials in **Figure 1**, above, this relies on the carbon dioxide equivalents for storage to be greater than the carbon dioxide equivalents of emissions. Further evaluation of proposed materials and their impacts will be dependent on the volume of the incumbent material used in building structures today and its emission reduction potential, along with the carbon sequestering capacity of the proposed material. Materials must be durable to reduce lifetime emissions and designed for end-of-life in a way that addresses the sequestered carbon, whether permanent (e.g., minerals) or temporary (e.g., biogenic). As such, life-cycle analyses (LCAs) are necessary to quantify the overall impacts of products and processes across their entire life-cycle from “cradle-to-grave" (i.e. production, manufacturing, construction, maintenance through end of life) (see **Figure 2**, below). The production stage (A1-A3) has the highest impact for new buildings, while the refurbishment stage (B4) contributes similar amounts in retrofit cases, depending on the end of service lifetime. Construction product manufacturers are beginning to publish environmental product declarations (EPDs), based on international standards such as ISO 14040/14044, that document the global warming potential of specific products or product categories. A variety of LCA tools exist, including active development on assessments at the whole-building level, as well as upstream material production.[16] Harmonization efforts are focused on addressing limitations to-date that includes inconsistencies in the bounds, as well as the underlying life cycle inventory data and modeling that prevent the addition of multiple EPDs.[17] Therefore, to evaluate the development of net carbon negative building materials, a fully cradle-to-grave (including the upstream source and end-of-life disposal) assessment will be key. Carbon sequestration measurements will also need to be incorporated.

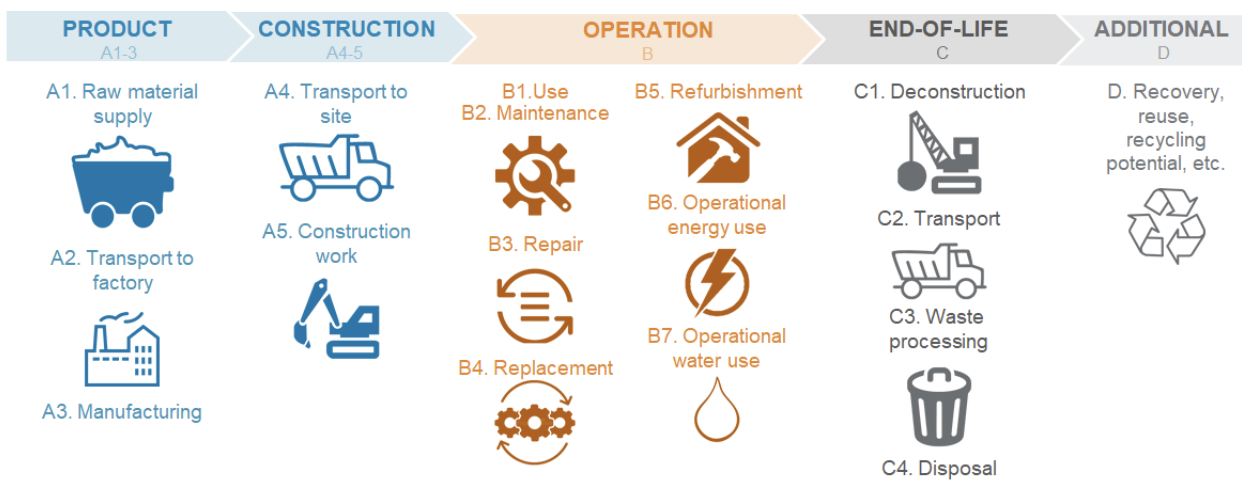

Figure 2. Stages of life-cycle analyses.

[16] LCA tools include those accessible through the following sites: https://www.athenasmi.org/our-software-data/overview/; https://www.buildingtransparency.org/en/; https://www.energy.gov/eere/buildings/downloads/life-cycle-analysis-advanced-building-construction-technologies; and https://ws680.nist.gov/birds.

[17] IEA Annex 72 Assessing Life Cycle Related Environmental Impacts Caused by Buildings, https://annex72.iea-ebc.org/.

More than half of embodied emissions come from manufacturing steel and cement, which are also two key emission categories in the industrial sector and critical to broader decarbonization strategies.[18] The production of ordinary Portland cement (OPC) for concrete, for example, accounts for more emissions than any other material. Strategies already exist to reduce the emissions of concrete (e.g., replacing OPC with other cementitious materials, reducing the cement fraction of the material, reducing concrete use, and tailoring project specifications).[19] Approaches that produce carbon neutral or carbon negative concrete are less developed, but rapid progress is being made with carbon storage in concrete achieved via carbon dioxide cured concrete, carbon dioxide-derived synthetic aggregates, and microbially induced calcite precipitation.[20] Remaining challenges include increasing carbon storage, driving down costs, and scalability. Alternatives to stone, brick, and masonry materials are also being developed in first market applications. Similarly, substitutes for steel are being explored, along with utilizing recycled versions that have a lower carbon footprint compared to virgin steel due to lower processing requirements. Recycled aluminum, used for window frames, moldings, and exterior wall panel siding, also emit less than virgin aluminum.[21]

In addition to the common uses of wood in building construction, mass timber and engineered woods (i.e. cross-laminated timber), are emerging as viable replacements to steel and concrete, as well as vinyl siding.[22] For example, mass timber, particularly glulam, has shown potential for replacing steel beams of equivalent or lower strength and stiffness. Chemical treatment of or composites formed with mass timber are useful in improving adoption, as well as increasing their carbon storage potential.[23,24] While timber is the biogenic material with the largest penetration into the building construction industry, concerns over forestry practices have obfuscated whether the carbon stored in wood presents a net benefit to greenhouse gas emissions. For example, wood from Forest Stewardship Council certified forests have been shown to sequester on average approximately 30% more carbon than wood from traditionally managed forests.[25] In contrast to purpose-grown feedstocks, use of agricultural residues does not necessarily require dedicated land use. These materials (e.g., straw, hemp, cork, and cellulose) have found application in the construction industry by compression with binders and in pre-fabricated panels. Using greenhouse gases directly, on the other hand, has the benefit of not impinging on arable land, but the technology for converting these gases efficiently to products is nascent. Carbon dioxide

[18] IEA, Material Efficiency in Clean Energy Transitions, March 2019, www.iea.org/publications/reports/MaterialEfficiencyinCleanEnergyTransitions/.

[19] Hasanbeigi, A.; Price, L.; Lin, E., "Emerging Energy Efficiency and CO2 Emission-Reduction Technologies for Cement and Concrete Production: A Technical Review," *Renewable and Sustainable Energy Reviews*, V. 16, 6220-6238, 2012.

[20] Siegel, R.P., "Cutting the Carbon from Concrete," *Mechanical Engineering*, V. 142(02), 38-43, 2020.

[21] Chen, T.Y.; Burnett, J.; Chau, C.K., "Analysis of Embodied Energy Use in the Residential Building of Hong Kong," *Energy*, V. 26(4) 323-340, 2001.

[22] Churkina, G.; Organschi, A.; et al., "Buildings as a global carbon sink," *Nature Sustainability*, V. 3, 269-276, 2020.

[23] Ramage, M. H., et al., "The wood from the trees: The use of timber in construction," *Renewable and Sustainable Energy Reviews*, V. 68, 333-359, 2017.

[24] Chen, C. et al., "Structure-property-function relationships of natural and engineered wood," *Nature Materials Reviews*, V. 5, 642-666, 2020.

[25] Diaz, D.D.; Loreno, S.; Ettl, G.J.; Davies, B., "Tradeoffs in Timber, Carbon, and Cash Flow under Alternative Management Systems for Douglas-Fir in the Pacific Northwest," *Forests*, V. 9(8), 2018.

mineralization and electro-reduction are being demonstrated to convert carbon dioxide into products, [26] but it is unclear whether costs can be driven low enough to compete in the low-margin construction materials industry. Other novel processes for or uses of mineralized carbon dioxide might also be successful. Methane pyrolysis, if widely adopted, would produce vast quantities of solid carbon, but thus far, products to utilize that carbon at scale have not been developed.

Polymers used traditionally in building materials are derived from petroleum sources. Promising examples to consider for improving the manufacturing and properties of building materials include, but are not limited to, bio- or air-derived carbon fiber and other structural materials, bio-derived and carbon dioxide-incorporating polymers for use in construction, and structurally robust and highly insulating materials. Strides have been made in polymers relevant to the building industry, such as polyurethane, from air-derived carbon as a means of carbon capture. Foams from bio-based feedstocks, such as soy-based and sugar cane, for insulation are also available.[27,28,29] Conversion to bio-based polymers is expected to reduce GHGs in polymers, as a result of the feedstock used. However, the extent of GHG reduction may be limited by the possibility of a higher carbon footprint due to logistics and processing requirements. In addition, adoption of bio-based polymers is contingent upon the ability to source large quantities of feedstock. At the end of service, challenges exist with optimizing GHG reduction. Even when environmentally friendly or carbon storing fillers are used in the creation of composite materials, the high weight fraction of matrix materials with high global warming potential can negate the value of the filler materials. Rather than limiting the weight of the matrix, an alternative route to limiting the impact of composites would be to use green matrix materials.

Other potentially transformative technologies for carbon storage in buildings could be possible when further considering improved or substitute materials for common building elements (e.g., structural framing and columns, foundations, roof, exterior facades and floors, as well as non-structural components such as interior walls, flooring, and insulation). Low-carbon versions of carpeting and flooring are already being commercialized, but have not yet achieved widespread adoption.[30] Ultimately, the building element selected will guide adoption in new construction versus retrofit applications for materials developed. Means of reducing embodied emissions at a whole-building level include emerging methods of fabrication, offsite manufacturing, and robotics.[31] More efficient construction methods and building designs also include the use of more efficient structural solutions to

[26] See, e.g., https://www.xprize.org/prizes/carbon.
[27] Khazabi, M.; Gu, R.; Sain, M., "Fiber Reinforced Soy-Based Polyurethane Spray Foam Insulation. Part 1: Cell Morphologies," *Bioresources*, V. 6(4), 3757-3774, 2011.
[28] Asdrubali, F.; D'Alessandro, F.; Schiavoni, S., "A Review of Unconventional Sustainable Building Insulation Materials," *Sustainable Materials and Technologies*, V. 4, 1-17, 2015.
[29] Abu-Jdayil, B., et. al., "Traditional, State-of-the-Art and Renewable Thermal Building Insulation Materials: An Overview," *Construction and Building Materials*, V. 214, 709-735, 2019.
[30] See, e.g., https://www.interface.com/US/en-US/about/press-room/carbon-negative-tile-release-en_US; https://commercial.tarkett.com/en_US/node/carbon-neutral-11914.
[31] Hasz, A.; Ryan, N.; Glickman, J., "Advanced Building Construction (ABC) – A Not Quite "Easy as 1-2-3" Initiative to Scale Deep Energy Retrofits and Transform U.S. Buildings," ACEEE Summer Study on Energy Efficiency in Buildings 5, 219-234, 2020. https://www.aceee.org/files/proceedings/2020/event-data/pdf/catalyst_activity_10749/catalyst_activity_paper_20200812132347405_15177b9e_4179_4fc7_83b4_14be6801bd33

maximize structural efficiency and reduce the amount of material used (e.g., advanced framing), as well as designing material size modules in standard sizes to minimize waste (e.g., 4x8 plywood, gypsum board). Using less material to lower embodied emissions will mean less available volume for carbon storage on an absolute basis across the building stock, but maximizing carbon sequestration capacity on a per unit level can still offer a pathway to near or net negative. Finally, while the adoption of lower carbon solutions has also traditionally focused on building energy codes to lower energy usage of building operations, discussion is now turning to evaluating embodied reductions as well.[32] Cities and municipalities are starting to incorporate embodied carbon impacts into their mandates.[33,34]

Please carefully review the REQUEST FOR INFORMATION GUIDELINES below. Please note, in particular, that the information you provide will be used by ARPA-E solely for program planning, without attribution. **THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO FOA EXISTS AT THIS TIME.**

Purpose and Need for Information

The purpose of this RFI is solely to solicit input for ARPA-E consideration to inform the possible formulation of future research programs. ARPA-E will not provide funding or compensation for any information submitted in response to this RFI, and ARPA-E may use information submitted to this RFI without any attribution to the source. This RFI provides the broad research community with an opportunity to contribute views and opinions.

REQUEST FOR INFORMATION GUIDELINES

No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E may contact respondents to request clarification or seek additional information relevant to this RFI. All responses provided will be considered, but ARPA-E will not respond to individual submissions or publish publicly a compendium of responses. **Respondents shall not include any information in the response to this RFI that could be considered proprietary or confidential.**

Responses to this RFI should be submitted in PDF format to the email address **ARPA-E-RFI@hq.doe.gov** **by 5:00 PM Eastern Time on April 21, 2021.** Emails should conform to the following guidelines:

- Please insert "Responses for Manufacturing Carbon Negative Materials to Reduce Embodied Emissions in Buildings RFI" in the subject line of your email, and include your name, title,

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[32] See, e.g., https://www.iccsafe.org/advocacy/embodied-carbon/; https://www.ashrae.org/news/esociety/2019-lowdown-showdown.

[33] Teshnizi, Z. "Policy Research on Reducing the Embodied Emissions of New Buildings in Vancouver," https://vancouver.ca/files/cov/cov-embodied-carbon-policy-review-report.pdf.

[34] Marin County Low-Carbon Concrete Code, https://www.marincounty.org/-/media/files/departments/cd/planning/sustainability/low-carbon-concrete/12172019-update/low-carbon-concrete-code.pdf?la=en.

organization, type of organization (e.g. university, non-governmental organization, small business, large business, federally funded research and development center (FFRDC), government-owned/government-operated (GOGO), etc.), email address, telephone number, and area of expertise in the body of your email.

• Responses to this RFI are limited to no more than 10 pages in length (12-point font size).

• Responders are strongly encouraged to include preliminary results, data, and figures that describe their potential methodologies.

Questions

I. **Life-cycle analyses (LCA) and End-of-life Considerations**

1. What are the gaps in readily available LCA tools and/or data for calculating embodied carbon and stored carbon of building materials? List the tool(s) and/or data source(s) and how well uncertainty is quantified.
2. What are the gaps in readily available LCA tools and/or data for addressing end-of-life of a building material, including forms of recycling and decomposition? Which of these options are included and how well is uncertainty quantified for the listed tool(s) and/or data source(s).
3. What are the gaps in readily available LCA tools and/or data to assess cradle-to-grave, beginning with feedstocks? List the tool(s) and/or data source(s) and how well uncertainty is quantified.
4. If new materials offer potentially “permanent” carbon storage, how do the benefits of the drawdown weigh against the environmental impacts of end of service options (e.g., landfilling)?
5. Are there other tradeoffs, including environmental factors, between manufacturing a new material that provides a negative carbon sink (e.g., land and water use concerns) versus reusing an existing material? Please provide specific examples and references.
6. If permanent carbon storage is possible for a given building element, how should it be defined, accurately projected, and validated? With limited measurements, how could it be confirmed that the carbon storage would last as long as claimed?

II. **Feedstocks**

1. Forestry products and other purpose-grown feedstocks:
    a. What anticipated changes in North American forestry practices over the next 30 years need to be considered for carbon accounting or the carbon impact on building materials?
    b. What are the land use or nutrient concerns for scaling associated with bringing a new material to market? Please include assumptions made about the scale of material and feedstock necessary.
    c. Are there emerging technologies to reduce limitations such as arable land or nutrient application? How low is the nutrient or land impact expected to reach?
2. Agricultural residues (e.g., straw, rice husks):

   a. What are the barriers, including competition with other uses, to incorporating agricultural residues into existing construction materials?
   b. What are the land use or nutrient concerns associated with scaling a potential new material from agricultural residues? Please include assumptions made about the scale of material and feedstock necessary.
   c. How should emissions be proportioned from growing the agricultural product with the residue when that residue is converted into building materials, and why?
3. Direct use of greenhouse gases:
   a. What are the projected scale and costs for materials directly derived from carbon dioxide? Please include assumptions about the process of converting carbon dioxide into a useful form.
   b. What carbon dioxide sources can be used (point source, ambient, etc.), and are there any limitations on concentration, purity, etc. that can be overcome with emerging technologies?
4. Other routes. Are there other feedstock sources that could be considered for the purposes of developing new building materials with the ability to store carbon? If so, name the source and explain why it should be considered.

III. **Construction Materials**

1. Concrete and Cementitious Materials
   a. Considering current technologies to produce carbon storing synthetic aggregates, what would be the cost of ready-mix concrete if enough aggregate was included to produce a carbon neutral concrete? What are the barriers to lowering this cost?
   b. What other routes to carbon neutral ready-mix concrete might be viable and what technical hurdles do these materials still need to overcome to show feasibility?
2. Steel Replacements
   a. Are there technical advancements that could transform the use of timber as a steel replacement for higher carbon storage per unit, or increase the amount of carbon storing materials in a building such that the total carbon storage of the building is increased?
   b. What emerging approaches exist for new adhesives, including bio-derived or environmentally benign, that may also lead to better structural performance? If so, what specific performance areas (physical properties, other) would be beneficial?
   c. Are there any design tradeoffs that may come into play for timber and/or adhesives when trying to increase carbon storage versus performance, where carbon storage refers to increased amount of carbon storing materials in a building such that the total carbon storage of the building is increased?
   d. What, if any, other low life-cycle carbon materials have the potential to replace steel in construction, and if so, for what targeted building element? What are the associated technical barriers for these materials to demonstrate feasibility?
3. Low Matrix and Low-Impact Matrix Composites

a. What is the state-of-the-art in reducing matrix requirements for materials produced with carbon storing fillers including forestry products, agriculture residues, and carbon allotropes derived from methane or carbon dioxide?
b. What is the state of the art in bio-derived and/or low emission matrix materials?

IV. **Building Elements**

Please respond to the following for each building element that could provide a measurable opportunity for carbon capture and emissions reduction while retaining building integrity requirements. Building elements include but are not limited to:

- Structural elements such as roof, foundation, beams/ slabs, walls and floors
- Non-structural elements such as interior walls, flooring (carpet, LVT, etc.).

Make sure to list the element in question in the response.

1. What is the expected service life or replacement rate of this element? Is there a push to extend the service duration of this element, and if so, by whom (building owners, architects, manufacturers, other)?
2. How is the element typically disposed of at the end of its useful life, and if known, what is the associated greenhouse gas emission footprint?
3. What is the rate of introduction for new products for this element, what are the drivers, and what is the typical cost at initial market introduction?
4. Are there technical challenges with the current products for this element that a new product could resolve?
5. What changes or additions to codes are anticipated for this product element in the coming years or decades and what will the challenges be to meeting them?